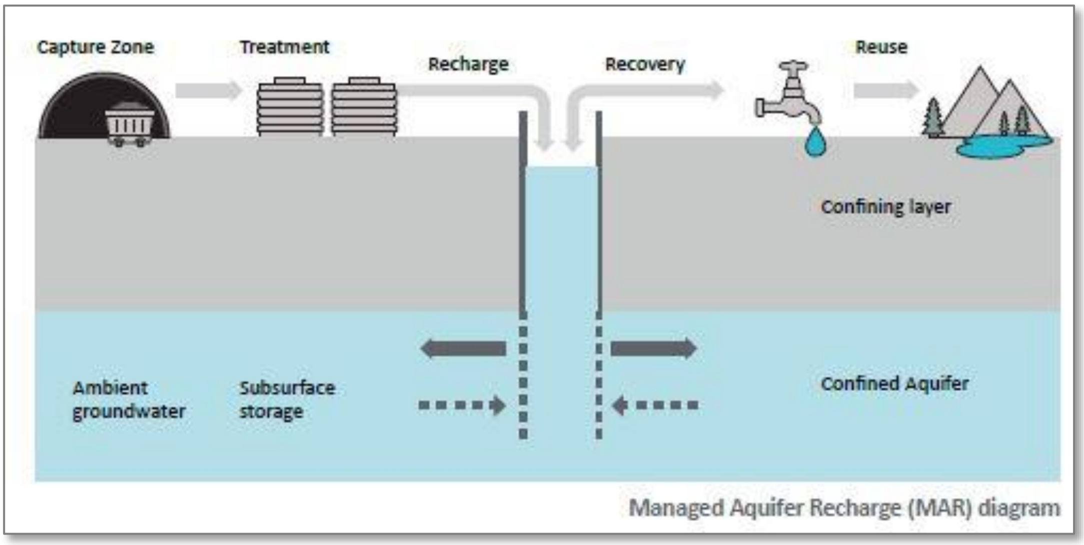
Bird in Hand Gold Project
Mining Lease Application
MC 4473

CHAPTER 10
GROUNDWATER



BIRD IN HAND GOLD PROJECT
MINING LEASE PROPOSAL

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10 GROUNDWATER

This chapter details the groundwater investigations undertaken to characterise the groundwater system of the Inverbrackie Creek Sub-Catchment and assesses the groundwater impacts and groundwater management of the BIHGP.

This chapter is to be read in conjunction with Chapter 3: Proposed Operations.

Australian Groundwater Technologies Pty Ltd (AGT) were commissioned by Terramin to undertake a comprehensive groundwater assessment for the BIHGP. Results of their assessment are contained in the report in Appendix H1. The overall objective of this report was to provide sufficient information on the state of the groundwater environment within the Project area and immediate surrounds, and to assess the potential impacts on groundwater levels and quality from development of the underground mine. This has been done to address any concerns regarding groundwater and surface water resources, groundwater dependent ecosystems and existing groundwater users.

This groundwater assessment investigated the groundwater system on a local scale, through a focused drilling and aquifer testing program of the proposed mine area, and on a catchment scale, through the development of a regional groundwater monitoring network and a groundwater census of private wells undertaken between 2014 and 2018. From this work a conceptual groundwater model and a numerical groundwater model was developed to:

- Assess the effects of the proposed mining operation on the groundwater system, in terms of groundwater inflows and the associated risk to existing groundwater users; and
- Assess best practice mine water management options, such as grouting for groundwater control and reinjection of mine water back into the same aquifer to mitigate groundwater related risks.

The groundwater study was extended in 2018 - 2019 to confirm the feasibility of the aquifer to be recharged with mine water, using a process known as Managed Aquifer recharge (MAR). This feasibility assessment was based on additional drilling and injection tests. The results were used to validate aspects of the existing conceptual groundwater and recalibrate the numerical groundwater model.

Control measures proposed to manage, limit or remedy groundwater impact events have been peer reviewed by a suitably qualified independent expert as required by the Ministerial Determination. Terramin have undertaken peer reviews on the grouting, the groundwater modelling and assessment, the managed aquifer recharge strategy, the water treatment plant and the site water balance. Peer reviewers were chosen for their qualifications and experience in the requisite areas. All peer reviewers qualifications are included in their respective reports.

In regards to the groundwater model, the final independent peer review report must include; an assessment of whether the model is fit for purpose, verification of model inputs, the results of the review of the model against Tables 9-1 and 9-2 of the Australian groundwater modelling guidelines (National Water Commission Waterlines Report Series No. 82, June 2012), the scope of the review and details of any actions undertaken as a consequence of the findings of the review. This has been completed by Innovative Groundwater Solutions during 2017, and again in 2019 with the updated groundwater model.

Peer reviews undertaken have been included in Table 10-1.

TABLE 10-1 | PEER REVIEWS UNDERTAKEN

Water Management Strategy	Report/Assessment	Peer Review
Grouting	Bird in Hand Gold Project – Grouting for Groundwater Control, Multigrout (Appendix H4)	Bird in Hand Gold Project – External Review – Proposed Grouting Programme, Golder Associates (Appendix H5)
Groundwater Modelling and Impact Assessment (including MAR modelling)	Groundwater Impact Assessment for the Bird in Hand Project, AGT (Appendix H1)	Outcomes of Peer Review of Bird in Hand Gold Project Groundwater Assessment Report, Innovative Groundwater Solutions (Appendix H2 and H3)
Site water balance	Water Balance, Terramin (Appendix K1)	Review of Mine Water Balance Model for BIH Project, Golder Associates (Appendix K2)
Managed Aquifer Recharge System	Managed Aquifer Recharge Investigation, Golder Associates, 2019 (Appendix H9)	Independent peer review of updated modelling for the Bird-in-Hand Gold Project, Innovative Groundwater Solutions Pty Ltd (IGS), 2019 (Appendix H10)
Water treatment proposal	Water Treatment Options Study, GPA, 2017 and 2019 (Appendix J1)	Water Treatment Options Study Peer Review, Golder Associates, 2017 (Appendix J2)

In brief, the groundwater study:

- Presents the first comprehensive hydraulic testing undertaken in the Inverbrackie sub catchment, involving 10 aquifer tests (comprising of pumping and injection tests) and 34 monitoring wells to characterise the aquifer properties, geometry, interconnectivity and boundary conditions.
- Involved over five years of groundwater monitoring from up to 19 site wells and a further 30 private regional wells, to benchmark the condition of the aquifer systems and to provide regional data required to support the development and calibration of a regional groundwater model.
- Involved the monitoring of the Inverbrackie Creek and other surface water features (dams and springs).
- Identified and documented the status, condition and use of over 58 private wells across 35 properties to identify the existing groundwater users and to obtain regional groundwater data (pumping and groundwater levels).

- Developed a conceptual and numerical groundwater flow model, incorporating the main hydrogeological processes and structural features, in order to predict groundwater related impacts of the proposed mining operation and to assess different water management options.

The location of site specific investigation wells, reinjection wells and regional groundwater monitoring wells (private wells, shown by unit number) are presented on Figure 10-1.

This chapter also provides context and a description of the proposed groundwater management system, including the pre-excavation grouting system and the managed aquifer recharge system, predictive modelling of the water management system and potential impacts to groundwater level against existing users and water dependent ecosystems, as well as proposed outcomes which have been workshopped with the community, and draft measurable criteria, which will be developed further through the PEPR process.

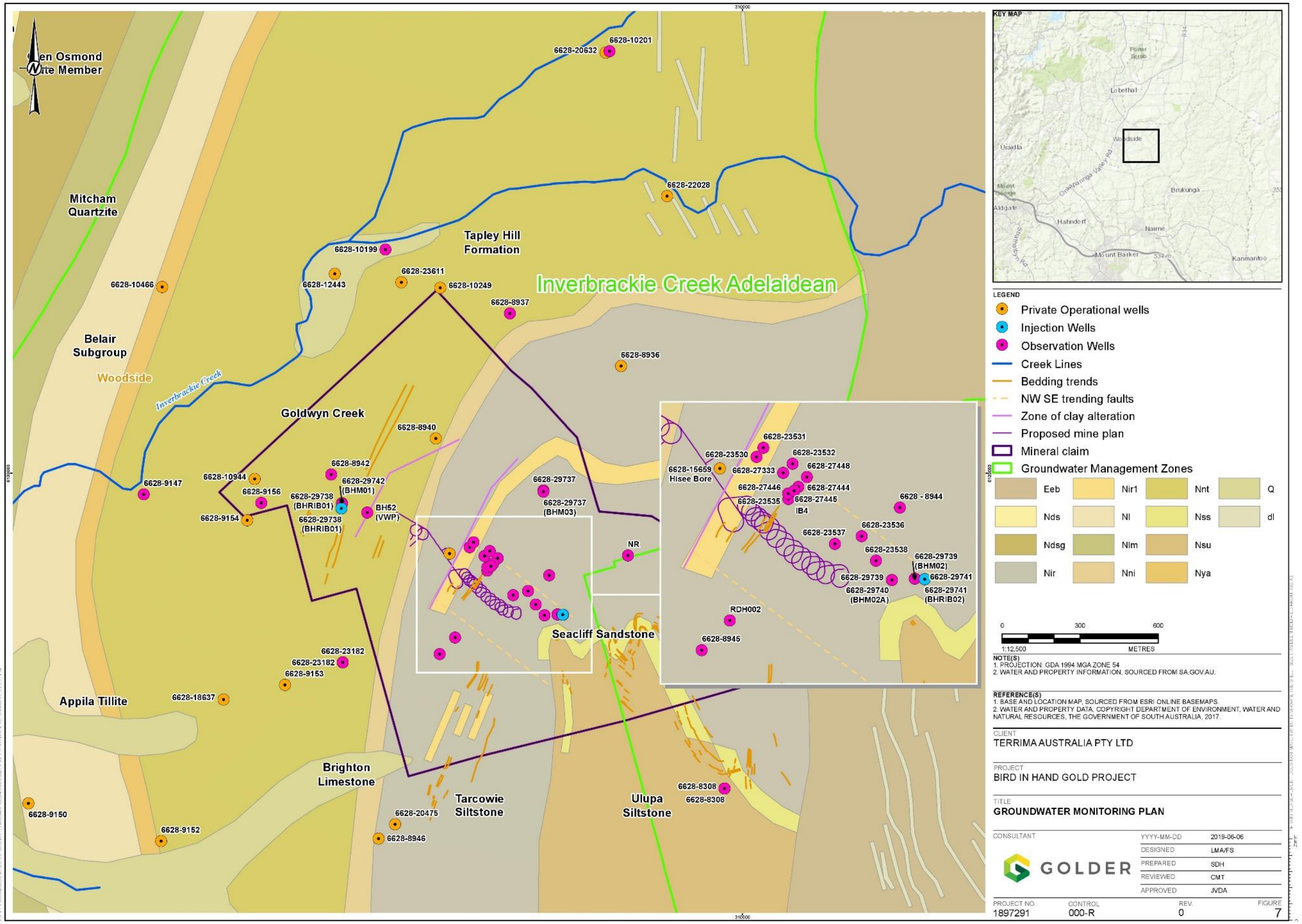

FIGURE 10-1 | GROUNDWATER MONITORING NETWORK SHOWING, SITE INVESTIGATION WELLS (IB, BH AND MB SERIES), REINJECTION WELLS (RIB) AND PRIVATE WELLS (SHOWN BY UNIT NUMBER)

10.1 APPLICABLE LEGISLATION AND STANDARDS

The relevant South Australian legislation regarding groundwater resources at the proposed mining lease is as follows:

- *Mining Act 1971*
- *Natural Resource Management Act 2004*
- *Environment Protection Act 1993*

10.1.1 *Mining Act 1971* (SA)

The *Mining Act 1971* is the premier legislation controlling mining and extractive industries in South Australia and is the legislation and associated regulations which authorised the creation of the modified Ministerial Determination (MD) for the Bird in Hand Gold Project (BIHGP) (Notice in accordance with regulations 30(3) and 49(3) of the Mining Regulations 2011). The BIHGP MD prescribes additional hydrogeology requirements at all stages of analysis, including the additional requirement for peer review of the groundwater model and groundwater management strategies.

10.1.2 *Natural Resources Management Act 2004* (SA) (NRM Act)

The *Natural Resources Management Act 2004* (NRM Act) promotes sustainable and integrated management of the State's natural resources and provides for their protection. The Act includes provisions relating to the sustainable extraction of groundwater resources and provides prescription of water resources to protect against over use and to minimise adverse effects from development.

In regards to the mine water management strategy, all water taken for consumption purposes in South Australia is regulated under the NRM Act. Under the Act, rights in relation to the ability of a person to take and use water include:

- water licences and water access entitlements
- stock and domestic rights (where these uses are not prescribed)
- Notice of Authorisation under s128 of the Act.

As the BIHGP lies within the Western Mount Lofty Ranges Prescribed Water Resources Area, a licence or authorisation under the NRM Act may be required for the extraction of the water from the mine[1]. Similarly, a permit under the NRM Act is required to recharge the water to the aquifer under the MAR[2].

Sections of the NRM Act particularly relevant to the BIHGP include Section 128, which is the [*C*]*ertain uses of water authorised*. This section may be utilised in order to allow the abstraction and subsequent drainage of groundwater as part of the overarching water management strategy for the Project. If necessary, the Bird in Hand Gold Project will apply for a section 128 authorisation under the NRM Act, to allow water to be abstracted from the Inverbrackie Creek subcatchment, and reinjected back into the aquifer, maintaining a net water neutral balance. In the alternative, Terramin may obtain the requisite groundwater allocation through the existing Water Allocation Plan and water trading framework under the NRM Act. Currently, water allocations have been sourced for the project under confidential agreements from within the Onkaparinga River catchment.

[1] Section 124(3)(a) or Section 128

[2] Section 127(3)(c) unless allowed under section 129(1)(f)(i) pursuant to an environmental authorisation under the *Environment Protection Act* 1992.

In addition, Water Affecting Activities (WAA) are regulated under Section 127 of the NRM Act. To undertake most types of WAA, a permit is required from the relevant authority, which in most cases is the Minister for Sustainability, Environment and Conservation, through the Department for Environment and Water (DEW) or the relevant Regional Natural Resources Management Board (NRM Board). To obtain a permit, the applicant must demonstrate that the WAA will be appropriately managed to protect environmental values. The proposed mine is located within the Adelaide and Mount Lofty Ranges NRM Board region and will require WAA permits to be obtained prior to operations commencing.

10.1.2.1 WMLR WATER ALLOCATION PLAN (WAP)

The Western Mount Lofty Ranges (WMLR) Prescribed Water Resources Area (PWRA) is located within the Adelaide and Mount Lofty Ranges Natural Resources Management Region. It is a regional-scale resource for which groundwater, surface water and watercourse water are prescribed under the NRM Act. The Project is predominantly located within the WMLR water allocation plan (WAP), which provides for the sustainable use of the water resources, and water management has been designed specifically to meet the objectives of the WAP.

The entire water management strategy for the BIHGP has been designed to meet the objective of the WAP, which is to *account for the needs of existing water users and protect them from the potential impacts of new users or people wanting more water (Western Mount Lofty Ranges Water Allocation Plan Fact Sheet | October 2013).*

A review against the WAP for both a project utilizing s 128 of the NRM Act, and through water trading through the WAP/NRM Act framework is included in Appendix B8.

10.1.3 *Environment Protection Act 1993* (EP Act)

The *Environment Protection Act 1993* (EP Act) also identifies Water Protection Areas in South Australia, which have been delineated for the purposes of providing them with special environmental protection. The majority of the proposed ML is located within the Mount Lofty Ranges Water Protection Area. This project is likely to be subject to section 64 of the *EP Act* as part of the EP authorisation under part 6 of the *EP Act*.

Further information regarding the requirements and relevance of the legislation is provided in Chapter 4.

The following standards provide a range of assessable criteria relevant to the protection and management of groundwater resources:

- Environment Protection (Water Quality) Policy 2015 (Water EPP)
- The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)
- AS 1940-2004: The storage and handling of flammable and combustible liquids
- AS 1692-2006: Steel tanks for flammable and combustible liquids
- EPA 080/12: Liquid Storage Guidelines – Bunding and Spill Management: update August 2012.

The Water EPP applies to all groundwaters in South Australia and seeks to achieve water quality objectives that will protect or improve defined environmental values. The protected environmental values for groundwater are beneficial uses of groundwater requiring protection against pollution:

- Aquatic ecosystems (freshwater)
- Recreational use and aesthetics (primary contact and aesthetics)

- Potable use
- Agriculture and aquaculture uses (irrigation, stock watering and aquaculture)
- Industrial use

Achievement of water quality objectives under the Water EPP is achieved by compliance with the Water Quality Criteria specified in Schedule 2 of the policy.

The ANZECC guidelines provide a framework for conserving water quality in rivers, lakes, estuaries and marine waters. In general, these Guidelines should also apply to the quality of both surface water and of groundwater since the environmental values which they protect relate to above-ground uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems).

The nominated Australian standards each contain specific design criteria that will be incorporated into the design of the proposed mining lease to protect the key environmental and stakeholder values relevant to groundwater resources. Specifically, this relates to the storage of hazardous materials onsite, such as hydrocarbons, grouting mixtures, herbicides, and is detailed in Chapter 11: Surface Water.

10.1.4 GROUNDWATER MODELLING

The Australian Groundwater Modelling Guidelines published in June 2012 (Barnett et al, 2012) have rapidly been adopted throughout the groundwater industry as a benchmark for best industry practice.

The guidelines are almost uniformly referenced by environmental regulators, model developers and groundwater modellers and have largely superseded the previous Murray–Darling Basin Groundwater Flow Modelling Guideline of 2001.

The Ministerial Determination for the Bird in Hand Gold Project requires the development of the numerical groundwater flow model as per the Australian Groundwater Modelling Guidelines (2012) to model the existing groundwater environment and to model the potential impacts of proposed mining operations on groundwater receptors (as required by Section 6 of the Determination). It is also a requirement of the Determination to include an independent peer review by an experienced hydrogeologist with modelling experience as per the Australian Groundwater Modelling Guidelines (2012).

10.2 ASSESSMENT METHOD

A groundwater impact assessment was undertaken to assess the effect of mining on groundwater including MAR.

The groundwater investigation commenced with a groundwater census to identify the receptors such as private wells and springs surrounding the BIHGP. This survey covered the Inverbrackie sub-catchment (within the Western Mount Lofty Ranges) and parts of the neighbouring Dawsley Creek sub catchment (within the Eastern Mount Lofty Ranges). The census involved documenting the location, status, condition and use of over 58 private wells across 35 properties and groundwater dependent ecosystems such as the Inverbrackie Creek and associated springs.

The assessment of aquifer characteristics was undertaken over two drilling programs, as follows.

- The first drilling program was undertaken in 2014 and involved the installation of five investigation wells to depths of 135 to 270 m and extensive pumping test to assess the hydraulic characteristics of the fractured rock aquifer (FRA) around the proposed mine workings.

- The second drilling program was undertaken in 2018 and involved the installation of a further six investigation wells (including two injection wells) around the periphery of the proposed mine area and extensive injection testing to assess the ability of the FRA to receive mine water through MAR and offset groundwater related impact.

Information obtained from the investigation wells (such as lithology, downhole geophysics, fracture characteristics, aquifer yield and permeability) were used to update an existing structural geological model which identified the main water bearing zones.

Routine water level and water quality monitoring of about 30 private wells, site monitoring wells and several springs within the Inverbrackie Creek commenced in 2013 and is ongoing. This information was used to benchmark the condition of the groundwater system and to provide the data needed to develop (and calibrate) a regional groundwater flow model.

The baseline groundwater monitoring, investigation well drilling and aquifer testing (pumping test and injection tests) has resulted in an enormous collection of hydrogeological information. From this information, construction of a regional conceptual hydrogeological model was undertaken. This assisted in the development of a numerical model in which structural elements, such as faults and fracturing could be incorporated.

The numerical model was used to simulate the effects of the mining operation on the groundwater system and assess best practice water management options. The robustness of the model was improved by the abundance of monitoring and investigation data (both historic and current) which provided the opportunity for a multiple-lines-of-evidence approach to model calibration. The model underwent four calibration processes, comprising:

1. a pre-mining steady-state calibration process.
2. a transient calibration process based on the pumping test of the underground mine area.
3. a regional transient calibration process based on seasonal abstraction for irrigation and the regional groundwater level response.
4. a transient calibration process based on two pumping and injection tests on wells surrounding the proposed mine.

A subsequent model validation phase included comparison with catchment modelling-based estimates of baseflow to Inverbrackie Creek, as well a scenario simulation for comparison with historical anecdotal observations of drawdown during mining operations.

The four calibration and two validation processes strengthened the ability of the model to replicate the behaviour of the real system such that it could be used for predicting future behaviour from underground mining and the effects on groundwater receptors.

The Groundwater Assessment and associated Modelling Report is located in Appendix H1.

10.3 EXISTING ENVIRONMENT

10.3.1 REGIONAL HYDROGEOLOGY

The prime aquifer system in the Inverbrackie Creek Sub-Catchment is a FRA which comprises of several hydro-stratigraphic units, namely, the Tapley Hill Formation, Brighton Limestone (Marble), Tarcowie Siltstone, Cox Sandstone and the Kanmantoo Formation, to the east (Figure 10-2). The hydrogeological characteristics of these hydrostratigraphic units derived from field investigations are summarised in Table 10-2.

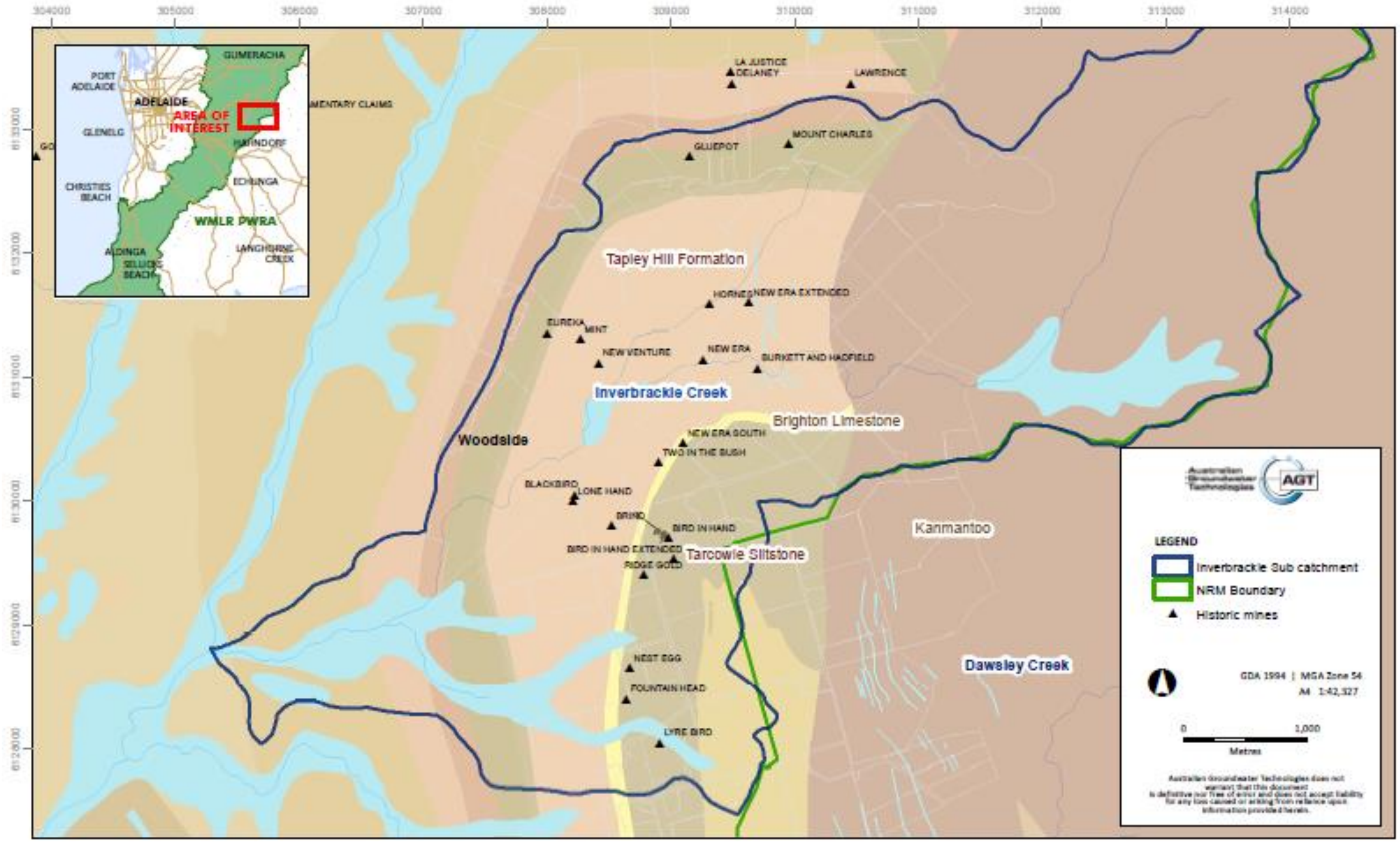

FIGURE 10-2 | STUDY AREA SHOWING INVERBRACKIE SUB CATCHMENT AND SURFACE GEOLOGY.

Almost half of the sub-catchment (eastern part) is underlain by the Kanmantoo Group which has been identified as a very poor aquifer and is not developed for irrigation. The younger geological sequences such as the Tapley Hill Formation and the Tarcowie Siltstone are most prominent in the rest of the catchment. Groundwater drawn from these formations is generally < 1,500 mg/L with yields typically ranging from below 5 L/s to mostly 10 L/s. Occasionally, higher yields are obtained.

There are also shallow colluvial/alluvial perched aquifer systems which are associated with modern day water courses. This is part of a localised perched groundwater systems associated with topographical lows/drainage lines. The closest of these is located to the south-east of the Bird-in- Hand and overlies the proposed mine area. Groundwater levels are very shallow, ranging from 1 m to 3 m below ground level (434 to 438 m AHD). These systems are disconnected from the deeper underlying FRA (which has a groundwater elevation of 409 m AHD at this location – shown by ONK018, ONK017, ONK025 and ONK020 in Figure 10-3). ONK023 is one of these abandoned wells targeting the perched aquifer – shown in Figure 10-3. These shallow groundwater systems are thin and not extensive and provide only a small portion of the groundwater resource, with all wells being abandoned but not decommissioned by private landholders.

Further confirmation of these systems are reported in the 2018 MAR drilling program, reported on in Appendix H8.

Water level and quality data for every well monitored in included in Appendix C1 and C2 of the Groundwater Assessment located in Appendix H1, as well as a 2018 update located in Appendix H11.

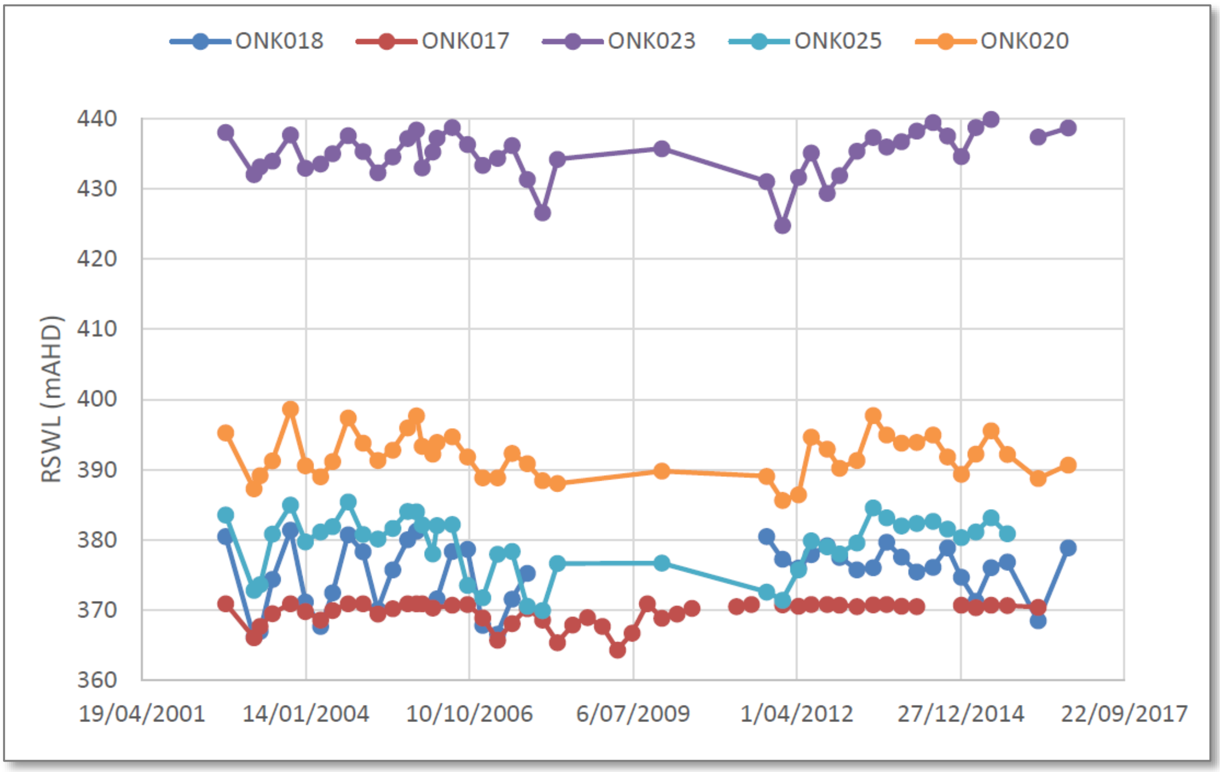

FIGURE 10-3 | SELECTED HYDROGRAPHS OF GOVERNMENT (ONK)

TABLE 10-2 | SUMMARY OF HYDROSTRATIGRAPHIC UNITS (INCLUDING UPDATES FROM 2018-9 MAR DRILLING AND TRIAL) (APPENDIX H1 AND H8)

Hydrostratigraphic unit	Groundwater Total Dissolved Solids (mg/L)	Electrical Conductivity uS/cm	Yield (L/s)	Transmissivity (m^2/d)	K (m/d)	Storativity	Formation thickness	Environmental values of particular waters (Water EPP)
Quaternary (Perched groundwater system)	<500 (200)	<250	Not evaluated	Not evaluated	Not evaluated	Not evaluated	<15 m	Drinking water for human consumption; Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Tarcowie Siltstone (multiple samples including Hanging wall fault)	774-1,400 (911 in fault)	1200 – 2200	up to 38 L/s	17 - 125 HWF interval *5 - 175.5* *(6628-8945 & 20475 Nest Egg)*	0.3 - 2.5 HWF interval	0.0004 to 0.007	Thickens to ~450 m Fracturing in HWF occurs over a 20-60 m interval	Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Tarcowie Siltstone (BHRIB02) *Multiple samples collected**	1440 (developed) 1480 (85m drilled) 1540 (151 m drilled)	2220 2270 2370	<30 L/s	33	0.31	2.3×10^{-5}	>151 m	Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Cox Sandstone	1,000	1900	1 L/s	0.1	0.003	Not evaluated	21 m	Drinking water for human consumption;

Hydrostratigraphic unit	Groundwater Total Dissolved Solids (mg/L)	Electrical Conductivity uS/cm	Yield (L/s)	Transmissivity (m^2/d)	K (m/d)	Storativity	Formation thickness	Environmental values of particular waters (Water EPP)
								Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Brighton Limestone (Marble)	1,100–1,300	1900 – 2050	0.2–2 L/s	0.05 - 10	0.001 - 0.15	0.0001	40 - 60 m	Drinking water for human consumption; Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Tapley Hill Formation (TDS data is from regional groundwater census, Appendix A, AppendicC.2)	363–1,480	600 – 2690	up to 20 L/s	0.5 - 1.5 Footwall interval *6* *(6628-8939)*	0.02 - 0.06 Footwall Interval	Not evaluated	Thickens to ~500 m Depth to productive zone varies from 50 to 150 m across irrigation area	Drinking water for human consumption; Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.

Hydrostratigraphic unit	Groundwater Total Dissolved Solids (mg/L)	Electrical Conductivity uS/cm	Yield (L/s)	Transmissivity (m^2/d)	K (m/d)	Storativity	Formation thickness	Environmental values of particular waters (Water EPP)
Tapley Hill Formation (BHRIB01) *Multiple samples collected**	1120(developed) 1100 (35m drilled) 1060 (72m drilled)	1370 1690 1630	< 50 L/s	24 - 84	0.32	1.5×10^{-5}	>72 m	Drinking water for human consumption or Primary industries— irrigation and general water uses
Kanmantoo Group	1,200 –4,000	2200 - 6000	<5 L/s	*11 (6628-8301)*	*0.1 m/day (6628-8301)* 0.01 - 001 (Coffey 2007)*		> 350 m	Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.

10.3.2 Hydrogeology of the Bird in Hand Project Site

A conceptual model of the site hydrogeology is shown on Figure 10-4. Also depicted is the historic Bird-in-Hand mine workings and investigations wells (IB-1 to -5) that were drilled to investigate aquifer properties beyond the depth of the old mine workings.

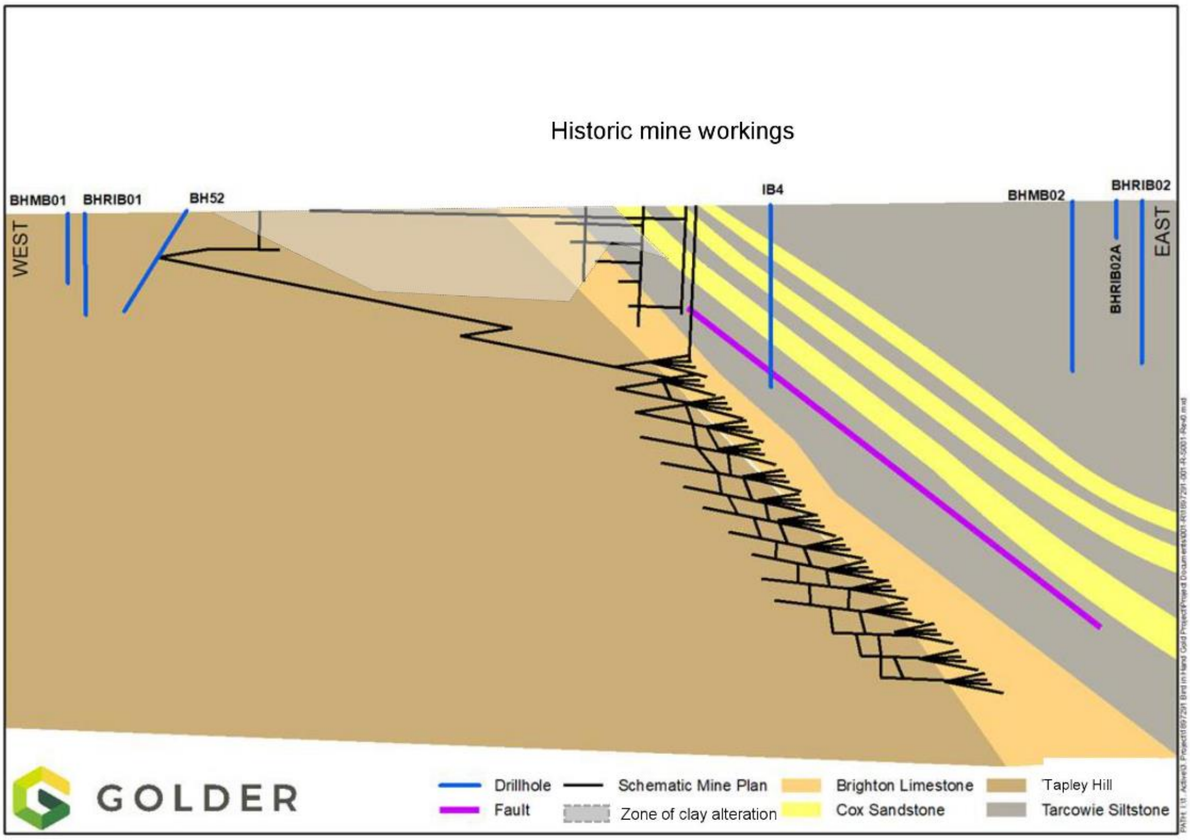

FIGURE 10-4 | CROSS SECTION SHOWING THE MAIN HYDRO-STRATIGRAPHIC UNITS.

Drilling investigations at BIHGP have provided a valuable new insight into the aquifer properties and fracturing beyond the depth of the old Bird-in-Hand mine workings

The investigation wells (IB-1 to -5) identified a significant water-bearing fracture zone in the hanging wall located above the gold deposit (Marble). This fracture, when modelled in conjunction with diamond drilling data, is shown to extend towards the old mine workings (located above the proposed mine), roughly coinciding with the depth where high water inflows were encountered in the old mine workings, at 113 metres. Anecdotal information (Department of Mines, 1945) suggests that in 1934 80% of the historic mine inflows were derived from this fracture zone.

The fracture has an airlift yield, measured in IB4 of up to 38 L/s and transmissivity of 68 m^2/day (geometric mean). This feature represents the most significant mode of groundwater flow if intercepted by mine workings. The fracture zone has a dip of ~45 degrees to the west and intercept the Marble, but elsewhere is separated from the Marble by lower permeability siltstone.

The transmissivity of the underlying Marble that contains the gold deposit was shown by investigation drilling to be very low (0.5 to 10 m^2/d), but this may not be representative as subsequent exploration (undertaken in 2016) drilling identified cave zones at shallower depths, leading to refinement of the site geological model. As water is hosted in a fractured rock aquifer, water quality is expected to be of the same quality as the host aquifer. Uncertainty analysis regarding volumes of water associated with caves is included in section 10.7.2. More information regarding caves can be found in Chapter 2: section 2.7.5.

Underlying the Marble and outcropping west and north of the BIHGP is the fine sandstone/siltstone of the Tapley Hill Formation, where it is utilised by the majority of private wells at depths typically less than 150 m deep (average well depth is 85 m).

The drilling at Bird-in-Hand Project site indicated that the Tapley Hill Formation, at the tested depth of 270 - 295 m, has a very low yield (0.25 L/s) and Transmissivity (1 m^2/d).

10.3.2.1 GROUNDWATER SALINITY

Extensive groundwater sampling was undertaken at site wells and private wells to understand the capacity of groundwater to support environmental and human uses. The groundwater salinity is a key indicator for this. The groundwater salinity of the FRA measured from >50 wells within Inverbrackie Creek subcatchment is typically TDS < 1,000 mg/L, with a few wells being < 1,500 mg/L (Figure 10-5). As defined by Schedule 1 of the Water EPP, the environmental value of groundwaters in the Inverbrackie Creek sub-catchment range from Drinking water for human consumption to Primary industries— irrigation and general water uses and Primary industries— livestock drinking water. A table can be referred to above - Table 10-2.

Private monitoring bores which targeted the Kanmantoo Group to the east of the sub-catchment revealed higher groundwater salinities (up to 4,000 mg/L) (Figure 10-2), owing to low groundwater recharge and signifying older groundwaters. These groundwaters have fewer beneficial uses (environmental values), and are generally restricted to livestock drinking waters, as outlined in Table 10-2.

The shallow perched alluvial systems have groundwater salinity of <500 mg/L due to high recharge rates, but these systems provide very limited groundwater supply – more detail on perched system is above in section 10.3.1.

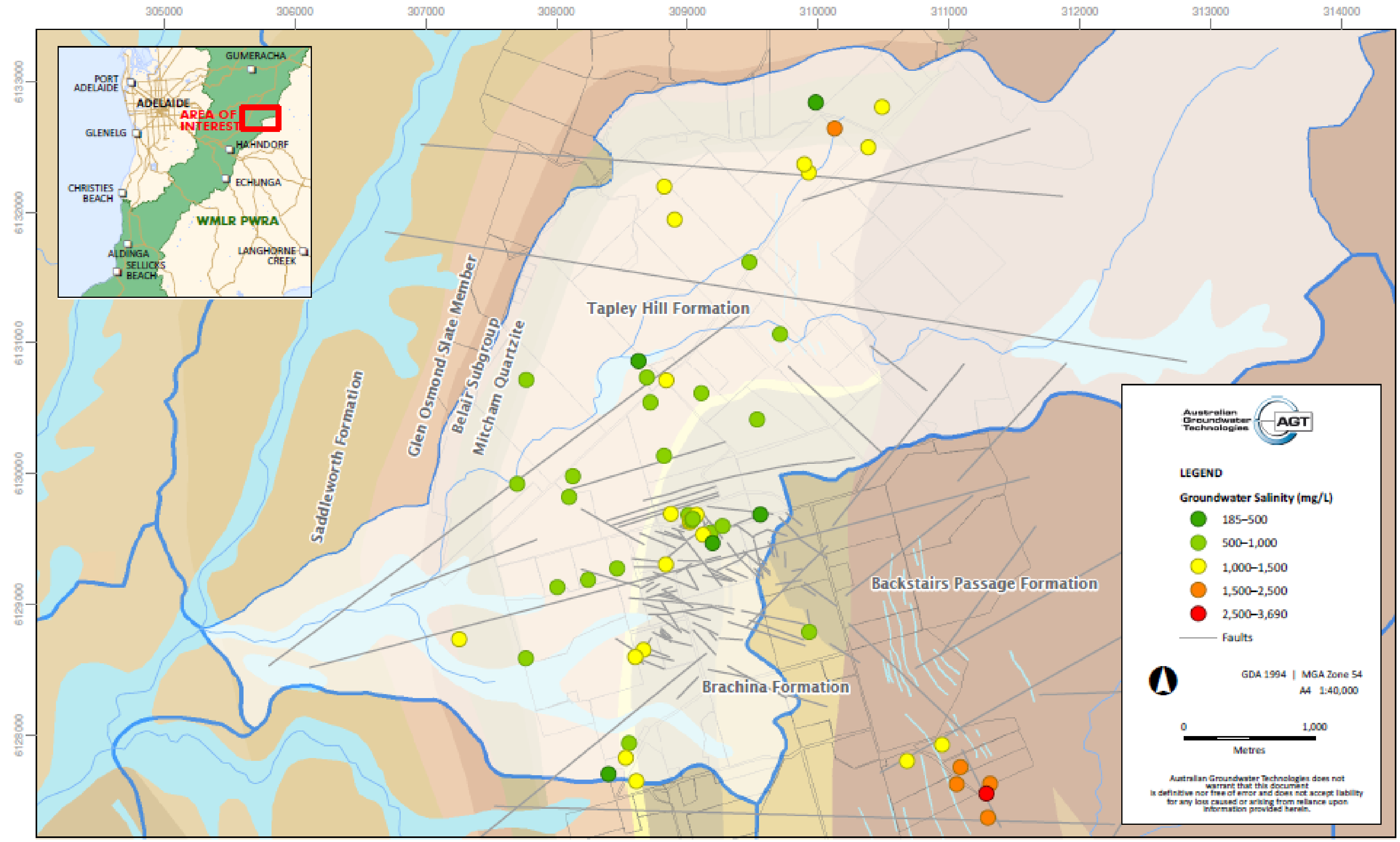

FIGURE 10-5 | SPATIAL DISTRIBUTION OF GROUNDWATER SALINITY

10.3.2.2 GROUNDWATER QUALITY

Comparison of the baseline IB well groundwater quality results for dissolved metals, nutrients and hydrocarbons against the ANZECC guideline values for Freshwater Ecosystem Protection (95%), which is the level recommended for slightly to moderately disturbed ecosystems (ANZECC, 2000) indicates a number of already existing (i.e. prior to any new mining operations) exceedances of the guideline values.

Investigation Wells IB-1 to -5

- The guideline limit for zinc (0.08 mg/L) was exceeded in ten samples across all wells (0.91 – 10.8 mg/L).
- The guideline limit for copper (0.0014 mg/L) was exceeded in all wells in sixteen samples (0.002 - 0.346 mg/L).
- The guideline limit for lead (0.0034 m/L) was exceeded in all wells in ten samples (0.004 – 0.05 mg/L).
- The guideline limit for phosphorous (0.02 mg/L) was exceeded in all wells in 18 samples (0.03 – 0.14 mg/L).
- The guideline limit for ammonia (0.9 mg/L) was not exceeded in any well.
- The guideline limit for selenium (0.011 mg/L) was not exceeded in any well.

Trends of major anolytes over the water census period are included in Appendix C1 of the Groundwater Assessment (Appendix H1).

Exploration monitoring wells BH-16, -34, -35, and -41 to -44

- The guideline limit for aluminum (0.055 mg/L) was exceeded in four samples in BH-42 and -44 (0.08 – 0.96 mg/L).
- The guideline limit for zinc (0.08 mg/L) was exceeded in thirteen samples across wells BH-41 to -44 (0.94 – 2.12 mg/L).
- The guideline limit for copper (0.0014 mg/L) was exceeded in all wells in 22 samples (0.002 - 0.023 mg/L).
- The guideline limit for lead (0.0034 m/L) was exceeded in all wells in seventeen samples (0.004 – 0.088 mg/L).
- The guideline limit for phosphorous (0.02 mg/L) was exceeded in all wells in 24 samples (0.03 – 0.77 mg/L).
- The guideline limit for ammonia (0.9 mg/L) was exceeded in eight samples in BH-42 and -44 (0.14 – 3.25 mg/L).
- The guideline limit for selenium (0.011 mg/L) was not exceeded in any well.

Trends of major anolytes over the water census period are included in Appendix C1 of the Groundwater Assessment (Appendix H1).

Private wells (census)

- The guideline limit for aluminum (0.055 mg/L) was exceeded in 56 samples (0.08 – 1.92 mg/L).
- The guideline limit for zinc (0.08 mg/L) was exceeded in thirteen samples (0.081 – 15 mg/L).
- The guideline limit for copper (0.0014 mg/L) was exceeded in 113 samples (0.002 - 0.149 mg/L).
- The guideline limit for lead (0.0034 m/L) was exceeded in 34 samples (0.004 – 0.12 mg/L).

- The guideline limit for phosphorous (0.02 mg/L) was exceeded in 145 samples (0.03 – 4.25 mg/L).
- The guideline limit for ammonia (0.9 mg/L) was exceeded at only one well in five samples (2.77 – 4.15 mg/L).
- The guideline limit for selenium (0.011 mg/L) was exceeded at only one occurrence (0.03 mg/L).

Water level and quality for each private bore assayed between 2014 and 2017 is located in Appendix C2 of the Groundwater Assessment (Appendix H1).

Further baseline data updates for all wells up to 2018 is included in Appendix H11, and water quality sample results obtained during the MAR trial are included in Appendix C of the MAR Investigation Report (Appendix H9).

10.3.2.3 GROUNDWATER ELEVATION

The regional groundwater flow pattern (potentiometric surface) is shown on Figure 10-6. At a regional scale, groundwater flow follows the form of the topography, from areas of high topography to the lowest, discharging in some areas to the Inverbrackie Creek.

Groundwater elevation ranges from 470m AHD in the north-east of the Inverbrackie Creek Sub-Catchment to 345 mAHD in the south-west of the sub-catchment, with one well (ONK 17) (with a depth of 44.8 metres (well head elevation of 370m AHD – depth to 326.1m AHD), near the Inverbrackie Creek, reporting artesian conditions.

Groundwater level monitoring undertaken to the east of Inverbrackie Creek sub-catchment indicated a groundwater divide which is aligned with the topographical high between the Inverbrackie and Dawsley Creek sub-catchments. On the eastern side of the divide groundwater flows towards Dawsley Creek and on the western side groundwater flows towards Inverbrackie Creek (Figure 10-6)

Horizontal hydraulic gradients vary from 1% in the Tarcowie Siltstone to much steeper gradients within the Tapley Hill Formation (3-4%), attributed to a change to lower aquifer transmissivities to the west of the Bird-in-Hand Project.

Water level for each bore measured between 2014 and 2017 is located in Appendix C1 and C2 of the Groundwater Assessment (Appendix H1), 2018 is included in Appendix H11.

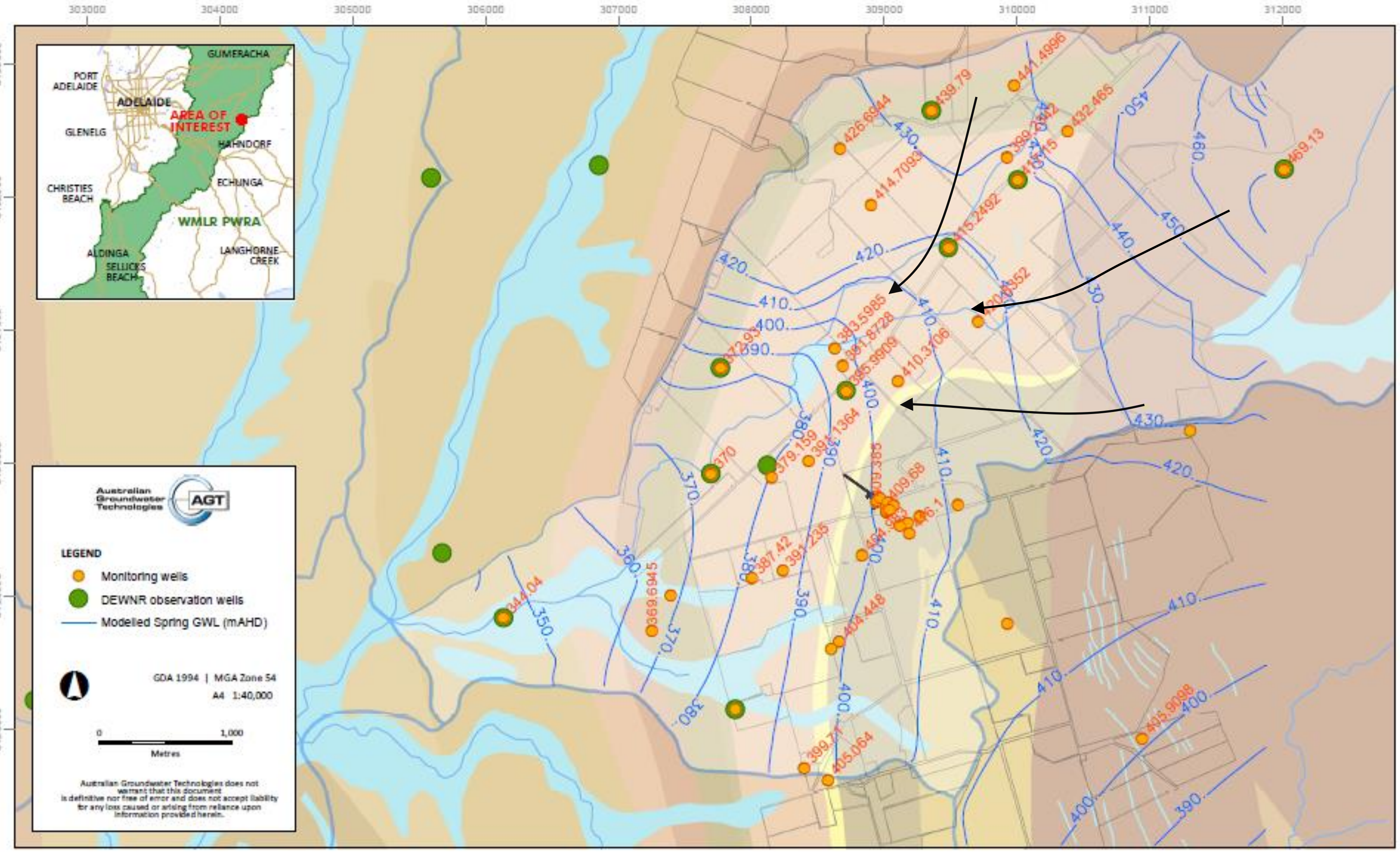

FIGURE 10-6 | POTENTIOMETRIC SURFACE OF THE FRA (APPENDIX H1)

10.3.2.4 ACID AND METALLIFEROUS DRAINAGE

An acid and metalliferous drainage (AMD) assessment was undertaken by Tonkin (2017) by examining the geochemical characteristics of 58 representative samples of selected country rock drill-core that represent the proposed mine geology (Appendix M2).

The Assessment found that pyrite mineralisation within the Tapley Hill Formation at BIHGP is relatively rare, and of the 46 samples tested only five had a Total Sulfur percent of >0.3%, and only six samples classified as Potentially Acid Forming (PAF), indicating a low potential for AMD generation.

Brighton Limestone material was classified as Non-Acid Forming (NAF) with abundant acid neutralising capacity due to the presence of carbonate minerals.

The Tapley Hill Formation immediately to the north-west of the Bird-in-Hand orebody contains an upper zone of highly weathered, bleached (kaolinised) siltstones and minor very fine grained sandstones. The maximum 90 m depth of the bleaching occurs immediately adjacent to the orebody. Both the intensity and depth of the bleaching decreases away from the orebody such that at 250 m to the north-west the depth of the bleaching has shallowed to 50 m and at distance of 350 m from the orebody bleaching is not present. Where bleaching is present a supergene sulphide layer has developed just beneath the water table. The supergene sulphide layer typically extends a further 10 m below the water table and contains trace levels of secondary sulphides. The supergene sulphides are typically present as fine, disseminated pyrite within a silty clay matrix (example provided in Figure 10-7), although higher concentrations of pyrite may occur in healed fractures.

The zone consists of silty clay, which has a very high surface area to void space ratio. It has a firm toothpaste-like consistency which makes it both impervious and impermeable (low permeability), and therefore virtually impossible to dewater. As such, it will retain water throughout the mining operation and preserve its present state of saturation with oxygen-poor water, maintaining the stability of the trace levels of pyrite within it.

The supergene zone has been analysed by Tonkin Consulting and is located in Appendix M2.

FIGURE 10-7 | EXAMPLE OF THE INTENSE CLAY ALTERATION WITHIN THE SUPERGENE SULPHIDE BLANKET

10.3.3 Seasonal groundwater level trends

Available groundwater level data includes monitoring records from the DEW Obswell network ('ONK' series wells), which date back to 2002 and monitoring of site wells and private wells undertaken by Terramin since 2013 (Figure 10-8).

Groundwater levels throughout the Inverbrackie Creek sub-catchment have remained steady over the preceding 13 years (Table 10-11). Of particular relevance are ONK018 and ONK020, which target the Tapley Hill Formation near the main irrigation area, and show no long-term groundwater level decline associated with groundwater abstraction.

Table 10-11 shows that historically, many 'ONK' wells revealed large seasonal drawdowns of greater than 10 m in the Tapley Hill Formation, due to seasonal pumping. Locations of ONK wells are shown in Figure 10-9. The seasonal drawdown has generally reduced post-2009, and may be due to a reduction of the reliance on groundwater that has been noted throughout the area by many long term landholders/farmers in the Inverbrackie Valley, owing to the reduction of irrigated pasture, dairies and potato farming in the region, and the increasing nature of fragmented land use and rural residential properties. This information was gathered during the groundwater census conducted between 2014 and 2018. Groundwater levels from private landholder bores have continued to be taken right up until submission of this mining lease application where land access is available.

During the irrigation seasons, the groundwater levels at the BIHGP site monitoring wells which target the Marble, Tarcowie Siltstone and Cox Sandstone revealed a 'muted' seasonal drawdown of only 1.5 m (Figure 10-10).

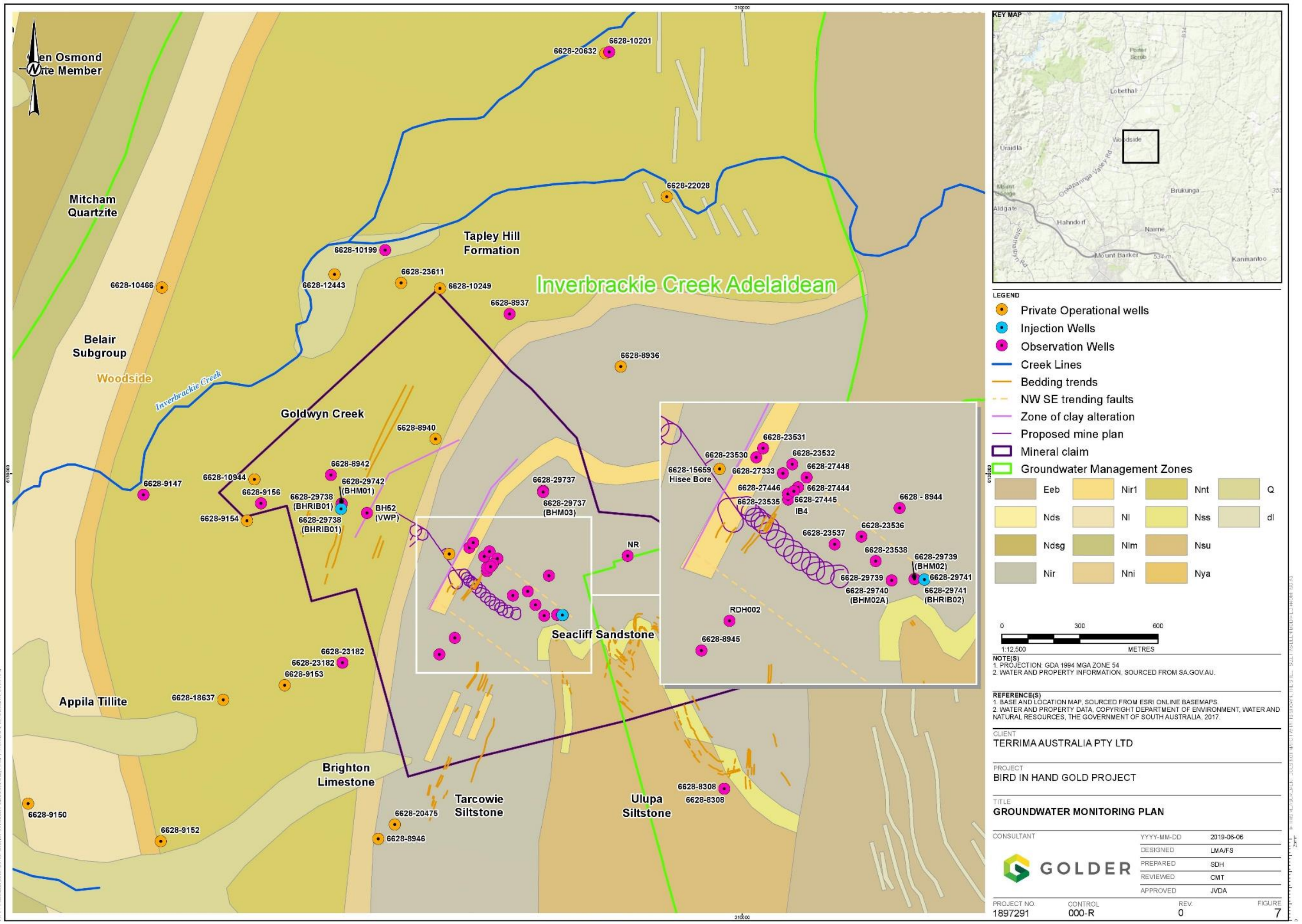

FIGURE 10-8 | LOCATIONS OF SITE AND REGIONAL MONITORING WELLS

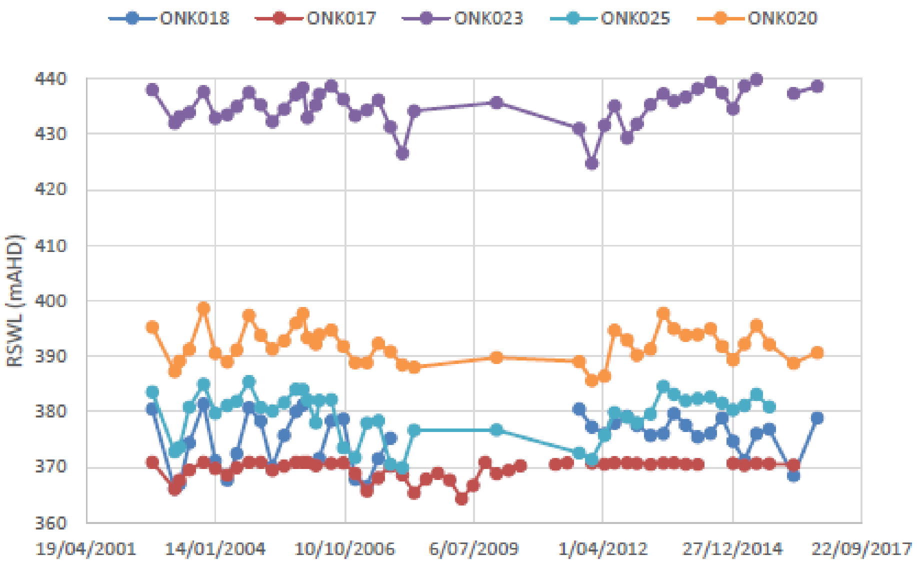

FIGURE 10-9 | HYDROGRAPHS OF REGIONAL DEW OBSERVATION MONITORING WELLS (ONK)

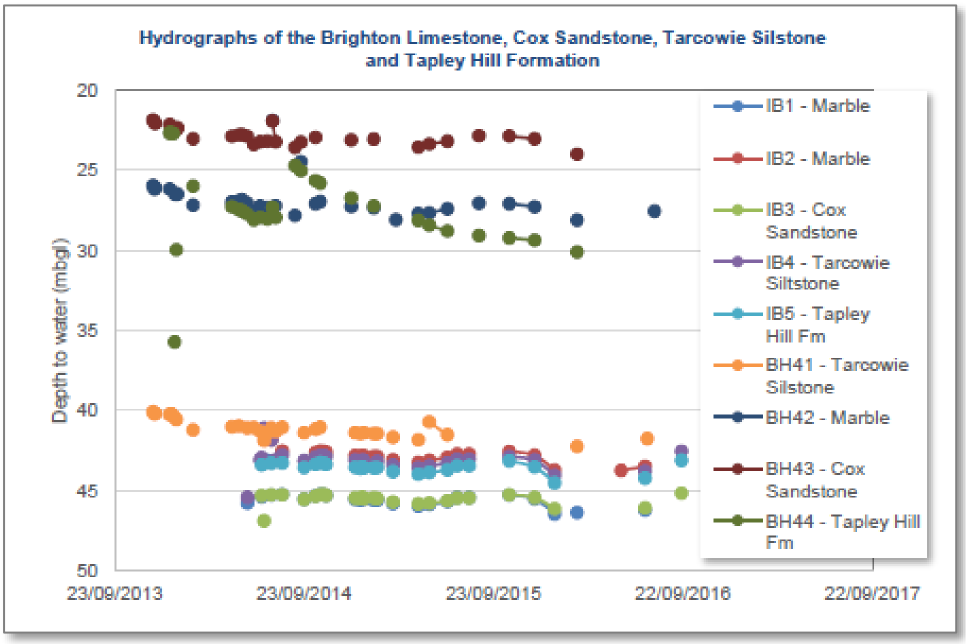

FIGURE 10-10 | HYDROGRAPHS OF SITE MONITORING WELLS

10.3.4 GROUNDWATER RECHARGE AND DISCHARGE

The FRA occurs in rolling to steep topography where the percentage of rainfall contributing to surface water runoff is significantly higher than more flat-lying areas. In addition, due to the age of the geological units forming fractured rock aquifers weathering commonly occurs along the upper surface of the rock mass. This weathering commonly results in the alteration of the rock materials to form clay minerals which inhibit the vertical movement of water.

Groundwater moves from the higher points in the landscape to the lowest, where discharge occurs to the Inverbrackie Creek (Figure 10-6). Consequently, the creek acts as drains for the FRA. This discharge constitutes the baseflow of the streams that dominates flow for most of the year, particularly over the summer and between rainfall events. The long-term average of baseflow to the Inverbrackie Creek was estimated by Zulfic (2003) to be 874 ML/y.

10.3.4.1 GROUNDWATER RECHARGE

Groundwater recharge was estimated using the Chloride Mass Balance (CMB) based on chloride concentrations measured from 51 wells. Within the Inverbrackie Sub catchment, groundwater recharge ranged from 15 mm/y to 60 mm/y. Lower recharge rates of <5 to 20 mm/y were calculated for the Kanmantoo Formation to the east.

10.3.4.2 INVERBRACKIE CREEK AND ASSOCIATED SPRINGS / BASEFLOW

The BOM GDE Atlas identified a low potential for the Inverbrackie Creek to be a Groundwater Dependent Ecosystem – by national assessment.

Monitored stream level and salinity together with groundwater level data captured over the winter and summer seasons has been assessed to understand the interaction between surface water and groundwater within the catchment area surrounding the Bird-in-Hand Gold Project site.

During field work, Terramin can confirm that the Inverbrackie Creek is a groundwater dependent ecosystem (identified by the groundwater census). At its closest point, the Inverbrackie Creek is located 700 m to the north-northwest of the proposed underground workings (Figure 10-2).

Topographic and creek bed level data along the Inverbrackie Creek suggests the creek is a losing system in the north eastern (higher relief) portion of the catchment, where winter groundwater elevations are more than 5 m below the creek level (Figure 10-11). This is supported by the historic creek level data recorded at Craigbank (Station A5030508) (Figure 10-12), which indicates that the Inverbrackie Creek is ephemeral, flowing during winter months and following major rainfall events only.

The historic data from the gauging station positioned downstream indicates that the baseflow contribution to the creek is small and variable (i.e., impacted by seasonal pumping for irrigation) (Figure 10-12). In summer for example, groundwater abstraction from the Tapley Hill Formation has resulted in the lowering of groundwater levels around most of the Inverbrackie Creek area, eliminating much of the baseflow contribution throughout the summer months.

The Inverbrackie Creek receives baseflow in the lower reaches, mostly during spring when the groundwater elevation is higher, significantly reducing during summer, caused by groundwater levels being lowered by irrigation pumping. Figure 10-11 shows that groundwater levels are higher than the base of the creek in a number of locations and this has been confirmed by the presence of a number of small discontinuous pools (springs) that persist during summer. The locations of these springs are shown on Figure 10-13.

Water samples taken from these springs show the Inverbrackie Creek is of poor condition, enriched with nutrients and high in sediment due to human disturbance and this has been reported in a separate baseline study (Terramin, 2017). It has a moderate diversity of invertebrates and lacks any rare or sensitive species (EPA, 2013).

The surface salinity of the creek upstream is 800 mg/L and downstream is 1,200 mg/l. During higher flows the salinity at both sites reduces to 400 mg/L. The higher salinity downstream could be attributed to some groundwater baseflow and possible evapoconcentration of pools (which are flushed during high flows). When compared to local groundwaters, the major ion chemistry of the pools suggested the waters were derived from groundwater baseflow.

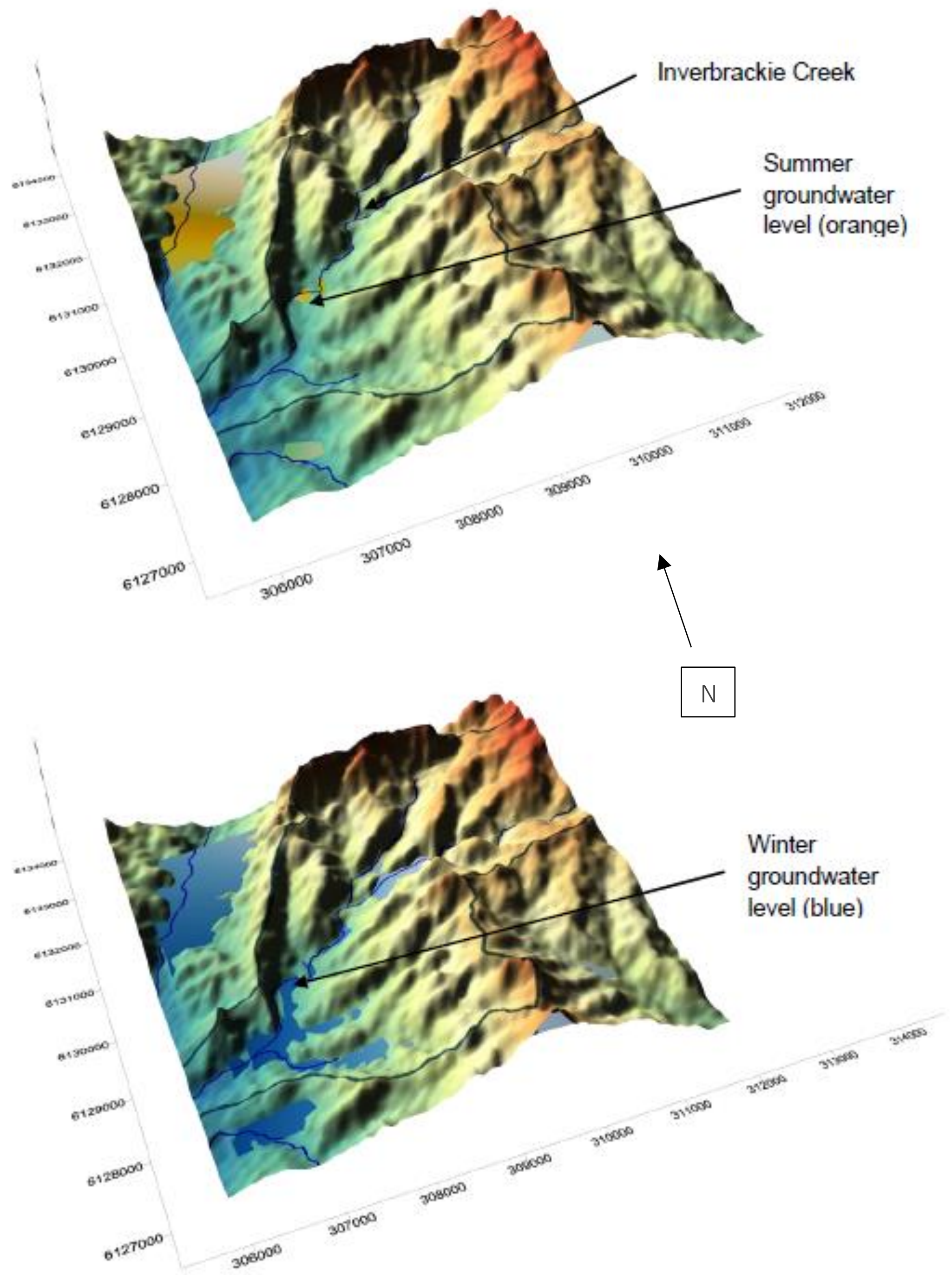

FIGURE 10-11 | TOPOGRAPHIC ELEVATION AND GROUNDWATER ELEVATION FOR SUMMER (TOP) AND WINTER (BOTTOM).

Areas where latter is visible above the former, interpolated groundwater pressure head is greater than land surface elevation, therefore representing surface expression

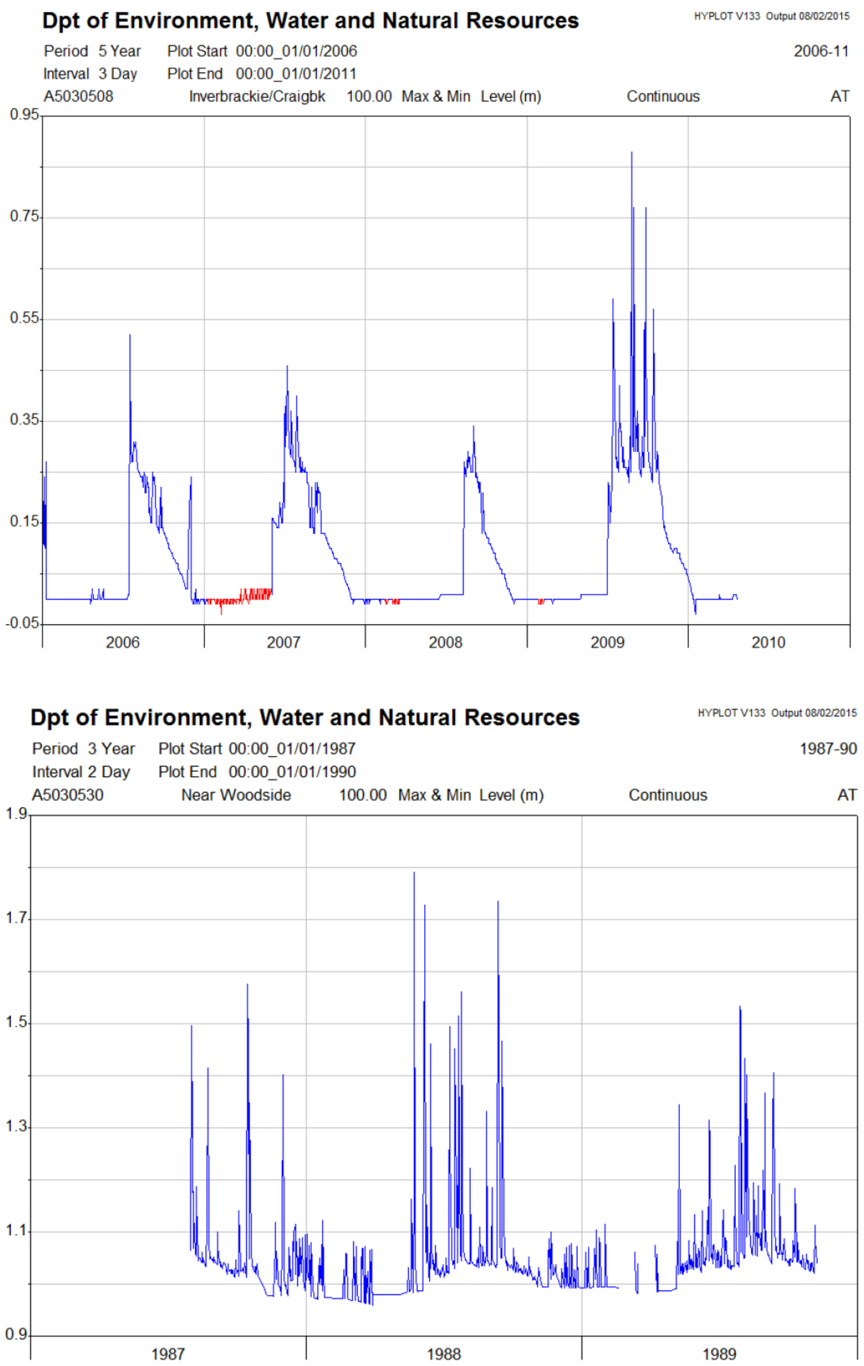

FIGURE 10-12 | SURFACE WATER GAUGING STATION FOR UPSTREAM (TOP) AND DOWN-STREAM

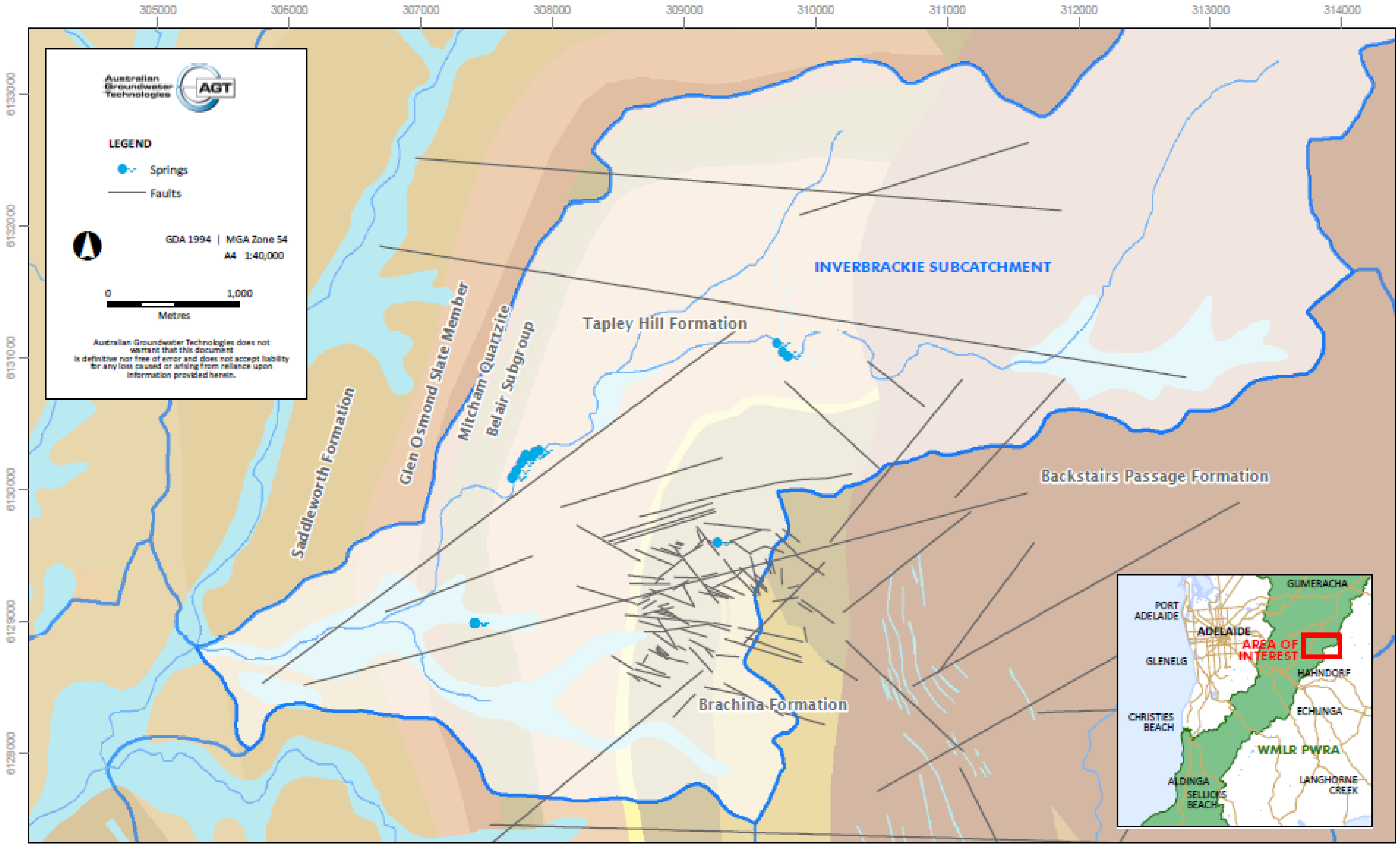

FIGURE 10-13 | SPRINGS

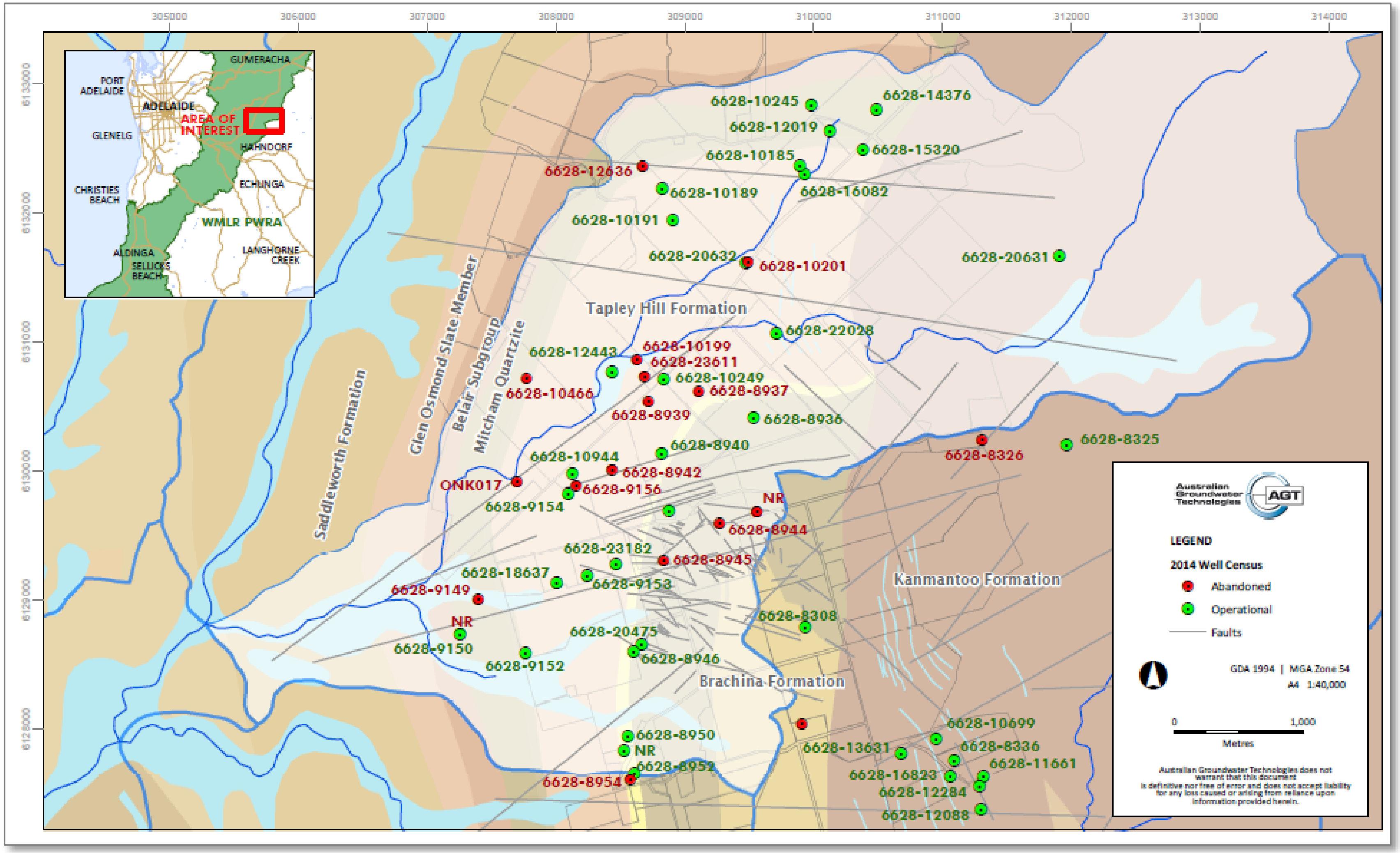

FIGURE 10-14 | PRIVATE WELLS CATEGORISED BY STATUS: OPERATIONAL (GREEN) AND ABANDONED (RED)

10.3.4.3 PRIVATE WELLS

The location of the surveyed wells identified as part of the 2014-16 Census, categorised by status (operational or abandoned) are shown on Figure 10-14.

The Census documented the status of over 58 wells, of which 30 are operational wells within the Inverbrackie Creek sub-catchment and a further 9 within the neighbouring Dawsley Creek sub-catchment to the east.

The majority of groundwater abstraction occurs from wells within the Tapley Hill Formation to the north and western side of the Marble outcrop, and to a lesser extent the Tarcowie Siltstone (Figure 10-14 and Table 10-3).

A number of shallow wells target shallow perched systems within topographical lows but these only provide a very small portion of the groundwater resource and all wells within this system have been abandoned.

Baseline water level and quality of private wells are located in Appendix H11.

TABLE 10-3 | OPERATIONAL WELLS CATEGORISED BY TARGET AQUIFER

Aquifer unit / formation	Number of operational wells
Quaternary (Perched groundwater system)	0
Tarcowie Siltstone	5 (1 outside Inv catchment)
Cox Sandstone	0
Marble	0
Tapley Hill Formation	18
Kanmantoo Group	(8 outside of Inv catchment)
Other hard rock units	7

10.3.4.4 GROUNDWATER USE

The groundwater census surveyed the groundwater use of 39 landholders within the Inverbrackie Creek sub catchment, and also some landholders in the neighbouring Dawsley Creek sub catchment between 2014 and 2018. Groundwater samples have continued to be taken right up until submission of this mining lease application, including updates throughout 2018.

Not all bores were equipped with flow meters and hence usage was estimated by the Landholder. This provided a reasonably accurate estimate of the total volume of groundwater abstracted from the FRA. Estimates of groundwater abstraction for each hydro-stratigraphic unit are presented in Table 10-4. Groundwater abstraction is up to 550 ML/y, the majority of which is sourced from the Tapley Hill Formation on the northern and western side of the Marble outcrop. The majority of use within the sub-catchment is for irrigation, as well as livestock. The groundwater allocation is 940ML.

DEW advised in May 2018 that the usage for the Inverbrackie catchment was 330ML during 2017, and 630ML during 2016. Utilising WaterConnect and land titles available on Nature Maps, Terramin estimate 1500 ML has been allocated in the Inverbrackie Creek subcatchment. This would mean approximately 20% of allocations were used during 2017 and 40% of allocations during 2016. This data supports AGT's estimation obtained from the groundwater census.

In the Eastern Mount lofty Ranges Water Allocation Plan, the aquifer system within the proposed Mineral Lease area is identified as the Bremer Kanmantoo aquifer. This aquifer has an allocation of

3,460 ML. The demand for groundwater in the Bremer Kanmantoo groundwater management zone is estimated by DEW to be 97 ML/year, including 15 ML of domestic use water, and 82 ML of stock use water (EMLR WAP, p.36). The groundwater census interviewed various landholders through the Dawesley Creek subcatchment and discussion with landholders confirmed this as reflective of the current general use.

TABLE 10-4 | GROUNDWATER ABSTRACTION

Aquifer unit	Estimated abstraction volume (ML/y)*	Environmental values of particular waters (Water EPP)
Quaternary (Perched groundwater system)	0	Drinking water for human consumption; Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Tarcowie Siltstone	up to 50	Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Cox Sandstone	0	Drinking water for human consumption; Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Marble	0	Drinking water for human consumption or Primary industries— irrigation and general water uses (well specific)

Aquifer unit	Estimated abstraction volume (ML/y)*	Environmental values of particular waters (Water EPP)
Tapley Hill Formation	up to 400	Drinking water for human consumption; Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.
Other hard rock units (Kanmantoo)	100	Primary industries— irrigation and general water uses; Primary industries— livestock drinking water; and, Primary industries— aquaculture and human consumption of aquatic foods.

10.4 SENSITIVE RECEPTORS

Sensitive receptors include environmental receptors including water dependent ecosystems as well as existing groundwater users, as defined by the WMLR Water Allocation Plan.

This includes both social and economic, as well as environmental, as outlined in the *Bird in Hand Proposed Mine Hydrogeological Review*, undertaken by CDM Smith on behalf of the Inverbrackie Creek Catchment Group (Sebben & Holder, 2017).

TABLE 10-5 | IDENTIFIED SENSITIVE RECEPTORS: GROUNDWATER

Sensitive Receptor	Summary	Impact ID
Agricultural land	Surrounding agricultural land reliant upon groundwater recharge. This includes modified grazing pastures, vineyards and horticulture	PIE_10_14 PIE_10_16
Surface water dependent ecosystem (Inverbrackie Creek)	The Inverbrackie Creek has identified springs along its course way – see section 10.3.4.2 and Figure 10-13	PIE_10_21 PIE_10_24 PIE_10_25 PIE_10_31
Groundwater Dependent Ecosystem (Stygofauna)	Stygofauna have not been identified through field studies to date within the vicinity of the area of the proposed underground workings	PIE_10_17 PIE_10_44 PIE_10_45
Local community	The wider community which have an interest in preserving the quality of groundwater	PIE_10_26

Sensitive Receptor	Summary	Impact ID
Existing groundwater users	Groundwater users which exist within the Inverbrackie Creek sub catchment	PIE_10_12 PIE_10_13 PIE_10_15 PIE_10_18 PIE_10_19 PIE_10_20 PIE_10_22 PIE_10_23 PIE_10_28 PIE_10_29 PIE_10_30 PIE_10_33 PIE_10_34 PIE_10_35 PIE_10_36 PIE_10_38 PIE_10_39 PIE_10_40 PIE_10_41 PIE_10_43 PIE_10_46 PIE_10_47 PIE_10_48 PIE_10_49 PIE_10_50 PIE_10_52 PIE_10_54
Existing groundwater users (6628-9153)	6628-9153	PIE_10_05
Existing groundwater users (6628-20475)	6628-20475	PIE_10_07
Existing groundwater users (6628-9154)	6628-9154	PIE_10_04
Existing groundwater users (6628-18637)	6628-18637	PIE_10_09
Existing groundwater users (6628-23182)	6628-23182	PIE_10_01
Existing groundwater users (6628-8308)	6628-8308	PIE_10_11
Existing groundwater users (6628-10944)	6628-10944	PIE_10_12
Existing groundwater users (6628-8952)	6628-8952	PIE_10_08
Existing groundwater users (6628-8940)	6628-8940	PIE_10_02
Existing groundwater users (6628-10249, 6628-8936)	6628-10249, 6628-8936	PIE_10_03
Existing groundwater users (6628-9152)	6628-9152	PIE_10_10
Existing groundwater users (6628-8946)	6628-8946	PIE_10_06
Vegetation Heritage Agreement Area (NVHA) and any remnant Blum Gum or Red Gum habitat within the ML	Located within the remnant vegetation patch within the central parcel of the proposed ML boundary. HA ID 1555.	PIE_10_32 PIE_10_37

Sensitive Receptor	Summary	Impact ID
Soil and land quality	Soil able to be impacted by sodicity/salinity from upward leakage	PIE_10_53
Third party infrastructure	Infrastructure owned by other parties.	PIE_10_27 PIE_10_51

FIGURE 10-15 | IDENTIFIED GROUNDWATER RECEPTORS (WELLS AND GROUNDWATER DEPENDENT ECOSYSTEMS)

10.5 POTENTIAL IMPACTING EVENTS

The term groundwater users used in Table 10-6 refers to users identified in Table 10-5.

TABLE 10-6 | IDENTIFIED POTENTIALLY IMPACTING EVENTS

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628-23182)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-23182)	Yes	PIE_10_01
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628-8940)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-10249, 6628-8936)	Yes	PIE_10_02
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628-10249, 6628-8936)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (Pfeiffer)	No	PIE_10_03
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628-9154)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-9154)	Yes	PIE_10_04
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628 - 9153)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628 - 9153)	Yes	PIE_10_05
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628-8946)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-8946)	Yes	PIE_10_06
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628-8950 & 6628-20475)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-8950 & 6628-20475)	Yes	PIE_10_07

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Lowered groundwater table on-lease as a result of mine water management results in loss of agricultural values (6628-8952)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-8952)	Yes	PIE_10_08
Lowered groundwater table on-lease as a result of mine water management results in loss of vineyard productivity (6628-18637)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-18637)	Yes	PIE_10_09
Lowered groundwater table on-lease as a result of mine water management results in loss of vineyard productivity (6628-9152)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-9152)	No	PIE_10_10
Lowered groundwater table on-lease as a result of mine water management results in loss of vineyard productivity (6628-8308, 6628-8301 bore)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (6628-8308)	No	PIE_10_11
Lowered groundwater table on-lease as a result of mine water management results in loss of vineyard productivity (Goldwyn bore 6628-10944)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users (Goldwyn bore 6628-10944)	Yes	PIE_10_12
Lowered groundwater table on-lease as a result of mine water management results in loss of stock, strawberry or hay productivity (existing bore users)	Operation, Closure	Mine water management	Lowered groundwater table	Existing groundwater users	No	PIE_10_12
Power outage stops depressurisation pumps/sump pumps which floods mine void resulting in decreased water quality, increasing treatment volumes which are higher than designed, pumping at higher rates required to remove excess water and mine inflows	Operation, Closure	Pump failure	Mine void inflows	Existing groundwater users	No	PIE_10_13

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Changes to aquifer transmissivity and/or gradients due to soil compaction under IML result in impacts on agricultural land	Operation, Closure, Post-closure	Soil compaction due to IML	Changes to aquifer transmissivity and/or gradients	Surrounding agricultural land	No	PIE_10_14
Blasting in mine void results in vibrations mixing aquifers through fractures impacting groundwater quality which affects existing groundwater users	Operations	Blasting vibrations	Mixing of groundwater of varying quality	Existing groundwater users	No	PIE_10_15
Contamination of groundwater from AMD or NMD from IML results in impacts on agricultural land	Operation, Closure, Post-closure	AMD or elemental toxicities in IML	Infiltration and seepage to groundwater	Surrounding agricultural land	No	PIE_10_16
Contamination of aquifers from AMD/NMD from depressurisation through AMD/NMD zone and water re-entering aquifer post-operations impacting groundwater quality for stygofauna	Post closure	Sulfide zone above mine workings	Groundwater flows	Groundwater dependent ecosystem (Stygofauna)	No	PIE_10_17
Contamination of aquifers from AMD/NMD from depressurisation through AMD/NMD zone and water re-entering aquifer post-operations impacting groundwater quality for local groundwater users	Post closure	Sulfide zone above mine workings	Groundwater flows	Existing groundwater users	No	PIE_10_18

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Grout does not provide adequate seal and inflows are higher than expected resulting in lowered groundwater table impacting existing groundwater users (70% effective, not 90%) - for life of project	Construction, Operation	Increased groundwater inflows from ineffectual grouting	Lowered groundwater table	Existing groundwater users	Yes	PIE_10_19
Grout unsuitable for potable water has the potential to contaminate aquifers and impact existing groundwater users	Construction, Operation, Closure, Post-closure	Grout	Contamination of groundwater	Existing groundwater users	No	PIE_10_20
Grout unsuitable for potable water has the potential to contaminate aquifers and impact surface water ecosystem (Inverbrackie Creek)	Construction, Operation, Closure, Post-closure	Grout	Contamination of groundwater	Surface water ecosystem (Inverbrackie Creek)	No	PIE_10_21
Spill of hazardous liquid in mine void has the potential to contaminate aquifers and impact on existing groundwater users	Construction, Operation, Closure	Spill of hazardous material in the mine void	Contamination of groundwater	Existing groundwater users	Yes	PIE_10_22
Ungrouted drillholes from exploration results in mixing of aquifers and changing water quality impacting existing groundwater users	Exploration	Ungrouted drillholes	Mixing of groundwater of varying quality	Existing groundwater users	No	PIE_10_23
Pre-excavation grouting impacts ground water quality (pH) resulting in NMD and reports to Inverbrackie Creek impacting surface water ecosystem	Operation	Grounwater pH changes from grout	Groundwater flows	Surface water ecosystem (Inverbrackie Creek)	No	PIE_10_24

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Lowered groundwater table as a result of mine water management impacts baseflow to surface water ecosystem (Inverbrackie Creek)	Operation	Mine water management	Lowered groundwater table	Surface water ecosystem (Inverbrackie Creek)	No	PIE_10_25
MAR scheme pressurises subsurface causing geotechnical failure of historic mine voids causing injury/fatality of local community	Operation	Pressurisation of subsurface from Managed Aquifer Recharge	Collapse of historic mine voids (BIH historic mine workings)	Local community	No	PIE_10_26
MAR scheme pressurises subsurface causing geotechnical failure of historic Bird in Hand mine voids causing damage to third party infrastructure	Operations	Pressurisation of subsurface from Managed Aquifer Recharge	Collapse of historic mine voids (BIH historic mine workings)	Third party infrastructure	No	PIE_10_27
Leakage from water storage dam impacting groundwater quality for existing groundwater users	Operation, Closure	Water storage dam	Infiltration and seepage to groundwater	Existing groundwater users	No	PIE_10_28
Pre-excavation grouting affects water quality - cement particles not set and travel through fractures impacting existing groundwater users bore quality (NTU)	Operation	Cement particles from grouting	Groundwater flows	Existing groundwater users	No	PIE_10_29
Probe drilling fails to identify water bearing fracture, resulting in higher mine inflows, reducing water level and impacting existing groundwater users	Operation	Higher than expected mine inflows	Lowered groundwater table	Existing groundwater users	No	PIE_10_30

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Water storage dam not at a capacity to cope with inflow rate causing dam to overflow and impact on surface water ecosystem (Inverbrackie Creek)	Operation	Overflow of the water storage dam	Surface water flowpaths	Surface water ecosystem (Inverbrackie Creek)	Yes	4
Water storage dam not at a capacity to cope with inflow rate causing dam to overflow and impact on the VHA area	Operation	Overflow of the water storage dam	Surface water flowpaths	Vegetation Heritage Agreement Area	No	PIE_10_32
Spill of hazardous liquid in mine void results in system or water treatment plant failure causing poor quality water to be reinjected via MAR system	Operations, closure	Spill of hazardous liquid in mine void	Groundwater MAR scheme	Existing groundwater users	No	PIE_10_33
Terramin extracts more than the total volume of water allocated to them impacting on local groundwater users.	Operation	Over extraction	Groundwater flows	Existing groundwater users	No	PIE_10_34
Terramin extracts their approved extraction limit, however, this has an adverse impact on proximal landholders (water trading)	Operation	Mine water management	Groundwater flows	Existing groundwater users	No	PIE_10_35
Terramin's extraction activities cause a buffer which overlaps the well buffer zone of another operational well	Operation	Mine water management	Groundwater flows	Existing groundwater users	No	PIE_10_36
Terramin's extraction activities impact on health of NVHA area	Operation	Extraction of groundwater	Lowered groundwater table	Vegetation Heritage Agreement Area	Uncertain	PIE_10_37
Well construction or rehabilitation not completed in accordance with Well Construction, Modification and Abandonment in SA (General Guidelines)	Operation, Closure	Mine water management	Groundwater flows	Existing groundwater users	No	PIE_10_38

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
resulting in impacts to the integrity of the aquifer(s)						
Water meter not correctly installed or operational causing errors in water extraction readings impacting existing groundwater users	Operation	Mine water management	Groundwater flows	Existing groundwater users	No	PIE_10_39
Well drilled in buffer zone of another operational well impacting existing groundwater users.	Operation	Mine water management	Groundwater flows	Existing groundwater users	No	PIE_10_40
Terramin utilise a MAR scheme which pressurises operational bores, causing them to become artesian impacting existing groundwater users	Operation	Mine water management	Groundwater flows	Existing groundwater users	Yes	PIE_10_41
MAR increases salinity levels and impacts on existing groundwater users	Operation	Mine water management	Groundwater flows	Existing groundwater users	Yes	PIE_10_43
MAR lowers salinity levels and impacts on water-dependent ecosystems (stygofauna)	Operation	Mine water management	Groundwater flows	Groundwater dependent ecosystem (Stygofauna)	No	PIE_10_44
MAR increases salinity levels and impacts on water-dependent ecosystems (stygofauna)	Operation	Mine water management	Groundwater flows	Groundwater dependent ecosystem (Stygofauna)	No	PIE_10_45
Taking or discharging of groundwater results in adverse affect to the aquifer(s) and abilities of other undergroundwater	Operation	Mine water management	Groundwater flows	Existing groundwater users	Yes	PIE_10_46

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
users to lawfully take underground water						
MAR lowers salinity levels and/or increases groundwater availability to existing groundwater users	Operation	Mine water management	Groundwater flows	Existing groundwater users	Yes	PIE_10_47
MAR or mine water changes water quality and impacts on existing groundwater users	Operation, closure	Mine water management	Water treatment	Existing groundwater users	Uncertain	PIE_10_48
Turbidity of recharge water exceed 20 NTU, leading to increase risk of transporting contaminants (which sorb to suspended solids) or be a primary cause for clogging	Operation	Mine water management	Water treatment	Existing groundwater users	Yes	PIE_10_49
Pathogens in recharge water from human effluent or animal waste impacts groundwater quality	Operation	Mine water management	Water treatment	Existing groundwater users	No	PIE_10_50
Overpressurising of MAR wells causing hydraulic failure of the overburden / overlying strata impacting third party infrastucture	Operation	Mine water management	Injection rate	Third party infrastructure	No	PIE_10_51
The faults targeted by the injection well represent preferential flow paths that may cause the recharged water to migrate further from the recharge bore than anticipated.	Operation	Mine water management	Water treatment	Existing groundwater users	Yes	PIE_10_52
Salinity and sodicity from upward leakage impacts soil quality	Operation	Mine water management	Groundwater flows	Soil and land quality	No	PIE_10_53

Potentially Impacting Events	Mine life phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Risk of oxygenated reinjection water reacting with sulphides impacts water quality	Operation	Mine water management	Injection rate	Existing groundwater users	No	PIE_10_54

10.6 CONTROL MEASURES TO PROTECT ENVIRONMENT

Control measures proposed to manage, limit or remedy groundwater impact events must be peer reviewed by a suitably qualified independent expert as required by the Ministerial Determination. Terramin have undertaken peer reviews on the grouting, the groundwater assessment, the managed aquifer recharge strategy and the site water balance. Peer reviewers were chosen for their qualifications and experience in the requisite areas. All peer reviewers qualifications are included in their respective reports. All peer reviews are relevant to all potential impact events, as the groundwater management system is designed to achieve the proposed outcome of "No adverse impact to the supply or quality of water caused by the mining operations to existing users and water dependant ecosystems".

Peer reviews undertaken have been included in Table 10-1.

TABLE 10-7 | PEER REVIEWS UNDERTAKEN

Water Management Strategy	Report/Assessment	Peer Review
Grouting	Bird in Hand Gold Project – Grouting for Groundwater Control, Multigrout (Appendix H4)	Bird in Hand Gold Project – External Review – Proposed Grouting Programme, Golder Associates (Appendix H5)
Groundwater Modelling and Impact Assessment (including MAR modelling)	Groundwater Impact Assessment for the Bird in Hand Project, AGT (Appendix H1)	Outcomes of Peer Review of Bird in Hand Gold Project Groundwater Assessment Report, Innovative Groundwater Solutions (Appendix H2 and H3)
Site water balance	Water Balance, Terramin (Appendix K1)	Review of Mine Water Balance Model for BIH Project, Golder Associates (Appendix K2)
Managed Aquifer Recharge System	Managed Aquifer Recharge Investigation, Golder Associates, 2019 (Appendix H9)	Independent peer review of updated modelling for the Bird-in-Hand Gold Project, Innovative Groundwater Solutions Pty Ltd (IGS), 2019 (Appendix H10)
Water treatment proposal	Water Treatment Options Study, GPA, 2017 and 2019 (Appendix J1)	Water Treatment Options Study Peer Review, Golder Associates, 2017 (Appendix J2)

10.6.1 Design Measures

Design measures are proposed to limit or prevent groundwater level reduction as well as maintain groundwater quality, as a result of mining activities. These measures are discussed below and include

- Mapping of water bearing zones and ongoing refinement of the geological model
- Design mine plan to avoid known water bearing zones
- Probe drilling to assess ground conditions ahead of excavation
- Pre excavation grouting
- Treatment and reinjection of mine inflows into the surrounding FRA through MAR

All of the proposed mitigation methods are used and well proven techniques throughout the mining and civil industries in the management of groundwater.

10.6.1.1 Geology Modelling, Geotechnical Modelling, Hydrogeology Modelling and Testing

Initial modelling is based on geological drilling and core logging.

Geological mapping is continuous as the mine development advances – information such as rock types, structures, voids etc. present in the rock are required to determine not only the ground support requirements, but also the groundwater controls, shown in Figure 10-16. This information is fed back into the 3D geological and geotechnical model for the mine and allows better prediction on where potential groundwater inflows could occur, as demonstrated in Figure 10-17.

The hydrogeological model has been discussed in detail in section 10.7.1.

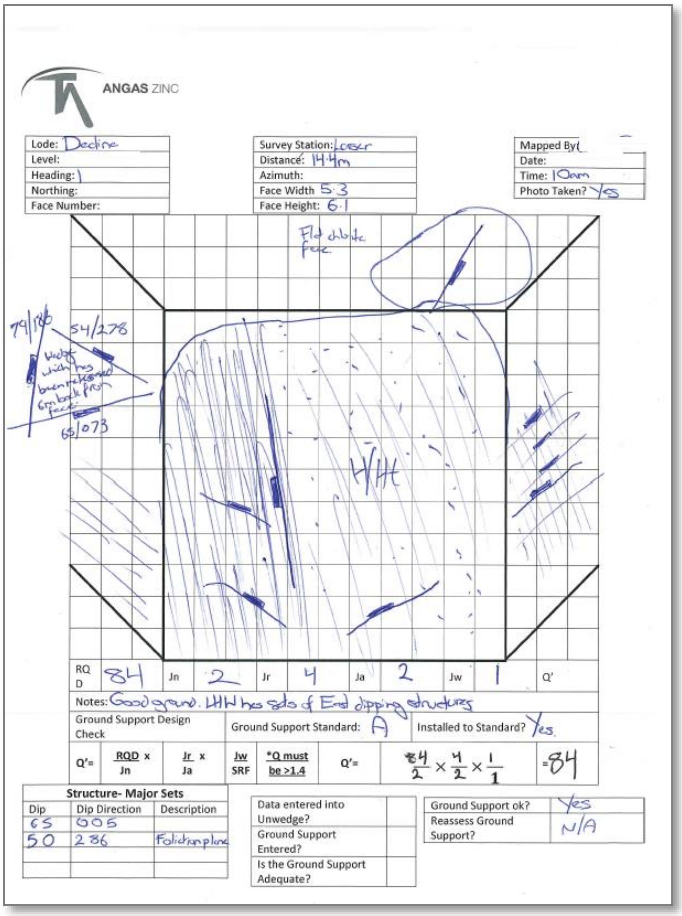

FIGURE 10-16 | EXAMPLE OF A GEOTECHNICAL FACE MAP USED IN THE MINING OF THE AZM DECLINE.

This information was fed back into the geotechnical and geological models.

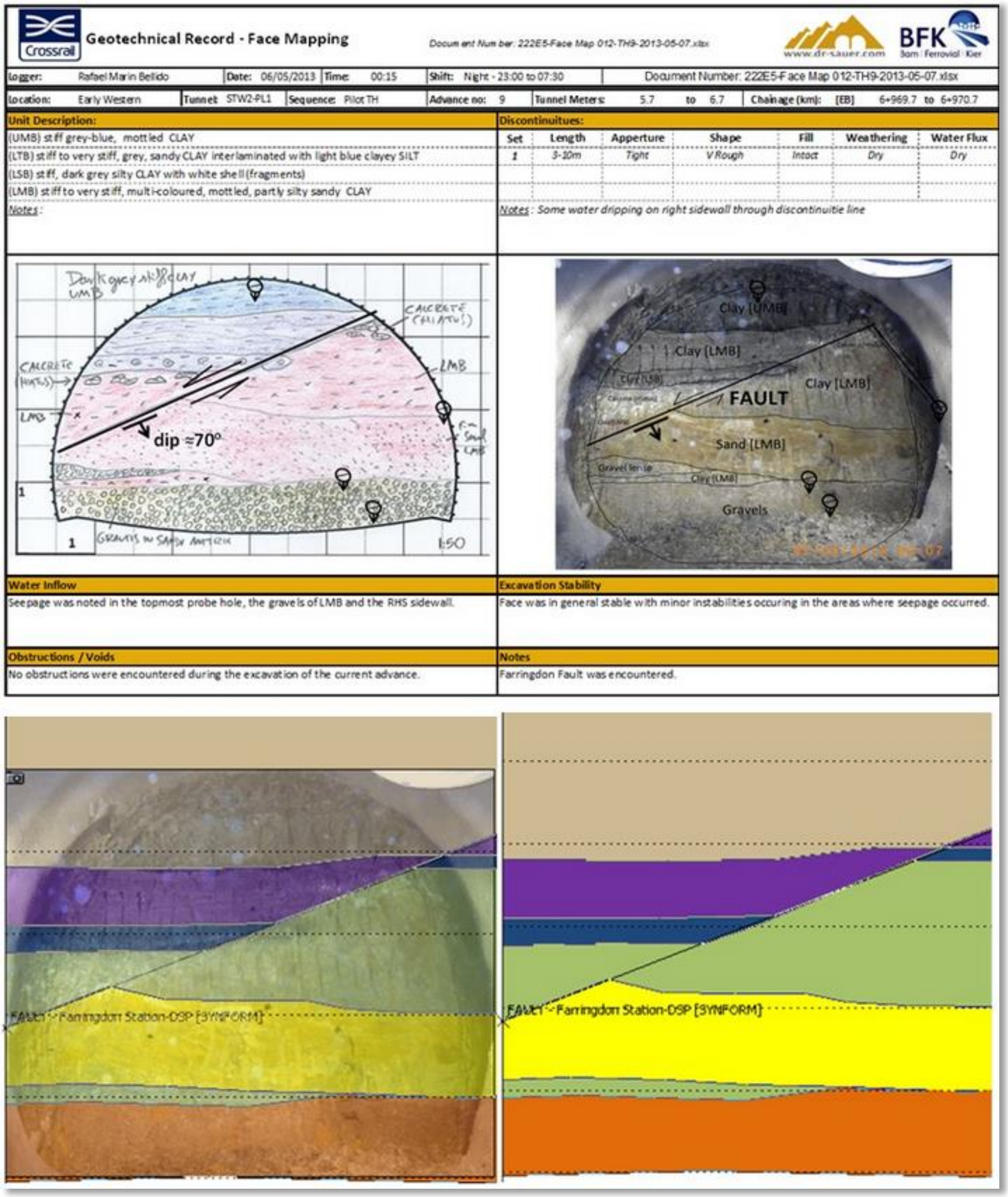

FIGURE 10-17 | STEPS OF INTEGRATION OF THE FARRINGTON FAULT INTO THE 3D MODEL.

The mapped data from the face (top) are digitised and imported at their respective position into the model (bottom) (Gakis, Cabrero, Entwisle, & Kessler, 2016)

10.6.1.2 MAPPING AND DATABASE OF ALL DRILL HOLES

The intersection of the mine workings, previously drilled exploration holes, service holes or similar have the potential to provide a conduit for groundwater to enter the mine, likely in large volumes and under high pressure. For this reason, all drill holes no longer required for use will be surveyed and sealed with grout as per the standard drill hole rehabilitation guidelines prior to decline development. Results of geological and hydrogeological mapping will be kept in a database (updated regularly) for use with mine design activities, and any known holes within a given radius will be marked on mining development plans. As well as for water, the database is useful in tracking the location of service holes containing live electricity and other infrastructure that can also pose a hazard in the underground environment.

10.6.1.3 MINE DESIGN

Where possible the mine plan has been designed to avoid water bearing fractures in order to reduce groundwater inflows.

In the case of the BIH mine design, the ore drives, which were originally designed (at the scoping study phase) to be accessed from the south where the footwall fault is located, were re-designed to access from the middle of the ore body and then drive out towards the north and south extremities of the reef. These extremities are intercepted by faults and higher permeable rock types and relocating the ore access drives away from the fracture zone reduces the risk of high groundwater inflows. This also reduces the quantity of ground support required to maintain the safety of the excavations.

Similarly, the decline has been designed to be mined within the known locations of the underground fractures where possible.

Vent raises have also been designed to avoid the high fracture zones.

10.6.1.4 PROBE DRILLING

Probe drilling acts in a similar method to the geological drilling, just on a much smaller scale and information is gathered from drill performance (based on the hardness of the rock) and the drill cuttings and groundwater inflows, rather than drill core to provide feedback on the ground properties immediately surrounding the excavated face.

A series of pre-determined drill holes are drilled in the direction of the face advance and information recorded on rock types, drilling penetration rates, groundwater inflows etc. are recorded. Anything reporting higher than trigger levels is immediately reported and initial groundwater management procedures can commence, including pre-excavation grouting.

Figure 10-18 demonstrates conceptually the process of probe drilling in order to identify and utilise pre-excavation grouting.

More information regarding the operational details of pre and post excavation grouting and the probe drilling process is located in Chapter 3, section 3.4.2.3.9.

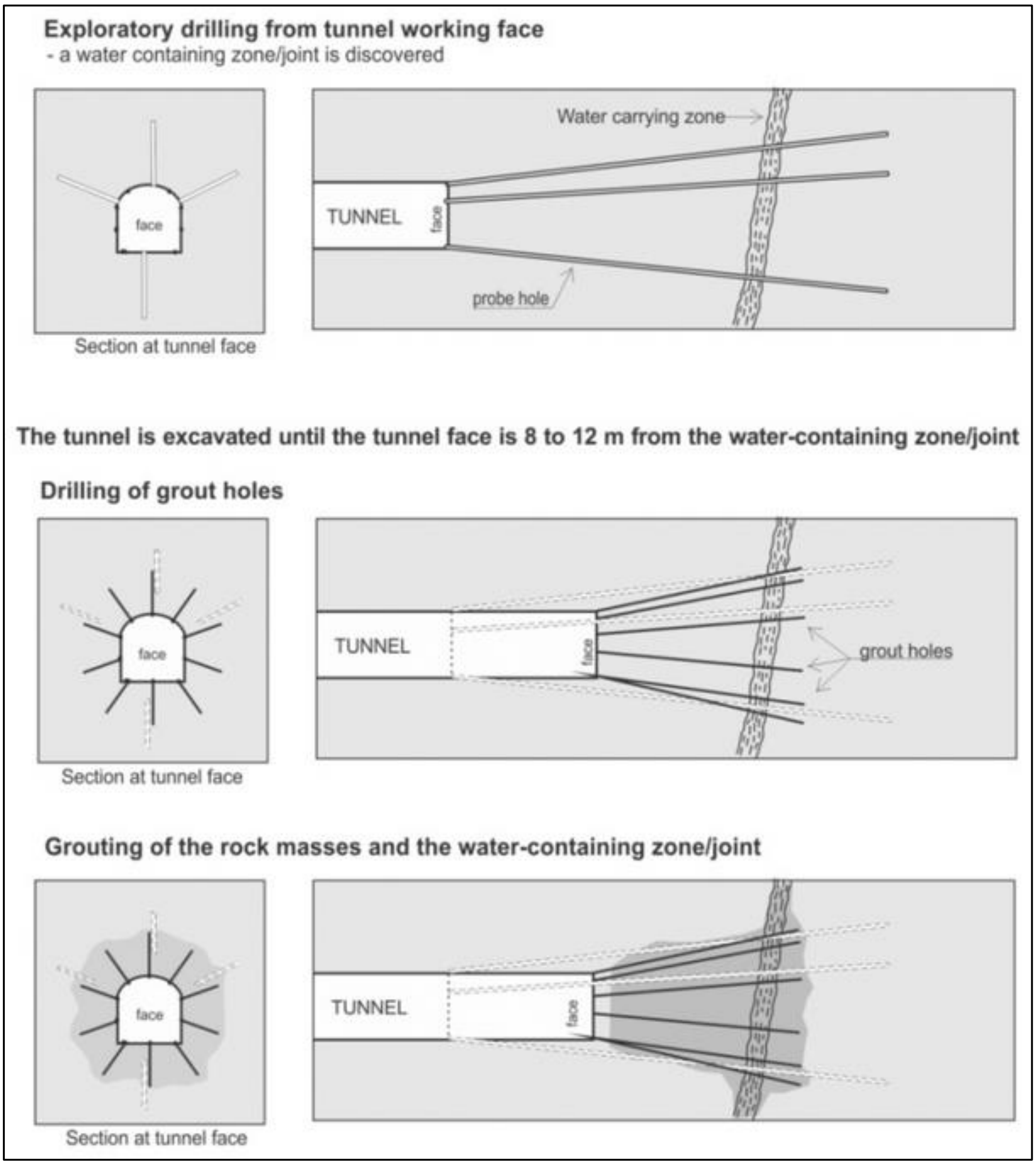

FIGURE 10-18 | PRINCIPLES OF PROBE DRILLING AND PRE-GROUTING

Typical length of probe drilling is 25-30m and the overlap is typically about 5m (From Nilsen and Palmstram, 2013)

10.6.1.5 PRE-EXCAVATION GROUTING AND POST-GROUTING

Pre-excavation grouting occurs after the probe drilling procedure indicates pre-excavation grouting is proposed.

The following description of pre-excavation grouting and post-grouting comes from the BASF book *Pre-Excavation Grouting in Rock Tunnelling* (BASF, 2011).

Tunnel excavation involves a certain risk of unexpected ground conditions. One of the risks is the chance of hitting large quantities of high pressure groundwater. Smaller volumes of groundwater ingress can also cause problems in a tunnel or its surroundings. Water is the most frequent reason for grouting the rock that surrounds tunnels. Groundwater ingress can be controlled or handled by drainage, pre-excavation grouting and post-excavation grouting (BASF, 2011).

Pressure grouting in rock is executed by drilling boreholes of a suitable diameter, length and direction into the bedrock, placing packers near the borehole opening (or using some other means of providing a pressure tight connection to the borehole), connecting a grout conveying hose or pipe between a pump and the packer, and pumping prepared grout by overpressure into the cracks and joints of the surrounding rock.

In tunnel grouting there are two fundamentally different situations to be aware of:

- Pre-excavation grouting, or pre-grouting, where the boreholes are drilled from the tunnel excavation face into virgin rock in front of the face. The grout is pumped in and allowed to set before advancing along the tunnel face through the injected and sealed rock volume. Sometimes, such pre-excavation grouting can be executed from the ground surface, primarily for shallow tunnels with free access to the ground surface area above the tunnel.
- Post-excavation grouting, or post-grouting, is where the drilling for grout holes and pumping in of the grout material takes place somewhere along the already excavated part of the tunnel. Such locations are usually selected where unacceptable amounts of water ingress occur. See Figure 10-19 below.

In cases where inflows might increase after a heading is mined (this could be immediately after, or some time), post excavation grouting can be applied to the zone of inflow. In the same way pre-excavation grouting is applied, a series of holes are drilled in the “wet” zone and grout pumped into the holes until the inflows are under control and have reduced to allowable levels. See Figure 10-19 below.

In cases where minor seepage is present, the application of surface shotcrete may be sufficient to control any further inflows into the mine voids. Other products are available on the market that proved a membrane type coverage to a seeping surface.

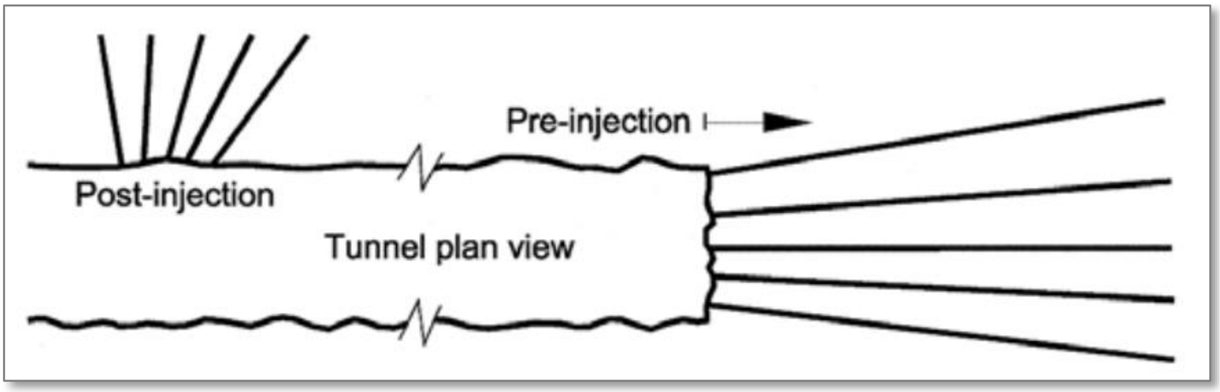

FIGURE 10-19 | PRE-EXCAVATION GROUTING AND POST-GROUTING

The purpose of tunnel grouting in the majority of cases is groundwater ingress control. Improvement of ground stability may sometimes be the main purpose, but will more often be a valued secondary effect of grouting for groundwater control. Cement based grouts are used more often than any other grout material in tunnel injection, but there are also a number of effective chemical grouts and mineral grouts available.

Pressure grouting (injection) into the rock mass surrounding a tunnel is a technique that has existed for more than 60 years, and it has developed rapidly during the last 20 years. An important part of developing this technology into a high-efficiency economic procedure has taken place in Scandinavia. Pressure injection has been successfully carried out in a range of rock formations, from weak sedimentary rocks to granitic gneisses, and has been used against very high hydrostatic head (up to 500 m water head), as well as in shallow urban tunnels with low water head.

10.6.1.5.1 GROUTING EXAMPLES

Grouting examples have been included in detail in Chapter 3: Section 3.4.2.7.5 and Appendix H4.

10.6.1.5.2 BIRD IN HAND GROUTING PROPOSAL

The result of correctly carrying out pre-grouting works ranges from drip free tunnels (less than 1.0 l/min per 100 m tunnel, (Davik, 2002), to groundwater ingress reduction that only takes care of the larger ingress channels. As an example, sub-sea road tunnels in Norway are mainly targeting an ingress rate of about 30 l/min per 100 m tunnel, as this produces a good balance between injection costs and lifetime dewatering costs (Blindheim, 2002).

In regard to the BIHGP, Multigrout Australia have prepared a pre-excavation grouting proposal based upon the site specific information of the BIH geology and hydrogeology. This proposal has been included in Appendix H4. Additional questions regarding the grouting processed were requested from DEM and have been included as an attachment to Appendix H4.

Table 10-8 below, obtained from the Groundwater Assessment (Appendix H1) provides information on the hydraulic conductivity of the various formations. This table has been extended to include additional units of measure, K (m/sec) and Lugeon, more commonly used in grouting analysis.

TABLE 10-8 | HYDRAULIC CONDUCTIVITY

INV Bore (IB)	Tested Zone	Hydraulic Conductivity K (m/d)	T (m^2/d)	Tested Depth (m)	Numerical model calibration K (m/d)	K converted to different units (m/sec)	K converted to fracture permeability in Lugeon unit
IB 4	Tarcowie Siltstone Fracture HW	2.5	105 (range 65-126)	125-155	2.5	2.9×10^{-5}	> 200
Not drilled	Tarcowie Siltstone (beneath fracture)	not tested	not tested	not tested	0.25	2.9×10^{-6}	22
IB 1	Marble	0.016	0.64	203-266	0.05	5.8×10^{-7}	4 - 5
IB 2	Marble	0.13	8	198-238	0.05	5.8×10^{-7}	4 - 5
IB 5	Tapley Hill (FW)	0.02	0.92	270-294	0.03	3.5×10^{-7}	2 - 3

The Lugeon unit is commonly used internationally in reference to grouting issues. It is a relatively simple site based test using a drilled hole into the rock, pumping water into the rock at a defined pressure and measuring the degree to which the rock accepts water. This, in turn, provides a measure of the openness or permeability of the particular rock mass.

1 Lugeon unit is defined as a water take of 1 litre per metre of hole test length per minute at 10 bars (1,000kPa or 150 psi) above static pressure. The Lugeon scale is sensitive at low values between 1 to 5 but with higher values of 50 or more and accuracy of +/- 10 Lugeons is adequate, and at more than 100 Lugeons an accuracy of +/- 30 Lugeons is appropriate.

Through analysis of the known geology and a review of the conceptual model, along with investigation drillhole water inflow yields form the IB bores, it is evident that the primary focus for ground treatment will be the hanging wall (HW) and adjacent fractured zones within the Tarcowie Siltstone formation.

The very high Lugeon values, above 20 and 200+ in the Tarcowie formation are indicative of highly fractured, open jointed rock of extremely high fracture permeability. Grouting will be a critical aspect of groundwater control practices. The rock conditions are likely to be very conducive to grouting and result in very significant groundwater inflow reduction.

The Marble formation, with relatively low Lugeon values, may need ground treatment in a much reduced scale to the Tarcowie Siltstone fracture zone. However, subsequent additional investigation bores have identified some fractured conditions within the Marble formation that have the potential to transmit high water volumes if encountered.

The Tapley Hill formation, generally appears to have low fracture permeability and typically may not require grouting.

As a general rule, Multigrout have based the following recommendations on extensive experience, and demonstrated more broadly around the world, certain cement types used in cementitious grouting have the potential to achieve groundwater inflow reductions into a tunnel down to limits as follows;

- Normal GP Type cement 30 – 50 litre/min/100m
- Micro-fine cement 10 – 15 litre/min/100m
- Ultra-fine cement 2 – 5 litre/min/100m

More information on grouting types is provided in the impact assessment - section 10.7.1.8.2

In summary, the pre-excavation grouting process will follow an established procedure, which will evolve over time as experience is gained in changing ground conditions, review and analysis of the outcomes. Grouting is a dynamic process and is analysed and modified continually to ensure that groundwater inflow requirements are being met and process continually refined for efficiency and economy.

10.6.1.5.3 GROUTING PEER REVIEW

The grouting proposal has been peer reviewed by Golder Associates Pty Ltd (Golder), which indicated that achieving groundwater inflows to be reduced by 90% of inflows with the use of grout (as compared to no mitigation in place (90% effective)) or greater as long as the grouting processes is adequately resourced (Appendix H5).

Golder provided further information in the peer review on effectiveness and groutability vs. cement type selection, as well as the grouting methodology. Overall, it was concluded that "*Multigrout has prepared a fair, reasonably detailed approach*".

The peer review of the grouting proposal is included in Appendix H5.

10.6.1.6 MANAGED AQUIFER RECHARGE

10.6.1.6.1 OVERVIEW

Some groundwater will enter the underground workings. Terramin recognise that to optimise the groundwater management system, Managed Aquifer Recharge is key to ensuring the protection of environmental values of groundwater and hence meeting the intent of the WMLR WAP. Managed Aquifer Recharge, or MAR, is the intentional recharge of water to suitable aquifers for subsequent recovery or to benefit the environment (protection of GDEs) (DEW, 2018).

In Australia in 2008, MAR contributed 45GL/yr to irrigation supplies and 7GL/yr to urban water supplies across Qld, SA, WA and NT. These include 3ML/yr of stormwater recharge recovered for drinking supplies, and up to 700 ML/yr of reclaimed water recharge to augment horticultural irrigation supplies (Dillon P, 2009).

Common reasons for using MAR include:

- securing and enhancing water supplies,
- improving groundwater quality,
- preventing salt water from intruding from other aquifers (i.e. from the Eastern Mt Lofty Ranges),
- reducing evaporation of stored water, or
- maintaining environmental flows and groundwater-dependent ecosystems, which improve Existing amenity, land value and biodiversity.

MAR has also been applied in mining to manage water from dewatering and to ameliorate environmental impacts of aquifer depressurisation owing to mine inlfows. In mining, MAR schemes using both injection and infiltration have been applied at numerous mine sites both in Australia and overseas.

MAR was utilised by Terramin at the Angas Zinc Mine to dispose of treated water into a fractured rock aquifer adjacent to the mine (Terramin Australia Ltd, 2008) [3]. The scheme was proposed at a reinjection rate of 2.5L/s, utilising existing bores. The initial trials were successful and the system was consequently expanded to six (6) reinjection bores (a total of eight (8) bores were tested). During 2012/2013 an average of 5.12L/s was recycled through aquifer reinjection. The capacity for reinjection at Angas was significantly higher than that injected, due to restrictions associated with reinjection water quality criteria. The reinjection system was managed among the bores with intermittent reinjection as part of the reinjection plan. Over the 12 month period 103.5ML of water was reinjected. Individual bores in the system predicted to handle 2.5L/s each accommodated reinjection rates of up to 13.3L/s[4] with average maximum reinjection rates of 8.3L/s. It is also used to replenish depleted aquifers that have reduced due to over irrigation or drawdown from mining operations, examples of this being undertaken in mining projects are Fosterville and Costerfield (Mandalay) mines.

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[3] Angas Zinc Mine – Aquifer Injection Modelling Report Submitted to PIRSA 9th May 2008, Terramin were issued a *Permit to undertake a Water Affecting Activity, Drain or Discharge Permit* into licenced well on 24th May 2012 from the Department of Water

[4] Angas Zinc Mine Reinjection Monitoring Report May 2013 issued to as part of Angas monitoring requirements

Cloudbreak mine in Western Australia is currently considered to have one of the largest MAR schemes in Australia and has been in operation since 2008. It returns approximately 73 per cent of extracted water from dewatering back into the aquifer via injection bores, greatly reducing their effect on groundwater levels and quality (Willis-Jones & Roos, 2013). Aquifer injection has been adopted as a primary water management tool and to date has proven to be practical and effective. The benefits of the system are conservation of brackish water for redraw over the life of the mine, minimisation of the drawdown footprint from the dewatering operation, and limiting the environmental and cultural concerns associated with the surface discharge of excess water to the nearby marsh.

An example of a MAR scheme using infiltration basins is Ophthalmia Dam in Western Australia. Constructed on the Fortescue River approximately 5 km upstream of the Ethel Gorge, this scheme started operation in 1982. It was constructed to enhance recharge and augment groundwater resources in the Ethel Gorge area and is important in supporting the eco hydrology of the gorge. Surplus water from the dewatering process is discharged and stored in Ophthalmia Dam; the dam is designed to retard the flow of some surface water and enable passive infiltration into the shallow alluvial aquifer (Douglas & Pickard, undated).

Cobre Las Cruces is an open-pit copper mine located in south-west Spain. The mine has a complex drainage and re-injection system consisting of 32 peripheral dewatering wells connected to a ring of 28 injection wells. Abstracted water is treated by reverse osmosis to remove metals and reinjected into wells located 0.7 to 2.5 km from the mine pit. The scheme has been operating without interruption since 2006 and balances the needs of mine dewatering versus maintaining the equilibrium in the aquifer. The system maintains the water balance in the aquifer and reduces the extent of the cone of depression from the open-pit (Baquero, Reyes, Custodio, Scheiber, & Vazquez-Sune, 2016).

MAR has the potential to provide many benefits to mines. Conserving water is one such benefit; improving operational efficiencies is another. When integrated into the dewatering process, mines can intercept water from an aquifer *before* it enters the open pit or underground workings (known as depressurisation), thereby reducing the volume that becomes degraded through contact with those workings. This in turn reduces the pumping and treatment costs normally associated with such water before it can be legally discharged from the mining site.

Furthermore, MAR schemes protect the water resources of existing communities that surround mines. Water that is extracted as part of the dewatering process can be re-injected at locations where it can benefit other users and/or the groundwater dependent ecosystems. MAR is a valuable tool for addressing the social tensions that commonly arise in nearby communities; increasing the public's access to agricultural water could help offset concerns about the potential impact of dewatering on the groundwater resources in the area.

Terramin propose a MAR system to prevent the potential for groundwater drawdown surrounding the underground workings for the majority of existing groundwater users and ecosystems identified through the groundwater census between 2014 and 2018 (sensitive receptors outlined in section 10.4), and greatly reduce the potential for drawdown for existing groundwater users and ecosystems located within the immediate vicinity of the underground workings, as shown in Figure 10-30.

10.6.1.6.2 RATES OF MINE WATER RECHARGE

The source and predicted flows of groundwater have been modelled as part of the impact assessment, and based upon expected impact as well as conservative scenarios. After studying similar operations and receiving advice from grout experts and specialists specifically on the Project's requirements and the Bird-in-Hand geological context (Multigrout), Terramin expects the groundwater inflows to be reduced by 90% of inflows (90% effective) with the use of grout. This approach was supported by the peer review of the grouting proposal (located in Appendix H5).

Adequate capacity must be built into the system to manage a credible worst case scenario, and for this reason, Terramin have designed the water management system with groundwater inflow management being only 70% effective. This allows for adequate infrastructure to be in place if higher inflows are encountered while ensuring the protection of the supply and quality of groundwater for all sensitive receptors (existing users and water dependent ecosystems) from the operation.

Terramin expect that the peak annual volume the MAR system will need to reinject will be approximately 141 ML, which equates to a peak of on average 4.5 L/s during the fourth year of mining. This is in contrast to the first year, which is on average 1.4 L/s (44 ML/yr). This is due to the difference in the permeability and structure of the rock types, with the Tapley Hill Formation, where the decline and approach development is located, having a much lower permeability (that is, $K = 3.5 \times 10^{-7}$ m/sec).

Note that the development located within the Tapley Hill formation will still be subject to the probe drilling and pre-excavation grouting program where required.

A summary of the volumes proposed for the MAR system are below in Table 10-9.

TABLE 10-9 | MODEL-PREDICTED GROUNDWATER ABSTRACTION AND REINJECTION

Year	90% Grout with MAR			70% Grout with MAR		
	ML/y	ML/d	L/s	ML/y	ML/d	L/s
1	44	0.1	1.4	131	0.4	4.1
2	81	0.2	2.6	242	0.7	7.7
3	113	0.3	3.6	339	0.9	10.8
4	141	0.4	4.5	423	1.2	13.4
5	141	0.4	4.5	422	1.2	13.4

10.6.1.6.3 SUMMARY OF MAR INVESTIGATIONS

The MAR investigations undertaken in support of the Bird-in-Hand Mining Lease Proposal and MAR feasibility assessment described above and the subsequent modelling of aquifer response to both mine depressurisation and MAR indicate the surrounding aquifer is suitable to undergo MAR.

Injection tests were performed on the Tapley Hill formation and Tarcowie siltstone within the Bird-in-Hand mineral claim. The combined injection rate was up to 20 L/s, and similar in nature to the range of mine inflows estimated by modelling and grouting under 70% grouting effectiveness.

In particular, a faulted area in the Tapley Hill formation offers the opportunity of developing high yielding MAR wells with storage held in adjacent less fractured rock. This faulted area promotes higher rates of recharge and the lateral spreading of recharge water.

Pumping and injection tests conducted in the Tarcowie siltstone showed evidence of some structural control around the underground mine area. These features could limit the spread of groundwater level drawdown induced by mining and likewise limit the recirculation of injected mine water towards the mine.

Groundwater modelling of aquifer response to both underground mining and MAR was refined using transient data collected during the pumping and injection tests. This represented a third transient calibration on the developed model and provided a means of refining the model's ability to predict the response of the system that is specific to the intended management actions (i.e. injection of water).

Revised model predictions of groundwater inflows and the associated groundwater level drawdown was consistent with predictions presented previously. Overall, groundwater modelling showed that groundwater level impacts to surrounding groundwater receptors (including the Inverbrackie Creek) are reduced by a combination of grouting for groundwater control and MAR compared to a no MAR scenario.

The revised model simulations are discussed under section 10.7.

The Groundwater Impact Assessment and Modelling Report is included in Appendix H1.

The updated Groundwater Impact Assessment including the MAR Investigation is in Appendix H9.

A peer review of this work was undertaken by Innovative Groundwater Solutions in 2017, and again in 2019 (review located in Appendix H2, H3 and H10).

10.6.1.6.4 BENEFITS OF MAR

The MAR system proposed for the BIH Gold project could assist the native vegetation in the NVHA to remain in good ecosystem health, one of the ways of ensuring good health (assuming other impacts such as pest, weeds, diseases and bushfire risk are managed by the landholder) is by clearly demonstrating if the NVHA is utilising groundwater or not and if so maintaining groundwater levels at baseline conditions. The MAR will ensure groundwater level changes in this area will be muted. The Blue gum, *Eucalyptus leucoxylon,* woodland component of the NVHA has been shown to have a groundwater level that is between 50 and 80 metres deep, beyond the tree root systems ability to utilise. It is thought the Bluegum trees utilise seasonal rainfall as a water source not groundwater. The Redgums, *Eucalyptus camaldulensis,* within the NVHA are located in ephemerally flowing riparian zones, these zones do not contain groundwater supplied springs, and are unlikely to be connected to the deeper groundwater aquifer.

If changes in the vegetation, due to changes in groundwater levels, were to occur it would constitute clearance under the *Native Vegetation Act 1991*, in order to offset this unlikely impact the existing vegetation will be monitored for health annually and if required the vegetation can be irrigated using an existing groundwater allocation. Additionally a provision of a Native Vegetation Heritage Agreement area (NVHA) and 3.5 hectares identified for this future land use. Over 25,000 endemic native trees and shrubs have been planted in the adjoining 'Goldwyn' property, including Redgums, Bluegums, Manna gum and Pinkgum's and associated select species from nearby plant communities. Historic photographs of the Bird-in-Hand mine from the 1880's show remnant woodland trees growing and these same trees appear to still be in place, indicating historic mine and water supply dewatering over much longer periods than the current ML proposal had little impact on woodland vegetation. These plantings have established and already provide considerable biodiversity benefit. 30,000 wetland sedges in the adjoining 'Goldwyn' Terramin owned property have also been planted in the Goldwyn riparian areas. It should be noted the revegetation was put into place for biodiversity (NVHA biodiversity buffer zones (as suggested by DEW in 2014) for woodland birds, pollinators and orchids), visual amenity and surface water quality reasons. The groundwater management during mining operations was considered and deemed not to negatively impact these plantings.

Lastly, there is clearly an ongoing existing demand or clearly defined environmental benefit to utilising a MAR system, as the area relies upon agricultural use of the groundwater, and the Inverbrackie Creek hosts several groundwater dependent springs. The Project is located within a Prescribed Wells Area, and is controlled by the Western Mount Lofty Ranges Water Allocation Plan.

In order to protect agricultural and ecological values, pipelines for the MAR network are planned for existing fence lines and cleared areas only, as shown in Figure 10-20. These locations for INJ_3 – 8 have been selected based on the hydrogeological model and the updated information gained from the 2019 MAR trial, detailed in Appendix H9.

FIGURE 10-20 | PROPOSED LOCATION OF MAR WELLS AND PIPEWORK

10.6.1.6.5 MANAGEMENT AND MAINTENANCE OF MAR SYSTEM

10.6.1.6.5.1 CLOGGING

Clogging causes impair injection performance, restricting the volume of water that can infiltrate or be injected into the target aquifer. In recharge bores, under a constant injection rate, clogging may lead to excessive pressure heads that result in the failure of either the aquifer formation or the overlying confining beds. More typically maximum injection heads are pre-set and the result is a reduced rate of injection.

Clogging can be divided into four principal types:

1. Chemical which includes precipitation of elements such as, iron or aluminium, aquifer matrix dissolution and temperature.
2. Physical which includes suspended solids, migration of interstitial fines (e.g. illite or smectite clays), unintentional fracturing of the aquifer, and formation damage during bore construction.
3. Mechanical such as entrained air/gas binding.
4. Biological which includes algae growth, iron or sulphate reducing bacteria (Martin, 2013).

Elevated turbidity or suspended solids in the recharge water may cause clogging and therefore result in a loss of injection efficiency or increased head build up in the injection bore. The turbidity of the source water is estimated to be less than 20 NTU. There are no guideline limits for TSS, other than it should be as low as reasonably practical. The Water Treatment Plant and inline filters are designed to remove suspended solids to greatly reduce this risk

Clogging rates of the injection wells will be assessed using changes to the specific capacity of the injection well and by comparing rates of water level rise in the injection well with those in the adjacent monitoring bore. Scheduled maintenance and cleaning plan for injection bores will be undertaken once the specific capacity of an injection well has reduced by 20%. Techniques include pumping (back flushing), airlift agitation, surge block, and acidification (using EPA approved agents) in the case of biological clogging. This would likely be completed with a service rig set-up over the bore site. Airlifted water and sediment would be directed to a containment bund on the drill site.

10.6.1.6.6 DEPRESSURISATION

Depressurisation of the hanging wall fracture (at a rate of 10-20 L/s) was partially (25%) effective at reducing groundwater inflows into the drives only, and no notable reduction to flows into the decline. For this reason, depressurisation has not been included at this stage of the project, however, should the need arise, may be reconsidered later in the project life.

Resultantly, this additional depressurisation mitigation strategy has not been relied upon or factored into the water balance for the site.

10.6.1.6.7 DAWESELY CREEK CATCHMENT GROUNDWATER SALINITY

The Bird-in-Hand Gold Project is located near the boundary of the Eastern Mt Lofty Ranges (EMLR) and Western Mt Lofty Ranges (WMLR), where there is a natural groundwater divide between the two catchments. In the EMLR, the FRA aquifer is older and less productive, with higher salinities (up to 4,000 mg/L) than the FRA around the Bird-in-Hand Gold Project (typically less than 1,500 mg/L).

A benefit of utilising MAR is to remove the potential for saline intrusion from other aquifers. In this case, MAR is proposed to manage the potential for saline intrusion from the EMLR (Kanmantoo Formation) into the fresher WMLR aquifers.

10.6.1.6.8 MANAGED AQUIFER RECHARGE PEER REVIEW

Innovative Groundwater Solutions (IGS) was contracted by Terramin to provide an independent peer review of the numerical groundwater flow model produced by Australian Groundwater Technologies Pty Ltd (AGT) to support the Mine Lease Proposal for the Bird in Hand Gold Project. The independent peer review is listed as a requirement by the Determination for a Mining Proposal for the Bird in Hand Gold Project.

After reviewing four iterations of the report and the additional work that has been carried out to quantify model sensitivity and uncertainty, IGS confirmed in a letter dated 24th October 2018 that the model, including MAR scenarios, is fit-for-purpose regarding the objectives stated for the project in the Ministerial Determination and the National Groundwater Modelling Guidelines.

Additionally, after the 2018-2019 MAR investigation, IGS peer-reviewed the additional model updates and reporting and confirmed that the work presented in the Golder (2019) report (Appendix H9) is consistent with industry best practice, and that the model remains fit-for-purpose in accordance with the Australian Groundwater Modelling Guidelines (2012).

IGS peer reviews are included in Appendix H2,H3 and H10. The scope of the peer review is included as an addendum to Appendix H10.

10.6.1.7 WATER TREATMENT

Any water which comes into contact with the underground workings, will be pumped to surface and filtered to ensure the water is of the required water quality for reinjection into the aquifer. Additionally, any surface water runoff from the IML, internal haul roads and other hard surfaces within the operational area will report to the water treatment plant circuit.

The objectives of the water treatment plant (WTP) are to:

- Treat a sufficient quantity of mine water for re-injection into the surrounding aquifers through licensed drainage wells, which allows the site water balance to be maintained in a neutral state.
- Treat the mine water and the mine-affected runoff water to remove a sufficient quantity of analytes that results in re-injecting clean water which meets or improves the quality of the surrounding aquifers as per the EPA Water Quality Policy – Environmental Protection Act and the National Resources Management Act (well drainage permits).
- Minimise the amount of waste generated from the WTP to as low as reasonably achievable.

The process for treating water on site at BIH will comprise of three stages.

1. Primary:
    - First stage solids removal
    - First stage analytes removal
    - pH adjustment if required
2. Secondary:
    - Second stage solids removal
    - Second stage analytes removal
3. Tertiary:
    - Third stage analytes removal
    - Final TDS reduction

Modelling of the proposed BIH WTP process was carried out using data collated from NATA laboratory water quality testing of bores surrounding the mining lease area, together with assumptions typically used for designing water treatment processes. Expected inflow rates required to be managed by the WTP range from 5 litres per second (l/s) in year 1 of operation at BIH to 24 l/s in year 5. Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) levels of 949 mg/L and 120 mg/L respectively were input to the model, along with the expected inflows of solids and other analytes at conservative levels from the mining process, to establish the quality of water to be treated.

The modelling conducted on the WTP process identified by GPA identified that all major process objectives could be achieved at the design flow rate through the WTP. This water will be treated to the quality defined by the MAR quality targets and well drainage permits.

The WTP concept design detailed by GPA in this Study provides sufficient flexibility and redundancy to enable a wide quality range of water to be treated to meet or exceed the targets. Information regarding source, treatment and receptor quality is located in detail in Chapter 3 (3.7.9.5).

Further detail on the Water Treatment Plant is included in Chapter 3, section 3.7.9.5, and proposed water quality targets based on the 2019 MAR investigation outlined in section 3.7.9.6.5.3.The water treatment proposal is included in Appendix J1.

10.6.1.7.1 PEER REVIEW OF WATER TREATMENT OPTIONS STUDY

Golder Associates Ltd. (Golder) was retained by Terramin Australia Ltd (Terramin) Ltd. to perform a Peer Review of the Water Treatment Options Study for the Bird In Hand (BIH) Gold Mine that was prepared by GPA Engineering (GPA) for Terramin Australia Ltd. (Terramin). This peer review is to support the Mine Lease Proposal and is a requirement of Section 6.2.1 of the Ministerial Determination for a Mining Proposal for Bird In-Hand Gold Project. This peer review deals solely with the water treatment options proposal.

10.6.1.7.1.1 SCOPE OF THE REVIEW

The scope of work for this peer review took into account the current and future mining layouts and interactions with all stakeholders and receptors. The treatment of water captured from all sources within the areas of the operation was included in within the scope. Each potential option for water treatment shall be investigated and suitably documented, outlining the benefits and limitations of each option considered.

Sections of the Ministerial Determination for the Bird-in-Hand Gold Project that must be considered in this review include (but not limited to):

- Section 3.4.6 Mine Dewatering
- Section 3.6.2 Other Processing wastes – relative to water treatment
- Section 3.7.8 Water Management
- Section 3.11.3 Water Sources
- 6.2.1 Control Measures

The following were used as base documents for the water treatment peer review;

- BIH Gold Project Ministerial Determination
- Water Treatment Options Study Report
- Groundwater impact assessment Report

- Draft BIH gold Project Water Balance spreadsheet and Golder Peer Review
- Latest conceptual mine design

10.6.1.7.1.2 OUTCOME OF THE REVIEW

Following the review of the GPA report, Golder submitted a Peer Review Report for discussion with GPA and Terramin. The Report was circulated to Terramin, who shared the document with GPA to allow for dialogue and feedback. Based on this, additional detail was added to the GPA report, which incorporated and addressed Golder's comments. Further detail on the inputs for final designs, including information that was gained from the MAR investigation (water quality) (see section 10.6.1.6 Managed Aquifer Recharge) was incorporated into a 2019 update and is included in an addendum to the Water Treatment Proposal in Appendix J1.

The water treatment options peer review undertaken by Golder can be found in Appendix J2.

10.6.1.8 SUMMARY OF DESIGN MEASURES

TABLE 10-10 | DESIGN MEASURES: WATER MANAGEMENT

<table>
<tr><th>Design Measures</th><th colspan="2">Impact ID</th></tr>
<tr><td>Geology modelling, geotechnical modelling, hydrogeology modelling and testing</td><td rowspan="9">PIE_10_01
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PIE_10_03
PIE_10_04
PIE_10_05
PIE_10_06
PIE_10_07
PIE_10_08
PIE_10_09
PIE_10_10
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PIE_10_12
PIE_10_13
PIE_10_14
PIE_10_15
PIE_10_16
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PIE_10_21
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PIE_10_24
PIE_10_25
PIE_10_26
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PIE_10_43
PIE_10_44
PIE_10_45
PIE_10_46
PIE_10_47
PIE_10_48
PIE_10_49
PIE_10_50
PIE_10_51
PIE_10_52
PIE_10_53
PIE_10_54</td></tr>
<tr><td>Mapping and database of all drill holes</td></tr>
<tr><td>Increase depth of decline earlier in order to avoid supergene zone</td></tr>
<tr><td>Mine design – avoidance of major water bearing zones where possible</td></tr>
<tr><td>Probe drilling</td></tr>
<tr><td>Pre-excavation grouting</td></tr>
<tr><td>Post-excavation grouting</td></tr>
<tr><td>Managed Aquifer Recharge</td></tr>
<tr><td>Water treatment design</td></tr>
</table>

10.6.2 Management Strategies

A summary of the proposed management strategies is included below under each specific subheading.

10.6.2.1 PRE-EXCAVATION GROUTING PROCEDURE AND RECORDING

The Pre-Excavation Grouting procedure, as outlined by BASF, would include:

- Always start the injection in the lowest hole in the face (tunnels) and progress successively towards the roof until all holes are injected.
- Unless special measures are required, the injection on an individual borehole is completed when the flow rate of grout into the hole is less than the trigger levels (L/s) at the maximum allowed pressure specified, or when more than the allowable limit of cement has been injected (the quantity limit will vary with project requirements and geological conditions and will be determined through the PEPR stage).
- If two or more holes become inter-connected during the injection process, the valves on the packers in holes that are connected to the injection point should be closed. The amount of grout specified per hole should be multiplied by the number of holes connected and pumped into all of them before regarding the grouting as completed.

During injection the following parameters would be accurately noted in the Injection Record and included in the Pre-Excavation Grouting procedure:

- All necessary and relevant general information about the project
- Groundwater flow from the holes
- Injection materials and mix design
- Pressure at the beginning and at the end of each injection, including grout flow rates
- Injection time per hole
- Total material consumption per hole
- Number of holes, stage of grouting
- Any surface leakages and backflow
- Grout hole inter-connections

All of this information would be used to iteratively update the hydrogeological model, as described in 10.6.1.1.

10.6.2.2 GROUNDWATER MANAGEMENT PLAN

Operational monitoring of a MAR scheme will be undertaken to check the performance of the measures used to safeguard third party groundwater users and environmental values of the FRA. Operational monitoring also ensures the MAR scheme is operating as expected and is used to identify ongoing improvements to the scheme (if required).

Operational monitoring will include in-line instrumentation to record recharge volumes, groundwater pressures (levels), water quality of the water being injected and water quality of receiving aquifer during recharge.

Procedures covering the management of the MAR scheme will be provided in supporting documentation of scheme design. As a minimum the documentation will consist of:

- The detailed design drawings of the system.
- Equipment and associated manufacturer’s operation specifications and warranty.
- Training of staff in the operation of instruments and data collection.

- Periodic sampling and laboratory analysis of recharge water and groundwater.
- Monitoring regime in accordance with the groundwater management plan.
- Professional management of water quality data via a comprehensive water quality database.
- Information on the operational performance of the scheme including calibration records and quality assurance procedures.
- Reporting framework in accordance with NRM Act authorisations.

10.6.2.2.1 MONITORING

A monitoring program will be designed to detect changes to groundwater levels, groundwater quality or to indicate that an abnormal condition relating to MAR has developed. The identification process and response protocols to potential adverse outcomes from the MAR scheme have been drafted in Appendix H7 – draft Groundwater Trigger Action and Response Plan. This draft would be further refined and developed through the PEPR stage to ensure it is aligned with project lease conditions and proposed outcomes. Appropriate triggers and corresponding response actions will be developed for prevention or mitigation of adverse impacts (risks) to nearby water users or the natural environment as a result of the MAR operation. This includes but is not limited to:

- Over-pressurisation of the FRA leading to upward leakage of groundwater (water logging)
- Artesian conditions being experienced at private wells
- Adverse water quality changes within the FRA from mixing of recharge water with native groundwater
- Clogging of injection bores
- Salinity and sodicity
- Contaminant pathways

10.6.2.2.2 DOCUMENTING AND REPORTING

The documentation and records relating to MAR should include the following as part of a document control/ business management system:

- Operational procedures and process controls including:
    - An operating methodology procedure;
    - Water quality sampling (locations, frequency, method, preservation, delivery, QA);
    - General procedure with references to specific schemes for 'Instrument calibrations';
    - Scheme specific procedure and forms relating to 'Routine inspections, readings and checks';
    - General procedure with references to specific schemes for 'Isolation of plant and equipment'
    - General procedure for data management'
- Critical control points, quality control points and critical and alert levels for operational monitoring
- Operation and maintenance manuals (analysers, sensors, pumps, valves)
- Monitoring information (baseline/background/operational, validation (e.g. new process data), verification (water quality monitoring data)
- Register of water balance (volume harvested, treated, injected, recovered, stored, supplied, transferred)
- Internal performance and compliance reports
- Incident/emergency/corrective action/response procedures

A Groundwater Trigger Action and Response Plan (TARP) will be developed and implemented through the operational and closure phase of the project, a draft has been included in Appendix H7. This draft would be further refined and developed through the PEPR stage to ensure it is aligned with project lease conditions and proposed outcomes.

TABLE 10-11 | MANAGEMENT STRATEGIES: WATER MANAGEMENT

<table>
<tr><th>Management Strategies</th><th colspan="2">Impact ID</th></tr>
<tr><td>Geology modelling, geotechnical modelling, hydrogeology modelling and testing</td><td rowspan="5">PIE_10_01
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PIE_10_49
PIE_10_50
PIE_10_51
PIE_10_52
PIE_10_53
PIE_10_54</td></tr>
<tr><td>Probe drilling and grouting procedure – including documentation procedures</td></tr>
<tr><td>Managed Aquifer Recharge Management Plan– including documentation procedures</td></tr>
<tr><td>Groundwater Management Plan to meet lease conditions and outcomes – including documentation procedures (to be developed through PEPR)</td></tr>
<tr><td>Groundwater TARP (draft included in Appendix H7)

This draft would be further refined and developed through the PEPR stage to ensure it is aligned with project lease conditions and proposed outcomes.</td></tr>
</table>

10.7 IMPACT ASSESSMENT

Terramin's groundwater risk assessment is based upon credible worst case scenarios. After studying similar operations and receiving advice from grout experts and specialists specifically on the Project's requirements and the Bird-in-Hand geological context, Multigrout Australia have prepared a pre-excavation grouting proposal based upon the site specific information of the BIH geology and hydrogeology, and pre-excavation grouting is expected to reduce inflows by 90%. This view is supported by various grouting reviewers, including Golder Associates and Sovereign Hydroseal. This proposal and additional information in conjunction with investigations on geotechnical grouting design by Mining One has been included in Appendix H4, and peer review included in Appendix H5.

Adequate capacity must be built into the system to manage a credible worst case scenario, and for this reason, Terramin have designed the water management system with groundwater inflow management being only 70% effective with the use of grout. This allows for adequate infrastructure to be in place if higher inflows are encountered while ensuring the protection of the supply and quality of groundwater for all sensitive receptors (existing users and water dependent ecosystems) from the operation.

All proposed water management components and the overarching water management strategy have been peer reviewed and are discussed in their respective sections.

10.7.1 Groundwater modelling

The information collected during the groundwater investigation assisted in the development of a numerical groundwater model. The numerical model is a representation of the FRA system, in which the main hydrogeological processes and structural elements were incorporated (Figure 10-21).

A three-dimensional finite-difference numerical groundwater model of the study area was developed using MODFLOW, which is widely regarded as the industry standard numerical groundwater modelling software package.

The model domain covers an area of approximately 26.5 km^2, comprising seven layers and approximately 900,000 grid cells. Cell dimensions range from 50 m x 50 m to 5 m x 5 m with progressive refinement in the vicinity of the mine area. The upper boundary of the model domain is defined by topography. The lateral boundaries of the domain generally follow the boundaries of the Inverbrackie Creek sub-catchment.

However, given the requirement to ensure that key simulated stresses (e.g., mine area depressurization) are far enough from boundaries such that they are not controlled by boundary conditions, it was necessary to extend the model domain beyond the south-eastern boundary of the Inverbrackie Creek sub-catchment and into the Dawesley Creek sub-catchment.

Model parameterisation was based on four calibration processes, comprising

1. a pre- mining steady-state calibration process, a
2. a transient calibration process based on the CRDT performed on IB-4
3. a transient calibration process based on the pumping and injection tests performed on BHRIB01 and BHRIB02
4. and a regional transient calibration process (based on seasonal abstraction for irrigation.

A subsequent model validation phase included comparison with catchment modelling-based estimates of baseflow to Inverbrackie Creek, as well a scenario simulation for comparison with historical anecdotal observations of drawdown during mining operations in the 1930s.

The four calibration and two validation processes strengthened the ability of the model to replicate the behaviour of the real system such that it could be used for predicting future behaviour from underground mining.

A summary of the inputs into the groundwater model is presented in Table 10-12

Table 10-12 | Summary of groundwater model inputs

Model input	Data Source used to inform numerical model development
Boundary conditions	The groundwater elevations obtained from at least 48 wells assisted with the assigning of model boundary conditions in order to simulate groundwater flow into and out of the model domain.

Model input	Data Source used to inform numerical model development
Model layers	Model layering was based on the hydro-stratigraphy (Tapley Hill, Marble, Tarcowie Siltstone (including the HW fracture zone). The dip and layer thickness was based on the Terramin geological model.
Aquifer geometry, connectivity and boundaries	Fracturing was modelled based on rock quality designation (RQD), downhole geophysics and water cut information. Aquifer type, hydraulic connection, aquifer properties and boundary conditions were determined from 6-day pumping test of IB4 together with anecdotal historical mine dewatering information.
Aquifer parameterisation K_h and S_s	Hydraulic properties of model layers were derived from 10 CRDT's and 2 injection tests using wells targeting multiple layers at and surrounding Bird-in-Hand. Parametrization refined during model calibrations (described below)
Recharge	Recharge was calculated spatially over the catchment based on CMB of 28 wells followed by calibration using PEST.
Pumping	Pumping volumes were determined from the well census conducted on 37 properties. Not all wells contained flowmeters, so abstraction was based on landholder usage estimates. In this case pumping centres were created in the model as assigning pumping rates to individual wells was not possible.
Groundwater – surface water interaction	Inverbrackie Creek bed elevation contours and measured water levels and water quality over different seasons.
Receptors	Well census of 37 properties (at least 58 private wells surveyed including groundwater level, well depth, target aquifer). Springs surveyed (associated with the Inverbrackie Creek).
Steady state calibration	Water level monitoring of 48 wells (36 routinely monitored) across the catchment (all surveyed and target aquifer confirmed)
Transient calibration (within the mineral claim)	6 - day pumping test and groundwater level monitoring of 34 wells (AGT, 2017 – Appendix H1) 11-day pumping and injection test into BHRIB01 (Golder 2019 – Appendix H9) 6-day pumping and injection test into BHRIB01 (Golder 2019 – Appendix H9)
Transient calibration (Regional)	Groundwater abstraction volumes obtained from well census and regional groundwater level monitoring (>30 wells)
Model validation	Compared against a simulation using anecdotal pumping information from the historic BiH mine.

A detailed understanding of how the groundwater model was developed is included in Appendix F of the Groundwater Impact Assessment, located in Appendix H1.

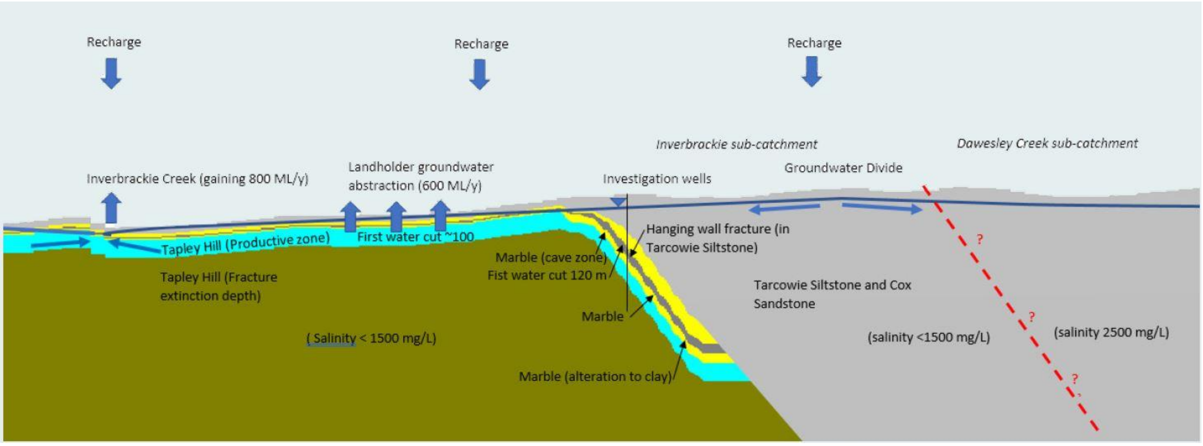

FIGURE 10-21 | EAST TO WEST CROSS SECTION OF NUMERICAL MODEL SHOWING LAYERING ACCORDING TO HYDRO STRATIGRAPHIC UNITS AND FRACTURES.

10.7.1.1 GROUNDWATER IMPACT ASSESSMENT

The numerical model was used as a tool to assess the groundwater related impacts of the proposed underground mining operation and to inform best practice water management options.

The assessed groundwater impacts included:

- Groundwater drawdown at existing operational wells.
- Baseflow reduction to the Inverbrackie Creek.
- The ingress of higher salinity groundwater from the older Kanmantoo Formation to the east of the Bird-in-Hand Project.
- The risk of acid mine drainage from lowering of groundwater levels and oxidation of the supergene layer.

The groundwater management options assess by the model included:

- Grouting ahead of mine development to reduce groundwater inflows by 70%.
- Grouting ahead of mine development to reduce groundwater inflows by 90%.
- Grouting ahead of mine development to reduce groundwater inflows and reinjection of treated groundwater back into the FRA via injection wells installed in a radial pattern around the proposed mine.

Terramin's groundwater risk assessment is based upon credible worst case scenarios. After studying similar operations and receiving advice from grout experts and specialists specifically on the Project's requirements and the Bird-in-Hand geological context, Grouting specialists and peer reviewers expect the groundwater inflows to be reduced by 90% of inflows (90% effective) with the use of grout (Appendix H4 and H5).

Adequate capacity must be built into the system to manage a credible worst case scenario, and for this reason, have designed the water management system with groundwater inflow management being only 70% effective with the use of grout. This allows for adequate infrastructure to be in place if higher inflows are encountered while ensuring the protection of the supply and quality of groundwater for all sensitive receptors (existing users and water dependent ecosystems) from the operation.

Overall, with the implementation of MAR, Terramin expect to have a **negligible** impact to existing groundwater users and water dependent ecosystems water level. Even under a credible worst case scenario of grouting only being 70% effective, Managed Aquifer Recharge limits the potential drawdown to a **minor** impact, however, this is **unlikely,** rating the residual impact as low.

10.7.1.2 GROUNDWATER INFLOWS

Groundwater inflows into the mine come from the Tapley Hill Formation, Marble and the overlying Tarcowie Siltstone (hanging wall fracture).

The most significant mode of groundwater flow into the proposed mine workings is from the hanging wall fracture. Therefore, the rate of groundwater inflow varies according to whether mine development intercept competent rock or the hanging wall fracture zone.

The mine plan has been designed to avoid the major water bearing fracture zones such as the hanging wall fracture. The groundwater model takes this structural feature into account. Particular attention was placed to replicate the separation distance between the hanging wall fracture and Marble which contains the gold reef deposit.

For representation of the underground mine grouting scenarios (90% and 70% grouting effectiveness), drain conductance values in the model were reduced from large values until the desired percentage reduction in total mine inflows was achieved (i.e. as dictated by the grouting scenario). It is important to note that the reduction of drain conductance in the AGT model to meet the MultiGrout grouting effectiveness target (5.5 L/s) resulted in slightly higher modelled peak inflows of 7.5L/s by the end of mining, however on average the inflows will be approximately 4.5 L/s in year 4.

Model predictions of groundwater inflow rates (annual average) with pre excavation grouting (90% and 70%) effectiveness are presented on Figure 10-22 and detailed in Appendix H9.

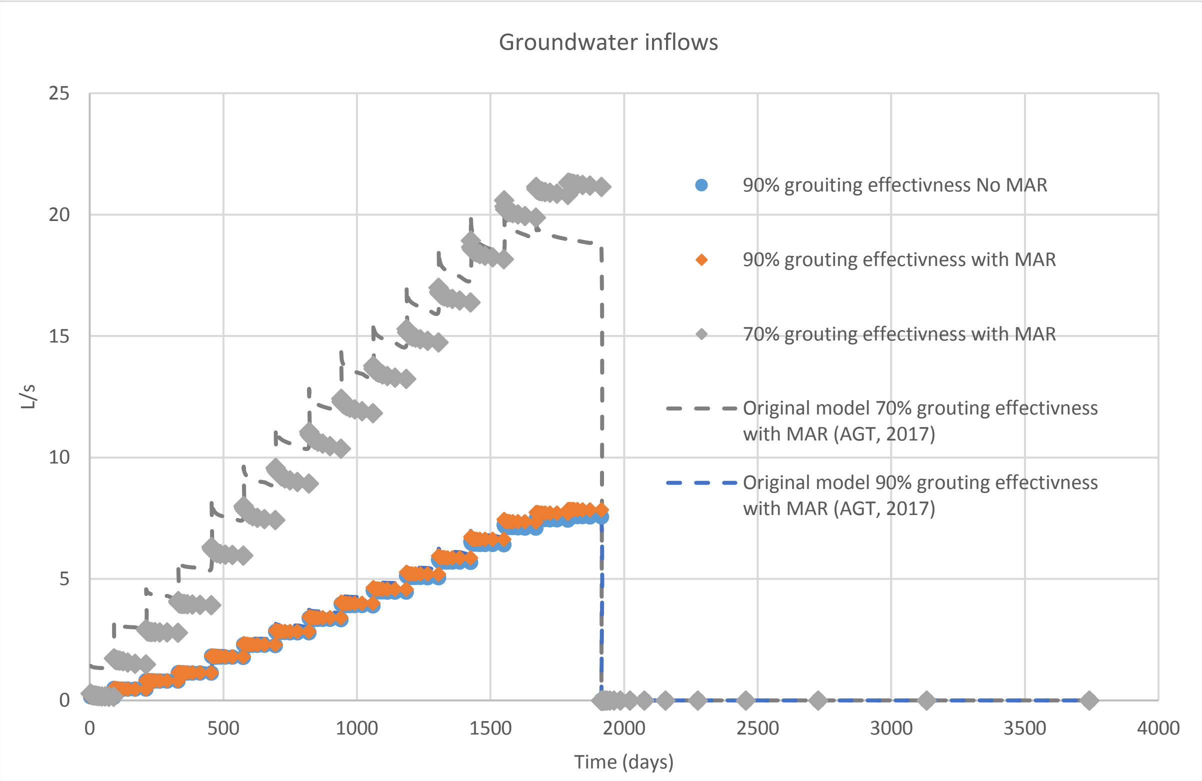

FIGURE 10-22 | SIMULATED GROUNDWATER INFLOWS WITH PRE EXCAVATION GROUTING TO 70% AND 90% GROUTING EFFECTIVENESS (APPENDIX H9)

10.7.1.3 DEPRESSURISATION OF THE FRA

The process of mining reduces groundwater levels in the surrounding FRA. The extent of the zone affected is dependent on the properties of the FRA, the presence of boundary conditions and mitigation measures (grouting and MAR). In the FRA this is referred to as the zone of depressurisation, and the impact reduces with distance from the underground mine.

The numerical model was used to estimate the extent of the zone of depressurisation within the FRA by comparing the simulated groundwater levels with and without the mine operating.

Several scenarios were simulated, assessing the depressurisation of the FRA with varying effectiveness of grouting and also reinjection.

Groundwater modelling showed:

- Without mitigation of groundwater inflows, the predicted maximum extent of depressurisation in the FRA extends about 2 km from the proposed mine by the end of mining (AGT, 2017 – Appendix H1).
- Grouting the mine to 70% or 90% effectiveness reduced the maximum radial extent of depressurisation to 1.6 km and 1.2 km, respectively and reduced the magnitude of depressurisation, particularly at private wells (AGT, 2017 – Appendix H1).
- The reinjection of treated mine water radially around the mine is effective at limiting the zone of depressurisation to a radial distance of 600 m, thereby maintaining groundwater levels at private wells and maintaining the groundwater divide between the Western and Eastern Mt Lofty Ranges (Golder, 2019 – Appendix H9). Figure 10-23 shows the simulated groundwater drawdown in the Tarcowie Siltstone and Tapley Hill formation resulting from 90% inflow reduction, with and without MAR at the end of mining (Golder, 2019 – Appendix H9),

In summary, with the implementation of Managed Aquifer Recharge, Terramin expect to have a **negligible** impact (1m or less drawdown at peak) to existing groundwater users and water dependent ecosystems water level

FIGURE 10-23 | DRAWDOWN CONTOUR RANGE ACROSS MINING SCENARIOS AT MINING YEAR 5.5 (TARCOWIE SILESTONE AND TAPLEY HILL FORMATION)

10.7.1.4 GROUNDWATER DRAWDOWN AT PRIVATE WELLS

A well census documented at least 30 operational wells within the Inverbrackie Creek Sub-Catchment and some outside the catchment to the east of the Bird-in-Hand Gold Project.

Most private wells abstract groundwater from the Tapley Hill Formation to the north and western side of the Marble outcrop, and to a lesser extent the Tarcowie Siltstone. The locations of operational wells are shown on Figure 10-23.

Groundwater inflows into the proposed mine will cause a radial zone of depressurisation during the mine life, which if not managed will likely impact groundwater supplies to some private wells.

Groundwater modelling showed that groundwater level impacts at private wells can be reduced by grouting ahead of development and eliminated by reinjection of treated mine water to offset groundwater drawdown around the mine.

Terramin expects the groundwater inflows to be reduced by 90% of inflows with no mitigation in place (90% effective) with the use of grout. Adequate capacity must be built into the system to manage a credible worst case scenario, and for this reason, have designed the water management system with groundwater inflow management being only 70% effective with the use of grout (a credible worst case scenario).

As outlined above, with the implementation of Managed Aquifer Recharge, Terramin expect to have a **negligible** impact (1m or less drawdown at peak) to existing groundwater users and water dependent ecosystems water level. Even under a credible worst case scenario of grouting only being 70% effective, Managed Aquifer Recharge limits the potential drawdown to a **minor** impact, however, this is **unlikely,** rating the residual impact as low.

The predicted drawdown at operational wells for each mining scenario is presented in Table 10-13 (based on revised modelled scenarios reported in Golder 2019). Negative drawdown values represent a groundwater level rise, whilst positive values represent a groundwater decline. Operational wells within the Inverbrackie Creek subcatchment which have not been specifically identified are outside the credible worst-case zone of impact and do not have a credible impact pathway, and thus will not be impacted.

TABLE 10-13 | PREDICTED DRAWDOWN AT OPERATIONAL WELLS – MINING YEAR 5.5

Well		Baseline DTW (m)	Well Depth (m)	Depth to Water	Pump depth	70% (m)	70% + MAR (m)	90% (m)	90% + MAR (m)
6628-8936	TS		50.9		27.4	7	-1.5	3	-1
6628-8940	TH		UKN			15	-2	8	-1
6628-10944	TH	11.69	76	11.84	60	6	-1.5	5	0
6628-9154	TH	4.2	51.5	22.20	30.5	7	-2	2	0
6628-23182	TH	13	64	13.2	~58	15	-1	9	0.5
6628-9153	TH	3.1 - 5.6	134	6.71	45.7	10	-2	5	0
6628-8946	TS	16.57 - 24.0	UKN	19.35		10	0	4	0
6628-20475	TS	20	70	25.08	60	10	0	4	0
6628-8950	TS	8.1	22.9	10.90	26	5	0	2	0
6628-8952	TS	26.8 - 30.14	45.7	24.10	50	5	0	2	0
6628-18637	TH	11.87 - 23.4	70	16.54	45.7	7	-1.5	3	0
6628-9152	TH	11.00	91			3	0	1.5	0

Well		Baseline DTW (m)	Well Depth (m)	Depth to Water	Pump depth	70% (m)	70% + MAR (m)	90% (m)	90% + MAR (m)
6628-10249	TH	12.07 - 21.31	98.8	18.00		3	0	1.5	0
6628-8301	K	9.14	100.58		80	7	0	3	0
Springs associated with Inverbrackie Creek - upstream		-	Not applicable			2	0	1	0
Springs associated with Inverbrackie Creek – down stream		-				2	0	1	0

Note: If a well is not included in this table, it is not expected to be impacted by Terramin's activities due to distance from the site.

10.7.1.4.1 ASSESSMENT OF INTERCEPTION OF THE HANGING WALL FAULT/FRACTURE ZONE

Terramin undertook additional work to understand the impact the operation could have if the identified hanging wall fault/fracture zone was intercepted by underground workings without grouting.

Figure 10-24 shows the simulated inflows from a 10 m existing (non-grouted) area within the hanging wall fracture at mining depths of 130 m and 300 m bgl, exclusive of any other depressurisation activities (maximum pressure head).

The modelled inflows indicated the hanging wall fracture will produce large amounts of water of ~50 to ~150 L/s, if exposed by 10 m non-grouted area. The resulting drawdowns at 2 weeks following simulated interception of hanging wall fracture are presented as Figure 10-25, which shows no additional drawdown to any of the identified sensitive receptors (existing groundwater users). This scenario includes the continued operation of the MAR system. Further discussion can be found in Appendix F of the Groundwater Assessment (Appendix H1).

All of the continued updating of geological and hydrogeological modelling will provide extensive information on the geological structures surrounding the hanging wall fault/fracture zone and further reduce any remaining uncertainty.

Contingencies will be in place to provide redundancy and capacity to manage any unexpected water inrushes effectively from both an environmental and safety aspect. If the hanging wall fault/fracture was intercepted unexpectedly, Terramin would expect to have the situation rectified significantly within the 2 week period to ensure no impact to identified sensitive receptors (existing groundwater users). In an unlikely worst case scenario, operations would need to be suspended until a further solution was identified and approved by the mining regulator. This presented scenario also does not include the potential for utilising all MAR bores simultaneously to increase reinjection rates over the short term. Underground pumping infrastructure has been selected on the assumption of a 40L/s inflow into the mine. This provides a factor of safety >1.5 on the maximum inflows with an assumed 70% grouting effectiveness (~25L/s). Detailed management of emergency inflows is outlined in Chapter 3: section 3.4.6.7.

Notably, the predicted inflows at 130 m bgl are consistent with the high inflows reported during depressurisation of the historic Bird-in-Hand mine (40 to 60 L/s) when the hanging wall fracture was intercepted at roughly the same depth of 130 m bgl.

Conservatism has been built into these two scenarios, as it is modelled in conjunction with groundwater inflow management being only 70% effective with the use of grout. Information on optimising the grouting pattern further has been completed by Mining one and is located in Appendix H4.Overall, the impact to existing groundwater users and water dependent ecosystems if the hanging wall fracture was intercepted would be **negligible**, as demonstrated in Figure 10-25.

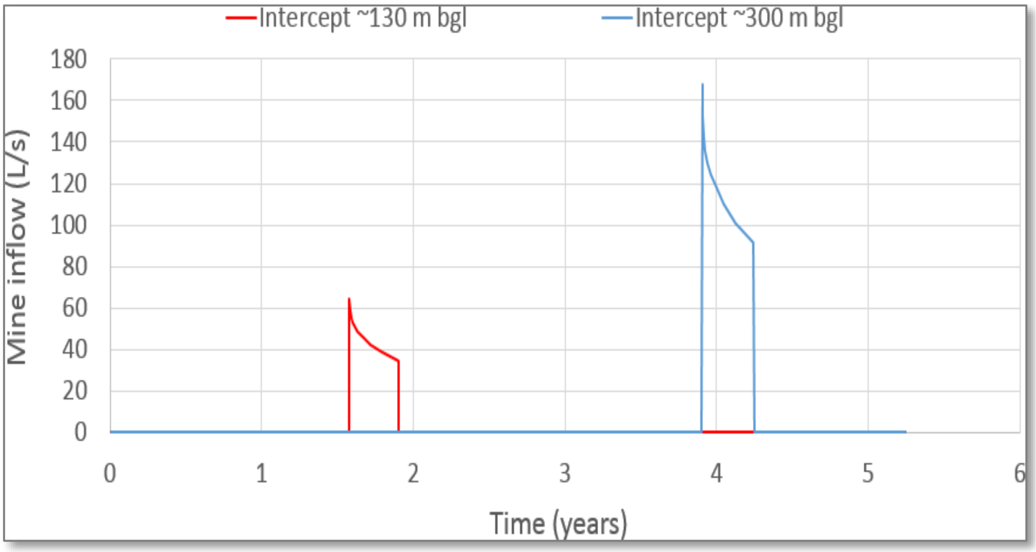

FIGURE 10-24 | GROUNDWATER INFLOWS DUE TO MINING IN THE HANGING WALL FRACTURE WITHOUT GROUTING

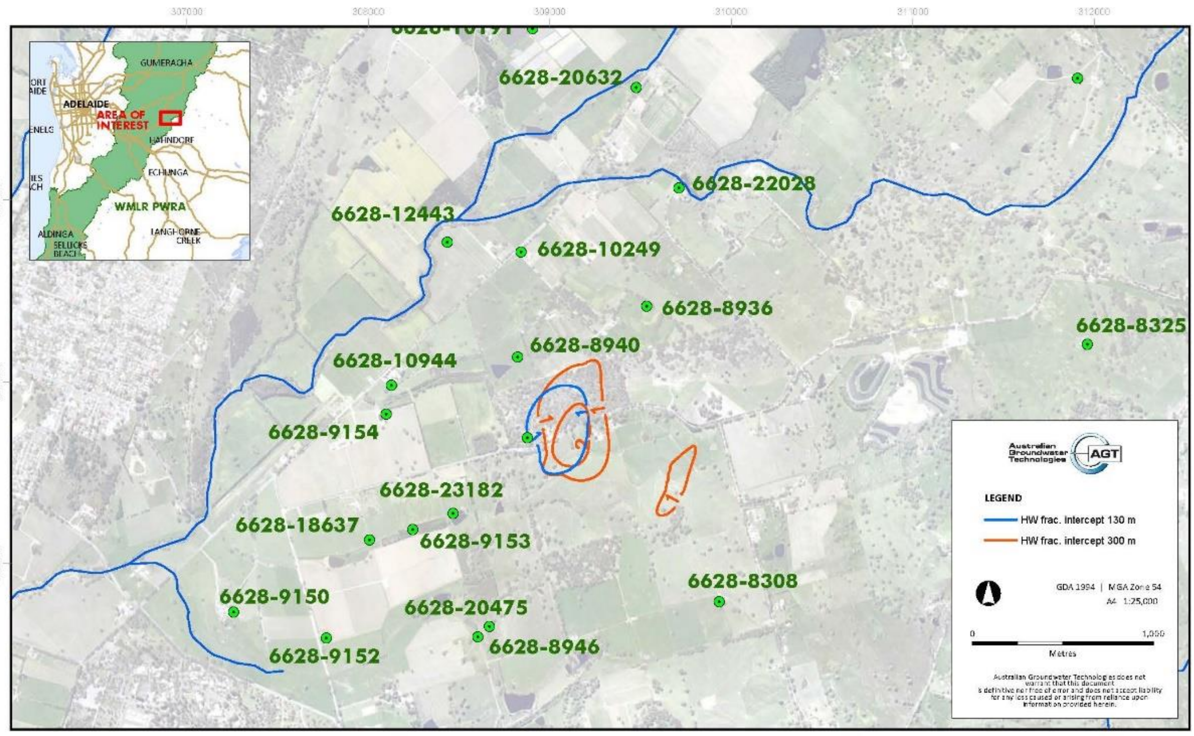

FIGURE 10-25 | DRAWDOWN DIFFERENCE (M) AT 2 WEEKS FOLLOWING SIMULATED INTERCEPTION OF HANGING WALL FRACTURE AT 130 M (BLUE) AND 300 M (ORANGE). (TAPLEY HILL FORMATION; 70% EFFECTIVE GROUT INCL. MAR SCENARIO.)

10.7.1.5 INVERBRACKIE CREEK

Surface water studies (Terramin 2017 and EPA 2013) have indicated that the Inverbrackie Creek is of poor condition, enriched with nutrients and high in sediment due to human disturbance. It has a moderate diversity of invertebrates and lacks any rare or sensitive species.

The Inverbrackie Creek is located about 700 m from the proposed mine workings and receives groundwater baseflow in the lower reaches, mostly during winter when the groundwater elevation is higher, significantly reducing during summer, caused by groundwater levels being lowered by irrigation pumping. The existing baseflow of the Inverbrackie Creek has been discussed in section 10.3.4.2.

Groundwater modelling (Figure 10-26) showed that by the last year of underground mining, baseflows to the Creek will:

- Reduce by 0.27 ML/d without any management of groundwater inflows (AGT, 2017).
- Reduce by 0.1 ML/d where grouting is 90% effective at reducing groundwater inflows (Golder 2019).
- Increase by 0.1 ML/d where MAR is adopted (either grouting scenario).

With the implementation of Managed Aquifer Recharge, Terramin expect to have a **negligible** impact to existing groundwater users and water dependent ecosystems water level. Even under a credible worst case scenario of grouting only being 70% effective, Managed Aquifer Recharge prevents further drawdown over the 5.5 years mine life and resultantly a **minor** impact, however, this is **unlikely,** rating the residual impact as **low**.

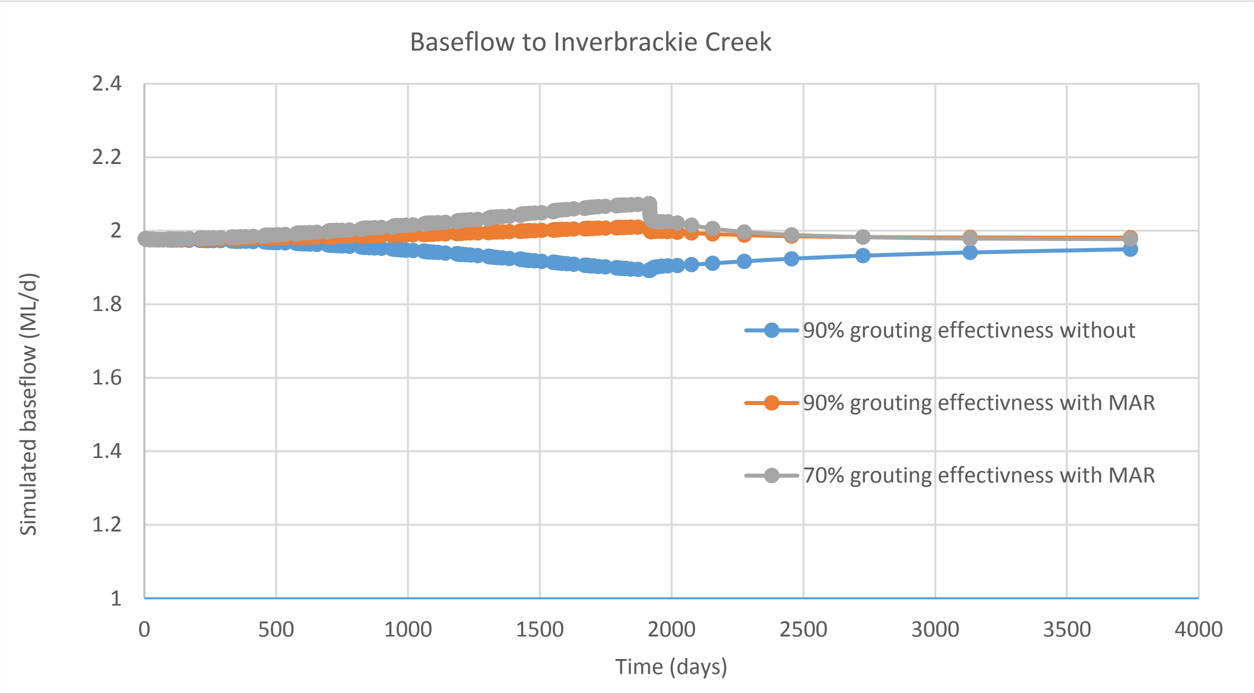

FIGURE 10-26 | BASEFLOW TO INVERBRACKIE CREEK FOR EACH MINING SCENARIO

10.7.1.6 EXPECTED FINAL WATER LEVELS

Groundwater inflows into the proposed mine will cause a radial zone of depressurisation during the mine life, which if not managed will likely impact groundwater supplies to some private wells.

Groundwater modelling showed that groundwater level impacts at private wells can be reduced by grouting ahead of development and eliminated by reinjection of treated mine water to offset groundwater drawdown around the mine.

Terramin expects the groundwater inflows to be reduced by 90% of inflows (90% effective) with the use of grout. Adequate capacity must be built into the system to manage a credible worst case scenario, and for this reason, have designed the water management system with groundwater inflow management being only 70% effective with the use of grout.

The predicted drawdown at operational wells for each mining scenario is presented in Table 10-13 (based on revised modelled scenarios reported in Golder 2019). Negative drawdown values represent a groundwater level rise, whilst positive values represent a groundwater decline. Operational wells within the Inverbrackie Creek subcatchment which have not been specifically identified are outside the credible worst-case zone of impact and do not have a credible impact pathway, and thus will not be impacted.

With the proposed system of ground water management, it will be a relatively short timeframe for the groundwater levels to return to their pre-mining state. Even if operations only achieve 70% effective sealing of inflow with grouting regime with MAR, modelling predicts that levels will return to within 2m of original, in the first 12 months after mining ceases.

A comparison of the residual groundwater drawdowns, with and without MAR at five years post mining are presented for the Tapley Hill Formation and the Tarcowie Siltstone (Figure 10-28). Groundwater modelling 5 years post mining shows that without MAR, there is a small residual drawdown of 1 to 4 m across the main irrigation area, and no residual drawdown with MAR.

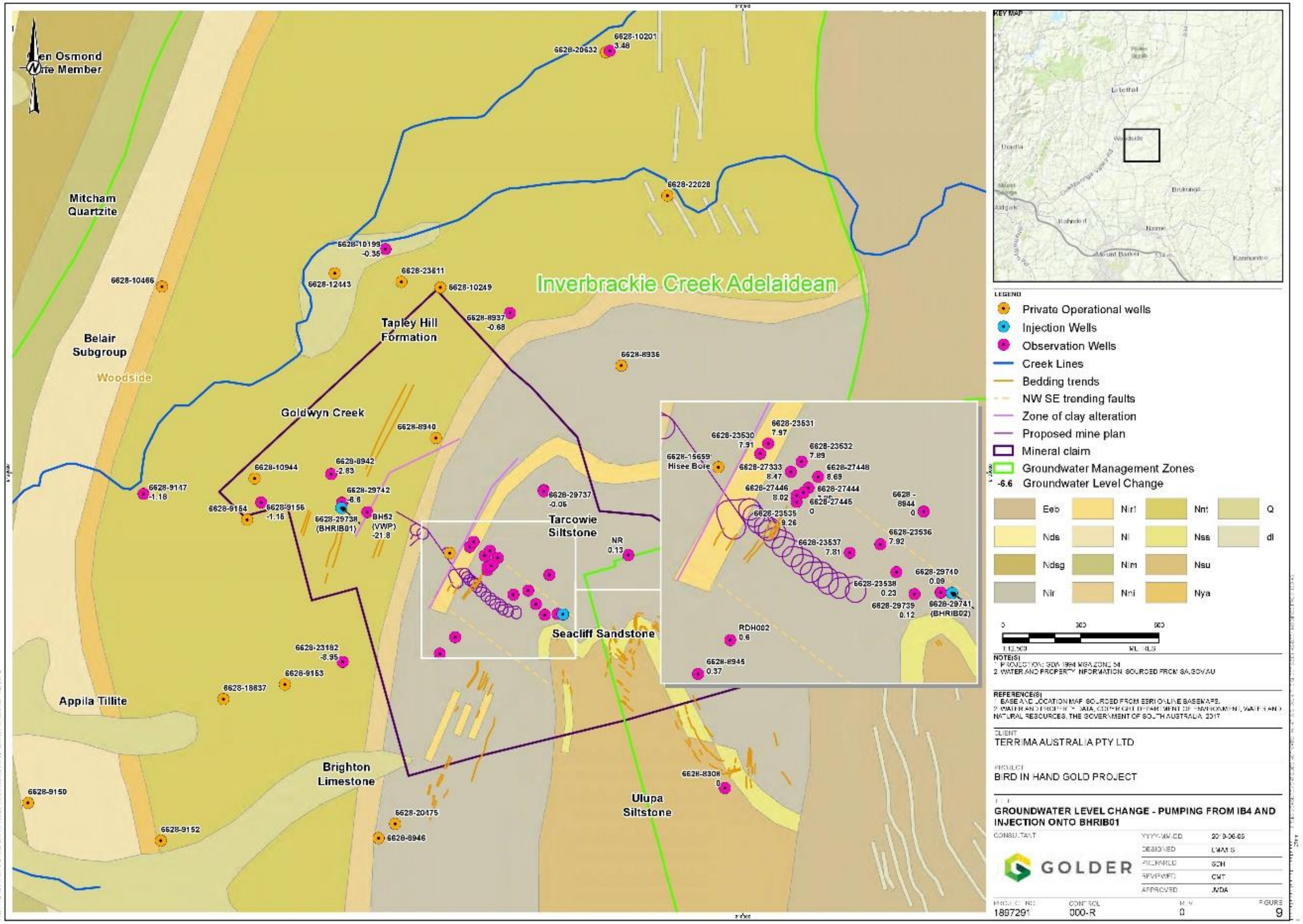

FIGURE 10-27 | OPERATIONAL WELLS, INSTALLED INJECTION WELLS, AND CREEK LINES (APPENDIX H9)

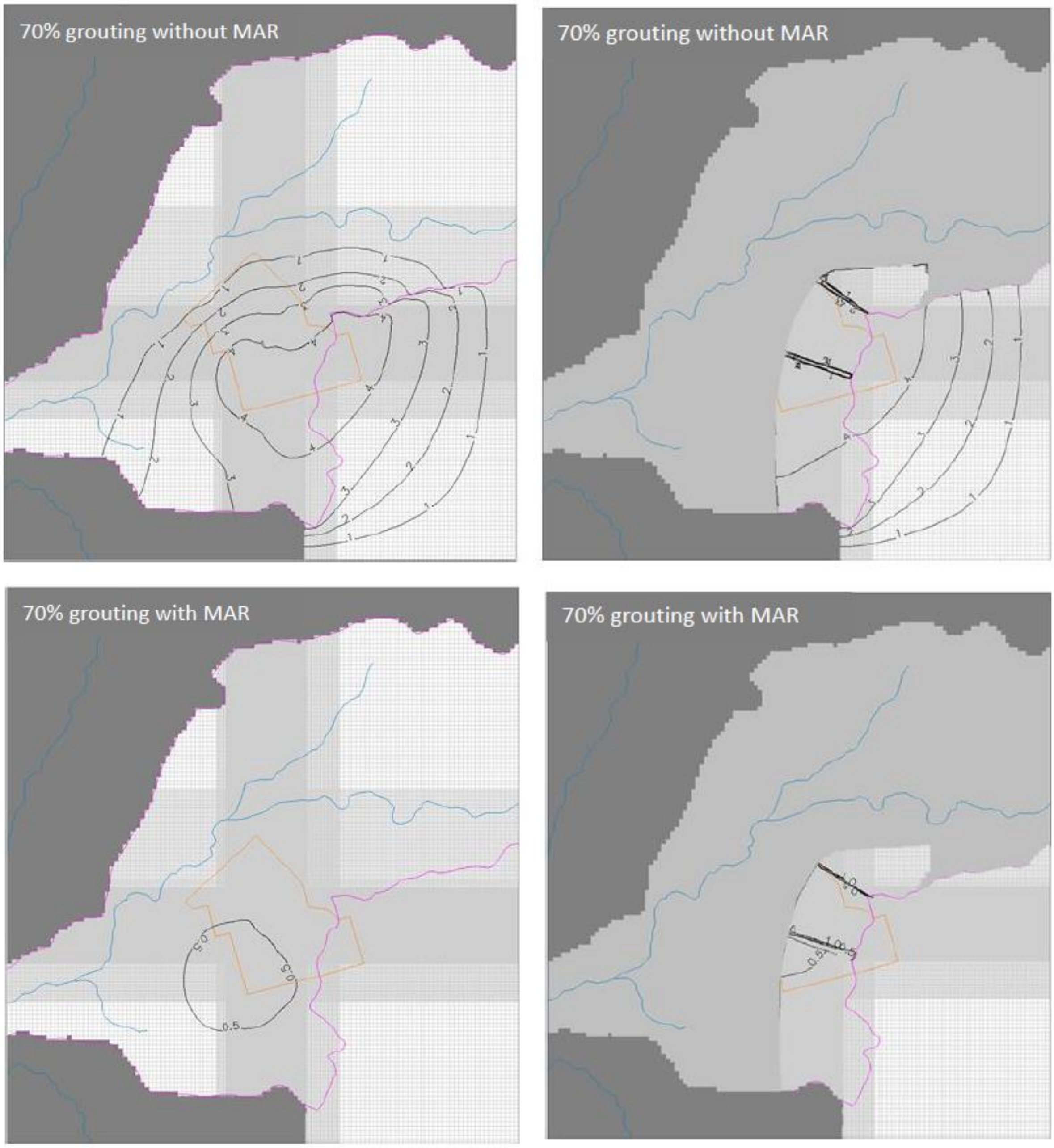

FIGURE 10-28 | RESIDUAL DRAWDOWNS FIVE YEARS POST CLOSURE TAPLEY HILL FORMATION (LEFT), TARCOWIE SILTSTONE (RIGHT)

10.7.1.7 BLASTING AND GROUNDWATER

10.7.1.7.1 THE POTENTIAL IMPACTS OF BLASTING ON BORE HOLES

Blasting is a mining method that can be used through all stages of mining (construction, development and production). Blasting operations for exploration or mining breaks up the rock material immediately surrounding the blast for easy removal. The impact of blasting on nearby wells or bore is a common concern for the public or neighbouring landowners, the concerns expressed areabout potential damage to bores, changes to water quality or specifically increased turbidity. This summary focuses on the potential impacts from blasting on groundwater wells surrounding the proposed Bird in Hand Mine operation.

Blasting operations impact the surrounding rock and may affect the connected aquifer. However, the surrounding bores themselves are unlikely to be affected by blasting operations (Frank & Beaver Jr, 1984). Past research has shown no significant changes in yield or water quality over a range of distances and charge weights (Sneddon 1981). Temporary and minor changes in water levels, and turbidity may be caused by blasting but are not a long term or permanent impact.

10.7.1.7.2 POTENTIAL DAMAGE TO WELLS

Blasting can impact the surrounding rock in three ways; creation of new fractures, expansion of existing fractures and joints, and collapse of fractures (Sneddon 1981, Golder Associates, 2005, Frank & Beaver Jr, 1984, Bender 2006, Hawkins, 2000). The literature suggests this only occurs within a contained area around the blast hole (~20m) and is very dependent on the size of blast and the rock formations (Golder Associates, 2005). In none of the literature, has there been any instances of physical damage to bores (Sneddon 1981, Golder Associates, 2005, Frank & Beaver Jr, 1984, Bender 2006, Hawkins, 2000). Even at a distance of just 10-50 ft (3-15 m) bore casing remained intact (Frank & Beaver Jr, 1984). One key reason is the propagation of vibrations through the subsurface reduces much more quickly than those on the surface (Bender 2006, Golder Associates, 2005).

10.7.1.7.3 POTENTIAL IMPACT ON AQUIFERS

Blasting may impact the local aquifer, because of any movement in localised fractures in the rock. This potential impact can cause new or expanded fractures and cracks to increase aquifer capacity and has the possibility to cause fracture collapse leading to reduced aquifer storage capacity or bore yields. The structure of the subsurface strata surrounding the bore can effect or modify the blast impact. For example, a bore located in a sandy aquifer can experience an increase in water yield as the fracturing from the blast increased its permeability. In contrast, a similar test on a bore into a coal aquifer yielded a decrease in aquifer capacity as the coal structure collapsed instead of expanding, leading to a decrease in permeability and yield. In addition to the capacity of the aquifer, changes in the strata structure can also affect other factors such as water quality.

It is worth nothing that in the Inverbrackie catchment it was common practice in the past to use dynamite down open (that is uncased) boreholes to increase bore yields (pers comm T.Kerber 2018) and this has been done on bores on and neighbouring the proposed BIH ML.

Aquifer water quality has been found to be generally unaffected over the long term (Frank & Beaver Jr, 1984 – no change except at very short range and even that was not permanent). Minor temporary changes in water quality have been noted in near field blast. However, these changes have been found to be small, and reversible and only recorded when the blast was less than 500ft (~170 m) away from the bore. There is a potential for increases in nitrites and nitrates from blasting material residuals (Kernen 2010 & Hawkins, 2000), and the breaking up of rock material may contribute to levels of dissolved solids such as sulphates, iron, manganese, aluminium, and sodium in the water. Water quality changes are described as short term only and quickly reversible.

Furthermore, there is the potential for movement in the rock to create temporary and short-term changes to the water level. Even though these impacts are possible, the literature highlighted that water level changes can occur briefly at the time of the blast, but are generally minor (~10cm (Golder Associates, 2005) 3cm at 500ft, and 30cm at 100ft (Frank & Beaver Jr, 1984)) and will correct themselves with time.

The final possible impact is a potential increase in the localised bores turbidity. This can be caused by; shaking loose naturally occurring sediment material from walls of the bore into bore water, similar to that cause by significant rainfall events, and washing naturally occurring sediment out of newly created or expanded fractures into the aquifer. (Frank & Beaver Jr, 1984, Hawkins,2000). Golder Associates (2005) suggests that vibration limit of 25mm/s should yield no apparent impacts on the bores or their water quality, and a limit of 50mm/s may see occasional instances of increased turbidity, but will protect bores from any other damage. Sand based bores may maintain a lower turbidity as the sand acts as a natural filter, while coal based bores were found to have an increase in turbidity after blasting, due to the naturally occurring material coming loose with the vibrations and movement of the rock. This was noted to be a temporary effect only.

10.7.1.7.4 HOW THIS RELATES TO THE BIHGP

Blasting method will be used during all three phases of the mine (construction, development and production). The blasting will be used during the excavation of the box cut and road cutting on the surface during construction and used in the subsurface during development and production. The report by Saros (2017) goes into detail on the methodology of the blasting during the three phases of mining, highlighting the minimal impact from the small-scale blasting on the surrounding environment. The short-term construction blasting in the box cut will be used to blast 5-10m benches using a maximum charge weight of 12-40kg. During the long-term development and production blasting, the blast dimensions are approximately 5m wide and 5m high, and target advance of around 3-4m per shot. These blasts will use a maximum charge weight of 5kg per blast hole. These dimension and charge weights are significantly smaller then though used in the above literature examples. Also, this blasting should be very well controlled as it only needs to be designed specifically to fracture the rock sufficiently to facilitate excavation.

In Australia, the requirement surrounding the use of explosives, and consequently both blasting activities and their subsequent environmental effects, are detailed in Australian Standard 2187.2 (SAI Global, 2006). It is important to note that regulatory compliance limits are based on human comfort levels rather than damage thresholds. The BIH location is classified as a sensitive site, which is required to have ground vibration limit of '5mm/s for 95% blasts per year, 10mm/s maximum unless agreement is reached with the occupier that a higher limit may apply (Saros (2017).' In the modelling undertaken by Saros (2017) on the proposed blasting activities indicated blast practices during all three phases of the mine can be conducted safely and maintain compliance with regulatory limits. Figure 10-30 shows the extent of blast induced ground vibration during the construction phase at BIH, which is the largest amount of vibrations which will be produced in the BIH blast operations. In Figure 10-30, the red line shows 10mm/s and the orange line shows 5mm/s. When compared to Figure 10-30, the location of the bore holes, all neighbouring boreholes are outside the 5mm/s limit. As a result, compliance with the licence conditions will minimise human discomfort and prevent any likelihood of damage to neighbouring structures including boreholes.

Several additional mitigation actions can be undertaken to reduce the potential impacts from blasting if required including:

- Pre-split blast holes to limit damage from bulk blasts
- Closer blast spacing
- Delayed intervals between blasts
- No stemming in blast holes
- Reduced burden
- Lower explosive densities to reduce peak blast pressure
- Blasting pressures designed to match compression strength of surrounding rock

10.7.1.7.5 CONCLUSION

The literature showed even with the possible impact on the surrounding rock, there is no evidence of blasting operations causing damage to surrounding wells. The literature also showed there is the potential for short term impacts to the local aquifer, including water quality, water levels and water turbidity, but these were all found to be very localised with no long term affects.

When comparing the proposed BIH blasting operations to the case studies in the literature, the BIH blasting operations are significantly smaller. It is highly unlikely for there to be any damage from blasting to the surrounding wells and minimal short term impacts on the local aquifers.

Based on the available literature, Terramin do not expect any impacts on water supply or quality on existing groundwater irrigation users.

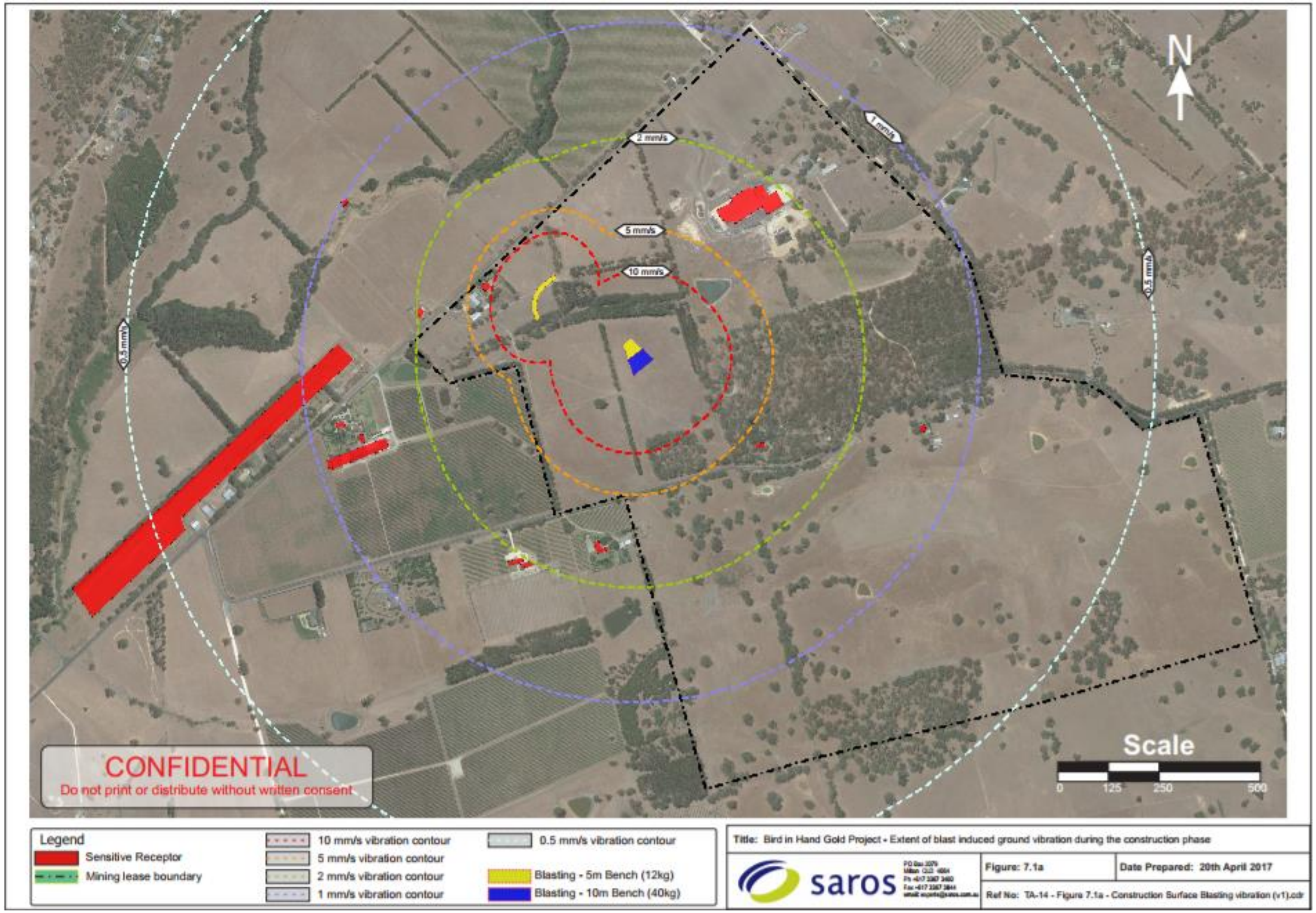

FIGURE 10-29 | EXTENT OF BLAST INDUCED GROUND VIBRATION DURING THE CONSTRUCTION PHASE AT BIH.

FIGURE 10-30 | LOCATION OF BOREHOLES SURROUNDING THE BIH OPERATIONS.

10.7.1.8 GROUNDWATER QUALITY

10.7.1.8.1 DAWESELY CREEK SALINITY

The Bird-in-Hand Gold Project is located near the boundary of the Eastern Mt Lofty Ranges (EMLR) and Western Mt Lofty Ranges (WMLR), where there is a natural groundwater divide between the two catchments. In the EMLR, the Kanmantoo Formation is older and less productive, with higher salinities (up to 4,000 mg/L) than the FRA around the Bird-in-Hand Gold Project (typically less than 1,500 mg/L).

Groundwater inflows, if left unmanaged have the potential to create a cone of drawdown in the FRA around the mine which could remove the groundwater divide and potentially cause more saline groundwater to migrate towards the Inverbrackie Creek sub-catchment. This risk was evaluated by solute transport modelling, which showed:

- Only minor risk of saline groundwater intrusion without any mitigation or management of groundwater inflows. This is due to the short mining life (model simulation time) of 5.5 years.
- No saline groundwater intrusion when groundwater inflows are managed, thereby preserving the groundwater quality of the WMLR.

The simulated salinity change at the end of mining (5.5 years) without any mitigation (no grouting or MAR) is shown by the 1,100 mg/L contour line on Figure 10-31 for the Tapley Hill Formation and Tarcowie Siltstone. This contour is chosen as it represents the boundary defining a small predicted increase in groundwater salinity (i.e., 100 mg/L) relative to the background salinity.

The simulation predicts very minor movement of the saline interface, even where no mitigation is applied (grouting or MAR) owing to the short mining life. Saline intrusion into the WMLR is prevented by utilising MAR and placing a MAR well between the two catchments, as shown in Figure 10-20.

Due to the implementation of MAR, Terramin expect the impact of saline intrusion to be **negligible**, and even in a credible worst case impact event the impact would below.

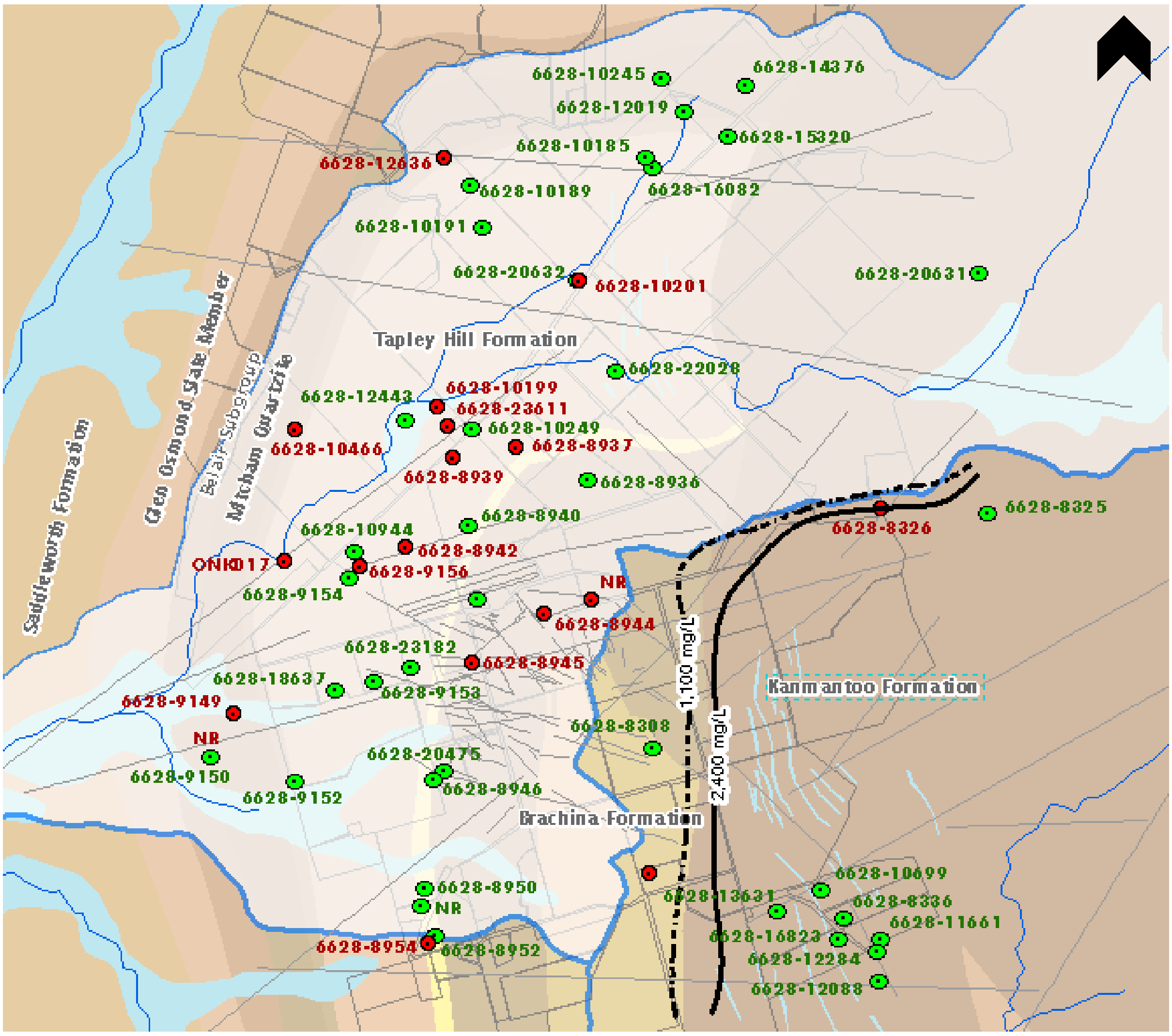

FIGURE 10-31 | SALINE GROUNDWATER WATER MOVEMENT

10.7.1.8.2 ACID AND METALLIFEROUS DRAINAGE

The identified supergene zone (outlined in section 10.3.2.4 above) will be largely avoided during development of the decline due to the poor structural integrity of the highly clay altered rock, being unsuitable for extraction. The tunnelling will be primarily within less weathered, more competent Tapley Hill Formation's calcareous metasediments.

The decline and lower decline spiral will be developed within less weathered rock units to keep excavations within competent ground conditions, as shown on Figure 10-32 below. Due to moving the decline to avoid this identified area, and numerical modelling of groundwater levels above the weathered zone, shows only minor depressurisation above the supergene layer, which will not cause the aquitard containing the supergene layer to dry (and potentially oxidise), Terramin expect the impact from this identified area to be **negligible**. The ongoing groundwater monitoring system will continue to assess the information to confirm no impact, both through operations and through the closure phase.

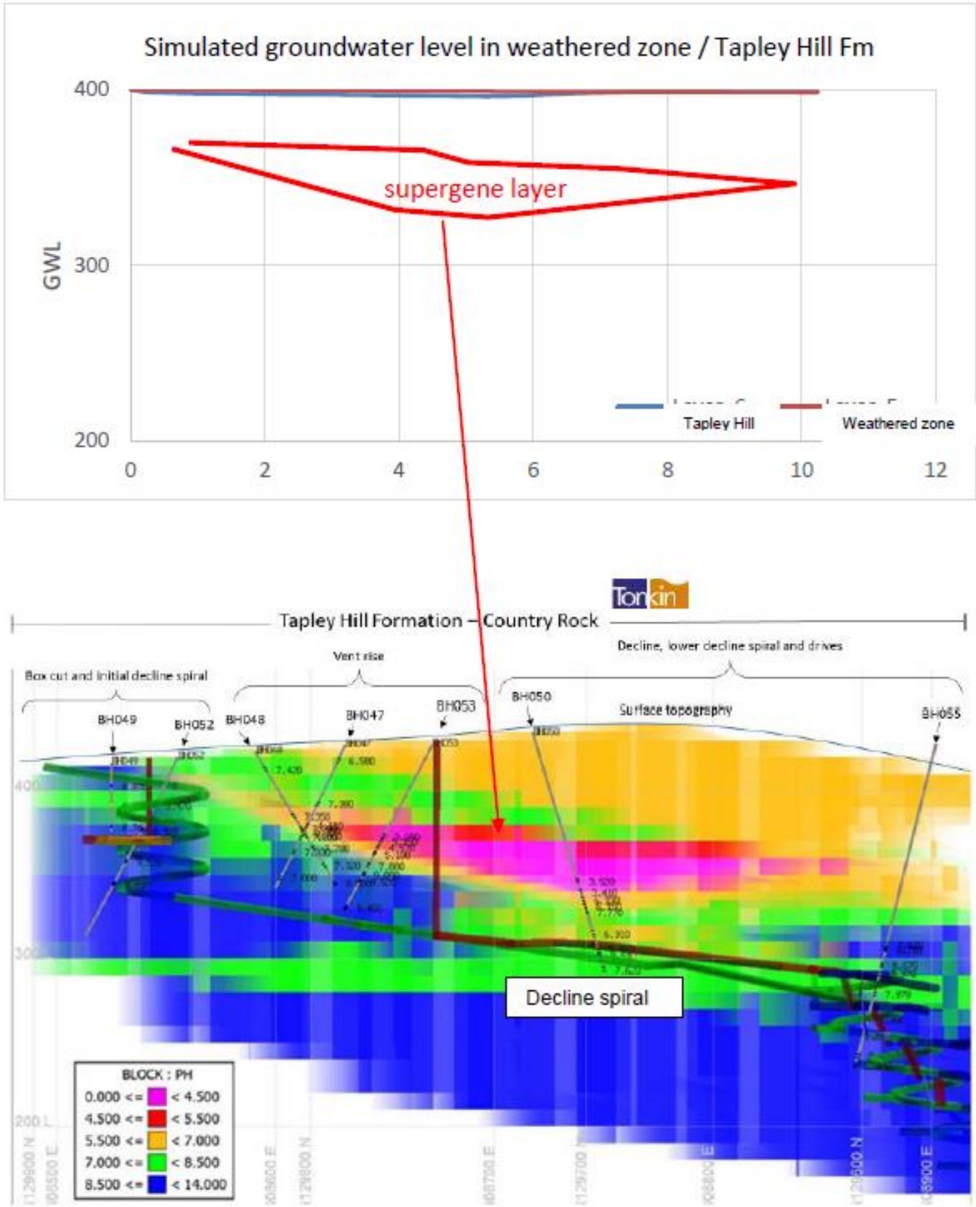

FIGURE 10-32 | GROUNDWATER DEPRESSURISATION ABOVE THE SUPERGENE LAYER

10.7.1.8.3 GROUT

Grout not suitable for drinking (potable) water has the potential to contaminate aquifers and impact existing groundwater users, as well as groundwater dependent ecosystems. With this in mind grouting products chosen will be based on applicable standards and legislation which ensures meeting EPA and DEW water quality standards.

Any type of cement may be used for pre-excavation grouting purposes, but coarse cements with a relatively large particle size can only be used to fill larger openings. Two important parameters governing the permeation capability of cement are the maximum particle size and the particle size distribution. The average particle size can be expressed as the specific surface of all cement particles in a given weight of cement. Particle size of some frequently used injection cements is presented in Table 10-14.

TABLE 10-14 | PARTICLE SIZE OF SOME FREQUENTLY USED INJECTION CEMENTS (BASF, 2011)

Cement type	Particle Size (µm)
Cementa Anleaggningscement	120 (d_{95}), 128 (d_{100})
Cementa Injekteringscement 64	64 (d_{95}), 128 (d_{100})
Cementa Injekteringscement 30	30 (d_{95}), 32 (d_{100})
RHEOCEM® 650	20 (d_{95})
Cementa Ultrafin cement 16	16 (d_{95}), 32 (d_{100})
Spinor A16	16 (d_{98})
Dyckerhof Mikrodur P-F	16 (d_{95})
RHEOCEM® 800	15 (d_{95})
Cementa Ultrafin cement 12	12 (d_{95}), 16 (d_{100})
RHEOCEM® 900	12 (d_{95})
Spinor A12	12 (d_{98})
Dyckerhof Mikrodur P-U	9.5 (d_{95})
Dyckerhof Mikrodur P-X	6 (d_{95})

From an injection viewpoint, these cements will have the following basic properties:

- A highly ground cement with small particle size will bind more water than a coarse cement, as it has a higher surface area to volume ratio. The risk of bleeding (water separation) in suspension created from a fine cement is therefore less, and a filled opening in the ground will stay more completely filled also after its setting.
- The finer cements will normally show quicker hydration and a higher final strength. This is normally an advantage, but also causes the disadvantage of a shorter open time in the equipment. High temperatures will increase the potential problems of the clogging up of lines and valves. The intensive mixing required for fine cements must be closely controlled to avoid heat development caused by friction in the high shear mixer and hence even quicker setting.

The finer cements will mostly give better penetration into fine cracks and openings. It is commonly said that the finest injectable crack is about 3 x the maximum particle size (including the size of flocculates). For standard cements, this means openings down to about 0.3 mm while the finest micro cements may enter openings of 0.06 mm (BASF, 2011). More detailed information on the chemical stability of grout and fill is included in Appendix H4.

The grout proposed is also used to rehabilitate wells - DPC "*M21 Mineral exploration drillholes - General specifications for construction and backfilling*" and no to negligible impact from cement on groundwater quality can be expected.

10.7.1.8.4 HYDROCARBONS

Hydrocarbons pose little to no risk throughout the operational life of the mine, due to any groundwater intercepted in the workings being drawn towards the mine void, and then pumped to the surface for treatment.

The Proposed Waste Management Plan outlines design measures and control strategies to reduce the likelihood of hydrocarbon spillage, however, spill kits, procedures and reporting are proposed to further reduce the likelihood of un-remediated hydrocarbon spills. The expected impact of hydrocarbon contamination impact groundwater is **negligible**.

10.7.1.8.5 FORMER RIDGE TAILINGS DAM

There was considered a possibility that metalliferous drainage may exist from former tails and mine waste areas from the historic Ridge mine. This includes a private landholder stock dam located directly downstream from the historic Ridge chimney and downstream from Terramin exploration sites - location shown in Figure 10-33 and Figure 10-34.

Water quality obtained from the dam from 2014-2016 indicates no traces of mercury, cyanide, and within average ranges of metals as all other dams and surface water in the region – as seen in Table 10-15. The dam was cleaned out during 2015 by the landholder and the sediment waste located to the south of the dam. The dam is currently used for stock. Stock access the dam and there are a number of shallow depressions within the floor of the dam, presumably from stock pugging whilst seeking water. Stock access has resulted in a low pH during 2018 due to low water levels and animal waste. The dam is located in the riparian zone and fills each year, overflows generally each winter and is equipped with a flow diversion for when the dam is full. This diversion flows each year and has been observed operating the last 4 years and presumably has done so since the property was used for agricultural uses. There is no additional credible risk to the soil quality from Terramin's exploration activities from these historic areas.

Regardless, exploration works will utilise the Exploration Management Plan, included in Appendix B7, and the SCMP (included in Appendix L4).

FIGURE 10-33 | RIDGE MINE'S TAILINGS DAM AND CHIMNEY. FACING SOUTH.

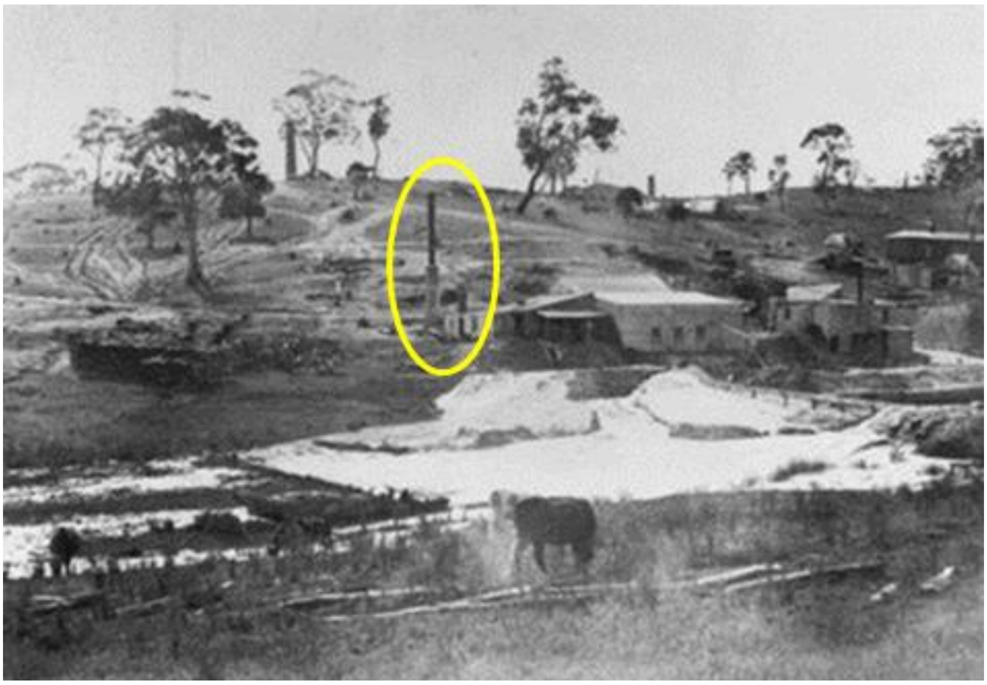

FIGURE 10-34 | VIEW OF CHIMNEY AND TAILINGS DAM FROM OTHER SIDE OF THE VALLEY, C1887

TABLE 10-15 | RESULTS OBTAINED FROM FORMER RIDGE DAM AND REGIONAL STATISTICS TO DATE (2018)

Date Sampled	pH	EC uS/cm	TDS mg/L	As Tot mg/L	Cd Tot mg/L	Cu Tot mg/L	Fe Tot mg/L	Mn Tot mg/L	Pb Tot mg/L	Zn Tot mg/L	Hg Diss mg/L	Hg Tot mg/L	Cn Tot mg/L
24-Mar-14	7.04	167	89	0.01	<0.0001	0.009	7.1	0.236	0.053	0.006	<0.0001	<0.0001	<0.004
30-Jun-14	7	156	291	0.004	0.0001	0.016	8.53	0.059	0.049	0.016	<0.0001	0.0002	<0.004
14-Jul-14				<0.001	<0.0001	0.007	1.36	0.021	0.005	0.015	<0.0001	<0.0001	
26-Nov-14	9.34	272	421	0.017	0.0003	0.021	13.2	0.276	0.093	0.05			
07-Sep-16	7.19	160	154	0.003	0.0001	0.006	1.91	0.043	0.011	0.005			
26-Apr-18	3.07	1310	769	0.033		0.027	18.4	0.805	0.153	0.041	<0.0001	<0.0001	
Regional surface water ranges (excl. former Ridge dam)	5.5-9.8	62-3930	99-3280	0.001-0.89	0.0001-0.0066	0.001-0.17	0.07-649	0.003-59.9	0.001-0.898	0.005-0.509	<0.0001	0.0012	<0.004
Sample count regionally (excl. former Ridge dam)	358	366	353	277	258	297	285	285	297	297	70	53	12

10.7.2 Uncertainty analysis

An uncertainty analysis was undertaken to assess the robustness of the model. This was undertaken to examine how the predictions, such as predicted inflows and drawdown from the numerical model change as the input assumptions to the models are varied.

The uncertainty in the model predictions was assessed by changing model input parameters individually to assess the impact upon the predictions. This included aquifer parameters K_h, Kv and S_s, as well as assessment of the influence of different aspects of the conceptual model, as follows.

- The significance of the hanging wall fault. This will produce large amounts of groundwater if exposed. To assess this a 10 m drain was placed in the fracture zone at different depths to assess the rate of groundwater inflow with depth.
- The effect groundwater flow boundaries, such as faults, have on inflows and drawdowns, by removing these from the model.
- The effect the upper weathered zone above the Tapley Hill Formation, around the decline has on mine inflows.
- Aquifer properties of different model layers (increasing and decreasing K and S). Of particular interest, was assessing the influence the permeability of fracture zones on mine inflows by increasing the K of the upper cave zone (in the Marble) and the hanging wall fracture (in the Tarcowie Siltstone).

The effect the above has on the unmitigated (ie not grouted) inflows resulted in a variation of about 7 L/s.

This uncertainty analysis was also included in the peer review of the groundwater model and assessment and confirmed to be fit for purpose based on the objectives stated in the report.

10.7.3 Peer review of Groundwater Model and Assessment

Innovative Groundwater Solutions (IGS) was contracted by Terramin to provide an independent peer review of the numerical groundwater flow model produced by Australian Groundwater Technologies Pty Ltd (AGT) to support the Mine Lease Proposal for the Bird in Hand Gold Project. The independent peer review is listed as a requirement by the Determination for a Mining Proposal for the Bird in Hand Gold Project, which states that the output of this peer review should be:

'*A final independent peer review report which must include; an assessment of whether the model is fit for purpose, verification of model inputs, the results of the review of the model against Tables 9-1 and 9-2 of the Australian groundwater modelling guidelines* (Barnett et al, 2012)*, the scope of the review and details of any actions undertaken as a consequence of the findings of the review*'.

10.7.3.1 SCOPE OF THE REVIEW

The details of the background data, conceptual and numerical models were provided to IGS in various versions of a draft report, titled *Bird in Hand Gold Project Groundwater Assessment Report* prepared by AGT. This was the main input for the review process.

The review focused on the following aspects of the modelling report:

1. Verification of data used to support the conceptual model of the study site, e.g. aquifer geometry and thicknesses, aquifer hydraulic properties, rainfall recharge, observations of groundwater and surface water levels, hydrochemistry and isotope data;

2. Implementation of the conceptual model in the numerical model, i.e. model design;
3. Model calibration;
4. Scenario modelling; and
5. Characterisation / quantification of model sensitivity to key parameters and impacts of the related uncertainty on model outcomes.

10.7.3.2 OUTCOME OF THE REVIEW

After reviewing four iterations of the report and the additional work that has been carried out to quantify model sensitivity and uncertainty, IGS recommended in a letter dated 30th June 2017 that the model, including MAR scenarios, is fit-for-purpose regarding the objectives stated above, provided the uncertainty around the high recharge zone to the southeast of the mine is documented in the final report submitted to the Regulator.

In a further letter dated 24th October 2017, IGS confirmed requested information on the sensitivity of model outcomes to the high recharge zone implemented to the southeast of the mine had been completed. The information provided indicates that both recharge / hydraulic conductivity scenarios are equally plausible based on the available data and that the choice of scenario has little impact on model outcomes. As a result, IGS confirmed that the groundwater flow model to be fit for purpose based on the objectives stated in the report.

Additionally, after the 2018-2019 MAR investigation, IGS peer-reviewed the additional model updates and reporting and confirmed that the work presented in the Golder (2019) report (Appendix H9) is consistent with industry best practice, and that the model remains fit-for-purpose in accordance with the Australian Groundwater Modelling Guidelines (2012).

IGS peer reviews are included in Appendix H2, H3 and H9.

10.8 POTENTIAL ENVIRONMENTAL BENEFITS ASSOCIATED WITH THE PROPOSAL

Detailed hydrological understanding of the region is a realised benefit, a detailed regional calibrated groundwater model could be used for future government updates of the Water Allocation Plan, impacts of seasonal irrigation in terms of standing water level and salinity are now well modelled and understood. The impacts of mining operation within the region are now well predicted, Managed Aquifer Recharge will provide a benefit of increased water security to sensitive receptors, including irrigation bores, springs and heritage listed vegetation. Baseline information including groundwater level and quality, as well as surface water quality and an increased understanding of the groundwater-surface water interface have all been provided to government and landholders to be used to inform better land management decisions both privately and at a state resource level.

10.9 DRAFT OUTCOME(S) AND MEASUREMENT CRITERIA

In accordance with the methodology presented in Chapter 6, draft outcomes have been developed for groundwater impact events with a confirmed linked between source, pathway and receptor, see Table 10-16.

All outcomes are supported by draft measurement criteria which will be used to assess compliance against the draft outcomes during the relevant phases (construction, operation and closure), and where relevant draft leading indicator criteria. These measurement criteria and leading indicators are indicative only and will be developed further through the PEPR.

Outcomes for the entire project are presented in Appendix D1.

TABLE 10-16 | PROPOSED OUTCOME AND MEASUREMENT CRITERIA

Draft Outcome	Draft Measurement Criteria	Draft Leading Indicator
No adverse impact to the quantity or quality of water caused by the mining activities to existing and future licenced users and water dependant ecosystems	The Mine Manager will ensure that monthly drawdown (SWL) measurements recorded by site staff in monitoring wells X, Y and Z (installed monitoring piezometers) and private bores A, B and C are compared with model predictions for the 70% grouting effective groundwater modelling scenario, presented in Table X and are within 2 standard errors of model predictions for two consecutive readings.[5]	Observed drawdown in monitoring wells X, Y and Z (installed monitoring piezometers) falls outside of 2 standard errors of model predictions for one reading.[3]
	The Mine Manager will ensure that monitoring of the water quality of the injectant (mine water) from the WTP during re-injection, undertaken on a monthly basis for field parameters TDS, pH and NTU[6] shows that field TDS and pH (and any other parameter of concern as determined by MAR trial) is as per DEW drainage permit conditions, and turbidity is below 5 NTU; or as per DEW drainage permit conditions, confirmed by Laboratory major ion testing of the injectant using a NATA accredited laboratory on a monthly basis.	Field TDS of the blended injectant greater than 2 standard errors of baseline data for each well (mg/L) or as per DEW drainage permit conditions. Field measurement of turbidity is above DEW drainage permit conditions or EPA Water Quality Quidelines.
	The Mine Manager will ensure that head impress at re-injection monitoring wells X, Y and Z is recorded and reviewed by site personnel on a monthly basis during re-injection to ensure that head impress is less than or equal to the defined fracture pressure level[3,7].	Impress head recorded at re-injection monitoring wells X, Y and Z is greater than or equal to XXX kPa. [3,7]
	The Mine Manager will ensure that monitoring of the water quality of the injectant (mine water) from the WTP during re-injection, undertaken on a monthly basis for field parameters TDS, pH and NTU[8] shows that field TDS and pH (and any other parameter of concern as determined by MAR trial) is as per DEW drainage permit conditions, and turbidity is below 5 NTU; or as per DEW drainage permit conditions, confirmed by Laboratory major ion testing of the injectant using a NATA accredited laboratory on a monthly basis.	Field TDS of the blended injectant greater than 2 standard errors of baseline data for each well (mg/L) or as per DEW drainage permit conditions. Field measurement of turbidity is above 5 NTU or as per DEW drainage permit conditions.
	The Mine Manager will ensure that the volume of water injected into re-injection wells during re-injection is recorded by site personnel on a weekly basis from flow meters installed on each well head to confirm that the total injection rate was maintained between XXXX and XXXX KL/day during mining operations[3,9].	None proposed
	The Mine Manager will ensure that monthly drawdown (SWL) measurements recorded by site staff in groundwater divide[10] monitoring wells D, E and F are compared with re-injection model predictions for the 70% grouting effective groundwater modelling scenario, presented in Table X and are within 2 standard errors of model predictions for two consecutive readings. [3]	Observed drawdown in groundwater divide monitoring wells D, E and F falls outside 2 standard errors of model predictions for one reading.
	Addition of streamflow monitor for baseflow for Inverbrackie Creek	

[5] Locations to be determined through the PEPR development
[6] any metals of concern in the source water will be determined during PEPR development
[7] Maximum injection pressures to be determined through DEW drainage permits for each well and PEPR development
[8] any metals of concern in the source water will be determined PEPR development
[9] To be determined during NRM Act authorisation and PEPR development
[10] Monitoring wells to be installed between reinjection system and Dawesley Creek groundwater divide

Draft Outcome	Draft Measurement Criteria	Draft Leading Indicator
	Groundwater modelling (data obtained from proposed ML and groundwater monitoring network) to be reviewed and recalibrated annually and demonstrates the groundwater model is reflective of aquifer changes (water levels with 2 standard errors of modelled levels and accounting for seasonal variation, water quality of injected water as per DEW drainage permits).	Numerical models to be reviewed and recalibrated after 6 months of operations if measurements fall outside of 2 standard error limits (observed versus predicted SWL).
	Constructed to design audit of MAR system within 3 months of completion of construction demonstrates MAR system is functioning as designed	
No adverse impact to the quantity or quality of water caused by the mining activities to existing and future licenced users and water dependant ecosystems	Monitoring, recording, reporting of water volume abstraction and reinjection demonstrates compliance with DEW licence/lease conditions	Mine water volume inflows exceeds modelled volume, over a 3 month period, reviewed quarterly
No adverse impact to the quantity or quality of water caused by the mining activities to existing and future licenced users and water dependant ecosystems	All chemical and hydrocarbon spills are remediated to meet EPA standards within 48 hours of the spill, or a longer time agreed by the Chief Inspector of Mines. Provision of a report once prior to entering closure monitoring phase by a suitably qualified site contamination consultant verifies that a site contamination assessment and if required remediation in accordance with the NEPM and relevant EPA legislation/guidelines has occurred, ensuring there is no unacceptable risk to human health or the environment as a result of the contamination when compared with relevant baseline concentrations and relevant NEPM investigation levels.	NA

10.10 FINDINGS AND CONCLUSIONS

The groundwater investigations undertaken to characterise the groundwater system of the Inverbrackie Creek Sub-Catchment and assesses the groundwater impacts and groundwater management of the BIHGP has been a long and detailed process. The work began in late 2013 and the fit for purpose model constructed and used to assess management options for the aquifers. The field work, model calibration, sensitivity analysis and has been one of the most extensive studies undertaken in the Mount Lofty Ranges.

Combined with the groundwater census, modelling, drilling and pumping tests, engineering studies undertaken, MAR trial, and the outcomes of the over 5 years of work has given confidence that the management of groundwater can meet the objectives of the *NRM act 2004* (SA), the proposed outcome of no adverse impact to the quantity or quality of water caused by the mining activities to existing and future licenced users and water dependant ecosystems is achievable and the risks to groundwater impacts are as low as reasonably practical as a result.

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