ADDENDUM

MAJOR PROJECT ASSESSMENT:
Dargues Reef Gold Project
(10_0054)

Director-General's
Environmental Assessment Report
Addendum

July 2011

Cover Photos:	Main Photo:	View to the north along Spring Creek drainage line.
	Small Photo:	View to the south from the ridgeline north of the proposed Tailings Storage Facility.
Note:	This report is an addendum to the Dargues Reef Gold Project Director-General's Environmental Assessment Report.	

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NSW Government
Department of Planning & Infrastructure

1 ADDITIONAL INFORMATION

This report provides an addendum to the Dargues Reef Gold Project Director-General's Environmental Assessment Report (May 2011).

The report has been prepared in response to questions raised in correspondence sent to the Department by the Planning Assessment Commission (PAC) on 29 June 2011 and issues raised during a briefing meeting held on 30 June 2011.

The italicised paragraphs represent questions raised by the PAC. The non-italicised paragraphs are the Department's responses to these questions.

1.1 Mine Plan

There is no mine plan in the Director-General's report.

Figure 2.5 of the Environmental Assessment (EA) provides an indicative mine design (refer to Figure 1) and Figure 2.6 of the EA provides a schematic of the sublevel open stoping mining method (refer to Figure 2).

Essentially the mine would create a void of around 600,000m^3. However, there would never be a void of this size at any stage during mining because the area behind the mining would be progressively backfilled. At the completion of mining around 35% of the total void would be backfilled with waste rock, leaving a final void of approximately 390,000m^3.

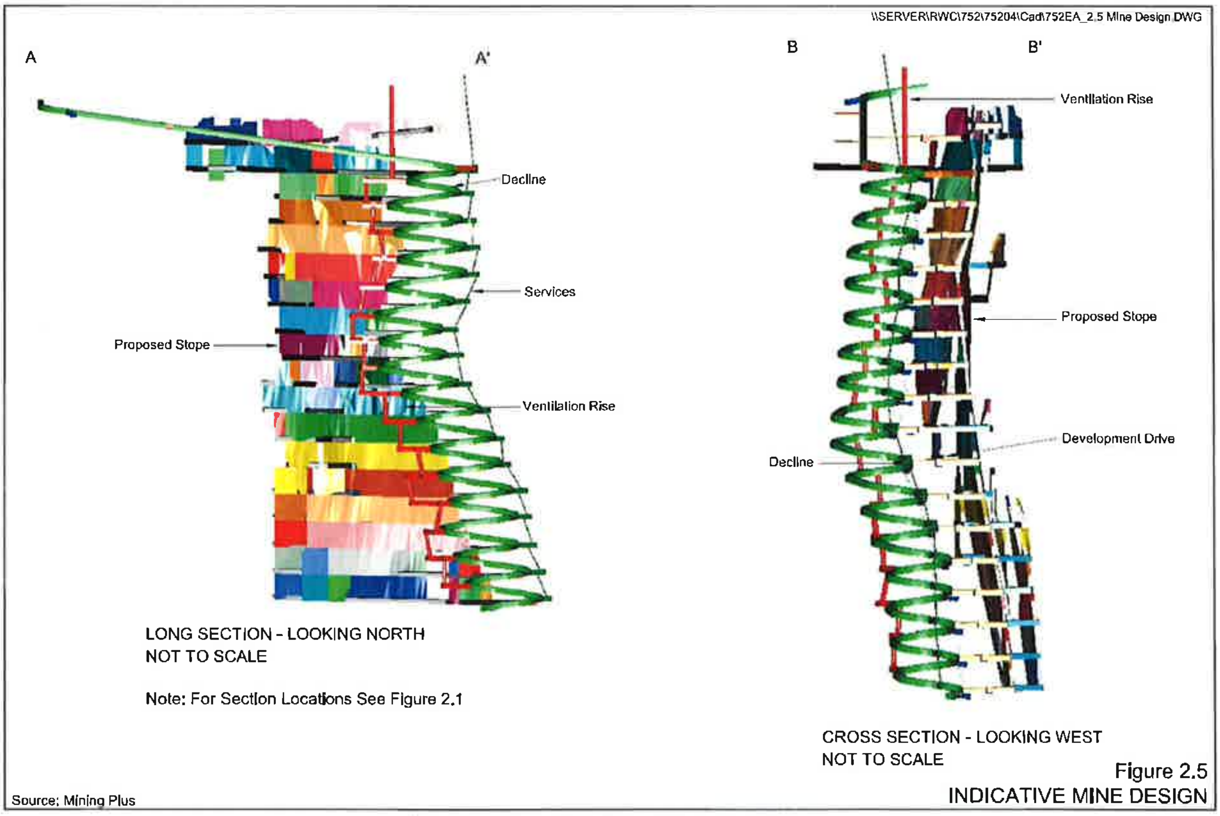
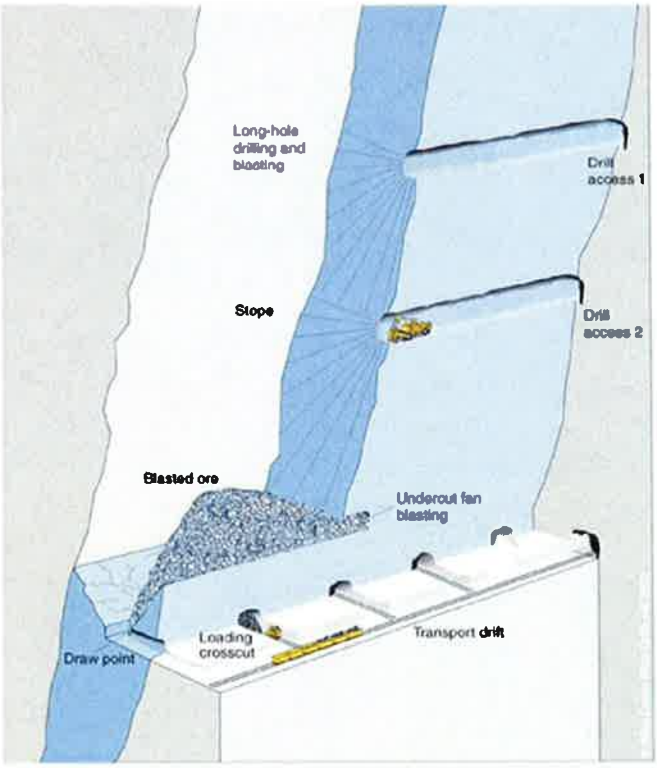


Figure 1: *Indicative Mine Design*

\\SERVER\RWC\752\75204\Cad\752EA_2 6 Stoping DWG



NOT TO SCALE

Figure 2.6
SCHEMATIC SUBLEVEL OPEN STOPING MINING METHOD

Source: Atlas Copco Rock Drills

Figure 2: *Sublevel Open Stoping Mining Method Schematic*

1.2 Non-Owned Parcel within Project Site

What activity is proposed in relation to the parcel of land within the project site that the proponent does not own?

A small parcel of privately-owned land exists on the western side of the project site. The land is indicated as Property Reference 98 on Figure 4.6 of the EA and is owned by B&C James (Lot 1 DP 194317, Lot 66 DP 755934 and Lot 210 DP 755934). The historic mine workings – known as "Snobs Workings" - are located on this land. Only limited works are required on this land as part of the project. These include:

- installation of a pump to extract groundwater from the existing mine void. Note that a bore is already installed on the site; and
- construction of a pipeline to allow the water to be transported to the harvestable rights dams and/or processing area.

The landowner has not objected to the proposed development.

Prior to carrying out any development on this landowners land, the Proponent will need to get an access agreement with the landowner.

The Proponent is in the process of getting such an agreement.

1.3 Aircraft Landing Ground

There is a landing ground indicated to the north-west of the site. Who uses it? Are there any potential impacts?

The "landing ground" indicated in Figure 1.2 of the EA is understood to be an old crop-dusting strip that has not been used for many years. The project would not result in any interference to the air space in the vicinity of the airstrip. No issues in relation to the landing ground were raised in submissions.

1.4 Water

1.4.1 Harvestable Rights

The Proponent argues that they are having no impact on surface flows in Majors Creek because they will only harvest their existing "harvestable rights" component of these flows. This is a facile argument unless the existing use of the land would have created an economic incentive to build the infrastructure to harvest this amount of water (which it clearly hasn't to date). What isn't clear from the supplied material is whether there is likely to be any significant impact on flows in Majors Creek and downstream from this additional surface water harvest.

Under the *Water Management Act, 2000* private land-owners can harvest a certain volume of water from their land. The concept underlying the harvestable rights policy is that this volume of water can be harvested from land without having a significant impact on downstream users or the environment.

The NSW Office of Water has confirmed that the maximum harvestable right dam capacity for the Dargues Reef gold mine site is 35 ML. This is based on the Proponent owning 396 ha of the land, which is located in a rainfall runoff area with a multiplier of 0.09ML/ha. It should be noted that the volume of water that would be collected would fluctuate depending on the weather conditions (ie. the dams would not harvest additional water during wet periods when they are already full).

The Department notes that the volume of surface water permitted to be harvested from the site is small. It would be harvested from an area that represents approximately 0.02% of the Moruya Catchment, which covers a total area of 1490 km^2. This would have negligible impacts on the regional water system. On a local scale, the Proponent has committed to specifically use its harvestable rights water to compensate for baseflow losses. The water would therefore be returned to the local creek system via the environmental flow release program.

NOW has accepted this approach.

1.4.2 Historic Mine Workings

The proposed use of water from the existing mines on the project site to supplement environmental flows when the "harvestable rights" dams cannot meet the supply commitments would appear to create a space that would be filled by further groundwater inflows. It is not clear from the papers how this can be treated as having no additional impacts on baseflow to Majors Creek, etc.

When there is insufficient water within the harvestable rights dams (i.e. during very dry periods) the Proponent intends to use groundwater within the existing historic underground workings (i.e. Snobs, Stewart & Mertons and United Miners Workings) to compensate for the loss of baseflow. This water-take represents a maximum of 33ML/year, which would only be required during very dry years.

If groundwater inflow rates into the mine are less than predicted, groundwater within historic workings may also be used to supplement process water requirements.

The maximum volume of water predicted to be required from the historic workings for both environment flows and process water is 79ML/year.

The Groundwater Assessment undertaken by Australasian Groundwater & Environmental Consultation (AGE) predicted the impact of dewatering the underground mine *and* extracting groundwater from the historic workings. The combined impact of these groundwater extractions on baseflow to Majors and Spring Creeks was predicted to be approximately 66ML per year, which is equivalent to approximately 2.1L/sec.

Condition 22, Schedule 3 of the project approval requires the Proponent to offset the loss of baseflow. The offset can be provided by the retirement of water entitlements or by releasing water back into the creek system.

As indicated above, the Proponent has committed to release water collected via its harvestable rights into Majors Creek to offset the baseflow losses. The Department prefers this approach to the retirement of entitlement, because it would ensure continued water flow to the downstream water users and the environment.

The Department accepts that the Proponent may need to extract a small volume of groundwater from the historic workings, and that this may result in a minor reduction to baseflow in Majors Creek. However, the Department is satisfied that the reduction in baseflow would be appropriately offset.

1.4.3 Groundwater Model

The groundwater model is controversial – in part because of the lack of data. The Department has included a condition to require ongoing refinement of the model throughout the life of the project. Given the history of groundwater modelling and underground mines, what management options are available if the model significantly under-predicts the impact on baseflows to the creeks? What "uncaveated" commitments are there? Note in this context that the Proponent's response to NOW (p.16) includes a commitment to prepare a Water Management Plan which would contain trigger levels, contingency plans, etc. Are there any realistic and enforceable performance criteria and realistic and enforceable options for dealing with any deviations?

The Proponent notes on p.77 of its RTS that the Groundwater Assessment was peer reviewed by RPS Aquaterra and that this review concluded that the assessment was "broadly consistent" with standard industry practice. The PAC has commented previously on the dubious worth of peer reviews of studies conducted on behalf of the mining industry. A finding of "broadly consistent" is therefore of significant concern given the lack of data supporting the model and the community profile of this issue. What steps has the Department taken to satisfy itself that the predicted impacts on groundwater are, in fact, robust?

The Department acknowledges the limitations of the groundwater modelling results, which are principally due to the limited baseline data. This situation is common with "greenfield" projects.

To address these limitations the Proponent (or AGE) has carried out a sensitivity analysis of the potential impacts of the project using extremely conservative estimates. These include:

- undertaking a sensitivity analysis on specific yield using an order of magnitude difference;
- assuming fractures in the granodiorite were open fractures that allow groundwater flow (in reality most would be infilled and inhibit groundwater flow); and
- incorporating a conservative range of rainfall recharge values (i.e. from 0.5% to 6.3% of rainfall).

RPS Aquaterra has carried out a peer review of the groundwater assessment (Attachment A to the Addendum). While the peer review has also identified the limitations of the modelling, it concluded that the groundwater model provides reasonable indications of inflow rates into the future mine workings, and the projected impacts on the environment and groundwater users.

The Department has considered whether the limitations of the modelling are a determinative issue, and concluded that they are not due to the relatively small scale and nature of the project.

This conclusion was based on assessment of the risks associated with the potential groundwater impacts, both for downstream water users and the environment. From the Department's perspective these risks are considered to be low, principally because:

- the voids associated with the mine and the existing historic mine workings are small, so the worst-case groundwater displacement would not be significant. The final void for the mine is approximately 390,000m^3 or 390ML and the existing void for the historic workings is 80,000m^3 or 80ML. This can be compared to the *annual* groundwater extraction licence held by just one downstream local landowner, which is 153ML;
- the predicted rainfall recharge rates have been accepted by both AGE and RPS Aquaterra. Therefore the system is likely to return to equilibrium within a short period of time (ie. less than 10 years compared to the decades that are commonly associated with underground coal mining projects in NSW); and

- the Proponent, unlike other groundwater users, is required to offset the loss of baseflow or compensate for reductions in groundwater in local bores.

Furthermore, even if the groundwater modelling predictions are flawed and the actual impacts are greater than predicted, the Department is confident that the groundwater take would not exceed 400ML/year (ie. the approximate size of the voids). Although this is considerably more than is predicted, the Department believes such an impact would still be well within the realms of acceptability, particularly when the broader social and economic benefits of the project are taken into consideration.

However, in the unlikely event that such impacts do occur, the Department believes the recommended conditions provide a suitable framework for managing the impacts. These include requirements to offset the loss of baseflows (Condition 22, Schedule 3) and provide compensatory water supply to any owner of privately owned land whose water entitlements are adversely impacted (Condition 23, Schedule 3).

1.4.4 Water Balance

How has the Department satisfied itself that the water balance predictions are robust?

Water balance modelling was undertaken by Andrew McCleod from Strategic Environmental Engineering Consulting (SEEC). Mr McCleod is a reputable surface water specialist.

The Department accepts that the water balance was based on conservative, worst case predictions. Those associated with the groundwater model have already been discussed. Those associated with the surface water model include:

- basing the water volumes required for production on the maximum production rate for the entire mining operations (when in reality this would only occur during year 4), therefore the actual demand would be less for the majority of production time; and
- basing the water to be sourced from the harvestable rights dams on the worst-rainfall year in a 100 year record (i.e. year 1981).

It is noted that RPS Aquaterra accepts that, given the size of the catchment, the expected demand of 2.1L/sec for baseflow compensation could be met by the system.

Together with the conservative assumptions made in the groundwater model, the Department is satisfied that the worst-case water balance predictions have been made and that the system can be managed to minimise impacts.

If the water balance predictions are wrong, the Department has required that the Proponent either adjust the scale of mining operations to match the supply of water (Condition 20, Schedule 3) and/or purchase adequate water entitlements (Condition 22, Schedule 3).

1.4.5 Surface Water Monitoring

How are environmental flows proposed to be monitored and maintained?

The specific mechanisms for monitoring of environmental flows will be detailed in the Water Management Plan (Condition 26, Schedule 3) and more specifically the Surface Water Monitoring Program which requires a program to monitor surface water flows, quality and impacts on water users. In practice water flows are generally measured by the installation of water level and gauging stations.

1.4.6 Effect on Downstream Households

On p.125 of the RTS, the Proponent gives a non-response regarding potential impacts on households that draw water from below the project site. How has the Department satisfied itself that there would be no impact on these households?

The predicted worst-case drawdown associated with the project is shown in Figure 4.26 of the EA (refer to Figure 3). The figure shows that groundwater extraction from the mine and from the historic workings would result in a 1m drawdown contour extending approximately 2.5km from the mine. The groundwater assessment indicated that 2 privately owned bores would be impacted (i.e. within the 1m drawdown contour) and 5 more potentially impacted (i.e. just outside the 1m drawdown contour).

Condition 23, Schedule 3 requires that the Proponent supply compensatory water to any owner of privately-owned land whose water entitlements are adversely impacted.

The Proponent has commenced negotiations with the landowners to compensate for the bore water loss. Potential outcomes may include deepening or re-equipping the bores, drilling new holes or providing water from the mine water supply for the duration of the anticipated impacts.

Groundwater levels are predicted to fully recover within 8 years after mining.

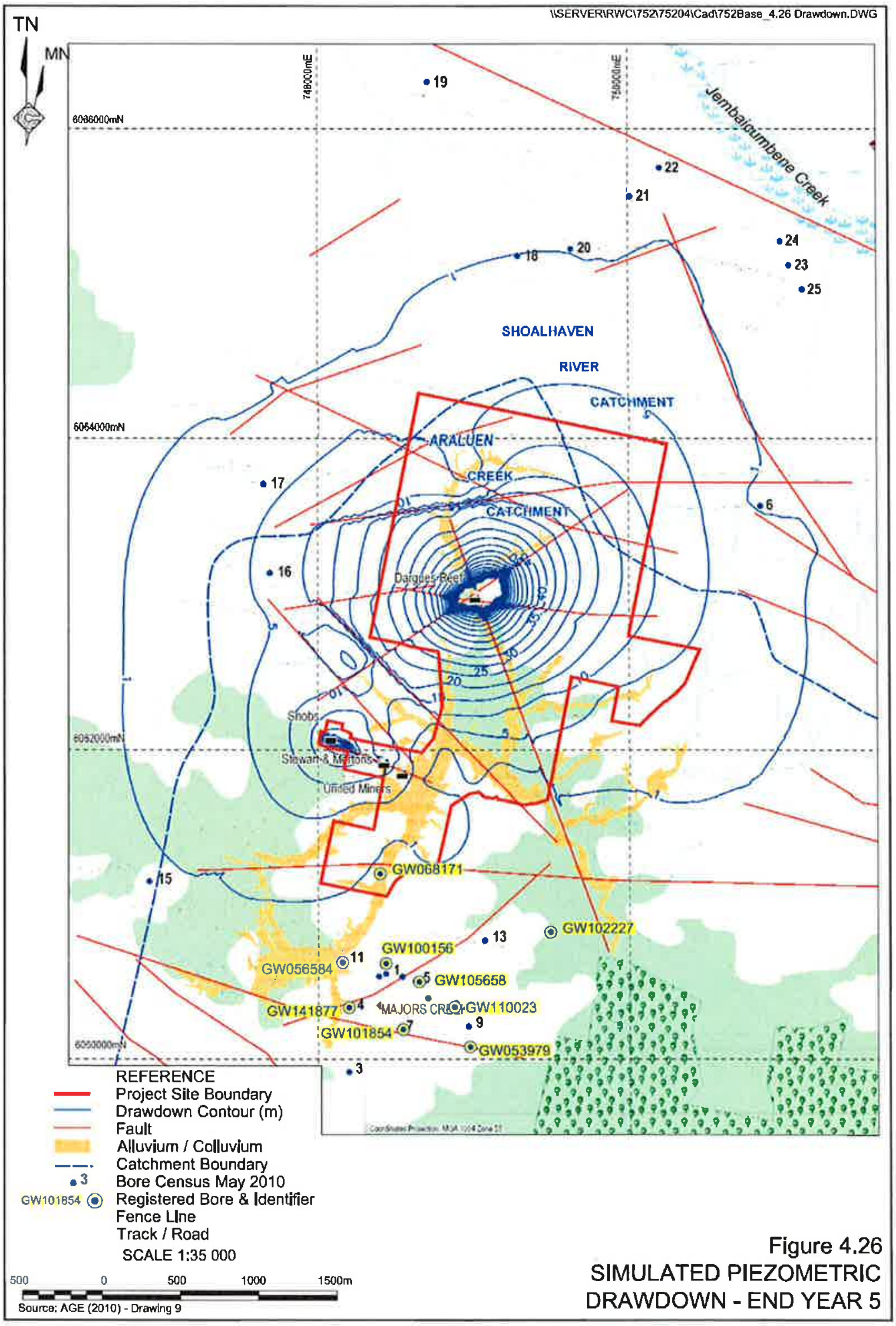


Figure 3: *Predicted Groundwater Drawdown at the end of Mining*

1.5 Blasting

1.5.1 Surface Blasting

The Assessment Report (p.27) refers to OEH proposing that all blasting be restricted to 9am-5pm Mon-Fri. However, the RTS refers to OEH proposing 9am-3pm Mon-Fri. If the Department agrees with OEH on surface blasting (see p.27), which is the correct figure?

The Department confirms that 9am-5pm is the correct blasting restriction times for surface blasts. During the assessment process the Department questioned OEH's requirement that blasting be restricted to 9am-3pm, since surface blasting is typically restricted to 9am-5pm. OEH subsequently accepted that its response to the RTS was a typo, and that 9am-5pm is the correct restriction.

1.5.2 Underground Blasting

The issue of 24 hour per day underground blasting is also addressed on p.27. What action is proposed if the criteria are exceeded? Should this be conditioned on a performance basis?

Underground blasting at night is common in NSW. Recent examples include the Cadia East Mine and the Northparkes Mine. The Department has typically allowed underground blasting because the charges used are small and the impacts imperceptible.

The Department has recommended that underground blasting be permitted 24 hours a day at the Dargues Reef Gold Mine. Again, this is because the underground blasts are very small. For comparison, the maximum instantaneous charge (MIC), or the mass of explosives used to construct the box cut, is 105kg. The MIC required for underground blasts is less than 10kg – an order of magnitude less than that used for surface blasting.

The Department has recommended that the same blast criteria that were included in the Cadia East Mine approval be reflected in the Dargues Reef Gold Mine approval. This includes a ground vibration criterion of 1mm/s at the closest non-project related residence, which is very low and would ensure that blasting impacts would be imperceptible at the nearest residence. The Proponent will be required to monitor blasts in order to confirm that the night-time blast criteria stipulated in Condition 6, Schedule 3 are being met.

1.6 Air Quality

1.6.1 Short-Term Impacts of Dust

The Proponent (p.95) contends that monthly and annual average rates of dust deposition are within guidelines, but doesn't deal with short-term impacts. How are these to be controlled?

The Air Quality and Greenhouse Gas Assessment (PAEHolmes, 2010) for the project predicted that the maximum 24-hour average PM_{10} levels at residential receptors in the vicinity of the project would be very low. The worst-case prediction from operations at the project alone is 9µg/m^3 which represents 18% of the assessment criteria of 50µg/m^3. The Proponent has committed to controlling short-term dust impacts by implementing standard mitigation and management procedures, including:

- minimising areas to be cleared;
- operating water carts; and
- ceasing dust generating activities during adverse weather conditions.

The Department is satisfied that the risks associated with dust impacts from the proposal are low.

1.6.2 Smelting

The Department appears satisfied that the smelting proposal poses no risks. Does OEH also accept this is the case?

As stated in the Director-General's Environmental Assessment Report, the Department "is satisfied that the environmental risk of the smelting process generating unacceptable impacts is *very small*". This does not indicate that the Department believes there are "no risks".

The Proponent has indicated that the smelting activities include the use of a small furnace/kiln. The kiln is approximately 1m x 1.2m in overall size and includes a holding volume of around 16 litres (less than two standard buckets in size), which is similar in size to a small domestic or craft level pottery kiln. It would be used to process the gravity concentrate to produce gold dore, or unrefined gold bars and would operate for approximately 10 hours every 3 days to process approximately 23.5kg of gravity concentrate material. The pyrite would breakdown under heating to produce SO_2, with a likely emissions concentration of approximately 0.3% of emissions. Traces of oxides of nitrogen would also be produced from the combustion of gas to fire the furnace. No other significant pollutants are expected to be produced. The plant would be designed to comply with the relevant limits identified in the *Protection of the Environment Operations (Clean Air) Regulation 2010.*

The Department is satisfied that the proposed furnace operations are a very small scale and highly unlikely to result in air quality impacts.

It is noted that OEH is willing to licence the discharges and have therefore accepted in principle that emissions can be controlled. OEH required that a Level 1 air quality impact assessment (AQIA) be undertaken on the potential impact of the furnace prior to construction. The Department has recommended that an assessment of the potential impacts of the project associated with the gold smelting process be included in the Air Quality and Greenhouse Gas Management Plan (Condition 17, Schedule 3).

1.7 Tailings Storage Facility

There appears to be a question as to whether there have been any failures of tailings dams in Australia and whether any such failures have been in tailings dams designed and maintained under supervision of the NSW Dam Safety Committee.

Is the Department satisfied that the proposed tailings dam poses either no risk to property outside the project site, or an acceptable risk? If risk is present, but considered acceptable, how was this conclusion reached?

Australia has an excellent dam safety record, with only one dam failure (which was in Tasmania over 70 years ago) recorded in the last 80 years. Prescribed dams in NSW are regulated by the Dams Safety Committee under the *Dams Safety Act, 1978*. The tailings storage facility (TSF) proposed to be constructed as part of the Dargues Reef Gold Mine is classified as a prescribed dam. The TSF will therefore need to be designed, constructed and operated in accordance with the dam safety requirements stipulated by the Dam Safety Committee.

The Proponent has confirmed that a Concept Design Report, prepared by Knight Piésold Pty Ltd has been sent to the Dam Safety Committee for approval.

The Department is satisfied that the regulatory dam safety requirements of the Dam Safety Committee are robust and would ensure that the TSF does not pose an unacceptable level of risk to property and/or the environment downstream of the project site.

The *Risk Management Policy Framework for Dam Safety* (NSW Dam Safety Committee, 2006) provides information on conducting preliminary safety risk analysis for dams. This analysis is based on consideration of flood capacity of dams, dam security, seismic risks and constructability.

Analysis of information provided to the Department indicates that there is nothing significant that would preclude the dam from being constructed to an acceptable standard at the Project site. The proposed location of the TSF in the upper most section of the Spring Creek catchment would ensure it is unlikely to be affected by flooding and that any surface water upslope from the dam could be readily diverted around the structure (refer to diversion drains in Figure 4). Fencing is proposed to be constructed around accessible areas of the TSF to ensure dam security. The geology in the area is dominated by the Braidwood Granodiorite, which is a massive fractured-controlled granodiorite occupying an area of about 1000 km^2. Finally, the Proponent has confirmed that the soils materials at the site are suitable for foundations and TSF embankments.

As requested by OEH, the Department has included conditions requiring that the tailings dam be constructed to meet the requirement of the *Environmental Guidelines – Management of Tailings Storage Facilities (VIC DPI, 2004)* and that the containment layers be designed to a very strict permeability level (Condition 24, Schedule 3).

Finally, the Proponent has committed to implementing a monitoring program to test for dam leakage and constructing surface and subsurface structures to capture and return any leakage from the dam.

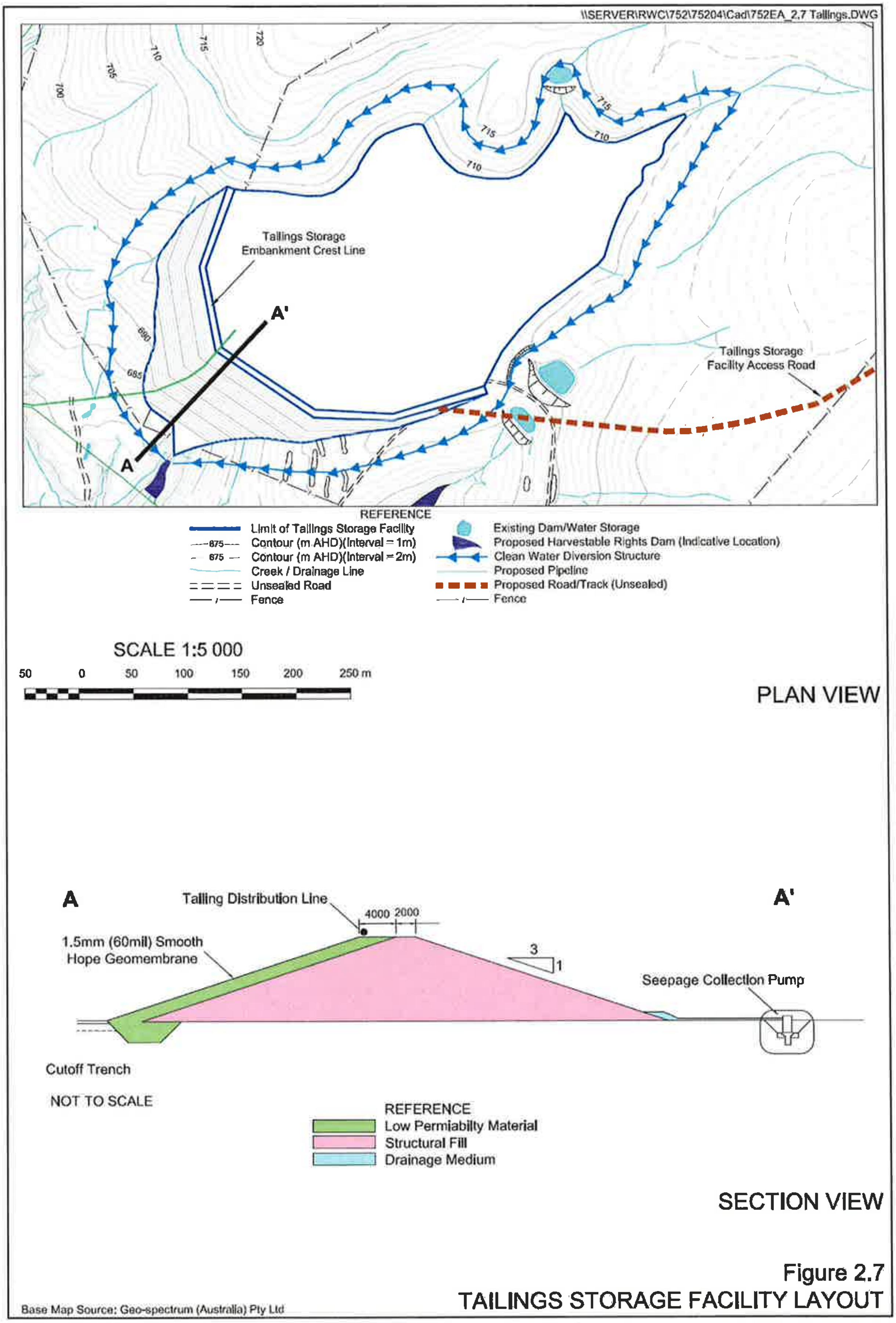


Figure 4: *Tailings Storage Facility Layout*

1.8 Risk Assessment

The Proponent notes on p.106 that the Risk Assessment was conducted prior to the commencement of the majority of studies that could inform such an assessment. The question is whether a new risk assessment would produce significantly different outcomes. Has this been considered?

The Director-Generals' Requirements required that the EA include "a risk assessment of the potential environmental impacts of the project, identifying key issues for further assessment". The intention of the risk assessment is therefore to identify key issues associated with the project, provide a "rating" of issues which would then provide an indication of the level of assessment which is required for specific specialist studies.

The risk analysis indicated high unmitigated risk for ground and surface water, biodiversity, noise, air, traffic and transport, visual and some socio-economic issues. Potential impacts of all these issues were thoroughly assessed in the EA and/or subsequent documentation. The Department does not believe a new risk assessment would produce a different result.

1.9 Noise Exceedance

In relation to noise the Proponent (p.140) responds to concerns about potential exceedances by suggesting a regime of review, additional noise mitigation measures and concluding with the statement that under certain circumstances obligatory acquisition of the affected property may be required.

It seems reasonable that the Proponent and the Department are either satisfied that the noise assessments are robust and that exceedances will not occur, or they are not and will not. It is clearly unacceptable to the local community for an industry to provide assurances that an impact will not occur and then have as its contingency plan that if such an impact does occur it will simply force the affected party out. The draft conditions would appear to reinforce this position and also establish more favourable trigger criteria for action by the proponent than the noise standards themselves. How is this position justified?

The Project Approval conditions in relation to noise acquisition and noise mitigation measures have been deleted on the basis that the Department considers that noise exceedances will not occur and that the conditions are therefore not necessary.

1.10 Compensation Duration

The consolidated statement of commitments (p.204) indicates that landowners who are impacted by reduced groundwater supplies would be compensated "for the life of the Project", but some impacts may continue for some years beyond this. How will this be dealt with?

The Project Approval prevails over any commitment made by the Proponent in the Statement of Commitments (refer to Condition 3, Schedule 1). Condition 23, Schedule 3 of the Project Approval requires the Proponent to provide a compensatory water supply to any owner of privately-owned land whose water entitlements are adversely impacted as a result of the Project. This condition is not time restricted and as such, the Proponent will need to compensate for any reduced groundwater supplies until such time that they can show that the groundwater supplies have recovered to pre-mining levels.

1.11 Traffic

What is the justification for allowing truck dispatch during both the day and evening? Could impacts be reduced by allowing more movements per hour but over a shorter period (eg just daytime hours)?

The number of heavy vehicle movements that would be generated by the Project is considered low. During operation, the project would generate 18 heavy vehicle movements per day. This represents an increase of 1% of heavy vehicle movements on the local road system and an increase of 5% on Majors Creek Road.

At the request of Council, OEH and the public, the Department has recommended that heavy vehicle movements be restricted for a total of 3.5 hours per day during school days (ie. 7am-8:30am and 3pm-5pm).

The Department does not consider it necessary to place additional operational pressure on the Proponent by further restricting heavy vehicle movements. Neither Council nor OEH raised any objections or concerns in relation to heavy vehicle movements in the evening. The Environmental Assessment clearly indicates that the predicted level of heavy vehicle movements during the evening would not result in adverse noise impacts or other transport-related issues.

DKitto 28/7/11

David Kitto
Director, Mining & Industry

28/7/11

Richard Pearson
Deputy Director-General

SHaddad

Sam Haddad
Director-General

29/7/2011.

ATTACHMENT A – RPS AQUATERRA PEER REVIEW

See attached *Peer Review of Groundwater Modelling* undertaken by RPS Aquaterra (11 January 2011).

RPS Aquaterra

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Our Ref: A177B/R001C

Date: 11[th] January 2011

Attn: Mitchell Bland

R.W. Corkery & Co. Pty Ltd

62 Hill Street

ORANGE, NSW 2800

Dear Mitchell,

RE: Dargues Reef Gold Project - Peer Review of Groundwater Modelling

1. EXECUTIVE SUMMARY

R.W. Corkery's Environmental Assessment (EA) for the Dargues Reef Gold Project (DRGP) includes a groundwater assessment supported by a numerical groundwater flow model, developed to predict the impact of the DRGP on the groundwater regime, in particular groundwater inflows to the mine due to dewatering, including the influence of the old mine workings, and impacts of mine dewatering on the alluvial and granodiorite aquifers, groundwater users and GDEs.

This review evaluates the results of groundwater modelling, suitability of hydrogeological conceptualisation and assumptions made, calibration and performance of the model and the potential need for any additional work.

The evaluated report was prepared by Australasian Groundwater and Environmental Consultants on of behalf Big Island Mining Pty Ltd, and clearly states both the project and modelling objectives. The report addresses the objectives with some limitations that are generally acceptable, as discussed further in later sections of this report. Notably, there are important issues regarding the water balance, and a more rigorous uncertainty analysis would also be beneficial to the project.

In our view the presented modelling work provides reasonable indications of inflow rates into the future mine workings and the projected impacts on the environment and groundwater users. The conceptual model, its implementation into a numerical model and parameterisation are broadly consistent with what is reported to be known about hydrogeological conditions in the area.

We suggest that the predictive capability of the modelling work could significantly benefit from more detailed work on sensitivity and prediction uncertainty analysis, with focus on evaluating the effect of various expected combinations of parameters since the current set of parameters – while plausible – is understandably not considered to represent a unique solution for this hydrogeological system.

Reporting of the computed water balance (currently not presented in the evaluated report) is essential to be consistent with best practice guidelines and to provide a better understanding of the hydrological process interactions and related impacts.

The specified make-up demand of 2 L/s to be sourced from groundwater should be achievable based on the modelling results, noting that these need to be confirmed by a more comprehensive sensitivity and uncertainty analysis that is needed in absence of spatially adequate field-derived data. We note that the predicted mine inflows are broadly consistent with typical bore yields in the modelled area and an estimate of yield from historical mining.

As with any modelling predictions they need to be confirmed by on-going monitoring results. We concur with the monitoring recommendation made in the evaluated report and suggest regular creek flow monitoring is also included in the monitoring program. Collation and evaluation of monitoring results will also enable to undertake transient calibration of the model, improve its performance and provide more reliable impact predictions.

2. INTRODUCTION

2.1 BACKGROUND

R.W. Corkery prepared an Environmental Assessment (EA) for the Dargues Reef Gold Project (DRGP), an underground operation at Majors Creek, approximately 13 km to the south of Braidwood in south-eastern New South Wales. The EA includes a groundwater assessment supported by a numerical groundwater flow model which was developed to predict the impact of the DRGP on the groundwater regime, in particular groundwater inflows to the mine due to dewatering, including the influence of the old mine workings, and impacts of mine dewatering on the alluvial and granodiorite aquifers, groundwater users and GDEs. The modelling report under review was produced by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) engaged by Big Island Mining Pty Ltd.

The total estimated makeup water requirement for DRGP purposes is up to 148.4 ML/yr when including dust suppression, out of which up to 66 ML/yr is to be sourced from groundwater. The evaluated options for groundwater supply include dewatering of the proposed DRGP, pumping from existing flooded workings approximately 1.2 km south of the proposed mine and dedicated water supply bores.

The agreed scope of the review is to:

- Review the report(s) provided on the groundwater model and supporting documentation in relation to the local/regional hydrogeology and predicted impacts, paying particular attention to the:
  - ~ Hydrogeological understanding and conceptualisation
  - ~ Understanding of dewatering and groundwater recovery effects
  - ~ Implementation of conceptualisation in the numerical model
  - ~ Model calibration performance, consideration of non-uniqueness and sensitivity/uncertainty, and prediction scenario approach and results.
- Assess whether any additional information, monitoring, assessment and/or modelling is required to gain a thorough appreciation of the groundwater impacts of the dewatering and groundwater recovery issues.
- Review/consider any management/mitigation measures proposed, monitoring requirements (location, frequency, duration, parameters, methods), and triggers/criteria for future independent assessment.

2.2 REVIEWED DOCUMENT

The reviewed document that describes groundwater modelling undertaken for the DRGP is:

- Australasian Groundwater and Environmental Consultants, 2010: Dargues Reef Gold Project Groundwater Assessment. Technical report for Big Island Mining Pty Ltd

The document summarises the results of the hydrogeological investigation (desktop and fieldwork), and Chapters 12 to 14 specifically describe the groundwater modelling work. The focus of this review is on the modelling work; however supplementary information was also drawn from the rest of the reviewed document.

As far as it can be determined, the reviewed document provides an adequate summary of the hydrogeological conditions at the DRGP.

2.3 MODELLING SOFTWARE

The Modflow Surfact software was used, and we concur with this selection for the purposes of the investigation. The software was selected because it is a version of the industry standard Modflow code that is refined with added ability to handle re-saturation of drained model cells. The report indicates that PMWIN software was also used to prepare model input files, and use was also made of PEST parameter estimation software for the process of calibration of the model. This software selection and use is appropriate.

2.4 GUIDELINES USED FOR MODEL APPRAISAL

The review is structured in conformance with the Australian best practice Groundwater Flow Modelling Guidelines (MDBC, 2001). The guideline is a standard tool used in peer reviews to assess the model as objectively and consistently as possible.

The model appraisal checklist that forms part of the guideline (Appendix E of the guideline document) was used to evaluate the modelling work.

3. THE REPORT

The report clearly states both the project and modelling objectives. The report addresses the objectives with various degrees of success that are generally acceptable, with some (largely non-critical) exceptions that depend on the scale of evaluation, as discussed further in later sections of this report. Notably, there are significant issues regarding the water balance, and a more rigorous uncertainty analysis would be valuable.

The level of model complexity is not explicitly stated, but AGE acknowledges and discusses model limitations. In our view the presented model is assessed as being of basic to moderate complexity and is suitable for use to inform and provide qualitative and quantitative estimates for impact assessments and mine planning purposes.

The report is deficient in not providing a water balance computed by the model, which would normally not be critical, but, in the context of comments below about the water balance, this becomes an issue that needs to be addressed before the work can be accepted.

Graphical presentation in the reports is generally of adequate standard.

4. DATA ANALYSIS

The geological and hydrogeological information used in the development of the conceptual model is considered to be briefly but adequately described in the report.

The report presents a water level contour map (February 2010) that we understand was used for steady state calibration. The water level contours were constructed using the data from open exploration and monitoring bores. The spatial distribution of the bores that were sourced to provide observed data is not ideal, but such a limitation is quite common for projects in hilly countryside areas. There is a reported lack of long term monitoring that could have been used in a transient (time-varying) calibration process, which means that the model has no demonstrated capacity as a predictive modelling tool (apart from the limited steady state match to the Feb 2010 snapshot of groundwater levels). The uncertainty that is invoked by this (acknowledged) limitation is best addressed by a rigorous process of parameter sensitivity assessment and predictive uncertainty evaluation. While this has been addressed to a certain degree in the work completed, there is scope for further work on uncertainty. The further work would have the aim of improving the model complexity and capability from the current assessed level of basic to moderate, towards a moderate complexity as a minimum, which would improve the overall robustness and usefulness of model predictions for mine planning as well as impact assessment and management.

Very little data is presented for recharge evaluation, but the qualitatively described recharge processes are plausible. Basic climate data is provided, but the report would also benefit from including the Cumulative Rainfall Departure plot, provided long term groundwater level monitoring data were also available.

The modelling report cites a DLWC report that stated that"... for the Araluen area comparison of rainfall data with recorded groundwater levels from the nine DLWC monitoring bores, shows a rapid response of both alluvial and weathered granodiorite aquifer systems to precipitation events". In this context it would be interesting to know whether any of the nine DWLC bores is within or close to the project area since the report states that no transient water level observations were available for model calibration and no water level hydrographs are presented in the report. Subsequent clarification by the Australasian Groundwater and Environmental Consultants Pty Ltd in this regard confirmed that the DWLC bores are indeed situated outside of the modelled domain

Other important points offered in recharge evaluation section include the following information on fluxes that provide useful semiquantitative targets or checks for model calibration:

- At least 60% of the flow in Araulen River (close to the Project area) comes from groundwater (baseflow)
- The episodic flow data from Spring Creek, situated in the upper part of the catchment with the project area, indicates that groundwater discharge contributes 0.3 L/s

Apart from a brief and simple analysis of baseflows in Spring Creek no other flow data is considered in the report. The V-notch weir arrangement shown in Figure 4 of the report indicates that the V-notch is flooded, so the data from it is probably not reliable, other than semi-quantitatively. Basic groundwater abstraction data (such as location details, depth, and bore yield) was collated from Government databases and borehole census.

While evapotranspiration (ET) is mentioned in the hydrogeological characterisation, it is not included in the list of discharge processes considered in the model development. ET may only be relevant in areas with shallow water levels, such as alluvium or low lying and flat sections of the project area, but will be a significant discharge process in those areas. The implication is that the overall discharge processes are likely to be underestimated in the model, and thus other elements of the water balance, including the recharge volume and predicted groundwater abstraction, are also likely to be underestimated, given the model performance that has been achieved.

5. CONCEPTUALISATION

The presented conceptual model is considered to be generally consistent with the project objectives, apart from the notable exception of the water balance issues identified above. Due to somewhat sparse and limited data on hydrogeological parameters and conditions the model approach has had to account for this uncertainty and address it in parameter sensitivity testing and prediction uncertainty analysis; while this has been partly undertaken, improvements are warranted.

The conceptual model is fairly described and is also presented graphically. There are some key processes that are poorly represented (or are disregarded) in the conceptual model and they include:

- Evapotranspiration and Creek Interactions with Groundwater: It can be argued that where the effect of ET is anticipated (eg. riparian zone and alluvium) there would be other processes that would "lump" this effect together with other effects (for example, drain boundary conditions could to some degree include the effect of ET), however the report does not discuss the reason for ET omission. More importantly, there is no detailed discussion of the water balance, other than reporting the impact effects on flows in Majors Creek (decreasing from about 3.5 to about 1.7 L/s), and a simple statement that all baseflow contributions from groundwater to Spring Creek would cease during mining (but no quantification as such). The reviewers have no choice but to conclude that that the overall water balance has likely been underestimated and thus the impact predictions are not reliable, given the information presented.
- Groundwater pumping: Although information on pumping was collated and is presented in the report, these pumping rates are low, as they relate to largely stock watering. While they represent a valid discharge process from the hydrogeological system, the volumes involved are so low as to be of little value as measurements to constrain model calibration; in fact, the model does not include these volumes.

6. MODEL DESIGN

The finite difference model grid is subdivided into seven layers which are thought to sufficiently reflect the geological conceptualisation and the setup for the mine development. The size of modelled cells is suitably small (12.5 m to 120 m), allowing for more accurate representation of modelled features and increased accuracy of computed results.

The model covers an area of 6 km by 7 km and the orientation of the grid is suitably aligned with the drainage and the prevailing groundwater flow.

All model boundaries are no flow and are based on the watershed boundaries that are considered by modellers to be placed sufficiently far from the modelled impact of the mining operation. This is a somewhat constraining boundary condition specification, and thus not ideal in terms of developing an eventual moderate complexity model, which should be considered for revision in any future work program. Again, the lack of a reported water balance impedes a detailed review of the importance of this process.

The only discharge outlet for water (when mine dewatering is not considered) is drains which represent the surface water drainage network in the modelled area. In other words, there is no allowance for deep groundwater throughflow, which would be expected to be a key process, although possibly not significant in terms of catchment water balance volume components, given the nature of the fractured rock aquifer system.

The only modelled input into the hydrogeological system is from rainfall recharge. Since creeks are represented as drains they do not supply any water into the system, although there is potential for the aquifer storage within the alluvium associated with the creeks to leak water under the influence of dewatering gradients (as reported in Figure 16 of the evaluated report).

Groundwater pumping for stock-watering and domestic purposes is not implemented; it is assumed that modellers discounted its impact on the basis of the relatively low yields. Groundwater pumping is, however, implemented in one of the prediction models that consider pumping from the abandoned mine workings, which are simulated using the Fractured Well package of Modflow Surfact, which is considered adequate for initial estimates.

ET is not implemented in the model, which is a limitation (as discussed above), and further work to include ET is warranted. Satisfactory representation of ET will allow an objective assessment of its importance in the catchment water balance, and allow interpretation of the impacts on water-dependent ecosystems (eg. riparian vegetation). It would also enable differentiation of baseflow contributions to be evaluated in model calibration and predictions of potential mine impacts.

7. CALIBRATION AND VERIFICATION

7.1.1 Calibration Method

Calibration performance is a key part of model development in that it allows for objective evaluation of the model value for predictive purposes. The calibration is usually undertaken to "history-match" the modelled results against measured observations of water levels or flows. Successful and thorough calibration enables the model to be considered fit for predictions of the effects of modelled management actions. For mine applications that includes prediction of groundwater inflows into the open pit and the effect of dewatering on the environment and groundwater users.

The calibration target set commonly consists of a regionally distributed set of groundwater levels from monitoring bores, baseflow contribution estimates to surface water features etc. Calibration in this case was undertaken by employing automatic routines through PEST software, but did not consider baseflow estimates that were developed for Spring Creek.

The calibration section of the report (or any other section of the report) does not provide any information on the model water balance so it is not appropriate to comment on the validity of accepted parameters other than concurring that they are within a plausible range of values.

The water balance summary would be also useful in specifying how much water is lost through the model drain features (which represent creeks), since they provide the only catchment outlet. In the steady state model the discharge from drains would be equal to groundwater recharge (in the absence of an ET feature), which needs to be put in perspective with what is known about baseflow in the creeks in the modelled area. For example, if the average recharge were 20 mm, this would generate an average baseflow of 27 L/s which does not seem to be completely consistent with existing baseflow measurements. This also reinforces the argument for considering evapotranspiration as a valid process that needs to be represented in the model.

Transient state calibration was not performed due to a reported lack of transient observations. Water levels obtained from the steady state calibration were used as initial water levels for prediction modelling in transient mode.

7.1.2 Parameter Values

The PEST calibrated parameters included hydraulic conductivity of model layers AND recharge. It has to be noted that simultaneous calibration of hydraulic conductivity and recharge should not be employed under normal circumstances, because the two parameters are inter-related in a sense that a change in one of the two parameters requires a due change in the other parameter. In this situation it would then be possible to obtain many solutions and produce equally good calibration sets, ie it is recognised that the obtained calibration solution is non-unique. The result of non-uniqueness is that, for example, the predicted cone of depression as a measure of the spatial impact of the mine operation, and the related dewatering volumes, may be under- or over-predicted compared to the eventual actual impact.

In order to tackle the non-uniqueness problem (it cannot be "solved" as such), the modellers constrained the ranges of input parameters which PEST can work with. The steady state calibration produced plausible results for both recharge and hydraulic conductivity.

It is acknowledged that hydrogeological data availability is less than comprehensive, compared to, for example, data from surface water investigations, which makes it difficult to fix one set of parameters and calibrate the other. One way to handle this uncertainty is to conduct a thorough calibration sensitivity and prediction uncertainty analysis that would be used to define the error margins associated with predicted solution. This is discussed further in the next section.

Vertical hydraulic conductivity values are assumed to be equal to the lateral values in this work, which in our view is an incorrect assumption for the fractured rock environment. Equality between lateral and vertical components of hydraulic conductivity is probably based on a reasonable assumption regarding the massive nature of granodiorite body. However, regolith and alluvial/colluvial sediments are very likely to show differences in these components of hydraulic conductivity. Since vertical hydraulic conductivity controls the flux exchange between the individual model layers, it can have a significant impact on the temporal progression of estimated inflow rates, and it is recommended that distinction between lateral and vertical components of hydraulic conductivity is implemented in any subsequent modelling work.

Storage or specific yield values were not calibrated because transient calibration did not proceed from the steady state calibration. Therefore arbitrary parameters were assigned to individual layers and used for prediction runs. While the values are theoretically plausible, the actual parameters can involve a wide range in values, although it is usually found that the deviation could be within the same or one order of magnitude. The uncertainty in this parameter was partly addressed in the prediction runs by having two values of specific yield applied to the granodiorite.

The selected set of parameters is compared to the few aquifer testing results available, which were obtained from slug tests and/or airlift estimates. It should be noted that estimates based on these methods are only approximate and more reliable results can only be obtained from more comprehensive pumping tests. It is recommended that a longer term pumping test is designed and executed at the feasibility stage to confirm aquifer parameters and firm up the model predictions.

8. SENSITIVITY AND PREDICTION UNCERTAINTY ANALYSIS

AGE acknowledges that the predictions are charged with uncertainty, but in our view this aspect should be addressed in more detail, as the analysis provided by this modelling work is very limited, especially for a fractured rock hydrogeological system with a variable storage and permeability characteristic. It is recommended that more rigorous uncertainty analysis be undertaken to confirm that the model can be used for predictive purposes with confidence.

The choice of key parameters for uncertainty analysis can be aided by the PEST run undertaken in sensitivity analysis mode that would produce sensitivity coefficients, ie a measure of sensitivity of the model solution outcome to a slight change in parameter.

To help address the aquifer storage parameter uncertainty, AGE prediction modelling was undertaken using a base and upper limit case for specific yield (0.001 and 0.01 respectively). Due to non-uniqueness of obtained calibration we suggest that uncertainty analysis be extended to recharge and hydraulic conductivity, either in stochastic fashion (by using a Monte Carlo approach) or by using plausible lower and upper ranges of parameters. Given the comments about vertical and horizontal hydraulic conductivity, these parameters should also be included in the sensitivity analysis, along with the stream bed conductance value applied to the model drain features.

The model calibration and prediction results will have to be verified in the future by monitoring water levels, baseflow to creeks and rates of pumping from bores.

9. PREDICTIONS

9.1.1 Inflow Predictions

Prediction scenarios of pit inflows in the evaluated work were produced for two sets of storage values. The computed values are plausible but the actual values may vary within an order of magnitude, due to prediction uncertainty. Mine dewatering will create a cone of depression that will be practically measurable within 2.5 km from the mine under currently adopted parameterisation.

9.1.2 Impact on GDEs and Groundwater Users

The report suggests that groundwater level will be depressed by up to 5 m in the alluvium and underlying regolith along Majors Creek which is believed to be consistent with the model parameterisation. It is assumed (as Figure 9 in the reviewed report indicates) that additional effects such as potential pumping from the abandoned shafts are considered in this impact.

The report is commendable in that it discusses in some detail the effect of dewatering on baseflow, embargoed water, Araluen water supply and Shoalhaven River Catchment. For example, dewatering is reported to result in baseflow reduction by about 50% along the 1.5 km section of Majors Creek. The presented results are considered plausible but will have to be complemented with more rigorous uncertainty analysis to evaluate the outcomes from the range rather than one set of input values that are likely to occur. A hydrograph of changes to all water balance components (ie. rather than a graph that simply describes changes to the Majors Creek baseflow) would be useful to understand the transient changes due to mining effects.

Inclusion of the ET process will be particularly important for improving predictions of impacts on groundwater dependent ecosystems (GDEs), such as riparian vegetation.

9.1.3 Groundwater Supply Considerations

AGE estimates of mine depressurisation/dewatering yields indicate that the expected demand of about 2 L/s is likely to be met from pumped water sourced from dewatering. Given the size and nature of the catchment, this conclusion appears to be physically realistic. AGE also evaluated the possibility of pumping from abandoned workings and found this source to be also viable. As with other predictions these results are related to one set of parameters and the predicted figures will have to be checked against a range of parameter sets to improve understanding of uncertainty in predictions.

10. FITNESS FOR PURPOSE

In our view the presented modelling work provides reasonable indications of inflow rates into the future mine workings and the projected impacts on the environment and groundwater users. The conceptual model, its implementation into a numerical model and parameterisation are broadly consistent with what is reported to be known about hydrogeological conditions in the area.

We suggest that the predictive capability of the modelling work could significantly benefit from more detailed work on sensitivity and prediction uncertainty analysis, with focus on evaluating the effect of various expected combinations of parameters since the current set of parameters – while plausible – is understandably not considered to represent a unique solution for this hydrogeological system.

The conceptual model and its numerical implementation will need to include the ET process, which is considered to be important element of the catchment water balance and thus vital for calibrating the model to observed baseflows and for understanding the impacts on GDEs.

Reporting of the computed water balance is essential to be consistent with best practice guidelines and to provide a better understanding of the hydrological process interactions and related impacts.

The specified make-up demand of 2 L/s to be sourced from groundwater should be achievable based on the modelling results, noting that these need to be confirmed by a more comprehensive sensitivity and uncertainty analysis. We note that the predicted mine inflows are broadly consistent with typical bore yields in the modelled area and an estimate of yield from historical mining. The report would benefit from clearer differentiation between any incremental impacts from mine dewatering, including combined pumping from historical shafts.

As with any modelling predictions they need to be confirmed by on-going monitoring results. We concur with the monitoring recommendation made in the evaluated report and suggest creek flow monitoring is also included in the monitoring program. Collation and evaluation of monitoring results will also enable to undertake transient calibration of the model, improve its performance and provide more reliable impact predictions.

Yours sincerely
RPS Aquaterra

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