HANSON CONSTRUCTION MATERIALS

SANCROX QUARRY EXPANSION

INDEPENDENT PEER REVIEW OF SANCROX QUARRY EXPANSION GROUNDWATER MODEL

GW-HANSON-20-02-REP-001

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Document No.	:	GW-HANSON-20-02-REP-001
Revision No.	:	A
Date	:	07 SEPTEMBER 2020

Rev	Description	Originator	Reviewer	Approver	Date
A	Issued for Client Review	JA	TA	JA	07 SEP '20

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1 INTRODUCTION

This report provides a review of the groundwater model that has been developed to address the impact assessment requirements of the NSW Aquifer Interference Policy. The groundwater model was developed by Environmental Resources Management Australia Pty Ltd (ERM) and the modelling components are described in the Sancrox Quarry Expansion Environmental Impact Statement (EIS) - Annex F: Groundwater Assessment[1].

1.1 Background

The site is an operational hard rock quarry, located in Sancrox approximately 8 km to the west of Port Macquarie. The quarry has been owned and operated by Hanson since 1998. Hanson owns approximately 145 ha of land, of which approximately 12 ha has been in use for the extraction, processing, and storage of aggregates. Infrastructure associated with the existing quarry includes the processing plant, offices, weighbridge, and workshop.

The Study Area includes the existing quarry site, the area identified for the quarry expansion and a 2 km radius from the perimeter of the final pit to identify groundwater users that may be impacted by the proposed activity. The eastern portion of the Study Area has been disturbed by active quarrying activities while the west and northwest portions of the Study Area are largely undisturbed and predominantly covered with remnant woodland vegetation. Some smaller sections of ground are covered with pasture. **Figure 1-1** shows the location of the existing quarry site.

Figure 1-1 Locality map

[1] ERM, 2019 Sancrox Quarry Expansion, Groundwater Assessment, Hanson Construction Materials Pty Ltd, 0418291_Final, August 2019

1.2 Scope of work

The key tasks for this review were as follows:

- Review the development and calibration of the groundwater model and comment on:
  - Adequacy of the modelling approach for the intended purpose; and
  - Appropriateness of the assumptions used in the model.

1.3 Modelling guidelines

The peer review has been structured according to the following guidelines:

- Australian groundwater modelling guidelines, June 2012[2]; and,
- The Standard Guide for Conceptualization and Characterization of Ground-Water Systems (ASTM 5979-96).

The modelling has been assessed according to the Model Review checklist in the Australian Modelling Guidelines. This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis. Not all questions are pertinent to a site-specific model. Appendix A includes a checklist for a groundwater model review.

The effort put into a modelling study is dependent on timing and budgetary constraints that are generally not known to a reviewer. Hence, reduced performance in one aspect of the modelling effort could be the result of a conscious decision by the modelling team to get the model finished on budget and/or on time, or to apply extra focus on specific issues arising during modelling.

1.4 NSW Planning Industry & Environment

The DPIE review on the EIS – "Annex F: Groundwater Assessment" is provided in Appendix B. This review mainly questioned whether a model review has been undertaken, as stated in the Australian Groundwater Modelling Guidelines, to ascertain model's applicability for the impact assessment. It examined the model verification, impact on third party bores and available historical data on groundwater level and quality.

The DPIE pointed out that the proponent has misidentified the applicable Water Sharing Plans and Water Sources potentially affected by this development and has failed to identify the New England Fold Belt Coast Groundwater Source of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 as the impacted water source. (The Hastings Alluvium sits adjacent to the quarry extent but partly within the project boundary.)

[2] Barnett et al, 2012, Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra

2 PEER REVIEW

2.1 Model objectives

The modelling guidelines are specific about defining the modelling objectives. These objectives should explain in detail the purpose or 'desired end' or 'outcome' of a groundwater model. Section 1.2 of Annex F discusses that the objective of the Groundwater Assessment is to meet the requirement of the Secretary's Environmental Assessment Requirements (SEARs):

- Identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000.
- An assessment of the likely impacts on the quality and quantity of existing surface and groundwater resources, including a detailed assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives.
- An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.
- A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.

The modelling objectives are to evaluate groundwater inflow rates into the expanded quarry as well as potential groundwater drawdown proximal to the quarry and the potential magnitude of drawdown at identified groundwater users.

The modelling objectives were stated in specific and measurable terms, along with the resource management objectives. However, it can be enhanced by discussing questions to be answered by the model and scenarios to be modelled.

2.2 Model confidence level classification

Models are used to produce predictions and the majority of models inherently have some degree of uncertainty associated with them. Hence, their predictions are imperfect. The potential for imperfection in predictions or the "wrongness" of model predictions arises from:

- Insufficient available data for unique estimation of parameterization detail; and
- Errors in its conceptual basis.

It is important to identify these constraints and how they affected the modelling process, especially in the development of a groundwater model of high complexity. This a schematic drawing or tabular form, showing all the hydrological stresses acting on the groundwater system and the reliability of the components obtained and input to the groundwater model.

Some of the hydrological stresses acting on the system are as follows:

- Rainfall recharge
- Evapotranspiration
- Groundwater extraction
- Groundwater seepage (quarry)

- Base flow discharge (gully catchment areas)

It is critical to provide a clear statement on how these hydrological input stresses were collated or simulated using the availablehistorical monitoring data. Three 50 mm dia. monitoring bores (SA1501 – SA1503) were drilled in 2015 for hydrogeological investigation and to record groundwater level fluctuations **Figure 2-1**.

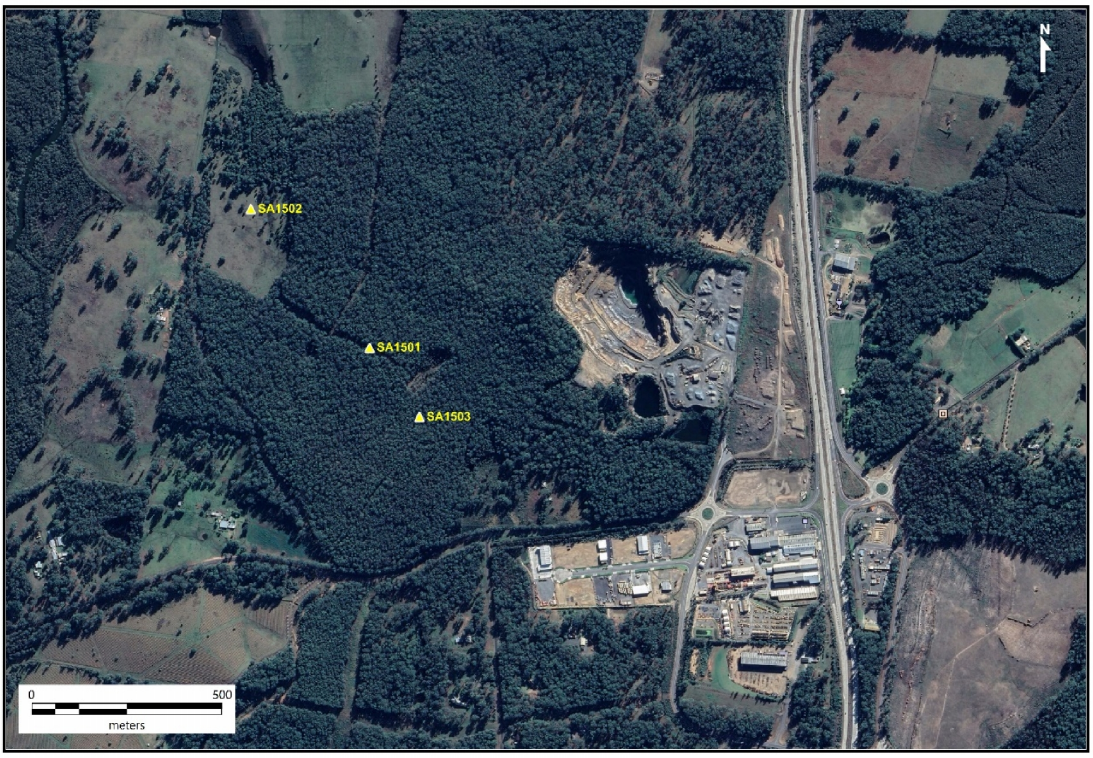

Figure 2-1 Groundwater monitoring bores

These bores are located in a near straight line which is not ideal for inferring groundwater flow directions spatially within the study area. Historical water levels that were collected from these bores were neither provided nor analysed to understand the hydrological stresses. It is also noted that no hydrogeological information from the surrounding groundwater bores, GW060512, GW060513, GW300120, GW301263, GW302376, GW303436, GW303749 and GW306269, has been included in the groundwater model development.

The model confidence-level classification (Class 1, Class 2, or Class 3 in order of increasing confidence) has been proposed in the Australian Groundwater Modelling Guidelines in order to assess whether or not the model has met this target. The confidence-level classification is mainly based on the available data (and the accuracy of that data) for conceptualisation, design, and construction.

The following limitations to the model are presented in the modelling report:

- The measured hydraulic conductivities were extrapolated throughout the model domain with the assumption that there are no structural or other geological features present with hydraulic characteristics significantly different to the pumping test results.

- Hydraulic conductivity of weathered rock and quarrying impacted rock and its effect on recharge rates are unknown.
- The rate of recharge was determined during model calibration and has significant uncertainty.
- A topographic high occurs in the southern portion of the domain which may present a groundwater flow divide, creating flow to the southwest as well as towards the Hastings River. There is no groundwater elevation information in this portion of the model to establish model outflows boundaries. This may result in overly elevated heads in the southwest portion of the Model.
- This model does not include a transient analysis (groundwater level and flow estimates varying over time). Therefore, the model-calculated pit inflows are stabilized long-term values that do not include groundwater in storage effects. These storage effects, although temporary, could increase the current estimates significantly within the initial stages of the quarry expansion where large amounts may be released from aquifer storage.
- Similarly, the drawdown estimates are stabilized long-term estimates that represent the largest cone to be formed by the quarry dewatering. In reality, the cone of depression will expand gradually over time.
- Pit inflow estimates are based on groundwater seepage only, and do not include directly precipitated waters or surface water runoff into pit, with direct precipitation through rainfall likely being the major component of pit dewatering requirements.
- The current model is not sufficiently detailed to identify pit wall-groundwater issues and does not include additional estimates for pit slope pore pressure reduction. Should such systems (e.g. horizontal pit wall wells) be required, groundwater flows would be higher than current estimates. A more detailed analysis including transient flows and more detailed pit geometry configurations would be required to assess such issues.

The confidence level of the Sancrox Quarry groundwater model may be classified as “Class 1”, as defined by the Australian Groundwater Modelling Guidelines, as three poorly distributed monitoring bores were relied upon to obtain groundwater and geological information. As such, the groundwater model may be used for predicting long-term impacts of proposed developments in low-value aquifers. The model results should be used to plan additional data gathering to improve the confidence-level of the groundwater model.

2.3 Data analysis

It is reported that water level loggers were deployed in all three monitoring bores, SA1501 (Oct’15 – Sep’17), SA1502 (Dec’16 – Sep’17) and SA1503 (Dec’16 – Jul’17), and the loggers were programmed to collect water level measurements at 12 hour intervals. A summary of the water level measurements has been included in the report. However, comparison of the recorded logger data with the residual rainfall might help to understand the hydrological stresses for the model calibration and verifications.

Two short-term pumping tests were carried out at monitoring bores SA1501 and SA1502 over the period 28/29 November 2017. The pre-pumping test standing water levels were 10.72 and 1.53 mbGL in Bores SA1501 and SA1502, respectively. The standing water level was 11.43 mbGL in Bore SA1503, however this bore was not included in the pumping test program due a blockage within the bore.

The field records suggest that variable discharge pumping tests were carried out at these bores. Pumping rates at SA1502 were increased from 1 L/min to 3 L/min and at SA1501 from 3 L/min to 6 L/min.Water level recovery was observed in both bores. As such, these pumping tests should be analysed using the variable discharge flow equations.

The investigation / quantification of the following matters has not been sufficiently documented in the modelling report.

- Comparison of historical groundwater levels with the residual rainfall
- Existing groundwater bore survey
- Seepage discharge and evapotranspiration processes

Investigation / quantification of the matters listed above may provide some insight into the quantification of errors in the derivation of hydrological stresses.

2.4 Hydrogeological conceptualisation

Gravity is the main driving force for groundwater flow, while topography and geology define the effects on groundwater flow. The topography of the Study Area can be characterised by low lying hilly terrain (**Figure 2-2**) of relatively low hydraulic conductivity metasedimentary rocks. In these areas, the groundwater flow field is controlled by the topography and the groundwater table closely follows the landscape topography.

The eastern portion of the Study Area has been disturbed by active quarrying activities. while the west and northwest portions of the Study Area are largely undisturbed. A conceptual model diagram that conveys the essential features of the hydrological system, denoting all recharge/discharge processes. would be a useful addition to the documentation. Such a diagram could serve a dual purpose of displaying the water balance components derived from data sources and the uncertainty associated with the derivation of the water balance components.

ASTM 5979-96 provides a stepwise method for the qualitative conceptualisation and quantitative characterisation of groundwater flow systems, including the unsaturated zone, for natural or human-induced behaviour or changes.

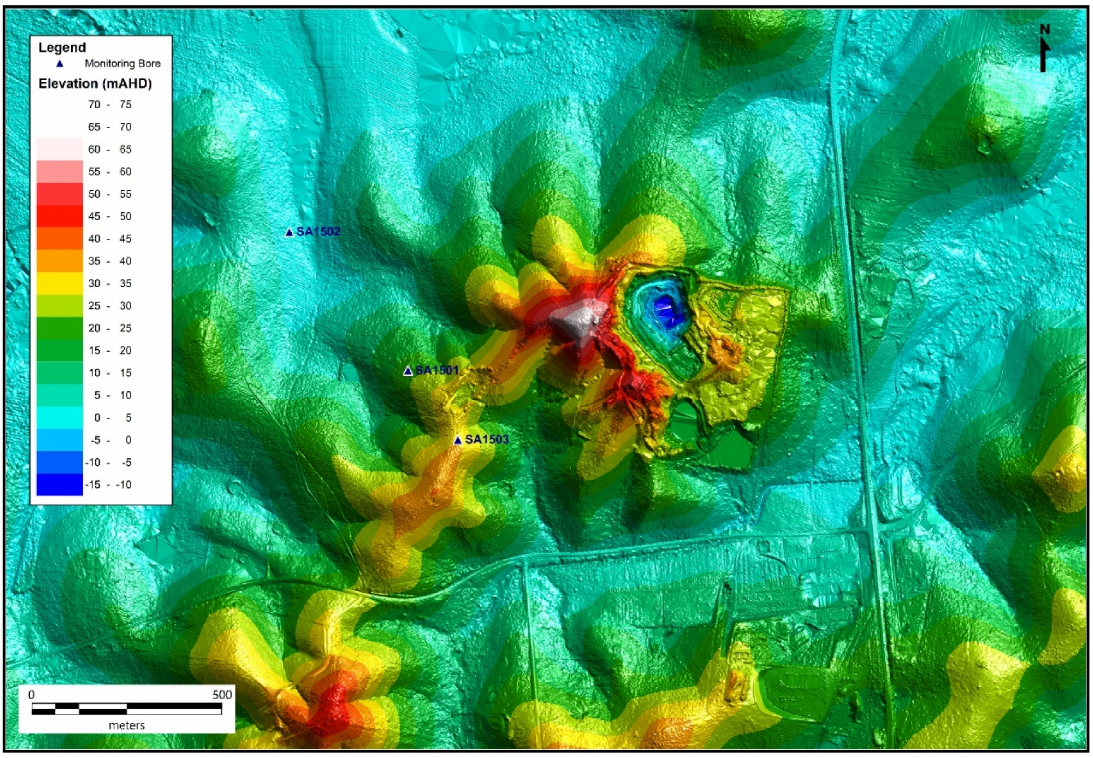

Figure 2-2 Topography of study area

Figure 2-3 Regional surface geology

The regional surface geology map (***Figure 2-3***) indicates that the Study Area is underlain by the Byabbara Beds of the Carboniferous Period. The Byabbara Beds' geology has been inferred to comprise conglomerate, sandstone, and siltstone to the north of the fault line and predominantly shale to the south of the fault line. The meta-sediments of the Byabbara Beds underlying the Study Area are considered to present a fractured rock aquifer, with groundwater storage and flow largely controlled by secondary porosity.

Three monitoring bores (SA1501 – SA1503) have been installed at the Study Area and the aquifer thickness values presented for SA1501 and SA1502 were 70 m and 36 m, respectively. It is recommended that a hydrogeological cross-section across SA1501 – SA1503 be provided showing hydro-stratigraphic units andstructural discontinuities to illustrate the key groundwater flow processes in the Study Area. In the absence of specific documentation relating to the bulk water movements between the layers of the model, the construction of a 4-layered model is potentially fraught with significant uncertainties.

The quantification of groundwater system water balance components was not documented in the modelling report for conceptual model development. The quantification of water balance components provides insight into potential deficiencies in the data collection.

2.5 Model design

A numerical groundwater flow model for the Study Area was developed using MODFLOW-NWT[3], a Newton formulation of MODFLOW-2005[4]. MODFLOW is a block-centred finite difference code and it views the three-dimensional system as a sequence of layers of porous material, though transmissivity within a layer may vary due to spatial variations in aquifer thickness and/or hydraulic conductivity. Finite difference grids are made of square or rectangular cells described as uniform or rectilinear grids, respectively.

The groundwater model is a four-layered MODFLOW based model. The model grid comprises 220 rows and 220 columns and is aligned with the primary groundwater flow direction across the Site towards the Hastings River. The model area was discretized with a uniform finite difference grid of 20 m x 20 m and covers an area of 19.36 km^2. Layer 1 was set to a constant 10 m thickness to represent quaternary alluvium and weathered meta-sediments. Layers 2 and 3 are a combined 100 m to represent the fractured meta-sediments and the full depth of the monitoring bores. Layer 4 is a constant 20 m thickness to allow for interaction of deeper metasedimentary rocks.

During normal MODFLOW operation, when the water levels in some model cells fall below the base of those cells, these cells are declared as "dry" and rendered inactive. Even though they can be "re-wet" at a later stage of the simulation process if necessary, numerical solution convergence difficulties are experienced due to the use of certain thresholds in the re-wetting process. Because of the limited implementation of drying-re-wetting functionality in MODFLOW, MODFLOW-NWT, which does not set dewatered cells as no-flow or inactive, was selected to overcome numerical instabilities during de-saturation. It is considered that MODFLOW-NWT code is an appropriate choice to achieve the objectives of the study. However, questions on the adequacy of field data for the spatially distributed MODFLOW

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[3] Niswonger, R.G., Panday, Sorab, and Ibaraki, Motomu, 2011: MODFLOWNWT, A Newton formulation for MODFLOW-2005: U.S. Geological Survey Techniques and Methods, Book 6, Chapter A37.

[4] Harbaugh, A.W., 2005, MODFLOW-2005: the U.S. Geological Survey modular groundwater model – the Groundwater Flow Process: U.S. Geological Survey Techniques and Methods 6-A16, variously paginated.

model has to be resolved. In order to address this deficiency, it is recommended that additional field investigations at key locations be carried out in order to gather data and to allow subsequent improvement of model performance.

2.6 Boundary conditions

The following four types of boundary conditions have been assigned to the groundwater model:

- No-flow boundaries were set as the bottom of Layer 4 and the northwest, southwest and southeast boarders.
- A constant head boundary (CHB) was set in Layer 1 as the domain outflow on the northwest boundary of the model to represent discharge to the Hastings River and the southwest corner to represent discharge to quaternary materials.
- Recharge rates of 2.7 and 40 mm/year were determined during model calibration over the meta-sedimentary rocks and quaternary alluvial units, respectively.
- Drainage package was used to model seepage into the quarry pit.

The modelling report Figure 5.1 does not clearly show the limits constant, no-flow boundaries at the northwest and southwest boundaries and the assigned constant head. The modelling report also does not provide supporting data nor discusses the basis for the above boundary conditions.

2.7 Model calibration

A number of performance measures have been prescribed in Australian Groundwater Modelling Guidelines to demonstrate that a model is robust, simulates the water balance as required and is consistent with the conceptual model on which it is based (***Table 2-1***).

Table 2-1 Performance measures and targets

Performance measure	Criterion
Model convergence The model must converge in the sense that the maximum change in heads between iterations is acceptably small.	The iteration convergence criterion should be one or two orders of magnitude smaller than the level of accuracy required in head predictions. Typically, of the order of centimetres or millimetres.
Water balance The model must demonstrate an accurate water balance, at all times and in steady state. The water balance error is the difference between total predicted inflow and total predicted outflow, including changes in storage, divided by either total inflow or outflow and expressed as a percentage.	A value less than 1% should be achieved and reported at all times and cumulatively over the whole simulation. Ideally the error should be much less. An error of >5% would be unacceptable, and usually indicates some kind of error in the way the model has been set up.

Performance measure	Criterion
Qualitative measures The model results must make sense and be consistent with the conceptual model. Contours of heads, hydrographs and flow patterns must be reasonable, and similar to those anticipated, based either on measurements or intuition. Estimated parameters must make sense and be consistent with the conceptual model and with expectations based on similar hydrogeological systems.	Qualitative measures apply during calibration, when comparisons can be made with historical measurements, but also during predictions, when there is still a need for consistency with expectations. There is no specific measure of success. A subjective assessment is required as to the reasonableness of model results, relative to observations and expectations. The modeller should report on relevant qualitative measures and discuss the reasons for consistency and inconsistency with expectations.
Quantitative measures The goodness of fit between the model and historical measurements can be quantified, using statistics such as RMS, SRMS, MSR and SMSR for trial-and-error calibration and the objective function in automated calibration.	Quantitative measures only apply during calibration. Statistics of goodness of fit are useful descriptors but should not necessarily be used to define targets. Goodness of fit of heads is only one part of a regularised objective function—the other relates to agreement between parameter estimates and prior estimates, so in this situation, the two components of the objective function should both be reported. Targets such as SRMS < 5% or SRMS < 10% may be useful if a model is similar to other existing models and there is good reason to believe that the target is achievable. Even if a formal target is not set, these measures may provide useful guides.

Model calibration was carried out for a steady state condition in which groundwater elevation data was collected from three monitoring bores (SA1501, SA1502 and SA1503) prior to the start of the pumping tests conducted on 28 November 2017. It appears that no other data such as water levels in the surrounding groundwater bores, hand-drawn groundwater level contours based on the topography for pre-mining and current conditions, etc. have been considered to demonstrate robustness to the calibration process.

The goodness of fit of the three target data points presented in the modelling report cannot be considered as a useful information on the model calibration. This is because target data does not adequately represent the groundwater flow processes within the Study Area. Furthermore, the simulated groundwater equipotential surface presented in the modelling report (Figure 5.4) may not agree with the topography of the Study Area (i.e. ground surface is appeared to be lower than the simulated groundwater equipotential surface). No modelling results were presented to show the effect of the existing quarry surface on the groundwater equipotential surface.

It is concluded that model calibration does not systematically address the performance measures and targets (***Table 2-1***) and the uncertainty and lack of data has to be resolved.

2.8 Sensitivity analysis and verification

Sensitivity analysis is a procedure for quantifying the impact on an aquifer's simulated response due to an incremental variation in a model parameter or a model stress. Its purpose is to identify those parameters which are most important in determining aquifer behaviour. A sensitivity scenario in which combined higher hydraulic conductivities in the metasedimentary unit and expanded locations of the southwest and southeast boundaries by 1,000 m has been documented in the report. The sensitivity analysis shows that the modelled drawdown at groundwater boreGW303749 increased from 2.90 m (base case) to 7.23 m and modelled drawdown in groundwater boresGW303436 and GW306260 increased by 0.90 m and 1.72 m, respectively. This indicates that the assignment of no flow boundary conditions at the southwest and southeast boundaries has to be reviewed and water levels at the groundwater bores GW060512, GW060513, GW300120, GW301263, GW302376, GW303436, GW303749 and GW306269 have to be included in the model calibration.

No verification of the model performance was reported. Verification is a test of whether the model can be used as a predictive tool by demonstrating that the calibrated model is an adequate representation of the physical system. The steady state model has been calibrated based on the groundwater elevation data collected on 28 November 2017 and the rainfall data available for the site from the DataDrill[5] climate repository (**Figure 2-4**) indicates that the Study Area experienced more than average rainfall in the latter part of 2017.

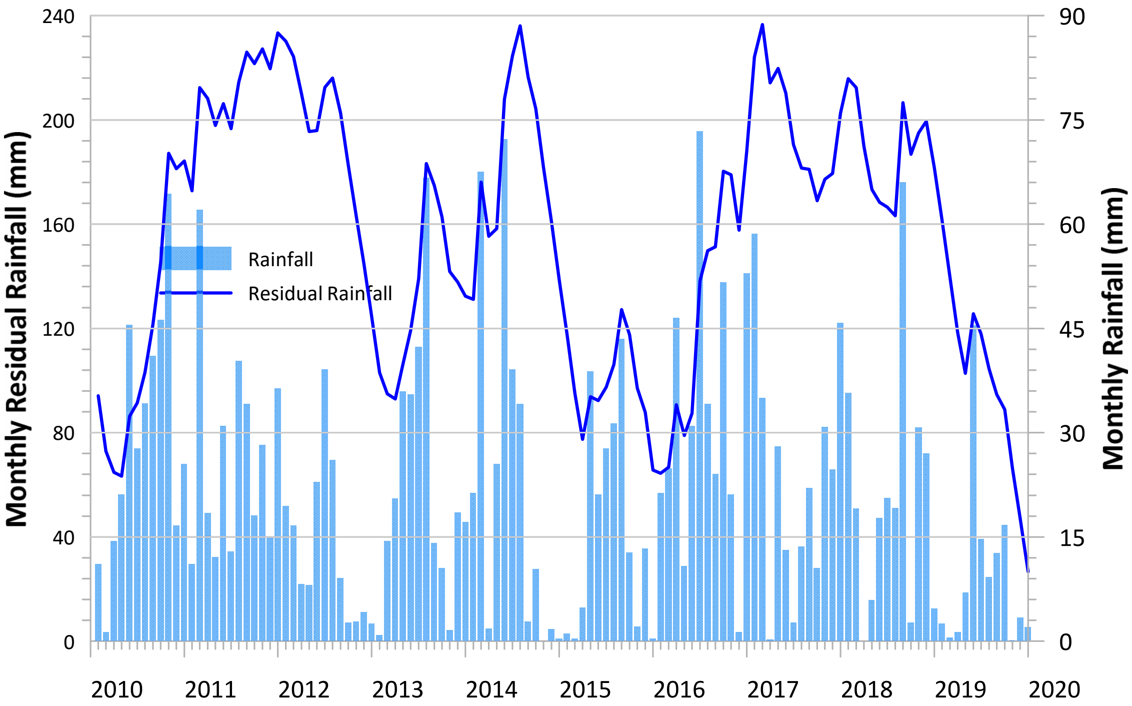

Figure 2-4 Plot of residual and monthly rainfall

Consideration should be given to verification of the model using the logger data to assess if the model is a reliable tool for the prediction of groundwater level fluctuation with varying climate data.

[5] https://www.longpaddock.qld.gov.au/silo/point-data/

3 SUMMARY AND CONCLUSION

The information provided in the Sancrox Quarry Expansion Environmental Impact Statement (EIS) – Annex F: Groundwater Assessment relating to groundwater modelling was reviewed based on the Australian Groundwater Modelling Guideline checklist. The groundwater model data files were not reviewed by REN.

The following conclusions were made:

- The statement of modelling objectives in the report could be enhanced by discussing questions to be answered by the model and scenarios to be modelled.
- A set of static groundwater elevation data collected at only three monitoring bores, SA1501, SA1502 and SA1503, prior to the pumping test has been included in the model development. Water level data that was collected from these bores was neither provided nor analysed to understand the hydrological stresses in the Study Area.
- No hydrogeological information from the surrounding groundwater bores, GW060512, GW060513, GW300120, GW301263, GW302376, GW303436, GW303749 and GW306269, has been included in the groundwater model development.
- The investigation / quantification of the following matters has to be analysed to provide some insight into the quantification of errors in the derivation of hydrological stresses:
    - Comparison of historical groundwater levels with the residual rainfall
    - Existing groundwater bore survey
    - Seepage discharge and evapotranspiration processes.
- The hydrogeological cross-section across the monitoring bores: SA1501, SA1502 and SA1503, should be presented to support the adopted model layer configuration.
- The quantification of groundwater system water balance components has to be provided in order to gain insight into potential deficiencies in the data collection.
- The modelling report neither provides supporting data nor discusses the basis for the adopted boundary conditions.
- Estimated pre-quarrying and current groundwater level contours have to be presented to verify the modelled groundwater level contours.
- The modelled groundwater equipotential surface presented in the modelling report may not agree with the topography of the study area (i.e. ground surface appears to be lower than the modelled groundwater equipotential surface).
- The model calibration does not systematically address the performance measures and targets as outlined in the Groundwater Modelling Guidelines and the uncertainty and lack of data have to be resolved.
- Sensitivity analysis of the assignment of no flow boundary conditions at the southwest and southeast boundaries has to be reviewed and water levels at the groundwater bores, GW060512, GW060513,

GW300120, GW301263, GW302376, GW303436, GW303749 and GW306269, have to be included in the model calibration.

- No verification of the model performance was reported. Verification of the model using the logger data is needed to assess if the model is a reliable tool for the prediction of groundwater level fluctuation with varying climate data.

The confidence level of the Sancrox Quarry groundwater model may be classified as "Class 1", as defined by the Australian Groundwater Modelling Guidelines, as three poorly distributed monitoring bores were relied upon to obtain groundwater and geological information. As such, the groundwater model may be used for predicting long-term impacts of proposed developments in low-value aquifers. The model results should be used to plan additional data gathering to improve the confidence-level of the groundwater model.

Appendix A – Review Checklist

Review questions	Yes/No	Comment
1. Planning		
1.1 Are the project objectives stated?	Yes	
1.2 Are the model objectives stated?	Yes	
1.3 Is it clear how the model will contribute to meeting the project objectives?	Yes	
1.4 Is a groundwater model the best option to address the project and model objectives?	Yes	
1.5 Is the target model confidence-level classification stated and justified?	No	
1.6 Are the planned limitations and exclusions of the model stated?	Yes	
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	No	
2.2 Is the aquifer system adequately described?	No	
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	No	
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	No	
2.2.3 aquifer geometry including layer elevations and thicknesses	No	
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	No	
2.3 Have data on groundwater stresses been collected and analysed?	No	
2.3.1 recharge from rainfall, irrigation, floods, lakes	No	
2.3.2 river or lake stage heights	n/a	
2.3.3 groundwater usage (pumping, returns etc)	No	
2.3.4 evapotranspiration	No	
2.3.5 other?		
2.4 Have groundwater level observations been collected and analysed?	No	
2.4.1 selection of representative bore hydrographs	No	
2.4.2 comparison of hydrographs	No	
2.4.3 effect of stresses on hydrographs	No	
2.4.4 water-table maps/piezometric surfaces?	No	
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	n/a	
2.5 Have flow observations been collected and analysed?	No	
2.5.1 baseflow in rivers	No	
2.5.2 discharge in springs	n/a	
2.5.3 location of diffuse discharge areas?	n/a	
2.6 Is the measurement error or data uncertainty reported?	No	

Review questions	Yes/No	Comment
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	No	
2.6.2 spatial variability/heterogeneity of parameters	No	
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	No	
2.7 Have consistent data units and geometric datum been used?	Yes	
2.8 Is there a clear description of the conceptual model?	No	
2.8.1 Is there a graphical representation of the conceptual model?	No	
2.8.2 Is the conceptual model based on all available, relevant data?	No	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	No	
2.9.1 Are the relevant processes identified?	No	
2.9.2 Is justification provided for omission or simplification of processes?	No	
2.10 Have alternative conceptual models been investigated?	No	
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	No	
3.2 Is the choice of numerical method and software appropriate (**Error! Reference source not found.**)?	Yes	
3.2.1 Are the numerical and discretisation methods appropriate?	Yes	
3.2.2 Is the software reputable?	Yes	
3.2.3 Is the software included in the archive or are references to the software provided?	Yes	
3.3 Are the spatial domain and discretisation appropriate?		
3.3.1 1D/2D/3D	Yes	
3.3.2 lateral extent	No	
3.3.3 layer geometry?	No	
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	No	
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	No	
3.4 Are the temporal domain and discretisation appropriate?		
3.4.1 steady state or transient	No	
3.4.2 stress periods	n/a	
3.4.3 time steps?	n/a	
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?		
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	No	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	No	

Review questions	Yes/No	Comment
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	No	
3.5.4 Are lateral boundaries time-invariant?	No	
3.6 Are the initial conditions appropriate?	n/a	
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	n/a	
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	n/a	
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	n/a	
3.7 Is the numerical solution of the model adequate?		
3.7.1 Solution method/solver		
3.7.2 Convergence criteria		
3.7.3 Numerical precision		
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?		
4.1.1 Groundwater head data	No	
4.1.2 Flux observations	No	
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	n/a	
4.2 Does the calibration methodology conform to best practice?		
4.2.1 Parameterisation	No	
4.2.2 Objective function	No	
4.2.3 Identifiability of parameters	No	
4.2.4 Which methodology is used for model calibration?		
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 parameters	Yes	
4.3.2 boundary conditions	Yes	
4.3.3 initial conditions	n/a	
4.3.4 stresses	n/a	
4.4 Have the calibration results been adequately reported?	No	
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	No	
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	No	
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Yes	
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?		
4.5.1 spatially	No	
4.5.2 temporally	No	
4.6 Are the calibrated parameters plausible?	Yes	

Review questions	Yes/No	Comment
4.7 Are the water volumes and fluxes in the water balance realistic?	No	
4.8 has the model been verified?	No	
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Yes	
5.2 Is predictive uncertainty acknowledged and addressed?	No	
5.3 Are the assumed climatic stresses appropriate?	No	
5.4 Is a null scenario defined?	n/a	
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	No	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	No	
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	No	
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	No	
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	No	
5.6 Do the prediction results meet the stated objectives?	No	
5.7 Are the components of the predicted mass balance realistic?	No	
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	n/a	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	n/a	
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?	n/a	
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Yes	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	n/a	
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	n/a	
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	n/a	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	n/a	
6.3 Are the sources of uncertainty discussed?		
6.3.1 measurement of uncertainty of observations and parameters	No	
6.3.2 structural or model uncertainty	Yes	
6.4 Is the approach to estimation of uncertainty described and appropriate?	n/a	

Review questions	Yes/No	Comment
6.5 Are there useful depictions of uncertainty?	n/a	
7. Solute transport		
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?	n/a	
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	n/a	
7.3 Is the choice of numerical method and software appropriate?	n/a	
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	n/a	
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	n/a	
7.6 Are the solver and its parameters appropriate for the problem under consideration?	n/a	
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?	n/a	
7.8 Has an assessment been made of the need to consider variable density conditions?	n/a	
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	n/a	
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	n/a	
7.11 Is the calibration based on meaningful metrics?	n/a	
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	n/a	
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	n/a	
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	n/a	
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?	n/a	
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	n/a	
8.2 Is the implementation of surface water–groundwater interaction appropriate?	n/a	
8.3 Is the groundwater model coupled with a surface water model?	n/a	
8.3.1 Is the adopted approach appropriate?	n/a	
8.3.2 Have appropriate time steps and stress periods been adopted?	n/a	
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	n/a	

Appendix B – Department of Planning Industry & Environment Review

OUT19/14564

Melissa Anderson
Environmental Assessment Officer
Planning & Assessments
NSW Department of Planning and Environment

melissa.anderson@planning.nsw.gov.au

Dear Ms Anderson

Sancrox Quarry Expansion Project (SSD-7293)
EIS Exhibition

I refer to your email of 25 October 2019 to the Department of Planning, Industry and Environment (DPIE) Water and the Natural Resources Access Regulator (NRAR) about the above matter.

The following recommendations for you to consider are provided from DPIE Water and NRAR. Please note Crown Lands, the Department of Primary Industries (DPI) – Fisheries and DPI - Agriculture all now provide a separate response directly to you. Please note more detail is provided in **Attachment A**.

Pre-Approval

Groundwater Assessment, Licencing and Monitoring

- Assess and classify the groundwater model against the Australian Groundwater Modelling Guidelines and have the model peer reviewed.
- Provide details on acquiring suitable surface/groundwater entitlement to cover estimated take.
- Correctly identify potentially impacted water sources and revise its Aquifer Interference Policy (AIP) (DPI 2012) assessment as required.

Post Approval

Groundwater Licencing and Monitoring

- If a Water Access Licence (WAL) is required it must be obtained prior to the commencement of works.
- Develop a groundwater monitoring plan in consultation with DPIE Water including threshold trigger values as well as a contingency strategy if triggers are exceeded.
- Develop a water quality monitoring plan for the in-pit sump(s) and existing monitoring bores while they remain accessible.

Surface Water Assessment

- Establish a sediment control structure adjacent to the northern aggregate stockpile to the southeast of the Project area.

Any further referrals to DPIE – Water and NRAR can be sent by email to: landuse.enquiries@dpi.nsw.gov.au.

Any further referrals to (a) Crown Lands; (b) DPI – Fisheries; and (c) DPI – Agriculture can be sent by email to: (a) lands.ministerials@industry.nsw.gov.au;
(b) ahp.central@dpi.nsw.gov.au; and (c) landuse.ag@dpi.nsw.gov.au respectively.

Yours sincerely

Simon Francis
Senior Project Officer, Assessments
Water – Strategic Relations
10 February 2020

ATTACHMENT A

Sancrox Quarry Expansion Project (SSD-7293)
EIS Exhibition

Groundwater Assessment, Licencing and Monitoring

The numerical groundwater model (herein the model) reported in the EIS was calibrated in steady state only and with no transient verification. The proponent has not referenced the Australian Groundwater Modelling Guidelines (2012) in the EIS or in Appendix F. No report is given of a peer review and no classification is made under the Guidelines. However, the model is appropriately constructed and well calibrated.

The model does not incorporate surface water harvesting and enhanced pit inflows, nor does it take into account harvested surface water storages close to the pit. These have the potential to alter the model final iterations in its current form.

The proponent has misidentified the applicable Water Sharing Plans and Water Sources potentially affected by this development, possibly misguided by the possibility that the Water Sharing Plan for the Hastings Unregulated and Alluvial Water Sources (2019) was yet to be gazetted at the time of the groundwater assessment.

In any event, the proponent has failed to identify the New England Fold Belt Coast Groundwater Source of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 as the impacted water source. (The Hastings Alluvium sits adjacent to the quarry extent but partly within the project boundary.)

Despite this, the minimum impact considerations of the AIP are correctly made for a less productive porous rock aquifer, but should be reassessed by the proponent in view of the other errors made and the shortcomings identified with the numerical model.

The bulk of the water demands are to be supplied from harvesting overland flows on site, with an estimated peak operational demand of at 131 ML/year. The groundwater seepage into the pit void is modelled at between 15 to 22 ML/year – representing the full volume of groundwater take.

The proponent has not provided details on acquiring suitable surface/groundwater entitlement for the predicted water take within the WSP. The predicted 100-year 2 m drawdown contour is not entirely within lands owned by the proponent (and quarry lease). The proponent has modelled drawdown impacts on two neighbouring third-party bores that breach the 2 m limit required under the AIP. The proponent will need to implement monitoring of these sites in the WMP and provide triggers for make good provisions on impacted bores.

There are currently three groundwater monitoring bores within the proponents lease area and a further 13 bores within a 2 km radius of the pit. Two years of water level data were collected in the three monitoring bores at 12 hr intervals between October 2015 and July 2017. Water quality monitoring was completed only once during the pump test completed in November 2017 – this is insufficient to represent baseline conditions.

A water monitoring plan will need to be developed in consultation with DPIE Water.

Surface Water Assessment

Surface water runoff flows into the main pit and is pumped into water holding dams in the southeast corner of the site. There is a sediment basin in the north east of the quarry that captures water from the crushing plant and stock pile. The northern aggregate stockpile area drains to the southeast and has minimal sediment control. The proponent has committed to reviewing sediment control on site. The quarry is surrounded by a bund at its extents.

The quarry sites represent a challenge for erosion control deemed “high risk”, due to the large areas of exposed soil surface (which is often unavoidable), and erosion control will only ever be partially effective. To protect receiving waters against pollution, sediment controls such as large sediment basins near final discharge locations and smaller sediment traps targeting problem areas, will be an important element of the Soil and Water Management Plan.

END ATTACHMENT A