OUT20/8971

Stephen O'Donoghue
Director Resources Assessment
Planning & Assessment
NSW Department of Planning, Industry and Environment

stephen.odonoghue@planning.nsw.gov.au

Dear Stephen

Dendrobium Mine Extension Project (SSD-8194)
RTS

The Department of Planning, Industry and Environment (DPIE) Water and the Natural Resources Access Regulator (NRAR) have reviewed South32's response (dated 22 June 2020) to our submission regarding the EIS exhibited in 2019.

DPIE-Water notes that the proposed mine extension is a large-scale, high-risk activity that may have significant impacts on sensitive receptors. Recent field observations by DPIE Water officers of ground surface fracturing, dry riverbeds, and loss of surface water flow above longwall panels in the Dendrobium Mine area suggest that mining impacts have propagated to the ground surface and surface water. The level of due diligence in environmental impact assessments and the models they depend on must be commensurate to the value of the potentially affected receptors and the level of risk.

We have reviewed the information provided by South32 and highlight that:

- DPIE is working to implement Government's decision to establish an appropriate regulatory regime to cover surface water take, however a preferred option is yet to be finalised
- there is a need to consider impacts and mitigation for lower order watercourses undermined by the project
- we do not believe that the groundwater model has the capability to adequately predict impacts and so require a detailed plan from the proponent to describe how the model will be upgraded.

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

Detailed explanation can be found in Attachments A and B.

Yours sincerely

Mitchell Isaacs
Director, Office of the Deputy & Strategic Relations
Department of Planning, Industry and Environment: Water
16 September 2020

Attachment A

1.0 Entitlement (refer to South32 response, comments 8 and 9)

Uncertainty remains as to the ability of the proponent to acquire the necessary water entitlement to account for the predicted and existing water take for the project. The Minister for Planning and Public Spaces in response to the expert panel announced in April 2020 that the NSW Government intended to implement a "*licensing regime to properly account for any water losses*". DPIE is currently working to implement this decision of Government, however is yet to finalise a preferred option.

1.1 Pre-approval recommendations

That the proponent continues to liaise with DPIE Water as it develops and implements the licensing framework announced by the Minister to ensure the existing and proposed project can operate in compliance with water legislation. This is to address the current inability to acquire all necessary entitlement to facilitate the development of the Project in the applicable surface water and groundwater sources. The entitlements that need to be acquired include the following:

- 3330 units in the Upper Nepean and Upstream Warragamba Water Source of the WSP for the *Greater Metropolitan Region Unregulated River Water Source* (1395 units for the existing project and 1935 units for the expansion).
- 10 units in the Illawarra Rivers Water Source of the WSP for the *Greater Metropolitan Region Unregulated River Water Source* (7 units for the existing project and 3 units for the expansion).
- 32 units in the Sydney Management Zone 1 of the WSP for the Greater Metropolitan Region Groundwater Source (25 units for the existing project and 7 units for the expansion).

2.0 Impact on watercourses (refer to South32 response, comment 13)

South32 have restated their criteria for identification of key stream features without further geomorphic or hydrologic justification and without revision.

The criteria used in the EIS to identify significant watercourses and watercourse features for protection restricts the ability to identify significant features of smaller order watercourses such as first, second and third orders. These watercourses are likely to be impacted by surface cracking and upsidence which can impact flow availability and connectivity. There is therefore the potential to significantly impact on these watercourses with no proposal for remediation.

2.1 Pre-approval recommendations

- A commitment to complete further watercourse assessments to identify the values of all watercourses to be undermined, and a proposal to monitor, minimise and mitigate these watercourse impacts. An objective of maintaining flow and connectivity within these systems is recommended. These assessments should include:
    - Explanation of the geomorphic and hydrologic justification for adoption of thresholds for 'key' stream features, being pools with holding capacity greater than 100 m^3 and waterfalls with greater than 5 m height
    - Justification of stream flow classification to group watercourses into ephemeral, intermittent and perennial streams
    - Include an assessment of 'key' stream features upland swamps and the geomorphic and hydrologic controls on their integrity. This should include mapping the spatial distribution of 'key' stream features not related to upland swamps along

with those associated with upland swamps so that proposed longwall locations can be considered against a more holistic representation of waterway values

- Consider alternative longwall locations that avoid key sensitive surface features including upland swamps, recognising the significant value of these waterways.

3.0 Impact on aquatic species (South 32 response, refer to comments 14 – 16)

We look forward to further consulting with South32 regarding ongoing monitoring for the project. DPIE-Water recommends the following post approval requirements for future monitoring and assessment for the project.

3.1 Post approval recommendations

- time series graphs for key water quality parameters (including pH, EC and heavy metals), should be provided for future aquatic ecology assessments
- a region-specific AUSRIVAS model should be used, if available
- macroinvertebrates should be identified to genus, this is particularly important for sensitive taxa from the families Ephemeroptera, Plecoptera and Trihoptera (EPT). Identification to genus would allow for the assessment of macroinvertebrate community sensitivity with greater taxonomic resolution
- all *Euastacus sp.* should be identified to species
- greater sampling effort for Macquarie perch, Baited Remote Underwater Videos and eDNA are potential methods for improving the knowledge of Macquarie Perch distribution in the area. The closest population of Macquarie perch to the proposed mining areas should be identified.

These recommendations should inform monitoring programs and future assessments.

4.0 Groundwater model

DPIE-Water notes that the proposed mine extension is a large-scale, high-risk activity that can have significant impacts on sensitive receptors that are believed to have already been impacted by deep coal mining. Recent field observations by DPIE Water officers of ground surface fracturing, dry riverbeds, and loss of surface water flow above longwall panels in the Dendrobium Mine area suggest that mining impacts have propagated to the ground surface and surface water. The level of due diligence in environmental impact assessments and the models they depend on must be commensurate to the value of the potentially affected receptors and the level of risk.

The objectives of DPIE-Water's groundwater model and assessment review are twofold:

1. To ascertain their suitability to inform decisions by the proponent and various stakeholders, including relevant government departments; and
2. To provide useful feedback to the proponent to help them improve the quality and reliability of the current and future versions of the model and assessment.

DPIE-Water reviewed the groundwater model information in the Groundwater Assessment report in the EIS (Appendix B, May 2019). DPIE Water identified necessary improvements to the groundwater model and communicated these to the proponent in our advice dated 23 October 2019. The proponent provided additional information in their correspondence to DPIE P&A dated 22 June 2020, held a meeting with DPIE Water on 15 July 2020 and provided additional information on August 11 2020. While the new information and the discussion alleviated some concerns, there remain matters that the proponent must resolve. Most importantly, a clear plan is required for model updating, including acceptable methodologies for data QA/QC for modelling purposes and model parameterisation.

Tables 1 and 2 in Attachment B present a more detailed assessment of the proponent's responses to DPIE-Water's groundwater model review.

DPIE-Water is particularly concerned about the model parameterisation (assignment of hydraulic property values), which is based on an oversimplified equation (Equation 5 in the Groundwater Assessment report, p82) and terms (depth and an assumed lithology related factor presented in Table 7-1 in the Groundwater Assessment, p83). In addition, the data used in the model construction and calibration have not been properly checked as required by best practice guidelines such as the Australian Groundwater Modelling Guidelines (AGMG, 2012). Hence we are concerned that the model has not been proven to be representative of the groundwater system and mining stresses. Subsequently, its ability to predict effects within acceptable bounds of uncertainty is unproven regardless of the model calibration statistics being within acceptable bounds according to the AGMG (2012).

DPIE-Water believes that the groundwater model in its current form is not adequately reliable as an impact prediction tool. Particularly, it is not fit for the purpose of predicting potential impacts on natural and artificial surface water features and surface water licencing requirements. The model calibration plots presented in Figures 7-3 to 7-20 in the Groundwater Assessment report do not indicate that the model can predict small-scale water level drops at shallow water supply works and small surface water features such as streams. In the meeting on 15 July 2020, the proponent explained that the groundwater model will not be used to assess potential impacts on surface water or surface water licensing requirements. The proponent advised that it will use the Surface Water Model for these purposes. We believe this is a closed loop water balance and is not meant to predict transient losses due to formation parameter changes.

The additional information provided in South32's letter dated 11 August 2020 does not alleviate DPIE-Water's concerns regarding the model representativeness of the area's natural and mining-affected hydrogeology, simulation of past behaviour of the modelled hydrogeological system and predicting future responses relating to the proposed mine extension into Areas 5 and 6.

DPIE-Water believes that the groundwater model should be revised and updated to make it a suitable tool to predict impacts and groundwater extraction rates. A complete model revision must be completed within two years of the project determination. Thereafter, the model must be revised and updated every three years.

We recognise that checking the huge dataset available for the area and updating the groundwater model is an extensive undertaking. Nonetheless, robust data and modelling are required for reliable assessment of impacts on the environment and water users, as well as for licencing purposes. The independent model reviewer recommended regular revision and updating of the groundwater model. DPIE-Water strongly endorses this recommendation.

AGMG (2012) emphasises the need for planning and stakeholder agreement in groundwater modelling. It also stresses the importance of quality-controlled data. Future versions of the groundwater model and assessment must be well-planned, agreed by stakeholders, and based on verified data.

DPIE-Water believes that the additional model runs proposed at the meeting on 15 July 2020 could help clarify the level of uncertainty around the model predictions of effects and licence requirements of the proposed mine extension. This will enable better informed decision making. Should the runs indicate that modelling uncertainty can be mitigated, well-thought out Trigger Response Action Plans (TARPs) will be required to effectively manage the actual effects of the proposed mine extension. This is particularly important to surface water, which cannot be assessed by the groundwater model due to scale, precision, and accuracy considerations.

4.1 Pre-approval recommendations

- As agreed in the meeting on 15 July 2020, the proponent is requested to complete and prepare a short supplementary report on the following model runs:
    - Conservative hydraulic properties and conditions scenario (as per IEPMC requirements).

- Most realistic values hydraulic properties and conditions scenario.

4.2 Post approval recommendations

- The proponent should prepare an acceptable plan within six months for Secretary approval to update the groundwater model within two years from project determination. The 'Groundwater Model Updating Plan' must include, but not be limited to, the following:
  a) Modelling steps and the agreement of the modelling approach with the Australian Groundwater Modelling Guidelines (2012) and subsequent relevant best practice notes and guidelines.
  b) QA/QC procedure for the monitoring datasets that will be used in the model.
  c) The intended methodology for model parameterisation based on lithology and considering depth, informed by field testing (e.g. packer tests). Noting DPIE Water has not been provided in the past with any confirmation of vibrating wire piezometer data being reliable compared to open hole piezometers.
  d) The intended approach for setting initial conditions for transient modelling.
  e) Intentions with regards to using surface water flow observations in model calibration.
  f) The target (acceptable) model calibration metrics, including average and maximum absolute error for groundwater heads, mine inflows and surface water flows.
  g) Whether the groundwater model will be used for surface water predications.
  h) What local scale models will be prepared for sensitive environments.
- The proponent must commit to updating the model in accordance with the agreed updating plan within two years of project determination.
- Within one year following project determination, prepare a comprehensive plan for a long-term QA/QC program for checking data for groundwater modelling purposes. This must include comparison of multi-level piezometer and Vibrating Wire Piezometer (VWP) groundwater level data.
- Prepare acceptable TARPs as part of the project Extraction Plans to manage actual effects on surface water and groundwater supply works.
- Commit to updating the groundwater model and assessment every three years through the life of the project, following the first update.
- DPIE Water recommends DPIE P&A request the proponent to implement subsidence monitoring using InSAR technology. The InSAR analysis should backtrack to the start of the operations over the mine area with monitoring outcomes linked to subsidence approval conditions and reported annually. This data would be an additional resource providing: support to the low confidence water level data informing subsidence, input for groundwater model updates, and informing any changes to hydraulic conductivity in future model updates.

Attachment B

Table 1 Assessment of model related information provided in the proponent's response to submissions (RtS) letter dated 22 June 2020 and the follow up online meeting on 15 July 2020.

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 1 – Groundwater head data used in model calibration has not been checked and assigned confidence weights.	– Groundwater level data were reviewed. Erroneous data points were removed. – It is not feasible to check all data used in the model due to the large number of monitoring instruments. – The model incorporates hydrogeological parameters that are well informed by an extensive site-specific dataset of hydraulic properties. – The model has the benefit of over a decade of measurement of mining effects. – Calibration statistics demonstrate that historic drawdown and mine inflows have been adequately replicated. – Conservative assumptions were used for parameters that cannot be directly measured (e.g. height of fracturing) or are variable (e.g. flows in ephemeral streams and regulated watercourses) in consideration of expert reviews and the recommendations of the Independent Expert Panel for Mining in the Catchment (IEP).	**Response is not adequate.** – Information on the data QA/QC process, the removed erroneous data points, and the reason for their exclusion has not been provided in the Groundwater Assessment report, the RtS, or the meeting held on 15 July 2020. – Modelling must be transparent and replicable to be credible. – Data must undergo appropriate QA/QC as part of the modelling process. – The proponent argues that the model is robust and reliable due to data abundance (aquifer properties, groundwater level, and tunnel inflow measurements). Data abundance is not advantageous if the data has not been inspected and analysed. – Abundance of aquifer hydraulic property data does not substitute for or guarantee the quality of calibration targets, namely, groundwater head (level) and flux (tunnel inflows and surface water baseflows) data. – The model is claimed to be fit for purpose because it is well calibrated against groundwater head and flux targets. However, because the quality of the calibration targets has not been checked, the model calibration is subsequently uncertain regardless of calibration statistics.

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 2 – Model parameterisation – The model parameterisation is based on complex theoretical assumptions. – No parametric sensitivity analysis of hydraulic properties has been undertaken to identify the most important parameters in model performance.	– Hydraulic conductivity (K) was estimated as a function of depth and using data from Southern Coalfield mining operations. This is a response to the Independent Expert Panel who suggested that previous groundwater model K estimates were not consistent between projects. – The model methodology was reviewed by Dr Frans Kalf. – Sensitivity analysis for all prediction types was not presented in the report. However, the effects of varying hydraulic parameters on the model calibration to and prediction of mine inflow are described in Section 9 and in further detail in the RtS.	**Response is not adequate.** – In the online meeting of 15 July, the proponent used Table 7-1 to clarify the model parameterisation process using a depth function and a lithology factor, but the issue remained unclear. – In the online meeting, the proponent noted that coal seams are 20–50 times more permeable than sandstones. – Estimates of intrinsic hydraulic properties in the model is based on depth, with a factor to represent lithology. This approach gives more weight to depth than lithology. Consideration should have been given to lithology before factoring depth, not the other way around. – Models are non-unique, which means that various combinations of hydraulic properties can produce similar results. Composite parametric sensitivity analysis help identifying which parameters must be focused on in model calibration. This does not eliminate model non-uniqueness but helps with hydrological understanding and model calibration. – The model is highly parameterised, i.e. each cell has been individually assigned hydraulic properties. This makes automated model calibration and composite parametric sensitivity checks unattainable due to excessive model runtime. In addition, it is difficult to assess the accuracy of representativeness of filed conditions of such models. When updating the model, the proponent must consider alternative modelling parameterisation approaches.

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 3 – Model calibration – The basis for manual calibration is not clearly presented in the report. – No automated calibration has been attempted. – Transient modelling is very sensitive to initial conditions. – Transient simulation is not based on satisfactorily calibrated steady state model. This has resulted in starting transient calibration based on unrealistic initial conditions as can be seen in few hydrographs. – The mismatch between transient observed and model calculated groundwater heads is large, commonly greater than 25 m. Such models cannot be used to predict effects on water supply works or surface water features. – Mine inflow data used as calibration targets are not real (direct measurements). They are calculated water balances (i.e. models). As such, they should be given less weight in the overall model calibration process.	– The proponent agrees that initial conditions are important to transient simulations. – The history of mining does not enable rigorous steady state calibration. Hence, calibration is focussed on transient simulation. – The proponent considers initial conditions to be appropriate, with limited exception. – There are a limited number of water supply works in the area. – Groundwater level predictions are affected by the model layers and location of piezometers within these layers. – The model replicates drawdown more adequately than groundwater levels as this parameter represents change [difference] in groundwater levels. – As calibration statistics for the model demonstrate that drawdown and mine inflows are adequately replicated, the model is considered to accurately predict drawdown at water supply works. – No water supply works are predicted to experience greater than 2 m drawdown due to the project. – The proponent considers mine inflow estimates to be the most important calibration dataset. – Mine inflows are calculated by a detailed mine water balance. – It is unlikely that actual impacts would exceed predictions due to the model conservative assumptions. This conclusion is noted in Dr Kalf's model review.	**Response is not adequate.** – In the online meeting of 15 July, examples of unfit initial conditions for transient modelling were pointed out (e.g. Figure 7-17). Starting transient modelling from unrealistic initial conditions will result in erroneous simulation of the hydrological system and prediction of effects. – Provision of water balance and calibration metrics for the pseudo steady state would have been useful to give insights and confidence in subsequent transient modelling. – Automated calibration has not been possible due to the long runtime of the produced highly parameterised model. – In the online meeting, examples of use of very short data records for history matching were discussed (e.g. Figure 7-11). Such plots cannot be used as evidence that the model is well calibrated as claimed. – In the online meeting, the value of automated calibration was discussed, including enabling undertaking composite sensitivity analysis (parameter identifiability) to inform model calibration. – The high error margin in groundwater level predictions does not allow for accurate enough assessment of drawdown at water supply works. – Robust TARPs are required to manage effects on water supply works. – Mine inflows are not direct measurements and have composite uncertainty. As such, they should be given lower weighting than groundwater level data in model calibration. – Predicted mine inflows can be used for groundwater licencing purposes but must be reviewed when the model is updated, or monitoring shows a need to do so.

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 4 – Model predictions – The model's regional scale and resolution in space and time are not suitable for predicting effects on significant natural and manmade surface water features (wetlands, dam lakes, streams, etc.). Potentially affected surface water features have not been adequately characterised, and no sensitivity or uncertainty analysis has been undertaken on relevant parameters, e.g. bed conductance. – Unsatisfactory simulation of the groundwater system behaviour and responses to historic mining stresses degrades confidence in the model's ability to predict effects of the proposed activity (drawdowns at receptors and inflows for licencing purposes).	– The model builds on efforts over the last decade and accounts for historic stresses in the Sydney Drinking Water Catchment. – The model grid has been refined to incorporate detail in areas where groundwater stresses occur, such as around longwall panels, or where sensitive natural and built receptors are located (reservoirs, watercourses, Upland Swamps and registered groundwater bores). – The model calibration statistics demonstrate that drawdown and mine inflows are adequately replicated. – The conservative model assumptions mean the model tends to overpredict total historic mine inflows. – The model sensitivity to riverbed conductance has been tested (Section 9). Lake bed conductance was modified during calibration, based on experience in preceding modelling studies, and was tested in the sensitivity analysis undertaken. – The hydrographs (Figures 7-4 to 7-20) indicate that the model is adequately calibrated. – Due to the model conservative assumptions, the risk of actual impacts (e.g. surface water losses) are unlikely to be significantly greater than predictions.	**Response is not adequate.** – The project is large-scale and has high-risk on sensitive receptors. The level of due diligence must be commensurate to the level of risk. – Model calibration plots including Figures 7-4 to 7-20 do not indicate that the model can predict small-scale water level drops at shallow water supply works and small surface water features such as streams. – Appropriate, robust TARPs are required to manage groundwater level drawdown on bores and surface water features. – Setbacks is an important methodology for mitigating impacts on surface water. – There are hydrographs in Appendix I to the Groundwater Assessment that suggest that the model is not well calibrated in certain areas, depths and/or times (e.g. S1096 and Dendrobium Swamp 15B). – Despite the claim that the model is conservative, impacts on swamps and streams may exceed predictions.

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 5 – The difference between modelled and observed inflows is generally large.	– The model tends to overpredict mine inflows due to its conservative assumptions, including the method used to estimate the height of connective fracturing. – Model calculated and measured inflows in Area 1 and Area 3B are approximately the same. – Modelled and measured inflows in Area 2 are less similar. – Conditions in the Areas 5 and 6 (the proposed extension) are similar to Areas 3A and 3B and significantly different than Area 2.	**Response is partially satisfactory.** – Mine inflows are calculated from a water balance model, not measured. They are useful in general calibration, but they do not have the same reliability (confidence level) as direct measurements. – In the meeting on 15 July 2020, the proponent agreed with DPIE-Water that inflow figures used in model calibration have been obtained from a model, rather than being direct measurements. Hence, they have lower confidence level than real measurements. – Model estimates of mine inflows can be used for groundwater taking licencing purposes. Licence volumes must be revised when the model gets updated or actual measurements show a need for revision. – Robust TARPs are required to manage greater than predicted effects on surface water and groundwater users (bores).

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 6 – Parametric sensitivity analysis is required to gain insights of parameters important to the model is missing. – Reported sensitivity and uncertainty analyses are for predictions only, not including history matching. – Better information is needed to enable well informed decision making about the acceptability of effects and licencing requirements of the proposed mine expansion.	– Section 9.1 described how changes in parameters affected mine inflow simulation and how changes in the assumed height of fracturing affected predictions. – The model calibration phase of the Groundwater Assessment investigated changing parameters and inspecting the model's capacity to match historic observations of inflow and groundwater levels as a result of those changes. – Uncertainty analysis has been carried out using a suite of deterministic scenarios. – Deterministic scenarios are compared against historic mine inflow, so there is consideration of model calibration as well as the effects of the parameter changes on predictions (e.g. mine inflow, drawdown contours, number of bores affected). – Due to the model conservative assumptions, the risk of actual impacts being significantly greater than those predicted can be considered low.	**Response is partially satisfactory.** – More robust sensitivity and uncertainty analysis and reporting are required, especially in light of the observed effects in the area which previous modelling did not predict. – The model is argued to be conservative. However, the assumed conservative assumptions contribute to making the model more uncertain. DPIE-Water does not agree with the proponent's claim that the model predictions are conservative as this argument cannot be reliably verified. – TARPs are required to manage the project risks and impacts.

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 7 The proponent should – Review available data to enable better model calibration. This must include systematic elimination or correction of outliers and assignment of confidence weights for the calibration data. – Agree with stakeholders on model acceptability (e.g. maximum difference between observed and model calculated groundwater heads). – Consider finer spatial and temporal discretisation and/or smaller models to assess effects on natural and manmade surface water features. – Revise the model and report, taking into consideration the above remarks. Detailed comments can be provided to assist the proponent with the concerns raised.	– Groundwater level data reviewed. Erroneous data points removed. It is not feasible to check all data in the model due to the large number of instruments and data points (approximately 40,000 groundwater targets). – Calibration statistics demonstrate that historic effects are adequately replicated by the model using this dataset which includes an extensive site-specific dataset of hydraulic conductivity and porosity or storage estimates. – The model was reviewed by an independent and experienced hydrogeologist and groundwater modeller as per the Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012). – The model domain accounts for historic stresses by incorporating historic, active and proposed mining operations in the Sydney Drinking Water Catchment. – The model contains approximately 700,000 cells in an unstructured mesh in 17 layers. The grid has been refined in areas of potential stresses such as around longwall panels and in areas of sensitive natural and built receptors like reservoirs, watercourses, Upland Swamps, and registered groundwater bores. – The model would continue to be updated as the mine layout changes. – Full review of the model (including verification) would be conducted every 3–5 years as per the recommendations of Dr Frans Kalf.	**Response is partially satisfactory.** – The report does not provide information on data checking and elimination process. Transparency and clarity are required in models to give them credibility. – Calibration statistics do not provide evidence with regards to data quality, especially when there are too many calibration targets. – None of the reviewers or agencies suggested that the data used in model set up and calibration should not be subject to QA/QC. – The model was reviewed using the brief MDBC 2001 checklist, not the more detailed AGMG 2012 checklists. – The proponent is referred to the AGMG 2012 '*Guiding Principle 3.3: The conceptual model should be developed based on observation, measurement and interpretation wherever possible. Quality-assured data should be used to improve confidence in the conceptual model.*' and 'Section 5.2.4, which states '*In principle, there is no reason to exclude any data from the model calibration process, but it is important that data be studied in detail and quality assured before attempting calibration.*' – As part of the required model updating plan, the proponent must prepare a practical plan to check and select data for use in the various stages of the model development.

Issue (summarised & referenced using numbered comments as per the South32, 22 June correspondence	Proponent comment (summarised)	DPIE Water comment
Comment 11 – There is a high degree of uncertainty regarding the accuracy of vibrating wire piezometers (VWP). Additional co-located stations (standpipe monitoring bores) next to vibrating wire piezometers measuring the same subsurface depth intervals in isolation are required. Comprehensive analysis of both datasets of an adequate baseline period is required.	– South32 installed few standpipes next to VWPs at the request of WaterNSW. – South32 would continue to investigate and assess co-located standpipes in the proposed Areas 5 and 6 should they be approved. – IEP recommendations regarding swamp monitoring include paired piezometers in swamp sediments and nearby bedrock, and flow gauges at the swamp exit stream, at minimum for representative large valley infill swamps, and complemented by soil moisture sensors at selected sites. This monitoring is in place for key swamps within the current mining area and all swamps in the proposed Areas 5 and 6 as reported in the Surface Water Assessment.	**Response is satisfactory.** – The required model updating plan must clarify how this data will be used in the regional model and/or more local scale models as may be required.
Comment 12 The proponent should: – Develop a suitable Trigger Action Response Plan (TARP) using the baseline data gathered across Areas 5 and 6 to demonstrate that potential future impacts can and will be satisfactorily mitigated or remediated if mining impacts were to occur. – Demonstrate the reliability of vibrating wire piezometers through the correlation of water level measurements with co-located standpipe monitoring bores measuring the same subsurface depth – intervals in isolation.	– South32 agrees with DPIE-Water's comment and would develop TARPs as part of Extraction Plans for the Project. – Refer to Comment 11 response.	**Response is satisfactory.**

Table 2 Comments on the additional information provided by South32 in correspondence dated 11 August 2020.

Item and South32 response	Department comment
Item 1 Further discussion on the lithological multiplier used to modify hydraulic properties between model layers. **Response** – Based on the packer testing and drill stem testing dataset (refer Section 4.7.1 and Figure 4-2 of the Groundwater Assessment [Appendix B of the EIS]), HydroSimulations developed a log-linear relationship between depth and horizontal hydraulic conductivity (Kh). This relationship is illustrated on Figure 1 below (grey series), as per Figure 4-2 of the Groundwater Assessment. **[Figure 1]** – In tandem, HydroSimulations has applied multipliers based on lithology (initially guided by the packer testing statistics on Figure 4-3 of the Groundwater Assessment). As a result, each model cell is initially assigned a Kh estimated from depth, then multiplied based on the stratigraphy/lithology. These factors are listed in the fifth column of Table 7-1 of the Groundwater Assessment. The result is similar to the orange series (Figure 1), which is varied from the grey series. – A number of examples of how this compares with data from specific bores is shown below (Figures 2 to 4), noting that there is significant variation between bores (i.e. significant scatter in the dataset presented in Figure 4-2 of the Groundwater Assessment). These figures show packer test records from two bores, one in Dendrobium Mine Area 3A and one in Area 3B, compared against the modelled Kh for the relevant vertical column of model cells. – These charts show the difficulty in matching to individual packer testing records, however, the main aim is to show representative (arithmetic mean to median) hydraulic conductivity, as shown on Figure 4-2 and Appendix B in the Groundwater Assessment. **[Figure 2]** **[Figure 3]** **[Figure 4]**	**Response is not adequate** – Figure 4-2 is too cluttered to enable visual appreciation of the importance of lithology in determining horizontal hydraulic conductivity (KH). – Dendrobium and Tahmoor packer test data presented in Figure 4-3 show that lithology is an important factor in determining KH. – Figure 4-2 indicates an influence of depth on the KH of the stratigraphic sequence. However, depth looks to be a secondary control on KH. – The '*Summary*' on p 52 states that '*Model Kh parameters are derived from the analysis of numerous packer tests and pumping tests which include measurements taken across discrete and connected fractures in bores. The selected model hydraulic parameters are therefore assumed to be representative of the rock mass, including the secondary porosity (i.e. joints, fractures), at the model scale which is regional and therefore small-scale geological structures (e.g. faults, joints, bedding planes) do not need to be explicitly included in a numerical model*.' This suggests that KH should have been assigned primarily on geological basis (lithology and structure). Depth could have been included as a secondary control. Nonetheless, the model has been set up with depth being the primary control on KH and geology being secondary to it. – Pilot Point parameterisation using packer test data may be more appropriate approach to model parameterisation than the simplified equation using depth and poorly constrained lithology factor.

Item and South32 response	Department comment
Item 2 Identifying relevant sections of the EIS Groundwater Assessment that describes processing and allocation of weightings to erroneous data for model calibration. **Response** – Section 7.5.1 of the Groundwater Assessment describes the extensive groundwater level dataset used for the groundwater model, as well as the feasibility of reviewing and checking all data used in the model (e.g. thoroughly cleaning all targets, through either the correction of all clearly incorrect data or weighting all [potentially] suspect data). – Further detail in regard to tabulating the percentage of targets that have been assigned different weightings between 0 and 1 is provided below. ○ >99.5% of groundwater targets have an assigned weight of 1 (i.e. assumed to be 'good'); ○ 0.3% of groundwater targets have an assigned weight of 0.1 (i.e. 'suspect', but not able to be corrected); and ○ 0.2% of groundwater targets have an assigned weight of 0 (i.e. not used in calibration statistics). – As noted in the Groundwater Assessment and discussed previously, it is often difficult to determine whether some data can be considered suitable. In this case, most data remain assigned with a weighting of 1.	**Response is not adequate** – Neither the Groundwater Assessment report, particularly Section 7.5.1, nor the response provide information on the adopted data QA/QC. – Model calibration entails the checking of the model calculations to prove that the model is replicating field measurements. As such, arguing that model calibration metrics prove that the model is calibrated against good quality data is inappropriate. – For a model to be considered fit for purpose, it must be calibrated against quality-controlled data. – The requirement to quality control the model calibration data cannot be waived due to difficulty in achieving this, particularly if the model is being claimed to be based on the largest hydrogeological dataset in Australia.

Item and South32 response	Department comment
Item 3 Clarification of predicted impacts to groundwater levels and Groundwater Dependent Ecosystems (GDEs). **Response** – The primary GDEs in the Project area are Upland Swamps and baseflow-fed watercourses. The other groundwater-related receptors are water supply bores (which are not located proximal to the Project) and the reservoirs. – The model is effective at replicating the differential drawdown resulting from historic stresses on the groundwater system through the sequence (e.g. the 150 metre [m] drawdown at depth [coal seams], the 80 to 100 m drawdown in the Scarborough Sandstone [SBSS] and Coal Cliff Sandstone [CCSS], the 30-50 m drawdown in the BGSS and the small drawdown in the HBSS). – In regard to Upland Swamps, monitoring shows that groundwater levels in swamps have been unaffected by longwall mining at Dendrobium Mine beyond 60 m from a panel edge (noting however that Upland Swamps have been affected by subsidence effects within that distance). Upland Swamps overlying the Project longwalls have been simulated via local models as part of the Surface Water Assessment (Appendix C of the EIS). However, drawdown in regolith in the regional model is shown to be conservative in areas above or adjacent to panels (e.g. Figures 7-5 and 7-9 of the Groundwater Assessment). – In regard to private bores, these are typically located in the HBSS, and are located at significant distances from the Dendrobium Mine and Project longwalls. The model shows the simulation of drawdown in the HBSS (e.g. Figures 7-6 [reproduced below], 7-9 and 7-10 of the Groundwater Assessment) close to longwalls is good. Considering the distance from the Dendrobium Mine to private bores (compared to these monitoring bores) and the use of deterministic uncertainty scenarios, the risks of potential impacts to private bores from the Project are low and are considered to be estimated in an appropriate manner. – South32 acknowledges DPIE-Water's concerns regarding potential drawdown proximal to the reservoirs. However, it is noted that the groundwater model shows calibration against one of the multiple monitoring bores located on the shoreline of Avon Reservoir (Figure 7-12 of the Groundwater Assessment), which shows that drawdown in the lower HBSS, the BHCS and upper BGSS (the units which host the reservoir or are located immediately below) are well represented by the model.	**Response is not satisfactory** – Section 2.7 in the Groundwater Assessment states that '*Upland Swamps are typically located at the headwaters of low order streams, on low relief plateau on low permeability Hawkesbury Sandstone.*' – Figures 2–4 in South32 letter dated 11/8/2020 show up to two orders of magnitude difference between modelled and measured KH at shallow depths, that most likely correspond to Hawkesbury Sandstone material. The uncertainty analysis reported in the Groundwater Assessment does not adequately correspond to such differences between measured and modelled parameters. Hence, the model's ability to reasonably predict groundwater level drawdown effects on surface water and water supply works remain highly uncertain.

Figures and Tables

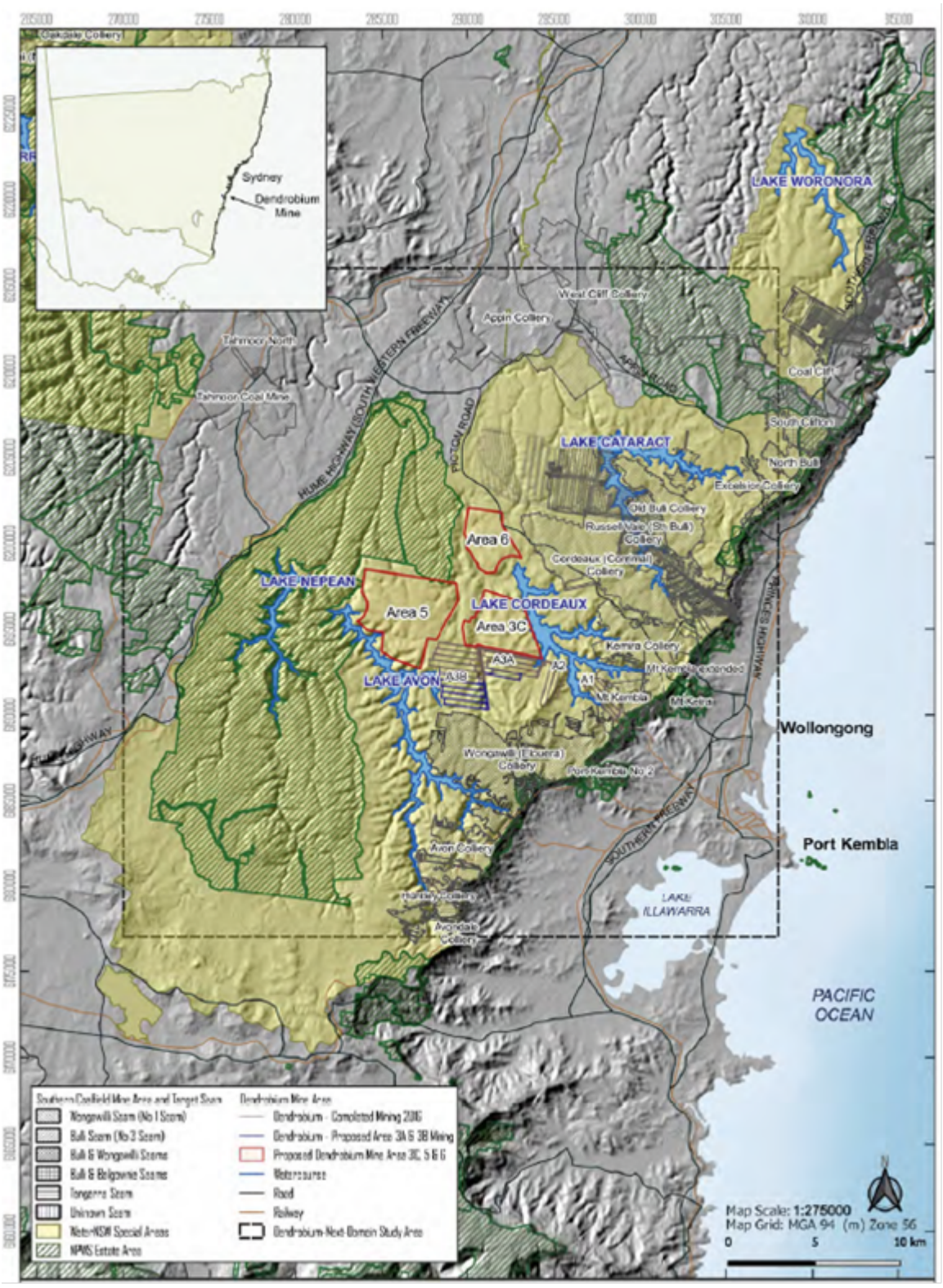

Figure 1. Location map showing different Dendrobium Mine areas.

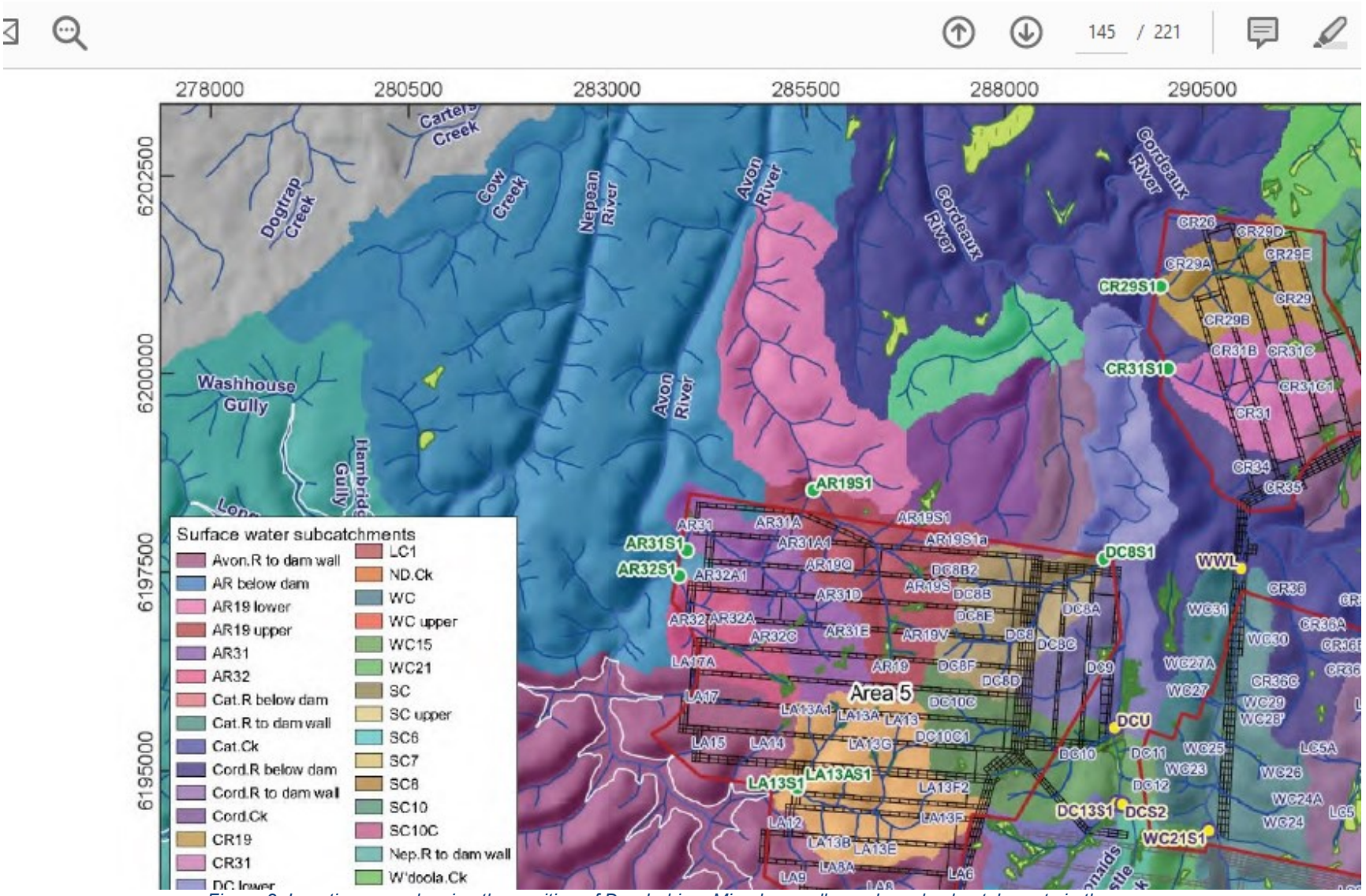

Figure 2. Location map showing the position of Dendrobium Mine longwall panels and subcatchments in the area.