22 June 2020

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Department of Planning, Industry and Environment
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via email: steve.o'donoghue@planning.nsw.gov.au

Dear Stephen,

RE: DENDROBIUM MINE – DPIE-WATER RESPONSE TO EIS SUBMISSION

In response to DPIE's letter dated 20 April 2020, please find enclosed (Enclosure 1) South32's responses to residual concerns raised by DPIE-Water in its submission on the *Dendrobium Mine – Plan for the Future: Coal for Steelmaking EIS* (the Project).

The purpose of this letter and its enclosures is to provide further responses to the concerns raised by DPIE-Water, in particular further detail in regard to the groundwater modelling undertaken for the Project.

South32 notes that the groundwater model developed for the Project builds on previous groundwater modelling efforts over the last decade in the development of best practice modelling methods, and is an extension of previous groundwater models developed for the Dendrobium Mine.

The Project model domain accounts for historic stresses in the groundwater system by incorporating historical, active and proposed mining operations in the Sydney Drinking Water Catchment.

The groundwater model developed for the Project has incorporated hydrogeological parameters that are well informed by an extensive site-specific dataset of hydraulic conductivity and porosity or storage estimates. This includes the consideration of pre- and post-mining observations to constrain parameters such as horizontal and vertical permeability.

In addition, the model also has the benefit of over a decade of data measuring the effect of historic mining operations to the groundwater system. The calibration statistics for the model demonstrate that these historic effects (e.g. drawdown and mine inflows) are adequately replicated, and comply with the Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012).

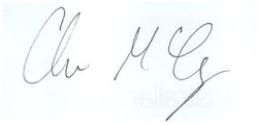
Where some parameters in the groundwater model were unable to be directly measured (e.g. height of fracturing) or are variable (e.g. flows in ephemeral streams and regulated watercourses) the groundwater modelling incorporated a range of conservative assumptions in consideration of expert reviews of groundwater modelling in the Southern Coalfield and the recommendations of the Independent Expert Panel for Mining in the Catchment.

The result of the conservative assumptions adopted is the risk of actual impacts (i.e. surface water losses) being significantly greater than those predicted from the groundwater model can be considered low, a conclusion supported by Dr Frans Kalf in the independent review of the Project groundwater model.

If you have any queries please don't hesitate to contact me (Chris.McEvoy@south32.net or 0407 060 163).

Yours sincerely

SOUTH32 LIMITED



Chris McEvoy
Approvals Manager
Dendrobium Next Domain Project

ENCLOSURE 1

RESPONSE TO DPIE-WATER COMMENTS

DPIE-WATER

Comment 1

DPIE-Water stated:

> *It is evident from the reviewed report that a large dataset has been compiled and used in the development of the conceptual and numerical models. However, the groundwater head dataset used in the model calibration has not been thoroughly checked and used without assignment of confidence weights.*

South32 Response

In development of the groundwater model for the Project, HydroSimulations (2019) reviewed and processed groundwater level data to remove erroneous data points.

However, it is not feasible to review and check all data used in the model due to the large number of monitoring instruments (approximately 700 instruments with approximately 40,000 groundwater targets to review), many of which are located proximal to historical mining areas (e.g. monitoring bores located near Elouera/Nebo/Cordeaux workings) and where the history of mining and dewatering are uncertain.

In addition to groundwater head data, the groundwater model developed for the Project has incorporated hydrogeological parameters that are well informed by an extensive site-specific dataset of hydraulic conductivity and porosity or storage estimates. This includes the consideration of pre- and post-mining observations to constrain parameters such as horizontal and vertical permeability.

In addition, the model also has the benefit of over a decade of data measuring the effect of historic mining operations to the groundwater system. The calibration statistics for the model demonstrate that these historic effects (e.g. drawdown and mine inflows) are adequately replicated.

Where some parameters in the groundwater model were unable to be directly measured (e.g. height of fracturing) or are variable (e.g. flows in ephemeral streams and regulated watercourses) the groundwater modelling incorporated a range of conservative assumptions in consideration of expert reviews of groundwater modelling in the Southern Coalfield and the recommendations of the Independent Expert Panel for Mining in the Catchment (IEP) (2019a, 2019b) (refer to comment 3).

Comment 2

DPIE-Water stated:

> *The main issues identified with the reported model are:*
>
> *1 Model parameterisation:*
>
> - *The modelling work is focused on representation of detailed characteristics and processes rather than the representation of the behaviour of the hydrological system (groundwater and interconnected surface water).*
> - *The model attempts to represent subsidence effects predicted through various geotechnical methods in as much detail as possible. This has resulted in a "highly parameterised" detailed model, in which every model cell has been assigned unique hydraulic properties based on theory and subjective expert opinion.*
> - *The model parameterisation (set up of hydraulic properties) 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.*

South32 Response

The groundwater model developed for the Project builds on previous groundwater modelling efforts over the last decade in the development of best practice modelling methods, as acknowledged by the IEP (2019a, 2019b), and is an extension of previous groundwater models developed for the Dendrobium Mine, including recommendations made by agencies, PSM (2017) and Mackie (2017) (refer to comment 1).

The representation of "*detailed characteristics and processes*" in the groundwater model as referred to by DPIE-Water is an appropriate and necessary approach in consideration of the recommendations of agencies and modelling requirements (some of which are discussed below).

The incorporation of various "*geotechnical methods*" is in direct response to IEP's recommendations that, where possible, geotechnical modelling (from FLAC2D by SCT in this case) be used in groundwater modelling.

The parameters (particularly hydraulic conductivity [K]) have been simulated using a K-with-depth relationship and using data from Dendrobium Mine and from other mining operations in the Southern Coalfield. This modelling methodology is in response to the IEP, who suggested that previous groundwater model estimates for K were not consistent between mines/projects. It is noted that the groundwater model methodology for the Project was peer reviewed by Dr Frans Kalf.

Although sensitivity analysis for all prediction types (e.g. prediction of mine inflows, drawdown at bores, surface water losses, losses from reservoir etc.) was not presented, the effects of varied hydraulic parameters on the calibration to (and prediction of) mine inflow is described in Section 9 of the Groundwater Assessment (Appendix B of the EIS) and in further detail below, noting that this key prediction is sensitive to specific yield (Sy) and K parameters.

Comment 3

DPIE-Water stated:

> *The main issues identified with the reported model are:*
>
> *…*
>
> *2 Model calibration:*
>
> - *The basis for manual calibration is not clearly presented (including reasons for definition of zones referenced in Table 7-1). The manual transient calibration was started using unrealistic initial groundwater heads. No automated calibration (e.g. using PEST) has been attempted. Transient simulation is not based on satisfactorily calibrated steadystate model. This has resulted in starting transient calibration based on unrealistic initial conditions as can be seen in the hydrographs presented in Figures 7-4 through 7-20. Transient modelling is very sensitive to initial conditions.*
> - *As a result, the mismatch between observed and model calculated groundwater heads is unacceptably large (commonly greater than 25 m). Such models cannot be used to predict effects on users where no more than 2 m drawdown at water supply works is acceptable (e.g. Sec 8.4.4) or effects on surface water features.*
> - *The model-calculated mine inflows achieve a better match with mine inflows calculated using other methods. Because the mine inflow data used as calibration targets are not direct (real) measurements (but are derived from a calculated water balance), they should be given less weight in the overall model calibration process.*

South32 Response

Groundwater Model Calibration

South32 agrees that appropriately simulating initial conditions is important to transient simulations. The groundwater model relies on an initial steady state stress period (Section 6.6 of the Groundwater Assessment) to initialise water levels using input recharge, water feature and hydraulic property estimates. As with many sites in the Southern Coalfield, the history of mining extends back further than the availability of suitable groundwater level records to enable more rigorous steady state calibration.

Therefore, by necessity, calibration is focussed on the transient simulation of processes and groundwater levels. Some of those groundwater levels are representative of "pre-mining" conditions, but at other monitoring sites, only "post-mining" observations are available.

HydroSimulations (2019) considers that the simulation of initial conditions is appropriate following review of the hydrographs in Figures 7-4 to 7-20 of the Groundwater Assessment, with the exception of coal seam pressures at sites S2187 and S2206 in Area 6 (potentially due to the effect of the Russell Vale Colliery [proximal to S2187], or uncertainty in groundwater level measurements, respectively). Notwithstanding, simulation of initial conditions are appropriate for other bores located in Area 6.

It is noted there are differences between the simulation of absolute groundwater levels, and the ability of the model to replicate and predict relative levels (i.e. drawdown). The hydrographs referred to by DPIE-Water (Figures 7-4 to 7-20 of the Groundwater Assessment) show the groundwater model's ability to capture the significant drawdown in deep units and the reducing drawdown that is observed up through the sequence into the Hawkesbury Sandstone.

Water Supply Works

With respect to predicting drawdown at water supply works, it is noted that there are a limited number of water supply works proximal to the Project (the majority are located to the north and north-west proximal to Bargo and to the south-east of the Illawarra Escarpment).

The Groundwater Assessment predicted there are no water supply works that would experience greater than 2 m drawdown due to the Project. Therefore, the Project is predicted to have a 'Level 1' (i.e. minimal) impact on these water supply works in accordance with the NSW Aquifer Interference Policy.

As described above, there is a difference in model accuracy between the simulation of absolute groundwater levels, and the prediction of relative levels (i.e. drawdown) compared to observations. The accuracy of model predictions for absolute groundwater levels in comparison to measured levels is affected by the model layers and location of piezometers within these layers. The model shows drawdown is more adequately replicated, as the prediction of drawdown represents a change in relative levels. Drawdown is the key consideration for assessing potential effects at water supply works.

It is noted that the majority of water supply works are not located proximal to the Project. Potential model accuracy in relation to predicting drawdown at these water supply works has been addressed by the use of the deterministic scenarios (i.e. testing of changes to hydraulic properties as per the IESC Uncertainty Guidelines – Middlemis and Peeters [2018]) and calibration to mine inflow for the model. As calibration statistics for the model demonstrate that drawdown and mine inflows are adequately replicated, the model is also considered to accurately predict drawdown at these water supply works.

Calibration to Mine Inflows

Groundwater inflows to the mine workings at the Dendrobium Mine are calculated by a detailed mine water balance that considers:

- continuous monitoring of water pumped underground; and
- measurements of water entering, circulating and leaving the mine, including via air moisture and coal moisture.

HydroSimulations (2019) considers that the water balance at Dendrobium Mine is one of the most comprehensive at NSW mine sites, and that groundwater model calibration to mine inflows is the most important calibration dataset. In addition, the water balance has not been criticised as unreliable by analysts who have used it (Coffey, 2012; Mackie, 2016; HydroSimulations, 2019; HEC, 2019).

The calibration statistics for the model demonstrate that drawdown and mine inflows are adequately replicated, and the conservative nature of the model assumptions means the model has a tendency to overpredict total historic mine inflows to Areas 1-3B by approximately 20%, in comparison to the 30-day average observed inflows (Figure 1).

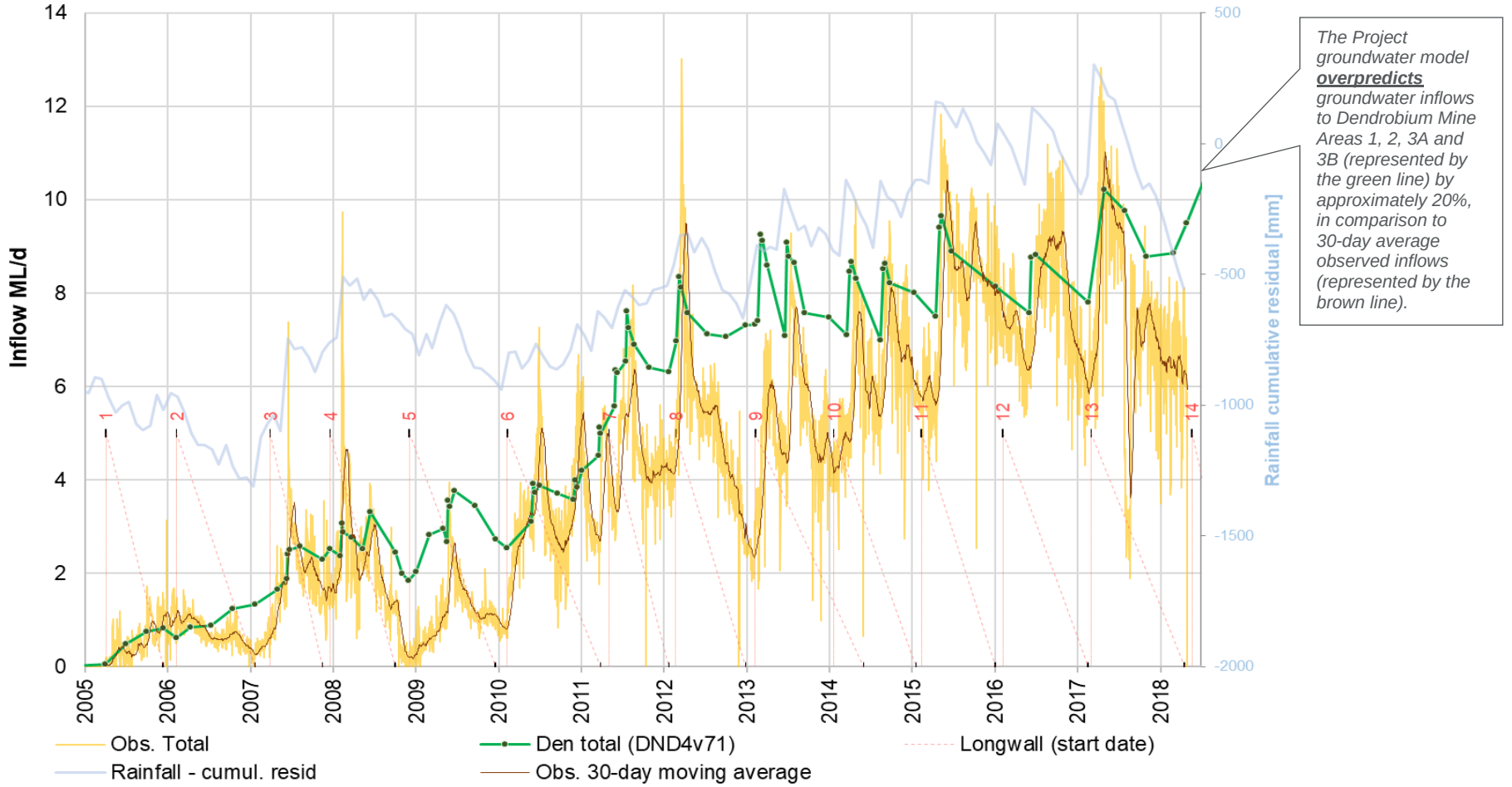


Figure 1 – Predicted vs Observed Mine Water Inflow at the Dendrobium Mine

As a result of the conservative assumptions adopted, the risk of actual impacts (i.e. surface water losses) being significantly greater than those predicted from the groundwater model can be considered low. This conclusion was supported by Dr Frans Kalf in the peer review of the Groundwater Assessment for the Project (Section 6.3.4 of the Submissions Report):

> *KA has no objection to the use of this 'Stacked Drain' method as it has been used by MER* [Mackie Environmental Research Pty Ltd] *for a number of years and has proved to be suitable. In addition it has been found on some projects by MER to overestimate the mining effects such as drawdown and overall inflow and therefore can be considered to be a conservative overall methodology for determining fracture propagation and associated draining in the geological profile.*
>
> *…*
>
> *… the 'stacked drains' approach by HS would very likely capture most flow and therefore would indeed be conservative with respect to mine inflow.*

Comment 4

DPIE-Water stated:

> *The main issues identified with the reported model are:*
>
> *…*
>
> *3 Model predictions:*
>
> - *The model [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.). In addition, potentially affected surface water features have not been adequately characterised and the no sensitivity or uncertainty analysis has been undertaken on relevant parameters, e.g. bed conductance (C) that controls leakage.*
> - *Unsatisfactory simulation of the groundwater system behaviour and responses to historical mining stresses degrades confidence in the model's ability to predict effects of the proposed activity (drawdowns for effects on users, strategic infrastructure and the environment, and inflows for licencing purposes).*

South32 Response

Groundwater Model Development

The groundwater model developed for the Project builds on previous groundwater modelling efforts over the last decade in the development of best practice modelling methods, and the Project model domain accounts for historic stresses in the groundwater system by incorporating historical, active and proposed mining operations in the Sydney Drinking Water Catchment.

The model grid or mesh 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 (such as reservoirs, along watercourses, Upland Swamps and registered groundwater bores) (Section 6.3.4 of the Submissions Report).

The model relies on an unstructured mesh to provide sufficient detail within/above and close to longwalls. Most longwalls are simulated with 50-60 m wide model cells, which reflects the conditions of Area 3C Subsidence Management Plan (SMP) applications for groundwater modelling.

As described above, the calibration statistics for the groundwater model demonstrate that drawdown and mine inflows are adequately replicated, and the conservative nature of the model assumptions means the model has a tendency to overpredict total historic mine inflows to Areas 1-3B by approximately 20%, in comparison to the 30-day average observed inflows.

The effects of varied hydraulic parameters on the calibration to (and prediction of) mine inflow is described in Section 9 of the Groundwater Assessment. Specifically, in regard to river bed conductance parameters, although not formally tested in sensitivity analysis, the parameter was modified during calibration by altering the assumed permeability of the bed material based on watercourse widths to characterise these features. Similarly, lake bed conductance was modified during calibration, based on experience in preceding modelling studies, and was tested in the sensitivity analysis undertaken (Section 6.8.4 of the Groundwater Assessment).

Figures 7-4 to 7-20 in the Groundwater Assessment, and in particular those with a better record of Dendrobium Mine's mining drawdown effects (Figures 7-5 to 7-13) and predictions of inflow (Figure 7-27) indicate that the groundwater model is adequately calibrated to drawdown and mine inflow and is, therefore, suited to simulating the required processes for assessment in relation to licensing and environmental impact purposes.

Due to the conservative nature of assumptions adopted in the groundwater model, the risk of actual impacts (i.e. surface water losses) being significantly greater than those predicted from the groundwater model can be considered low (refer to comment 1).

Comment 5

DPIE-Water stated:

> *The main issues identified with the reported model are:*
>
> *…*
>
> *4 In addition, the mismatch between model calibrated inflows and calibration targets is still generally large.*

South32 Response

Overall, the conservative nature of the groundwater model assumptions (i.e. height of connective fracturing assumed to extend from the seam to the surface using FLAC2D modelling) means the model has a tendency to overpredict total historic mine inflows to Areas 1-3B by approximately 20%, in comparison to the 30-day average observed inflows (refer to comment 1).

The simulation of inflow (Figure 7-27 of the Groundwater Assessment) is generally reflective of measured inflows in Area 1 and Area 3B. Although predicted inflow in Area 2 is less accurate compared to measured inflow, Area 2 is significantly different in terms of depth of cover, topographic relief and geology than the proposed Areas 5 and 6 for the Project (which are similar to Areas 3A and 3B).

The simulation of inflow in Area 3A and the latter period for Area 3B is generally higher than observed, due to the conservative nature of assumptions adopted in the groundwater model (e.g. height of connected fracturing), as recommended by PSM and others. As such, the predictions made for inflow to Areas 5 (in particular) and 6 are conservative.

The conservatism in the groundwater model is described in the Groundwater Assessment, other modelling studies commissioned by Dendrobium Mine as well as the Submissions Report.

It is noted that if other recognised methodologies were used to estimate the height of connective fracturing, such as the 'Tammetta Equation', then the height of connective fracturing would not extend to the surface or interact with the surface fracture network for the majority of the Project area.

Comment 6

DPIE-Water stated:

> *The main issues identified with the reported model are:*
>
> *…*
>
> *5 Sensitivity analysis and uncertainty analysis:*
>
> - *The work does not include parametric sensitivity analysis that is required to help focus of efforts on the refinement of important parameters in the model.*

- *Furthermore, the reported sensitivity and uncertainty analyses are focused on the potential effects of changing parameters on predictions without sufficient consideration of the effects of the varying of the parameters on the model's capability to match observations (history).*
- *The reported sensitivity and uncertainty analyses are inadequate. Better information is needed to enable well informed decision making about the acceptability of effects and licencing requirements of the proposed mine expansion.*

South32 Response

The Groundwater Assessment described how changes in parameters affected mine inflow simulation (Section 9.1 of the Groundwater Assessment), in addition to how changes in the assumed height of fracturing affected predictions.

The model calibration phase of the Groundwater Assessment investigated changing parameters (including hydraulic conductivity), and inspecting the model's capacity to match historical observations of inflow and groundwater levels as a result of those changes. Furthermore, the deterministic scenarios are compared against historical 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), as described in Section 9 of the Groundwater Assessment.

The uncertainty analysis carried out for the Project groundwater model adopts the method of employing a suite of deterministic scenarios (uncertainty analysis method 1 of Middlemis and Peeters [2018]), which tests a number of changes to model properties. Although this is not the more rigorous calibration-constrained Monte Carlo analysis, the Dendrobium Mine and Project groundwater model simulates a larger number of geotechnical changes than other groundwater models for NSW mining operations, and as such, a more practical modelling method has been adopted. This approach is supported by the IEP (2019b), who state the following in regard to quantitative uncertainty analysis:

> *"this requires careful consideration of achieving the suitable balance between model complexity and robustness of the quantitative uncertainty analysis (the complexity and computational burden of the current models may not permit the more comprehensive approaches to quantitative uncertainty analysis)".*

Notwithstanding, due to the conservative nature of assumptions adopted in the groundwater model and overprediction of mine inflows, the risk of actual impacts (i.e. surface water losses) being significantly greater than those predicted from the groundwater model can be considered low (refer to Comment 8 for licencing considerations).

Comment 7

DPIE-Water stated:

> *The proponent should:*
>
> - *Review the compiled dataset to enable better model calibration. This must include systematic elimination of errors and assignment of confidence weights for the remaining data.*
> - *Reach agreement with stakeholders and relevant agencies on model acceptability measures, e.g. acceptable maximum difference between observed and model calculated groundwater heads.*
> - *Consider more detailed models (finer 3D space and/or temporal resolution) and/or smaller models (thinner and/or smaller area) to assess effects on natural and manmade surface water features.*
> - *Revise the numerical model and modelling report taking into consideration the above remarks. Additional detailed comments on the modelling are not included here but can be provided if necessary to assist the proponent to address the concerns raised.*

South32 Response

As described above (refer to comment 1), HydroSimulations (2019) reviewed and processed groundwater level data to remove erroneous data points in development of the groundwater model for the Project, noting it is not feasible to review and check all data used in the model due to the large number of instruments and data points (i.e. approximately 700 instruments with approximately 40,000 groundwater targets to review).

Notwithstanding, calibration statistics demonstrate that historic effects (e.g. drawdown and mine inflows) are adequately replicated by the groundwater model using this dataset (which includes an extensive site-specific dataset of hydraulic conductivity and porosity or storage estimates).

The groundwater model has been regularly reviewed and updated throughout the life of the mine through the development of SMP's, incorporating recommendations made by Government agencies, PSM (2017) and Mackie (2017), as well as by the IEP.

The groundwater model developed for the Project builds on previous groundwater modelling efforts over the last decade in the development of best practice modelling methods, as acknowledged by the IEP (2019a, 2019b), and is an extension of previous groundwater models developed for the Dendrobium Mine.

In addition, the model has been peer-reviewed by an independent and experienced hydrogeologist and groundwater modeller as per the Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012).

Regarding model set-up, the Project model domain accounts for historic stresses in the groundwater system by incorporating historical, active and proposed mining operations in the Sydney Drinking Water Catchment.

The model contains approximately 700,000 cells in an unstructured mesh (refer to Figures 6-3 and 6-4 of the EIS) to simulate the 17 model layers. The model grid or mesh has been further refined to incorporate detail in areas where groundwater stresses could occur, such as around longwall panels, or where sensitive natural and built receptors are located (such as reservoirs, along watercourses, Upland Swamps and registered groundwater bores).

As the Project mine layout is refined during the development of Extraction Plans for the Project (e.g. as a result of mine design setbacks, adaptive management etc.), the groundwater model would continue to be updated. Consistent with the recommendations of Dr Frans Kalf (Attachment 5 of the EIS) a full review of the groundwater model would be conducted every 3 to 5 years, including comparison (verification) of monitoring data against predictions and recalibration of the model if necessary.

Comment 8

DPIE-Water stated:

> *The EIS has not demonstrated that the project will be able to acquire the 1935 units of entitlement necessary to account for the predicted water take resulting from the proposed expansion in the Upper Nepean Tributaries Headwaters Management Zone of the Upper Nepean and Upstream Warragamba Water Source. This is due to inadequate entitlement currently available for purchase and no viable options available for additional entitlement to become available. This represents a significant risk to the ability of the project to be in compliance with water policy and legislation and this needs to be addressed prior to project determination.*
>
> *…*
>
> *Further information is required to confirm the ability to acquire this entitlement and to comply with the relevant water sharing plan rules to trade the entitlement to this project.*

South32 Response

South32 currently holds licences (9,530 ML) to account for the volume of predicted groundwater plus surface water that may ultimately be diverted from the surface to the mine workings.

However, these licences are all held in the water sharing plan relevant to groundwater sources only. As outlined in the Minister's 18 April media release, the NSW Government intends to implement a "*licensing regime to properly account for any water losses*".

As such, South32 would apply for and hold appropriate licences under the *Water Management Act 2000* to account for surface water losses for the Project.

Comment 9

DPIE-Water stated:

> *The proponent should:*
>
> - *Ensure that sufficient licensed water entitlement can be obtained prior to approval or seek to modify the project accordingly. 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 for the proposed expansion include the following:*
> - *1935 units in the Upper Nepean and Upstream Warragamba Water Source of the WSP for the Greater Metropolitan Region Unregulated River Water Source.*
> - *3 units in the Illawarra Rivers Water Source of the WSP for the Greater Metropolitan Region Unregulated River Water Source.*
> - *7 units in the Sydney Management Zone 1 of the WSP for the Greater Metropolitan Region Groundwater Source.*

South32 Response

Please refer to response to comment 8 above in regard to Project licencing requirements.

Comment 10

DPIE-Water stated:

> *The TARPs currently in place for the Dendrobium Mine were found to be ineffective by the Independent Expert Panel for Mining in the Catchment for both surface water flows (page 116 of 5 the interim report) and for upland swamps (page 117 of the interim report). The proponent does not appear to have refined the triggers during the period over which the mine has been operating (and, in particular, recently when significant impacts have been widely reported), to attempt to better manage the consequences of mining.*
>
> *Due to the differences in geology and topography between the existing and proposed mining areas, new location-specific plans need to be documented that more appropriately respond to detected adverse impacts. Because of the inadequacies identified by the independent expert panel of the current TARPs, the new versions should be prepared and made available for review prior to any determination of the project.*

South32 Response

It is noted that a process is in place to facilitate the review and update of surface water flow TARPs for the approved Dendrobium Mine in consultation with WaterNSW and DPIE, which has been undertaken since late 2018 (surface water flow TARPs were subsequently revised in January 2020). Further detail is available in the Dendrobium Mine Area 3B *Watercourse Impact, Monitoring, Management and Contingency Plan* (WIMMCP) or in Watershed HydroGeo (2019).

It should be noted that swamp offsets will be required for the Project under the Swamp Offset Policy. In addition, South32 has committed to provide surface water offsets such that a “net gain” to Metropolitan drinking water supplies would be achieved.

For the Project, relevant performance measures and TARPs would be developed in consideration of the following:

- monitoring data from the Dendrobium Mine (noting that a network of surface water monitoring sites [and swamp piezometers] is already in place in Areas 5 and 6 to provide baseline data);
- existing SMP approvals; and
- in consideration of any Development Consent issued for the Project.

These performance measures and TARPs would be outlined in Extraction Plans developed for the Project longwalls.

Comment 11

DPIE-Water stated:

> *There remains a high degree of uncertainty around the accuracy of vibrating wire piezometers that has not been resolved by the additional information provided by the consultants. Additional co-located stations (standpipe monitoring bores next to vibrating wire piezometers measuring the same subsurface depth intervals in isolation) are required, as are the collection of an adequate baseline period of data and a comprehensive analysis of the results from both approaches.*

South32 Response

It is noted that vibrating wire piezometers allow the monitoring of pressure at multiple levels within a single deep (300-600 m) bore.

South32 has installed a number of co-located standpipes next to vibrating wire piezometer sites at the Dendrobium Mine at the request of WaterNSW. South32 would continue to investigate and assess co-located standpipes within the Dendrobium Mine and in the Project mining areas, should these areas be approved.

The IEP (2019a) recommended the following in regard to swamp monitoring:

> *v. 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 (i.e. paired piezometer monitoring) is in place for key swamps within the current mining area and all swamps in Area 5 and Area 6 and is specified in the Project Surface Water Assessment (refer to Table 20 of Appendix C of the EIS).

Comment 12

DPIE-Water stated:

> *The proponent should:*
>
> - *Develop a suitable Trigger Action Response Plan using the baseline data gathered across Area 5 and Area 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 Response

South32 agrees with DPIE-Water's comment, and would develop TARPs as part of Extraction Plans for the Project.

As described above (refer to comment 11), South32 has installed a number of co-located standpipes next to vibrating wire piezometer sites at the Dendrobium Mine and is investigating the results of this monitoring. South32 would continue to investigate and assess co-located standpipes for the Project.

Comment 13

DPIE-Water stated:

> *Protective setbacks and other measures are proposed for the Avon River, Cordeaux River and Donalds Castle Creek. Other watercourses, including five 3rd order watercourses in Area 5 and three 3rd order watercourses in Area 6 are not protected to the same level. The effectiveness of the proposed protection is uncertain. These other watercourses are predicted to have valley closure impacts of between 275-1150 mm and upsidence impacts of between 400-875 mm.*
>
> *We are concerned about the criteria used to assign significance to watercourses overlying or adjacent to the predicted subsidence zone for Dendrobium Areas 5 and 6. The EIS does not provide geomorphic or hydrologic justification for the use of the 'Key' stream features of pools with holding capacities greater than 100m^3 capacity or waterfalls greater than 5 m height.*

…

The proponent should:

- *Revise the geomorphologic criteria used to nominate significance in relation to watercourses and upland wetlands and identify key threats to geomorphic features that form controls on pool form, wetland outlets and elevated chutes, cascades or waterfalls.*

South32 Response

It is not feasible to develop a mine plan that would avoid the undermining of all watercourses and stream features.

South32 has considered the significance of streams on the basis of the following characteristics (generally consistent with the Bulli Seam Operations NSW Planning Assessment Commission [PAC] Report [PAC, 2010]), as a component of the Stream Risk Assessment (Appendix B of Appendix C of the EIS) undertaken for the Project, including:

- permanence of flow (i.e. if the stream is ephemeral or perennial in nature);
- whether the stream is a regulated watercourse for water supply transfer;
- individual stream catchment area;
- importance to catchment yield;
- Strahler stream order;
- environmental quality (e.g. pristine, modified or severely modified); and
- ecological importance (e.g. presence of mapped Key Fish Habitat as per the habitat mapping provided by NSW DPIE which was confirmed during field surveys, where possible).

The identification of key stream features has also been informed by the findings of the investigation into potential subsidence-related impacts to tributary WC21 at Dendrobium Mine Area 3B.

As a consequence of the above, and in consideration of stakeholder feedback, South32 has identified and adopted longwall setbacks from the following features considered to be relatively more significant to reduce potential subsidence impacts:

- named watercourses (i.e. the Avon River, Cordeaux River and Donalds Castle Creek); and
- key stream features identified by South32, which are defined as:
  - pools with volume greater than 100 m^3 and holding water; and
  - steps/waterfalls greater than 5 m height with a permanent pool at the base.

It is noted the Bulli Seam Operations NSW PAC Report (PAC, 2010) acknowledged that determination of 'significance' of features was inherently difficult and subjective:

> *… the range of use and non use values of the waterways: water supply, ecological significance, conservation value, community value and recreational value are all recognised. However little progress is made in the EA toward interpreting the catalogue of raw data to provide any link to the significance of an individual stream or a collective of streams in a catchment. Furthermore, only a subset of the values appear to be carried forward for assessment of the acceptability of impacts. The difficulty of these steps is acknowledged by the Panel and it is not suggested that any deterministic process can be called upon to deliver incontestable outcomes. However, without an assignment of values to streams or groups of streams, and without consistent appreciation of all the values in the system, it becomes impossible to make an holistic assessment of the risks to those values from mining.*

If damage to named streams and key stream features occurs due to the Project as a result of subsidence impacts, remediation techniques would be implemented to repair the physical damage where possible.

In addition, South32 acknowledge that there are unnamed drainage lines located above the Project longwalls that are proposed to be directly undermined, and are considered to be less significant than the named watercourses, on the basis that they:

- are ephemeral (i.e. do not exhibit permanent flow);
- are not mapped Key Fish Habitat;
- have relatively small sub-catchments and therefore small associated contributions to total catchment yields; and
- are of lower stream order (generally first and second order with small sections of third order), are common throughout the catchment area and are not regulated watercourses for water supply transfer.

However, the residual impact of undermining sections of unnamed and ephemeral drainage lines is an increase in low and no flow days and localised water quality impacts and iron staining. At the catchment scale these impacts are expected to be negligible.

In addition, for relevant fauna species listed under the *NSW Biodiversity Conservation Act, 2016* (BC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) that potentially have habitat along streams/swamps overlying the Project underground areas, biodiversity offsets are proposed to account for potential subsidence-related impacts to streams and the associated consequences to streamflow and habitat for these species (Section 6.5.3 of the Submissions Report).

Comment 14

DPIE-Water stated:

> *DPIE Water does not consider the advice that the assemblage of macroinvertebrates is impaired due to natural factors has been justified. There is a reasonable likelihood that the assemblage has been affected by other mining activities in the catchment.*
>
> *The proponent should use a more appropriate model than the OE50 model. DPIE Water recommends that a regional AUSRIVAS model should be used which accounts for taxa found in this region or the proponent undertake a comprehensive assessment of regional macroinvertebrate diversity at relevant sites identifying organisms to at least genus level with the exception of the taxa listed in 4.2.2.4.1 of Appendix E - Aquatic Ecology Assessment.*

South32 Response

Baseline aquatic ecology surveys for the Project were undertaken at a total of seven sites within, as well as upstream and downstream of the Project area across the Avon River, Cordeaux River and Donalds Castle Creek (Section 6.9.3 of the Submissions Report).

The majority of streams located above or proximal to the proposed longwalls are not affected by historical mining (i.e. are not located downstream of historical mining areas). With the exception of survey sites located on Donalds Castle Creek, survey sites located along the Cordeaux River (i.e. CR2) and the Avon River (i.e. AR1 and AR2) are located remote from or upstream of historical mine workings (Figure 2).

Macroinvertebrate sampling was undertaken in accordance with the Australian River Assessment System (AUSRIVAS) Rapid Assessment Protocol (RAM) (Turak et al., 2004) and results were assessed against AUSRIVAS modelling software, which concluded the populations were somewhat impaired.

Based on available information, the EIS concluded that there is no evidence that this is mining-related (noting that surveys were undertaken within, as well as upstream and downstream of the Project area).

In regard to AUSRIVAS surveys undertaken at sites along Donalds Castle Creek, the Aquatic Ecology Assessment for the Project (Appendix E of the EIS) concluded that potential disturbance may be due to natural effects (noting these sites being located downstream of mining in Area 3B):

> *It is possible that the relatively low pH levels in this watercourse, and others that traverse the Dendrobium Mine area, may be influencing the type of macroinvertebrates that are present. Other measures of water quality, such as naturally occurring levels of some heavy metals, may also influence the type of macroinvertebrates, and other organisms, present (Cardno Ecology Lab 2012b; Ecoengineers 2006).*

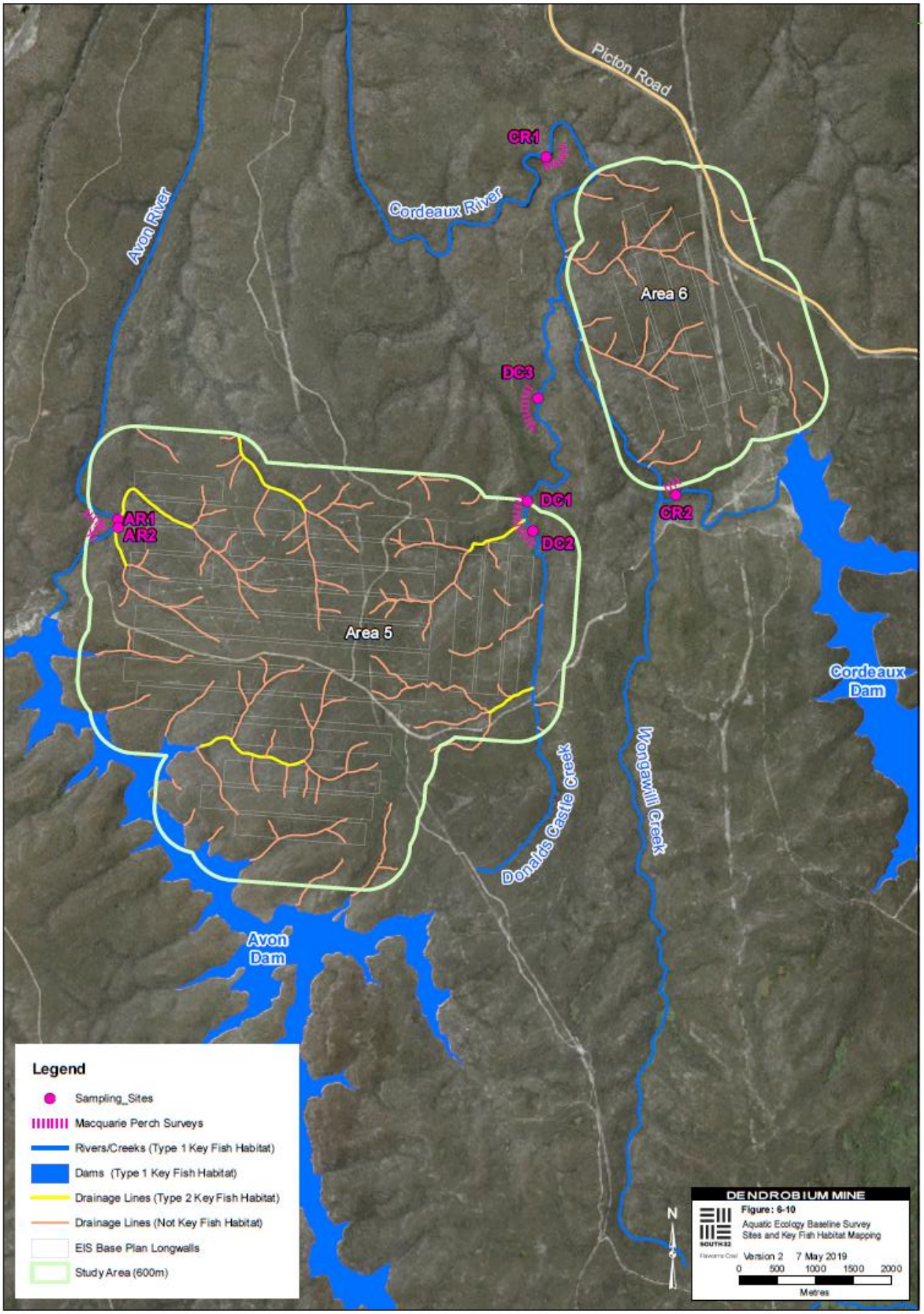


Figure 2 – Aquatic Ecology Survey Locations

No threatened aquatic ecology species under the *Fisheries Management Act, 1994* (FM Act) or *Environmental Protection and Biodiversity Conservation Act, 1999* were recorded during the baseline surveys.

Comment 15

DPIE-Water stated:

> *As Macquarie perch have been recorded previously within this area, the survey methods are insufficient. This cryptic species would have been best surveyed with the addition of Baited Remote Underwater Videos, night surveys, and more extensive surveys using the methods already incorporated. Further, the identification of Euastacus to only genus is inappropriate. The freshwater crayfish Euastacus hirsutus is listed as Critically Endangered by the IUCN and occurs in ephemeral streams within the catchment. The proponent should identify a genus to species if there is a threatened species within that genus.*

South32 Response

Aquatic ecology surveys for the Project were undertaken consistent with relevant guidelines and methodologies, and included targeted surveys of Macquarie Perch. South32 acknowledges DPIE-Water's comment regarding the use of additional survey methodologies for this species, and would continue to consult with DPIE-Water regarding survey effort for the Macquarie Perch for the Project. Details of proposed monitoring and management measures for this species would be detailed in Extraction Plans developed for the Project as well as relevant management plans.

Macquarie Perch were not recorded during surveys for the Project, however, have been historically recorded within the Dendrobium Mine area within Wongawilli Creek. Wongawilli Creek is further than 600 m from the Project longwalls and, therefore, is not predicted to experience impacts to aquatic ecology as a result of the proposed underground mining.

The Project also setbacks from perennial watercourses (i.e. Avon River, Cordeaux River and Donalds Castle Creek) (refer to comment 13).

Limited suitable Macquarie Perch habitat exists within the streams overlying the proposed underground mining area (first, second and third order ephemeral drainage lines which overlie the Project underground mining areas consist generally of disconnected pools, some also separated by waterfalls, providing barriers to fish movement and limiting the value of this habitat for fish) and, therefore, the Project is not expected to have a significant impact on the Macquarie Perch or any other threatened aquatic ecology species.

It is noted that the species of freshwater crayfish listed by DPIE-Water, *Euastacus hirsutus,* is not listed as a threatened species under the FM Act. A small number of freshwater crayfish (genus *Euastacus* sp.) were located during surveys along Donalds Castle Creek, in the north-east portion of Area 5.

Notwithstanding, the consequences of subsidence-related impacts to relevant threatened fauna species listed under the BC Act and EPBC Act would be offset, as the Project Biodiversity Offset Strategy accounts for potential losses of habitat due to hydrological changes to ephemeral drainage lines overlying the Project underground mining areas.

No significant impacts to aquatic ecology in watercourses downstream of the Project area are predicted as reductions in streamflow are predicted to result in negligible changes in water yields to Avon Dam and downstream of Pheasants Nest Weir (Section 6.9.3 of the Submissions Report).

Comment 16

DPIE-Water stated:

> *The proponent should provide the following:*
>
> - *A baseline description of existing environment so impacts of reduced baseflow can be monitored. This should include reassessing the macroinvertebrate assemblage using more appropriate methods.*
> - *Identification of the closest population of Macquarie perch in the Avon or Cordeaux Rivers.*
> - *The monitoring design for macroinvertebrates and native fish to be revised to ensure appropriate baseline is collected.*

South32 Response

Surface Water Monitoring

In regard to surface water monitoring, South32 maintains a surface water monitoring and management program for the approved Dendrobium Mine (including both surface water flow and quality monitoring). The existing program includes stream flow monitoring of a number of ephemeral drainage lines proximal to Area 5, Area 6 and Donalds Castle Creek (Figure 3).

South32 continues to improve the accuracy of stream flow monitoring, and following consultation with Government agencies has installed new half-pipe weir structures at all flow sites in order to more accurately measure low flows. The new half-pipe weir structures (refer Plate 1), combined with Orpheus water level sensors facilitate more accurate discharge measurements and corresponding water levels during low flows. In regard to the new monitoring in place, Enviromon (2020), concluded:

> *"There is a significantly decreased uncertainty over most of the low flow range that can be achieved by using the half-pipe weir structures".*

Consistent with the recommendations of HEC (2019), the existing Area 5 and Area 6 surface water monitoring networks would be expanded and augmented for the Project.

Further description of the existing surface water environment, including detail of surface water flow monitoring is described in Section 6.6 of the Project EIS and Section 6.3 of the Submissions Report.

Plate 1 – Example of half-pipe weir structures installed at surface flow monitoring sites in Areas 5 and 6

Macroinvertebrate and Macquarie Perch Monitoring

Macquarie Perch have previously been recorded in the Avon and Cordeaux dams, and previously recorded, or potentially present, in the upper reaches of the Avon River and Cordeaux River (Cardno, 2019).

While Cardno (2019) identified that the Avon and Cordeaux Rivers provide suitable aquatic habitat (i.e. Type 1 – Highly Sensitive Key Fish Habitat) for the Macquarie Perch, the species was not identified during surveys undertaken for the Project.

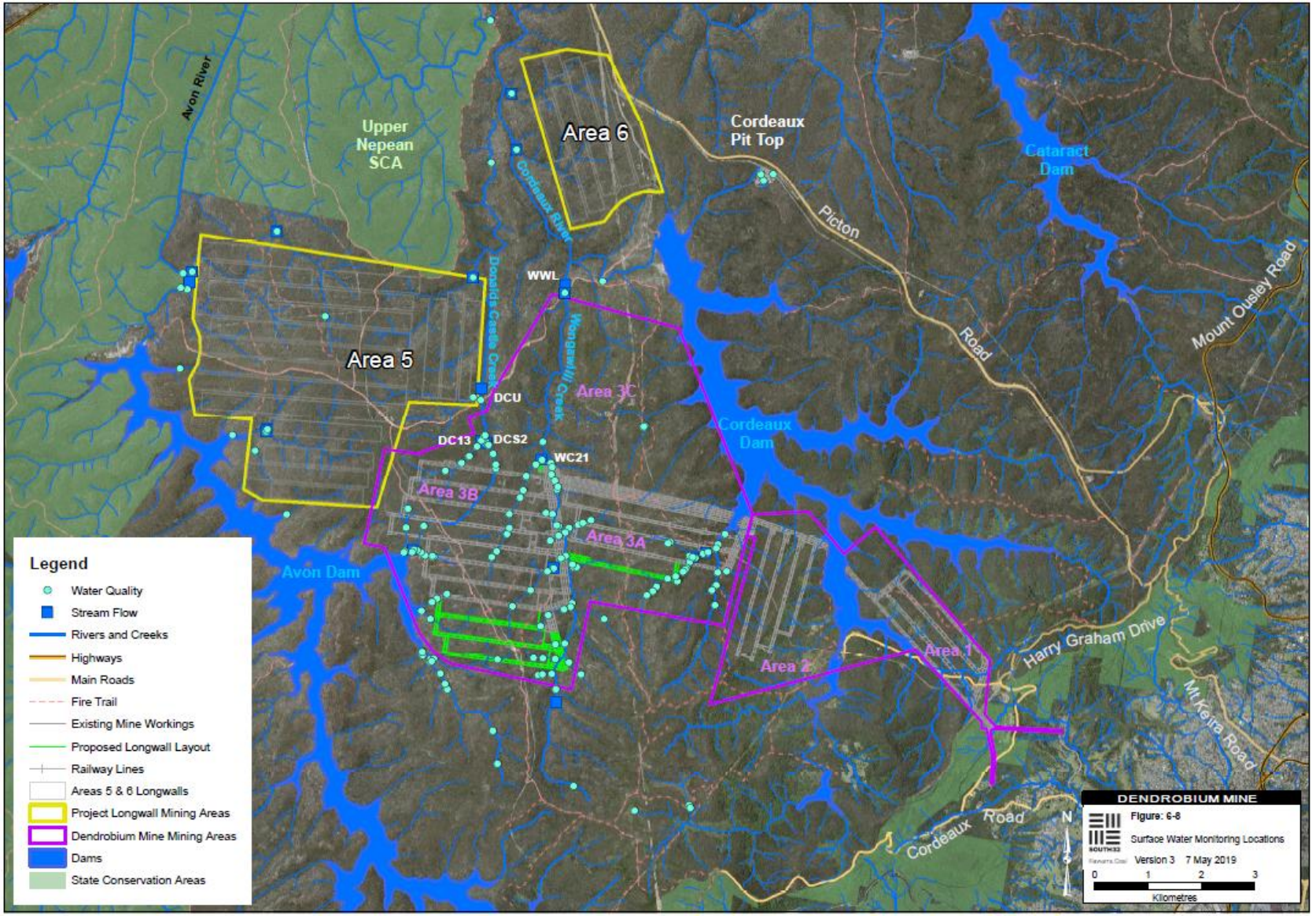


Figure 3 – Surface Water Monitoring Locations

Within the Dendrobium Mine area, the Macquarie Perch have been historically recorded within Wongawilli Creek. It is noted that Wongawilli Creek is further than 600 m from the Project longwalls and, therefore, is not predicted to experience impacts to aquatic ecology as a result of the proposed underground mining.

The Project is not expected to have a significant impact on the Macquarie Perch or any other threatened aquatic ecology species.

South32 would continue to consult with DPIE-Water regarding survey effort for the Macquarie Perch and macroinvertebrates. As described above, aquatic ecology surveys were undertaken consistent with relevant guidelines and methodologies, and included targeted surveys of Macquarie Perch.

South32 would continue to conduct aquatic ecology monitoring within the Project underground mining area throughout the Project life, consistent with the methods outlined in the *Dendrobium Area 3B Watercourse Impact, Monitoring, Management and Contingency Plan* (South32, 2017a), as amended for the Project.

Details of proposed monitoring and management measures for aquatic ecology, including collection of baseline data would be described in Extraction Plans developed for the Project, as well as relevant management plans.

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