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Dear Stephen,

RE: DENDROBIUM MINE – RESPONSES TO DAMS SAFETY NSW SUBMISSION ON EIS

In response to DPIE's letter dated 20 April 2020, please find enclosed (Enclosure 1) South32's responses to residual concerns raised by Dams Safety NSW (DSN) in its submission on the *Dendrobium Mine – Plan for the Future: Coal for Steelmaking EIS* (the Project). Additional supporting information is provided in the enclosed letter prepared by MSEC (Enclosure 2).

The purpose of this letter and its enclosures is to provide further detail in regard to South32's commitments to protect the Avon and Cordeaux dam walls and to provide further responses to the concerns raised by DSN in its submission on the Project EIS.

South32 has previously outlined its commitments and assessment in regard to protecting the Avon and Cordeaux dam walls in the EIS and the Submissions Report, in particular the minimum 1,000 m setback from secondary extraction to avoid adverse impacts to the dam walls.

Further to this commitment, South32 commits to achieving a subsidence performance measure such that the safety and serviceability of the Avon and Cordeaux dam walls is always maintained, and that there is negligible additional risk to public safety as a result of the Project.

This commitment will be achieved through the implementation of appropriate monitoring and adaptive management measures throughout the life of the Project.

South32 acknowledges the concerns raised by DSN in regard to the selection of a setback distance from the Avon and Cordeaux dam walls to the Project longwalls. As described in the Submissions Report, the intention of South32's existing commitment regarding a minimum distance of 1,000 m from dam walls is for the protection of this infrastructure (i.e. the Project is not seeking approval to damage the dam walls).

MSEC considers that based on currently available information, absolute subsidence movements at both the Avon and Cordeaux dam walls at 1,000 m from secondary extraction are expected to be very small, differential movements are expected to be negligible and within the range of survey tolerance (i.e. are not anticipated to be measurable) and that a monitoring and adaptive management approach be developed.

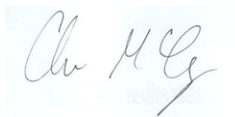
MSEC considers that this conclusion would remain the same if the minimum setback distance to the dam walls was revised to 1,500 m (i.e. differential movements would be negligible and within the range of survey tolerance, and recommend an adaptive management approach be developed).

The consequence of a 1,500 m setback from the Avon and Cordeaux dam walls would be the sterilisation of an additional 5.1 Mt of ROM coal worth some \$723 million and \$45 million in associated royalties, resulting in further Project value loss and coal sterilisation.

However, the ultimate setback distance from the dam walls to the Project longwalls will be determined by the requirement to achieve South32's additional commitment, as well as the performance measures in any development consent for the Project.

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

Yours sincerely
SOUTH32 LIMITED

A handwritten signature in black ink, appearing to read 'Chris McEvoy', is placed over a light blue rectangular background.

Chris McEvoy
Approvals Manager
Dendrobium Next Domain Project

ENCLOSURE 1

RESPONSES TO DAMS SAFETY NSW SUBMISSION ON EIS

DAMS SAFETY NSW

Comment 1

Dams Safety NSW (DSN) (formerly Dams Safety Committee) stated:

To reduce the likelihood of cracking the dam walls, longwall extraction should approach no closer than 1,500 m to the dam walls.

An assessment by an appropriately qualified Dams Engineer is required to determine if the longwalls should be moved further away from the dam walls.

...

South32 Response

South32 Commitment – Always Maintaining Safety and Serviceability

South32 is not seeking to damage or compromise the Avon or Cordeaux dam walls, and agrees with DSN's comments about the importance of protecting this infrastructure.

As such, South32 commits to achieving the following subsidence performance measures regarding the Avon and Cordeaux dam walls:

- Always safe and serviceable.
- Negligible additional risk to public safety.

These performance measures are consistent with the Bulli Seam Operations (BSO) Project Approval (08_0150) conditions for key infrastructure that is highly sensitive to subsidence-related movements, namely the Main Southern Railway and Hume Highway (i.e. Condition 3 of Schedule 3 of Project Approval 08_0150 for BSO).

Achieving Performance Measures via Adaptive Management

South32's commitment to always maintain the safety and serviceability of these structures, as well as negligible additional risk to public safety will be achieved through the implementation of appropriate monitoring and adaptive management measures, which would inform the final longwall layout as the mine progresses (e.g. Trigger Action Response Plans [TARPs]).

The implementation of an adaptive management approach to achieve this outcome (i.e. the performance measures above) is consistent with the precautionary principle as described by Justice Preston, Chief Judge of the NSW Land and Environment Court in *Newcastle & Hunter Valley Speleological Society Inc v Upper Hunter Shire Council and Stoneco Pty Limited* [2010] NSWLEC 48 at [184]:

In adaptive management the goal to be achieved is set, so there is no uncertainty as to the outcome and conditions requiring adaptive management do not lack certainty, but rather they establish a regime which would permit changes, within defined parameters, to the way the outcome is achieved.

It is envisaged that the Project would be conditioned such that the specific details of monitoring requirements and TARPs would be determined as part of the development of Extraction Plans for the Project, including for other key infrastructure that would be sensitive to subsidence movements. The monitoring and management strategies would be developed in consultation with an appropriately qualified Dams Engineer.

The development of appropriate monitoring and adaptive management measures to achieve performance measures during active longwall mining, including the development of appropriate TARPs, would occur in consultation with Government, WaterNSW, DSN and an appropriately qualified Dams Engineer.

Relevant performance measures, monitoring and adaptive management measures (e.g. TARPs) conditioned for the Project would be similar in nature to those adopted at other mining operations located proximal to sensitive infrastructure in the Southern Coalfield (e.g. BSO and Metropolitan Mine), as described above. The adaptive management approach adopted for the Project would include:

- Mine design such that any secondary extraction is setback from the dam walls (with a minimum of 1,000 m).
- Monitoring of any movements of the dam walls and nearby ground from the commencement of mining in each of Area 5 and Area 6 for the Avon and Cordeaux dams, respectively.
- Development of TARPs in consultation with WaterNSW and DSN, with triggers for monitored movements set below the tolerable levels established by an appropriately qualified Dams Engineer to achieve the performance measure described above (refer to discussion below).
- Contingency measures in the event triggers are exceeded, which if necessary, would include stopping and/or shortening of longwalls.

The proposed monitoring and adaptive management approach would be used throughout the life of the Project, noting the longwall series in Area 5 would be extracted from the south to the north (i.e. move towards the Avon Dam wall allowing progressive implementation of the adaptive management approach) and similarly the longwall series in Area 6 progresses from the west to east (i.e. towards the Cordeaux Dam wall). In addition, Area 5 would be extracted prior to Area 6.

Proposed 1,000 m Setback from the Avon and Cordeaux Dam Walls

South32 acknowledges the concerns raised by the DSN in regard to the selection of a setback distance from the Avon and Cordeaux dam walls to the Project longwalls.

South32's existing commitment regarding setbacks of secondary extraction from dam walls is "*setbacks from the Avon and Cordeaux dam walls to the Project longwalls by a minimum distance of 1,000 m*" (Section 6.6.3 of the Submissions Report). As described above, the intention of this setback was the protection of the dam walls (i.e. the Project is not seeking approval to damage the dam walls) (Figures 1 and 2).

The ultimate setback distance of secondary extraction from the dam walls to the Project longwalls will be determined by the requirement to achieve South32's commitment of always maintaining the safety and serviceability of these structures, as well as no additional risk to public safety (i.e. a final longwall layout informed by monitoring and adaptive management measures).

Notwithstanding, a minimum setback distance was developed to inform the Project mine design and assessment. The minimum setback distance of 1,000 m was selected based on the previous longwall setbacks adopted at the Dendrobium Mine and on the conclusion of MSEC (2019) that predicted differential subsidence movements are unlikely to be measurable at this distance.

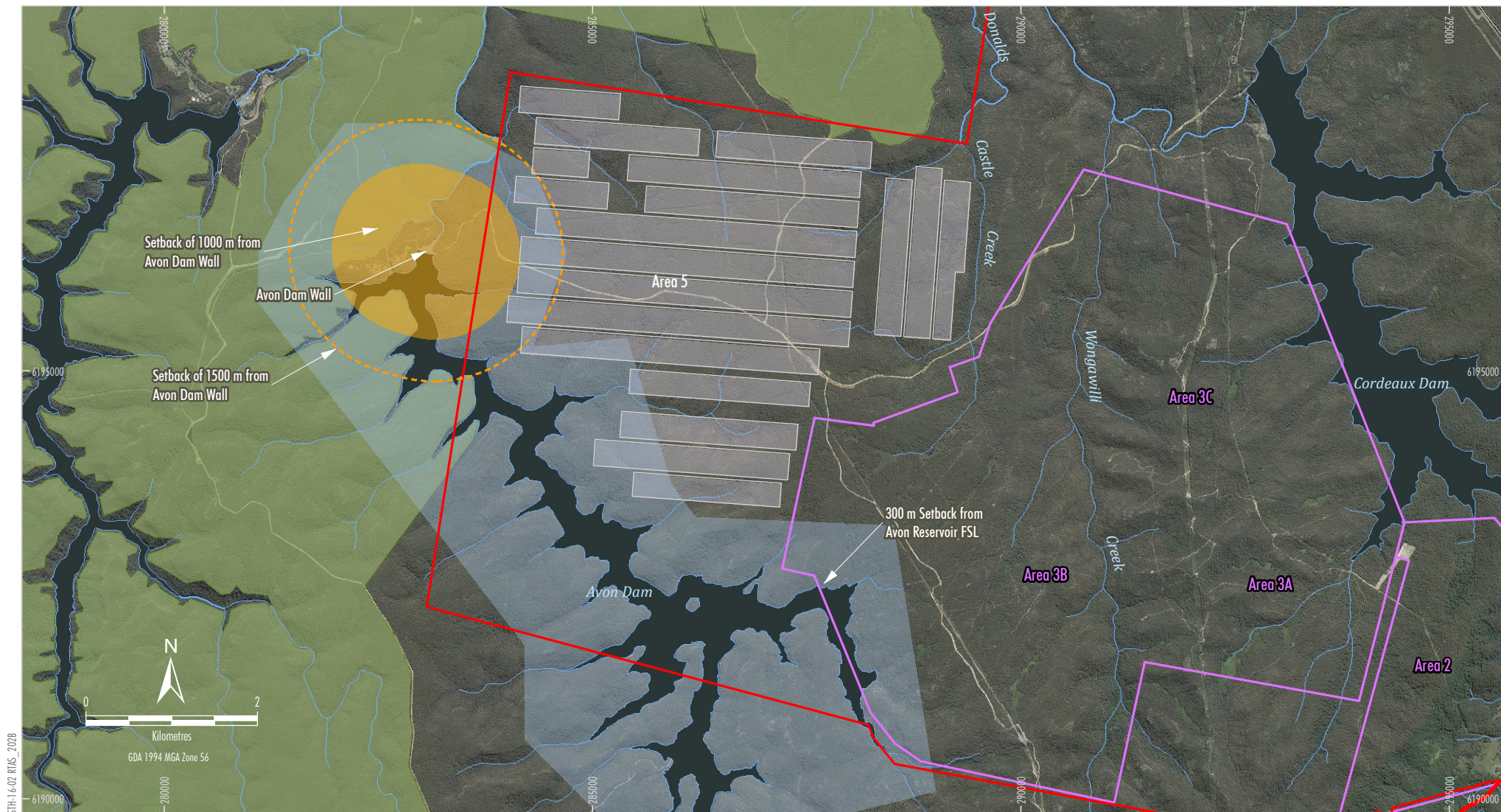
In addition, this minimum setback distance was developed in consideration of previous recommendations of the DSN, which stated that extraction of 'full-sized' longwalls within 1.7 times the depth of cover would be unlikely to be tolerable (DSC, 2010). The proposed setback distance of 1,000 m is greater than 1.7 times the depth of cover for the Project (i.e. 1.7 times the depth of cover would be approximately 750 m).

However, any final setback from the dam walls to the Project longwalls would be developed in consideration of engineering advice and such that South32's commitment (and performance measures outlined in conditions of any consent for the Project) would be achieved.

MSEC Predictions in EIS

South32 notes that at this stage of the Project, MSEC has employed best practice subsidence modelling methodologies for the prediction and assessment of potential subsidence impacts for the Project, including for the Avon and Cordeaux dam walls.

As described above, subsidence predictions at the Avon and Cordeaux dam walls were undertaken with the adopted minimum setback distance from secondary extraction of 1,000 m from the dam walls in the Project mine layout.



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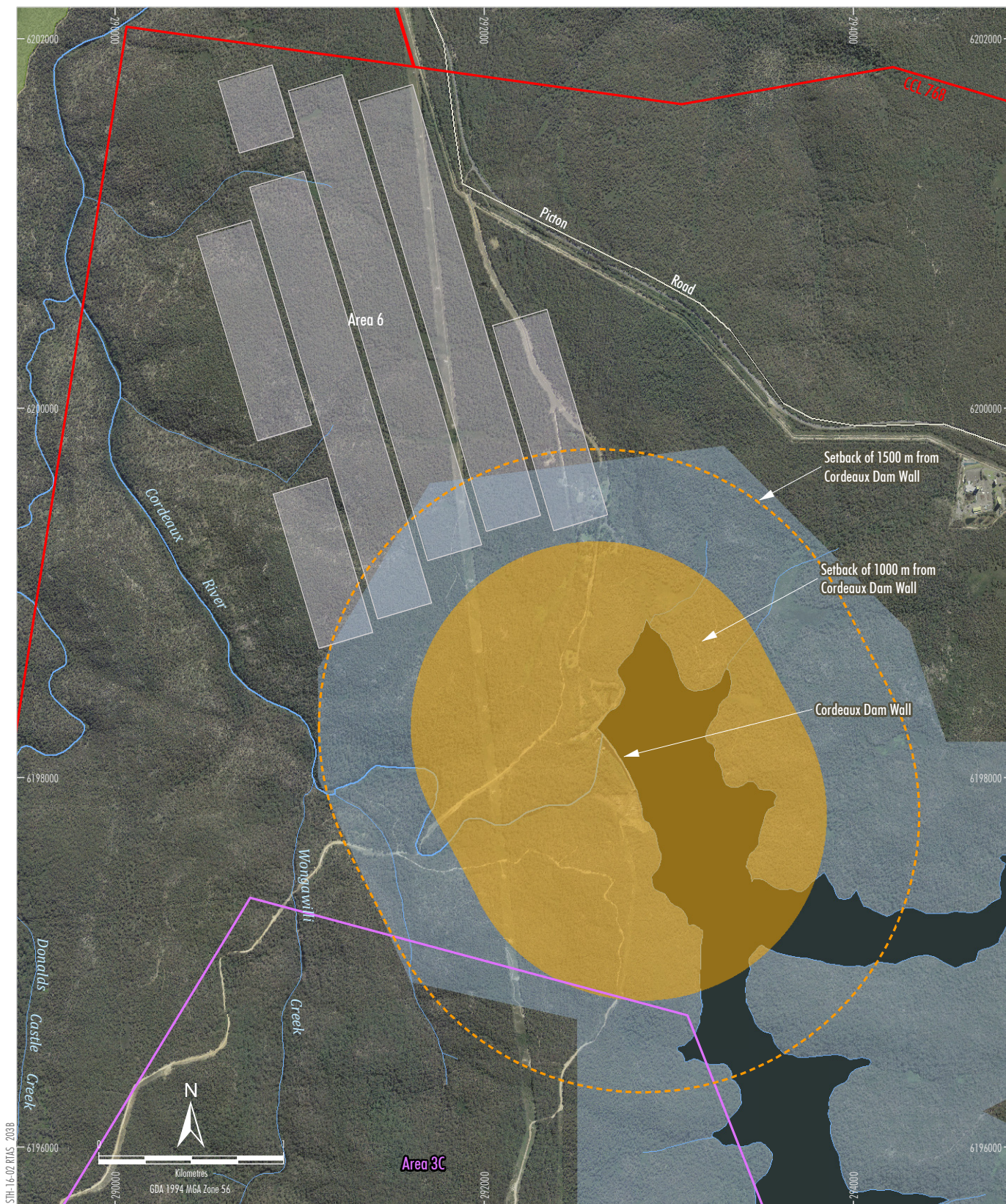
- LEGEND**
- Dendrobium Mining Lease
 - Road
 - National Park, Nature Reserve and State Conservation Area
 - Dendrobium Underground Mining Area - Existing Mine (DA 60-03-2001)
 - EIS Base Plan Longwalls

- 1000 m Setback from Dam Wall (Avon Dam)
- 1500 m Setback from Dam Wall (Avon Dam)
- DSC Notification Area (Avon Dam)

Source: Geoscience Australia, 2006; Department of Industry (2018);
Department Finance, Services & Innovation (2018);


DENDROBIUM MINE
 Setback from Avon Dam Wall

Figure 1



Source: Geoscience Australia (2006); Department of Industry (2018);
Department Finance, Services & Innovation (2018);

- | | |
|--|--|
| <p>LEGEND</p> <ul style="list-style-type: none"> Dendrobium Mining Lease Road National Park, Nature Reserve and State Conservation Area Dendrobium Underground Mining Area - Existing Mine (DA 60-03-2001) EIS Base Plan Longwalls | <ul style="list-style-type: none"> 1000 m Setback from Dam Wall (Cordeaux Dam) 1500 m Setback from Dam Wall (Cordeaux Dam) DSC Notification Area (Cordeaux Dam) |
|--|--|



DENDROBIUM MINE
Setback from Cordeaux Dam Wall

Figure 2

On this basis, MSEC predicted that with the implementation of a 1,000 m setback from the dam walls, absolute far-field movements at both the Avon and Cordeaux dam walls are expected to be very small. Note that “absolute” movements are distinct to “differential” movements (i.e. strain). Differential movements are expected to be negligible and within the range of survey tolerance (i.e. are not anticipated to be measurable – refer to discussion below in regard to survey tolerance for this monitoring equipment).

Far-field Horizontal Movements

The predicted subsidence movements of the Avon and Cordeaux dam walls as a result of the Project are supported by observations at the Dendrobium Mine and from the Southern Coalfield. These observations show that at distances of 1,000 m or greater from previously mined longwalls at Dendrobium Mine, the majority of measured absolute far-field horizontal movements (i.e. 98 % of cases) are less than the nominal survey tolerance of 25 mm for absolute position.

The far-field horizontal movements measured at the Dendrobium Mine are also typically less than those measured elsewhere in the Southern Coalfield, due to the shallower depths of cover. This results in greater movements directly above the longwalls, however, reduced movements further afield (i.e. reduced movements at the dam walls and reservoir water bodies) compared with higher depths of cover (Section 6.5.3 of the Submissions Report).

Differential Horizontal Movements

Notwithstanding, the key mechanism with potential to impact the Avon and Cordeaux dam walls is not absolute far-field horizontal movement, but from the differential horizontal movements (i.e. strain).

While there is limited strain monitoring data at Dendrobium Mine, there is extensive data elsewhere in the Southern Coalfield. The monitoring data shows that at distances of 1,000 m or greater from extracted longwalls, the majority of the measured strains (i.e. 94 % of cases) are less than the nominal survey tolerance of 0.25 mm/m (nominal survey tolerance for strain represents a change in length [i.e. horizontal distance] of 3 mm to 5 mm measured over a 20 m survey bay) (MSEC, 2020).

As stated above, the ultimate setback distance from the dam walls to the Project longwalls will be determined by the requirement to achieve South32’s commitment of always maintaining the safety and serviceability of these structures, as well as negligible additional risk to public safety (i.e. a final longwall layout informed by monitoring and adaptive management measures).

Further subsidence predictions and assessments of the dam walls and assessment by an appropriately qualified Dams Engineer will be detailed in Extraction Plans prepared for the Project based on the specific mine plan for that Extraction Plan. It is not considered necessary at this stage of the approval process to conduct additional subsidence assessment or detailed engineering studies of the dam wall given this level of detail is more suitable at the Extraction Plan stage when the final conditions of approval have been confirmed.

Implications of 1,500 m Setback

As a consequence of the setbacks incorporated into the Project mine layout from built and natural features, South32 has sterilised approximately 25 Mt of ROM coal within its existing mining tenement (Consolidated Coal Lease 768), worth some \$3.58 billion and \$222 million in associated royalties.

The consequence of a 1,500 m setback of secondary extraction from the Avon and Cordeaux dam walls would be the sterilisation of an additional 5.1 Mt of ROM coal worth some \$723 million and \$45 million in associated royalties.

This would result in further Project value loss and coal sterilisation when compared to the Project EIS minimum setback of 1,000 m, noting the ultimate Project longwall layout would be determined by the requirement to achieve South32’s commitment (and performance measures outlined in conditions of any consent for the Project).

However, MSEC (2020) considers that the recommendations of the Subsidence Assessment (Appendix A of the Project EIS) would not change if the minimum setback distance from secondary extraction to the dam walls was revised to 1,500 m.

Extraction Plan Process

As described above, South32 would develop Extraction Plans for the Project, subject to the conditions of any development consent granted for the Project.

The Extraction Plans would provide further detail of the proposed longwall layout as the mine progresses, which would be informed by the results of the ongoing monitoring and adaptive management approach adopted (noting the adaptive management approach adopted for the first longwall[s] would inform subsequent mine design), as well as by the outcomes of additional assessments undertaken during the preparation of each Extraction Plan (e.g. Subsidence Assessment, Risk Assessment, assessment by a Dams Engineer etc).

As such, specific details of monitoring requirements, adaptive management measures, TARPs and contingency measures would be included in Extraction Plans for the Project, which would be developed in consultation with Government, as well as WaterNSW, DSN and an appropriately qualified Dams Engineer (where appropriate).

Specifically, TARPs will form a key component of the monitoring and adaptive management approach to manage potential impacts to the dam walls. The development of TARPs and relevant triggers would be informed by a risk assessment undertaken during the preparation of Extraction Plans for the Project.

The risk assessment would include input from an appropriately qualified Dams Engineer, which may include the following:

- assessment of the existing condition, structural integrity and stability of the dam walls;
- provision of advice of the allowable mining-induced movements that the dam walls can accommodate and appropriate factors of safety, noting that the dam walls would already experience, and have been designed to account for the following:
 - movements due to thermal expansion/ contraction;
 - movements induced by changes in the water load against the structures as the dam levels vary; and
 - the risk of earthquakes.
- recommendations of preventative measures that may be implemented.

The risk assessment would also include input from DSN and WaterNSW as well as relevant experts (including geology, mining and subsidence experts) as described above.

This process would facilitate the development of appropriate trigger levels which would be established for relevant subsidence-related impact mechanisms at the dam walls, incorporating the advice of the Dams Engineer and relevant experts.

South32 would monitor the potential subsidence-related impact mechanisms for the dam walls using real-time monitoring methods to inform ongoing assessment against the established trigger levels for the Project. Potential monitoring methods for the dam walls that would likely form part of the monitoring and adaptive management approach for the Project are described below in Table 1.

It is anticipated that an independent committee would be established to assess the results of the ongoing monitoring against established trigger levels for the Project.

Conclusion

South32 agrees with DSN's comments regarding the importance of protecting the Avon and Cordeaux dam walls, and is not seeking to damage or compromise this infrastructure.

As such, South32 commits to always maintain the safety and serviceability of the Avon and Cordeaux dam walls, as well as negligible additional risk to public safety as a result of the Project. As suggested by DSN, South32 will engage an appropriately qualified Dams Engineer during the development of Extraction Plans prior to mining.

This commitment will be achieved through the implementation of appropriate monitoring and adaptive management measures, which would confirm the final longwall layout as the mine progresses (e.g. TARPs) and be informed by the sequential mining of the longwalls in Area 5 followed by Area 3C and then Area 6.

Based on best practice subsidence modelling methodologies, South32 considers the adoption of a minimum setback distance for secondary extraction of 1,000 m from the dam walls to be suitable for the selection of the Project EIS base case mine layout, including assessment of potential subsidence impacts at the Avon and Cordeaux dam walls.

Notwithstanding, the ultimate setback distance from the dam walls to the Project longwalls will be determined by the requirement to achieve South32's commitment and the performance measure in any development consent for the Project.

Table 1: Potential Subsidence Movements and Monitoring Methods for Dam Walls

Potential Subsidence Movement/ Impact Mechanism	Monitoring Method	Survey Tolerance
Differential Movements	3D survey prisms: fixed along the top of both dam walls at regular spacings (nominally 20 m, to be advised by the specialist Dam Engineer) High-resolution 2D survey line: between the ends of the walls (fixed prism each end)	3D survey prisms: ± 1 mm vertical, +3 mm horizontal across the wall and ± 1 mm along the wall (similar to that used for the Upper Cordeaux No. 2 Dam Wall) 2D survey line: ± 1 mm for opening and closure
Absolute Movements*	Global Navigation Satellite System units placed at both ends of dam walls Movements measured and viewed in real-time	± 5 mm for absolute position ± 10 mm for absolute level
Valley Closure Movements	As per monitoring methods described for differential movements	
Valley Upsidence Movements	As per monitoring methods described for differential movements Additional prisms could be located along the base of the dam walls to measure movements at the base (location to be advised by the specialist Dam Engineer)	
Geology	As per monitoring methods described for differential movements An inclinometer could also be established within the geological units/ structures near the dam walls and near the valley base downstream of each dam wall to monitor potential basal shear movements Shape Array Accelerometer could be used to provide real-time monitoring and/or manual inclinometers	

* This monitoring would provide informative data (i.e. would not necessarily have trigger/actions in the TARP) as potential for impacts at the dam walls is affected by the differential horizontal movements (i.e. strain) rather than the absolute movements.

Comment 2

DSN stated:

As discussed in MSEC856:

- Avon Dam wall is 72m high and dam crest is 223m long.
- Cordeaux Dam wall is 57m high and the dam crest is 405m long.

These large structures with extreme consequence categories are sensitive to differential movement, but the subject has not been addressed by the report.

South32 Response

South32 has considered the sensitivity of the Avon and Cordeaux dam walls for the Project.

This is highlighted by the incorporation of a minimum 1,000 m setback of secondary extraction from the dam walls to the Project longwalls, which is a fundamental design consideration for the protection of the dam walls (i.e. predicted differential subsidence movements are unlikely to be measurable at this distance).

The subsidence predictions, and consideration of the sensitivity of the dam walls is addressed in the Subsidence Assessment for the Project (Appendix A of the EIS), the Submissions Report (Section 6.6) as well as by South32's commitments above in regard to the protection of these structures (refer to response to Comment 1).

Comment 3

DSN stated:

The amount of movement these extreme consequence dams can receive without impacting the safety of the dam needs assessment and a Management Plan needs to be developed.

South32 Response

South32 agrees with DSN's comment, and commits to preparing Built Features Management Plans for (BFMPs) for the Avon and Cordeaux dam walls as part of the Extraction Plans for the Project. These BFMPs would provide specific detail on monitoring requirements, adaptive management measures, TARPs and contingency measures to ensure South32's commitment is achieved (refer to response to Comment 1 above).

The development of monitoring and adaptive management measures would be undertaken in consultation with Government, WaterNSW, DSN and an appropriately qualified Dams Engineer (where appropriate).

Comment 4

DSN stated:

Adding extraction of longwalls in Area 3C, at a similar time to extraction of Area 6, increases the potential movement at the Cordeaux dam wall. Area 6 is north of Cordeaux Dam wall while Area 3C is south of the Cordeaux Dam wall. At 1000m distance from the dam wall (as proposed by South32) to each extraction area, the far field horizontal movement is 60mm towards each area (from chart above). That is, a potential to elongate the dam wall by 120mm. The potential for this amount of movement has not been addressed by the MSEC report.

South32 Response

The EIS proposes extraction of Area 3C (2033 to 2043) prior to extraction of Area 6 (2043 to 2048).

This statement that there is "a potential to elongate the dam wall by 120 mm" is not correct. The chart referred to by DSN shows absolute horizontal movements rather than differential movements due to mining. Further detail is provided below.

As stated by the DSN, the Cordeaux Dam wall may experience far-field horizontal movements towards each of Area 6 and Area 3C as a result of these mining areas (i.e. each area would mine on either side of the wall sequentially and not simultaneously).

The far-field horizontal movements are expected to be global (i.e. en-masse) movements that are associated with very low levels of strain. The potential for impacts is affected by the differential horizontal movements (i.e. strain) rather than the absolute movements. At the distances of the dam walls from the proposed mining areas, the predicted differential horizontal movements are not expected to be measurable (MSEC, 2020).

Future mining will also be carried out in the already approved Area 3C, to the south of the Cordeaux Dam wall, which will be the subject of a separate Subsidence Management Plan process. Area 3C secondary extraction would be located at a minimum distance of 1000 m from the dam wall.

The mining in Area 3C will result in far-field horizontal movements towards this mining area. However, these absolute movements are not additive to the absolute far-field horizontal movements due to mining in Area 6 (MSEC, 2020).

Mining in Area 3C will result in absolute movements towards the south and the subsequent mining in Area 6 will result in absolute movements back towards the north (i.e. reducing the net absolute horizontal movement). In both cases, the far-field effects are expected to be global (i.e. en-masse) movements towards each of the mining areas, where the predicted differential horizontal movements are not expected to be measurable. The potential for impacts to the dam wall is affected by the differential horizontal movements (i.e. unlikely to be measurable) rather than the absolute horizontal movements (MSEC, 2020).

The cumulative differential horizontal movement due to mining in both areas will be confirmed first in the Subsidence Management Plan for Area 3C and then in the Extraction Plan for Area 6 (based on the proposed sequence of mining) using the adaptive management approach to achieve the performance measure described in Comment 1 above.

The Avon and Cordeaux dam walls are located within river valleys and, therefore, could experience low level valley closure effects. The majority of measured valley closure movements at Dendrobium Mine at distances of 1,000 m or greater from the extracted longwalls (i.e. 93 % of cases) are less than the nominal survey tolerance of 3 mm to 5 mm (MSEC, 2020).

Similarly, the valley closure movements measured at distances of 1,000 m from previous longwall mining in the Southern Coalfield are generally similar to the order of survey tolerance (i.e. not measurable) (the majority of the measured valley closure movements [i.e. 89 % of cases] are less than the historic survey tolerance of 5 mm to 10 mm, which is greater than contemporary survey tolerance as the monitoring data includes older surveying techniques) (MSEC, 2020).

Movements greater than survey tolerance have been measured at 1,000 m from previous longwall mining, however, these are likely to include components of survey tolerance and possibly affected by disturbed survey marks (MSEC, 2020).

Low level opening movements have also been measured outside of mining due to conventional subsidence effects. The mining of Longwalls 12 to 15 in Area 3B, on the eastern side of Avon Dam, have resulted in measurable net openings across the reservoir.

However, these longwalls mined beneath the valley side and at a minimum distance of 300 m of the Full Supply Level of the Avon Dam. The potential net opening movements at the Avon and Cordeaux dam walls, due to the proposed mining in Areas 5 and 6, are expected to be very small and are likely to be similar to the order of survey tolerance (i.e. not measurable) (MSEC, 2020).

The potential impacts on the Avon and Cordeaux dam walls would be managed through the implementation of a monitoring and an adaptive management approach. The individual longwalls in Area 5 will be mined in sequence from south to north (i.e. towards the Avon Dam wall) and the individual longwalls in Area 6 will be mined in sequence from west to east (i.e. towards the Cordeaux Dam wall), allowing for an adaptive management approach (refer to response to Comment 1).

Comment 5

DSN stated:

3. *A subsidence assessment of possible impacts on the dams and development of a monitoring plan, in consultation with WaterNSW, similar to that used to protect Sandy Creek Waterfall.*
...
4. *A Risk Assessment concentrating on the safety of the dams and security of the stored waters, with input from a dams engineer.*

South32 Response

South32 agrees with DSN's comment, and has committed to preparing BFMPs as part of the Extraction Plans for the Project which would provide specific detail on monitoring and adaptive management measures adopted (refer to response to Comment 1 above).

The Extraction Plans would provide details of the outcomes of additional assessments which would be undertaken during the preparation of each Extraction Plan (e.g. Subsidence Assessment, Risk Assessment etc). South32 agrees with DSN's recommendation to conduct a Risk Assessment concentrating on the safety of the dams and security of the stored waters during preparation of Extraction Plans, with input from a Dams Engineer.

The development of monitoring and adaptive management measures would be undertaken in consultation with Government, WaterNSW, DSN and an appropriately qualified Dams Engineer (where appropriate).

Comment 6

DSN stated:

The typical stratigraphic section for the Mine from MSEC856 (Fig. 1.7) shows that the Stanwell Park Claystone and Coalcliff Sandstone are not present in the proposed areas to be mined.

MSEC856 says "it is also possible that higher subsidence has developed in Area 3B, as the Coalcliff Sandstone is not present in this area, with higher compression of the overburden occurring within the thicker Wombarra Formation above the chain pillars."

MSEC adjusted their prediction model using the latest subsidence data from Area 3B. This resulted in a 30% increase in predicted subsidence for Area 3B.

MSEC says that Area 5 width-to-depth ratios are similar to Area 3B LW9 & LW10 and then says "that the 30% increase in the incremental vertical subsidence has not been applied for the proposed longwalls in Area 5".

More explanation of the geology in Areas 5 & 6 and the method of subsidence prediction is required.

South32 Response

MSEC has employed best practice subsidence modelling methodologies for the prediction and assessment of potential subsidence impacts for the Project using the Incremental Profile Method (IPM).

The IPM has been used throughout the life of the Dendrobium Mine and has been calibrated to incorporate monitoring data from Dendrobium Mine Areas 1, 2, 3A and 3B. This approach and calibration of the model to monitoring data from the Dendrobium Mine for the Project is supported by the IESC (2019) (Section 6.5.3 of the Submissions Report).

As noted by the DSN, measured vertical subsidence, in some cases, has historically exceeded the subsidence predictions using earlier calibrations of the subsidence model by up to approximately 30% due to the influence of geology in the Dendrobium Mine areas (i.e. due to increased pillar compression from the thicker Wongawilli Seam for Area 3A and Area 3B) (Section 6.5.3 of the Submissions Report).

For the Project, these historical underpredictions were accounted for by increasing the subsidence predictions in Area 6 by 30% (similar to Area 3B, Area 6 is also proposed to mine the Wongawilli Seam).

This correction has not been applied to Area 5 as it is proposed to be mined in the Bulli Seam, which has a thinner seam thickness. Notwithstanding, the component of pillar compression in the model has been increased for Area 5 so that the maximum predicted subsidence values are similar to the maximum achievable subsidence for any single-seam mining in the Bulli Seam. This conclusion is supported by ground monitoring data from NSW coalfields (Section 6.5.3 of the Submissions Report).

Although monitoring at the Dendrobium Mine shows that some observed subsidence movements have historically exceeded the predictions, these occurrences are limited to a local scale and while measured movements can be greater than predictions, exceedances are also expected to be within the orders of accuracy of the predictive methods (Appendix A of the EIS).

Overall, since the model re-calibration to account for historical underpredictions, the IPM model used at the Dendrobium Mine has shown that subsidence movements observed at Dendrobium Mine are typically less than the subsidence predictions, and provides reasonable, if not, conservative predictions of the conventional and non-conventional subsidence effects (Section 6.5.3 of the Submissions Report).

Subsidence predictions for the Project would continue to be refined throughout the life of the Project during the development of Extraction Plans, and would be informed by the progressive update to the geological information available. This would include the refinement of predictions for the Avon and Cordeaux dam walls, to inform the requirement to achieve South32's commitment (refer to response to Comment 1).

Comment 7

DSN stated:

What impact will the proposed mining have on the stability of these dams with geological structures present in the foundations? This has not been addressed in the EIS.

South32 Response

Geological structures identified in Area 5 and Area 6 were considered in the Subsidence Assessment for the Project (Appendix A of the EIS), which concluded that geological structures are unlikely to affect the subsidence predictions for these mining areas (Section 6.6.3 of the Submissions Report). Geological structures were also considered in the Geological Structures Review by Pells Sullivan Meynink (PSM) (Appendix P of the EIS). Based on the information provided, PSM concluded there is no strong evidence suggesting there are geological structures persistent from seam to surface which would be affected by Areas 5 or 6 mine subsidence.

This is supported by evidence from Dendrobium Mine Area 3B, where the effects of lineaments and geological structures on the measured subsidence effects were reviewed based on the ground monitoring data from Area 3B (Section 6.6.3 of the Submissions Report).

It was subsequently identified that there was no apparent increase in subsidence and closure movements measured at the locations where mapped lineaments and geological structures were present, when compared with the predictions and measurements at locations where these mapped features were not present (Section 6.6.3 of the Submissions Report).

The geological structures mapped above Area 5 and Area 6 are of a similar nature to those mapped in Area 3B, therefore, it is unlikely that these structures would affect the subsidence predictions for the Project (Section 6.6.3 of the Submissions Report). It is noted that geological structures are present under the Cordeaux Dam wall, therefore, monitoring and adaptive management measures (i.e. TARPs) would need to consider the risk of movement at the dam wall as a result of these structures.

South32 would continue to refine the identification of geological structures based on the ongoing investigations at the Dendrobium Mine and during the development of first workings for the Project.

The Project longwall layout would be reviewed based on the progressive update to the geological information available and, if required, will be modified to avoid the major geological features during the preparation of the Extraction Plans for the Project (and in consultation with a specialist Dams Engineer).

Comment 8

DSN stated:

An assessment of the potential for movement at the dam walls as a result of Basal Shear Plane movement triggered by the extraction of longwalls in Areas 5 & 6 is needed. This movement may also impact the foundation of the dams and therefore needs assessment.

Uplift on the valley floor below the dam walls has not been addressed. Movement of the valleys that Avon and Cordeaux are located in may be triggered by Basal Shear Planes and Far-Field Horizontal Movement. This potential for adverse movement of the dam foundations needs assessment of the likely impact to the dams.

South32 Response

As described above, further assessment of the potential for geological features (including basal shear planes) to effect subsidence movements at the Avon and Cordeaux dam walls would be assessed during the preparation of Extraction Plans for the Project (refer to response to Comment 7 above).

Comment 9

DSN stated:

Given the DSC's Tolerable Limit has already been approached by Area 3B at Dendrobium, the DSC can't endorse further longwall extraction within the Avon Notification Area which will cause further losses from the Reservoir.

South32 Response

DSN's statement that the tolerable loss limit from the Avon Dam (i.e. 1 ML/d) has "already been approached by Area 3B" is not supported by the predictions of the calibrated, best-practice regional groundwater model developed for the EIS (HydroSimulations, 2019).

DSN's statement is based on the uppermost predictions from a local-scale Dendrobium Mine Area 3 model developed for Avon Dam, however, unlike the regional groundwater model developed for the Project, the local-scale model is not constrained by, or calibrated to, measured mine inflows.

As such, the regional groundwater model conservatively predicts a maximum loss from the Avon Dam of 0.48 ML/d cumulatively from the Project and the Dendrobium Mine. The local-scale model developed by HGEO (2018) estimated losses of 0.7 ML/day for the section of the Avon Dam shoreline proximal to approved Longwalls 12 to 16, while previous estimates by SCT (2018) were losses ranging from a minimum of 0.01 to 1 megalitres per day per kilometre (i.e. a range of two orders of magnitude) (Section 6.3.4 of the Submissions Report). Recent assessment undertaken by HGEO (2020) estimated seepage losses from Avon Dam of 0.47 ML/day following the extraction of Longwall 15 (lower than previous estimates as the latest drilling information has shown that on average the post-mining permeability between the Avon Dam and Area 3B has reduced since the initial post-mining permeability measurements).

The estimate from the regional model as presented in the EIS is lower than the estimate of HGEO (2018) and similar to the estimate of HGEO (2020) using the local-scale model.

If the regional model was revised to incorporate the seepage estimates from the local-scale model, this would reduce calibration performance against mine inflows (i.e. it would result in greater mine inflows when compared to what has been observed in Area 3B, noting that the regional model already overpredicts these inflows) (Section 6.3.4 of the Submissions Report).

While South32 acknowledges DSN's existing tolerable loss limit from reservoirs (i.e. 1 ML/d), the IEP Part 2 report recommended that the thresholds for losses from reservoirs due to mining in the catchment be reviewed and revised (IEP, 2019):

Developing an objective and up-to-date tolerable loss for individual reservoirs needs to have regard to tolerable cumulative losses from the Special Areas and account for current and possible future losses from all reservoirs. The submission to the Panel from WaterNSW recommended creation of an interagency taskforce to establish thresholds for catchment water loss. The Panel agrees with this approach. Thresholds for the Special Areas and new thresholds for individual reservoirs should be established by the taskforce.

It is noted that while updated thresholds for tolerable losses from reservoirs have not yet been established, the IEP (2019) recommends the following in regard to offsetting surface water losses:

Options identified for offsetting water loss from the Special Areas include:

- *'purchasing' the water lost from the catchment that can be attributed to mining operations, the financial offset could be used to fund make-up water sources, such as through the operation of desalination plants and borefields, or*
- *treating the water pumped from the mine to a standard that enables it to supplement water that would otherwise be drawn from the Greater Sydney Water Catchment.*

Consistent with the IEP's recommendations, South32 has committed to implement or fund works such that the Project results in a net gain to Sydney's drinking water supplies from subsidence-related surface water losses from the Metropolitan Special Area (i.e. which include losses from the Avon Reservoir), including:

- beneficial use of mine water to reduce existing demands on the drinking water system, and/or funding or implementing works that reduce existing losses (e.g. pipe losses or evaporation);
- payment to WaterNSW for the maximum predicted take; and
- holding of sufficient licenses to account for this take.

The overall effect of the offset measures is that there would be a net gain to the drinking water supplies of the Avon Reservoir (as well as the Metropolitan Special Area) through either the direct or indirect replacement of water take from the reservoir.

References

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- Mine Subsidence Engineering Consultants (2019). *Dendrobium Mine – Plan for the Future: Coal for Steelmaking Subsidence Impact Assessment*.
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- WaterNSW (2018). *Greater Sydney's water supply system yield May 2018*.

ENCLOSURE 2

MSEC LETTER REPORT (2020)

15 June 2020

South32 Illawarra Coal
Dendrobium Mine
Wollongong NSW 2500

For the attention of: Mr Gary Brassington, Approvals Manager

Dear Gary,

**RE: Dendrobium – Plan for the Future: Coal for Steelmaking
Dams Safety NSW Submission**

Illawarra Metallurgical Coal, a wholly owned subsidiary of South32 Limited (South32), has submitted an Environmental Impact Statement for proposed mining in Areas 5 and 6 at Dendrobium Mine, referred collectively as *Dendrobium – Plan for the Future: Coal for Steelmaking* (the Project). Mine Subsidence Engineering Consultants (MSEC) prepared the subsidence report (MSEC, 2019) that provides the predicted subsidence effects and assessed impacts for the Project.

Dams Safety NSW (DSN), formally the Dams Safety Committee, has provided comments on the Project (DSN, 2019). The comments relate to the predicted subsidence effects and assessed impacts on the Avon Dam and Cordeaux Dam walls. South32 has provided responses to these comments in their submissions report (South32, 2020a) and supplementary letter (South32, 2020b). This letter supports the submissions report and supplementary letter prepared by South32.

The proposed secondary extraction in Areas 5 and 6 are located at minimum distances of 1000 m from the Avon Dam and Cordeaux Dam walls. The dam walls are predicted to experience far-field horizontal movements towards the proposed mining areas. The measured incremental far-field horizontal movements due to the extraction of longwalls at Dendrobium Mine and elsewhere in the Southern Coalfield are illustrated in Fig. 4.4 of the subsidence report (MSEC, 2019) and it has been reproduced in Figure 1. These data represent absolute horizontal movements.

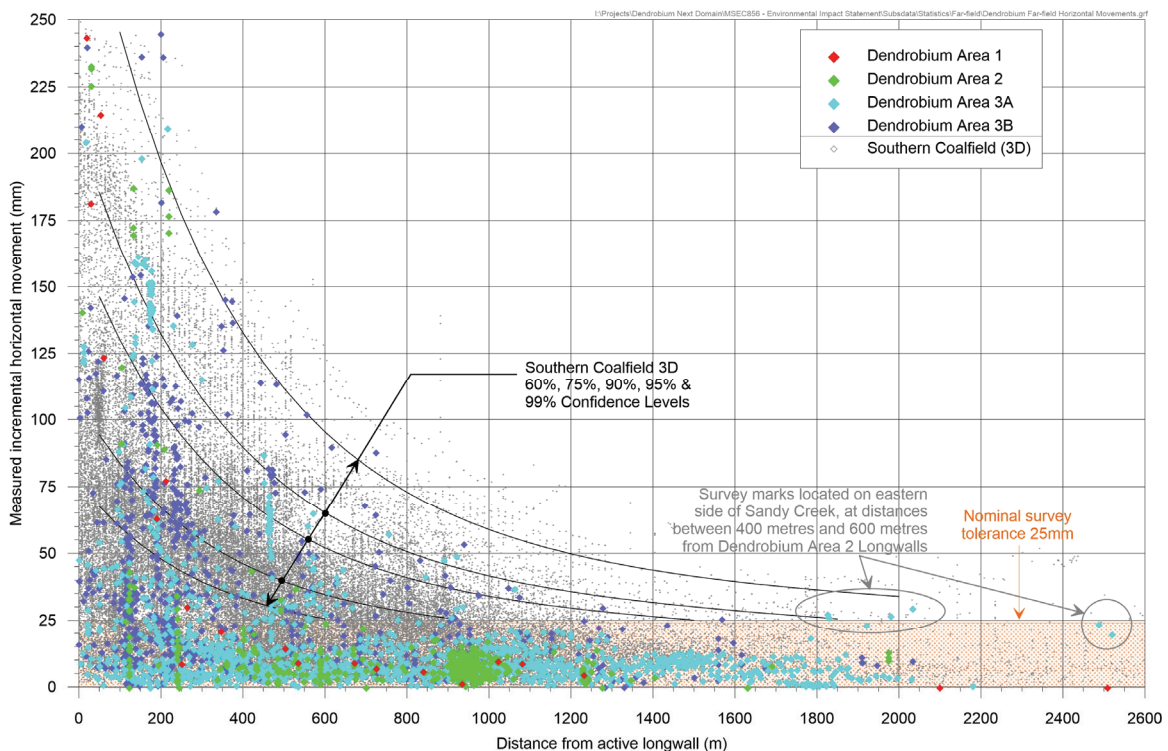


Figure 1 Measured incremental far-field (absolute) horizontal movements at Dendrobium Mine and elsewhere in the Southern Coalfield (Source: Fig. 4.4 from MSEC, 2019)

The far-field horizontal movements measured at Dendrobium Mine are shown as the red, green, cyan and blue diamonds in Figure 1. At distances of 1000 m or greater from the extracted longwalls at the mine, the majority of the measured far-field movements (i.e. 98 % of cases) are less than the nominal survey tolerance of 25 mm for absolute position. The survey tolerance for far-field horizontal movements is greater than that for other subsidence parameters, such as strain, as it is measured using GPS. In a small number of cases, far-field horizontal movements greater than the nominal survey tolerance have been measured at distances of 1000 m or greater, in the order of 25 mm to 60 mm.

The far-field horizontal movements measured elsewhere in the Southern Coalfield are shown as the grey diamonds in Figure 1 for comparison. At distances of 1000 m or greater from the extracted longwalls, the movements measured at Dendrobium Mine are less than those measured elsewhere in the Southern Coalfield. The reason is the shallower depths of cover at Dendrobium Mine result in greater subsidence effects directly above the mining area but lesser effects further afield outside the mining area.

The potential for impacts on the Avon and Cordeaux Dam walls do not result from the absolute far-field horizontal movement but from differential horizontal movements. Differential horizontal movements are represented by various parameters including strain, as measured by changes in long bays (including valley closure or valley opening).

There is limited strain monitoring data at Dendrobium Mine; however, there is extensive data elsewhere in the Southern Coalfield. At distances of 1000 m or greater from the extracted longwalls, the majority of the measured strains (i.e. 94 % of cases) are less than the nominal survey tolerance of 0.25 mm/m. The nominal survey tolerance for strain represents a change in length (i.e. horizontal distance) of 3 mm to 5 mm measured over a standard survey bay length of 20 m.

The far-field horizontal movements are expected to be global (i.e. en-masse) movements that are associated with very low levels of strain. The potential for impacts is affected by the differential horizontal movements (i.e. strain) rather than the absolute movements. At the distances of the Avon and Cordeaux Dam Walls from the proposed mining areas, the strains are predicted to be in the order of survey tolerance, i.e. not measurable.

Future mining will also be carried out in the already approved Area 3C, to the south of the Cordeaux Dam wall, which will be the subject of a separate Subsidence Management Plan process. The secondary extraction will also be located at a minimum distance of 1000 m from the dam wall. The mining in Area 3C will result in far-field horizontal movements towards this mining area. However, these absolute movements are not additive to the absolute far-field horizontal movements due to mining in Area 6, as described further below. The mining sequence in the EIS is Area 5, Area 3C and then Area 6.

Mining in Area 3C will result in absolute movements towards the south and the subsequent mining in Area 6 will result in absolute movements back towards the north, i.e. reducing the net absolute horizontal movement. In both cases, the far-field effects are expected to be global (i.e. en-masse) movements towards each of the mining areas, where the strains are predicted to be less than the nominal survey tolerance, i.e. not measurable. The potential for impacts on the dam wall is affected by the strains (i.e. unlikely to be measurable) rather than the absolute horizontal movements.

The Avon Dam and Cordeaux Dam walls are located within river valleys and, therefore, could experience low level valley closure effects. The measured total valley closure movements due to the extraction of longwalls at Dendrobium Mine and elsewhere in the Southern Coalfield are illustrated in Fig. 6.17 of the subsidence report (MSEC, 2019) and it has been reproduced in Figure 2.

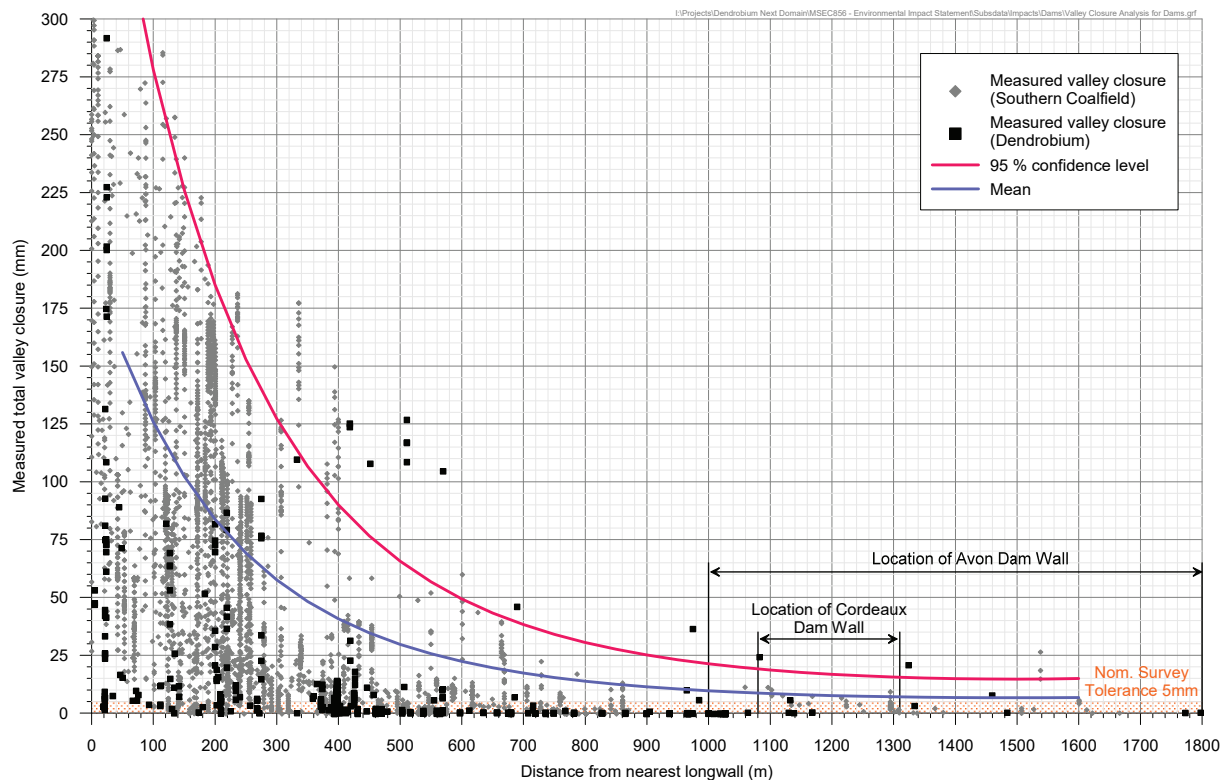


Figure 2 Measured total valley closure versus distance from nearest longwall
(Source: Fig. 6.17 from MSEC, 2019)

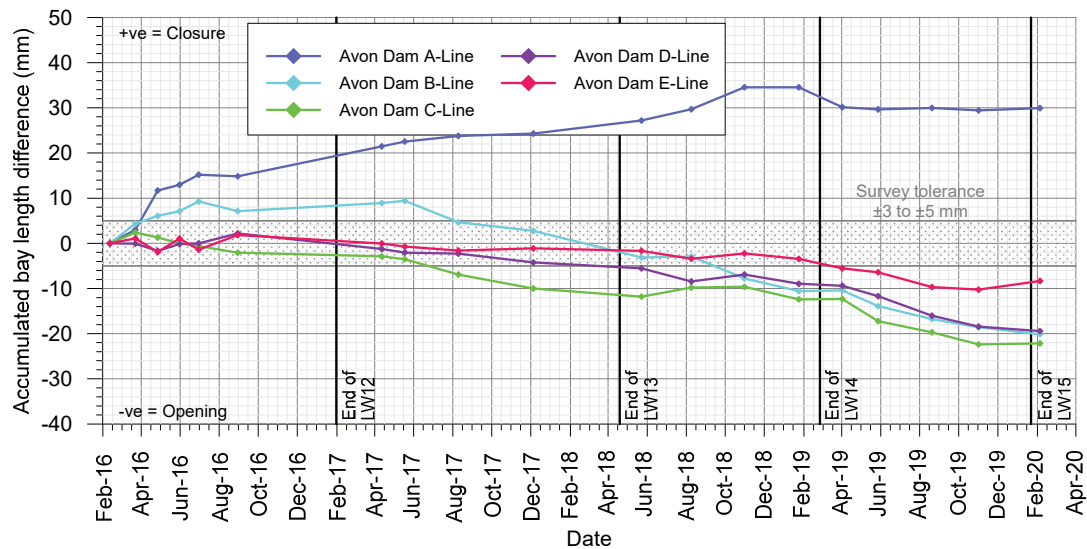
The valley closure movements measured at Dendrobium Mine are shown as the black squares in Figure 2. At distances of 1000 m or greater from the extracted longwalls at the mine, the majority of the measured valley closure movements (i.e. 93 % of cases) are less than the nominal survey tolerance of 3 mm to 5 mm. Valley closures of 20 mm to 35 mm have been measured at the Wongawilli Creek C-Line after the mining of LW9 to LW11 in Area 3B; however, these values include the measured movements due to previous mining in Area 3A at a minimum distance 370 m. Excluding this monitoring line, the maximum valley closure movement measured at distances of 1000 m or greater at Dendrobium Mine is 8 mm.

The valley closure movements measured elsewhere in the Southern Coalfield are shown as the grey squares in Figure 2 for comparison. At distances of 1000 m or greater from the extracted longwalls, the majority of the measured valley closure movements (i.e. 89 % of cases) are less than the historic survey tolerance of 5 mm to 10 mm. The historic survey tolerance is greater as the monitoring data from the Southern Coalfield includes older surveying techniques. Some data also appear to include results where survey prisms have been disturbed.

At the distances of the Avon and Cordeaux Dam Walls from the proposed mining areas, the valley closures are predicted to be in the order of the survey tolerance of 3 mm to 10 mm. The actual movements are expected to be towards the lower end of the range; however, the older monitoring data from the Southern Coalfield could not measure valley closure less than the upper value.

Modern surveying techniques can measure valley closure to much higher accuracy. For example, the high resolution monitoring for Sandy Creek Waterfall and Harris Creek Cliff Line have accuracies in the order of 1 mm. It is likely therefore that these more accurate surveying methods could measure valley closure movements at distances of 1000 m from longwall mining.

Low level opening movements have been measured outside of mining due to conventional subsidence effects. This occurs when longwall mining occurs directly beneath the valley side causing it to move in the direction of extraction. For example, the mining of Longwalls 12 to 15 in Area 3B, on the eastern side of Avon Reservoir, have resulted in measurable net openings across the reservoir. These longwalls mined beneath the valley side and at a minimum distance of 300 m of the Full Supply Level (FSL) of the reservoir. The movements measured at the Avon Dam closure lines are shown in Fig. 2.3 of the LW15 End of Panel Report (MSEC, 2020) and it has been reproduced in Figure 3.



**Figure 3 Measured accumulated opening and closure for the Avon Dam closure lines
(Source Fig. 2.3 of MSEC, 2020)**

Valley closure of 20 mm was initially measured along the Avon Dam A-Line during the mining of LW12 and increasing to 35 mm during the mining of subsequent longwalls. The northern end of this monitoring line is located 330 m from the commencing end of LW12. Closure was also initially measured along the Avon Dam B-Line during the mining of LW12, with its eastern end located 520 m from this longwall.

Valley opening was measured at the Avon Dam C-Line during LW13, the Avon Dam B-Line and D-Line during LW14 and the Avon Dam E-Line during LW15, at distances ranging between 250 m and 850 m from the mining area. These longwalls mined beneath the valley side at a minimum distance of 300 m of the FSL of the reservoir.

The proposed longwalls in Areas 5 and 6 are located at minimum distances of 1000 m from the Avon Dam and Cordeaux Dam walls and, therefore, the potential for valley opening is considerably reduced. The potential net opening movements at the dam walls, due to the proposed mining, are predicted to be less than the nominal survey tolerance of 3 mm to 5 mm. It is possible; however, that high resolution monitoring techniques (with accuracies in the order of 1 mm) could measure low level opening movements.

The potential impacts on the Avon Dam and Cordeaux Dam walls could be managed with the implementation of monitoring and an adaptive management approach. The individual longwalls in Area 5 will be mined in sequence from south to north (i.e. towards the Avon Dam wall) and the individual longwalls in Area 6 will be mined in sequence from west to east (i.e. towards the Cordeaux Dam wall), allowing for an adaptive management approach.

The subsidence assessment (MSEC, 2019) recommended that the appropriate monitoring and management strategies be developed, in consultation with WaterNSW and DSN, including a Trigger Action Response Plan (TARP). This would include a detailed assessment of the dam walls by a suitably qualified Dams Engineer to establish the appropriate monitoring, triggers and action responses. It is considered appropriate that the detailed assessment and development of the monitoring and management plans are developed as part of the Extraction Plan applications.

The recommendations would not change if the minimum distance of the proposed secondary extraction from the Avon Dam and Cordeaux Dam walls was increased to 1500 m. While the predicted differential horizontal movements at the dam walls would not be expected to be measurable, it would still be recommended that a monitoring and adaptive management approach be adopted. It is expected that the appropriate monitoring, trigger levels and action responses would be similar to those based on a minimum distance of 1000 m.

I trust that this letter is of assistance. Please let me know if you have any questions or require further information.

Yours sincerely,

James Barbato

Dr James Barbato
Mine Subsidence Engineering Consultants

References

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