APPENDIX P

Geological Structure Review

Dendrobium Mine

Plan for the Future: Coal for Steelmaking

Geological Structures Review

PSM3021-007R REV1 26 April 2019

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1 Introduction

Pells Sullivan Meynink (PSM) was engaged by South32 – Illawarra Coal (South32) to undertake a review of geological structures within Dendrobium Areas 5 and 6 of the proposed Dendrobium Mine Plan for the Future: Coal for Steelmaking (the Project). The objective of this review was to assess the potential for geological structures of sufficient persistence and scale such that they could potentially be affected by mine subsidence, thus affecting predicted subsidence movements. Specifically, structures that potentially impact the Avon and Cordeaux Dams.

It is understood this review is intended to be included as an appendix in South32's Environmental Impact Statement (EIS) for the Project.

This review consists of a detailed investigation of existing geological and related data with limited field verification of identified structures. It is not possible to exhaustively identify the existence nor extent of all geological structures due to physical limitations on subsurface investigations. Hence, it is possible that some geological structures that occur at the surface have not been identified in this study, or their extent not fully realised.

2 Scope of Work

The scope of work for this review includes:

- Preparation of a Geological Structure Review including:
  - consideration and addressing the Secretary's Environmental Assessment Requirements (SEARs);
  - a description of the exploration activities to date that inform the conclusions; and
  - an explanation of the exploration and in-seam drilling that is ongoing throughout operations to inform and validate South32's understanding of the geology (with the implementation of adaptive management where unexpected features are encountered).

A desktop review of available literature and previous studies for relevant matters has been completed (including the reports and information outlined in the Previous Assessment section). Additionally, this review is to consider the relevant Project SEARs and the requirements of the New South Wales (NSW) Dams Safety Committee (DSC) and WaterNSW, including:

- Page 2 of the SEARs from the NSW DSC:

  A study of the geology in the proposed areas of development;

  a. Focus on identifying:

  i. Any structures that extend towards the dam wall.

  ii. Any structures that connect the reservoirs to the mine working, either directly or via a secondary means, such as a shear plane and connected fracture network.
- Page 19 of the SEARs from the WaterNSW:
  - Preparation of mapping that shows location and nature of any geological structures including faults, dykes, sills, and other intrusions within the study area.

3 Data Sources

Several key sources of information used in this review include:

- South32 provided data:
  - *Report on the Geology, Quality and Mineral Resources of Dendrobium Area 2* (Reference 1);
  - *Inspection of Surface Outcrops over Dendrobium Mine Area 1* (Reference 2 and 3);
  - *Timing of brittle faulting and thermal event, Sydney region: association with the early stages of extension of East Gondwana* (Reference 4);
  - *An inspection of certain surface geological features in Area 5 of Dendrobium Mine* (Reference 5);
  - *Surface mapping of Dendrobium Area 3A* (Reference 6);

  - aerial photographs for both Dendrobium Mine Areas 5 and 6;
  - topographic contour data (1 and 10 metres [m] contours);
  - core photos of selected boreholes within Dendrobium Mine Areas 5 and 6;
  - selected acoustic televiewer logs;
  - proposed mine plan; and
  - Commonwealth Scientific and Industrial Research Organisation (CSIRO) interpretive plans:
    - *Air photograph interpretation* (Reference 8).
    - *Landsat imagery interpretation* (Reference 9).
    - *Bedrock fracture trends* (Reference 10).
    - *Structural synthesis* (Reference 11).
- publicly available data:
  - *Southern Coalfield 1:100k geological map* (Reference 12);
  - *Wollongong-Port Hacking 1:100k geological map* (Reference 13); and
  - NSW digital elevation model - hillshade.

Appendix A presents a full list of the data provided by South32.

4 Previous Work

Investigations conducted by South32 within the study area were considered by PSM to be directly relevant to this assessment. The subsections briefly describe relevant investigations conducted within Areas 5 and 6.

4.1 South32

Contents and findings of South32's work focused on Area 5 and the associated exploration of the Bulli Coal Seam. The following points summarise South32's investigative work:

- Exploration:
  - Exploration drilling began in the early 1990's, which included eleven boreholes to assess underground conditions within the study area.
  - At least 55 and 42 boreholes have been drilled in Areas 5 and 6 respectively over the past 3 years. Boreholes are mostly RC collars with diamond tails. Figure 1 presents the borehole location plan.
  - Since 1987, five aeromagnetic survey and four seismic programs have been conducted over the study area. The location and results have been provided for comment, however, the report states there is good coverage over Area 5.
- Faulting:
  - No significant faulting was observed over Area 5. However, one significant zone of disturbance was identified in seismic lines towards the north west of Area 5. This disturbance is described as an offset of approximately 3 m of the Bulli Coal seam with a disturbed zone 200 millimetres (mm) wide and has been called the Potential Bulli Fault. The disturbance was not observed in any other seismic line data therefore there is uncertainty in the potential structure's orientation. Future site investigations aim to further define this feature.
- Igneous Intrusions:
  - Several igneous sills have been intersected in boreholes and inferred from airborne geophysics.
  - In-seam drilling have confirmed the location and extent of an east-west striking dyke south of the projected dyke. The dyke (DD25) is approximately 24 to 30 m thick and projects from the main heading development from Area 3B to Area 5. The location of this dyke is not apparent in the provided data.

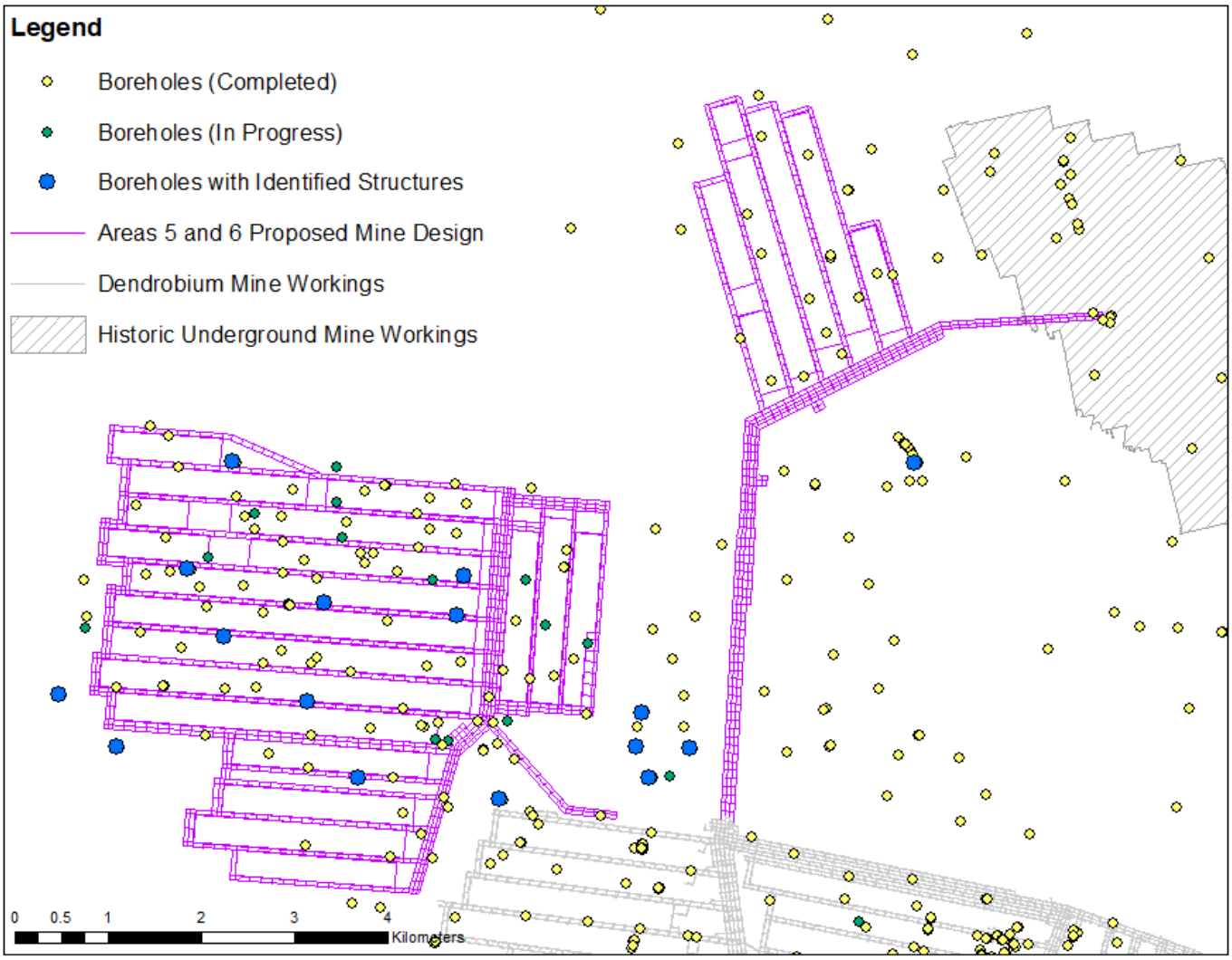

Figure 1: Plan showing boreholes (completed/in progress) within the study area.

Figure 1 shows boreholes with structures identified by South32 in Area 5. Identified boreholes with structure were verified where core photographs and/or televiewer data were available. This is discussed further in Section 5.

4.2 Surface Geological Features Inspection

This study focused on an inspection of geological features observed at the surface of Area 5. The following points summarise the inspection report (Reference 7):

- Previously mapped structures:
  - Three dykes located about the Cordeaux Dam structure based on Jensen 1975 mapping and borehole data:
    - Approximately 300 mm wide sinuous dyke striking 098 with dextral sense of movement.
    - Approximately 200 mm wide dyke intersected in a single borehole – assumed to be striking east-west.
    - Greater than 1 m wide dyke, estimated strike is east-west, this dyke is projected into Bay I of the Cordeaux Dam structure. More recent mapping failed to confirm this structure.
  - The dominant joint set strikes between 290 and 310.
  - Two dykes, oriented east-northeast with strike lengths of approximately 400 and 1000 m, located near the Avon Dam structure were mapped by C. McElroy and Associates in 1975. They are inferred to intersect the reservoir only.

  - A series of geological structures along Avon Dam road were mapped in 2010 by Doyle (Reference 8), these include:
    - Two dykes, 1.2 m and 0.25 m wide, oriented northwest-southeast. These two structures do not trend towards the dam structure or reservoir.
    - A 0.5 m thick dyke and minor fault structure 15 m long are located east of the Avon Dam road. Both structures are oriented northwest-southeast.
- Geological Survey of NSW major structures inferred within Areas 5 and 6 include:
  - Avon River Lineament.
  - Nepean Monocline.
  - Nepean River Lineament.
  - Cordeaux River Lineament.
  - Bargo Fault/Nepean Fault Structures.
- Boreholes drilled for exploration in Area 5 were placed away from potential geological structures to optimise the potential coal sample. However, some boreholes intersected structures that may extend to the surface. These are presented in Drawing 2.
- Photographic, linear, residuals, and gradient analyses identified the following:
  - Dominant joint set trends 280 to 305.
  - Offset of lineaments was not observed.
  - Lineaments were probably a strong joint zone, possibly associated with dykes, and not fault related.
  - No evidence of faulting was noted within Area 5.
- A field inspection of geological anomalies was undertaken, with the following points noted:
  - Several dykes were identified. We have presented the location and orientation of the identified dykes and these are presented in Drawing 3.
  - No documented faults found to potentially affect the proposed mine plan were identified at the surface. The Reference 7 author states this finding supports the normal behaviour of faulting within the Southern Coalfield where faults typically diminish in displacement up sequence to the base of the Hawkesbury Sandstone.
  - A fault, with approximately 15 m displacement, was reported east of the Avon Dam road. The fault was noted as trending south east across Area 5.

This report lists several recommendations to inspect potential structures in and around Area 5.

4.3 CSIRO Interpretative Studies

In 1983, the CSIRO conducted a fracture analysis of the Sydney Basin. This analysis resulted in the production of the following plans at 1:100k scale for the Wollongong-Port Hacking area:

- Air photograph interpretation (Reference 8).
- Landsat imagery interpretation (Reference 9).
- Bedrock fracture trends (Reference 10).
- Structural synthesis (Reference 11).

Lineaments based on the interpretation of air-photograph and Landsat imagery are presented in this report. The structural synthesis appears to be the basis for both the 1:100k geological sheets for Wollongong and Port Hacking, and the Southern Coalfield.

5 Borehole Structures

Work completed by South32 and the field inspection reports summarised in Section 4 identify boreholes which intersected structures within boreholes. Drawing 2 presents the location of boreholes with structures.

Table 1 presents the boreholes where structures were identified and the structure type.

Table 1 – Summary of PSM verification of structures identified by others in boreholes

Study	Borehole ID	Feature	Verified by PSM
Surface geological features inspection (Reference 7)	S0222	Not described	Data unavailable
	S705	Dyke with faulted contact	
	S0777	Dyke	
	S0797	Probable dyke	
	S1796	Dyke	
	S1800	Probable dyke	
	S2381	Dyke	
	S2393	Probable dyke	Three probable dykes observed in core photos between 339 - 379 m. Orientation data not available for review.
South32 work	S2314	Not described	No major structure observed in data provided
	S2319	Not described	No major structure observed in data provided
	S2325	Not described	Data unavailable
	S2340	Not described	Minor jointing only
	S2342	Not described	No major structure observed in data provided
	S2343	Not described	Data unavailable
	S2348A	Not described	No major structure observed in data provided
	S2352	Not described	Minor jointing 352 to 356 m only
	S2353	Not described	No major structure observed in data provided
	S2365A	Not described	No major structure observed in data provided

Core photographs, logs, or televiewer images were not provided for all structures observed in boreholes. PSM are unable to verify the structures listed in Table 1 nor comment on the potential for these to impact the surface during mine subsidence where this data is unavailable.

6 Site Visit

Daniel Strang, Associate Engineering Geologist and Angela Mabee, Engineering Geologist from PSM, conducted a site visit on 19 February 2019. Drawing 2 presents the tracks covered and the locations of geological structures observed during the site visit. The purpose of the site visit was to inspect Areas 5 and 6 to identify and describe any geological structures along accessible tracks and trails at the surface.

Areas inspected during the site visit include:

- publicly accessible areas around Cordeaux Reservoir dam wall;
- cuttings along fire trails (6, 6b, and 6x);
- a 1.3 kilometre (km) portion of the disused Maldon-Dombarton Rail Line;
- exposures of rock in creek beds along Fire Trail 6; and
- the northern portion of the Avon Reservoir (eastern edge) by drone.

The bushland at the site is densely vegetated. Field observations were restricted to just a few metres either side of the trail where rock outcrops were observed.

Relevant photographs and figures derived from the site visit are presented throughout this report.

7 Lithostratigraphy

The stratigraphy of Dendrobium Areas 5 and 6 is invariably documented as the well-recognised Sydney Basin sedimentary sequence. A detailed stratigraphy profile is presented in Figure 2. For the purpose of this review the stratigraphy has been simplified into seven units or intervals:

- Hawkesbury Sandstone (HBSS);
- Newport Formation (NPFM);
- Garie Formation (GRFM);
- Bald Hill Claystone (BACS);
- Bulgo Sandstone (BGSS);
- Stanwell Park Claystone (SPCS) to Wombarra Claystone (WBCS) interval. Where the SPCS is not recognised in sequence the entire sequence (Bulgo Sandstone to Scarborough Sandstone) is known as the Colo Vale Sandstone (SS); and
- the interbedded coal seams and beds from the Wombarra Claystone (WBCS), to the Wongawilli Coal (WWCO) and including the Bulli Coal (BUCO) and other coal units.

In summary there are essentially two very thick, massive sandstone intervals of HBSS and BGSS which are each underlain by lower strength shale/claystone units (BACS and SPCS/WBCS). This is then underlain with a relatively thinly interbedded interval directly overlying the coal mining horizons (WWCO and BUCO).

The depths of cover above the proposed longwalls in Area 5 (BUCO coal mining horizons) vary between a minimum of 250 m in the southern part of the mining area and a maximum of 390 m in the north-eastern part of the mining area (Reference 18). The average depth of cover within the mining area is 360 m (Reference 18).

The depths of cover above the proposed longwalls in Area 6 (WWCO coal mining horizons) vary between a minimum of 375 m in the south-western part of the mining area and a maximum of 460 m in the north-eastern part of the mining area (Reference 18). The average depth of cover within the mining area is 440 m (Reference 18).

The uppermost units are HBSS and the Narrabeen Group comprising sandstones and claystones. Maximum thickness of HBSS is generally accepted to be approximately 160 m. Reference 5 states this thickness is generally less than this in the study area due to erosion and incision, being an average of only 110 m at Area 5.

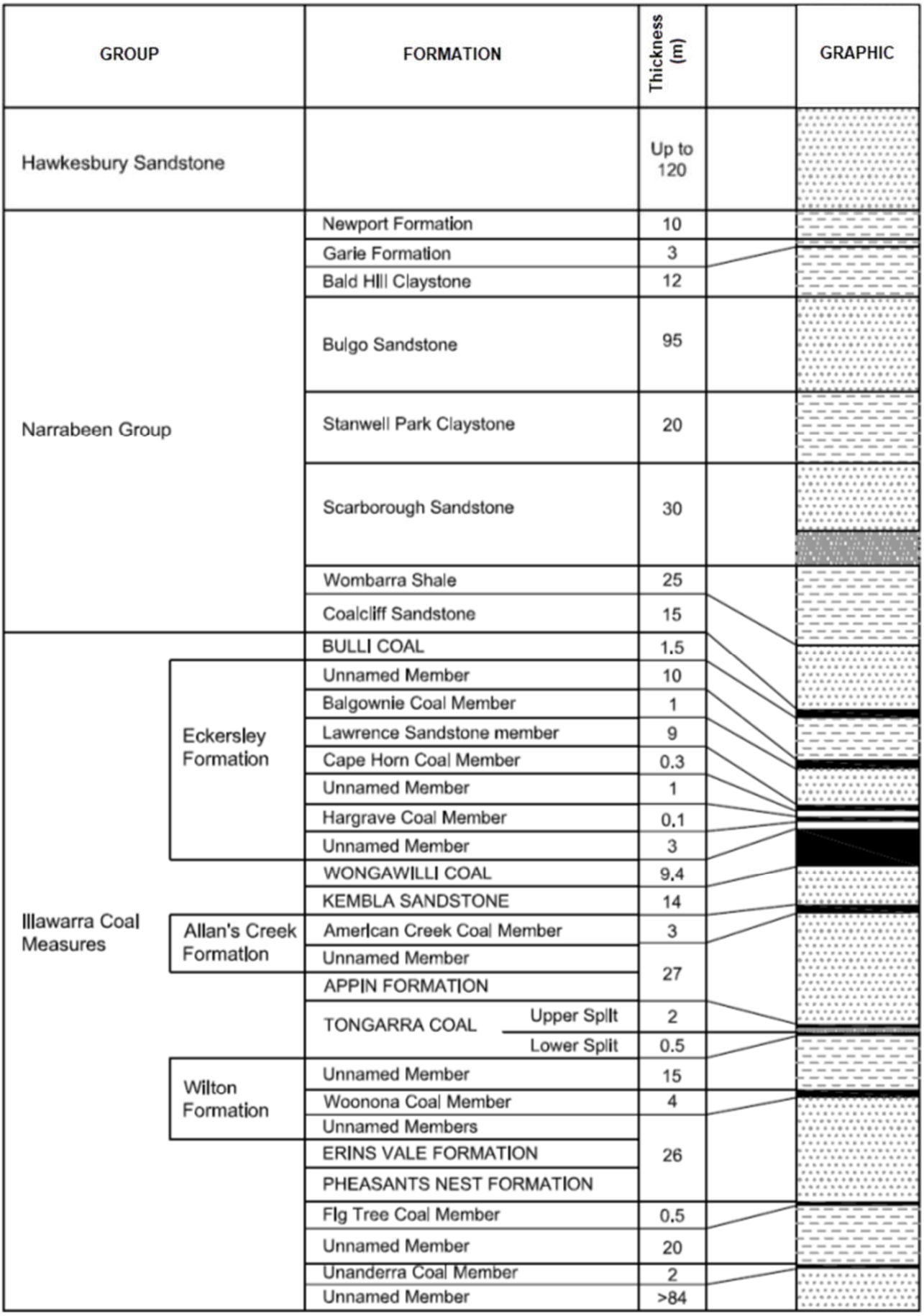

Figure 2: Stratigraphic profile (Reference 14)

8 Site Characteristics and Geomorphology

The Project is situated on the Illawarra plateau, between and to the north of the Avon and Cordeaux Reservoirs. There are a small number of access roads within the mine area through natural bushland, these being controlled by WaterNSW. The study area is covered by dense eucalypt bush.

The geomorphology of the area is described as deeply dissected plateaus. The plateaus are primarily HBSS, incised down to the claystones, such as the BHCS in parts of Wongawilli Creek and within Avon Reservoir. Most outcrops observed across the plateau in earlier investigations were HBSS. The geomorphology of the study area is likely controlled by the massively-bedded HBSS and joint sets. Figure 3 presents a long section with vertical exaggeration through Dendrobium Areas 1, 2, 3A and 3B to illustrate the surface profile and surficial units.

The arms of the Avon and Cordeaux Reservoirs and Wongawilli Creek form the main dissecting valleys across the study area as seen in Drawing 1.

Deep valleys and gorges are dominated by structure. Short, moderately spaced joints appear to control the shape and orientation of the valley edges.

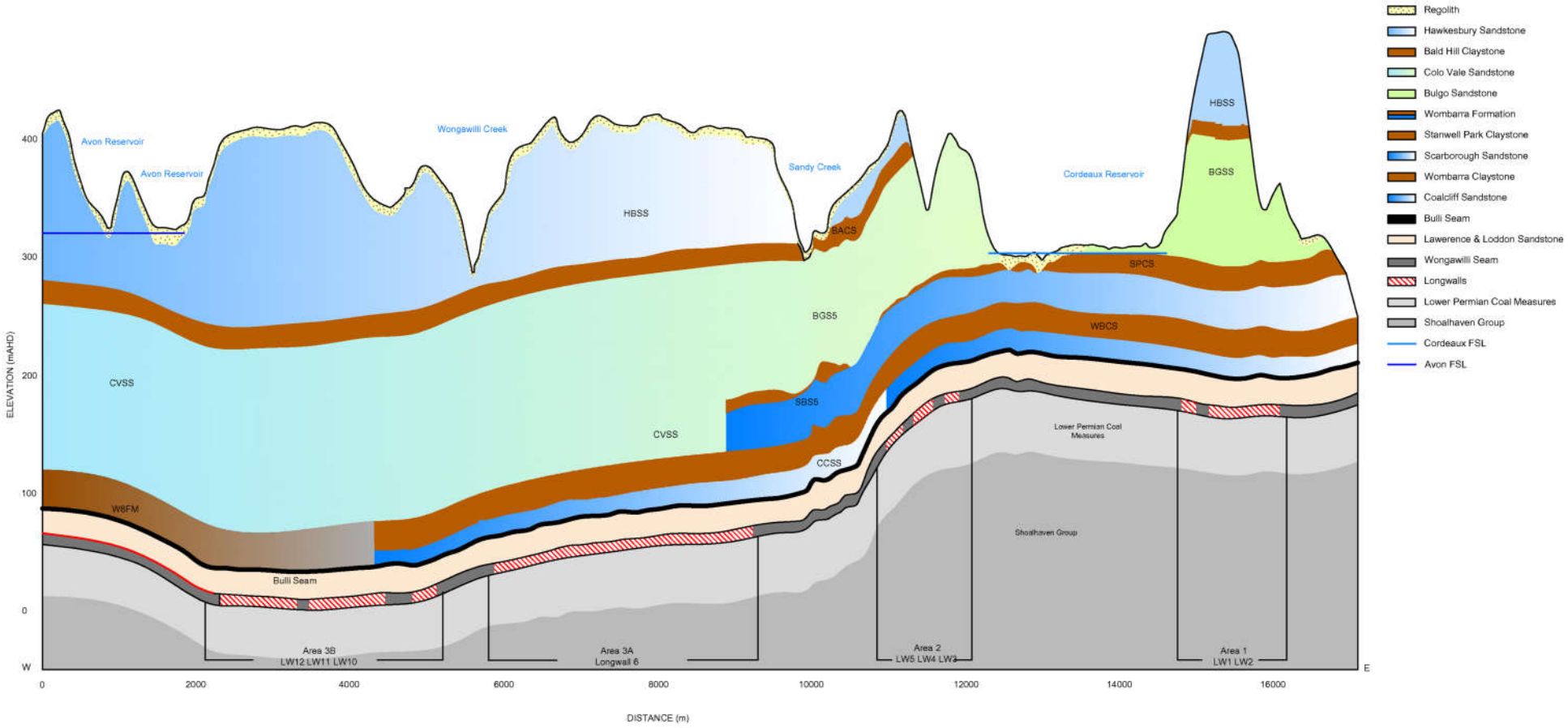

Figure 3: Schematic cross-section through Dendrobium Areas 3A, 3B, 2 and 1 presenting the lithostratigraphy, and topography (15x vertical exaggeration) (Reference 14).

9 Structural Geology

The main intrusive units and major structures at Dendrobium Mine have been collated from surface and underground mapping, drilling (both surface and in seam) as well as geophysical and LiDAR surveys. This section describes the major geological structures observed or described in literature within the study area.

9.1 Folding

Regionally, the Southern Coalfield consists of a broad syncline with a north-south to north northwest trending axis. Dips associated with this folding are commonly below 2 degrees (°) and rarely exceed 5°. The regional context indicates the stratigraphy above the Bulli seam dips gently to the north-northwest, on average about 0.5 to 1° (Reference 15 and 16).

The study area is bound by two fold axes: to the west by the Camden Syncline, and to the east by the Kemira Anticline, Drawing 4 (Reference 12). Although the site is close to several fold axes, folding of the basinal rocks is gentle and is typically less than 10°. The maximum bedding dip recorded during the PSM site visit was less than 3°.

The confluence of the Nepean Monocline and Camden Syncline is projected near the Avon Dam structure. A noticeable change in bedding orientation was not observed along the eastern edge of the northern portion of Avon Reservoir nor near the eastern abutment of the dam structure. The Nepean Monocline may project into Area 5, but no evidence of change in bedding orientation was observed by PSM.

According to the Southern Coalfield geological sheet (Reference 12), the Kemira Anticline strikes parallel approximately 1 km to the east of Area 6. There is uncertainty in the length of this structure with earlier versions of the geological sheet showing the Kemira Anticline terminating south of Cordeaux Reservoir.

9.2 Faulting

Regional faulting is dominated by normal faults trending sub parallel to the regional fold axes in a northwest to north-northwest orientation. Subordinate strike slip and reverse (low angle) thrust faults are also known to occur in the Southern Coalfield but occur less frequently than normal faulting.

The Lapstone Structural Complex, which includes the Lapstone Monocline, is a major north-trending association of monoclines and faults that forms the frontal ridge of the Blue Mountains Plateau (Reference 17). Faults associated with this complex are located less than 20 km to the west of the site.

Large regional scale faults have been drawn across the study area in the Southern Coalfield 1:100k geological sheet (Reference 12).

Locally, faults and fault zones have been identified by South32 using a range of field exploration techniques such as surface boreholes, seismic surveys, and aeromagnetic surveys.

This section presents and discusses known faults that occur in the vicinity of Areas 5 and 6, Drawing 5.

9.2.1 Regional Faults

The regional faults described here are based on published geological sheets (Reference 12 and 13). The basis for regional faults inferred in published maps is unknown as they could be based on as little as desktop review. Confidence in these published structures is low. Three regional faults are inferred within Areas 5 and 6, they are unnamed, and the sense of movement and basis of the inference is not provided in Reference 12 and 13. Drawing 5 presents the locations of the inferred faults.

Unnamed Fault 1 strikes northeast across both Area 5 and the Avon Reservoir. The fault trace does not appear to align with depressions or ridges identified in the topographic surface, and the basis for the fault is unknown. South32 have conducted five seismic lines across this feature in order to prove its existence – no displacement has been observed. Therefore, this inferred structure is unlikely to be present and will be excluded from further assessment.

Unnamed Fault 2 strikes north-northwest along the eastern edge of Area 6. Similarly, oriented dykes have been found in this location, and they appear to delineate the boundary of economic coal. This is unlikely to be coincidental.

The fault trace for Unnamed Fault 3 terminates on the western bank of Avon Reservoir, however this fault trace may be extended across the reservoir to the east bank.

These three regional faults were not observed during the PSM site visit, nor do they align with structures mapped at the surface by others.

Approximately 1000 m to the east of the Area 6 study area are a series of inferred fault traces striking northeast and northwest. The northwest striking faults are common within the Southern Coalfield, Rixons Fault and Corrimal Fault are located approximately 7 to 9 km east-southeast of Area 6. There is a trace that appears to align with these two faults and trends towards Area 6, we have labelled this 'Rixons/Corrimal Fault'. This trace trends towards the Cordeaux Dam structure.

9.2.2 Mine Scale Faults

Mine scale faults have been identified across the study area and are more reliable than the regional scale faults inferred in published geological sheets. Identified mine scale faults are mostly located near Area 6 and strike either west, north-northwest, north, or northeast.

Drawings 6 and 7 present mine scale faults inferred by South32 for Areas 5 and 6 respectively. Fault characteristics presented were provided by South32.

Area 5 - Bulli Fault

The potential Bulli Fault is located within Area 5 and is based on seismic survey. Figure 4 presents the disturbed zone of which the Bulli Fault is based. The potential fault appears to offset the Bulli Coal seam reflector by approximately 3 m with a disturbance zone estimated to be 200 mm wide. The feature was not observed in any other survey lines; however, several other less disturbed zones were observed in other seismic lines but were assessed as being of low confidence.

The orientation of this structure is uncertain but aligns with the regional scale Unnamed Faults 1 and 3. There is no apparent geomorphic feature that corelates with the Bulli Fault. There may be a low chance that the Bulli Fault is a continuation of Unnamed Fault 3.

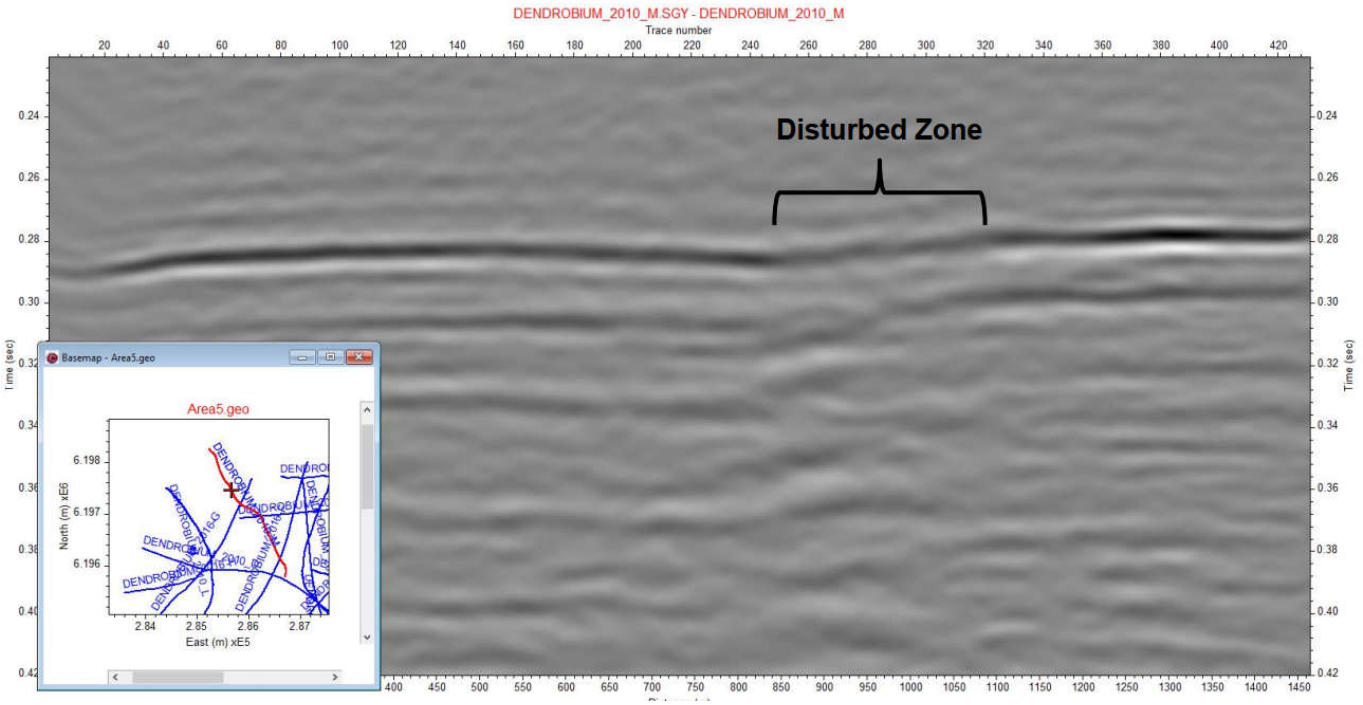

Figure 4: Disturbed zone observed in two-dimensional seismic survey.

Area 6 - Faults

Three two-dimensional seismic survey lines traverse Area 6. The survey lines typically strike east-northeast. Fault structures have not been identified from these lines within Area 6. Faults have been identified to the south near the Cordeaux Dam structure (Faults A6FW2 A6FW3) and to the east of Area 6.

Faults A6FNNW1 to 3 align with the regional Unnamed Fault 2 and delineate the eastern edge of Area 6. These faults are largely based on seismic survey. The vertical displacement of these three faults is approximately 8 to 30 m.

9.3 Igneous Intrusions

The Southern Coalfield is known to have igneous rocks intruded into the basinal sedimentary rocks such as dykes, sills, plugs and diatremes.

Dykes are the most commonly observed volcanic intrusion and are generally coincident with the orientation and frequency of regional faults and fold axes. They are typically sub vertical, around 3 m in width, but known to reach up to 15 m wide, and reach up to 5 km in length (Reference 15).

The following sources of information are assessed for the occurrence of igneous intrusions:

- Published Maps:
  - one dyke is shown on the published 100k geological map (Reference 12), which is a north or northwest trending dyke between 4 km and 5 km long and about 3 km northeast of the site.
- Surface Mapping:
  - dykes and plugs have been identified at the surface over the last 100 years of exploration and land development (Reference 6). South32 has compiled the location of igneous rocks identified at the surface.
- South32 Investigations:
  - South32 have conducted airborne aeromagnetic and radiometric surveys of the site to identify geological structure; and
  - exploration drilling has intersected several sills and dykes.

Drawing 3 presents location, extents, and orientations of known igneous intrusions. Evidence for these dykes is derived from one or a combination of the above sources of information as presented and discussed below.

9.3.1 Sills

Area 5 is affected by several large mostly doleritic sills as identified by exploratory drilling. Most of the sills occur within the Illawarra Coal Measures. Drawing 3 presents the approximate extents of identified sills in the study area.

There are significant sills underlying the Bulli seam in the Balgownie, Cape Horn, Wongawilli, American Creek and Tongarra Seams or the interburden between these seams. Some of these sills are significant in both thickness and extent, with one borehole intersecting particularly thick and pervasive sill between the American Creek and Tongarra Seams having a thickness in excess of 40 m, Reference 6.

Sills range in thickness from less than 3 m up to 40 m thick. Sills are variably altered, generally, thinner sills (<3 m) are completely altered to clay, and thicker sills (<40 m) are fresh, Reference 6. Photo 1 presents an example of the Bulli Sill intersected in S2368, the sill is less than 3 m thick.

Two large sill areas have been identified by South32, including an extensive area between Area 3B and Area 5.

The second is an area in the northern parts of Area 5. This sill is largely confined to the Wongawilli Seam and appears to be responsible for heat affecting the Bulli Seam. Targeted boreholes have been drilled to refine the limit of the sill in the Bulli Seam in order to avoid the sill in the mine plan. The extent of the heat affected Bulli Seam is based on seismic survey and borehole intersections. The extent of the sill is relatively well understood, although its extent to the north and northwest is less certain.

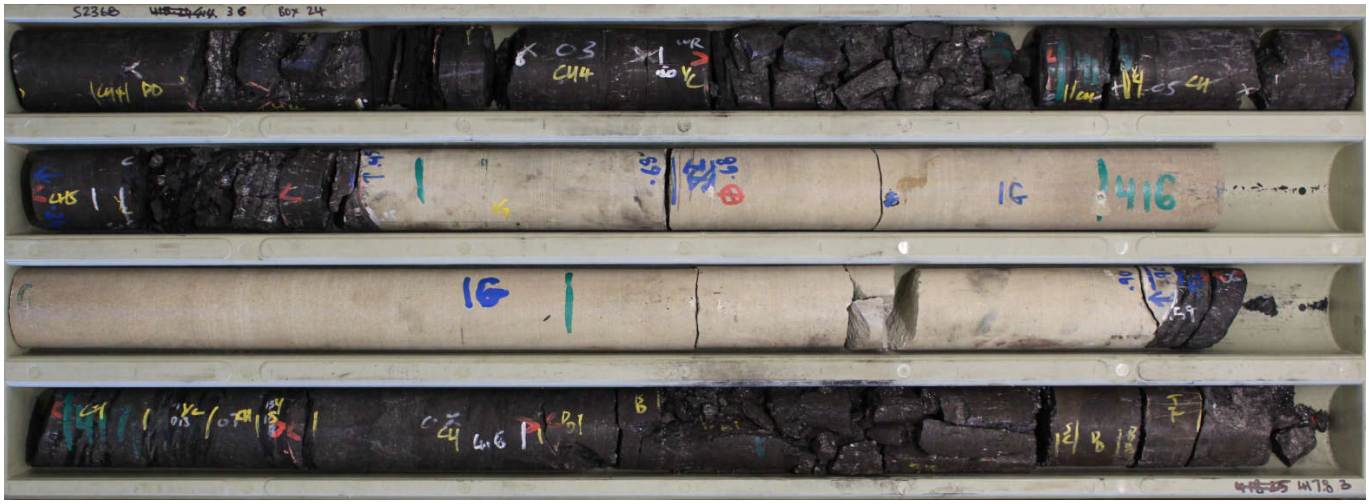

Photo 1: Example fresh dolerite sill in borehole S2368 at approximately 416 m.

Additional drilling and seismic activities are required to refine the extents of sills in Area 5.

To date, there are no sills identified in Area 6. However, the level of exploration in Area 6 is lower than Area 5.

9.3.2 Dykes

There are no regional scale dykes inferred within the study area. However, there are regional scale dykes nearby trending towards Area 6 but terminating approximately 3 km away. South32 have inferred or identified several dykes:

- Dykes A5DNE2 and A5DNW2 in the north-western corner of Area 5 (Drawing 3) are inferred from dykes mapped and projected. Dyke labelled A5DNE2 is based on a 2 m wide dyke mapped 2 km north of Area 5. South32 have projected the dyke along strike intersecting the corner of Area 5 based on the single mapping point only. Confidence in the strike length and orientation of the dyke within Area 5 and near Avon Dam is low.
- A major dyke zone identified north of Dendrobium Areas 1, 2 and 3A is inferred across Area 5 striking east-west. Elsewhere, this dyke zone is characterised by a series of discontinuous dykes over a zone up to 500 m wide.
- East-west striking dykes (A6DEW1 and 2) south of Area 6 are based on mapped underground intersection in the Corrimal workings.
- North-south striking dyke (A6DN1) lies along the eastern edge of Area 5. This dyke also aligns with the regional scale Narellan Lineament (Drawing 8) and associated valley.

Dykes have mostly been inferred from airborne magnetometers. This method has limited success in identifying a contrast between the host rock and the igneous intrusions. This is further complicated in Area 5 where widely spread sills are present.

Photo 2 presents a dolerite dyke intersected in a vertical borehole. The dolerite appears fresh with a sharp contact with the surrounding sandstone. This dyke does not align with inferred dykes but does align with the potential Bulli Fault. Basaltic lavas are generally under pressure when being emplaced, which if sufficiently high, can generate its own fracture network within the host rock (Reference 14). More commonly, lavas exploit existing fractures such as faults and joints, which is likely in the case of the Bulli Fault.

Photo 2: Example of a dolerite dyke intersected in borehole S2393 at approximately 340 m depth.

A5DN1 appears to align with both PSM derived and regional scale lineaments, and the eastern edge of Area 5, indicating the dyke may delineate the economic coal resource. Photo 3 shows a 200 mm wide dyke, located 380 m east of A5DN1 of which the minor dyke parallels. These are strong indicators the dyke extends from seam to surface.

Photo 3: Dyke, approximately 200 mm wide, observed by PSM during site visit.

Apart from A5DN1, large persistent dykes identified within the study area do not align with regional or PSM derived lineaments indicating the identified dykes may not extend to the surface.

9.4 Lineaments

Lineaments are linear features on a surface, such as defined breaks in slope, linear ridges and valleys that may represent an intersection with major structures such as faults, shear zones, dykes, or joints.

Drawing 8 presents the regional lineaments (based on published geological sheets) and lineaments identified by PSM.

9.4.1 Regional Lineaments

Regional lineaments are based on published lineaments, namely the Southern Coalfield 1:100k Geological Map (Reference 12), as presented in Drawing 8. Lineaments crossing the study area include:

- Narellan Lineament – aligns with the eastern edge of Area 5;
- Cordeaux River Lineament – traverses the middle of Area 5; and
- Avon River Lineament – located west of Area 5.

All three regional lineaments strike north-south and align with valleys at the surface.

9.4.2 PSM Lineament Assessment

A lineament assessment has been conducted over the study area to identify potential geological structures not identified in other data sources. The lineament assessment was conducted on topographic surface only which was based on the provided 1 m contour surface. The topographic surfaces were rotated in 3D and viewed from different angles to ensure that major lineaments were identified, and any potential bias was minimised.

The common lineament orientations were found to trend northwest, north, and northeast. Some of identified lineaments align with identified faults, dykes, and regional lineaments

9.4.3 CSIRO Lineaments

The CSIRO conducted lineament assessment of aerial photographs (Reference 8) and Landsat imagery (Reference 9). These plans have been scanned, digitised and presented in Drawing 8. The accuracy of the lineaments is questionable.

Some inferred structures align to lineaments identified by PSM and structures inferred by South32. This may indicate structures that are persistent from seam to surface

Table 2 presents the structures that align with lineaments.

Table 2 – Summary of structures and aligning surficial lineaments

Area	Structure	Aligning Lineament
5	A5FW3	PSM
		CSIRO Air Photo Interpretation
	A5DN1	PSM
	Potential Bulli Fault	CSIRO Air Photo Interpretation
	A5DNW2	CSIRO Landsat Imagery Interpretation
6	A6FNNW2	CSIRO Air Photo Interpretation

9.5 Jointing

Jointing was observed at several exposures across the site during this review. The orientations correspond to the two major joint sets, namely sub vertical joints striking northwest and north (Reference 10). This is consistent with joints mapped in Area 3B to the south of the study area (Reference 14), where northwest striking joints are considered the master joint set, with the north-south striking set being the conjugate set.

The joints observed within the study area were typically planar and often terminated against bedding partings, see Photo 4. Generally, the persistence of joints was no greater than 10 m and spaced, see Photo 5.

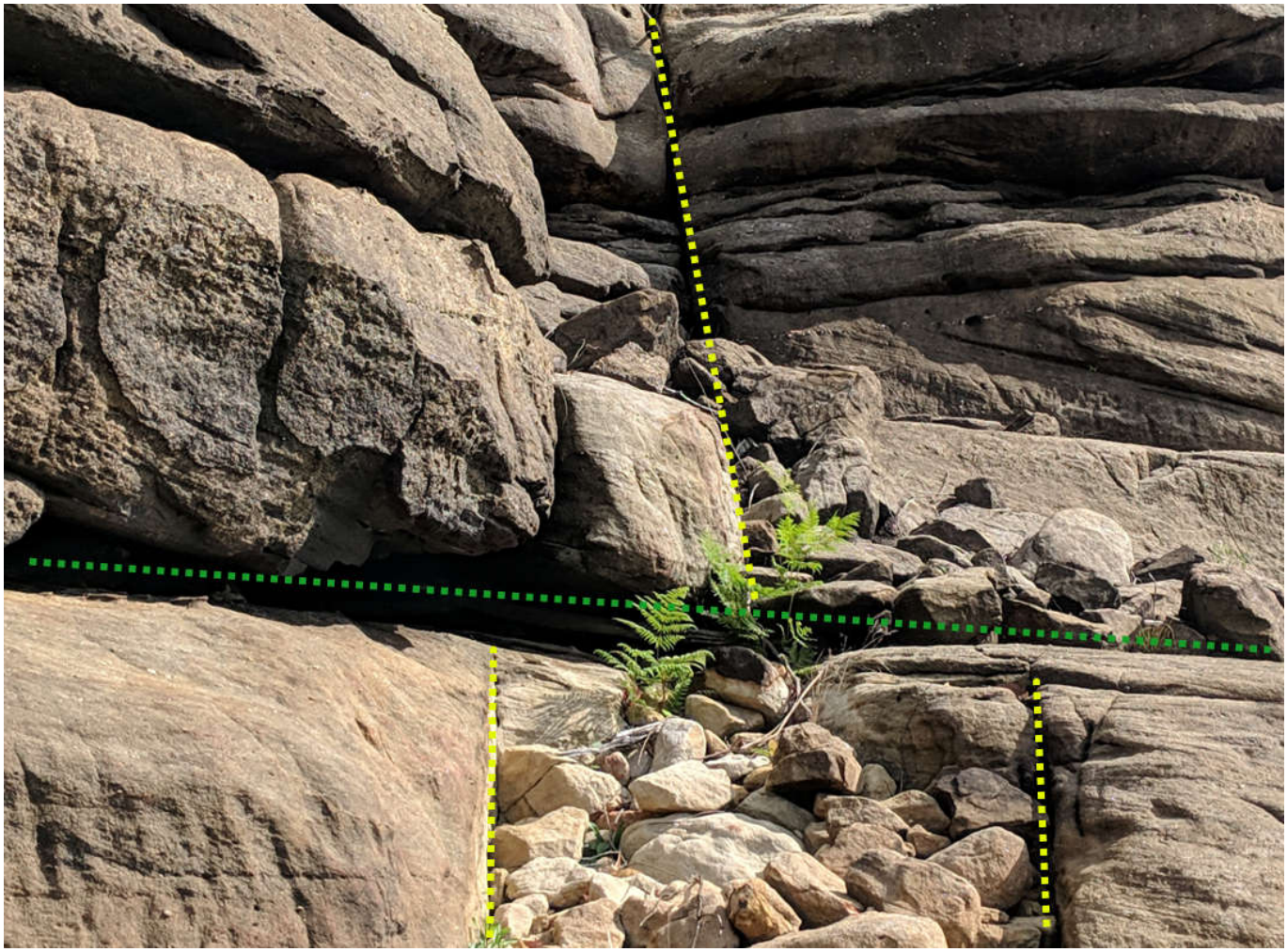

Photo 4: **Sub-vertical joints (yellow) terminating against a horizontal bedding parting (green) near northeast shore of Cordeaux Reservoir.**

Photo 5: **Joints (indicated by yellow arrows) striking northwest spaced approximately 3 m on northwest shore of Avon Reservoir.**

PSM consider it is unlikely that the joints observed at the surface persist to seam level.

10 Potential Interaction between Dams and Mine Subsidence

This section presents the geological structures identified within the study area that could lead to interaction between Areas 5 and 6 mine subsidence and the Avon and Cordeaux Dams and associated reservoirs.

10.1 Assessed potential

Drawing 9 presents all identified and inferred geological structures and mapping points. The following structures cross from the mining area to the dam or reservoir:

- South32 inferred dyke A5DNE2 near Avon Dam – if projected further, may cross Area 5 and Avon Reservoir; and
- PSM derived lineaments A5LNE1 (possible extension of regional scale Unnamed Fault 3) and A5LNE2 – cross Area 5 and Avon Reservoir.

Dyke A5DNE2 inferred across Area 5 is based on a solitary mapping point 2 km north of Area 5. There is no evidence supporting the inference of this dyke across Area 5 or extending to Avon Dam or Reservoir. The structure was not observed in cuttings where the dyke is projected during the site inspection. Based on the lack of evidence, the dyke is unlikely to project into the Avon Dam or reservoir from seam to surface.

The PSM derived lineaments are based on topographic expression only, there is no evidence suggesting these are major geological structures persistent from seam to surface.

Based on the information provided, 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.

11 Recommendations

In order to provide certainty for mine planning, South32 has undertaken surface-based exploration, including boreholes, 2D seismic surveys, and aerial magnetic surveys. The surface-based exploration techniques are used to infer or identify faults, dykes, and sills as a basis for mine planning. The exploration techniques define areas of relatively undisturbed ground suitable for longwall mining, and the location of major structures which delineate mining domains but do not necessarily identify whether structures are hydraulically charged.

In addition to surface-based exploration, Dendrobium relies on in-seam exploration to collect information on the character of geological structures. This exploration activity is conducted during operations; therefore, the information is not available prior to approval for the Project and development of roadways (i.e. approval of the Project would be a prerequisite for the development required to conduct in-seam exploration).

In-seam drilling is routinely undertaken between development roadways and the reservoirs within the DSC Notification Area and exploration is used to define:

- geological structure extent and character - the location (margin and extent) of a geological structure that was not detected by the surface exploration techniques e.g. sills or dykes with no magnetic signature or faults smaller than the resolution of the surface exploration techniques; and
- pore water pressure due to geological structure - whether the area in advance of the development is hydraulically charged due to a geological structure. In-seam drilling is undertaken through standpipes to control high pressures should a zone of high pore water pressure be intersected.

After in-seam drilling has been completed, newly inferred structures are identified and added to the geological model prior the mining of development roadways. The roadways allow access for geological and geotechnical mapping of structures as well as recording water inflow. The mapping enables the extent of the longwall to be further refined by adding additional detail such as fault displacement, sense of movement, or geotechnical instability due to associated jointing.

Recommendations for post Project approval exploration activities for identifying potential structures linking the mining area and reservoirs include:

- Area 5 and Avon Dam and Reservoir:
  - Future exploration boreholes should be inclined towards possible structures and drilled diamond core from surface with televiewer conducted over the entire borehole.
  - Undertake at least one two-dimensional seismic line along the western edge of Area 5. This type of line is more likely to identify previously unidentified structures traversing Area 5 and the Avon Dam structure and Reservoir.
  - Mapping of the Avon Reservoir Full Supply Level (FSL), and around the Avon Dam structure.
- Area 6 and Cordeaux Dam and Reservoir:
  - Future exploration boreholes should be inclined towards possible structures and drilled diamond core from surface with televiewer conducted over the entire borehole.
  - Map the Cordeaux Reservoir FSL, particularly the north shore, and around the Cordeaux Dam structure.
  - Confirm the location of the fault (A6FNNW3) along Area 5 eastern edge.

For and on behalf of
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SENIOR PRINCIPAL

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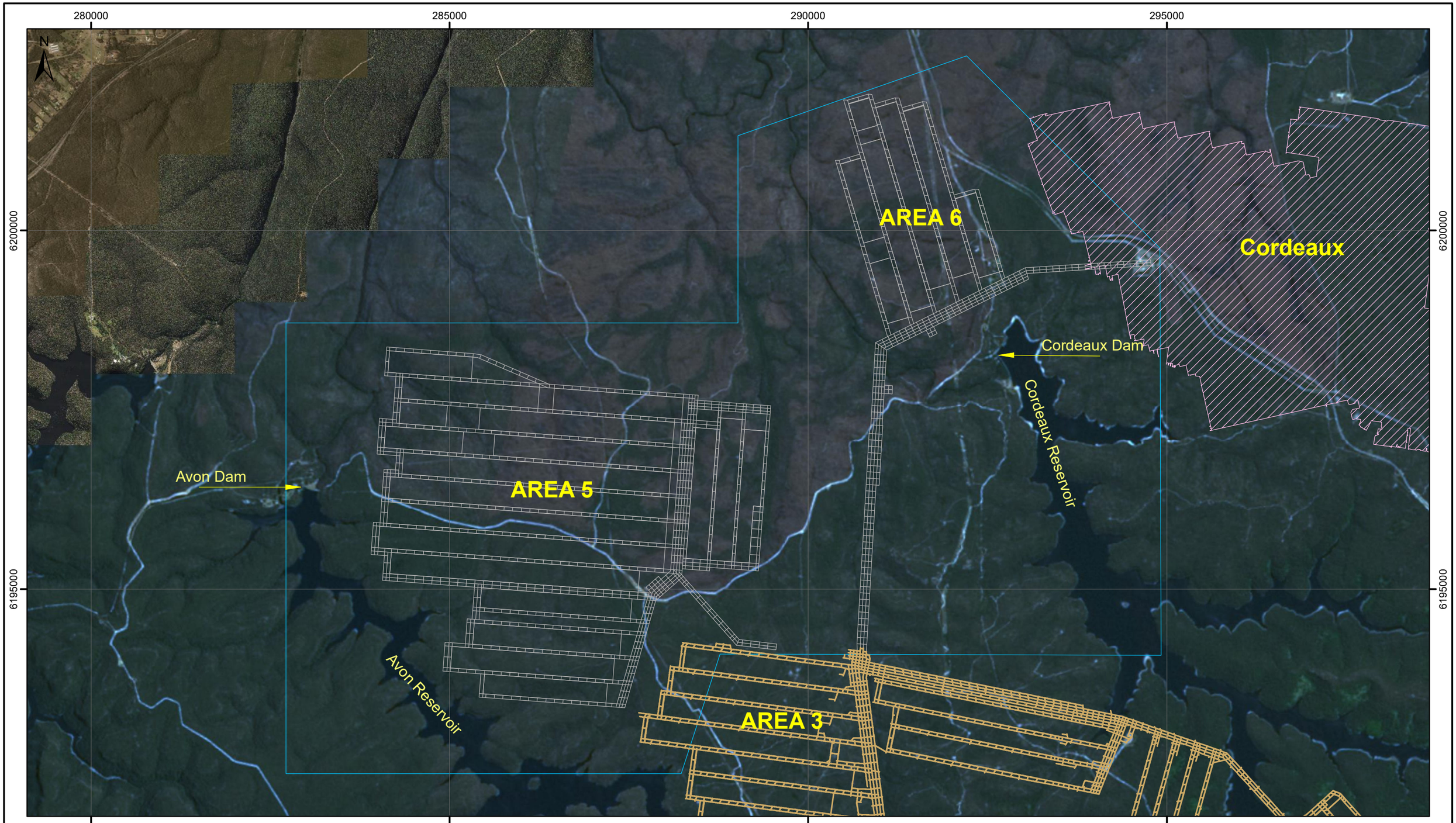
Drawings



Legend

- Dendrobium Mine Workings
- Areas 5 and 6 Proposed Mine Design
- Historic Underground Mine Workings
- Geological Structures Review - Study Area

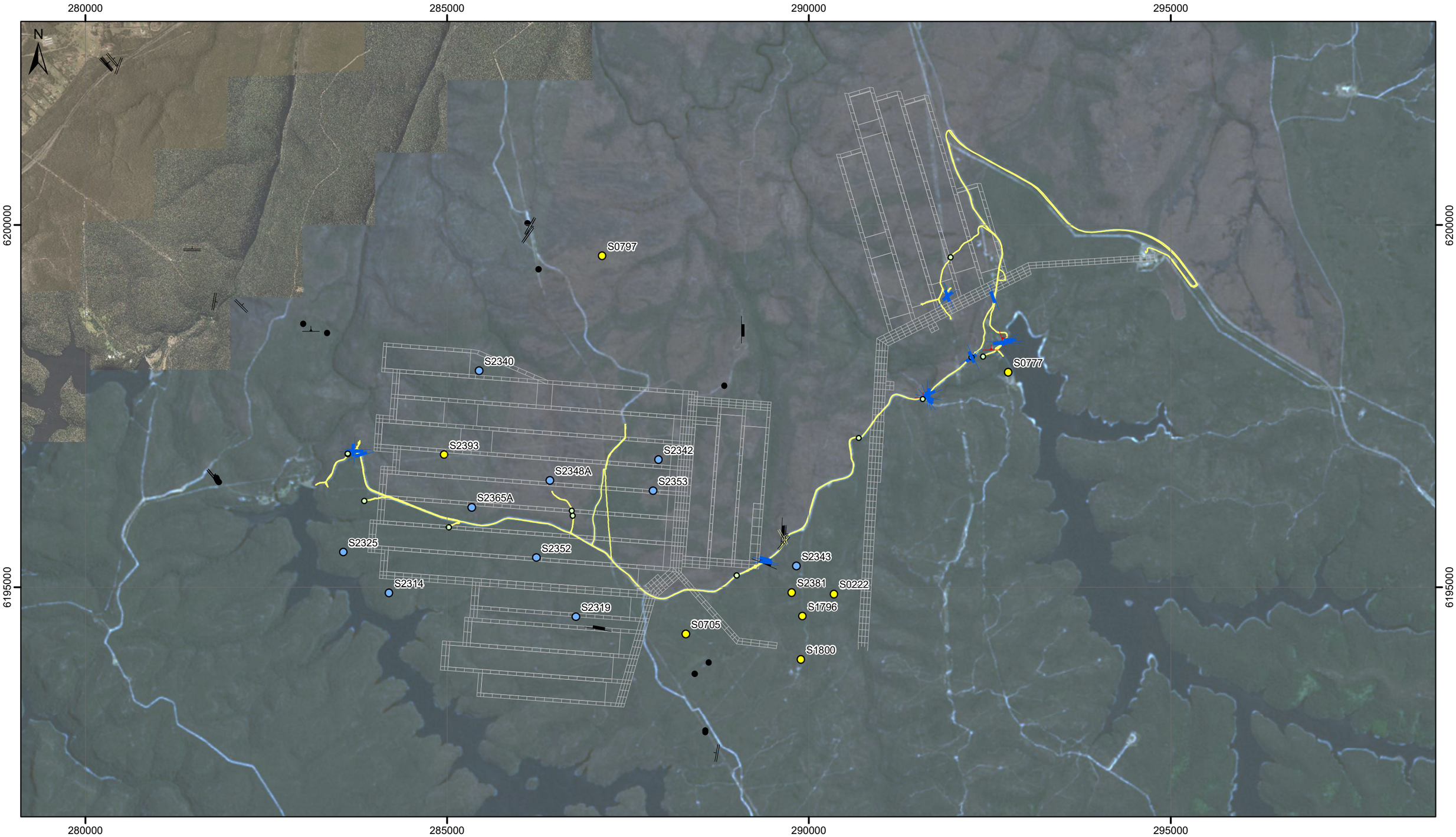
Scale at A3: 1:50,000

0 0.5 1 2 3 4 Kilometers

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

OVERVIEW

PSM3021-007R | Drawing 1



Legend

- PSM Site Inspection Tracklog
- Areas 5 and 6 Proposed Mine Design
- Borehole with Structure (Identified by South32)
- Borehole with Structure (Identified by Others)

PSM Mapping Points

- Observation
- Dyke
- Shear
- Joint

Mapping Points by Others

- Observation
- Dyke
- Fault
- Joint

Scale at A3: 1:50,000

0 0.5 1 2 3 4 Kilometers

P S M

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

STRUCTURE MAPPING POINTS & BOREHOLES WITH STRUCTURE

PSM3021-007R	Drawing 2

Legend

- Areas 5 and 6 Proposed Mine Design
- Dykes (Inferred by South32)
- Bulli Sill
- Bulli Heat Affected
- Published Dykes

PSM Mapping Points
- Dyke

Mapping Points by Others
- Dyke

Scale at A3: 1:50,000

0 0.5 1 2 3 4 Kilometers

P S M

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

IGNEOUS INTRUSIONS

PSM3021-007R | Drawing 3

Legend

Areas 5 and 6 Proposed Mine Design

Published Fold Traces

Scale at A3: 1:50,000

0 0.5 1 2 3 4 Kilometers

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

PUBLISHED FOLD TRACES

PSM3021-007R | Drawing 4

280000 285000 290000 295000

6200000

6195000

N

A6FW1
A6FNE3
Unnamed Fault 2
A6FNNW2
A6FNNW3
A6FNE4
A5NE5
Potential Bull Fault
Rixons/Corrimal Fault
A5FW2
A5FW3
Unnamed Fault 1
A5FW5
A5FNW2
Unnamed Fault 3

Legend

- Areas 5 and 6 Proposed Mine Design
- Faults (Inferred by South32)
- Published Inferred Faults
- Mapping Points by Others
- Fault

Scale at A3: 1:50,000

0 0.5 1 2 3 4 Kilometers

P S M

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

FAULTS

PSM3021-007R | Drawing 5

PSM FAULT ID	FAULT TYPE	DISPLACEMENT (m)	PROVENANCE	PERVASIVENESS
Potential Bulli Fault	Normal	3	Seismic survey, 1 line only; zone of disturbed reflectors rather than distinct displacement	Displacement of Bulli seam. Partially aligns with surficial lineament
A5FNE5	Possibly strike-slip	?	From aeromagnetic data - this feature appears to offset a dyke so was interpreted as a strike-slip fault	?
A5FW5	?	1	S2112 STIS hole and some evidence of structure in S0705	?
A5FNW2	?	0	Seismic sections 2009-C, 2009-A, and 2005-C in Bulli Seam only. In the middle of LW9 and no faulting was observed during mining the Wongawilli Seam; Seismic anomaly probably sill related	Low
A5FW2	?	Minor	2010 2D Seismic Survey - low confidence	
A5FW3	Normal	2-3	Projection from underground mapping at Kemira Workings (Bulli Seam)	Displacement of Bulli seam. Partially aligns with surficial lineament

Legend

Areas 5 and 6 Proposed Mine Design

Faults (Inferred by South32)

Scale at A3: 1:30,000

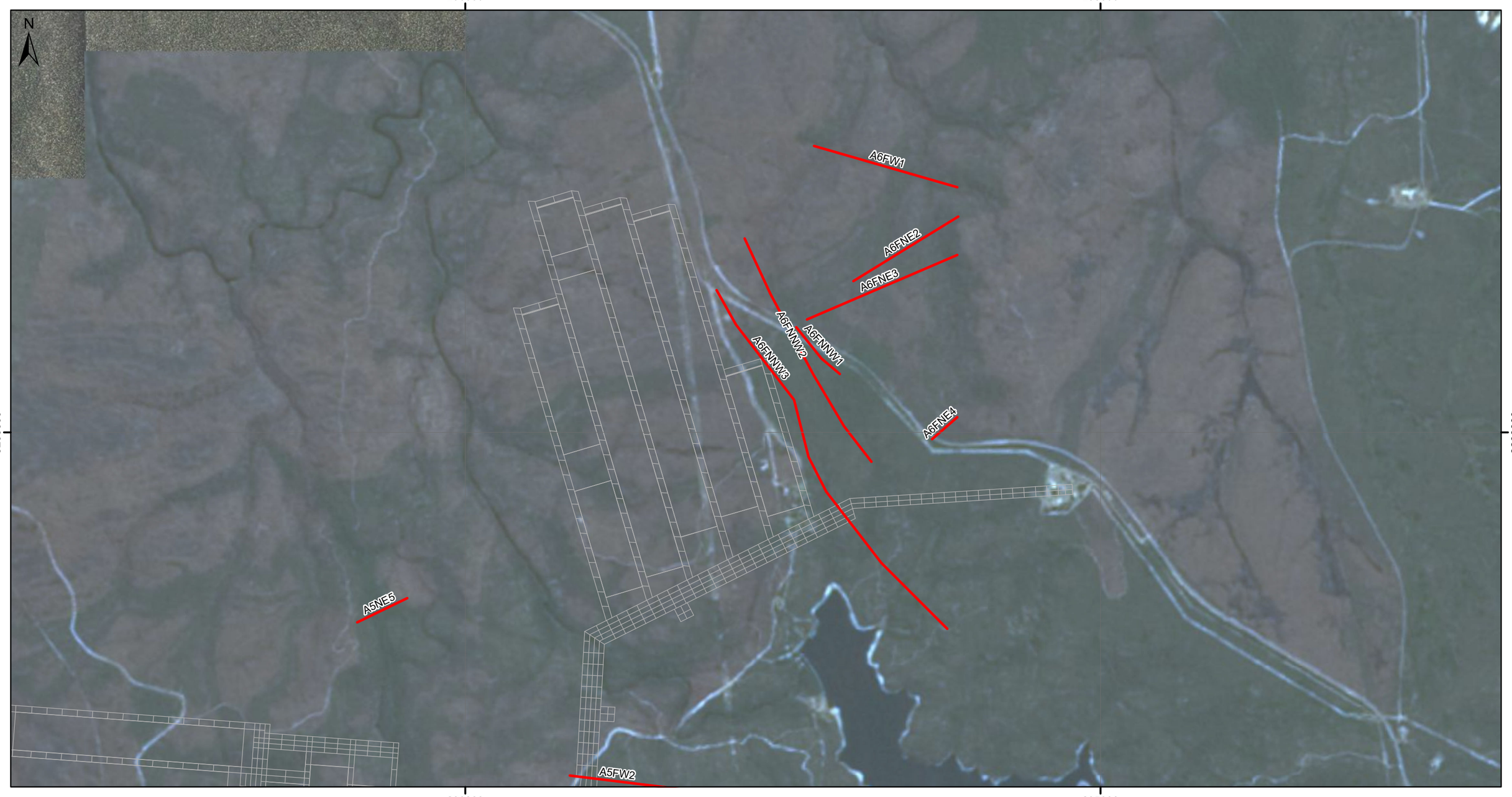
0 0.3 0.6 1.2 1.8 2.4 Kilometers

P S M

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

AREA 5 - INFERRED FAULTS

PSM3021-007R | Drawing 6



PSM FAULT ID	FAULT TYPE	DISPLACEMENT (m)	PROVENANCE	PERVASIVENESS
A6FW1	Normal	5-8	Cordeaux record tracings and 1994 2D seismic data	Known strike length of 7 km a Bulli Seam level. Existence on surface is unknown
A6FNE2	?	?	Associated with dyke - possible from South Bulli workings mapping	?
A6FNE3	Normal	0.2-1.2	UG Mapping at Cordeaux Workings (Bulli Seam)	Mapped in Bulli Seam; Associated with dyke; presence in Wongawilli Unknown; Not observed at surface
A6FNE4	Normal	0.1-1.1	UG Mapping at Cordeaux Workings (Bulli Seam)	Mapped in Bulli Seam; Associated with dyke; presence in Wongawilli Unknown; Not observed at surface
A6FNNW1	Normal	5 - 30	1990 & 2011 2D Seismic Surveys	Displacement of Bulli and Wongawilli Seams; Not observed on surface
A6FNNW2	Normal	5 - 30	1990 & 2011 2D Seismic Surveys	Displacement of Bulli and Wongawilli Seams; Partially aligns with surficial lineament
A6FNNW3	Normal	8 - 10	1990 & 2011 2D Seismic Surveys	Displacement of Bulli and Wongawilli Seams; Not observed on surface

Scale at A3: 1:30,000

0 0.3 0.6 1.2 1.8 2.4 Kilometers

Legend

Areas 5 and 6 Proposed Mine Design

Faults (Inferred by South32)

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

AREA 6 - INFERRED FAULTS

PSM3021-007R | Drawing 7

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Avon River Lineament

Nepean River Lineament

Nepean River Lineament

Cordeaux River Lineament

Narellan Lineament

Avon River Lineament

A5LINE1

Cordeaux River Lineament

Nepean River Lineament

Nepean River Lineament

Mt. Burke Dome

A5LINE2

Legend

- Areas 5 and 6 Proposed Mine Design
- CSIRO Landsat Imagery Interpretation Lineaments
- CSIRO Air Photograph Interpretation Lineaments
- PSM Derived Lineaments
- Published Lineaments

Scale at A3: 1:50,000

0 0.5 1 2 3 4 Kilometers

P S M

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6

LINEAMENTS

PSM3021-007R | Drawing 8

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6200000

6195000

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AREA 6

AREA 5

A6FW1
A6FNE3
A6FNNW2
A6FNNW3
A6FNE4
A6DEW1
A6DEW2
A5DN1
A5DNE1
A5DNW2
A5DNE2
Potential Bulli Fault
A5FW2
A5FW3
A5LNE1
A5LNE2
A5DNW1
A5FW5
A5FNW2

Cordeaux Dam
Cordeaux Reservoir
Avon Dam
Avon Reservoir

Legend

- Areas 5 and 6 Proposed Mine Design
- Dykes (Inferred by South32)
- Faults (Inferred by South32)
- Published Dykes
- Rivers
- Tributaries
- Dams
- Stream Mapping
- Swamps
- Mapped Waterfall

Scale at A3: 1:50,000

0 0.5 1 2 3 4 Kilometers

PSM

South32 Illawarra Coal
Geological Structures Review
Area 5 & 6
POTENTIAL GEOLOGICAL STRUCTURE INTERACTION WITH DAMS/RESERVOIRS

PSM3021-007R | Drawing 9

Appendix A
Data provided by South32

Area5_MGA

Area6_MGA

Dendrobium Area 2 Geology report

Dendrobium Reservoir Mapping

Dendrobium Surface Mapping 1.2

Och et al AJES 2009 Sydney region faulting and volcanism

Overburden geology of Dendrobium 5 and 6 ver 1.0

South32 Mafic Intrusions consultancy report Part A March 2018

South32 Mafic Intrusions consultancy report Part B S2309 petrography 2018

South32 Mafic Intrusions consultancy report Part C (2)

South32 Mafic Intrusions consultancy report Part D

Shape Files DND rpt

Televiewer Interpretation
S2319_SAS_SCT
S2323_SAS_SCT
S2333_SAS_SCT
S2342_SAS_SCT
S2344_SAS_SCT
S2345_SAS_SCT
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