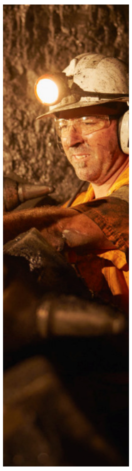

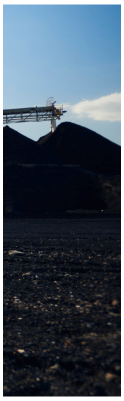


Ashton-Ravensworth Underground Mine Integration Modification

Ravensworth Underground Mine Modification Report

APPENDIX A

Subsidence Review

RAVENSWORTH UNDERGROUND
GLENCORE

YANCOAL
兖煤澳大利亚有限公司

Strata Control Technology

Ravensworth Underground Mine

Subsidence Review

ASH5348

Mining Research and Consulting Group

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REPORT TO Phillip Brown
Environment and Community Relations Superintendent
Ashton Coal Operations Pty Ltd
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TITLE Ravensworth Underground Mine: Subsidence Review

REPORT NO ASH5348

PREPARED BY Stephen Wilson
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DATE 8 November 2021

Stephen Wilson
Mine Planner

Report No	Version	Date
ASH5348	Draft1	7 September 2021
ASH5348	Draft2	27 September 2021
ASH5348	Draft3	19 October 2021
ASH5348	Final	4 November 2021
ASH5348	Rev1	8 November 2021

Ken Mills
Principal Geotechnical Engineer

SUMMARY

The Ashton Underground Mine is operated by Ashton Coal Operations Pty Ltd (ACOL), a wholly owned subsidiary of Yancoal Australia Ltd and the Ravensworth Underground Mine (RUM) is owned and operated by Resource Pacific Pty Ltd. The Ashton Underground Mine and RUM are neighbouring underground coal mining operations located approximately 14 kilometres northwest of Singleton in the Hunter Valley of New South Wales. The Ashton Underground Mine has development consent for underground longwall mining in four seams and RUM has development consent for mining in multiple seams but has been in care and maintenance since 2014 following completion of Longwall 9 in the Pikes Gully Seam.

ACOL is seeking to modify the development consents for both mines to allow Ashton Underground Mine to extend operations into the RUM lease area to extract approved coal reserves in the Pikes Gully and Middle Liddell Seams at RUM. ACOL commissioned SCT Operations Pty Ltd (SCT) to undertake a review of the expected subsidence effects and impacts from the proposed mining and prepare this report to support applications to modify the development consents for both Ashton Underground Mine and RUM.

Our review indicates the mining layout proposed represents a smaller footprint than the footprint approved in Modification 9 to Development Consent DA104/96 for RUM. Impacts from the proposed mining are expected to be compliant with the performance measures in DA104/96.

The magnitudes of subsidence effects are likely to be greater than previously forecast in some areas and less in other areas. The changes to magnitudes of subsidence effects are a result of a combination of subsidence monitoring conducted since the subsidence assessment for DA104/96 was prepared in 2012, physical changes to the site, and advances in the understanding of multi-seam subsidence behaviour since 2012. The greater subsidence effects do not necessarily result in greater impacts and consequences because the areas of greater subsidence are on rehabilitated areas of the now completed Ravensworth Narama open cut mine.

No increase in impacts to natural and built features is expected from the proposed mining compared to those previously predicted. Almost all the built features and infrastructure within the assessment area for the proposed mining are owned by Glencore or AGL Energy Ltd. The impacts to all features are expected to be minor and manageable. No additional risk to public safety is expected.

SCT recommends subsidence monitoring, subsidence management processes, risk assessments, geotechnical assessment and subsidence assessments that are consistent with the statement of commitments and conditions in DA104/96 continue to be appropriate for the modified RUM layout.

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1. INTRODUCTION

The Ashton Underground Mine is operated by Ashton Coal Operations Pty Limited (ACOL), a wholly owned subsidiary of Yancoal Australia Ltd and the Ravensworth Underground Mine (RUM) is owned and operated by Resource Pacific Pty Ltd. The Ashton Underground Mine and RUM are neighbouring underground coal mining operations located approximately 14 kilometres northwest of Singleton in the Hunter Valley of New South Wales (NSW). The Ashton Underground Mine has development consent for underground longwall mining in four seams and RUM has development consent for mining in multiple seams but has been in care and maintenance since 2014 following completion of Longwall (LW) 9 in the Pikes Gully (PG) Seam.

ACOL is seeking to modify the development consents for both mines to allow Ashton Underground Mine to extend its underground operations into the RUM lease area to extract approved coal reserves in the PG and Middle Liddell (MLD) Seams at RUM. ACOL commissioned SCT Operations Pty Ltd (SCT) to undertake a review of the expected subsidence effects and impacts from the proposed mining and prepare a report to support applications to modify the development consents for both Ashton Underground Mine and RUM. This report is structured to provide in:

- Section 2: A site description, with background on the proposed modifications, including relevant information and a comparison of approved and proposed mining geometries, and a general description of significant surface feature within the Assessment Area.
- Section 3: A review of the existing subsidence assessments for single and multi-seam mining at RUM with reference to the subsidence monitoring database for the site incorporating any relevant information obtained since approval was granted.
- Section 4: Revised forecast of subsidence effects and assessment of impacts based on the proposed mining geometry, changes to the site (e.g. surface topography) and advances in the understanding of multi-seam subsidence since approval was granted.
- Section 5: A review of the potential for impacts from interaction between underground longwall and open cut surface mining operations due to revised longwall timeframes.
- Section 6: An overview of the recommended subsidence assessment and monitoring.
- Section 7: Conclusions and recommendations.

Figure 1 shows an overall site plan with the existing longwall voids in the PG, Upper Liddell (ULD) and Upper Lower Liddell (ULLD) Seams at Ashton Underground Mine and PG Seam at RUM, the proposed longwall layouts relative to the approved longwall voids for the PG and ULD/MLD Seams at RUM and surface features. An Assessment Area based on an angle of draw of 26.5° (equal to 0.5 times depth) over natural ground and 45° (equal to 1.0 times depth) over waste rock fill material is also shown.

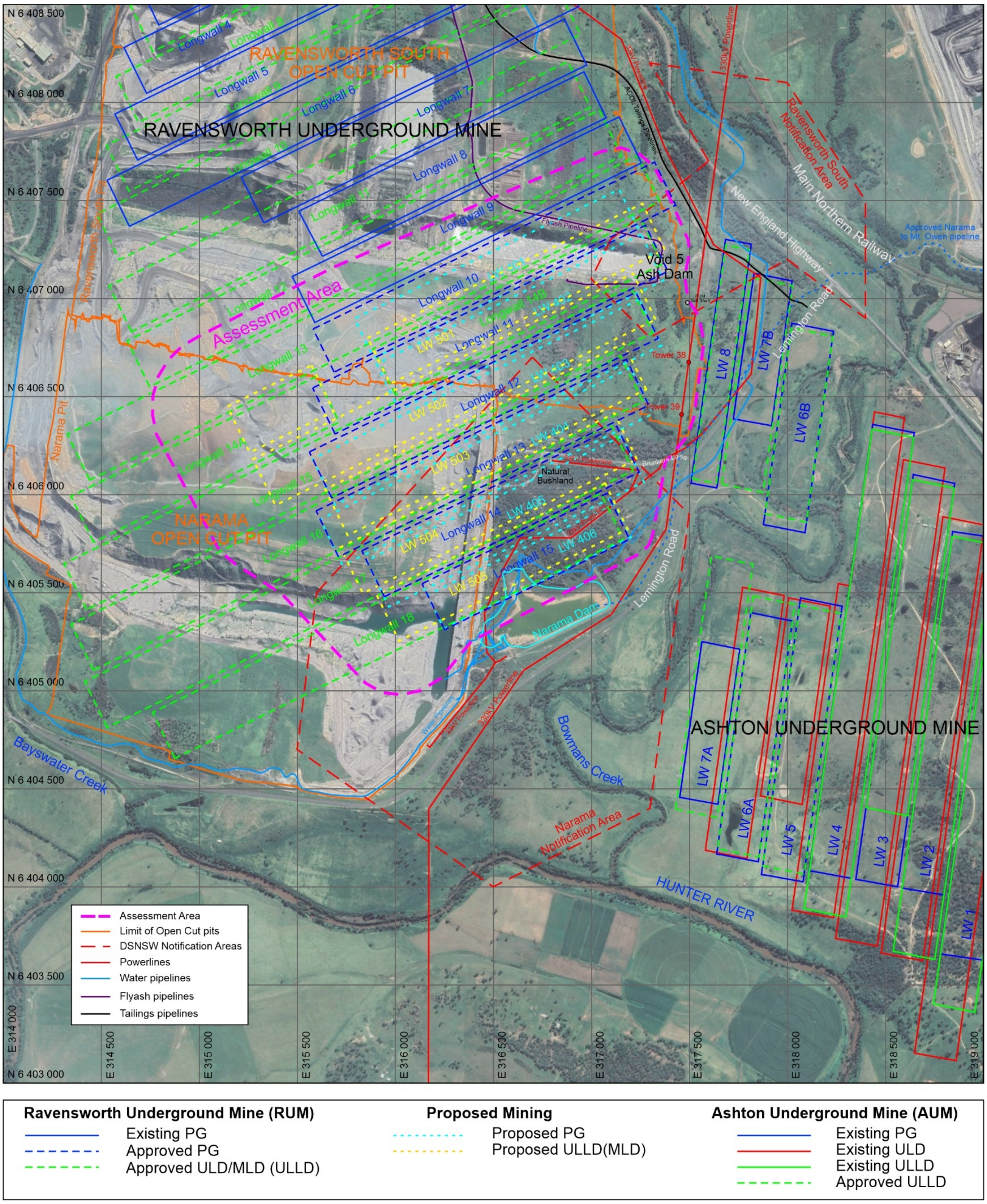

Figure 1: Overall site plan showing existing, approved and proposed longwall voids relative to surface features.

Any subsidence effects or impacts outside the Assessment Area are expected to be imperceptible for all practical purposes.

The subsidence effects and impacts to surface features are estimated and assessed in the context of the subsidence impact performance measures, and the statement of commitments pertaining to subsidence from Modification 9 (MOD9) to development consent DA104/96 for the RUM. Subsidence impacts are also assessed in consideration of the requirements under the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* to manage risks to health and safety associated with subsidence.

This report presents the results of our review to satisfy the supplied scope of works. It is envisaged that a detailed assessment would also be undertaken as part of a revision to the approved Subsidence Management Plan (SMP) for the PG Seam longwalls that re-assesses impacts of the Pikes Gully extraction only, should the application for modification be successful. A new Extraction Plan (EP) would also be required for the MLD Seam longwalls.

2. BACKGROUND AND SITE DESCRIPTION

This section provides background and a description of the site including the existing and proposed longwall geometries at Ashton Underground Mine and RUM.

Figure 1 shows the existing approved and proposed mining in the various seams. This overall site plan shows the existing longwall voids in the PG, ULD Seam and the ULLD Seam at Ashton Underground Mine and PG Seam at RUM, and the approved longwall voids for the PG and ULD/MLD Seams at RUM. The MLD Seam at RUM is equivalent to the ULLD Seam at Ashton Underground Mine. To avoid confusion, this seam is referred to as the ULLD(MLD) Seam.

For clarity, the proposed mining in each seam is shown in separate figures. Figure 2 shows the existing and approved longwall voids in the PG Seam at RUM relative to the proposed PG Seam longwall voids. Figure 3 shows the approved longwall voids in the ULD and ULLD(MLD) Seams at RUM relative to the proposed ULLD(MLD) Seam voids

These layouts are superimposed onto a recent (June 2021) aerial image of the area with surface features of relevance and the Assessment Area based on an angle of draw of 26.5° (equal to 0.5 times depth) over natural ground and 45° (equal to 1.0 times depth) over waste rock fill material from the deepest, outermost goaf edge in both seams.

An Assessment Area of this size is considered conservative for the identification of features likely to be affected by subsidence movements from the proposed mining and for impact assessment purposes. No perceptible subsidence effects or impacts are expected outside the Assessment Area.

2.1 Background

ACOL is seeking to modify the development consents for both mines to allow Ashton Underground Mine to extend its underground operations into the RUM lease area to extract approved coal reserves in the PG and MLD Seams at RUM.

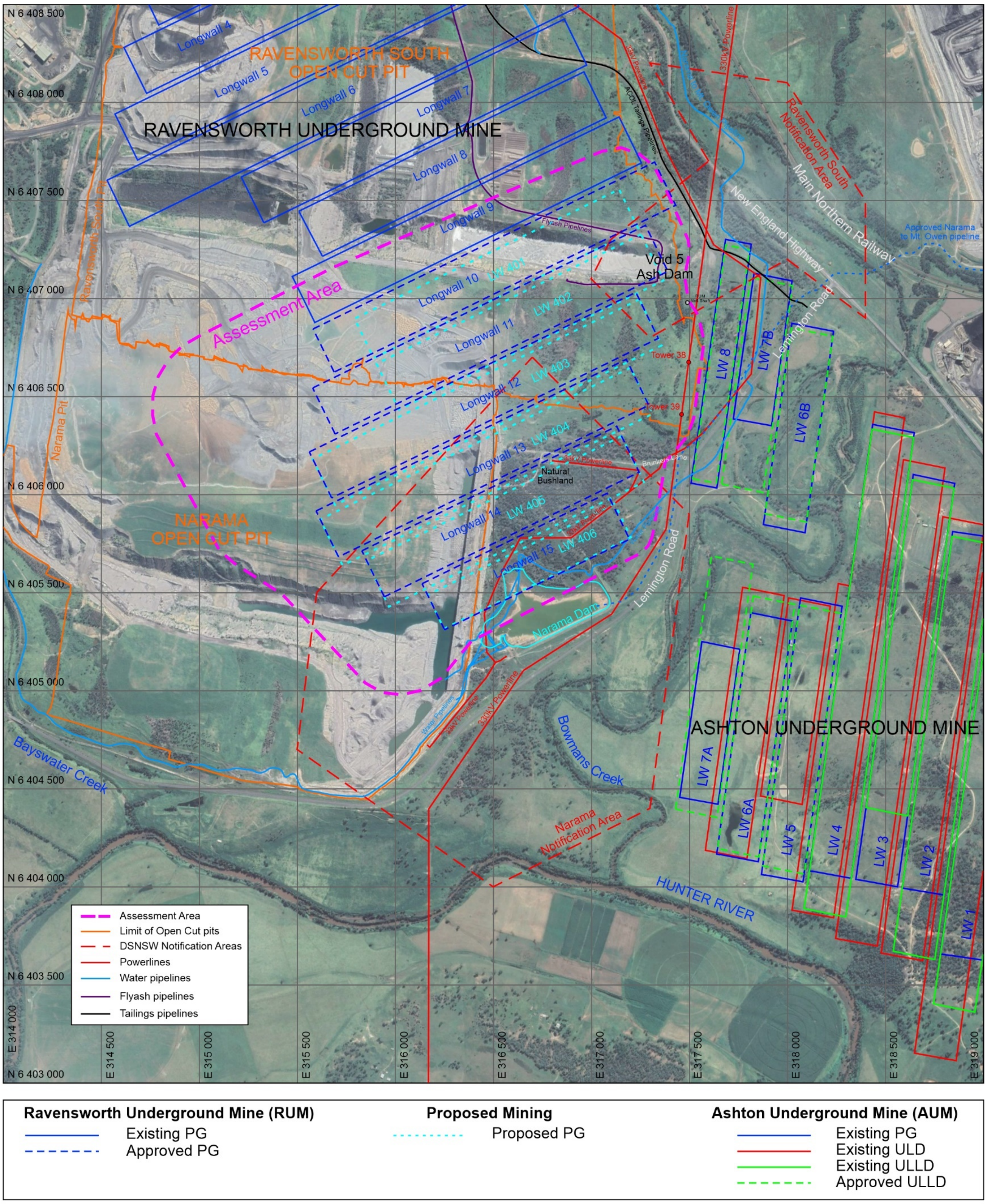

Figure 2: Overall site plan showing existing, approved and proposed PG Seam longwall voids at RUM.

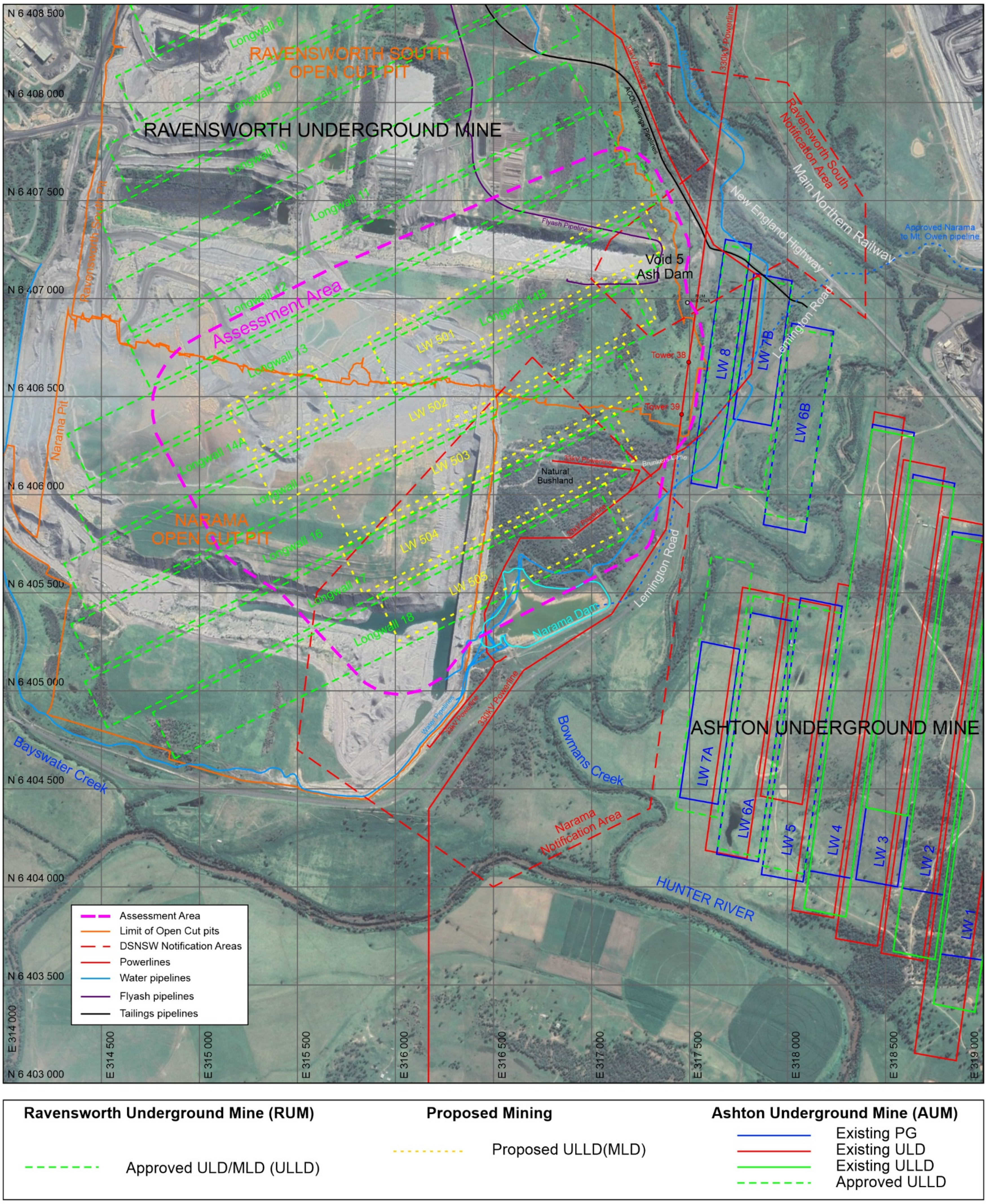

Figure 3: Overall site plan showing existing, approved and proposed ULLD (MLD) Seam longwall voids at RUM.

ACOL operates the Ashton Underground Mine under modified development consent DA 309-11-2001i for the Ashton Coal Project (ACP). The ACP includes the underground longwall mining of four seams. ACOL has mined, in descending order, the PG and ULD Seams, is currently mining the ULLD Seam and plans to mine the Lower Barrett (LB) Seam. The completed seams have all been mined within the existing Ashton Underground Mine lease area.

Eight longwalls were mined in the PG Seam, six longwalls in the ULD Seam were mined and currently the fifth longwall (LW205) in the ULLD Seam is in operation. ACOL is not seeking to modify the ACP longwall layout under the proposal.

Glencore operated RUM under modified development consent DA104/96. RUM has approval for Longwalls 1 to 15 in the PG Seam. However, underground operations ceased after the completion of Longwall 9 in 2014. The mine was then placed into care and maintenance.

The approved RUM includes underground longwall mining within the Lemington (B and C), PG, ULLD(MLD) and Barrett coal seams. PG Longwall panels 1-9 at the RUM have been mined prior to the RUM entering care and maintenance in 2014. Longwall mining has not commenced in the Lemington, ULLD(MLD) or Barrett coal seams.

2.2 Mining Geometry

The proposed modification involves Ashton Underground Mine mining the approved longwalls in the PG Seam at RUM and longwalls below in the ULLD(MLD) Seam. The proposed multi-seam mining layout is designed with offset panel geometries.

The unmined area of the current RUM lease, subject to this proposed modification, is adjacent to the existing PG, ULD and ULLD Seam workings of Ashton Underground Mine.

Under the proposed modification, the six PG Seam longwall panels to be mined at RUM are referred to as Longwalls 401-406. These panels were previously approved as PG Longwalls 10-15 at RUM. The five ULLD(MLD) longwall panels are referred to as Longwalls 501-505. These panels are generally within the area approved for ULLD(MLD) Longwalls 13-18 at RUM. Longwalls 501-505 are 800-1400 metres (m) shorter at the western end than Longwalls 13-18.

Both Longwalls 401-406 and Longwalls 501-505 and within the southern edge of the approved RUM mining footprint for each seam.

The longwall panel sequence is from north to south, and the mining directions is from west to east.

The proposed mining plan for the modification is designed to keep the mines physically separated. The mining layout for the PG Seam leaves a narrow barrier of coal between Ashton Underground Mine and RUM. No longwall extraction is planned below the existing PG Seam Longwalls 1 to 9 at RUM. First workings development roadways in the ULLD(MLD) Seam are proposed below existing PG Seam workings at RUM but not below any PG Seam longwall extraction areas.

SCT understands the overall mining sequence would be, the ULLD (MLD) Seam at Ashton Underground Mine, the PG and ULLD(MLD) Seams at RUM followed by the LB Seam at Ashton Underground Mine.

The proposed longwall panels for the PG Seam are of a similar or narrower width. Longwall 401 is 22m narrower to allow for a barrier against the existing RUM longwalls to separate the mines. Longwall 406 is 70m narrower to keep within the approved footprint. The proposed PG Seam longwall panels are either shorter in length or of similar length. The proposed ULLD(MLD) Seam panels are the same width as the approved geometry but substantially shorter than the approved. Table 1 summarises the approved and proposed geometries.

Table 1: Comparison of Approved and Proposed Longwall Geometries

Approved for RUM			Proposed for modified RUM		
PG Seam					
Panel	Width (m)	Length (m)	Panel	Width (m)	Length (m)
LW10	245	1945	LW401	223	1505
LW11	261	1895	LW402	261	1505
LW12	261	1860	LW403	261	1860
LW13	261	1765	LW404	261	1765
LW14	261	1450	LW405	261	1450
LW15	261	1055	LW406	191	1065
ULLD(MLD) Seam					
LW14	261	3235	LW501	261	2360
LW15	261	3220	LW502	261	2160
LW16	261	3125	LW503	261	1700
LW17	261	2990	LW504	261	1560
LW18	261	2550	LW505	261	1300

Nominal mining heights for the proposed layout is assumed to be 2.3m in the PG Seam and 2.8m in the ULLD(MLD) Seam. The interburden thickness between the PG and the ULLD(MLD) Seams ranges from approximately 50m to 75m in the subject area but is typically 60m to 70m.

Most of the proposed mining area, 83% of the total 294 hectares (ha), is located below the now completed and substantially backfilled Ravensworth South and Narama opencut mines. The remaining 49ha is located below natural ground where the overburden strata has not been disturbed or modified by opencut mining. This surface land has been partially cleared by mining related activities and infrastructure (e.g. access roads, pipelines and part of the Narama Dam).

Ravensworth South and Narama open cut mines both mined to the floor of the Bayswater Seam. The overburden thickness from the shallowest PG Seam to the as-mined floor of the Bayswater Seam ranges from 150m to 160m.

In the area of natural ground, undisturbed by opencut mining, the thickness of overburden strata to the PG Seam ranges from 190m to 240m.

The maximum overburden depth including waste rock backfill is approximately 315m for the PG Seam and 375m for the ULLD(MLD) Seam. The thickness of waste rock fill above the proposed PG Seam longwall mining areas ranges from zero, over natural ground, up to 160m, with the greatest depth being over areas of Narama Pit currently being rehabilitated. The thickness of waste rock fill material reaches a maximum of approximately 175m over the backfilled Narama Pit in an area where only the ULLD(MLD) is proposed to be mined.

2.3 Surface Features

The longwall panels shown in Figures 1-3 are superimposed onto a recent (June 2021) aerial image of the area that shows surface features. Figure 4 focuses on the area of proposed mining layout for the modification.

The majority of the surface above the proposed mining is significantly modified by previous and minor ongoing open cut mining activities. Surface features of relevance to this assessment include:

- the back-filled topography within the Ravensworth South Pit, (also known as the Ravensworth No 2 Pit or Bayswater Pit);
- the Void 5 Dam within the Ravensworth South Pit currently being filled with fly ash from nearby power stations;
- the completed Narama Pit currently being back-filled and rehabilitated but also used as a water storage facility;
- approximately 44ha of bushland, within the 49ha of natural ground, where seven extant Aboriginal heritage scatter sites are located;
- Narama Dam, designed as a nominally 1,000 megalitres (ML)[1] water storage facility (but maximum capacity is now 561ML) and is a licensed discharge point;
- pumping equipment, pipelines, overhead 33 kilovolt (kV) powerlines and other mining related infrastructure, including a ventilation shaft for RUM; and
- a 330kV electricity transmission line.

The land above the proposed mining is owned by Glencore and AGL. The land is used primarily for mining related activities and ash disposal activities associated with power generation.

AGL is currently filling Void 5 above the Ravensworth South Pit with fly ash from nearby power stations. The Void 5 Dam wall was constructed in 2014. The discharge line and discharge infrastructure are located over Longwalls 402 and 501.

[1] The maximum design storage volume of the dam is 1,000 ML however, the storage limit was reduced to 700 ML to reduce seepage from the dam and then further reduced to 561 ML to account for the second spillway adjacent to the Narama Void.

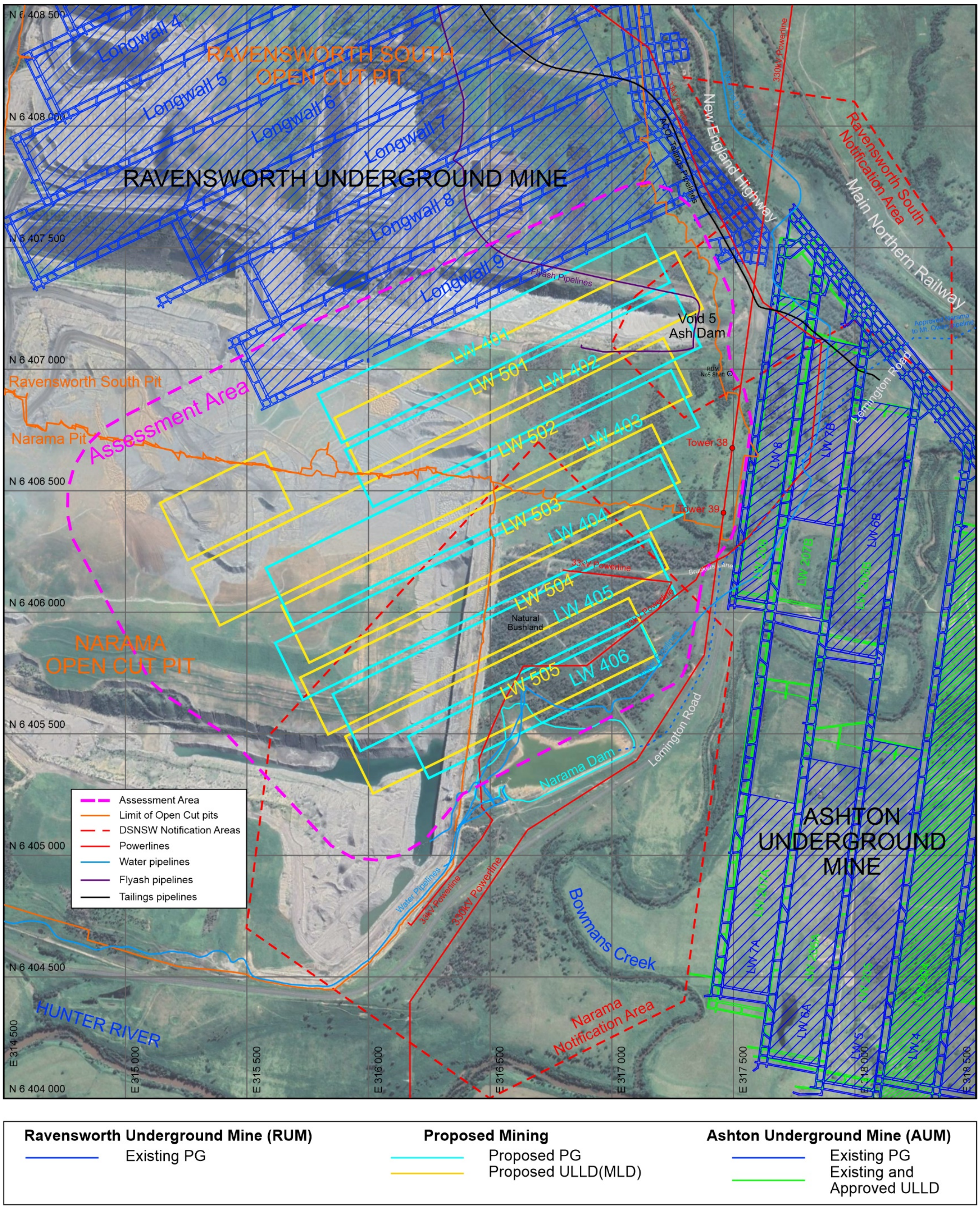

Figure 4: Details of proposed longwall voids for the PG and ULLD (MLD) Seams.

The remaining void of the Narama Pit is also being back filled with waste rock and is used as a water storage. Other areas of the Narama Pit are being progressively back filled with waste rock material and rehabilitated.

The small area of natural ground is located immediately to the north of the Narama Dam. Aboriginal heritage artefact scatter sites are located on this land. SCT understands that there are seven extant artefacts overlying or adjacent to PG Longwalls 405 and 406 (i.e. the most southern two longwalls).

The Narama Dam wall is located southeast of the Assessment Area. This dam is used for water storage and as a licensed discharge point. An arm of the reservoir extends into the Assessment Area.

Both the Narama and Void 5 dams are declared dams under the Dams Safety Regulation 2019 administered by Dams Safety NSW (DSNSW). Mining in the PG Seam within the notification areas around these dams was previously consented to by DSNSW and approved by the Director, Mine Safety Operations (Chief Inspector of Coal Mines - CICM).

The 330kV powerline owned by TransGrid is the only public utility or amenity located within the Assessment Area. Towers 38 and 39 are located on back-filled waste rock material within the boundary of the Ravensworth South Pit. The tower foundations on this section of line were designed to accommodate the ground movements associated with subsidence from the proposed mining. They are located between 0.5 and 1.0 times depth from the nearest RUM longwall panels and at 0.5 times depth from Longwall 8 at Ashton Underground Mine.

There are no farmland and facilities, industrial, commercial, or business establishments and no residential establishments within the Assessment Area.

Other built features above the proposed mining are infrastructure owned by Glencore, AGL or ACOL. These features include:

- sections of overhead 33kV powerlines servicing pumping stations
- sections of a number of pipelines for water, tailings and fly ash delivery
- RUM No 5 Ventilation Shaft that was constructed ahead of mining the main headings at RUM but has not yet been intersected and is currently capped
- gas drainage, ventilation and dewatering infrastructure that have yet to be constructed.

2.4 Surface Features Not Impacted

The features described in this section are outside the Assessment Area but in the general vicinity. They are included for completeness, but no subsidence impacts are expected, and they are not discussed further in this report.

The ACOL tailings disposal pipelines cross the surface outside the Assessment Area to the north.

Lemington Road and Brunkers Lane intersection, a Telstra telecommunications cable and Ravensworth Operations fibre optic cable to the east of Lemington Road are all located to the east of the Assessment Area and remote from the proposed mining.
Natural and built features detailed in the subsidence impact performance measures in DA104/96 are remote from the proposed mining. These include:

- the watercourse and alluvium of Bowmans Creek, Bayswater Creek, and the Hunter River (Bowmans Creek alluvium boundary enters the Assessment Area, but the zone of saturated alluvium does not)
- New England Highway and adjacent infrastructure
- Main Northern Railway.

None of these features are expected to be impacted by mining subsidence from the proposed extraction of Longwalls 401-406 and 501-505.

3. REVIEW OF PREVIOUS SUBSIDENCE ASSESSMENTS FOR RUM

The most recent subsidence assessments of relevance to the proposed modifications include:

- SCT Report RAV3737 dated March 2012 "Multi-seam assessment for MOD9" (SCT 2012).
- SCT Report RAV4186 dated December 2013 "Single seam SMP assessment for LW10-15 in PG Seam" (SCT 2013).

This section reviews the previous subsidence assessments conducted for RUM. The findings from those two reports are discussed below.

3.1 RAV3737 - MOD9 Multi-Seam Assessment

The MOD9 subsidence assessment presented in SCT Report RAV3737 was divided into four areas based on the composition of the overburden strata and previous mining.

1. A few small areas of single seam mining where there is no waste rock backfill.
2. Single seam mining below waste rock backfill.
3. Multi-seam mining in two seams where there is no waste rock backfill.
4. Multi-seam mining in two seams below waste rock backfill.

The mining height was assumed to be 2.6m in the PG Seam and 2.6m in the ULLD(MLD) Seam.

3.1.1 Subsidence

Maximum subsidence in single seam areas below natural ground with no waste rock backfill was expected to range 50-65% of seam thickness mined or 1.3-1.7m for single seam mining in the PG Seam. There is no single seam mining in the ULLD(MLD) Seam below natural ground.

In areas of single seam mining below waste rock backfill, maximum subsidence was estimated to be generally less than 2.0m depending on the thickness of the waste rock backfill material.

The multi-seam subsidence estimates for MOD9 were based on 85% of the combined seam thickness (Li et al 2010) in all areas where two seams are mined. Maximum vertical subsidence of 4.4m was estimated on natural ground and up to 4.9m estimated where waste rock backfill material is present.

3.1.2 Total and Incremental Subsidence Profiles

The final subsidence profile expected in the MOD9 assessment was expected to vary across the site from 20 millimetres (mm) at a distance of 100m outside the outermost panel in either seam to 0.5m at the solid goaf edge of either seam.

In areas where there has been no PG Seam mining, maximum subsidence in the centre of the ULLD(MLD) panels was expected to reach 2.0m with 0.4m over the intervening chain pillars.

In areas where both seams are mined and the geometries in the two seams are offset, maximum subsidence in the centre of the overlapped panels was expected to reach 4.9m with about 2.0m of subsidence above the chain pillars in both seams.

The incremental subsidence associated with mining the ULLD(MLD) Seam longwall panels is expected to be mainly limited to within the footprint of mining in both seams with up to 2.6m in the central part of the overlapped panels and up to 1.5m above both the PG Seam chain pillars and the PG Seam chain pillars. Incremental subsidence of less than 0.5m tapering to 20mm at 100m from the outside goaf edge was also expected.

3.1.3 Tilts and Strains

The estimation of maximum tilts and strains was based on the total maximum subsidence and the approach described by Holla (1991) for single seam mining even in areas of double seam mining. It was expected that as monitoring results from RUM and other sites where multi-seam mining is undertaken become available, predictions would be refined noting that any refinement of maximum values would be unlikely to significantly change impacts.

The approach described by Holla (1991) for estimating tilts and strains is based on the general formula:

$$E_{max} = K\, S_{max} / D$$

where E_{max} is the maximum tilt or strain, K is a constant, S_{max} is the maximum subsidence and D is the overburden depth. For the purposes of estimating subsidence parameters at RUM, K values of 3000 for tilt and 2000 for strain are consistent with the subsidence observed at RUM over Longwalls 1 to 4 in the PG Seam and take account of the influence of the waste rock fill material.

For single seam mining, maximum subsidence of 2.0m was expected to generate maximum tilts of up to 30mm/m and maximum strains of 20mm/m.

In multi-seam mining areas, maximum subsidence of 4.9m was expected to generate maximum tilts of up to 60mm/m with maximum strains of up to 40mm/m.

The tilts and strain expected in the bottom of Voids 4 and 5 are not influenced by the waste rock backfill and were expected to range up to 100mm/m and 40mm/m respectively.

Goaf edge subsidence was expected to be in the range 0.2-0.5m and subsidence was expected to be perceptible beyond the goaf edge to a distance equal to half overburden depth or about 100m.

3.2 RAV4186 – SMP Single Seam Assessment

The single seam SMP assessment for LW10-15 in the PG Seam presented in SCT RAV4186 (Dec 2013) was based on updated subsidence monitoring results from Longwalls 5 and 6.

Maximum vertical subsidence was revised to 2.7m up from 2.3m based on actual measurements where the waste rock backfill was approximately 70m thick. Maximum subsidence was also recognised to be highly variable depending on the character of the waste rock fill material emplaced.

3.3 Additional Information

Since the multi-seam assessment was prepared for MOD9 in 2012 there have been three significant changes to parameters that influence subsidence forecasts:

1. Some 400mm of additional subsidence was observed at RUM when mining the PG Seam below waste rock backfill material.

2. Changes to the surface features/topography due to completion of the Narama opencut mining, construction of the Void 5 Dam wall and further emplacement of waste rock backfill as part of rehabilitation, increasing the total thickness of backfill by more than 90m.

3. Significant advancement in understanding of multi-seam subsidence behaviour from the longwall mining at Ashton Underground Mine in two and three seams. This improved understanding includes the additional subsidence from the modified or previously disturbed overburden, the release of latent (extra) subsidence when mining below overlying pillar edges, subsidence behaviour near stacked goaf edges and the effect of mining direction on subsidence outcomes.

4. REVISED FORECAST OF SUBSIDENCE EFFECTS

In this section, revised estimates of the primary subsidence parameters are presented based on the contemporary understanding of multi-seam subsidence behaviour, the subsidence monitoring database from RUM and Ashton Underground Mine and the current topography of the site. The advances in understanding of multi-seam subsidence are presented in Mills and Wilson (2017 and 2021).

The forecasts of subsidence parameters are provided as best estimates recognising that maximum vertical subsidence in a single seam mining environment is naturally variable by about 15% for any given panel geometry and overburden depth. In a multi-seam situation, the variability is expected to be greater, particularly given the sensitivity of subsidence to the interaction between mining geometries in each seam. Where waste rock fill material is present in the overburden the variability is expected to be greater yet again.

Any variations in mining heights from the assumed 2.3m and 2.8m for the PG and ULLD (MLD) seams respectively, are expected to proportionally influence the maximum subsidence and other subsidence parameters.

4.1.1 Vertical Subsidence

The proposed multi-seam mining below areas of waste rock backfill material is expected to cause maximum subsidence of approximately 5.9m over sections of the rehabilitated Narama opencut mine. This maximum subsidence is approximately 1m more than previously forecast in SCT (2012) and approximately the same as currently observed at Ashton Underground Mine after three seams of mining without the presence of waste rock backfill in the overburden.

The increase in maximum subsidence now expected below the waste rock backfill (i.e. an increase of approximately 1m) is due primarily to a greater thickness of waste rock backfill. The additional subsidence caused by160m of waste rock backfill present over the Narama pit is expected to be 1.8m compared to the 0.3-0.7m expected for 70m of backfill (SCT 2012) and 1.1m measured (SCT 2013). Improved understanding of the interaction between multi-seam longwalls gained from mining at Ashton Underground Mine also indicates a slight increase in maximum subsidence at certain locations is possible due to 300-500mm of latent subsidence at the edges of overlying chain pillars and longwall panels for the second and third seam of mining at that site.

Subsidence due to single seam mining in the PG Seam is expected to be generally less than 1.5m in natural ground but may range up to 1.7m. Single seam subsidence is expected to increase in areas where there is waste rock backfill material present. The additional subsidence is difficult to estimate with a high degree of confidence and is likely to be variable, but additional subsidence in the range 1m per additional 100m of waste rock backfill would be reasonable based on previous monitoring at RUM. Maximum single seam subsidence is expected to range up to 3.4m after completion of mining in the PG Seam in areas where the maximum thickness waste rock backfill material of 160m is located.

Multi-seam mining below the small areas of natural ground is expected to cause maximum subsidence of approximately 4.2m. Approximately 0.2m less than the 4.4m forecast in SCT (2012).

4.1.2 Tilt

Tilt is expected to depend on the relative locations of the panel edges in the two seams mined. Multi-seam subsidence at Ashton Underground Mine indicates maximum cumulative tilt occurs when mining in the underlying seam causes a stacked goaf edge to be undercut by a distance of 0.3-0.5 times the interburden between the seams.

On the basis of multi-seam mining experience at Ashton Underground Mine, tilt is expected to be highest along the edges of panels where the panel geometry in the lower seam is stacked below the longwall panels in the upper seam. This can occur along the sides of panels at the start and finish lines of longwalls. The maximum magnitudes of these effects are either temporary or permanent depending on the final mining geometry.

For the proposed offset layout at RUM, elevated tilt of up 120mm/m is expected where ULLD(MLD) Seam longwalls start near the start lines of PG Seam longwalls and along the southern edge of Longwall 505 in the vicinity of the edge of Longwall 406. Maximum tilt of up to 175mm/m is expected where the finish lines of the PG Seam longwall are undercut by the ULLD(MLD) Seam longwalls.

The impacts from these very high tilt values are likely to occur in narrow zones at predictable locations.

For single seam mining in the PG Seam only, maximum subsidence of 1.7m is expected to generate maximum tilts of up to 50mm/m in areas where there is no waste rock backfill. The presence of waste rock backfill is expected to increase the subsidence but soften surface tilts and reduce the magnitude of maximum tilt. In areas of waste rock backfill, maximum tilt is expected to range up to 30mm/m.

4.1.3 Strain

Strain is expected to follow a similar pattern to tilt and change depending on the relative locations of the goaf edges in the two seams and the multi-seam interactions.

Elevated strains of up 60mm/m are expected where ULLD(MLD) Seam longwalls start near the start lines of PG Seam longwalls and along the southern edge of Longwall 505. Maximum strains up to 90mm/m is expected where the finish lines of the PG Seam longwall are undercut by the ULLD(MLD) Seam longwalls.

For single seam mining in the PG Seam only, maximum subsidence of 1.7m is expected to generate maximum tilts of up to 20mm/m in areas where there is no waste rock backfill material.

The presence of waste rock backfill is expected to increase the subsidence but soften surface strains and reduce the magnitude of maximum strains. In areas of waste rock backfill, maximum strain is expected to range up to 15mm/m.

Tensile strains and compressive strains are expected to be of a similar magnitude. Tensile strains are likely to cause tension cracks. Compressive strains are expected to cause compression overrides and local ground distortions.

4.1.4 Horizontal Movements

Horizontal movements are expected to comprise two main components:

- a component associated with systematic subsidence whereby movement of 100-300mm is generally towards the active longwall panel and subsequently toward the retreating longwall face
- a component associated with strata dilation and movement toward voids that may reach more than 30% of the vertical subsidence or more than 2m adjacent to voids.

In areas of flatter terrain, the systematic component is likely to dominate. In areas close to opencut voids and rehabilitation areas that are sloping, the strata dilation component is expected to dominate. The horizontal movements associated with strata dilation occur in a direction of maximum downslope gradient i.e. directly downslope toward voids.

4.1.5 Cracks

Surface cracks are likely to become perceptible in natural ground wherever the strains exceed 5-10mm/m and in waste rock backfill wherever the strains exceed 10-15mm/m. Maximum tensile strains and therefore surface cracking is most likely to occur around the edges of each active panel and any overlying panels where cracks associated with previous mining are reactivated.

Differential horizontal dilation is expected to occur at the transition between flat terrain and steeply sloping terrain. Large cracks are therefore expected along, and slightly back from, the crest of open cut voids. These cracks may be more than 1m wide.

4.1.6 Unconventional Subsidence

Unconventional subsidence effects considered in this section include:

- far-field horizontal movements outside the mining area
- horizontal movements associated with strata dilation in uneven topography
- shear movements on low strength bedding planes leading to the formation of ripples on the surface
- stepping in the ground surface associated with geological structure.

At Ashton Underground Mine, all four mechanisms have been observed during the previous longwall mining below natural ground but none of them caused subsidence effects or impacts to surface features significantly greater than forecast.

For proposed mining at RUM, the presence of the waste rock fill material and the previous opencut mining boundaries over the majority of the area is expected to mask and limit any of these unconventional subsidence effects.

In general, the effects of unconventional subsidence movements tend to be localised along narrow zones, so impacts and environmental consequences need to be considered in the context of sensitive surface features that may be close to these zones once they are identified.

4.2 Revised Subsidence Impacts Assessment

In this section, the potential impacts to the natural, built features and infrastructure within the Assessment Area as shown in Figures 1 and 2 are discussed. These features include all those listed as having performance measures for DA104/96 excepting biodiversity which requires assessment by other specialists.

4.2.1 Natural and Heritage Features

The only natural features in the Assessment Area are located within the 44ha of natural bushland immediately to the north of Narama Dam. All the remaining surface area has been previously disturbed by opencut mining activities.

It is recognised that potential impacts to items of biodiversity require assessment by other specialists as this is outside the expertise of SCT. However, the estimates for vertical subsidence in the area of natural ground have reduced and the magnitude of impacts are expected to have reduced as well.

SCT understand that there are seven Aboriginal heritage sites within the small area of natural ground and that all these sites are identified as isolated finds and artefact scatter sites.

Consistent with the previously approved RUM longwall layout, subsidence is expected to cause surface cracking. The location of any scattered artefacts could be impacted by cracking of the ground surface but the artefacts themselves are not expected to be impacted. Any disturbance to these sites is likely to be associated with surface works undertaken to remediate surface cracks so that overland flow following rainfall is able to flow across the surface and not be diverted into the overburden strata.

It is noted that OzArk Environmental & Heritage Management Pty Ltd (2012) completed an Aboriginal Heritage Due Diligence Assessment for the PG Longwalls 10-15 SMP and recommended an Aboriginal heritage assessment be completed prior to secondary extraction of the PG Longwall 405 to ground truth and re-locate the seven apparently extant AHIMS registered sites in the footprint of PG Longwalls 405 and 406.

4.2.2 Built Features

The built features located within the Assessment Area are all either mining related or associated with fly ash emplacement by AGL.

4.2.2.1 33kV Electricity Transmission Line

Two 33kV powerlines cross the surface above the proposed Longwalls 404, 405 and 406 in the PG Seam and the corresponding Longwalls 504 and 505 in the ULLD (MLD) Seam. These powerlines, owned by Glencore (Ravensworth Operations), supply pumping infrastructure at the Narama Dam and the Narama Pit. The conductors on these lines are supported on single poles.

Further to the north these powerlines have been previously mined under by longwalls at Ashton Underground Mine. Longwalls 7B and 8 in the PG Seam mined below this powerline and Longwalls 207B and 208 in the ULLD (MLD) Seam are planned to mine under this line again.

Impacts to this infrastructure from the proposed mining are expected to be similar to those already experienced from the mining at Ashton Underground Mine. The single pole structures have been found to be tolerant of increased vertical subsidence and tilt values from multi-seam mining.

Management measures and strategies used by ACOL during the previous mining below these 33kV powerlines, and the AusGrid 132 kV powerline that traverses east-west above the southern longwalls at Ashton Underground Mine to the south of the Assessment Area, are expected to be effective in minimising impacts from the proposed mining.

4.2.2.2 Narama Dam

Narama Dam wall is located southeast of the Assessment Area. This dam is used by Glencore operations for water storage and as a licensed discharge point. Narama Dam is a declared dam under the *Dams Safety Regulation 2019* administered by DSNSW. Mining of the PG Seam within the notification areas around this dam was previously approved by the CICM after consent from DSNSW.

The proposed mining is not expected to cause any significant subsidence movements in the vicinity of the dam wall. Impacts to the Narama Dam wall and the dam storage itself are expected to be similar to those presented in SCT (2012).

The geotechnical assessment and detailed review of the likely impacts of any low level subsidence movements on the dam wall suggested in SCT (2012) and captured in the statement of commitments, is recommended as part of the process to obtain DSNSW consent and approval from the CICM for the proposed multi-seam mining. Only the edge of the full supply level of the dam would be directly mined under and, given the dam is not operated at full capacity for operational reasons, impacts to the dam storage are also expected to be minor and manageable as indicated in SCT (2012).

An arm of the dam storage extends into the Assessment Area. Longwalls 406 and 505 mine below this arm, in a slight offset geometry. Ground strains of 30mm/m and 60mm/m are expected at the completion of both longwall panels. Significant surface cracking is expected to occur at these strain levels. Subsidence of up to 1.7m is expected following mining of Longwall 406 and 4.2m following mining of Longwall 505.

Given the mining geometry and the cracking expected, remediation of the surface is expected to be required to maintain a flow path from the drainage line catchment into the dam for a free-draining landform and to avoid excess water migrating into the underground mine workings. This remediation is likely to involve infilling of surface cracks in the bed of the drainage line and dam. Additional remediation is likely to be required to avoid a small pond forming upstream of the reservoir that is unable to flow into the reservoir due to the 4m change in elevation. This remediation may involve excavation of a channel up to 2-3m deep and 50-100m long depending on local grades or backfilling the area of subsided ground to a level that allows a free-flowing gradient to the dam.

Impacts from ponding on the drainage line upstream of the dam are expected to be greater than previously identified. The remediation works likely to be required after Longwall 505 to ensure a free-draining surface are expected to be similar to those previously undertaken or to be undertaken at the completion of mining at Ashton Underground Mine to maintain a free-draining landform. The works are expected to be limited to a small area near the full supply level and upstream in the drainage line.

4.2.2.3 Void 5 Dam

The Void 5 Dam wall is constructed from waste rock placed across the eastern end of Void 5. Void 5 Dam is a declared dam under the *Dams Safety Regulation 2019* administered by DSNSW. Mining of the PG Seam within the notification area around the dam wall was previously approved by the CICM following consent from DSNSW.

The proposed mining is not expected to cause any significant ground movements at the dam wall and no significant impacts to the dam wall.

Mining is expected to cause subsidence of up to 5.0m along the sides of Void 5, horizontal movements of 1-1.5m along the crest of the batter slopes and the possibility of cracking up to 0.5-1m parallel to the crest.

Some remediation activities may be required to manage surface runoff to avoid overland flow entering the batter slope and causing slope instability and/or erosion of the batter slopes.

4.2.2.4 AGL Fly Ash Emplacement Infrastructure

AGL are currently using Void 5 as a disposal area for waste fly ash from nearby power stations. An ash disposal pipeline runs along the northern crest of Void 5, across the dam wall and back along the southern crest to a discharge point used to fill the void. The pipeline crosses the surface above Longwalls 401-402 and Longwalls 501-502. The characteristics of the pipeline and the discharge point are not known. They had not been constructed at the time of the SCT (2012) assessment and SCT has not had the opportunity to inspect them subsequently.

Further work is recommended to inspect and confirm the nature of impacts that may result to the AGL infrastructure from the 4-5m of subsidence and 1-1.5m of horizontal movements with associated cracking expected along the crest of Void 5. It is recommended that the existing Environmental Management System for Macquarie Generation (AGL) Owned Land and Infrastructure approved under the SMP is reviewed, and if necessary updated, in consultation with AGL. However, impacts are expected to be manageable with appropriate mitigation and/or remediation measures in place.

4.2.2.5 RUM No5 Shaft

No significant impacts to the shaft are expected for the proposed mining.

Horizontal shear movements at multiple bedding plane horizons are expected but these are considered unlikely to affect the function of the shaft if used for ventilation purposes. The shaft was designed to accommodate the subsidence movements anticipated.

4.2.2.6 Narama Pit

Areas of the Narama Pit area expected to experience the full range of subsidence effects estimated for the proposed mining. Some cracking is expected at the top of steeper slopes and along the exposed eastern highwall in the vicinity of the proposed longwall panels. This cracking may allow ingress of surface runoff causing localised slope instability.

Perceptible cracking is expected along the section of highwall above, and in the vicinity of the longwall panels, with potential for localised rock falls along about 20% of the length of highwall mined under. As mining activities are now complete, consequences from any impacts are expected to be manageable. The potential for water to migrate from the open void into the underground mine workings is also expected to be manageable.

4.2.2.7 330kV Electricity Transmission Line

No changes are expected to the impacts to the TransGrid 330kV powerline presented in SCT (2012). Any subsidence movements are expected to be small with any impacts expected to be minor and manageable.

This powerline was relocated into the corridor along the lease boundary between RUM and Ashton Underground Mine to minimise impacts from future mining as part of the Ravensworth North Opencut expansion. Only two towers (Tower 38 and Tower 39) are located within the Assessment Area. These towers are positioned on waste rock fill material within the boundary of the Ravensworth South Pit but more than 0.5 depth from the proposed longwalls. These towers were designed and constructed to accommodate combined subsidence movements from mining four seams proposed at both Ashton Underground Mine and RUM.

Absolute vertical and horizontal movements at the towers are expected to be less than 100mm and imperceptible for all practical purposes. The tower foundations are expected to be able to accommodate, through design, any small differential movements that may occur.

No impacts to towers or the continued operation of the 330kV powerline are expected from the proposed mining. Nevertheless, a program of regular monitoring during the period of active mining near each of the towers is recommended. Monitoring of the full three-dimensional subsidence movements in the general vicinity of towers at the end of each longwall panel is also recommended.

4.2.2.8 Water Pipelines

Sections of water pipelines, are or will be, located above the proposed Longwalls 406 and 505 panels near the FSL of the Narama Dam storage. These pipelines are owned by Glencore and used for water management at Ravensworth Operations and at the Mt Owen Complex (Mt Owen, Ravensworth East and Glendell mines) as part of the Greater Ravensworth Water and Tailings Strategy (GRWTS). Impacts to water pipelines from the proposed mining are expected to be minor and manageable.

The existing Narama Dam to Mt Owen water transfer pipeline follows a western route from the Narama Dam to Dam 22 at Ravensworth East. No significant impacts are expected to this pipeline from the proposed mining with appropriate mitigation and/or remediation measures in place.

Glencore have recently sought and obtained approval for a second Narama Dam to Mt Owen water transfer pipeline as part of the GRWTS. This pipeline will follow an eastern route from the Narama Dam to the western rail dam (WRD) at Mt Owen. The WRD is also known as TP2 or Ravensworth East Tailings Pit or Mt Owen Stage 5 Tailings Dam.

The approved route for this yet to be constructed pipeline is outside the Assessment Area. No impacts to this pipeline would be expected from the proposed mining.

4.3 Public Safety

The only areas readily accessible by the general public in or within the vicinity of the Assessment Area are the Brunkers Lane intersection, Lemington Road and the New England Highway corridor. These areas are outside the Assessment Area where no perceptible impacts are expected.

The subsidence impact performance measure for public safety is 'negligible additional risk'. The proposed mining is not expected to pose any additional risk.

5. POTENTIAL FOR INTERACTIONS WITH OTHER MINING OPERATIONS

Based on the 10 year mining sequence plans provided by Glencore for the Ravensworth Operations it appears the main open cut surface mining operations within the Assessment Area are complete other than rehabilitation activities. These rehabilitation activities include the backfilling of the open void of the Narama Pit over the life of the proposed underground mining.

No significant interactions between the proposed underground longwall mining and surface activities for fly ash emplacement and general rehabilitation are expected. Interactions of subsidence with backfilled areas resulting in spontaneous combustion as previously observed and managed are expected to continue during the proposed mining. Any surface activities in the vicinity of the active longwall mining and subsidence are expected to be easily coordinated to minimise the potential for interactions, impacts and consequences.

6. SUBSIDENCE ASSESSMENT AND MONITORING

Subsidence monitoring consistent with SCT (2012) and captured by the statement of commitments in Appendix 3 of DA104/96 (MOD9) is recommended.

The statement of commitments details subsidence management processes, risk, geotechnical and subsidence assessments as well as surveying and visual inspections for subsidence monitoring of the MOD9 mining layout.

Other than the requirements specifically for Void 3 and Void 4 dams (as these are neither outdated or these voids are outside the Assessment Area) these requirements are still considered appropriate as a basis for a subsidence monitoring program for the proposed mining to:

- Manage the risks to health and safety associated with subsidence.
- Validate subsidence predictions.
- Analyse predicted and actual subsidence effects, impacts and any environmental consequences.
- Inform contingency plan and adaptive management processes.

7. CONCLUSIONS AND RECOMMENDATIONS

Our review indicates the mining layout proposed represents a smaller footprint than the footprint approved in MOD9 to Development Consent DA104/96.

Impacts from the proposed mining are expected to be compliant with the performance measures in DA104/96 (MOD9).

The magnitudes of subsidence effects are likely to be greater than previously forecast in some areas and less in other areas. The changes in the magnitude of subsidence effects are a result of a combination of subsidence monitoring conducted since the subsidence assessment for DA104/96 (MOD9) was prepared in 2012, physical changes to the site, and advances in the understanding of multi-seam subsidence behaviour since 2012. The greater subsidence effects do not necessarily result in greater impacts and consequences because the areas of greater subsidence effects are on rehabilitated areas of the now completed Narama open cut mine.

No increase in impacts to natural and built features is expected from the proposed mining compared to those previously predicted. Almost all the built features and infrastructure within the Assessment Area for the proposed mining are owned by Glencore or AGL Energy Ltd (AGL). Impacts to all features are expected to be minor and manageable. No additional risk to public safety is expected.

Further work is recommended to inspect and assess the potential for impacts to the Fly Ash emplacement infrastructure at Void 5 ash dam. It is recommended that the existing Environmental Management System for Macquarie Generation (AGL) Owned Land and Infrastructure approved under the SMP is reviewed, and if necessary updated, in consultation with AGL. However, any impacts are expected to be manageable with appropriate mitigation and/or remediation measures in place.

Subsidence monitoring, subsidence management processes, risk assessments, geotechnical assessment and subsidence assessments that are consistent with the statement of commitments and conditions in DA104/96 (MOD9) continue to be appropriate for the modified RUM layout.

8. REFERENCES

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