MAXWELL PROJECT

Review of adequacy of rehabilitation of Maxwell Underground and Maxwell Infrastructure including Mine subsidence

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Prepared for:

Hunter Thoroughbred Breeders Association
including Coolmore Australia and Godolphin Australia

EXECITIVE SUMMARY

Key points:

- The Rehabilitation bond is likely to be inadequate for the full project area $49.5M provisioned but an estimated $105.7M + is likely to be required.
- There is Uncertainty in Maxwell Infrastructure rehabilitation plan.
- There will be a large area of subsidence 2134ha due to proposed Maxwell Underground project.
- There will be significant consequential impacts from mine subsidence underestimated
- The Maxwell EIS is conceptual with minimal detail; uses averages rather than ranges of values, and did not identify and test for impacts adequately;
- There is likely to be permanent damage to the groundwater aquifers (shallow and deep) in the Maxwell Underground mine footprint;
- Impacts on major features: Saddlers Creek, Hunter River alluvials, Edderton Road, Golden Highway, Stud land, and drainage lines, natural land surface within the influence of Maxwell underground etc.

The following summarises the main issues raised in the preceding dot points in regard to matters of concern regarding rehabilitation of the Maxwell Project and subsidence impacts associated with the underground mining.

- There are concerns associated with the extent and quality of reactive mine waste materials and how these will affect the rehabilitation standard of the Drayton North mine area, specifically the final mine voids and associated pit water and the tailings/coarse reject emplacement areas.
- The final pit voids, while geotechnically stable, are likely to be too steep to successfully stabilise and establish a suitable vegetation cover
- The extent of subsidence is likely to be significant and will adversely affect the suitability of lands for subsequent rural uses, specifically the viability of grazing on improved pasture. This will have long term consequences however the proponent has only committed to subsidence monitoring for a period of two to five years following cessation of mining. The acceptable standard to be achieved for subsidence has not been defined.
- Uncertainty regarding subsidence from multi seam extraction generally due to the lack of data and uncertainty of the extent of subsidence regarding longwall seam extraction below bord and pillar seam mining. For Maxwell proposed mining will extract 4 seams (the upper seam by bord-and-pillar extraction and the remaining 3 seams by longwall extraction) in some locations, and 3 seams in most locations of the mine footprint. Other multi seam data cited by MSEC involves extraction of 2 seams. Implications of longwall extraction under bord and pillar unknown. IESC suggested this could lead to collapse of the pillars, that could be within the proposed mining operation timeframe or post mine closure. There is so little data available for multi-seam extraction in the Hunter coalfields.
- Closure costs are likely to be significantly in excess of the current Security Deposit held by the NSW government.

- The timeframe to restore land for suitability for an approved post-mining landuse is likely to be significant, and a 2-5 year timeframe commonly used in mine closure and rehabilitation is by far too insufficient to achieve an acceptable sustainable post mine landform.
- The direct impacts resulting from subsidence associated with the underground mining are predicted to include surface cracking of 25 to 50 mm (with isolated cracks to 100 mm) and depressions in the land surface up to 5600 mm but could be significantly higher.
- Proposed underground mining at Maxwell using bord and pillar and longwall techniques within the Gateway certificate application area is predicted to result in subsidence of 2,134 ha of the GCAA
- The extraction is largely critical to supercritical causing the greatest subsidence and deformation of the overlying strata and land surface – It can be predicted by the ratio of the panel extraction width (W) to the thickness of the overburden or cover rocks (H) – W/H. Extractions where W/H is smaller than the critical range are termed sub-critical, and those where it is larger are termed super-critical; the latter causing maximum subsidence over a larger area
- Potential impacts from subsidence may include:
    - The natural land surface including drainage lines and vegetation ecosystems above the Maxwell underground operation;
    - Hunter River alluvial flats located immediately south of the mine area where the four seams will be mined;
    - Saddlers Creek located northwest and outside the proposed limit of secondary extraction;
- The studies for subsidence use rule of thumb and average factors to predict subsidence and the extent of areas where subsidence >20mm will occur. Rule of thumb appropriate if no info and sensitivity low - While this is not incorrect the studies should also look at factors such as angle of draw that are higher than the average 26.5 degrees, to estimate what potential risk may exist if the values for key components are changed, (i.e. undertake a sensitivity analysis given this is an Environmental Impact assessment that must look at a range of critical values
- Subsidence movements is likely to result in surface deformations, with cracking in flatter areas expected to be between 25 and 50 mm, with widths greater than 300 mm in some places
- The key physical driver of concern is the extent to which mining causes surface cracking and near-surface ground movement, which has important consequences for the interactions between groundwater and surface waters and their dependent resources. The estimates of surface subsidence are likely underestimated within watercourses and near faults. There has to be little confidence in the estimates of non-conventional subsidence at the local scale (and other associated ground movements) in areas that are most vulnerable to ecological decline.
- Given the number of vertically successive coal seams to be mined, the proposed Maxwell Project will result in a range of potential subsidence-related impacts to water resources. These would include changes to surface watercourse gradients, flows and erosion, and surface ponding as well as surface and shallow fracturing.

- The maximum conventional vertical subsidence is predicted to be 5.6 m where all four coal seams are proposed to be extracted. However, conventional vertical subsidence will occur progressively as each subsequently deeper coal seam is mined. The seam with the greatest individual contribution to subsidence is predicted to be the Woodlands Hill Seam, which is the second to be mined, is the first series of longwalls and the first to undermine the bord and pillar workings within the Whynot Seam.
- The extraction of three underlying coal seams beneath the Whynot Seam will likely result in the collapse of retained coal pillars, which would likely result in increased subsidence evident at the surface. The IESC notes that elsewhere in the Hunter Valley (North Wambo Underground Mine) the extraction of longwalls beneath bord and pillar mined seams has resulted in localised subsidence in excess of 100 per cent of the total mining height.

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1 INTRODUCTION

Please find set out below a review of mine rehabilitation program for the Maxwell Project as set out in the Maxwell project EIS documents and other documents relating to the project including NSW Mining & Petroleum Gateway panel documents, SEAR's documents etc. Due to the timeframe an exhaustive review of all documents could not be completed and only documents directly relevant to mine rehabilitation of the lands covered by the Maxwell Project were reviewed.

My name is Peter Scott and I compiled this review. I am a geoscientist with 48 years' specialist experience in assessment, management and rehabilitation of mining waste for mine sites including mine subsidence in Australia, Asia-Pacific, Africa, and the Americas, specialises in mine closure and mine rehabilitation and specifically managing and remediating mining waste and mine landforms.

1.1 Scope of Works

The author was commissioned by the HTBA and its members Coolmore and Godolphin to review the rehabilitation activities proposed for the Maxwell Underground and Infrastructure project, including review the potential impacts from mine subsidence identified by the Maxwell EIS specialists.

1.2 Project description

The target coal seams for the Project belong to the Jerrys Plains Subgroup of the Wittingham Coal Measures and include the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams. "*The Project would involve extraction of coal from four seams within the Wittingham Coal Measures using*

the following underground mining methods:

- *bord and pillar with partial pillar extraction in the Whynot Seam; and*
- *longwall extraction in the Woodlands Hill, Arrowfield and Bowfield Seams*."

The coal is soft coking coal that can be used to blend with hard coking coal but makes a lower quality coking coal. The soft coking coal can be used as thermal coal. So it is questionable that the coal from Maxwell is a high quality coking coal. The Jerrys Plains Subgroup consists of sediment deposits up to 800 metres (m) thick comprising several coal bearing and non-coal bearing deposits. The non-coal bearing strata typically consist of claystones, siltstones, sandstones and to a lesser extent conglomerates.

Maxwell Ventures (Management) Pty Ltd, a wholly owned subsidiary of Malabar Coal Limited (Malabar), is seeking consent to develop a new underground coal mining operation, referred to as the Maxwell Project (Maxwell). Malabar proposes to extract bord and pillar panels (with partial pillar extraction) in the Whynot Seam and longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams within Exploration Licence (EL) 5460.

EL 5460 is located in the Hunter Coalfield of New South Wales (NSW) east-southeast of Denman and south-southwest of Muswellbrook. The locations of EL 5460 and the proposed Maxwell underground mining area are shown in Figure 1-1 and Figure 1-2. The proposed Maxwell underground mine is located ~7-10 km south of Mt Arthur Operation main pit and ~7-10 km west of Hunter Valley Operations. The proposed area for UG mining is ~11 km from the site of the Drayton CCHPP and coal load out area to be repurposed for storage , handling and coal loading and rebranded as Maxwell Infrastructure. No mining has occurred on the proposed Maxwell underground area, which is the most westerly and southerly proposal for coal extraction of the Wittingham Coal measures. The lack of mining activity and information on mine subsidence and the location for the proposed Maxwell underground places it in the "greenfields development" category. It is not a brownfield site.

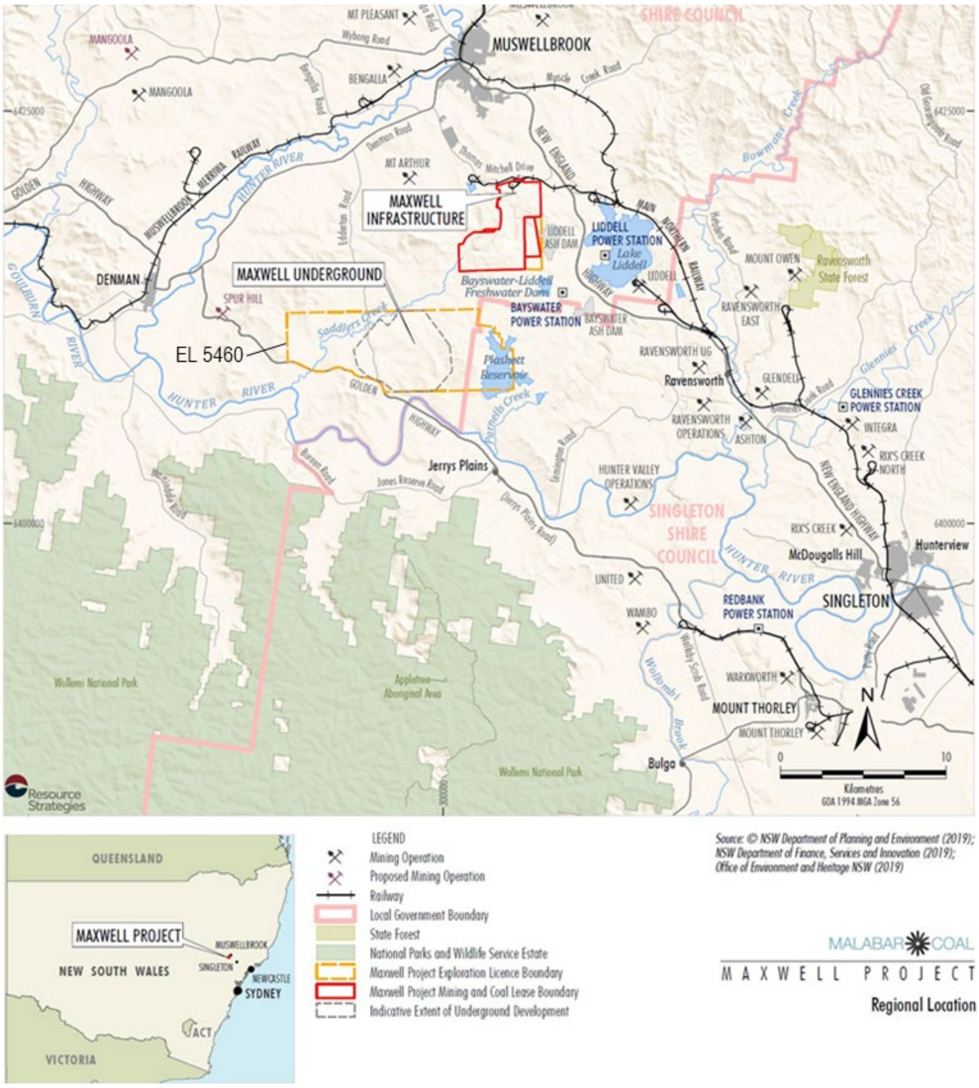
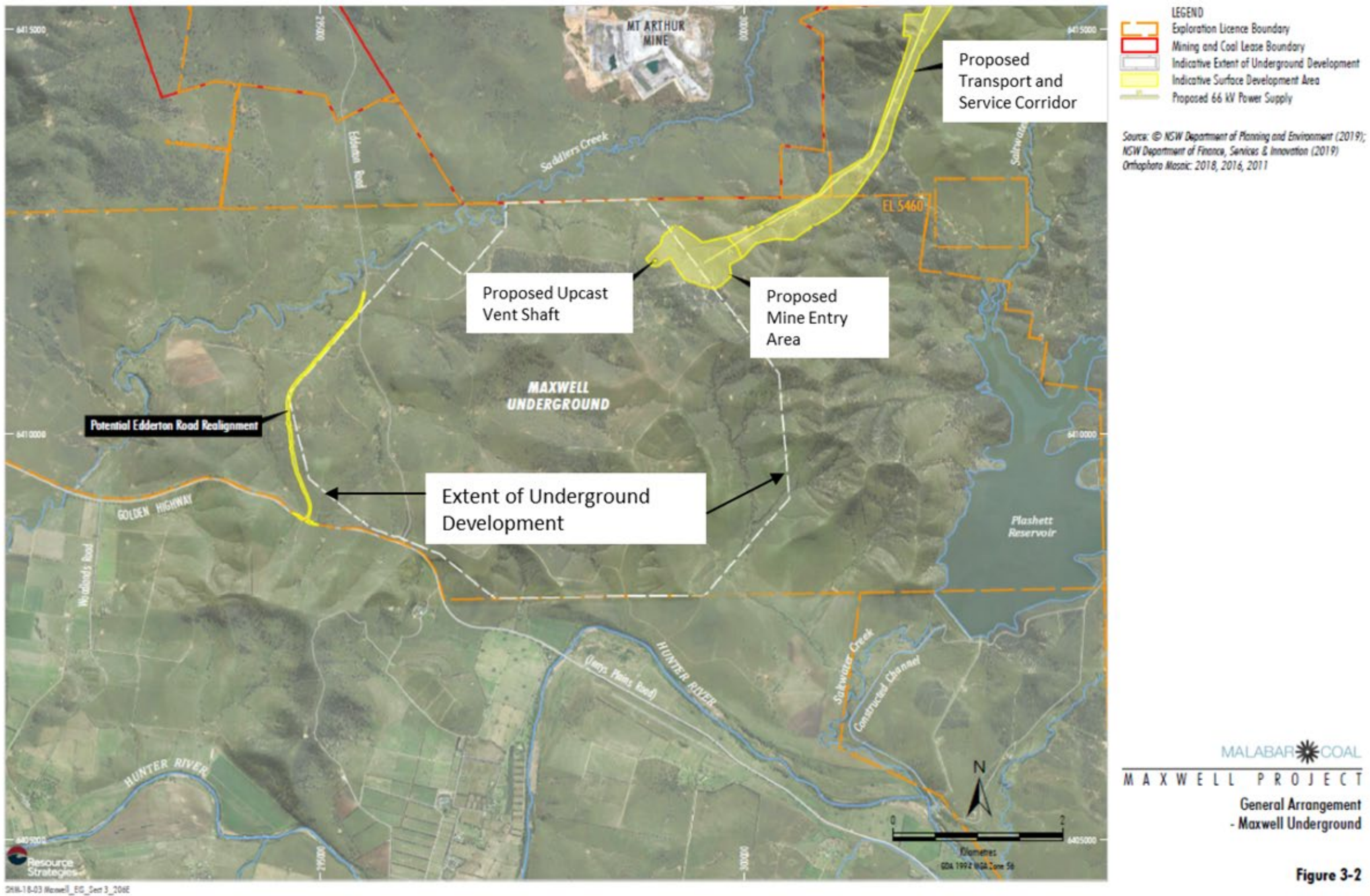


Figure 1 1: Locations of EL 5460 and the proposed underground mining area



Source Section 3 – Project Description Maxwell EIS

Figure 1 2: Indicative Extent of Maxwell Underground Development

The Maxwell project includes the old Drayton North site that includes the partially rehabilitated spoil dumps, roadways, pits (north, East and South pits), Coal Preparation facility (CHPP), rail loops, coal stockpile areas, water ponds etc. referred collectively as the Maxwell Infrastructure Area; and the proposed underground operation to mine the coal seams defined by previous owners (Anglo Coal) referred to as Maxwell underground operation (previously known as Drayton South), and includes the access portal, ventilation shafts and the transport and service corridor.

Items identified as influencing rehabilitation of the proposed project include:

- Rehabilitation of Maxwell Infrastructure
- Disposal of reactive coal rejects
- Final Void Water quality derived from washery rejects from Maxwell Underground
- High and Low wall stabilisation
- Rehabilitate the transport and service corridor
- Seal and secure access portal and ventilation shafts
- Subsidence and remediation of subsided land
- Subsidence and remediation of impacts on Biophysical Strategic Agricultural Land (BSAL)

1.3 Source Data reviewed

Advisian (2016) Literature Review of Underground Mining Beneath Catchments and Water Bodies

Ashurst (2020) MAXWELL PROJECT (SSD 9526) Submission to the Independent Planning Commission on greenhouse gas emissions and climate change; 22 October 2020

DPIE (2020) Maxwell Underground Coal Mine Project; State Significant Development Assessment SSD 9526; September 2020

Geo-Environmental Management (GEM) 2019. Environmental Geochemistry Assessment of the Maxwell Project. Report prepared for Malabar Coal Ltd. Appendix P of EIS

Gippel CJ 2019. Maxwell Project, Environmental Impact Statement, Technical Study Report, Geomorphology Assessment. Fluvial Systems Pty Ltd, Stockton, Malabar Coal Ltd, Sydney, June. Appendix D of EIS.

Hansen and Bailey, (2019) Maxwell EIS,

Hazelton, P. and Bacon, P. (2020) Assessment of the impacts of the proposed maxwell project on the soil, water and land productivity

Hebblewhite, B.K. (2019) Peer Review – Maxwell Underground Project Subsidence Assessment (MSEC Report 986, Revision A, July 2019)

HydroSimulations (2019) Maxwell Project: Groundwater Assessment (Including Appendix J Height of Fracturing Analysis); Appendix B Maxwell EIS

IESC (2014) Subsidence from coal mining activities, Background review, Commonwealth of Australia

IESC (2018) Advice to decision maker on coal mining project – IESC 2018-098: Maxwell Project – Expansion. Advice dated 9 November 2018. Commonwealth of Australia [Online]. Available: http://www.iesc.environment.gov.au/system/files/iesc-advice-maxwell-2018- 098.pdf

IESC (2019) Advice to decision maker on coal mining project IESC 2019-109: Maxwell Underground Coal Mine Project (SSD 9526/ EPBC 2018/8287) – Expansion; Commonwealth of Australia

IMC (2011) Surface Subsidence Prediction for the Red Hill Mine (RHM); Draft report to BMA Coal

Li, G., Steuart, P., Pâquet, R. (2007). A Case Study on Multi-seam Subsidence with Specific Reference to Longwall Mining under Existing Longwall Goaf. Mine Subsidence Technological Society Seventh Triennial Conference. The University of Wollongong, November 2007. pp111 ~ 125.

Li, G., Steuart, P., Paquet, R., Ramage, R. (2010). A Case Study on Mine Subsidence Due to Multi-Seam Longwall Extraction. Proceedings of the second Australasian Institute of Mining and Metallurgy Conference on Australian Ground Control in Mining, Sydney 23 to 24 November 2010.;

Malabar (2020) Maxwell Underground Project (SSD 9526) – Management of Edderton Road - Letter to Chair of the IPC NSW; 23 October 2020

MSEC 2007: Introduction to Longwall Mining and Subsidence; prepared by Mine Subsidence Engineering Consultants; Revision A, August 2007

MSEC 2007: General Discussion on Systematic and Non Systematic Mine Subsidence Ground Movements; prepared by Mine Subsidence Engineering Consultants; Revision A, August 2007

MSEC 2019: MAXWELL PROJECT: Environmental Impact Statement – Subsidence Assessment; Subsidence Predictions and Impact Assessments for Natural and Built Features due to Multi-seam Mining in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams, in Support of the Environmental Impact Statement: Maxwell EIS Appendix A

MPGP, (2013) Drayton South Coal Project Advisory Report, State of NSW through the NSW Mining & Petroleum Gateway Panel; 10 Dec 2013

MPGP, (2015) Report by the Mining & Petroleum Gateway Panel to Accompany a Conditional Gateway Certificate for the Drayton South Coal Project

MSEC (2007), Introduction to Longwall Mining and Subsidence

Rio Tinto (2006). Kestrel Coal Mine. Subsidence and Agriculture. Fitzroy Basin Association CQ Mining Forum. Emerald Memorial Club 18 October 2006 Presentation.

SEARs (2019) Planning Secretary's Environmental Assessment Requirements State Significant Development SSD9526 The Maxwell Underground Coal Mine Project

SCT, (2012) Subsidence Assessment for Upper Liddell Seam, Longwalls 1-8 Extraction Plan; Report to Ashton Coal Operations Ltd

Suchowerska Iwanec, A.M., Carter, J.P. and Hambleton, J.P. (2016) Geomechanics of subsidence above single and multi-seam coal mining; Journal of Rock Mechanics and Geotechnical Engineering

Waddington and Kay (2002). Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Ximin Cui et al (2020) Calculation of Residual Surface Subsidence Above Abandoned Longwall Coal Mining; MDPI

The MSEC (2019) report in Appendix A of Maxwell Project EIS is a key document used throughout the EIS as source information on mine subsidence.

1.4 Geological setting

EL 5460 lies in the Hunter Coalfield within the Northern Sydney Basin. The target seams lie within the Jerrys Plains Subgroup of the Wittingham Coal Measures. The general stratigraphy of the Hunter Coalfield and the Wittingham Coal Measures are shown in Table 1.8 and Table 1.9 (MSEC (2019)., The Newcastle Coal Measures and overlying groups are generally not present in the proposed mining area.

There have been a number of drilling campaigns within EL 5460 from the late 1940's through to the present. Other geological exploration included: 3D seismic surveys in 2003, 2004, 2005 and 2006; a high-resolution ground magnetic survey in 1998; a low-level aero-magnetic survey in 2002; and a radiometric survey for the purposes of detecting and mapping intrusive bodies (MSEC, 2019).

Geophysical logging has been generally carried out on the drillholes since 1998. The testing identified the coal seam floors, coal seam roofs, partings, igneous intrusions and tuff marker bands, lithological boundaries and structural features (MSEC, 2019). Geotechnical logging to identify natural fractures has been carried out since 2008.

Groundwater investigations also provide data to document the geological characteristics of the coal seams and overburden stratigraphy.

Geological structures in EL 5460 that encompasses the proposed Maxwell underground are documented in in Drawing No. MSEC986-22 of MSEC (2019) .

The faults have been interpreted from the seismic surveys and from the structure contour plans. The positions and throws of some faults have been confirmed using a series of closely spaced non-core drillholes (MBGS, 2018). These drillholes indicate that the throws of the normal faults are generally consistent through the target coal seams.

A complex north-northwest orientated graben structure crosses the western part of EL 5460, comprising the East Graben Fault and the Randwick Park Fault, which is part of a regional graben system. The East Graben Fault has a dip of 70° and a throw of up to 20 m near the proposed mining area. The Randwick Park Fault is sub-vertical and it has and a throw of up to 30 m.

The south-western ends of the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams have been set back from the graben structure.

Despite being a "greenfield site" a lot of geological, geophysical and geotechnical data are available to assist identifying geological/geotechnical conditions that will influence mine subsidence, particularly if analogue sites are selected from other parts of the NSW coalfields.

2 REHABILITATION

2.1 Rehabilitation of Maxwell Infrastructure

The existing Security Deposit for rehabilitation **($50.642M** in present day value terms) is likely to be inadequate to meet the proposed rehabilitation design and commitments for Maxwell Coal Project as well as the existing Drayton (North) mine referred to as the infrastructure for the Maxwell Project. The previous EIS estimates the final rehabilitation costs for the combined project comprising Drayton North and the open cut Drayton South Mine plus the infrastructure at a future net value (in 2031) of ~$66M. However, estimates presented in the previous report by this author (2016) indicated that the Drayton North rehabilitation costs alone would then have been around $50.51M (including contingency and third party project management).

The following comments are made in relation to the current rehabilitation measures implemented at Drayton (North) mine Maxwell Infrastructure:

- Areas have been shaped to the final landform, topsoiled and grassed. Rehabilitation effectiveness in terms of land stability appears to be good on most of these areas. On the ground investigations would be necessary to confirm the acceptability of rehabilitation measures implemented to date, and these have not been provided in the EIS documents and supporting studies.
- Final landforms created to date comprise relatively simple planar to convex slopes with a similarly simple drainage network
- Reshaping of waste dumps has been undertaken in recent months with many areas recently topsoiled or awaiting the application of topsoil and seeding, however detail on the rehabilitation works provided in the EIS and supporting documents is minimal
- Almost all high walls require reshaping to achieve the designated batter slopes (<37 degrees) and facilitate revegetation. It is noted later that this angle (while commented as being acceptable in terms of geotechnical stability) is likely to be far too steep to achieve a stable non-eroding landform suitable for vegetation establishment. No reshaping of the highwalls and low-walls was reported in the EIS or supporting documents.
- Minimal landform shaping/ rehabilitation has been undertaken in the final pit areas
- Only minor areas have been planted to native forest /woodland that presently demonstrate significant growth. There is no information provided regarding the commitment to re-establish woodlands as required under the rehabilitation commitments for the Drayton North mine site that has been incorporated in the Maxwell Infrastructure precinct.
- Rehabilitate pit water acidity derived from washery rejects from Maxwell coal; this is a long term requirement and is likely to increase in costs
- Remediation of sodic overburden and interburden. This remains a continuing costs with the addition of gypsum to manage sodicity and lime to manage acidity to the top surfaces of the rehabilitated spoil dumps. While this was noted in the EIS there is limited information on the magnitude and ongoing success of the remediation works.

The main needs in terms of cost are the reshaping of the remaining waste dumps, highwalls and low walls and the capping of the East Pit tailings and coarse rejects. It is noted that up to a 4m depth of capping material may be required to establish a suitably consolidated and stable landform in the East Pit. It has been assumed in previous review of this project that a previous proposal to use flyash sourced from the adjacent Bayswater Power Station will not be available for covering the tailings and coarse reject material in the Drayton (North) mine East and North pits.

Overburden and interburden associated with the Greta seams are known to spontaneously combust when exposed to air and water. The MOP for Drayton (North) mine indicates that material subject to spontaneous combustion is handled separately using clay rich material to limit air and water entry after placement prior to placement of topsoil. The Closure Plan and MOP indicate that most of the reactive material in question will be rehabilitated and encapsulated. There remains some uncertainty regarding the stability of the highwall post mining and prior to the void reaching final water level that is likely to cover the Greta seams. Also, there is little inventory information on sufficient quantities of suitable material (compactable clay rich overburden) available to complete rehabilitation.

The full infrastructure area will require decommissioning, decontamination and rehabilitation.

In summary:

- The rehabilitation of the Drayton North mine site (now referred to as the Maxwell Infrastructure) involves creation of a relatively simple landform similarly to most coal mines in NSW. For most aspects, cost estimation for this mine is relatively straightforward for landform rehabilitation and infrastructure rehabilitation.
- There are nevertheless likely to be some practical and cost constraints for some matters at Drayton (North) mine, specifically the proposed highwall rehabilitation and gaining successful tree colonisation, suitable remediation of spontaneous combustion and achieving the committed extent of woodland revegetation
- There may also be issues associated with obtaining the required volume of material within the Drayton (North) mine area for both amelioration of spontaneous combustion and capping of the tailings dam and coarse rejects placement areas.
- The cost estimate also assumes that there is sufficient topsoil has been stockpiled to meet the rehabilitation design requirements. If there is a shortfall, the “winning” of further topsoil will add the cost of rehabilitation.

2.2 Rehabilitation of Maxwell Underground

There will need to be a significant increase in the existing Security Deposit **(**estimated to be an additional **$55.080M)** to cover the additional costs associated with the rehabilitation of the underground area. There are significant uncertainties associated with the costs that would apply to successfully rehabilitate the likely extensive area of subsidence, particularly in the long term. This aspect is further addressed below.

Additional costs associated with the rehabilitation of the Maxwell Project (underground component) have not been estimated but would be likely to take overall costs well in excess of the existing Security Deposit amount.

The Maxwell project rehabilitation costs will likely include:

- Decommissioning of Surface Infrastructure, overland conveyor and towers, admin offices, bath house, sewerage system, workshops and store
- removal of underground infrastructure, such as mining equipment and service infrastructure, underground conveyors;
- Decommission Power Supply
- de-energising equipment (e.g. removing connections to power, water, gas, compressed air and sewerage) and isolation of power to the site (if appropriate);
- Demolition and removal of infrastructure from ventilation shaft site;
- Filling and/or sealing portals, ventilation shafts and underground roadways in accordance with the Mine Closure Plan and NSW Resources Regulator requirements;
- Rehabilitate the transport and service corridor
- Seal and rehabilitate ventilation fans shafts (assumed 2 vent shafts, based on supplied information)
- removal and disposal of any hazardous materials such as fuel, lubricants, chemicals or other substances of concern;
- Erosion and Sediment Control
- Management of Offset Areas
- Weed and Pest Control

Subsidence is an integral component of the rehabilitation of the Maxwell project, and is discussed in more detail in Section 5.

- Rehabilitate the subsidence areas;
- Remediation of mine affected Biophysical Strategic Agricultural Land (BSAL).
- Manage subsidence of Edderton Road

Limited data were available to assess the Financial Assurance for rehabilitating Maxwell underground.

2.2.1 Additional Comments

Rehabilitation trials have been identified as part of the rehabilitation works, however, a significant amount of rehabilitation works have been completed or are in progress at Drayton North area that will inform future rehabilitation design. There is no attempt to integrate the findings and data collected from this work into future rehabilitation design and implementation.

Other unknowns include:

- Potential for spontaneous combustion and need to install and Decommission nitrogen atmosphere equipment;
- Management of explosive gases and spontaneous combustion
- Decommissioning sewerage treatment facility
- Rehabilitation of mine impacted riverine areas
- Close portal and vent shafts.

3 MAXWELL SOLAR PROJECT INFRASTRUCTURE AREA

As a separate project, and in parallel with the Maxwell Project, Malabar submitted approval a development application for a solar farm, known as the "Maxwell Solar Project" (SSD 18_9820). The Solar project was approved. The solar panels will be located on areas of previous open cut mining disturbance within CL 229.

The Maxwell Solar Project allows for beneficial use of an area previously subject to open cut mining. The location is adjacent to a major electricity generating hub in NSW (Liddell and Bayswater Power Stations), and in proximity to high voltage power lines.

The Maxwell Solar Project does not constrain or negatively impact the development of this Project.

It is noted that the presence of solar infrastructure may impede activities associated with achieving a suitable final rehabilitation standard. For example, any erosion that may occur in the future on the solar area may be difficult to rectify due to the interference of solar infrastructure.

The solar Project has not been included in the rehabilitation cost estimate for Maxwell underground or Maxwell infrastructure area.

4 DISPOSAL OF REACTIVE COAL REJECTS

A total of 13 composite samples, including 6 samples representing clean coal, 6 samples representing the coal rejects, and one sample representing the Milbrodale Claystone forming the base of the sequence, were prepared by SGS Australia Pty Ltd (SGS) in Mayfield West. The clean coal and coal reject samples were composited into the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams.

The 7 composite samples of coal rejects were tested for AMD comprised Whynot seam (1), Woodlands Hill seam (2), Bowfield seam (2), and Arrowfield seam (1) for the four seams that were constructed from 16 samples collected and tested for AMD from Whynot seam (3), Woodlands Hill seam (5), Bowfield seam (4), Arrowfield seam (3) and Milbrodale Claystone (1).

The coal rejects produced at the Maxwell Infrastructure CHPP and to be disposed within the existing voids, are expected to be moderately to highly saline and have an acidic pH, most likely due to the presence of organic acids. The rejects are also expected to have moderate S, the majority of which is likely to occur as reactive sulphide, and low ANC. Based on these characteristics it is expected the rejects will typically be PAF with only a low capacity to generate acid (i.e. PAF-LC).

Importantly it needs to be noted that a very limited number of samples (15) were collected to represent 7 potential rejects, and 5 of the coal samples, i.e. the majority, were classed as PAF, one was marginal PAF i.e. positive NAPP and NAG pH of 4.5, and only one the Milbrodale Claystone was truly NAF material, Additionally all four seams tested returned positive NAPP results i.e. all four seams generate PAF rejects.

The rejects are expected to be enriched with As, Sb and Se in varying degrees and the contained Se is likely to be readily soluble.

Based on these findings, the following recommendations were put forward by Malabar for further characterising the coal rejects:

- As part of the ongoing process for managing CHPP rejects emplacements, geochemical characterisation should be undertaken to maintain an understanding of the materials classification.
- The recommended geochemical characterisation of the CHPP rejects should include kinetic NAG testing to determine the geochemical lag period (period of exposure to atmospheric oxidation before acid conditions are developed) of this material. Surface alkali treatment to extend the geochemical lag period of the rejects or over-dumping with rejects within the geochemical lag period may be required so that acid conditions do not develop during active dumping.
- Due to the expected presence of moderate salinity, PAF-LC material, the closure plan for the in-pit reject emplacement where applicable should be designed to prevent the reactive rejects from oxidising and the salts from migrating to the revegetation layer.
- It is recommended that the water quality monitoring program for the reject emplacement facilities includes pH, EC, alkalinity/acidity, sulphate (SO4), As, Sb and Se. This program is designed to identify the ongoing processes of sulphide oxidation, and acid generation and neutralisation resulting from the exposure of PAF-LC materials prior to acid conditions developing.

- However, due to the risk of this material being sodic, it is recommended that allowance is made to treat these materials (e.g. gypsum) to negate the sodicity, as required. No untreated sodic materials should be used for construction or site earthworks.

The above information indicates that there is a significant degree of uncertainty associated with the quality and consequent handling and rehabilitation needs associated with mine waste and reject materials. In particular, the water quality of the pit water where the rejects will be discharged for storage (principally the North pit that is adjacent to the CHPP) may require management of acidity and metals including As, Sb and Se over the long term.

5 SUBSIDENCE

5.1 SEARs

The Secretary's Environmental Assessment Requirements (SEARs) Relating to subsidence state: The EIS must address the key issue of "*Subsidence – including an assessment of the likely conventional and non-conventional subsidence effects and impacts of the development, and the potential consequences of these effects and impacts on the natural and built environment (including Edderton Road), paying particular attention to those features that are considered to have significant economic, social, cultural or environmental value.*"

5.2 Background

The Maxwell Coal Project proposes an underground coal mine within a 3,215 ha Gateway Certificate Application Area (GCAA). Figure 5-1 and Figure 5-2 show the area investigated by MSEC for mine subsidence from the proposed Maxwell underground, referred to as the Study Area by MSEC.

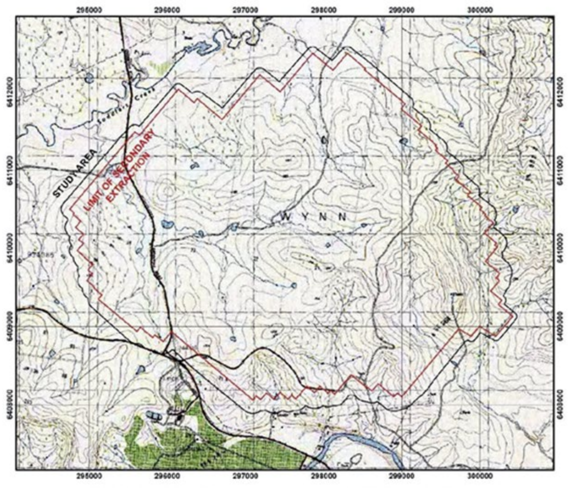


Figure 5-1: Subsidence Study Area showing limit of secondary extraction

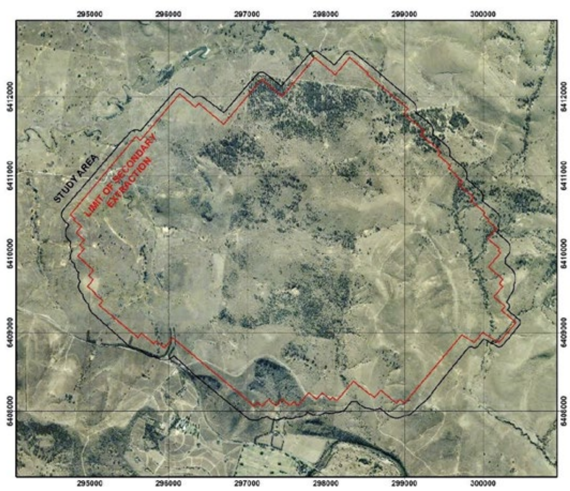


Figure 5-2: Aerial photo showing Subsidence Study Area and limit of secondary extraction

Mine Subsidence Engineering Consultants (MSEC) was commissioned by Malabar to:

- review the proposed mining layouts in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams to identify mining geometry, surface and seam information and geological details relevant to subsidence predictions and impact assessments;
- prepare predicted subsidence contours after the extraction of the proposed panels and longwalls within each of the seams;
- identify and describe the natural and built features within the proposed mining area;
- provide subsidence predictions and impact assessments for each of these natural and built features; and
- provide recommendations for strategies to manage the potential impacts resulting from mining.

MSEC did not undertake any geotechnical or hydrological assessment of potential impacts of mine subsidence.

The MSEC study area for subsidence prediction and impacts is defined as:

*"the surface area that is likely to be affected by the secondary extraction of the proposed panels and longwalls in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams. The extent of the Study Area has been calculated, **as a minimum**, as the surface area enclosed by the greater of the 26.5° angles of draw from the limits of secondary extraction in each seam and by the predicted total 20 mm subsidence contour" (MSEC, 2019).* The Study Area is shown in Figure 5-1 and Figure 5-2.

5.3 Subsidence predictions

MSEC (2019) report (9 July 2019) was prepared to support the Maxwell EIS that was submitted to the Department of Planning and Environment (DP&E); The MSEC report is Appendix A of the EIS. The MSEC study is the principal source document used in the EIS for potential subsidence impacts.

"The general behaviour of the rock mass in the area of longwall underground coal mining that initiates mine subsidence and surface ground movements is well established and understood. The actual behaviour varies on a site-by-site basis and is influenced by the depth of the mine, the geometry of the mine, the amount of coal extracted and geological and topographical factors.

Suitable methods and models are available for subsidence prediction, including a variety of empirical, analytical and numerical methods. However, in complex geological environments, predictions may have a high level of uncertainty. The most common modelling prediction methods used in Australia are experience-based, such as the Incremental Profile Method (IPM). This relies on initial monitoring at a mine site during the early stages of mining and is generally the most reliable of the various methods. Subsequent development of site-specific parameters to model and predict subsidence during its expansion can support the initial prediction using the Incremental Profile Method. The prediction allows subsidence impact assessments for natural and built features located above or near a proposed mine layout." EISC (2014).

Figure 5-3 show the different zones of deformation formed by mine subsidence. Figure 5-4 shows components used describe mine subsidence from Longwall Mining including the areas within the overburden impacted.

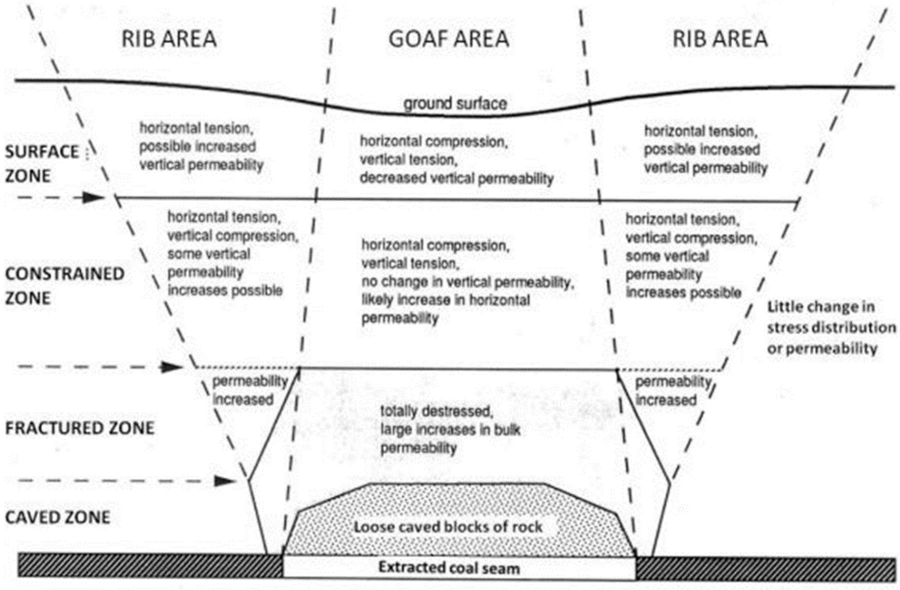


Figure 5-3: Caving, fracturing and subsidence above a longwall panel (© Copyright, Forster 1995 in MSEC 2007)

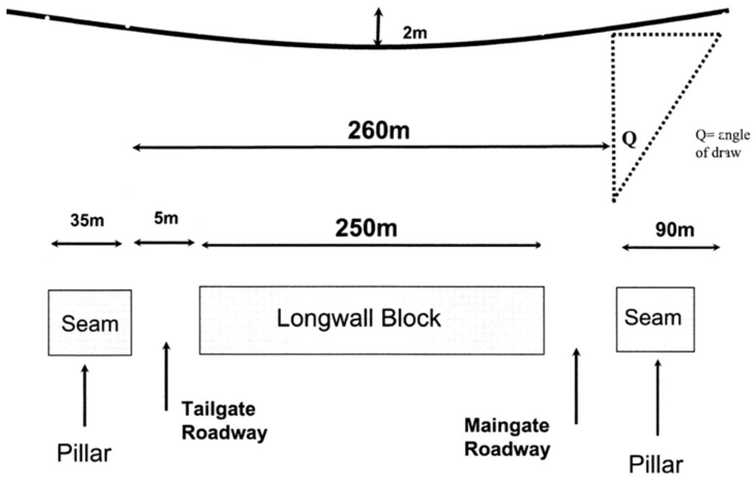


Figure 5-4: An example of subsidence: Estimated subsidence under a 250m wide longwall block for the Kestrel Mine near Emerald (Copied from Rio Tinto, 2006)

MSEC used the Incremental Profile Method (IPM) to predict subsidence for the proposed Maxwell underground operation. has built an extensive empirical database and developed standard subsidence prediction curves for the Southern, Newcastle and Hunter Coalfields. The prediction curves can be refined and adapted for the local geology and local conditions, based on the available monitoring data from the area. It can only be assumed that in the absence of monitoring data for proposed mine site analogue sites must be used to drive the IPM modelling.

MSEC indicate that the prediction of subsidence is a three-stage process where,

i. Firstly, *the magnitude of each increment is calculated, then, the shape of each incremental profile is determined and, finally, the total subsidence profile is derived by adding the incremental profiles from each longwall in the series. In this way, subsidence predictions can be made anywhere above or outside the extracted longwalls, based on the local surface and seam information.*

For longwalls in the Newcastle and Hunter Coalfields, the maximum predicted incremental subsidence is initially determined, using the IPM subsidence prediction curves for a single isolated panel, based on the longwall void width (W), the depth of cover (H) and the extracted seam thickness (T). The incremental subsidence is then increased, using the IPM subsidence prediction curves for multiple panels, based on the longwall series, panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (Wpi/H). In this way, the influence of the panel width (W), depth of cover (H), as well as panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (Wpi/H) are each considered.

ii. The shapes of the incremental subsidence profiles are then determined using the large empirical database developed by MSEC of observed incremental subsidence profiles from the Hunter Coalfield. The profile shapes are derived from the normalised subsidence profiles for monitoring lines where the mining geometry and overburden geology are similar to that for the proposed longwalls. Most of the data are based on single seam extraction or longwall extraction beneath an existing Bord-and-Pillar mined seam.

iii. Finally, the total subsidence profiles resulting from the series of longwalls are derived by adding the predicted incremental profiles from each of the longwalls.

The shapes of multi-seam subsidence profiles depend on, amongst other factors, the depths of cover, interburden thickness, mining heights and the relative locations between the longwalls within each seam, but, also geological and geotechnical properties of the seams and overburden, and geological structures such as faults and seam dip, and surface topography. The Maxwell project involves underground mining within four coal seams including (in order of shallowest to deepest): bord and pillar mining of the Whynot Seam and longwall mining of the Woodland Hill Seam, Arrowfield Seam and Bowfield Seam.

Mining of the Woodlands Hill, Arrowfield and Bowfield seams will result in multi seam extraction of seams undermining successively the Whynot, the Woodlands Hill and the Arrowfield seam.

Given the number of vertically successive coal seams to be mined, the proposed Maxwell Project will result in a range of potential subsidence-related impacts to water resources. These would include changes to surface watercourse gradients, flows and erosion, and surface ponding as well as surface and shallow fracturing. The maximum conventional vertical subsidence is predicted to be 5.6 m where all four coal seams are proposed to be extracted. However, conventional vertical subsidence will occur progressively as each subsequently deeper coal seam is mined. The seam with the greatest individual contribution to subsidence is predicted to be the Woodlands Hill Seam, which is the second to be mined, is the first series of longwalls and the first to undermine the bord and pillar workings within the Whynot Seam. The extraction of three underlying coal seams beneath the Whynot Seam will likely result in the collapse of retained coal pillars, which would likely result in increased subsidence evident at the surface. The IESC notes that elsewhere in the Hunter Valley (North Wambo Underground Mine) the extraction of longwalls beneath bord and pillar mined seams has resulted in localised subsidence in excess of 100 per cent of the total mining height.

5.3.1 Subsidence prediction for the Maxwell Study area

There are no existing workings within the Maxwell Study Area and, therefore, the panels extracted in the first seam were assumed by MSEC to be governed by single-seam mining conditions. The proposed bord and pillar and longwall mining of the 4 seams at Maxwell were modelled and the data compared with single seam extraction of the Whynot seam by bord and pillar and by longwall extraction of the Woodlands Hill Seam; and multi-seam extraction for Woodlands Hill Seam, Arrowfield Seam and Bowfield Seam. The IPM subsidence prediction analysis used by MSEC included data on seam width, seam thickness, seam depth, overburden thickness and depth, from the Maxwell seams. The subsidence prediction analysis results were compared with standard IPM on single seam and multi-seam extraction from mines in the Hunter Coalfield at a number of nearby collieries in the same or similar coal seams, including Beltana, Blakefield South, Integra Underground, United and Wambo.

There is no indication in the MSEC report that geological, hydrogeological and geotechnical data compiled for the Maxwell underground deposit since it was discovered, and accumulated over the years were used to validate the assumptions of comparing the IPM results for Maxwell with IPM results from mines in the region. It is not clear from the EIS and the MSEC report that a geotechnical analysis of potential subsidence has not been undertaken by a geotechnical engineer specialising in mine subsidence and mining geology. MSEC in their report state that they (MSEC) did not undertake a geotechnical or groundwater assessment of subsidence that is likely to occur from the mining of the proposed Maxwell underground operation.

The maximum predicted subsidence effects due to the proposed mining in the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams modelled by MSEC are:

- *vertical subsidence of 5600 mm (58 % of the total mining height in all seams);*
- *tilt of 50 mm/m (i.e. 5 %, or 1 in 20);*
- *hogging and sagging curvatures of 2.0 per kilometre (km-1, i.e. minimum radius of curvature of 0.5 km); and*
- *strains typically between 10 mm/m and 20 mm/m, with localised strains greater than 20 mm/m.*

A critical extraction is one which is sufficiently large compared with the mining depth so as to result in the maximum possible subsidence to the centre of the panel. Extractions smaller than critical extractions are termed sub-critical, and those larger are super-critical, causing the greatest subsidence and deformation of the overlying strata and land surface. The extraction of the Woodlands Hill, Arrowfield and Bowfield seams for the Maxwell project is largely critical to super-critical (MSEC, 2019). (i.e. for each of these seams a maximum level of subsidence is likely).

MSEC, 2019 specifically comments on the potential impacts from subsidence for two water sources and adjacent road infrastructure, being

- Hunter River and its alluvial flats located immediately south of the area where the four seams will be mined;

- Saddlers Creek located northwest and outside the proposed limit of secondary extraction;
- Edderton Road ;
- Golden Highway immediately south of the limit of secondary extraction

The following discussion on key waterways and roadways utilises information compiled and reported by MSES (MSEC, 2019).

Surface subsidence estimated by MSEC (2019) is 5600mm as 58% of the total mining height in all 4 seams. MSEC also noted, that the percentage of the total mining height is less than the percentages of the mining heights for individual seams for multi-seam conditions, as the positions of maximum subsidence do not coincide due to the stagger of the longwalls.

As described by Li, et al. (2007 and 2010), the maximum additional subsidence resulting from the extraction of longwalls beneath existing longwall goaf (i.e. multi-seam mining conditions) can be estimated.

MSEC (2019) note that there is limited multi-seam monitoring data from the NSW coalfields, especially where longwalls have been extracted directly beneath or above existing longwalls or panels. MSEC (2019) present a summary of the details, measured vertical subsidence and mining heights for the multi-seam mining case studies where longwalls were mined beneath or above previously extracted longwalls or panels from the Blakefield South, Cumnock Colliery, Liddell Colliery, Newstan Colliery and NWUM. All examples are for two seam conditions.

The additional vertical subsidence measured due to the extraction of the second seam varied between 60 % and 116 % of the mining height. MSEC note that in many of these cases, however, the maximum measured vertical subsidence was localised. On average, the additional subsidence observed for these available multi-seam mining cases was around 85 % of the mining height in the second seam.

The additional vertical subsidence can be greater than 100 % of the seam thickness adjacent to the chain pillars in the upper seam. The initial extraction of the first seam results in voids adjacent to the chain pillars due to the angle of break over the caving zone. The subsequent extraction in the lower seam can fail the cantilevering strata resulting in locally increased subsidence adjacent to the chain pillars. Whilst the additional subsidence due to the extraction of the lower seam can be greater than 100 % of its thickness, the total subsidence from mining both seams is less than the combined thickness of these seams.

Table 5-1 summarises the depths of cover, interburden thicknesses, working sections and proposed mining heights for each of the seams.

Table 5-2 contains maximum predicted additional subsidence parameters for each seam.

Table 5-3 lists the maximum predicted cumulative conventional subsidence parameters after each seam is mined.

Table 5-4 is a comparison of the mined geometry for the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams with Blakefield South Mine and the North Wambo Underground Mine.

Table 5-1: Depths of cover, interburden thicknesses, working sections and proposed mining heights for each of the seams (MSEC, 2019)

Seam	Depth of cover (m)	Interburden thickness to the overlying seam (m)	Working section thickness (m)	Mining height (m)
Whynot Seam (WN)	40* ~ 180 (100 average)	N/A (Single-seam)	1.3 ~ 2.3 (2.0 average)	1.5 ~ 2.3
Woodlands Hill (WH)	125 ~ 365 (260 average)	155 ~ 185 (165 average)	1.7 ~ 3.5 (2.7 average)	2.1 ~ 3.5
Arrowfield (AF)	165 ~ 415 (315 average)	40 ~ 75 (50 average)	2.1 ~ 3.7 (2.9 average)	2.1 ~ 3.7
Bowfield (BF)	215 ~ 425 (330 average)	20 ~ 45 (30 average)	2.2 ~ 3.3 (2.8 average)	2.4 ~ 3.3

*Note: * denotes that secondary extraction will only occur at depths of cover greater than 50 m.*

Table 5-2: Maximum predicted additional subsidence parameters for each seam. (MSEC, 2019)

Due to each seam	Maximum predicted additional vertical subsidence (mm)	Maximum predicted additional tilt (mm/m)	Maximum predicted additional hogging curvature (km^{-1})	Maximum predicted additional sagging curvature (km^{-1})
Whynot Seam (single-seam conditions)	350	15	0.5	1.0
Woodlands Hill Seam (including reactivation)	3100	45	2.0	1.5
Arrowfield Seam (including reactivation)	2700	20	0.5	0.5
Bowfield Seam (including reactivation)	2500	20	0.5	0.5

Table 5-3: Maximum predicted cumulative conventional subsidence parameters after each seam is mined (MSEC, 2019)

After each seam	Maximum predicted cumulative vertical subsidence (mm)	Maximum predicted cumulative tilt (mm/m)	Maximum predicted cumulative hogging curvature (km^{-1})	Maximum predicted cumulative sagging curvature (km^{-1})
Whynot Seam	350	15	0.5	1.0
Woodlands Hill Seam	3200	45	2.0	1.5
Arrowfield Seam	5400	50	2.0	2.0
Bowfield Seam	5600	50	2.0	2.0

Table 5-4: Comparison of the mined geometry for the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams with Blakefield South Mine and the North Wambo Underground Mine. (MSEC, 2019)

Parameter	Proposed longwalls at the Maxwell Project			Longwalls used in the strain analysis
	Woodlands Hill Seam	Arrowfield Seam	Bowfield Seam	
Void width (m)	305	305	305	260 ~ 410 (325 ave.)
Depth of cover (m)	200 ~ 365 (280 ave.)	170 ~ 415 (315 ave.)	215 ~ 425 (340 ave.)	80 ~ 300 (190 ave.)
W/H ratio	0.84 ~ 1.5 (1.1 ave.)	0.73 ~ 1.8 (0.97 ave.)	0.72 ~ 1.4 (0.90 ave.)	0.9 ~ 3.3 (1.8 ave.)
Interburden (m)	155 ~ 185 (170 ave.)	40 ~ 75 (50 ave.)	20 ~ 45 (30 ave.)	50 ~ 120 (80 ave.)
Mining height (m)	2.6 ~ 3.5 (3.0 ave.)	2.1 ~ 3.7 (2.9 ave.)	2.4 ~ 3.3 (2.8 ave.)	2.1 ~ 3.4 (2.6 ave.)

In the absence of data on subsidence such as a new proposed underground mine like Maxwell, information from similar mines such as the Blakefield South Mine can be used as analogues. MSEC have looked at the Blakefield South Mine (Blakefield South), part of the Bulga Coal Complex, is located approximately 5 km north of the township of Broke in the Upper Hunter Valley of NSW for their analysis of subsidence at the Maxwell mine.

Bulga Coal Management (BCM) operated Blakefield South from approximately 2008 to 2018. Blakefield South involved longwall extraction from the Blakefield Seam beneath the existing Bulga South longwalls in the Whybrow Seam (i.e. multi-seam mining conditions).

Blakefield South Longwall Panels 1 to 4 were mined beneath the Broke and Charlton Roads. Both roads were managed in situ for the duration of longwall mining. During extraction, BCM measured mine subsidence ground movements along various survey monitoring lines, including along Broke and Charlton Roads.

End-of-panel monitoring undertaken for Blakefield South Longwall Panels 1 to 4 demonstrated that actual mine subsidence ground movements were typically less than the maximum predicted to occur in the relevant pre-mining subsidence assessment (Table 5-5). This highlights the conservatism inherent in the approach to subsidence assessment used in NSW.

Table 5-5 : Comparison of Observed and Predicted Subsidence at Blakefield South

Blakefield South Longwall	Type	Maximum Total Vertical Subsidence (mm)	Observed : Predicted ratio %	Maximum Total Tilt (mm/m)	Maximum Total Tensile Strain (mm/m)	Maximum Total Compressive Strain (mm/m)
Broke Road						
Longwall 2	Observed	1,895	60%	37	12	37
	Predicted	3,175		60	25	40
Longwall 3	Observed	2,025	66%	28	7	35
	Predicted	3,050		55	20	20
Longwall 4	Observed	2,229	69%	23	12	8
	Predicted	3,250		60	20	20
Charlton Road						
Longwall 1	Observed	2,453	88%	48	13	13
	Predicted	2,800		100	55	50
Longwall 2	Observed	2,701	86%	72	22	16
	Predicted	3,125		100	55	65
Longwall 3	Observed	2,794	89%	89	13	16
	Predicted	3,150		95	55	65

The data for Blakefield Mine longwalls listed in Table 5 indicate that observed maximum subsidence ranges from 60% to 89% of predicted. Maximum total subsidence resulting from the extraction of the first seam (single-seam conditions) plus the extraction of the second seam (multi-seam conditions) as a proportion of total extracted seam thickness of both seams was predicted by MSEC from multi-seam ground monitoring data range from 61-86%. Potentially the maximum subsidence may by higher than 58% of the combined mining heights in the four Maxwell seams. MSEC noted that that *the "percentage of the total mining height is less than the percentages of the mining heights for individual seams for multi-seam conditions, as the positions of maximum subsidence do not coincide due to the stagger of the longwalls."*

5.4 Mining induced surface cracking

The IESC (IESC, 2014) in their background review of subsidence from coal mining activities provided the following statement:

"*Longwall mining can result in cracking, heaving, buckling, humping and stepping at the surface, especially where the soil cover is 1 m or less. Alternatively, deep soil masks bedrock cracking. These surface deformations are influenced by factors such as ground curvature and differential horizontal movement. Ground curvature and differential horizontal movement is dependent on the mining geometry, depth of cover, extracted seam thickness, nearby topography and subsurface geology.*

The surface crack widths and frequencies may also reflect joint patterns in the bedrock. Wide joint spacing can lead to concentrations of strain and development of fissures at rockhead that are not necessarily coincident with the joints. Mining-induced subsidence can cause fresh fracturing in the overlying bedrock and also buckling of the near-surface beds during the compressive phase of the subsidence wave. As a subsidence trough develops surface cracks will generally appear in the tensile zone, typically a horizontal distance equivalent to 0.1 to 0.4 times the depth of cover inwards from directly above the panel edges and aligned parallel to these.

At shallow depths of cover, it is also likely that surface cracks will open above and parallel to the moving extraction face. This cracking tends to be transient, since the tensile phase of the travelling wave is generally followed by a compressive phase which closes them. Shearing also occurs and the surface cracks may not fully close, generating compressive ridges. The depth of surface cracking appears to be in the order of 5 to 20 m but can be deeper above shallow workings where more shearing occurs.

At shallow depths of cover surface cracking and heaving can occur in any location above the extracted longwalls. However, the larger and more permanent cracks are usually located in the final tensile zones around the perimeters of the panels. Open fractures and heaving can also occur due to the buckling of surface beds that are subject to compressive strains".

IESC also noted that in the Bowen Basin although the strength of rock varies across the Basin, where the overburden includes some high strength sandstone with significant spanning capacity, fractures will form at wider spacings than normal. Surface crack widths up to 100 mm and step heights of 100 mm have been commonly observed at shallow depths of cover of less than 200 m. Even wider cracks have been observed where thick seams are extracted at shallow depths or near steep terrain. These larger tensile cracks tend to be located around the perimeters of the longwall panels and along tops of steep slopes. They can usually be identified and plugged to prevent loss of surface water

5.4.1 Height of Fracturing

HydroSimulations were commissioned to undertake a groundwater assessment for the Maxwell Project EIS. It included modelling and assessment of fracturing of the overburden as a result of mine subsidence. A report was prepared by HydroSimulations as a supporting document for the Maxwell EIS and is Appendix B of the EIS document.

HydroSimulations (2019) identified that as a result of longwall mining and subsequent subsidence a sequence of deformational zones (as shown in Figure 4) will be produced comprising:

- Deformed floor strata (Z);
- Mined seam (O);
- The caved zone (AA);
- A fracture zone, consisting of a lower zone of connective-cracking (A); and an upper

zone of disconnected cracking (B);

- Constrained zone (C); and the surface zone (D).

"The rocks in the connective-cracking part of the fracture zone (A) would have a substantially higher vertical permeability than the undisturbed host rocks. This would encourage groundwater to move out of rock storage downwards towards the goaf. In the upper part of the fracture zone, where disconnected-cracking occurs, the vertical movement of groundwater should not be significantly greater than under natural conditions. Depending on the width of the longwall panels, the depth of mining, the thickness of the seams, the number of seams mined, and the geological and geotechnical properties of the overburden rock layers are likely to sag without breaking, and bedding planes are likely to open. As a result, increase in horizontal permeability can be expected at least over the dimension of a longwall panel. A constrained zone (C) does not occur in areas where the connective-cracking zone (A) reaches the surface."

"In the surface zone (D), near-surface cracking can occur due to horizontal tension at the edges of a subsidence trough. Cracking would be shallow (<15 m), often transitory, and any loss of water into the cracks may not continue downwards towards the GOAF.

The strata movements and deformation that accompany subsidence would alter the hydraulic and storage characteristics of aquifers and aquitards, likely to be permanent. As there would be an overall increase in rock permeability, groundwater levels would be reduced either due to actual drainage of water into the goaf or by a flattening of the hydraulic gradient without drainage of water. At the base of the fractured zone, groundwater pressures would reduce towards atmospheric pressure."

There are no published case studies relevant to above-seam fracturing for the multi-seam nature of the Project. HydroSimulations assumed a multi-seam correction can be derived from the incremental subsidence due to mining of individual seams. HydroSimulations (2019) suggests that actual subsidence is more likely to be 70-90% of total combined seam thickness (based on multi-seam subsidence data from North Wambo, Liddell and Cumnock Collieries). This matches data for the Blakefield Mine as summarised in Table 5-5.

Figure 5-5 shows photographs of surface cracking resulting from extraction BSLW1 and BSLW5 at the Blakefield South Mine (i.e. multi seam conditions) (MSEC, 2019).

Figure 5-5: Surface cracking above Blakefield South mine (multi-seam conditions) (MSEC, 2019)

Table 5-6 shows the adopted height of fracturing as metres above the upper seam. Comparing the data in Table 5-6 with the depth of cover (Table 5-1) for each of the seams suggests that surface cracking will occur. Unfortunately, data presented in the EIS makes it difficult to identify areas where surface cracking is likely to occur.

HydroSimulations (2019) applied the adopted height of fracturing for each multi-seam mining zone to the groundwater model to determine the uppermost layer that would be fractured. Areas where the adopted height of fracturing reaches Layer 1 (regolith) are representative of fracturing to the surface. Application of this conservative multi-seam fracturing approach indicates fracturing to the surface would occur across approximately half of the Maxwell Underground area.

Table 5-6: Height of Fracturing Parameters for each Mining Zone (HydroSimulations, 2019)

Mining Zone	Extracted Seams	Average Upper Seam Cover Depth [m]	Upper Seam Panel Width [m]	Average Total Thickness [m]	Adopted Height of Fracturing* (m above upper seam)
1	Woodlands Hill	191	268	2.7	154
2	Whynot Woodlands Hill	92	60	4.6	66
3	Woodlands Hill Arrowfield	278	300	5.6	258
4	Whynot Woodlands Hill Arrowfield	129	60	7.5	97
5	Woodlands Hill Arrowfield Bowfield	246	300	8.5	288
6	Whynot Woodlands Hill Arrowfield Bowfield	94	60	10.4	95

5.5 Angle of Draw

The Angle of Draw (AoD) varies with geology and depth of cover and typically ranges from a few degrees, such as the case of a near-vertical step at the panel edge, up to 60°. Most commonly, AoD is in the range of 10° to 35° (MSEC 2007); Ren and Li (2008) report a range of values for AoD varying between 19 and 50° based on limited data from the Newcastle coalfield. A rule of thumb used in NSW is to adopt an AoD of 26.5°, if no better information is available (MSEC 2007). This angle describes a subsidence trough extending a distance equivalent to half the mining depth beyond the edge of mining and is close to average in the Sydney Basin.

The surface subsidence usually extends outside the limits of extraction for a certain distance (i.e. the angle of draw). The angle of draw distance is usually less than or equal to 0.5 to 0.7 times the depth of cover (or angles of draw to the vertical of 26.5° to 35°) in the NSW and QLD Coalfields.

5.6 Potential Impacts on major watercourses

The potential impacts on watercourses and their alluvial flats were estimated by MSEC (Appendix A). The Limit of Measurable Subsidence (LOMS) was used by MSEC to look at potential impact on the Hunter River and Saddlers Creek and the respective alluvial flats. LOMS is typically used to define a boundary outside of mine workings beyond which no measurable subsidence (equal or less than 20mm) is predicted. Precedence in NSW indicates that an angle of draw of 26.5° is normally accepted as the LOMS outside any type of mine workings. HydroSimulations (2019) suggests that fracturing to the surface will occur across approximately half the site of the proposed Maxwell underground operation.

5.6.1 Hunter River

The Hunter River is located to the south of the proposed mining area. MSEC 2019 has identified that the thalweg (i.e. centreline) of the river channel (that is ~100m wide at the point assessed by MSEC, 2019) is at a minimum distance of 525 m from the proposed panels and longwalls and a minimum distance of 375 m outside the 26.5° angle of draw. At these distances, the river channel itself is expected to experience negligible vertical subsidence. The river channel could experience low levels of far-field or valley related effects. MSEC has accordingly concluded that it is highly unlikely that these low-level movements would result in adverse impacts on the river channel itself. (MSEC, 2019). The Hunter River width (not including flood width) is ~100m at closest point of the proposed Woodlands Hill Panel (WHLW12). As the river swings south (upstream) the alluvial flood plain widens significantly.

The mapped limit of alluvium for the Hunter River within the relevant Water Sharing Plan is located more than 50 m outside the 26.5° angle of draw lines from the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The alluvium is predicted by MSEC to experience less than 20 mm vertical subsidence and is therefore not expected to experience measurable tilts, curvatures or strains. The potential impacts on the alluvium and associated aquifer are discussed by the specialist surface water and groundwater consultants for the EIS. (MSEC, 2019).

The AoD varies with geology and depth of cover and typically ranges from a few degrees, such as the case of a near-vertical step at the panel edge, up to 60 degrees. Most commonly, AoD is in the range of 10 to 35 degrees (MSEC 2007); Ren and Li (2008) report a range of values for AoD varying between 19 and 50 degrees based on limited data from the Newcastle coalfield. A rule of thumb used in NSW is to adopt an AoD of 26.5°, if no better information is available (MSEC 2007). This angle describes a subsidence trough extending a distance equivalent to half the mining depth beyond the edge of mining and is close to average in the Sydney Basin.

In general, for wide extraction panels, the stronger the overburden rocks or the shallower the mining, the smaller the AoD. With weak and thinly bedded strata and where deep soils are present at the surface, the AoD may increase beyond 35 degrees (IESC, 2014). MSEC should have investigated higher angles of draw rather than a single rule of thumb 26.5 degrees. The assessment is deficient in identifying potential impacts.

It is emphasised that the AoD concept should not be used to limit or protect surface and groundwater resources. It is only a measurement of the limit of observed vertical subsidence movements. Many additional steps need to be taken to protect surface water and groundwater resources.

Table 5-7 is the predicted minimum distances of the Hunter River from the proposed panels and longwalls.

Table 5-7: Predicted minimum distances of the Hunter River from the proposed panels and longwalls. (MSEC, 2019)

Seam	Nearest panel or longwall	Minimum distance from the nearest panel or longwall (m)	Minimum distance from the 26.5° angle of draw (m)
Whynot Seam	WNP16	1650	1580
Woodlands Hill Seam	WHLW12	525	375
Arrowfield Seam	AFLW12	550	380
Bowfield Seam	BFLW11	610	410

While 26.5° angle of draw is used when predicting limits of subsidence, if the angle of draw is greater than 26.5° say 35° - 40° then the area of subsidence deformation becomes closer to the Hunter River: based on the Woodlands Hills seam minimum distance from 35° angle of draw becomes 270m, and is a 100m closer to the alluvial flats. Figure 6 shows estimated limits of deformation for Angles of Draw for 26.5° and 35°. The application of 35° AoD hasn't been modelled but illustrates the need for a range of different angles of draw to be assessed and modelled as part of the environmental impact assessment process, not just the rule of thumb. The EIA process must look at a wide range of parameters that can be and are used to define an indicate potential subsidence deformation and potential extent of surface and near surface effects. This process also needs to be coupled with known geology and geotechnical data for the Maxwell mine as recommended by MSEC.

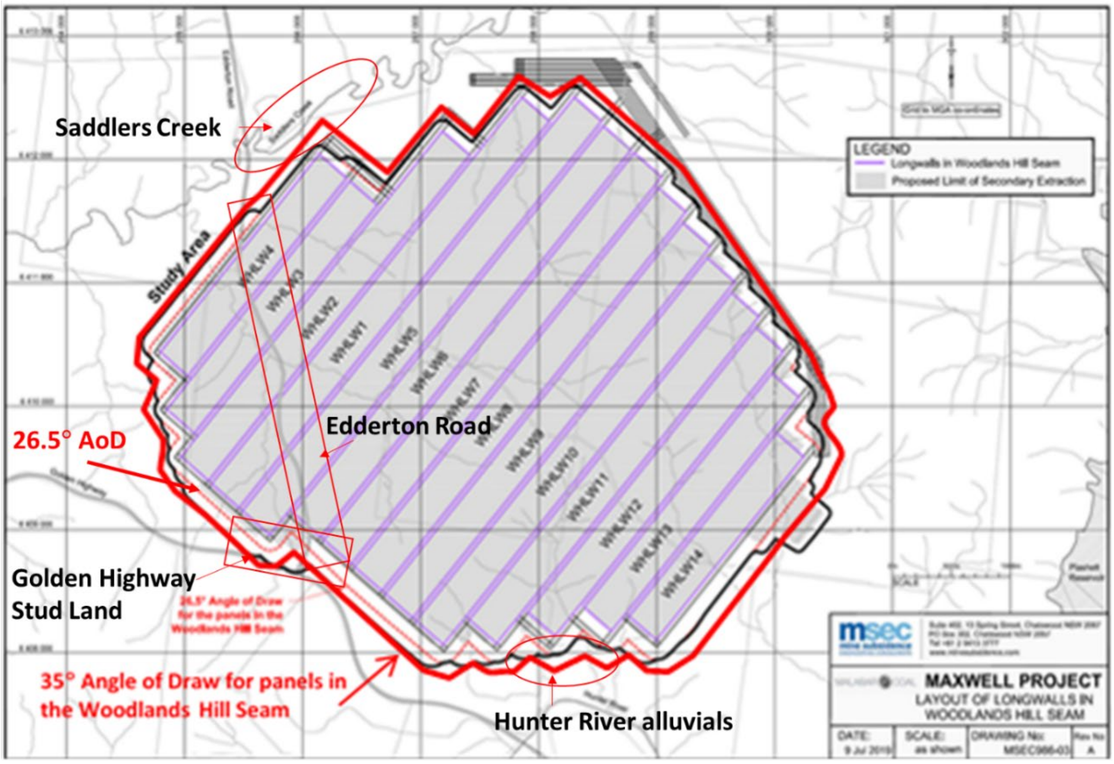


Figure 5-6: Layout of Longwalls in Woodland Hill Seam

MSEC (2019) does recommend that "*Extraction Plans for the Project include a subsidence effects monitoring program to monitor subsidence movements, including valley closure, and compare measured movements with predictions. Further recommendations for the Hunter River were provided by the specialist surface water and groundwater consultant for the EIS, including the development and implementation of a monitoring program"*. This suggests need to cover uncertainty about predictions of subsidence impacts on the Hunter River and its alluvial flats.

5.6.2 Saddlers Creek

Saddlers Creek is located to the north of the proposed mining area. A summary of the minimum distances of the thalweg (i.e. centreline) of the creek from the proposed panels and longwalls within each seam is provided in Table 5-8. The minimum distances of the creek from the 26.5° angle of draw for each seam are also provided in Table 5-8.

Table 5-8: Predicted minimum distances of Saddlers Creek from the proposed panels and longwalls (MSEC, 2019)

Seam	Nearest panel or longwall	Minimum distance from the nearest panel or longwall (m)	Minimum distance from the 26.5° angle of draw (m)
Whynot Seam	WNP5	880	860
Woodlands Hill Seam	WHLW4	240	170
Arrowfield Seam	AFLW1	390	300
Bowfield Seam	BFLW1	370	270

Using a higher angle of draw to calculate minimum distance from the Woodlands Hill seam averages 58m rather than 170m. Similar to the Hunter River there is potential to impact on the Saddlers Creek watercourse and mining in this area should be reviewed and options to minimise impacts to Saddlers Creek assessed and proposed.

5.6.3 Predictions for the Golden Highway

"The Golden Highway is located outside of the proposed mining area at a minimum distance of 150 m. At this distance, the highway is predicted to experience less than 20 mm vertical subsidence. Whilst the highway could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The highway is located at minimum distances between 150 m and 210 m from the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The depths of cover at the south-western ends of the nearest proposed longwalls are 245 m above WHLW5, 310 m above AFLW6 and 335 m above BFLW5. The range of potential strains for the Golden Highway resulting from the extraction of the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams, for multi-seam mining conditions, has been based on the observed strains for multi-seam mining in the Hunter and Newcastle Coalfields." MSEC(2019)

Table 5-9 is the predicted minimum distances of the Golden Highway from the proposed panels and longwalls.

Table 5-9: Predicted minimum distances of the Golden Highway from the proposed panels and longwalls. (MSEC, 2019)

Seam	Nearest panel or longwall	Minimum distance from the nearest panel or longwall (m)	Minimum distance from the 26.5° angle of draw (m)
Whynot Seam	WNP1	1700	1650
Woodlands Hill Seam	WHLW5	210	90
Arrowfield Seam	AFLW6	150	0
Bowfield Seam	BFLW5	160	Partially inside

The Golden Highway is located outside of the proposed mining area at a minimum distance of 210 m. At this distance, the highway is predicted to experience less than 20 mm vertical subsidence. Whilst the highway could experience very low-levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The highway is located at minimum distances between 150 m and 210 m from the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. The depths of cover at the south-western ends of the nearest proposed longwalls are 245 m above WHLW5, 310 m above AFLW6 and 335 m above BFLW5.

Using a higher angle of draw puts the Golden Highway inside the area affected by subsidence of longwall panels.

MSEC (2019) identified potential issues with subsidence and recommended that a Built Features Management Plan (BFMP) be developed for the Golden Highway in consultation with RMS prior to mining within 500 m of the highway. The management plan could include ground monitoring and periodic visual inspections of the highway during the extraction of the proposed longwalls closest to it. The monitoring and inspections should include the small cutting to the east of Edderton Road and the surface projection of the East Graben Fault.

5.6.4 Edderton Road

Edderton Road crosses the western part of the Study Area and it is located directly above the proposed longwalls in the Woodlands Hill, Arrowfield and Bowfield Seams. A summary of the longwalls that were proposed to be extracted directly beneath the current alignment of Edderton Road is provided in Table 5-10. Edderton Road is a critical transport route for Woodlands and Godolphin and it should not be allowed to be impacted by mining the seams in areas likely to cause mine subsidence and impact on Edderton Road. Table 8 is the is the Maximum predicted total vertical subsidence, tilt and curvature for current alignment of Edderton Road. This suggests a maximum surface subsidence is 5100mm.

It is noted that the remediation option for Edderton Road is to relocate the southern portion of the road that currently transects land that is subject to subsidence from the mining of the Woodlands Hill seam. The proposed new location of the road is still proximal to the areas of subsidence based on 26.5° and within the area of subsidence for AoD greater than 26.5°.

Table 5-10: Maximum predicted total vertical subsidence, tilt and curvature for current alignment of Edderton Road. (MSEC, 2019)

After completion of seam	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Whynot Seam	< 20	< 0.5	< 0.01	< 0.01
Woodlands Hill Seam	2300	35	1.4	0.90
Arrowfield Seam	4300	45	1.6	0.90
Bowfield Seam	5100	45	1.6	0.90

Malabar Resources Limited issued a letter to the Chair of the IPC dated 23 October 2020 in which they advised that the Woodlands Hill Seam will be the only seam mined by Longwall Mining beneath the Edderton Road. Before relocation this would result in single seam subsidence rather than multi-seam subsidence. Predicted maximum total vertical subsidence above a longwall mined Woodland Hill seam is 2300mm.

MSEC (2019) describes that the subsidence impacts to Edderton Road (under the assessed multi-seam mining conditions) would have been similar to the impacts observed along the Broke and Charlton Roads following extraction of the Blakefield South longwalls. Further information regarding the subsidence impacts observed at the Broke and Charlton Roads was provided.

In light of the observed impacts to Broke and Charlton Roads and the management measures implemented by the operators of the Blakefield South longwalls, MSEC (2109) concluded:

"The potential impacts on Edderton Road could be managed using visual monitoring and undertaking remediation of the road pavement during active subsidence. These strategies may require temporary lane closures to undertake the repairs and temporary speed restrictions along the section of the road that is impacted by mining."

While reducing the mining activity beneath Edderton Road to one seam is a positive outcome, it does not remove the probability that surface subsidence will occur and will damage Edderton Road, which will impact traffic flow. There is no guarantee that temporary road closure will eliminate impact on the roads usage. The information supplied by Malabar Resources to the IPC is not clear on where the longwall mining will stop as it proceeds westward along the Woodland Hills seam. Also at what point will mining of the Whynot, Arrowfield and Bowfield seams cease as mining approaches the Edderton road corridor? Will further mining of the other seams recommence at some point west of the Edderton Road corridor? Bord and Pillar mining of the Woodlands Hill seam should be considered if it will result in no disruption of Edderton Road

A comparison of the key subsidence parameters for the proposed Maxwell Underground longwall panels beneath Edderton Road (Woodlands Hill Seam only) and the Blakefield South longwall panels beneath the Broke and Charlton Roads is provided in Table 5-11. Consistent with the findings in MSEC (2019), Table 5-11 indicates that the subsidence predicted for Edderton Road due to the Project is similar to and typically less than the maximum subsidence observed at Broke and Charlton Roads due to mining at Blakefield South.

Table 5-11: Summary of Subsidence Parameters

Road	Maximum Total Vertical Subsidence (mm)	Maximum Total Tilt (mm/m)	Maximum Total Tensile Strain (mm/m)	Maximum Total Compressive Strain (mm/m)
Maxwell Underground – Woodlands Hill Seam Only (Predicted Subsidence Parameters)				
Edderton Road	2,300	35	14	9
Bulga Mine – Blakefield South and Beltana No. 1 Multi-seam Mining (Observed Subsidence Parameters)				
Broke Road	2,229	37	12	37
Charlton Road	2,794	89	22	16

5.7 Subsidence and remediation of impacts on Biophysical Strategic Agricultural Land (BSAL)

The Maxwell Coal Project proposes an underground coal mine within a 3,215 ha Gateway Certificate Application Area (GCAA) that incorporates 72 ha of protocol-verified Biophysical Strategic Agricultural Land (BSAL) as determined by the Applicant. The Applicant states that no verified BSAL will be used for mining infrastructure.

Proposed underground mining using bord and pillar and longwall techniques within the GCAA is predicted to result in subsidence of 2,134 ha of the GCAA and cause direct subsidence impacts to the 72 ha of applicant-verified BSAL. Drs Pam Hazelton and Peter Bacon's report suggest the extent of BSAL is much larger at least **300ha** of verified BSAL.

The direct impacts resulting from subsidence associated with the underground mining are predicted by MSEC to include surface cracking of 25 to 50 mm (with isolated cracks to 100 mm) and depressions in the land surface up to 5600 mm. However, as explained above e.g., the area likely to be affected is greater and insufficient information for confidence Further, subsidence movements is likely to result in surface deformations, with cracking in flatter areas expected to be between 25 and 50 mm, with widths greater than 300 mm in some places (MSEC 2019).

The Planning Secretary's Environmental Assessment Requirements (SEARs) Maxwell Project (SSD 9526) that lists requirements for the assessment of Land Resources associated or impacted by the Maxwell underground project, requires an assessment of the likely impacts of the development on the soils and land capability of the site and surrounds, paying particular attention to biophysical strategic agricultural land (BSAL), including:

- verification of the extent and condition of BSAL within the site and assessment of potential direct and indirect impacts of the development on the agricultural productivity of verified BSAL;
- justification for any significant long term changes to potential agricultural productivity post-mining, paying particular attention to any highly productive agricultural land that would be affected by the development;
- an assessment of the agricultural impacts of the development, including preparation of an Agriculture Impact Statement, in accordance with the Strategic Regional Land Use Policy, paying
- particular attention to the likely impacts of the development on nearby equine and viticulture industry clusters;

- a description of measures that would be implemented to avoid, minimise or mitigate adverse impacts on nearby equine or viticulture critical industry clusters; and
- an assessment of the compatibility of the development with other land uses in the vicinity of the development, in accordance with the requirements of Clause 12 of State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007, paying particular attention to nearby equine and viticulture critical industry clusters.

In regard to the impacts of subsidence on the rural landscape, these are expected to be significant. The proponent has indicated that 630ha of the affected land will be returned to pasture. Given the likelihood that cracks up to 100mm and depressions up to 5.6m below the original surface are predicted, this will essentially make the affected lands unsuitable for any form of agricultural pursuit and unsuitable for improved pasture development for grazing in the short term.

The timeframe over which subsidence is likely to occur is difficult to define but may be measured in decades. The proponent has committed to rehabilitation monitoring for subsidence for a period of 2 to 5 years following cessation of mining activity. This is clearly too short a period in which to assess the extent and severity of subsidence and consequent remediation measures that may be necessary.

Further assessment of impacts on BSAL lands and documented in Hazelton and Bacon (2020).

5.8 Subsidence Remediation

Minimal remediation of subsidence impacted land, watercourses and groundwater is proposed by the EIS other than to backfill any surface cracks:

- The identified potential mitigation measures for subsidence-induced surface cracking include ripping, re-grading or in-filling of large to medium size surface cracks
- Re-grading and erosion controls in surface drainage lines
- Repairing or reinstating damaged groundwater bores.
- Watercourses are likely to develop ponding and knickpoints.
- Shallow and deep groundwater aquifers are likely to have long term damage.
- Edderton road remediation will comprise two options: ongoing remediation to fix pavement cracking and subsidence; or re-alignment if needed.
- Golden Highway remediation is monitoring for surface disruption plus repair (although the EIS does not identify the highway as an issue .

Subsidence movements is likely to result in surface deformations, with cracking in flatter areas expected to be between 25 and 50 mm, with widths greater than 150 mm in some places (MSEC 2019).

The EIS proposes that surface cracking would be monitored and remediated as required. The Subsidence Assessment prepared by MSEC (2019) describes that surface cracks requiring remediation, are more likely to occur on steeper slopes directly above underground mining areas – No information was provided in the EIS to quantify the surface area occupied by steep sloped land. Remediation of the larger surface cracks would generally be undertaken using conventional earthmoving equipment (such as backhoe or grader), and would involve ground disturbance associated with:

- in-filling of surface cracks by cultivation of the ground surface or in-filling with suitable soil or other material; and/or

- localised regrading or reshaping to limit the potential for water ponding.

Prior to any remediation of surface cracks, Malabar propose to undertake a review of environmental impacts that may result from the remediation at the specific location and consider if remediation of surface cracks is environmentally beneficial or if alternative methods of remediating the crack are warranted (e.g. without machinery). The review would consider, among other factors, the known locations of threatened flora species and populations as well as mapped rocky areas that may provide habitat for threatened lizards. Malabar's proposed remediation strategy does not identify or address matters relating to the protection of aboriginal heritage or native vegetation.

Minor cracks (i.e. less than 50 mm) that develop elsewhere are not expected to require remediation, as geomorphological processes would result in these cracks filling naturally over time.

5.9 IESC November 2018

The IESC identified in November 2018 a number of concerns relating to subsidence impacts including:

- Localised subsidence could be >100%
- Presence of geological features at the site that could give rise to anomalous subsidence impacts

IESC 2018 advice on the Gateway application is summarised in EIS Appendix B Groundwater. This document pre-dates the July 2019 MSEC Report. However, there is no evidence in MSEC 2019 that it was considered. The IESC 2018 advice includes the following statements on subsidence effects.

> *IESC 1: Given the number of vertically successive coal seams to be mined, the proposed Maxwell Project will result in a range of potential subsidence-related impacts to water resources. These would include changes to surface watercourse gradients, flows and erosion, and surface ponding as well as surface and shallow fracturing. The maximum conventional vertical subsidence is predicted to be 5.8 m where all four coal seams are proposed to be extracted. However, conventional vertical subsidence will occur progressively as each subsequently deeper coal seam is mined. The seam with the greatest individual contribution to subsidence is predicted to be the Woodlands Hill Seam, which is the second to be mined, is the first series of longwalls and the first to undermine the bord and pillar workings within the Whynot Seam. The extraction of three underlying coal seams beneath the Whynot Seam will likely result in the collapse of retained coal pillars, which would likely result in increased subsidence evident at the surface. The IESC notes that elsewhere in the Hunter Valley at the North Wambo Underground Mine, the extraction of longwalls beneath bord and pillar mined seams has resulted in localised subsidence in excess of 100 per cent of the total mining height.*

The MSEC 2019 report on subsidence selected 58% of total mining height for the combined four seams to define the total vertical (conventional) subsidence of 5.6m. **However, the IESC 2018 advice has identified that the longwall extraction beneath the bord and pillar mined seams could result in localised subsidence > 100%.**

> *IESC 2: While the subsidence assessment utilises an appropriate methodology for both single- and double-seam subsidence predictions, there is a higher level of uncertainty regarding the predictions for subsidence from the mining of the third and fourth seams. This uncertainty is due to empirical evidence not being available to support model calibration for the mining of three and four vertically successive seams. Given this uncertainty, the IESC considers a risk-based, or precautionary, approach should be used when interpreting total cumulative subsidence, particularly in proximity to geological features (faults, igneous sills, etc,) and important water resources (e.g. the Hunter River and its alluvium).*

Limited assessment is documented in the MSEC 2019 report other than noting and recognising*: "that there is greater uncertainty in the predictions for the Arrowfield and Bowfield Seams since there is* limited multi-seam data available for third and fourth seams*. However, the proposed longwalls in the Arrowfield and Bowfield Seams are critical to super-critical in width and the maximum predicted additional subsidence presents close to 100 % of their respective seam thicknesses. The predictions of vertical subsidence for these seams are therefore considered to be conservative since the actual subsidence is limited by the available voids defined by the overall seam thicknesses.*

The high level of uncertainty regarding the predictions for subsidence from the mining of the third and fourth seams was not analysed in detail other noting that uncertainty in subsidence prediction exists due to limited multi-seam data available for third and fourth seams. MSEC (2019) *proposed longwalls in the Arrowfield and Bowfield Seams are critical to super-critical in width and the maximum predicted additional subsidence presents close to 100 % of their respective seam thicknesses*. **No risk-based or precautionary approach to interpreting cumulative subsidence was undertaken**

> *IESC 3: A number of structural features (igneous sills and fault zones, including the East Graben Fault) have been identified that may result in non-conventional, anomalous or irregular subsidence. These various types of subsidence potentially pose a higher risk to water resources outside of the conventional subsidence (26.5 degree angle of draw) impact zone. The resulting impacts at the surface from these subsidence episodes could be severe where the structural features are associated with water resources such as surface watercourses, alluvial aquifers and other GDEs or groundwater infrastructure (e.g. monitoring bores).*

The use of the geological and geotechnical characteristics and properties of the mine stratigraphy which is known and was available was not documented in the subsidence assessment. Instead the prediction assessment/modelling used other mine site data with single seams and limited two seam extraction data as well as average values or rules of thumb for key parameters such as percentage predicted subsidence, or angle of draw.

None of these issues addressed in the EIS and supporting documents.

5.10 IESC November 2019

The IESC (2019) note that *the proposed project lies in a catchment which has previously been evaluated as degraded. Despite this, the areas of planned clearance and anticipated subsidence contain a total of 1,619 ha of ecological communities (White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland, Central Hunter Valley Eucalypt Forest and Woodland, Hunter Valley Weeping Myall (Acacia pendula) Woodland) listed as Critically Endangered under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Additionally, habitat for native species is provided by* *remnant and regrowth vegetation, particularly riparian vegetation along Saddlers Creek and other waterways in the area.*

The Maxwell EIS ignored the importance of 1,619 hectares of ecological communities that are likely to be impacted by mine subsidence.

IESC identify key potential impacts from the Maxwell Project that will effect mine rehabilitation including:

- groundwater drawdown, with predicted peak drawdown of the watertable of approximately 10 m and a recovery period over centuries;
- reduced flow and increased erosion and sedimentation in local watercourses, due to subsidence of up to 5.6 m and surface cracking between 25 and 300 mm wide predicted above the mining area;
- decreased groundwater and surface water quality should seepage occur from the rejects, tailings and brine in the East Void;
- decreased surface water quality from potential overflows of mine-affected water from the Rail Loop Dam and Access Rd Dam during flood events, or brine and other runoff from the Mine Entry Dam and Savoy Dam;
- impacts to riparian zone vegetation and EPBC Act-listed ecological communities, although their groundwater-dependence has not been determined; and
- cumulative impacts on surface and groundwater resources, water quality and ecological communities.

The IESC 2019 report identified several issues in which additional work is required to address key gaps in the understanding of potential impacts including:

Quantitative estimates of all surface water losses resulting from subsidence should be provided. This should include analysis of the impacts on the flow regime, including increases in the duration and number of low- and zero-flow days as these changes may affect instream and riparian biota (e.g. Swamp Oaks, Casuarina glauca) along Saddlers Creek and other waterways. Ponding may also adversely affect existing vegetation and recruitment (e.g. through waterlogging). This is covered in more detail by Hazelton and Bacon (2020).

The IESC has identified areas where additional undertakings are required to monitor and mitigate potential impacts. These are summarised below.

- There are substantial uncertainties in subsidence prediction associated with multi-seam mining.
    - Subsidence monitoring should be designed and implemented to verify predictions, particularly along and across drainage lines. In addition to the proposed monitoring, the proponent should undertake shallow borehole monitoring of saturated alluvium underlying Saddlers Creek near its confluence with the Hunter River, as recommended by the groundwater model peer reviewer. These data could be integrated with riparian zone assessments and revegetation strategies.
    - The next update to the numerical groundwater model should include quantitative uncertainty analysis that takes into account the potential influence

of subsidence on finer-scale variability in hydraulic properties.

- Revegetation of riparian areas above the underground workings (ahead of mining) is needed. This should improve the resilience of stream ecosystems to subsidence impacts and help compensate for ecological impacts.

- The proponent should undertake an analysis to determine whether the normal fault located at Saddlers Creek materially affects groundwater flow and, if so, incorporate these findings into the updated groundwater model. Use of environmental water tracers (e.g. major ions, stable water isotopes) to identify possible inflows to the creek in the vicinity of the fault could be considered.
- Given uncertainties about the volumes of surface water lost through subsidence, the proponent should monitor to verify these losses. Depending on the volumes, the proponent may require additional water licences.
- The surface water quality monitoring program should be expanded to include metals, at least including molybdenum, selenium, antimony and arsenic as recommended in the geochemistry assessment (GEM 2019).
- Additional targeted ecological surveys should be undertaken to inform adaptive management as part of a risk-based approach guided by an appropriate ecohydrological conceptual model showing potential impact pathways and predicted ecological responses.
- Management plans should incorporate and justify triggers to define the circumstances in which geomorphic and erosional impacts would be (actively) remediated. Proposed groundwater mitigation measures need to be detailed in a trigger-action-response plan.
- The final landform design should address the recommendations listed in the geochemical assessment (GEM 2019, pp. 27–28).
- Assuming that the final void(s) of the existing mine will be used for the proposed project, the design and management should include:
    - a sensitivity analysis that tests assumptions in final-void modelling and tests whether there is a chance that final voids could overtop;
    - an assessment of the likely water quality in final void(s) and how it changes over time;
    - an analysis of the potential for high-density saline void water to cause density-driven flow to the wider groundwater system; and
    - if void(s) might overtop, a strategy to monitor and mitigate any adverse effects
- The EIS for Maxwell Project has undertaken a detailed assessment to characterise groundwater resources within the project area. The IESC identified the high uncertainty in predicting impacts of subsidence on groundwater, as there are no published case studies relevant to above-seam fracturing for the multi- seam nature of the proposed project. This is not addressed as an issue or backed up with a risk-based analysis or sensitivity analysis by HydroSimulation groundwater assessment.
- Very limited groundwater quality monitoring data were provided in the EIS, with no information on location or timing of groundwater bores sampled. Several exceedances of water quality guideline values for aquatic ecosystem protection for

aluminium, copper and manganese were observed; however, it was unclear how exceedances would be addressed in future annual monitoring.

- The IESC 2019 document noted that the key physical driver of concern is the extent to which mining causes surface cracking and near-surface ground movement, which has important consequences for the interactions between groundwater and surface waters and their dependent resources. The estimates of surface subsidence are likely underestimated within watercourses and near faults. Accordingly, the IESC has little confidence in the estimates of non-conventional subsidence at the local scale (and other associated ground movements) in areas that are most vulnerable to ecological decline.
- The proponent provides an overview of the current condition of streams in the project area. The geomorphology report (Gippel 2019) provides a thorough assessment of watercourses that will be subject to subsidence.
- No explicit modelling has been done to assess the potential losses to surface hydrology due to subsidence and thus it is not possible to provide comments on these aspects
- The IESC encountered difficulty in predicting the precise locations where knickpoints will occur following subsidence so the proponent argues that hard engineering approaches (e.g. rock grade-control structures) are more appropriately used in response to impacts.
- Surface runoff reduction will occur due to ponding in depressions caused by subsidence. On the basis that sediment will gradually infill depressions as mining progresses, the proponent estimates the volume of ponding by assuming a depth of only 0.5 m compared to maximum predicted subsidence of 5.6 m. Moreover, while the total volume of ponding is estimated, the effects on seasonal low flow measures are not quantified.
- Gippel (2019, p. 93) argues that loss of surface flow into cracks will be rare, as there are few areas of exposed bedrock in the subsidence area. However, the IESC considers that there is also potential for cracking of bedrock beneath sediment-covered streambeds which could result in drainage of substantial volumes of surface water if streambed material has moderate or high permeability. This potential for underlying bedrock should be assessed by the proponent, especially where semi-permanent pools occur along Saddlers Creek and other watercourses in the project area.
- WRM (2019, p. 94) argues that streams in the subsidence area are ephemeral and that ‘in times of heavy rainfall, the majority of the runoff would flow over the natural surface soil beds and would not be diverted into the dilated strata below’. However, there has not been any quantification of the likely rates of flow into streambed cracks (e.g. by undertaking recession analysis or tracer studies) and so it is not demonstrated that these cracks will not substantially reduce surface flow. [This suggests the EIS investigations are inadequate to address surface flow impacts form mine subsidence.]
- The subsidence report (MSEC, 2019) notes that surface cracking of between 25 and 50 mm is generally expected. However, cracks of up to 300 mm are predicted in some areas (MSEC 2019, pp. 39 – 40). Cracks this large could be conduits for substantial volumes of water into the subsurface.

- No explicit modelling has been done to assess the potential losses to surface hydrology due to subsidence and thus it is not possible for IESC or anyone else to provide comments on these aspects. [Note MSEC (2019) were not commissioned to undertake a hydrological assessment pertaining to mine subsidence.]
- The IESC also notes that there is potential for some direct impact on water-dependent ecosystems vegetation from subsidence (e.g. root shear, toppling). Due to the multi-seam operations, these impacts may be greater than those observed at other underground coal mines.
- The IESC 2019 document noted that the key physical driver of concern is the extent to which mining causes surface cracking and near-surface ground movement, which has important consequences for the interactions between groundwater and surface waters and their dependent resources. The estimates of surface subsidence are likely underestimated within watercourses and near faults. Accordingly, the IESC has little confidence in the estimates of non-conventional subsidence at the local scale (and other associated ground movements) in areas that are most vulnerable to ecological decline.

Question 5: Groundwater inflows within the Maxwell Underground workings are predicted to peak at 1,387 ML/year in Year 12 of the Project. The average annual inflows over the life of the Project are predicted to be in the order of 750 ML/year. Does the IESC consider that the decision makers can have confidence in these predictions?

- The IESC does not have confidence in groundwater inflow predictions presented in the EIS to the stated inflows at ML/year accuracy. Appropriate use of inflow data from existing operations at neighbouring mines within the model domain as a history-matching (i.e. calibration) target would increase confidence in these predictions. As **there are no published case studies relevant to above-seam fracturing for the multi-seam nature** of the proposed project, reactivation of the goaf and workings could result in additional unpredicted subsidence and inflows from fracturing.
- The IESC does not have confidence in predicted changes to groundwater quality. The proponent does not describe potential changes to groundwater quality resulting from subsidence and the likely resulting changes in the chemistry of water infiltrating through the freshly exposed surfaces of fractured bedrock.
- The IESC considers that the likely groundwater quality changes within the shallow aquifers require quantification to determine potential impacts to GDEs, as these changes may exceed the physiological tolerance of some species. There is considerable uncertainty in likely groundwater impacts post mining, as few data are available for expected water quality from spoil leachate and the effects of subsidence-induced cracking on groundwater quality are uncertain.
- 2019 IESC - reiterate reactivation of goaf issue re multi seam p12, drainage of substantial volumes of surface water from streambed due to cracking [26b], substantial uncertainty in subsidence prediction associated with multi seam (p3)

5.11 DPIE

The Department of Planning Infrastructure and Environment have recommended the Maxwell Underground Project for approval. They have identified in Schedule 1, Part C Specific Environmental Conditions – Underground Mining for Subsidence performance measures – Natural and Heritage Features etc. C1: The Applicant must ensure that the development does not cause any exceedances of the performance measures in Table 9. Table 5-12 contains the performance criteria for subsidence as per Table 9 Section C1 -Subsidence performance measures

Table 5-12 has been annotated with comments and a summary of the proposed performance criteria identified in the Subsidence prediction report by the Maxwell EIS (in red).

Importantly the EIS subsidence prediction assessment:

Relied on information from other mine sites in the Hunter Region.

- The assessment did not undertake a risk based analysis using a range of key parameters but relied on rule of thumb values and averages given the supposed limited data for the site
- There is no reference to the local geology and geophysical properties of the overburden or any attempt to use this information to validate assumptions used in the modelling and no documentation was provided to support the applicability of the data used for the Maxwell underground subsidence.
- The DPIE report has assumed that the EIS subsidence assessment is correct and didn't request a risk-based assessment, or a sensitivity analysis, or adopting a precautionary approach, or the use of a range of values rather a single average or rule of thumb value despite the high degree of uncertainty of predicting subsidence for multiple seam extraction. It is deficient as an assessment of potential environmental impacts
- There has not been an analysis of subsidence impacts undertaken by an expert geotechnical engineer despite regular recommendations to undertake a geotechnical engineering assessment throughout the MSEC report
- There has been no assessment of groundwater or surface water impacts associated with the proposed subsidence impacts

The DPIE Assessment Report concludes that "*Both the Department and the Resources Regulator are satisfied that the subsidence impacts of the Project can be appropriately managed, and if necessary remediated, under the recommended conditions of consent."*

Table 5-12: Subsidence impact performance measures – natural and heritage features

Water Resources	**Performance measures**	**Summary**	**Comments**
All watercourses within the Subsidence Area	No greater subsidence impacts or environmental consequences to water quality, water flows (including baseflow) or stream health (including riparian vegetation), than predicted in the document/s listed in condition A2c		Recharge with saline water to shallow aquifers will impact on soils and alluvial deposits. This has been overlooked in the EIS
Saddlers Creek, Saltwater Creek and Hunter River alluvial aquifers	Negligible impacts to any alluvial aquifer as a result of the development, beyond those predicted in the document/s listed in condition A2(c), including:	Negligible vertical subsidence <5mm	Combined dewatering and subsidence will reduce near surface groundwater table up to 20m
	- negligible change in groundwater levels;		Combined dewatering and subsidence will reduce near surface groundwater table up to 20m
	- negligible change in groundwater quality; and		Recharge with saline water to shallow aquifers will impact on soils and alluvial deposits. This has been overlooked in the EIS
	- negligible impact to other groundwater users		
	Negligible impacts to GDEs as a result of the development, beyond those predicted in the document/s listed in condition A2(c)		
Land			**No risk analysis undertaken**
All land within the Subsidence Area	No greater subsidence impacts or environmental consequences than predicted in the document/s listed in condition A2(c)	<20mm	Not possible particularly if the angle of draw is >26.5 degrees
All land outside the Subsidence Area Biodiversity	Negligible subsidence impacts or environmental consequences	negligible vertical subsidence	Not possible particularly if the angle of draw is >26.5 degrees
Threatened species, threatened populations, or endangered ecological communities	No greater subsidence impacts or environmental consequences than predicted in the document/s listed in condition A2(c)	negligible vertical subsidence	Not possible particularly if the angle of draw is >26.5 degrees
	Negligible impacts on threatened species, populations or communities due to remediation of subsidence cracking	negligible vertical subsidence	Not possible particularly if the angle of draw is >26.5 degrees
Heritage sites			
Aboriginal cultural heritage sites shown in Figure 8 in Appendix 4	No greater subsidence impacts or loss of heritage values than predicted in the document/s listed in condition A2(c)		Doesn't consider impacts on aboriginal heritage sites which could destroyed or buried by subsidence disruption
Historic Homesteads identified as 'Historic Heritage Sites' in Figure 9 in Appendix 4	Negligible subsidence impacts or environmental consequences		
Mine workings			
First workings	· To remain long term stable and non-subsiding		

Water Resources	Performance measures	Summary	Comments
Second workings	· To be carried out only within the approved mine plan, in accordance with an approved Extraction Plan		No Plan available to review+A2:D19

5.12 Indicative Extent of the Underground Development

Finally there is doubt on the values quoted in the EIS for mining panels distances from key natural and built features such as: Hunter River, Hunter River alluvials; Saddlers Creek and Saddlers Creek Alluvials; Golden Highway and Stud Land etc.

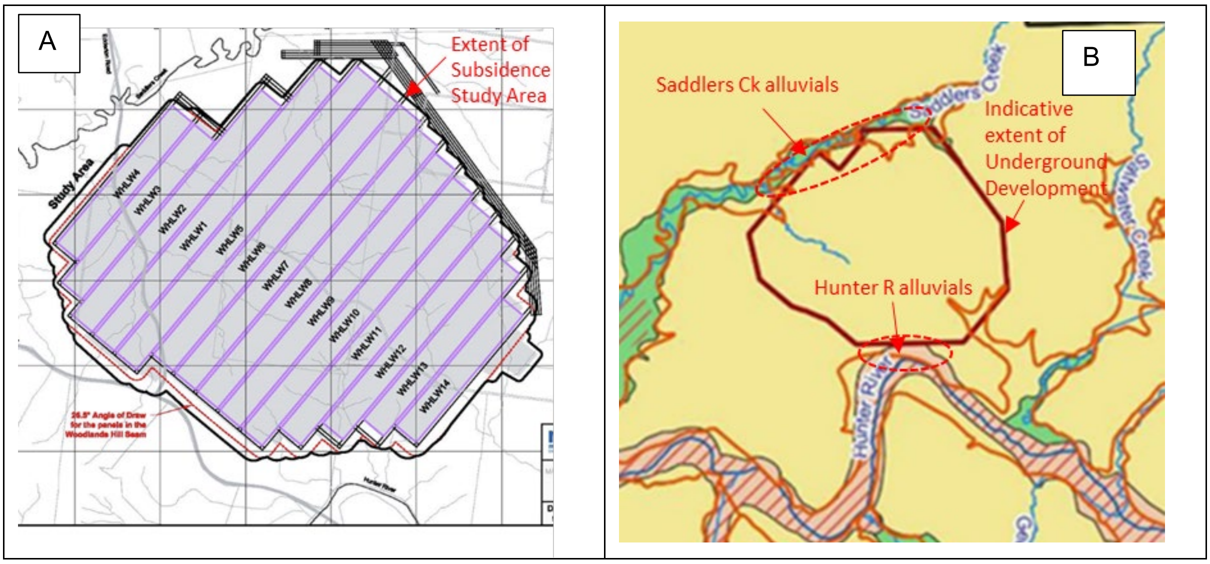


Figure 5-7: Extent of Maxwell underground Development

Figure 5-7 shows two location plans: A is from the EIS Appendix A – MSEC subsidence assessment, and B is from the EIS Appendix B: HydroSimulations groundwater report. The plan from the HydroSimulation groundwater report shows the indicative extent of Underground Development boundary limits are much closer to the natural and built features, including the Saddlers Creek alluvials and the Hunter River alluvials, than the plan of the Study Area from the MSEC subsidence report. The outline of the indicative extent of underground development is used throughout the EIS. Also the uncertainty of accurately predicting the extent of subsidence increases the risk of impacts on the natural environment features. There is nothing stated in the EIS that coal extraction will not mine up to the Indicative extent of the underground development. Given the importance of proximity to natural and built features for assessment of risk of impact from subsidence this should have been picked up by DPIE and at least questioned, and importantly insisted a risk assessment, which it wasn't.

6 FINAL VOID MANAGEMENT

A geotechnical assessment of the final void highwalls was undertaken by Coffey (2014) for the approved MOP to address issues raised during consultation with DRE (now the NSW Resources Regulator). The geotechnical assessment concludes that the existing highwalls in their current conditions are modelled as having a demonstrable factor of safety greater than 1.5 and Coffey considers the highwalls to be adequate in terms of geotechnical stability. Notwithstanding, Coffey (2014) makes several recommendations for the proposed mine closure, including highwall blasting, to improve overall and sustained stability.

A Peer Review of the Coffey (2014) report was undertaken by Sherwood Geotechnical and Research Services (2014), which concurred that the final void highwalls would be sustainable in the long-term. Notwithstanding the assessment by Sherwood Geotechnical the Coffey (2014) recommendations have been included in the approved Final Void Management Plan (which forms part of the approved MOP). The closure plan for final voids includes the following steps:

- Drilling and highwall blasting to reduce highwall slope. Drill and blast inert material above equilibrium water level. Dozer push loose material from blasting into void to form a buttress against the highwall below equilibrium water level.
- Capping of slope immediately above equilibrium water level with inert material.
- Establishment of a bench immediately above the final void water level.
- Construction of a bund along the top of the highwall to divert water off-site.
- Rapid establishment of vegetation (including grasses, trees and shrubs) to manage erosion.
- Daily inspection of highwalls by the Open Cut Examiner during rehabilitation activities and monthly inspection by the Environmental Superintendent following vegetation establishment.
- Ongoing earthworks to manage/repair erosion.

Implementation of the approved Final Void Management Plan would be deferred until the end of the Project life, when nearby surface infrastructure would be decommissioned and removed, and the voids are no longer required for water storage and/or CHPP reject emplacement.

As noted above, no on-the-ground inspection has been undertaken by the authors of this report. It is possible that other matters requiring specific (and possibly costly) remediation/rehabilitation actions could be present at the Drayton (North) mine site.

For the proponent to comply with the intent of this plan, extensive additional areas of forest will need to be established and maintained. It is understood that some 143ha is required to be planted to woodland/ forest so a significant effort will be required to achieve this target in the near future.

7 SUMMARY

The following summarises the main issues raised in the preceding discussion in regard to matters of concern regarding rehabilitation of the Maxwell Project and subsidence impacts associated with the underground mining.

- There are concerns associated with the extent and quality of reactive mine waste materials and how these will affect the rehabilitation standard of the Drayton North mine area, specifically the final mine voids and associated pit water and the tailings/coarse reject emplacement areas.
- The final pit voids, while geotechnically stable, are likely to be too steep to successfully stabilise and establish a suitable vegetation cover
- The extent of subsidence is likely to be significant and will adversely affect the suitability of lands for subsequent rural uses, specifically the viability of grazing on improved pasture. This will have long term consequences however the proponent has only committed to subsidence monitoring for a period of two to five years following cessation of mining. The acceptable standard to be achieved for subsidence has not been defined.
- Uncertainty regarding subsidence from multi seam extraction generally due to the lack of data and uncertainty of the extent of subsidence regarding longwall seam extraction below bord and pillar seam mining. For Maxwell proposed mining will extract 4 seams (the upper seam by bord-and-pillar extraction and the remaining 3 seams by longwall extraction) in some locations, and 3 seams in most locations of the mine footprint. Other multi seam data cited by MSEC involves extraction of 2 seams. Implications of longwall extraction under bord and pillar unknown. IESC suggested this could lead to collapse of the pillars, that could be within the proposed mining operation timeframe or post mine closure. There is so little data available for multi-seam extraction in the Hunter coalfields.
- Closure costs are likely to be significantly in excess of the current Security Deposit held by the NSW government.
- The timeframe to restore land for suitability for an approved post-mining landuse is likely to be significant, and a 2-5 year timeframe commonly used in mine closure and rehabilitation is by far too insufficient to achieve an acceptable sustainable post mine landform.
- The direct impacts resulting from subsidence associated with the underground mining are predicted to include surface cracking of 25 to 50 mm (with isolated cracks to 100 mm) and depressions in the land surface up to 5600 mm but could be significantly higher.
- Proposed underground mining at Maxwell using bord and pillar and longwall techniques within the Gateway certificate application area is predicted to result in subsidence of 2,134 ha of the GCAA
- The extraction is largely critical to supercritical causing the greatest subsidence and deformation of the overlying strata and land surface – It can be predicted by the ratio of the panel extraction width (W) to the thickness of the overburden or cover rocks (H) – W/H. Extractions where W/H is smaller than the critical range are termed sub-critical, and those where it is larger are termed super-critical; the latter causing maximum subsidence over a larger area

- Potential impacts from subsidence may include:
    - The natural land surface including drainage lines and vegetation ecosystems above the Maxwell underground operation;
    - Hunter River alluvial flats located immediately south of the mine area where the four seams will be mined;
    - Saddlers Creek located northwest and outside the proposed limit of secondary extraction;
    - Edderton Road ;
    - Golden Highway immediately south of the limit of secondary extraction
- The studies for subsidence use rule of thumb and average factors to predict subsidence and the extent of areas where subsidence >20mm will occur. Rule of thumb appropriate if no info and sensitivity low - While this is not incorrect the studies should also look at factors such as angle of draw that are higher than the average 26.5 degrees, to estimate what potential risk may exist if the values for key components are changed, (i.e. undertake a sensitivity analysis given this is an Environmental Impact assessment that must look at a range of critical values
- Subsidence movements is likely to result in surface deformations, with cracking in flatter areas expected to be between 25 and 50 mm, with widths greater than 300 mm in some places.