

5.0 PROJECT OPTIMISATION AND ANALYSIS OF ALTERNATIVES

5.1 Mine Plan

As part of the pre-feasibility and feasibility phases undertaken for the Mandalong Southern Extension Project, a detailed mine design exercise was undertaken in parallel with the exploration drilling program, baseline environmental surveys and the development of the subsidence model for the Southern Extension Area. Various mine layouts were developed and assessed in response to information being received on geological, geotechnical, environmental, surface infrastructure and mining constraints. The preferred layout at the conclusion of the feasibility phase for coal extraction within the Southern Extension Area is the proposed mine plan shown on **Figure 21**.

The proposed mine plan in the Southern Extension Area encompasses a total of 40 longwall panels (LWs 25 to 64) ranging in length from 1,000 to 3,500 metres, depending on seam conditions and site constraints, and ranging in width from 160 to 200 metres. Longwall panel widths between 250 and 300 metres are common in Australia as mines strive towards more cost-efficient production, with some operations even adopting 400 metre longwall widths. The panels proposed within the Southern Extension Area are narrower due to subsidence constraints. Furthermore, the proposed longwalls in the western extent of the Southern Extension Area are relatively short due to geological and other surface infrastructure constraints.

The proposed mine plan in the Southern Extension Area aims to maximise resource recovery while at the same time maintaining similar subsidence-related surface impacts to those currently being experienced by the community and environment as a result of the existing Mandalong Mine workings.

The main constraints and issues considered during the mine planning design are summarised in the following sub-sections.

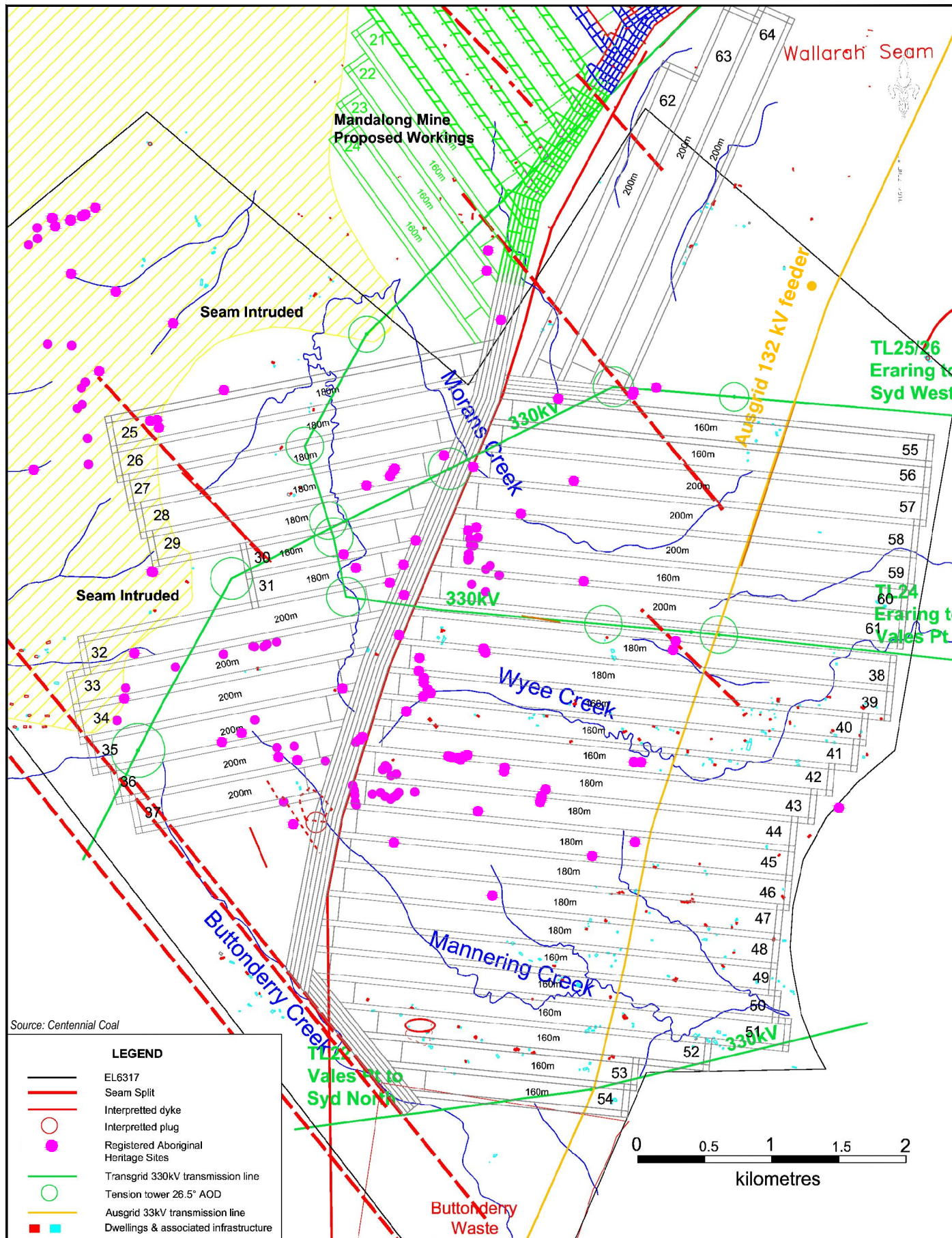
5.1.1 Geological Constraints

The exploration drilling program determined the likely economically mineable extent of the West Wallarah and Wallarah-Great Northern Seams within the Southern Extension Area. As shown on **Figure 28**, a number of igneous intrusions in the form of a sill, two diatremes and a number of dykes were identified during exploration, along with a split in the coal seam and variable seam thickness.

The sill that intrudes the West Wallarah Seam in the western extent of the Southern Extension Area and the seam split both present major constraints to the mine layout. The eastern edge of the sill defines the extent of mining on the western side of the mine plan, resulting in the length of the longwalls in this area being restricted, particularly LWs 25 to 29.

The seam split strikes generally north-south near the centre of the Southern Extension Area, with the lower plies of the seam splitting away quickly and ending up 8 to 10 metres below the resource section. For ventilation, logistics and equipment purposes, the main headings are required to be driven in the thick seam area, which is to the west of the seam split. Therefore, in order to maximise longwall recovery in the thick seam area the main headings have been designed immediately parallel to the seam split along the north-south alignment (see **Figure 28**).

Seam thickness is a significant constraint to the mine layout and Project economics. Centennial Mandalong plans to extract the thick seam coal to the west of the main headings first (LWs 25 to 37) for the best financial outcome over the first six years of the Project. New development and longwall equipment will need to be purchased for the thin seam area to the east of the main headings. Seam thickness has a major influence on the design of longwall and chain pillar widths for subsidence and mine serviceability.



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5.1.2 Geotechnical Constraints

The primary geotechnical constraint that influenced the mine layout is the Munmorah Conglomerate, which sits between 80 and 110 metres above the West Wallarah and Wallarah-Great Northern Seams. This beam has a significant impact on the subsidence profile for the Mandalong Mine due to its spanning potential.

The characteristics of the beam within the Southern Extension Area recorded during the exploration program were used in the subsidence model to categorise it in terms of subsidence reduction potential (SRP) and give it a rating of high, moderate or low depending on the beam thickness, distance from the seam and depth of cover. This rating, along with the surface constraints, assisted in determining the maximum width that each longwall can be to maintain acceptable subsidence impacts.

5.1.3 Environmental Constraints

Groundwater

GHD (2013a) identified three different groundwater sources within the Southern Extension Area, these being the alluvium, weathered and/or fractured sandstone and the coal seams. The alluvium groundwater was identified as a constraint to the mine layout, particularly in relation to the maximum width of longwall panels. Within the Southern Extension Area the alluvium generally extends to no more than 15 metres below the surface and the water has relatively low yield and poor quality (GHD 2013a).

On this basis, the mine layout has been designed with the intention of not creating continuous cracking from the underground mine workings to the alluvium, which would cause draining of the alluvium into the workings. The Munmorah Conglomerate plays an important role in terms of limiting sub-surface cracking and it appears very unlikely that continuous cracking will extend above the conglomerate beam with the longwall widths being limited to 200 metres (DGS 2013).

There is some groundwater in the strata between the alluvium and the coal seam in the weathered and/or fractured sandstone. This strata has low hydraulic conductivity, is not in continuous flowing aquifers and has highly variable quality. On this basis, this groundwater was not considered a constraint to the mine layout from a surface stakeholder or underground workings perspective.

The coal seam aquifers are not a usable groundwater source for surface stakeholders due to the water quality, and were only considered in the mine planning process in terms of underground safety and coal extraction. The previous and current experience at Mandalong Mine and the former Cooranbong Colliery is that groundwater inflow into the mine workings has been relatively low and easy to manage (Centennial Mandalong 2013).

Creeks

The creeks traversing the Southern Extension Area present a major constraint to the mine layout, again, particularly in relation to maximum longwall widths and associated subsidence impacts. As outlined in **Section 10.5**, the three most significant creeks in terms of location over the mine plan and proximity to residences in terms of potential increased flooding risk are Morans Creek, Wye Creek and Mannering Creek. While Buttoderry Creek is considered a significant creek, it is to the south of the proposed mining area and therefore subsidence impacts should be negligible. Umwelt (2013) carried out an assessment of different mine layouts with longwalls at 160 metres, 200 metres and 300 metres wide in order to understand the likely level of impact of subsidence on surface water flows and to assist with the mine planning exercise. This assessment showed that the main impacts expected from subsidence were ponding and erosion due to grade changes in different sections of the creeks. Umwelt (2013) concluded that the 160 metre and 200 metre wide longwalls would result in manageable subsidence impacts, while the 300 metre wide longwalls would result in subsidence impacts that were considerably more significant than those previously experienced at Mandalong Mine.

During the pre-feasibility and feasibility phases, there were a number of mine layouts considered with north-south oriented longwalls in the eastern extent of the Southern Extension Area. One of the main reasons for selecting east-west oriented longwalls, as per the proposed mine plan, is to ensure a reduced subsidence impact on Wyee Creek and Mannering Creek.

Ecology

The detailed ecological baseline surveys undertaken by RPS indicate that the only ecological constraint to the mine layout is associated with those species reliant on surface water and groundwater within the surface watercourses. As the mine layout has already been constrained in terms of subsidence under the creeks to avoid substantial changes in flow and ponding (see above), the ecological constraint has already been addressed. The orientation of longwalls sub-parallel to Wyee Creek and Mannering Creek will assist in minimising subsidence impacts that could impact on water-dependent species.

Aboriginal Heritage

Within the Southern Extension Area a total of 113 registered sites of Aboriginal cultural heritage significance have been identified (see **Figure 28**). These sites are scattered across the area and therefore it is not possible to avoid undermining them entirely. Where practicable, the mine plan has been adjusted or refined to avoid or minimise the potential for impact on Aboriginal cultural heritage sites. This included, wherever possible, adjusting the widths of the proposed longwalls and locating the Aboriginal sites over gateroad pillars to minimise subsidence effects.

Based on the levels of subsidence predicted with longwalls being limited to between 160 and 200 metres wide, only 13 of the identified Aboriginal heritage sites (12 percent) are “likely” to be impacted by the Project and 15 (13 percent) may “possibly” be impacted by the Project (RPS 2013b). The remaining 85 identified Aboriginal heritage sites (75 percent) are “unlikely” or “very unlikely” to be impacted (RPS 2013b).

5.1.4 Social Considerations

Community expectations were identified as a significant consideration to the mine layout. Mandalong Mine has been conducting longwall mining since 2005 and has a very good record of maintaining manageable and acceptable subsidence impacts. As previously advised, one of the aims of the Project is to maximise resource recovery while at the same time maintaining similar subsidence-related surface impacts to that currently being experienced by the community and environment as a result of the existing Mandalong Mine workings. This is the primary reason longwall widths in the proposed mine plan have been limited to between 160 and 200 metres (rather than attempting to mine longwall widths of 250 metres or more, as most Australian longwall mining operations do).

5.1.5 Surface Infrastructure Constraints

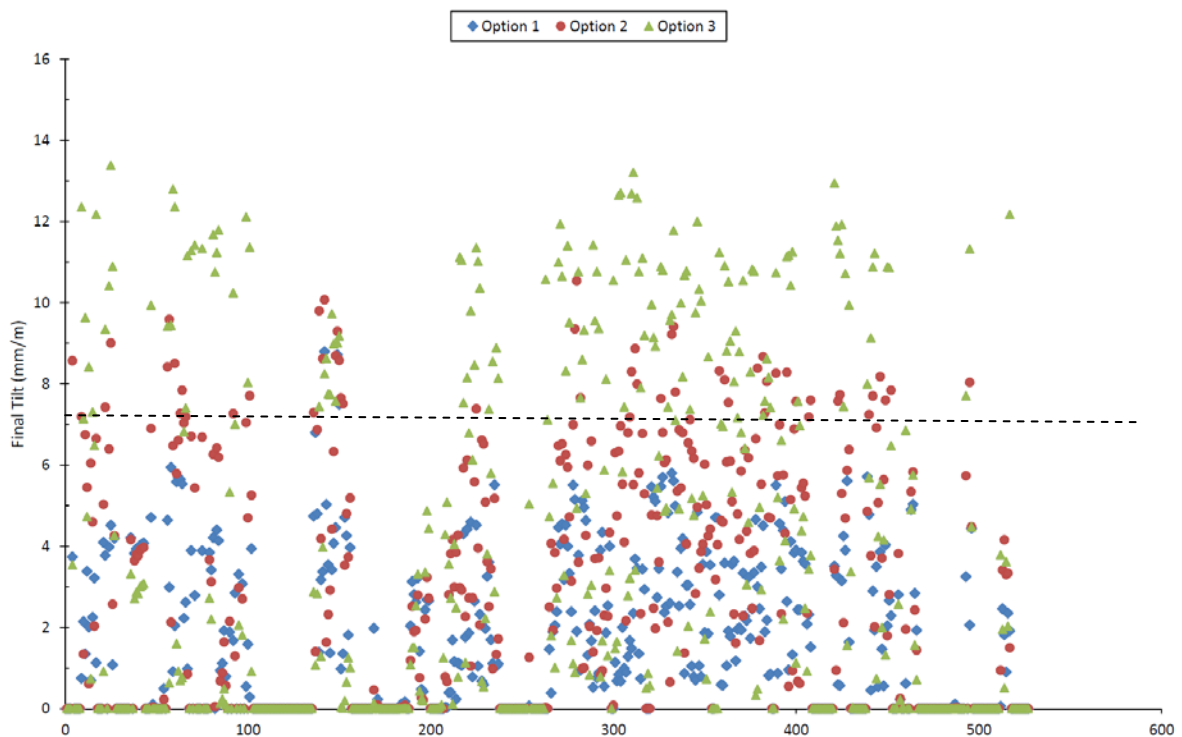
Private Residences, Business and Associated Infrastructure

Private residences present the greatest constraint to the mine layout, due to the number of residences and the fact they are located across most of the Southern Extension Area. A preliminary survey using cadastral mapping, aerial photography and visual observations identified 135 privately owned parcels of land (lots) and 114 houses (primary residences). The location of these primary residences is shown on **Figure 28**.

Of the 114 primary residences, it appears that 24 are of brick construction, which is typically least able to withstand subsidence movements, while 90 are non-brick construction, which is generally better suited to subsidence movements. The mine planning process aimed to design a mine layout that limited the impacts to primary residences within the safe, serviceable and repairable (SSR) standards defined by the Mine Subsidence Board (MSB) and relevant Australian Standards (AS).

In general terms, the MSB advises that for buildings to have no greater than “slight impact” (as per AS2870 2011) and remain within the SSR standards, tilts should not exceed 7 millimetres per metre (mm/m) and tensile or compressive ground strains should not exceed 4 mm/m. Between 7 mm/m and 10 mm/m of tilt there could be a need to re-level the structure to maintain serviceability, which would mean that the impact increased to “moderate” (as per AS2870 2011), however remaining within the SSR standards. Above 10 mm/m most houses will need some re-levelling work and if it is of low tolerance to ground movement (for example, brick construction) there could be a “severe impact”. If that were the case, it is likely that the house would need to be vacated during undermining and the property acquired by the mining company, or another arrangement established with the landholder prior to mining. On this basis, the intention of the detailed mine design exercise was to limit impacts so that severe impact is avoided and property acquisition is not required.

As part of this mine design exercise, an assessment was undertaken by DGS (2012) to compare the predicted subsidence impacts to houses with 160 metre (Option 1), 200 metre (Option 2) and 300 metre (Option 3) wide longwalls. **Figure 29** illustrates the predicted tilts at identified built structures within the Southern Extension Area. This demonstrates that a mine layout with longwall widths between 160 metres and 200 metres can achieve the aim of maintaining the majority of residences within SSR standards, while 300 metre wide longwalls would result in a large number of residences sustaining impacts beyond the SSR standards.



Source: DGS 2012

Option 1 – 160 metre wide longwalls; Option 2 – 200 metre wide longwalls; and Option 3 – 300 metre wide longwalls

Figure 29 – Predicted Subsidence Impacts on Built Structures with Varying Longwall Widths

The constraint on the mine layout associated with minimising subsidence impacts to residences means that impacts to other surface improvements, such as sheds, dams, access roads and fences, should remain within the SSR standards.

While vertical subsidence does not typically result in structural damage to a house, if the house is situated close to a watercourse, subsiding the house may increase the flooding risk. While there are a number of houses within the Southern Extension Area located in close proximity to the 100 year ARI flood level, the detailed modelling undertaken in the surface water assessment (Umwelt 2013) indicates that these residences are not actually within the 100 year ARI flood level for either the pre-mining landform or post-mining landform (i.e. with surface subsidence impacts). Regardless, Centennial Mandalong will confirm the existing floor levels of these residences prior to undermining as part of the Extraction Plan process.

Electricity Transmission Lines

There are four 330 kilovolt TransGrid electricity transmission lines within the Southern Extension Area, two of which present a major constraint to the mine layout. As shown in **Figure 5**, the transmission lines identified as TL25/26 and TL24 are located in the northern part of the Southern Extension Area and have a number of suspension and tension towers located within area. Suspension towers, which are those where the line passes through without changing direction, can withstand a certain amount of tilt and strain. On the other hand, tension towers, which are those where the line is fixed to the towers and there is usually a change in direction of the line or the line is crossing over another line, have very low tolerance to tilt and strain due to the lines being tightened or slackened and the instability of the structure due to the change in line angle.

A number of mine layouts were drawn up in an attempt to avoid the tension towers within the Southern Extension Area by relocating longwalls around them or developing main headings under them. However due to the location of the tension towers in the thick seam area (LWs 25 to 37) at the start of the Project and in an area where the proposed longwalls are already short, the impact on the Project's financial viability made these options unfeasible.

As evident on **Figure 21**, a few adjustments have been made to the proposed mine plan, where possible, to avoid or limit impact to TransGrid infrastructure. This includes limiting the length of LWs 30 and 31 to avoid undermining a tension tower, and providing a narrow corridor between the gateroads of LWs 38 and 61 to avoid undermining a section of the transmission line TL24.

TransGrid is undertaking a feasibility study to determine the best way to further avoid and/or manage subsidence-related impacts on its infrastructure within the Southern Extension Area. Centennial Mandalong is engaging in on-going consultation with TransGrid in this regard. If it is determined that relocation of a section of TL24 is necessary, approval will be sought for the relocation as a separate development application.

Telecommunications Infrastructure

The proposed mine plan comprises longwall panels under Telstra and Nextgen infrastructure in the form of aerial and buried copper cables and buried fibre optic cables. Mandalong Mine currently extracts coal, using the same longwall extraction method as that proposed in the Southern Extension Area, under Telstra telecommunications infrastructure and in accordance with a Telstra Subsidence Management Plan. The proposed mine plan is anticipated to have similar subsidence impacts to those currently being experienced at Mandalong Mine and, on this basis, the telecommunication infrastructure in the Southern Extension Area is not considered a constraint to the mine layout.

5.1.6 Analysis of Alternatives

Overview

Using the information obtained from the exploration drilling program, baseline environmental surveys and development of the subsidence model, Centennial Mandalong assessed various mine plan layouts in consideration of the above geological, geotechnical, environmental and surface infrastructure constraints, as well as constraints associated with mine ventilation, gas management and mining equipment.

Alternative of 300 Metre Wide Longwall Panels

Due to the presence of the Munmorah Conglomerate, the increase in depth of cover and the thin seam area in the eastern portion of the Southern Extension Area, longwall widths of up to 300 metres were considered. A mine plan with 300 metre wide longwall reduces the amount of development roadways (gateroads) that need to be excavated to access the coal, which, in turn, increases the resource recovery and provides a better financial outcome for the Project. However early subsidence modelling indicated that a mine plan with 300 metre longwall widths would result in the following adverse impacts associated with increase subsidence levels:

- A large number of dwellings and associated building structures would likely exceed the SSR standards defined by the MSB;
- Watercourses traversing the Southern Extension Area would see moderate levels of erosion and increased ponding;
- Potential impacts to groundwater dependent ecosystems;
- In areas where there are shallower depths of cover there could be connective cracking between the mine workings and the alluvial groundwater aquifers; and
- Tilts and strains above the SSR standards for dwellings could also cause damage to Aboriginal cultural heritage items located within the Southern Extension Area.

As these potential impacts do not meet the aim of continuing to conduct mining at Mandalong Mine in an environmentally responsible manner, and despite the better financial outcome for Centennial Mandalong, the mine plan option with 300 metre longwall widths was rejected.

Alternative of Longwall Panel Widths Less Than 200 Metres

After assessing various other mine layouts, it was concluded that a mine plan with longwall panels of 200 metres wide and less, even though it will be harder to maintain a production level of 6 Mtpa, should be adopted in order to reduce surface subsidence impacts. The economic impact to Centennial Mandalong associated with this decision is detailed in the *Economic Impact Assessment* (Aigis 2013) contained in **Appendix F** and summarised in **Section 10.17**.

As illustrated on **Figure 21**, the proposed mine plan has a combination of 160 metre, 180 metre and 200 metre wide longwall panels. Notably:

- Longwall widths of 200 metres are proposed in the south-west and north-east extents where there are fewer residences, creeks and heritage items identified;
- Longwall widths of 180 metres are proposed in the north-west extent to minimise the potential for connection between the underground mine workings and the alluvial groundwater aquifer associated with Morans Creek; and
- Longwall widths of 160 metres are proposed in the east where the majority of the residences are concentrated along Wyee Creek and Mannering Creek.

While Centennial Mandalong did consider longwall widths less than 160 metres wide it was determined very early in the feasibility phase that there would not be any significant reduction in surface impacts and it was not a financially viable option. Longwalls widths of less than 160 metres would require additional development gateroads and longwall moves, which would reduce the coal available for extraction and reduce mining efficiencies.

The factors that influenced the orientation of the longwalls within the proposed mine plan include:

- The western longwalls are orientated in an east-north-east to west-south-west direction to maximise their length between the sill and the seam split, while allowing the mine to continue with uninterrupted production from the currently approved Mandalong Mine longwalls (LW 1 to 24) to the proposed longwalls in the Southern Extension Area; and
- The eastern longwalls are orientated in an east to west direction in order to –
 - avoid undermining TransGrid’s electricity transmission lines TL25/26 and TL24;
 - minimise erosion and ponding along Wyee Creek and Mannering Creek by running the longwalls sub-parallel to these watercourses; and
 - avoid undermining WSC’s Buttonderry Waste Management Facility.

Alternative of Not Proceeding

If the Project were not to proceed, there would be the following implications:

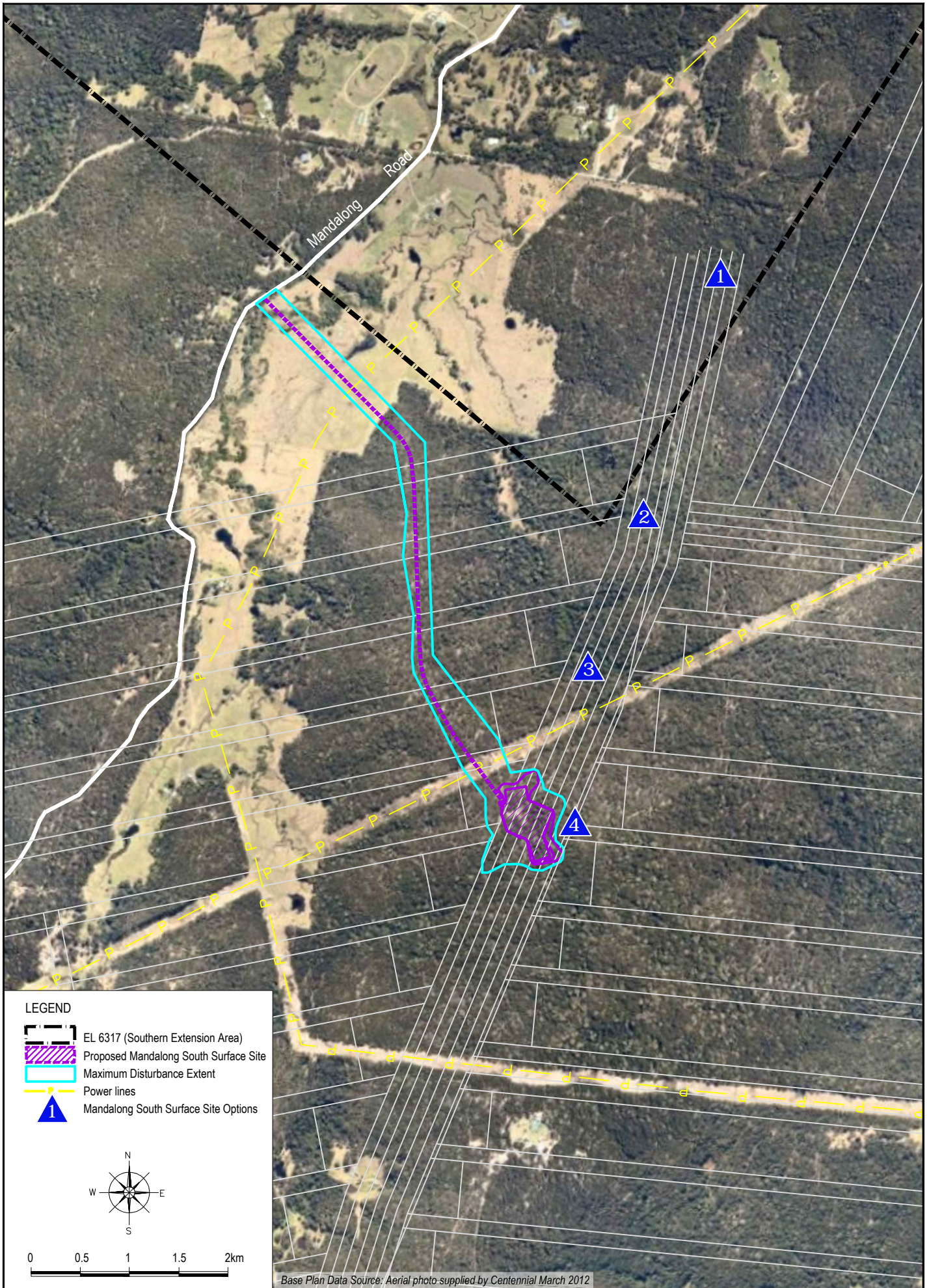
- Mining of the coal resources within the approved mining areas would need to cease by 2019 upon expiry of the development consent. This would result in the sterilisation of a substantial coal resource within the Southern Extension Area, as it is unlikely that this area would be extracted independently or as part of any other mining proposal.
- Upon cessation of mining, the Mandalong Mine would close and all economic and associated social benefits would cease to be realised beyond this time (see **Section 10.17**). The exception would be the benefits associated with a relatively brief period of decommissioning and rehabilitation activity.
- The employment of the 305 full-time personnel associated with the Mandalong Mine operations would be placed in jeopardy.

5.2 Mandalong South Surface Site

As shown on **Figure 30**, four locations within the Southern Extension Area were considered by Centennial Mandalong for the proposed Mandalong South Surface Site. In short, the proposed location was identified and selected as the optimal option in light of the following constraints:

- The location and concerns of privately-owned residences;
- The existing surface environment, including vegetation communities, heritage items and watercourses; and
- Engineering design and construction requirements for both the surface site and access road.

Based on the issues and concerns raised during site visits undertaken by Centennial Mandalong with concerned residents (see **Section 8.1.9**), further investigations were undertaken to identify potential alternative locations for the proposed Mandalong South Surface Site in an attempt to reduce potential impacts. As a result of these investigations, and in conjunction with the assessment of the existing surface environment and construction requirements, the proposed location was identified and nominated as the preferred option. Subsequent communication with the concerned residents indicated that the majority of concerns initially raised had been alleviated.



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Options for Mandalong South Surface Site Location

FIGURE 30