

DESKTOP MINE SUBSIDENCE ASSESSMENT

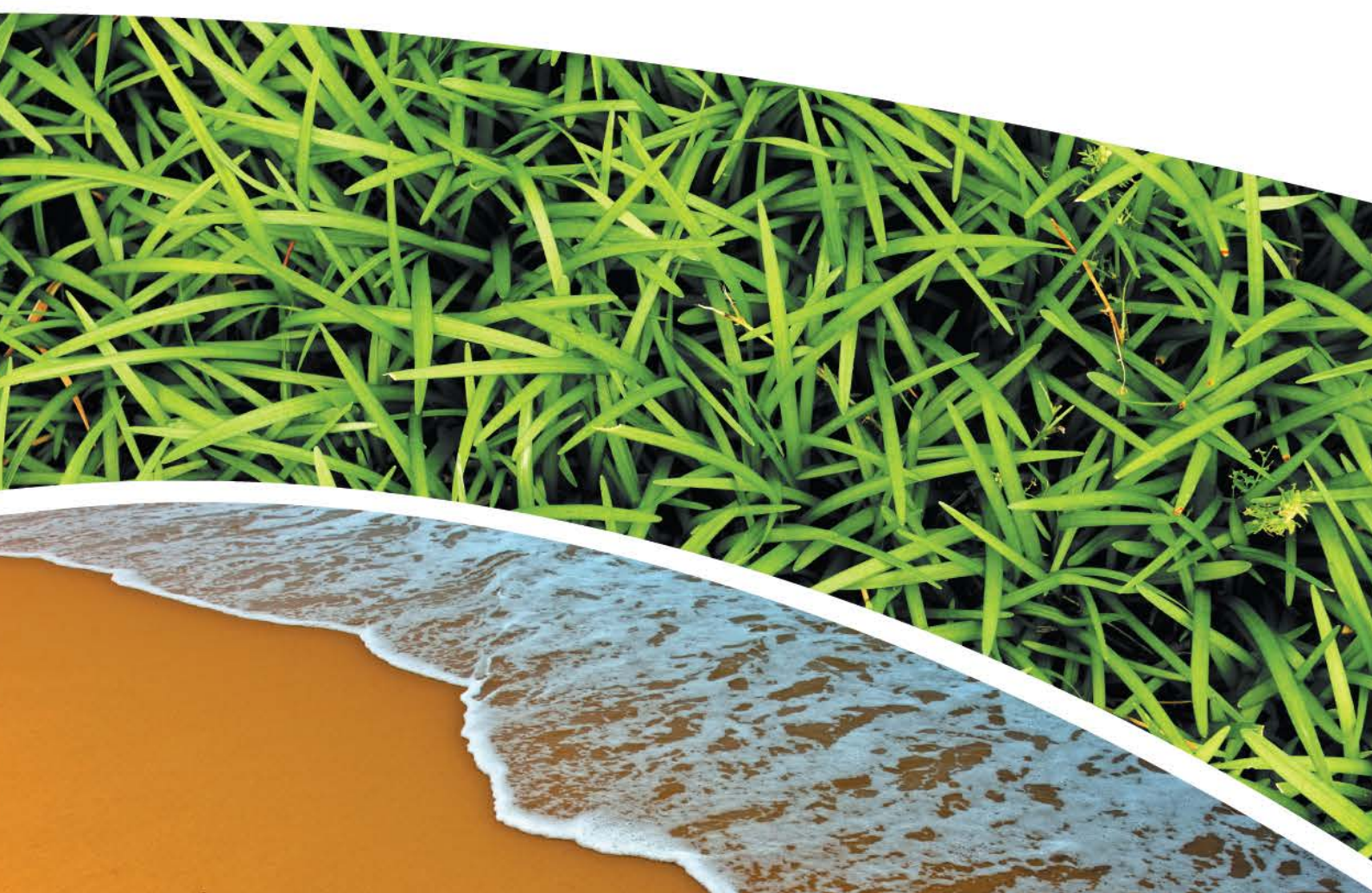
Huntlee Stage 2

Prepared for Huntlee Pty Ltd

Prepared by RCA Australia

RCA ref 16890-201/2

November 2023



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PILLAR STABILITY CALCULATIONS



RCA ref 16890-201/2

27 November 2023

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Attention: Glenn Swan

Geotechnical Engineering

Engineering Geology

Environmental Engineering

Hydrogeology

Construction Materials Testing

Environmental Monitoring

Noise & Vibration

Occupational Hygiene

DESKTOP MINE SUBSIDENCE ASSESSMENT

HUNTLEE STAGE 2

1 INTRODUCTION

This Desktop Mine Subsidence Assessment supports an Environmental Impact Statement and State Significant Development Application (SSDA) that seeks consent for the Huntlee New Town Stage 2 development, comprising the concept development for the Stage 2 sites including Villages 2 and 3, land off Old North Road and the Town Centre North area, and the detailed development for the central and southern areas of Village 2. The proposal represents the next phase of an extensive planning, assessment and consultation process completed to date for the development of the Huntlee New Town site.

Specifically, this SSDA proposes the following works for the Huntlee New Town:

- A Concept Master plan for the Stage 2 site, comprising:
 - Overall Stage 2 development footprint, including:
 - The remaining Town Centre North area,
 - Villages 2 and 3, and
 - A large lot residential area located to the south of the site on Old North Road;
 - Proposed land use and development yield, including the provision for residential subdivision of approximately 5,000 lots;

- Associated new road network and required upgrades to existing network;
- Site-wide open space and riparian areas;
- Detailed development of Village 2 Central and South and eastern connection to the Town Centre, comprising:
 - Demolition and clearing of existing built form structures;
 - Clearing of existing vegetation within proposed development footprints;
 - Open space, recreation, community and riparian areas;
 - Construction of road and access infrastructure;
 - Bulk earthworks;
 - Stormwater and drainage works;
 - Utilities and services, including
 - Sewer and potable water reticulation;
 - Electricity and communications infrastructure;
 - Subdivision to facilitate approximately 1,750 lots across the Village 2 Central and South areas and Town Centre development lots, comprising approximately 1,730 residential lots, eight (8) medium density superlots, two (2) commercial/mixed use lots and open space areas; and
 - Select clearing and grading to establish temporary Asset Protection Zones where development interfaces with the Concept Master plan area.

Figure 1 demonstrates the location of the Stage 2 Concept and Detailed areas, in the context of the surrounding development.

With reference to **Figure 1** below and **Drawing 1** in **Appendix A** it is noted that Village 2 of the proposed Stage 2 development lies completely outside the Branxton Mine Subsidence District, is not affected by mine workings and will not be subject to any mine related restrictions. Parts of the remaining areas of the proposed Stage 2 development (ie. Village 3, the extension of the Town Centre and the Old North Road site) do lie within the Branxton Mine Subsidence District and are affected by mine workings as outlined in this report. The affected areas are located within the Concept Area of the subject SSDA and it is therefore recommended that mine subsidence is further investigated as part of the lodgement of future detailed applications for those areas of the site.

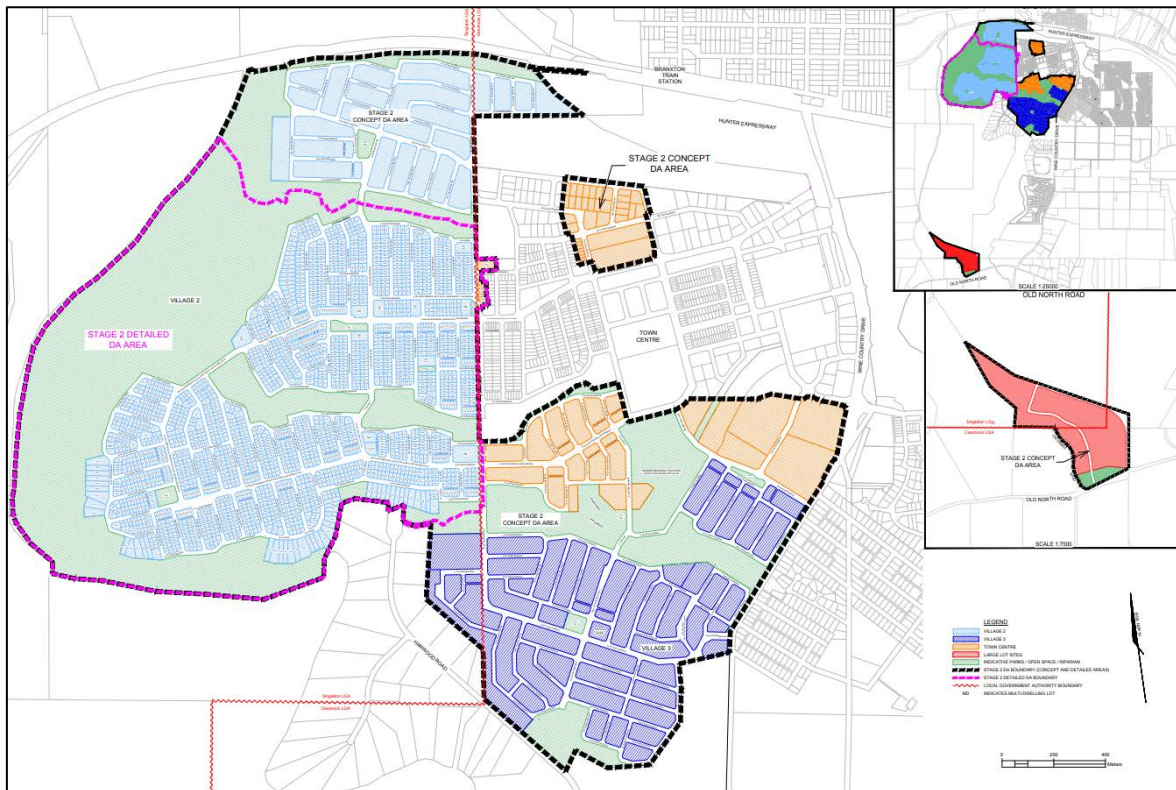


Figure 1 Proposed Concept and Detailed Area layout (Source: Daly Smith)

It is understood that the Secretary's Environmental Assessment Requirements (SEARs) for the project include the following comments with reference to mine subsidence:

- Identify and assess geotechnical issues, noting the implications for slope stability and rehabilitation
- Identify and assess mine subsidence issues noting any risk factors associated with the former mining uses at or surrounding the site
- Outline measures that would be implemented to avoid, minimize, manage or remediate potential subsidence or geotechnical issues encountered at the site.
- Address matters raised by Subsidence Advisory NSW (copy attached for reference in **Appendix B**)

This desktop report has been prepared to support a State Significant Development Application for the proposed Huntlee New Town Stage 2 development and has been prepared using Ref [1] as a guide.

2 THE SITE

The subject site forms a large component of the 1,622 hectare Huntlee New Town, situated to the south of Branxton in the Hunter Valley. It is located approximately 20km north of Cessnock, 23km south-east of Singleton, and 55km north-west of Newcastle.

The subject Site comprises a number of allotments located in both Cessnock and Singleton Local Government Areas (LGAs). It has a combined area of approximately 541.71ha, is irregular in shape and is generally extended to the west and south of the approved Huntlee Town Centre. The site is bound to the west by the Black Creek and floodplain. An aerial photo of the site is provided at **Figure 2**.

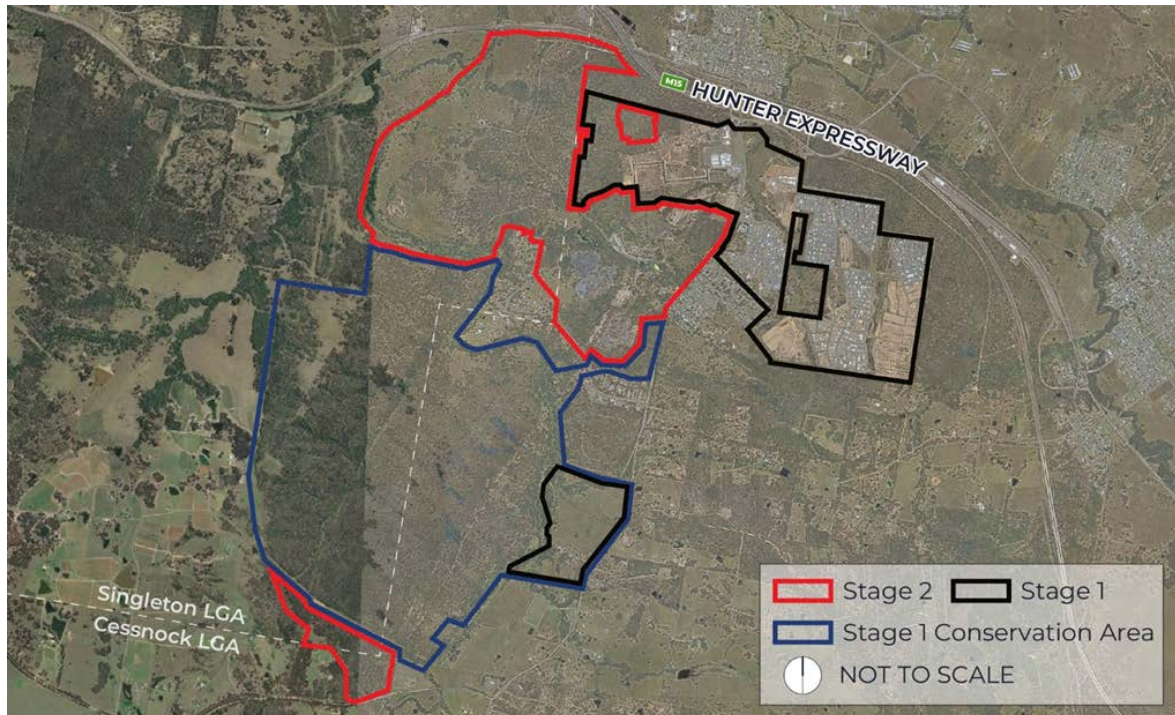


Figure 2 Site aerial (Source: Nearmap and Ethos Urban)

3 MINING BACKGROUND

3.1 MINE HISTORY

Significant areas of the Huntlee development that lie on the western side of Wine Country Drive lie within the Branxton Mine Subsidence District and are undermined by abandoned coal mine workings of a number of collieries (principally the Ayrfield No 3 Colliery). See **Drawings 2-5** which show the mine workings on site plan.

Abandoned mine workings lie underneath extensive areas of the Stage 2 Concept Development Area and comprise workings in two seams of the Greta Seam. The seams strike north south, outcrop within the Stage 2 site and dip steeply to the west.

Mining at the site was undertaken over an extended period by various Collieries. Mining was commenced by Rothbury Colliery in 1910, changed briefly to Branxton Colliery then was changed to Ayrfield No 3 Colliery by R W Miller and Company in 1936. The name Ayrfield No 3 Colliery applied to all the mines developed on the original lease by earlier owners and taken over or developed by R W Miller and Company.

The original pit top of the Colliery was developed immediately west of Rothbury village near the northern limit of the seam outcrop. A series of mines then developed south along a narrow strip of land following the north south strike of the seam sub crop.

The Rothbury mine workings commenced in 1910 following sinking of exploratory shafts and tunnels from 1908. The exploration work identified that the Greta Seam in this area was split into three parts – Top, Middle and Bottom Seams. The splits were each separated by approximately 14m – 18m of sandstone/conglomerate rock. The Top seam was found to be unsuitable for mining and only the Middle and Bottom Seams were worked.

Levels on the record tracing (RT) indicate that:

- Near the pithead near the northern limit of Stage 2 the mine workings dipped at 16° in a westerly direction for about 180m depth and before the dip increased with depth.
- The seam dip steepens to the south and in the area of the southern area of Stage 2 (adjacent to Old Road) the seam dip is approximately 35° with mine history suggesting seam dip increased with depth to up to 60°.

Mine entry was by tunnels developed from the outcrop of the Middle and Bottom Seams, with vertical ventilation shafts located close to the entries of the tunnels. The main haulage and traveling roads in the Middle Seam were developed 3.7m (12 feet) wide and 2.1m (7 feet) high. Later the traveling road was widened out to 6.1m (20 feet). A ventilation tunnel was developed in the Bottom Seam. It was 3.05m (10 feet) wide and 3.05m (10 feet) high.

Whilst the main mine development was at the original Rothbury Colliery site a series of smaller mines were developed along the strike to the south. These were named Maitland Extended mines by R W Miller & Company in 1937. They were numbered 1-6 from north to south with the Maitland Extended No 6 being relevant to the southern portion of Huntlee Stage 2 as described later in this report. As these pits were abandoned mining concentrated on the main former Rothbury (Ayrfield No 3) Colliery until its closure in 1974.

As mines were developed further south away from the original Rothbury or Ayrfield No. 3 Colliery the dip of the coal seam increased. The Maitland Extended No. 1 and No. 2 Entries were developed at a dip of 27°, while Maitland Extended No. 6 at the southern end of the line of mines developed at 45° dip and finished at 60° dip.

All early workings in these collieries were first workings only. It was not until the 1960's that pillar extraction commenced. Pillar sizes were variable in the Rothbury workings, but generally increased with increasing depth of workings. In general, within 100m of the surface pillars were 4m in width, or slightly less. Between 100m and 250m depth pillar widths increased to around 5m to 6m. Below 250m depth pillar width increased gradually from 6m to 19m.

Many of the smaller Maitland Extended pits created bords (or side roads) every 22m. This meant pillars were about 16m wide, if allowance is made for 6 yard, or approximately 6m, wide roads.

Some of the mines worked both the Middle and Bottom Seams, whilst some had entries in one seam and drove tunnels underground to connect the workings in the two seams, such as Maitland Extended No. 3 Mine.

In the Ayrfield No 3 Colliery, the total seam thickness of the Middle Seam is shown on the mining record of RT436 to be variable. Several coal sections are given and the coal section nearest the northern end near Huntlee shows 12' (3.65m) of coal and bands.

In the Ayrfield No 3 Colliery, the total seam thickness of the Bottom Seam is shown on the mining record of RT577 at the nearest point to Huntlee to be 7' (2.13m). On the coal section on RT436 the Bottom Seam thickness is shown to be 4' (1.2m) including bands.

3.2 EXISTING HUNTLEE MINE ASSESSMENTS

Desktop and detailed mine subsidence assessments have previously been undertaken in relation to approvals for Stage 1 of Huntlee (individual development stage approvals are being obtained from Subsidence Advisory NSW (SA NSW) for areas within the Mine Subsidence District as planning and development proceeds). See **Figure 2** for the context of Stages 1 and 2.

Relevant previous reports include:

- Geotechnical Desktop Assessment of Mine Workings – Huntlee Stage 1 Town Centre, RCA Australia Report 10915-201/0, December 2014. (Ref [2])
- Mine Subsidence Assessment – Huntlee Town Centre, RCA Australia Report 10915f-201/1, October 2021. (Ref [3])

This desktop assessment extends the findings of the Stage 1 Desktop Report (Ref [2]) and also makes reference to the detailed mine subsidence assessment (Ref [3]). In general Stage 2 lies to the south and west of the Stage 1 and Huntlee Town Centre area as illustrated on **Figure 2**.

For context, **Drawing 1** in **Appendix A** shows an overall plan of the development site including features of relevance to this assessment such as the Branxton Mine Subsidence District boundary and the Stage 2 boundaries.

It is noted, with reference to **Drawing 1**, that large areas of Stage 2 lie outside the Branxton Mine Subsidence District, including the entirety of Village 2 and the Stage 2 detailed DA area, and these areas will have no constraints placed on them by mine subsidence.

In summary the Stage 1 Desktop Report (Ref [2]) found:

- The workings of the Ayrfield 3 Colliery are bord and pillar workings with all workings originally first worked but with subsequent pillar removal at later date in some areas.

- Mine records indicate that abandoned workings of the Ayrfield 3 Colliery in the Bottom Seam and Middle Seams lie within the vicinity of the Stage 1 development area. Bord and pillar workings in the Middle Seam under Stage 1 were widespread while there were only some workings in the Bottom Seam towards the southern end Stage 1.
- The coal seams strike north south and dip steeply to the west and northwest and were worked to up to about 270m depth in the Stage 1 area.
- Seam thickness of the Middle Seam is shown on the mining record of RT436 to be variable and it was assumed that up to 2.5m of the seam may have been mined.
- Seam thickness of the Bottom Seam is shown on the mining record of RT577 at the nearest point to the Town Centre to be 2.13m.
- A site inspection by RCA Australia in 2014 identified numerous mine subsidence features in the shallow cover area (to about 25m cover).
- Pothole subsidence risk was considered to be present at the site at depths of cover less than 25m and potential trough subsidence of a maximum of 0.7m was assessed elsewhere in mined areas based on empirical models.
- Stability assessment of select pillars suggested that shallow pillars at the site were likely long-term stable with FOS reducing with increasing depth (increasing pillar load).
- The report provided likely constraints/treatments over four depth of cover zones:
 - 0-25m – subject to pothole risk and requiring remediation to allow development
 - 25-50m – subject to trough subsidence and likely constraints placed on building type and density
 - 50-75m – building controls to manage the risk of subsidence - possible application of Guideline 2.
 - >75m – building controls to manage the risk of subsidence - likely application of Guideline 2.

Ref [3] included significant geotechnical investigation within Stage 1 including boreholes and deep ground penetrating radar. The investigation works provided ground truthing of the desktop assessment and the report provided design subsidence parameters for residential and building category B1 and B2 buildings. The report concluded that some areas of the site further to the south (ie parts of Stage 2) where both seams were mined extensively would require separate further assessment and approval at an appropriate stage of development.

4 SITE DESCRIPTION

4.1 GEOLOGY

Based on the Hunter Coalfields 1:100,000 series geology map, the proposed Huntlee Stage 2 development lies over the following geological units:

- The Kitchener Formation of the Greta Coal Measures, generally noted to comprise coal seams, siltstone, sandstone and conglomerate rock types.
- The Dalwood Group, generally noted to comprise sandstone, lithic sandstone, conglomerate, siltstone and basalt rock types.

Within the Greta Coal Seam, workings in middle and Bottom Seam lie beneath the Huntlee Town Centre site as discussed in Ref [2].

A geological section of the Greta Coal Measures, showing the sequence of units that underlie the proposed town center is shown as **Figure 3**.

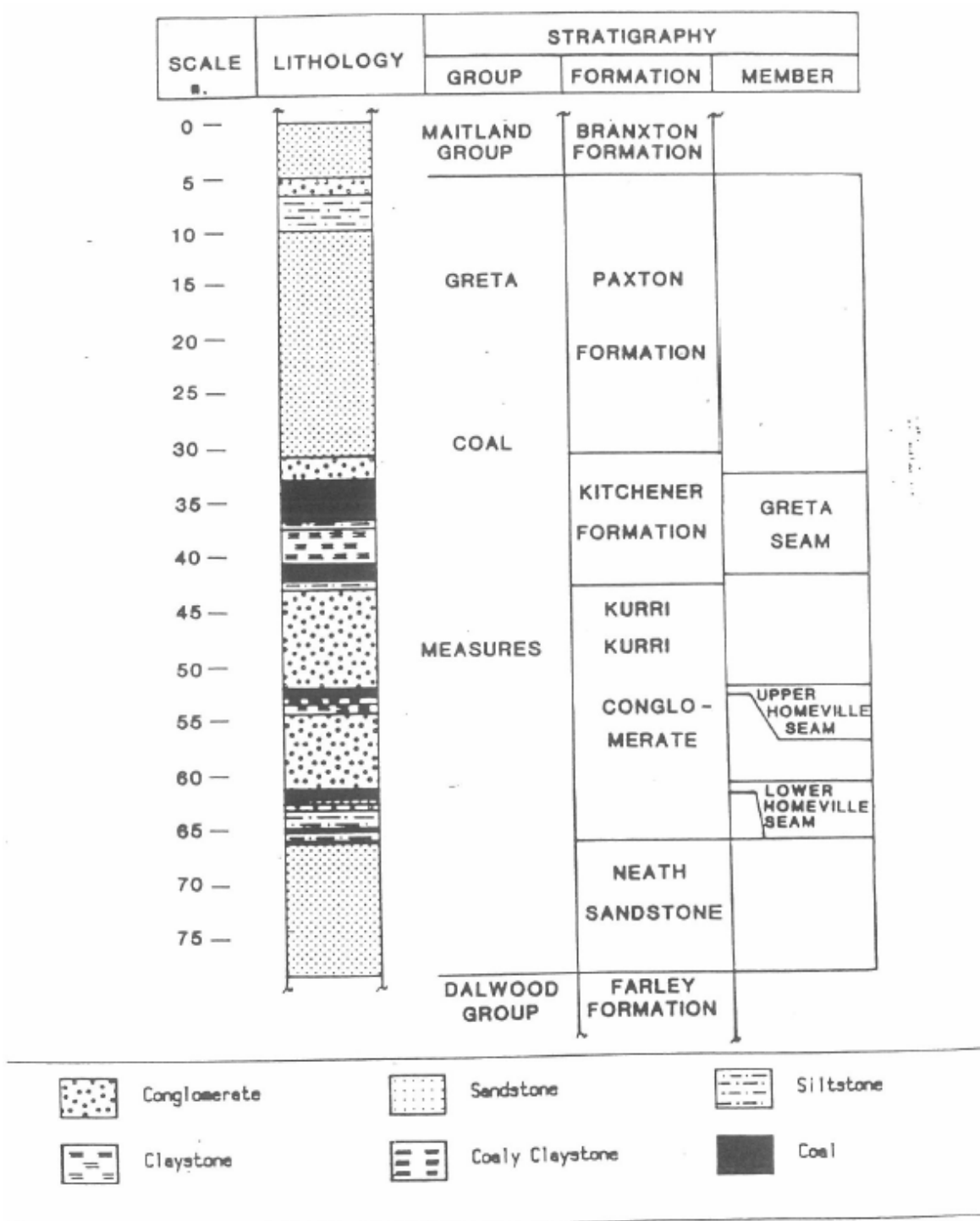


Figure 3 Stratigraphy of the Greta Coal Measures

The Huntlee development lies on the western flank of the Lochinvar anticline and the seam dips steeply in a general west and northwesterly direction. Reference to the Hunter Coalfields 1:100,000 geology map shows the Greta Fault generally trending NW to SE passing through the area of the proposed Huntlee Town Centre. The fault has resulted in the Greta Seam on the northern side of fault lying about 3km to the east where the coal was exploited by separate collieries. The faulting has also resulted in the coal seam swinging to the east near the fault as may be observed on the mine overlay plans presented in this report. Some bores and the deep ground penetrating radar survey undertaken as part of investigation presented in this report were in part aimed at accurately locating the Greta Fault. The location of the fault taken from the Hunter Coalfields 1:100,000 geology map is included on Drawings in Ref [3].

4.2 SURFACE CONDITIONS

The Huntlee development site lies on undulating terrain. Much of the area is covered by bushland although there are areas that have been cleared for farming, especially in the western areas.

The Stage 2 area within the Branxton MSD includes a number of areas that have been subject to significant surface disturbance through construction, earthworks (cutting, filling and quarrying) and mining. At an appropriate stage of development these areas will require detailed geotechnical investigation, assessment and remediation. These areas include:

- Coal preparation areas.
- Rail facilities and relic mine structures present at the site.
- Numerous shafts and tunnels which will require location and remediation.
- Disturbed ground from quarrying, mining activities and subsidence.

5 LOCATION AND DEPTH OF WORKINGS

The mined area within the Stage 2 development area is well documented by record tracings. Record traces for the Middle Seam (RT436) and for the Bottom Seam (RT577) were obtained from the Department of Regional NSW. The RTs have been used to prepare mine overlay plans of the Stage 2 areas underlain by mine workings. The presence of some concrete plaques at sites of former tunnel entries and shafts of the Ayrfield No. 3 and Maitland Extended workings also provides some assistance in locating the workings. The record tracings include seam depth data and along with bores within Stage 1 reported in Ref [3] this has allowed indicative depth of cover contours to be prepared. It is stressed that at this desktop stage the contours provided are indicative and will require confirmation and refinement by drilling and further assessment.

For the purpose of this assessment of the mine affected areas of Stage 2 are defined as the Stage 2 North area comprising parts of Village 3 and the extension of the Town Center and the Stage 2 South area adjacent to Old North Road.

Drawings 2 to 5 present mine overlay plans of the Stage 2 development areas prepared by overlaying RT436 and RT577 over the development areas. The RTs have been located with reference to known surface features and zone boundaries. This process is only approximate and it is noted that the position of the workings will need to be ground truthed and the position of the workings should only be considered as approximate.

Drawing 2 presents a mine overlay plans for Stage 2 North for the Middle Seam. The mine workings on this drawing affect the Town Centre and Village 3 area of the site.

Drawing 3 presents a mine overlay plan for Stage 2 North for the Bottom Seam. The mine workings on this drawing affect the Town Centre and Village 3 area of the site.

Drawing 4 presents a mine overlay plan for Stage 2 South for the Middle Seam. The mine workings on this drawing affect the Old North Road Concept Area of the site.

Drawing 5 presents a mine overlay plan for Stage 2 South for the Bottom Seam. The mine workings on this drawing affect the Old North Road Concept Area of the site.

The mine affected Stage 2 areas (North and South) are large and underlain by extensive and complex mine workings in two seams. The workings were bord and pillar workings and typically took the form of working roadways/tunnels downdip with bords mined along strike leaving elongated pillars. Widespread shading of pillars in both seams under the Stage 2 North area indicates secondary pillar removal. The RTs show only first workings beneath the Stage 2 South area (Maitland Extended No 6).

Indicative depth of cover contours have been developed based on drilling results from Stage 1 and depths of workings included on the RTs. Depth of cover contours are presented on **Drawing 6** for the Stage 2 North area and on **Drawing 7** for the Stage 2 South area. Contours are provided for assumed sub crop of the Bottom Seam and 25m, 50m and 75m depth of cover to the roof of the Middle Seam. A diagram of the interpretation is illustrated in **Figure 4**. By this interpretation the 0-25m depth of cover zone is widened due to the double seam.

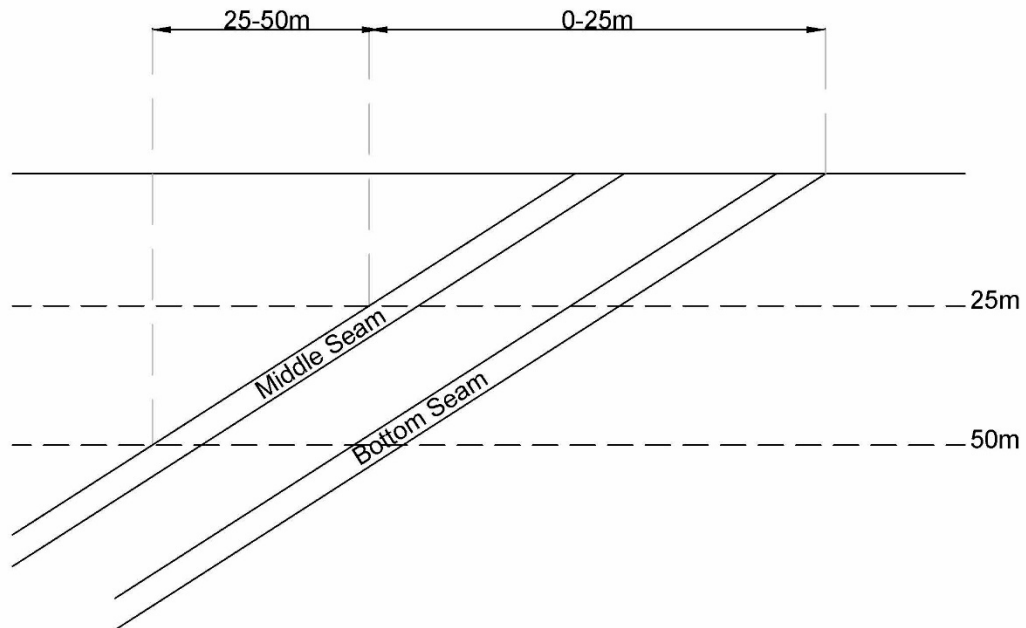


Figure 4 Interpretation of Depth of Cover Contours

6 SITE INSPECTION

A walkover of the Huntlee Stage 2 area was undertaken on 31 August 2023 by a Principal Geotechnical Engineer.

Features of note in the Stage 2 North area include:

- In the quarried area in the north of the Stage 2 North area the Middle Seam is exposed in ground exposed by quarrying (see **Photograph 1**)
- The presence of several potholes in the shallow cover zone (see **Photograph 2** and **Photograph 4** for examples).
- Presence of several mine entries (see **Photograph 3** and **Photograph 4** for examples)
- Widespread hummocky and disturbed ground representative of subsided and mine affected lands (see **Photograph 5** for example)



Photograph 1 *Exposed middle seam outcrop (Town Centre Area)*



Photograph 2 *Pothole – Stage 2 north (Village 3 Area)*



Photograph 3 *Subsided mine entry adjacent to rail line (Village 3 Area)*



Photograph 4 *Ayrfield No 4 entry plaque dated 1990 with pothole adjacent (Village 3 Area)*



Photograph 5 *Apparent subsidence scarp in the Stage 2 North area (Village 3 Area)*

No evidence of mining or subsidence was observed within the Stage 2 South area. Evidence of the tunnel entries and 16-foot-deep shaft associated with No 5 mine were observed just to the north of the Stage 2 South area (the Old North Road Concept DA Area).

7 MINE SUBSIDENCE ASSESSMENT

7.1 LIKELIHOOD

7.1.1 GENERAL

Two seams have been extensively mined beneath the parts of the Stage 2 North and South sites (Town Centre, Village 3 and Old North Road areas) with worked seam thickness of possibly over 2m in each seam.

There is well documented history at the site and in the broader Greta Coal Seam workings of pothole and trough subsidence.

In the absence of detailed investigation providing alternative evidence, it is suggested that there remains a credible risk within the mine affected areas of Huntlee Stage 2 of:

- Pothole formation in the area of depth of cover to about 25m depth to the roof of the relevant mined seam.
- Trough subsidence in areas with depth of cover greater than about 25m.

A discussion of the likelihood of pothole and trough subsidence follows.

7.1.2 POTHOLE SUBSIDENCE

Pothole formation over shallow workings (<25m) is a potential risk. A pothole forms where a roof collapse over a bord is able to progress to the surface. Generally, in the Hunter Valley the depth of cover for pothole risk is considered to be up to about 25m. Evidence of potholes and subsidence in the shallow mined area through Stages 1 and 2 is consistent with this. Given that the majority of the shallow workings underlying proposed Stage 2 are shown to be first workings, it is possible that sections of the workings are still standing, and therefore present a risk of future pothole subsidence.

The highest risk of potholing is likely to exist where depth of cover is less than 15m as weathering is possible to this depth, and weathered rock can lose its ability to span effectively over open bords. It is known that the roof strata over the Middle and Bottom Seams is massive conglomerate and experience with potholing over these seams at this site and elsewhere is that potholes are typically confined to weathered roof strata.

It will be necessary to manage the risk of pothole subsidence in the concept DA area of the proposed Stage 2 over shallow workings (<25m). The risk of voids migrating to the surface will be intolerable and will require detailed investigation and management. Management is likely to comprise remediation in any areas of proposed improvement by means such as grouting. In the interim is recommended that access to these areas be minimized.

7.1.3 TROUGH SUBSIDENCE

In areas of cover deeper than about 25m the primary mechanism of subsidence is through trough subsidence which may be initiated by the collapse of one or more standing pillars.

As indicated in Section 4 and illustrated on the mine overlay plans, areas of Stage 2 are undermined by first and second workings in both mined seams. It is possible that second worked areas could have subsided, however in the absence of investigation it is assumed at this stage, in the worst case, that all workings may be standing and may be subject to trough subsidence.

A preliminary assessment of pillar stability follows.

It is noted that assessment of pillar stability in this general area has been undertaken at least twice previously:

- Ref [7] assessed stability of selected pillars through Ayrfield 3 Colliery area and concluded that most of the first workings are in strong coal with strong overburden, and pillar analysis of selected smaller pillars indicated that pillars are permanently stable. The report considers that there was a clear inference that if the smallest pillars indicate adequate Factors of Safety then virtually all other larger pillars will likewise be stable.
- Ref [2] assessed stability of selected pillars in Stage 1 of Huntlee and concluded that the pillars analyzed in the Middle Seam had a range of factors of safety of 1.26-4.44. For the assumed mined height of 2.5m the stability calculations suggest that the shallower pillars (less than about 50m) were long term stable while at greater depth long term stability becomes uncertain.

The stability of a limited number of representative pillars in first worked areas of the seams has been assessed on the basis of the available data using the methodology presented by Galvin et al, 1998 (Ref [4]). Reference to the RTs indicates the following general features of the mining within the Ayrfield 3 Colliery:

- In the Stage 2 North area, in general within 100m of the surface pillars are 4m in width, or slightly less. Between 100m and 250m depth pillar widths increased to around 5m to 6m. Below 250m depth pillar width increased gradually from 6m to 19m.
- In the Stage 2 South area, pillars are about 16m wide with approximately 6m wide bords.

The pillars selected for analysis are identified on **Drawings 6 & 7** (except for Pillar 4). Input variables and the results of the analysis are attached in **Appendix C**. The assessment does not include account of any abutment loading which is likely of relevance in the Stage 2 North area where areas of second worked pillars are likely to have collapsed and loaded adjacent first worked pillars. Pillar dimensions have been scaled off the RTs. It is noted that the site conditions comprising steeply dipping seams, long narrow pillars and irregular workings would generally not be considered ideal for this type of analysis, however the results are provided at least as a guide. As noted in later sections the stability of pillars may be ignored in SA NSW approval based on the current SA NSW Subdivision assessment policy.

A summary of the results is presented in **Table 1**.

Table 1 *Pillar Stability Analysis – Ayrfield No 3 Colliery*

Pillar	Seam	Area	Depth of Cover (m)	Extraction (%)	FOS
P1	Middle	Stage 2 – North (Village 3 and the Town Centre Extension)	20	40.8	13.95
P2	Middle	Stage 2 – North (Village 3 and the Town Centre Extension)	35	49.7	6.79
P3	Middle	Stage 2 – North (Village 3 and the Town Centre Extension)	90	43.0	3.63
P4	Bottom	Stage 2 – North (Village 3 and the Town Centre Extension)	40	57.5	4.24
P5	Bottom	Stage 2 – South (old North Road site)	25	42.8	14.06
P6	Bottom	Stage 2 – South (old North Road site)	80	38.4	3.32

Notes: FOS= Factor of Safety.

On the basis of the probabilistic analysis of pillar performance data in NSW and Queensland presented by Galvin et al, 1998 (Ref [4]), a relationship between Factor of Safety and Probability of Failure has been defined. The relationship for the Power Law formula is listed in **Table 2**.

Table 2 *Relationship between FOS and Probability of Failure (Galvin et al, 1998)*

Probability of Failure	Factor of Safety (Power Law)
8 in 10	0.87
5 in 10	1.00
1 in 10	1.22
5 in 100	1.30
2 in 100	1.38
1 in 100	1.44
1 in 1000	1.63
1 in 10000	1.79
1 in 100000	1.95
1 in 1000000	2.11

Long-term pillar stability is generally thought to be accepted for FOS greater than around 2.1 (ie, at probabilities of failure less than 1 in 1000000).

Features of note with respect to pillar stability are:

- All the pillars analysis have FOS in excess of 3.
- The Stage 2 south workings within the Maitland Extended No 6 mine have relatively narrow worked panels and numerous wide pillars that based on analysed Pillar 5 have no credible risk of failure.

Detailed investigation will be required to confirm the condition of the workings and pillars beneath the development.

7.2 CONSEQUENCE

7.2.1 POTHOLE SUBSIDENCE

Pothole risk to improvements will not be tolerated and development in pothole risk zones (0-25m cover) in the Stage 2 North and South areas (Town Centre Extension, Village 3 and Old North Road sites) should be avoided or alternatively all improvements proposed for the pothole risk zone (0-25m cover) should allow for remediation by excavation and filling, or grouting.

7.2.2 TROUGH SUBSIDENCE

Various methods are available for estimating subsidence where either standing or partially collapsed pillars were to collapse over abandoned mine workings including empirical methods and numerical methods. For the purpose of this desktop assessment an empirical model has been adopted as a guide to possible site constraints and approval conditions. It is noted that:

- Two mined seams are present at the site. The empirical subsidence model has only considered one seam. This is a simplification; however, it is noted that based on pillar stability calculations, pillar collapse and trough subsidence is a remote risk in any one seam and assuming that two seams would both collapse at the same location requires two remote risks to coincide and or/interact.
- The steep nature of the seams makes assessment of meaningful subsidence parameters difficult.

The empirical subsidence predictions should be considered preliminary at this stage to be used for planning purposes. They are based on desktop data and have used some assumptions about the mine and pillar conditions that will need to be confirmed. It is assumed that further assessment and modeling of subsidence risk at the site will be undertaken during detailed investigation stage.

For the purpose of this desktop assessment indicative estimates of trough subsidence have been made using the empirical subsidence model for the Newcastle Coalfield presented by Holla (1987) (Ref [5]). The components of ground movement that are of significance include subsidence, tilt and strain. These components are illustrated in **Figure 5** and the variation of the ground movement components is illustrated in **Figure 6**. The key element of the model is a relationship between maximum subsidence (S_{max}) and the panel width/cover depth ratio (W/H). This relationship is shown in **Figure 7**. It is noted that the empirical model makes no account of geological discontinuities such as faults and dykes. It is also noted that the empirical data is unlikely to include data from steeply dipping strata as is present at this site.

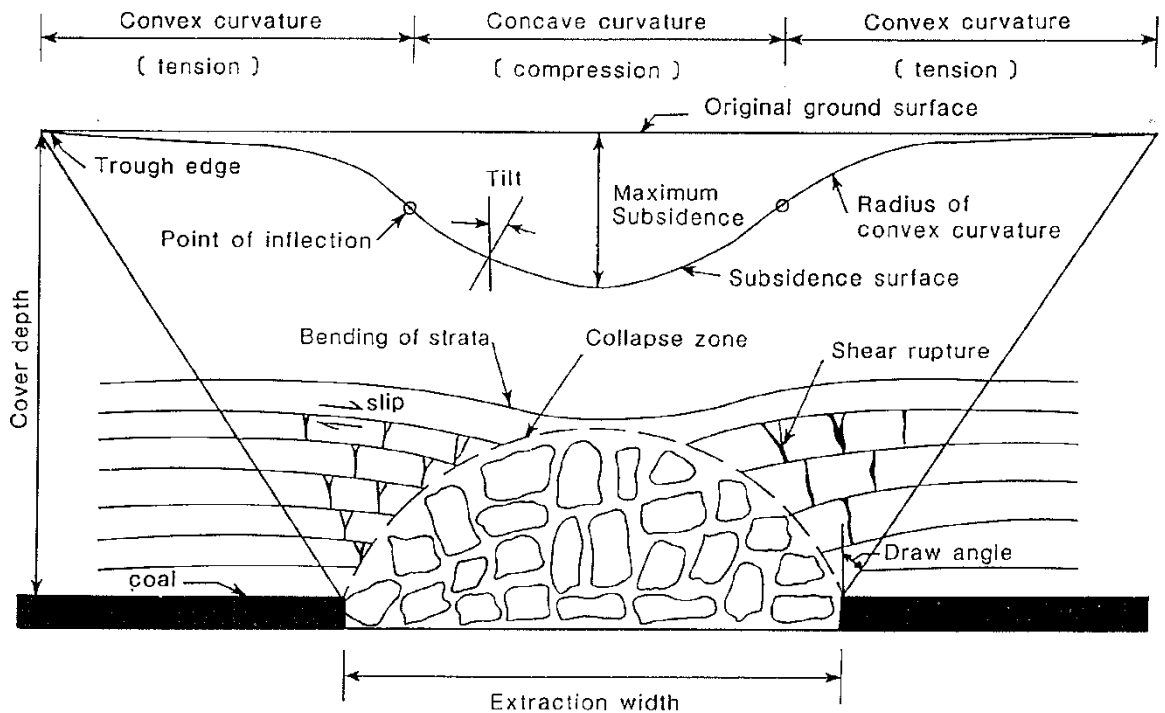


Figure 5 Components of Trough Subsidence (Holla, 1987)

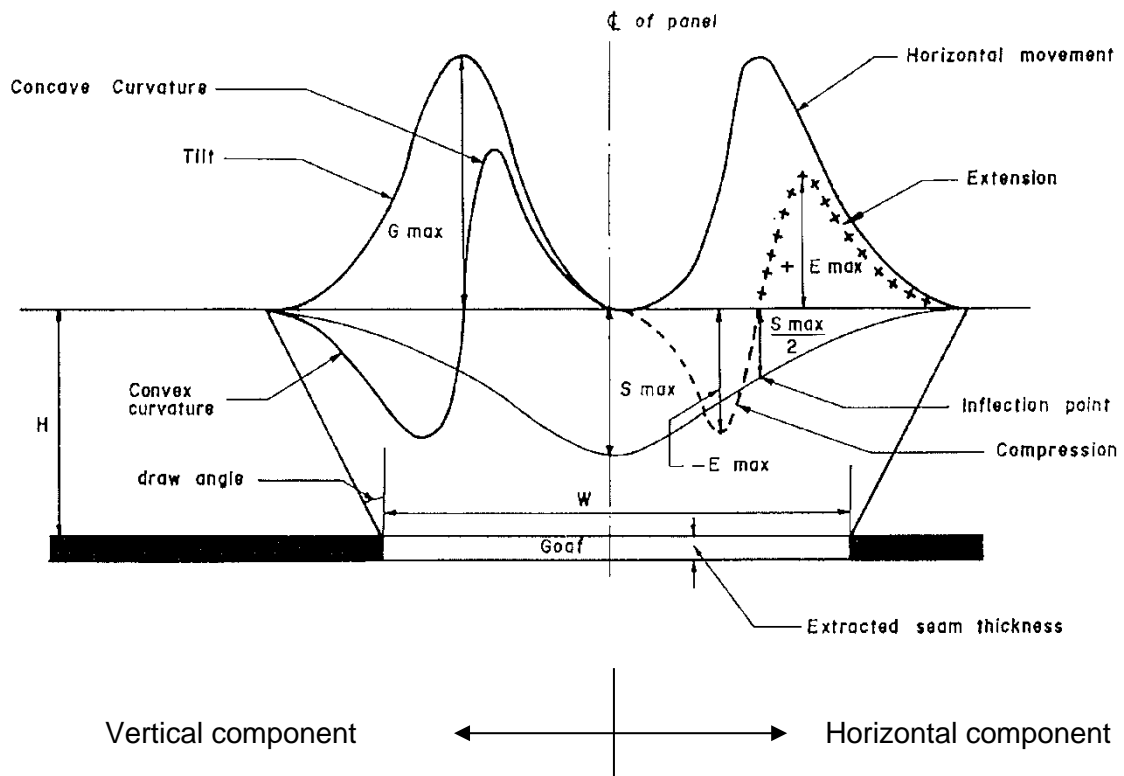


Figure 6 Characteristics of Trough Subsidence (Holla, 1987)

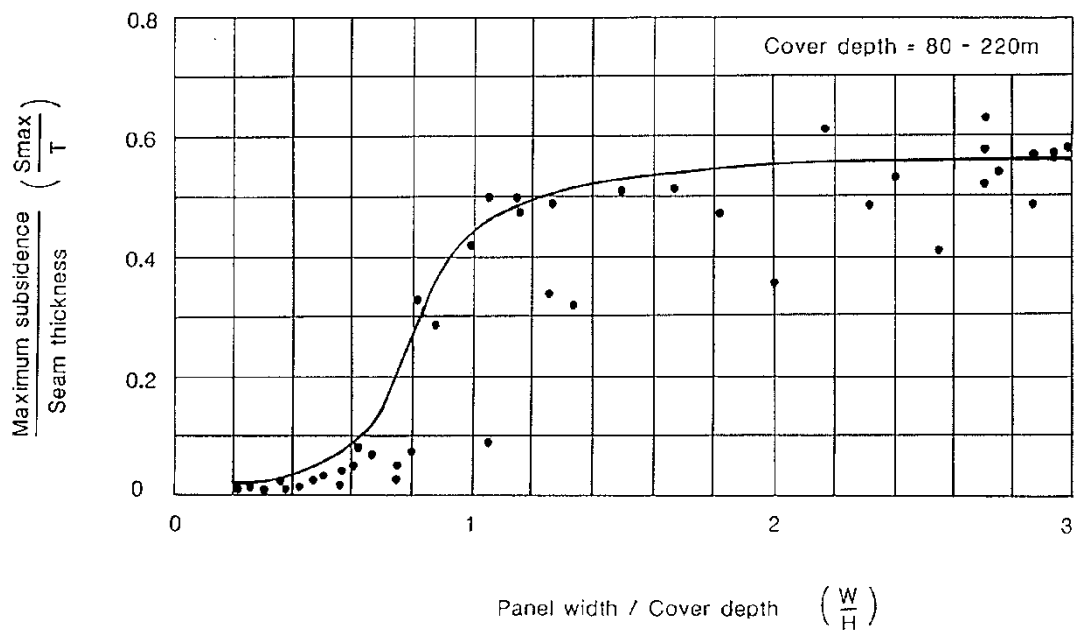


Figure 7 Relationship between Maximum Subsidence and W/H (Holla, 1987)

Strains and tilts are a function of S_{max} and H . For critical conditions (wide panel widths eg, $W/H > 1.5$) (Ref [5]) suggests the following relationships for estimating maximum ground movement parameters:

- Subsidence (S_{max}) = $0.55 \times T$ (m)
- Tensile strain (E_T) = $400 \times S_{max}/H$ (mm/m)
- Compressive strain (E_C) = $600 \times S_{max}/H$ (mm/m)
- Tilt (G) = $1800 \times S_{max}/H$ (mm/m)

The model shown in **Figure 7** indicates that:

- at $W/H > 1.5$ the maximum probable subsidence is approximately 0.55 the effective extracted mine thickness;
- at $W/H < 0.6$ the maximum probable subsidence is less than approximately 0.05 the effective extracted mine thickness;
- at intermediate W/H ratios there is a transition.

The effective extracted mine thickness will approximate the mined thickness where complete extraction was undertaken. In areas of first workings the extracted mine thickness needs to be adjusted to account for the crushed pillars filling the void during crushing. For the purposes of this assessment, it has been assumed that the adjusted extracted mine thickness is the mined height multiplied by the extraction ratio (ie, the effective extracted mine height is about 50% of the pillar height). It is noted that this makes no allowance for bulking of the crushed coal or remnant voids in the profile, which would reduce the subsidence if allowed for.

Using this model, if a large extent of pillars were to completely crush in the worst case, it could be expected that a surface subsidence near the centre of the crush of $0.55 \times 0.5 \times$ pillar height. For a full assumed seam thickness of 2-2.5m this would equate to up about 0.5-0.7m of subsidence.

Allowing for bulking of crushed pillars and incomplete closure (all Stage 1 bores in deeper areas where collapse has occurred indicate remnant voids) it is suggested that maximum worst-case subsidence be assumed to be 0.5m for depths of less than 75m.

At this stage, based on the evidence of goafing and pillar collapse in areas investigated in Stage 1 with over 75m of cover to the Middle Seam it is assumed that allowance for worst case remaining subsidence in these areas is 50% of the original potential subsidence (ie 0.25m).

Indicative subsidence parameters for Stage 2 North (Town Centre and Village 3) calculated based on the empirical model (Ref [5]) are listed on **Table 3**. It is noted that the subsidence estimates listed on **Table 3** are equivalent to those previously provided for Stage 1 (Ref [3]) based on similar empirical assessment.

Table 3 *Indicative Empirical Subsidence Estimates (Stage 2 North)*

Depth (m)	Subsidence (m)	Strain +/- (mm/m)	Tilt (mm/m)	Curvature (km)
0-25	NA	NA	NA	NA
25-50	0.5	4-12	18-36	1-1.65
50-75	0.5	3-6	12-18	1.65-4
75-150	0.25	0.7-2	3-6	5-15
>150	0.25	1	3	15

Stage 2 South (Old North Road) comprises less widespread mining with relatively narrow mined panels and oversized pillars that were identified in Section 6.1.3 as having no credible risk of failure. It is probable that lower subsidence than those provided for Stage 2 North (Town Centre and Village 3) will be applicable to the Stage 2 south area, subject to additional investigation and numerical modelling of subsidence.

It is reiterated that the parameters provided in **Table 5** are indicative only and may be optimised or refined by undertaking detailed numerical modelling. No parameters are provided for less than 25m cover as this area lies within the pothole risk zone and in accordance with Subdivision Assessment Policy any development (lots, roads and public spaces) will require remediation by suitable means such as grouting.

8 APPROVAL POLICY

8.1 SUBSIDENCE ADVISORY NSW APPROVAL FRAMEWORK

SA NSW has established development Guidelines to help landowners building within a mine subsidence district. The Guidelines set out the requirements for building on a property based on potential subsidence risks.

SA NSW's Guidelines include requirements related to the nature and class of any development on a property, the size, height and location of new structures, and the use of certain building materials and construction methods.

The Huntlee Stage 2 site is listed on the NSW Government Planning Portal as Guideline 7. Guideline 7 applies to properties within mine subsidence districts where special consideration of the likely subsidence issues is required prior to approval of development. This includes properties assessed as being at risk of subsidence with unknown or severe parameters, properties affected by shallow mine entries or shafts, and properties that are only partially undermined.

Any development application within a Guideline 7 area will be assessed on its merit in accordance with the Coal Mine Subsidence Compensation Act 2017.

As part of the assessment process for development applications that do not comply with Subsidence Advisory's standard Guidelines, the following factors are considered:

- Likelihood that mine subsidence events will occur.
- Consequence of mine subsidence events on surface infrastructure and public safety.
- Reliability of information used to determine the above, including mine plans, assumed pillar and extraction dimensions, and assumptions regarding geotechnical modelling.
- Risks arising from the proposed engineering controls.

For the purpose of the assessment of the likely approval process that follows reference is made to the relevant SA NSW assessment policy:

- Subdivision Assessment Policy, Version number: 2, Date: Friday, April 5, 2023 (Ref [1])

With reference to the approval process the following is noted:

- The 2023 version of the Subdivision Assessment Policy is very new and incorporates significant changes for the previous 2018 version under which assessment was made for the Stage 1 Development (see Ref [3]).
- The Subdivision Assessment Policy has been adopted for this assessment. Structures that are outside the scale of a typical residence or structure covered by AS2870 such as commercial or civic structures that may be considered as a part of the Stage 2 development may require separate merit assessment in accordance with the complimentary SA NSW policy document: Development Application – Merit Assessment Policy Ref [6].

8.2 SUBSIDENCE ADVISORY NSW ASSESSMENT PROCEDURES

8.2.1 POTHOLE SUBSIDENCE

In accordance with the Subdivision Assessment Policy pothole risk is assessed based on:

- Cover depth
- Borehole information on the state of the workings.
- Overburden characteristics
- Seam dip
- Previous history of pothole formation.
- The age and type of mine workings present.

It is noted that for the workings at the site, the geotechnical risk factor (GRF) is assessed by RCA Australia to be **HIGH**.

With reference to Table B3 of Ref [1] for a subdivision with high GRF the design requirements for areas with pothole risk (0-25m cover) are likely to comprise:

- Effective elimination of the risk of mine subsidence by grouting will be required. This will include a Grout Design, Implementation and Verification Plan.

8.2.2 TROUGH SUBSIDENCE

In accordance with the Subdivision Assessment Policy trough subsidence risk is assessed based on:

1. The assessed level of geotechnical risk (geotechnical risk factor (GRF))
2. The assessed stability of remnant coal pillars based on calculated factors of safety and slenderness (or width to height ratio)
3. The estimated subsidence impact should pillar failure occur.

For the workings at the site, the geotechnical risk factor (GRF) is assessed by RCA Australia to be **HIGH**.

With reference to Table B2 of Ref [1], large scale subdivisions (>20 lots) with high GRF are likely to have the following approval requirements:

- No minimum allowable pillar FOS will be applicable. This means that the design requirements will be applied in mine affected areas regardless of pillar stability assessments.
- Design requirements will be “*Subdivision infrastructure is to be designed to be serviceable and repairable under the estimated ground subsidence movements (subdivision infrastructure incorporates kerb & gutter, drainage, services etc). Pavements are either to be flexible or may be bound/rigid if designed to be repairable*”. The definition of serviceable and repairable may be found in Section 4.6 of Ref [1].

8.2.3 MINE OPENINGS, SHAFTS AND DRIFTS

All mine openings, shafts and drifts will need to be fully remediated by a suitable means such as excavation and refilling, or grouting.

9 RECOMMENDATIONS

9.1 GENERAL

Parts of the Huntlee Stage 2 development area lie within the Branxton Mine Subsidence District and SA NSW approval will be required for all improvements proposed in the parts of the Huntlee Stage 2 development area that lie within the Branxton Mine Subsidence District. Village 2 lies completely outside the Branxton Mine Subsidence District, is not affected by mine workings and will not be subject to any mine related restrictions. Parts of the remaining areas of the proposed Stage 2 development (ie. Village 3, the extension of the Town Centre and the Old North Road site) do lie within the Branxton Mine Subsidence District and will require SA NSW approval.

The mine workings within the Stage 2 development area comprise workings in two seams that are well documented by the record tracings. The north-south strike of coal seams, along with the steep dip of the seams means that the zones of significant building restrictions are relatively narrow and only affect a proportion of the development area.

In accordance with SA NSW Subdivision Assessment Policy, as a consequence of at least two factors:

- The mine affected area of the site is assessed to have a high geotechnical risk factor (GRF),
- The Stage 2 area lies within an area with a history of subsidence,

the site will require a subsurface investigation, analysis, assessment and reporting at an appropriate stage of approval and development (eg. during subdivision approval). Given that the detailed area of the subject SSDA will sit wholly outside of the mine affected area, it is suggested that mine subsidence be further investigated as part of the lodgment of future detailed applications for the concept areas.

The mine constraints at the site are generally considered to be manageable and numerous examples now exist in the mine affected areas of the Hunter Valley where residential subdivision development has been successfully achieved in similar conditions.

9.2 SUBSIDENCE RESTRICTIONS

Mine subsidence conditions at the site are relatively complex. It is recommended that plans for development and improvements within the 0-25m depth of cover zone be avoided as far as possible. The subsidence parameters for 25-50m are likely to be onerous for development and consideration should be given to either avoiding development or potentially treating by grouting to mitigate the constraints.

SA NSW will assess applications for development within the Branxton MSD based on merit under Section 22 of the Coal Mine Subsidence Compensation Act 2017 and will provide conditions of approval. Based on SA NSW Subdivision Assessment Policy (Ref [1]) and data provided in this report it is considered that the approval conditions for the Stage 2 area that lies within the Branxton MSD are likely to include allowance for design for subsidence parameters of the order of those listed in **Table 4**. Possible approval conditions based on Ref [1] are also listed in **Table 4**.

Table 4 *Indicative Design Subsidence Parameters for Stage 2 Areas within the Branxton Mine Subsidence District.*

Depth of Cover Area (m)	Strain +/- (mm/m)	Tilt (mm/m)	Curvature (km)	Possible Approval Conditions
0-25	Pothole Risk	Pothole Risk	Pothole Risk	Remediation by grouting
25-50	10	20	1.25	Any improvements designed to be SR ¹ subject to subsidence parameters
50-75	5	12	2.5	Any improvements designed to be SR ¹ subject to subsidence parameters
75-mine subsidence district boundary	1	3	15	Surface development Guideline 2 (G2) ²
Outside mine subsidence district	No restriction	No restriction	No restriction	Nil

Notes:

- 1 SR - serviceable and repairable
- 2 Based on the current SA NSW Policy Framework it is considered that SA NSW Guideline 2 may be applied to residential development within the mine subsidence district in areas with greater than 75m depth of cover to workings.

Drawings 6 and 7 provide approximate contours of depth of cover across Stage 2 that provide zones that the approval conditions are likely to apply to.

A grout plan will be required for all areas that require grouting. As a preliminary guide grouting is likely to comprise bores to intersect both seams at close centres (~5m) on a grid pattern with injection of grout back to the surface with the objective of filling all voids or fractures. A verification set of bores will be required to certify the filling. The steeply dipping nature of the seams will need to be accounted for in the grout plan as the grout will tend to flow down dip and it will be necessary to establish a barrier with viscous grout or by 'building' the grout to restrict the loss of the less viscous bulk fill grout into the deeper workings. The nature of the working with bords along the dip and limited cut throughs and roadways down dip will aid this process and the presence of drifts or headings down dip will need to be targeted.

It is noted that given the intensive mine activity in the vicinity of the sub crop line including drifts and coal processing activities that a degree of ground disturbance in these areas should be expected. This conclusion is reinforced by the presence of many surface features observed during the site inspection around the sub crop area. This feature of the site should be factored into planning, design and construction at the site.

Based on the SA NSW Subdivision Policy (Ref [1]) it is noted that approval conditions may also require subdivision infrastructure (eg. infrastructure other than buildings) within the MSD to be designed to accommodate estimated subsidence impacts and that all buried services should be located for ease of repair if required. Any infrastructure (eg. roads) with less than 25m cover to the workings will require treatment to remove pothole risk (grouting or excavation and replacement).

Impacts of mine subsidence on infrastructure can be minimised and mitigated by measures such as:

- Road pavements constructed of flexible Asphalt Concrete (AC).
- Stormwater pipes laid on minimum longitudinal grades 0.5% steeper than current Council minimum requirements to offset minor ground tilts i.e. $1\% + 0.5\% = 1.5\%$ minimum grade.
- Concrete kerbs to have crack control joints at 3m centres and full isolation joints at 6m centres to ensure only minimum length of kerb would need to be replaced in a subsidence event.
- Sewer pressure pipes to be bedded in sand and be constructed from fully welded HDPE or similar.
- Water pressure pipes (potable and recycled water) to be bedded in sand backfill and constructed from maximum 6m lengths of UPVC and rubber ring joints to minimise the impact of ground strains.

It is suggested that allowance be made for such measures within the areas of Stage 2 covered by the Branxton MSD defined in **Drawing 1**.

9.3 FURTHER INVESTIGATION

This desktop has been developed to support a State Significant Development Application and provides general advice in accordance with SA NSW Guidelines. Significant investigation will be required at an appropriate stage of approval and development within the affected areas of Stage 2 including Village 3, the extension of the Town centre and the Old North Road Site. Further investigation should include:

- Detailed site mapping in parallel with survey to locate and identify all mine features (shafts, tunnels, subsidence features etc) and improve accuracy of the mine overlay plans.
- Boreholes at the site to assess the findings of this desktop assessment. In particular the conduct of multiple series of boreholes across the seam strike are recommended to:
 - Assess depth of cover zones defined on the Drawings.
 - Check seam thickness.
 - Check for evidence of voids and or pillar crushing/seam closure.

- Numerical modelling to provide subsidence design estimates across the areas of Stage 2 affected by mining.

10 LIMITATIONS

This report has been prepared for Huntlee Pty Ltd in accordance with the agreement with RCA. The services performed by RCA have been conducted in a manner consistent with that generally exercised by members of its profession and consulting practice.

This report has been prepared for the sole use of Huntlee Pty Ltd for the specific purpose and the specific development described in the report. The report may not contain sufficient information for purposes or developments other than that described in the report or for parties other than Huntlee Pty Ltd. This report shall only be presented in full and may not be used to support objectives other than those stated in the report without permission.

The information in this report is considered accurate at the date of issue with regard to the current conditions of the site. The conclusions drawn in the report are based on interpretation of mine records. Conditions can vary between test locations that cannot be explicitly defined or inferred by investigation.

Yours faithfully

RCA AUSTRALIA



Dr Mark Allman
Principal Geotechnical Engineer

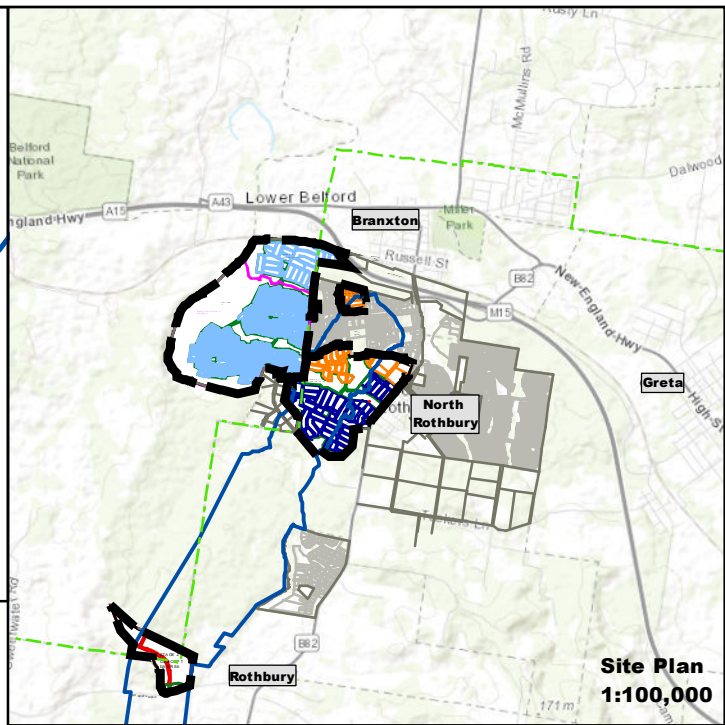
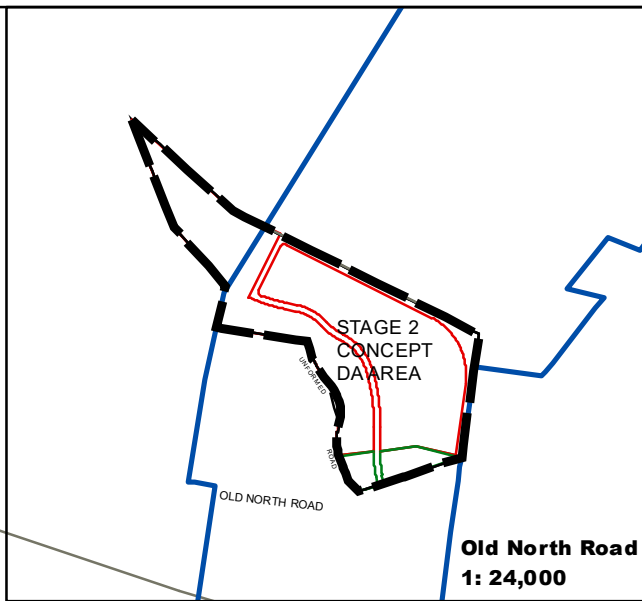
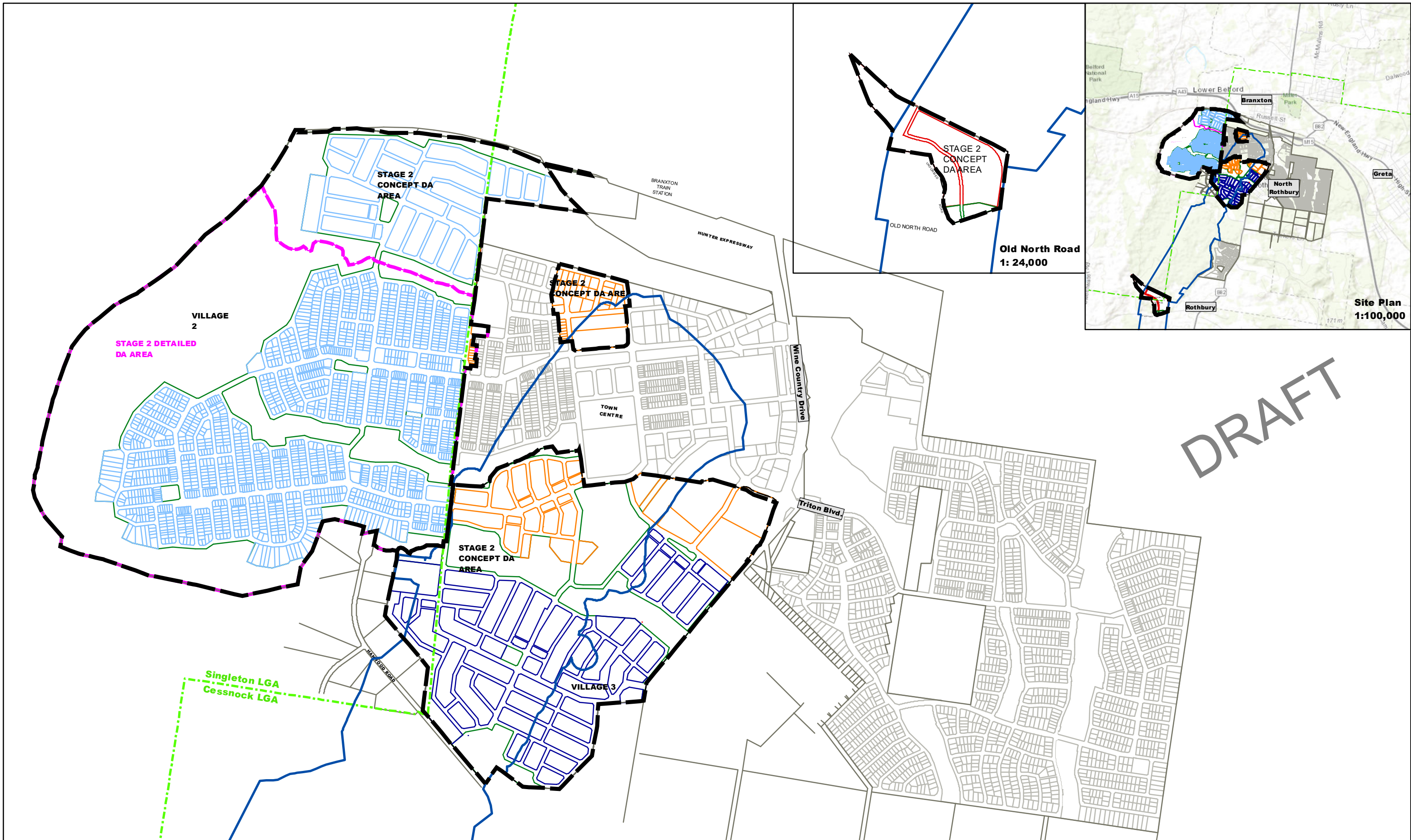
REFERENCES

- [1] Development Application – Subdivision Assessment Policy, SA NSW ver 2 April 2023.
- [2] Geotechnical Desktop Assessment of Mine Workings – Huntlee Stage 1 Town Centre, RCA Australia Report 10915-201/0, December 2014.
- [3] Mine Subsidence Assessment – Huntlee Town Centre, RCA Australia Report 10915f-201/1, October 2021.
- [4] Galvin, JM, Hebblewhite, BK, Salamon, MDG and Lin, BB (1998) “Establishing the Strength of Rectangular and Irregular Pillars” ACARP Research Project No. C5024.
- [5] Holla, L (1987) Surface Subsidence Prediction in the Newcastle Coalfield, Department.

- [6] Development Application – Merit Assessment Policy, SA NSW ver 5 April 2023.
- [7] Mine Subsidence Investigation, Sweetwater Area near Branxton, NSW, prepared by GE Holt & Associates October 2005.

Appendix A

Drawings

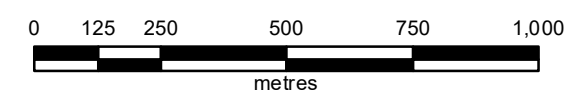


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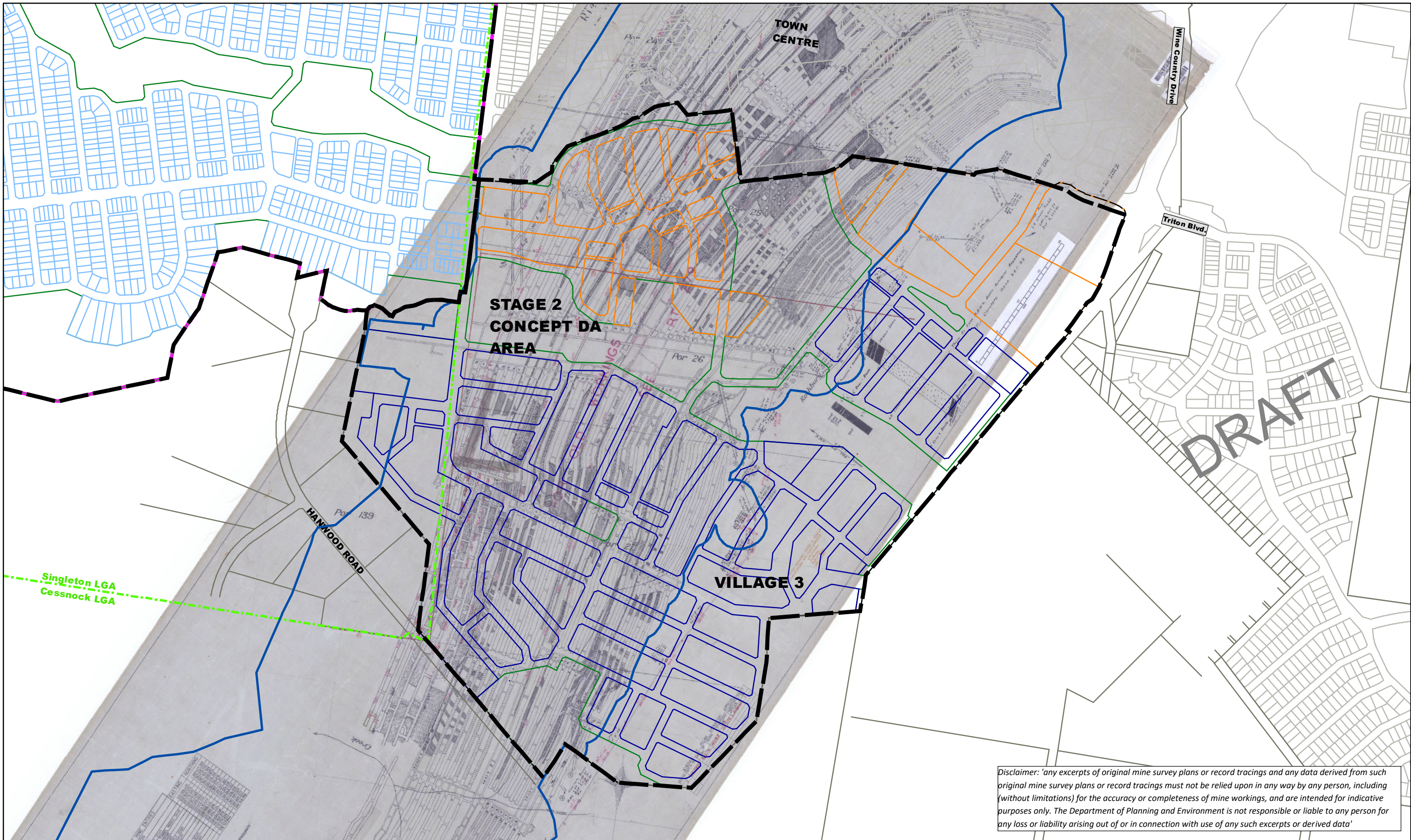
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Stage 2 detailed DA boundary	Village 3
Branxton MSD amended (20180308)	Town Centre
Local Government boundary	Large Lot sites
	Indicative parks/open space/riparian

Note:
 Drawing adapted from plan supplied by Huntlee Pty Ltd
 (Drawn by Daly Smith, Dwg No. 20406, Sheet 1 of 1, Issue 13, Dated 17/10/2023)



**HUNTLEE STAGE 2 SITE PLAN
 WINE COUNTRY DRIVE
 HUNTLEE**

CLIENT	Huntlee Pty Ltd	RCA Ref	16890-201/2
DRAWN BY	MA	SCALE	1:15,000 (A3)
APPROVED BY	MA	DATE	17/11/2023
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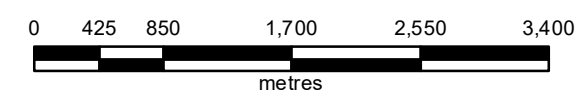


Disclaimer: 'any excerpts of original mine survey plans or record tracings and any data derived from such original mine survey plans or record tracings must not be relied upon in any way by any person, including (without limitations) for the accuracy or completeness of mine workings, and are intended for indicative purposes only. The Department of Planning and Environment is not responsible or liable to any person for any loss or liability arising out of or in connection with use of any such excerpts or derived data'

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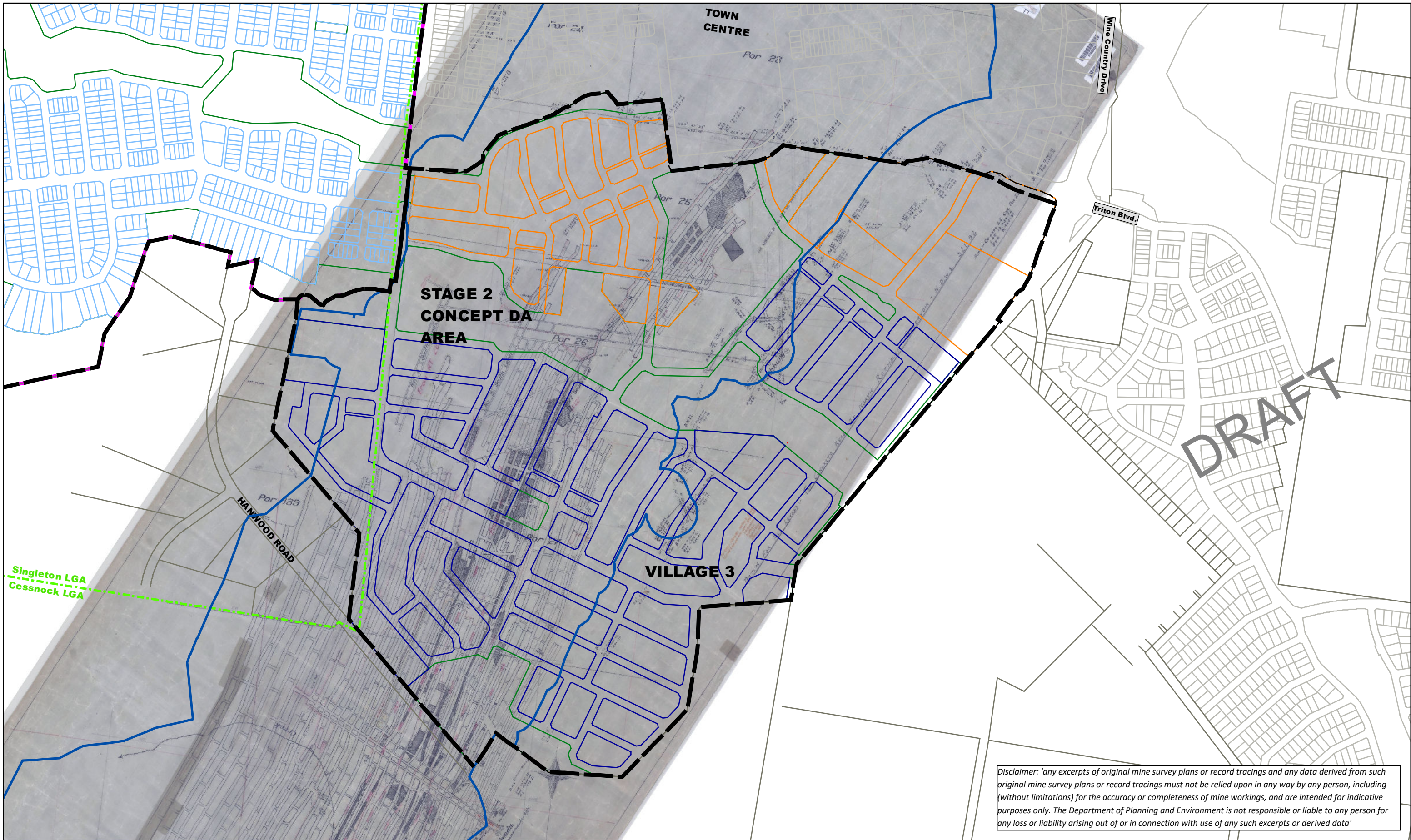
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Branxton MSD amended (20180308)	Town Centre
Local Government boundary	Large Lot sites
Singleton LGA	Indictive parks/open space/riparian
Cessnock LGA	

Note:
 Drawing adapted from plan supplied by Huntlee Pty Ltd
 (Drawn by Daly Smith, Dwg No. 20406, Sheet 1 of 1, Issue 13, Dated 17/10/2023)
 RT436 Plan of Workings Sheet 1 of 2, Middle Seam



**MINE OVERLAY PLAN
 MIDDLE SEAM
 STAGE 2 - NORTH
 WINE COUNTRY DRIVE
 HUNTLEE**

CLIENT	Huntlee Pty Ltd	RCA Ref	16890-201/2
DRAWN BY	MA	SCALE	1:7,500 (A3)
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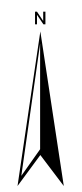
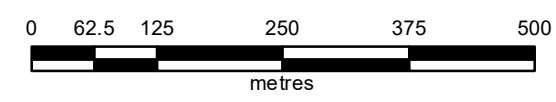


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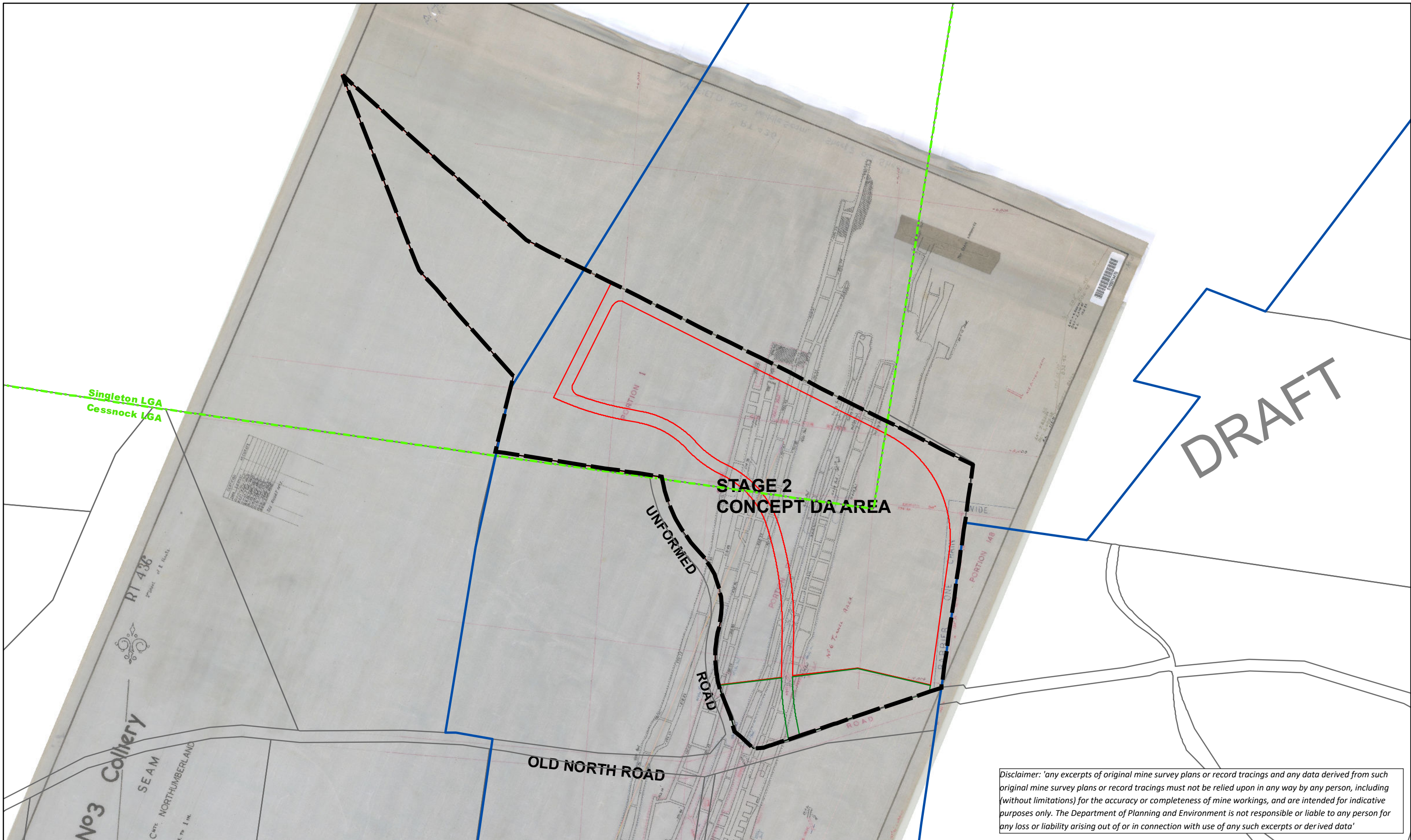
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Branxton MSD amended (20180308)	Town Centre
Local Government boundary	Large Lot sites
Indicative parks/open space/riparian	

Note:
 Drawing adapted from plan supplied by Huntlee Pty Ltd
 (Drawn by Daly Smith, Dwg No. 20406, Sheet 1 of 1, Dated 25/07/2023)
 RT577 Plan of Workings Sheet 1 of 3, Bottom Seam



**MINE OVERLAY PLAN
 BOTTOM SEAM
 STAGE 2 - NORTH
 WINE COUNTRY DRIVE
 HUNTLEE**

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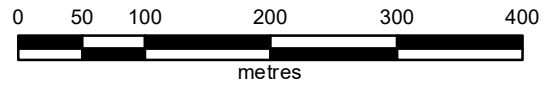


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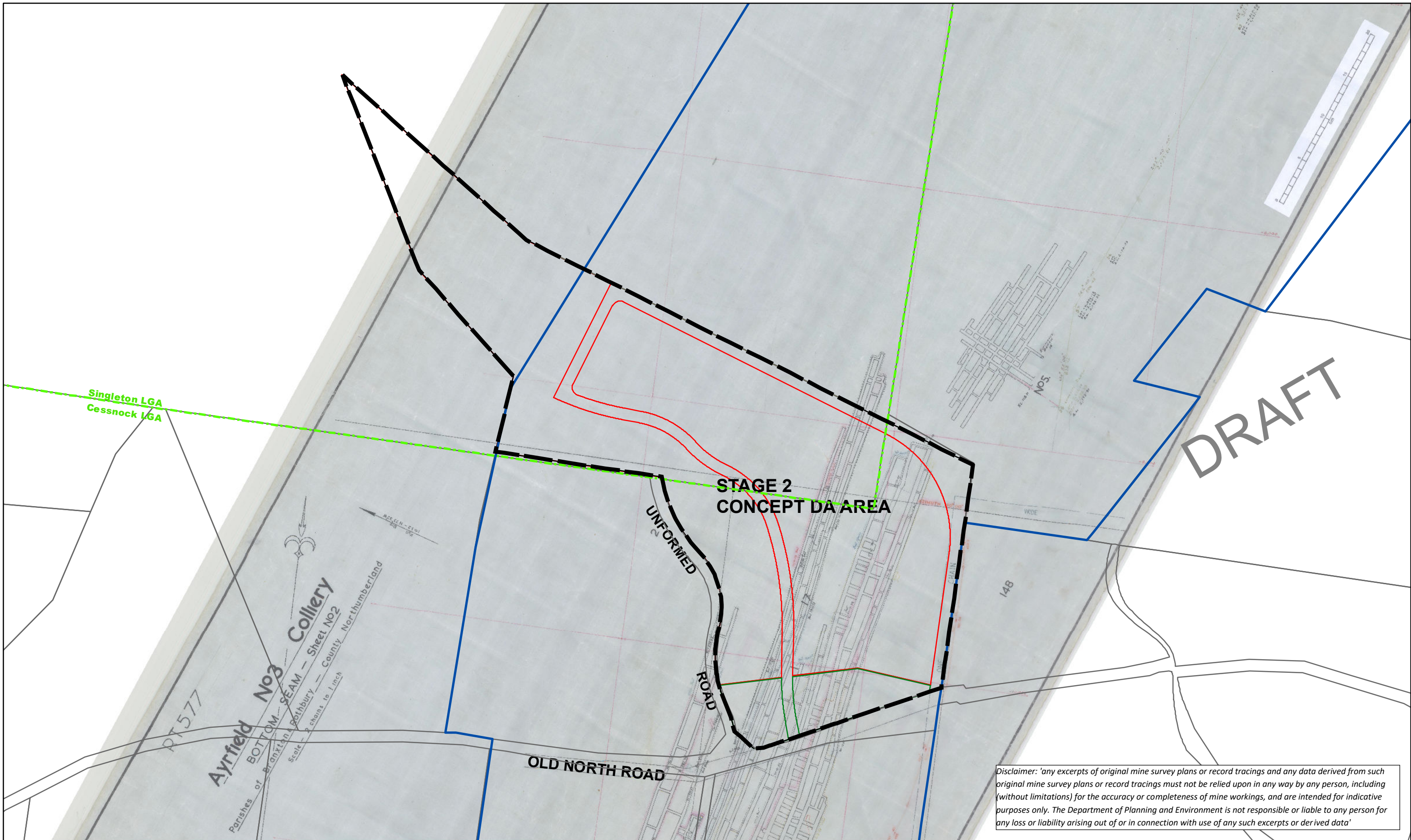
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- Stage 2 DA boundary (concept and detailed areas)
 - Branxton MSD amended (20180308)
 - Local Government boundary
 - Large Lot sites
 - Indictive parks/open space/riparian

Note:
 Drawing adapted from plan supplied by Huntlee Pty Ltd
 (Drawn by Daly Smith, Dwg No. 20406, Sheet 1 of 1, Issue 13, Dated 17/10/2023)
 RT436 Plan of Workings Sheet 2 of 2, Middle Seam



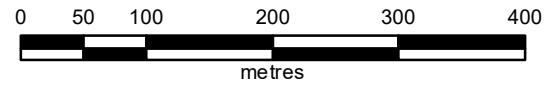
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 MIDDLE SEAM
 STAGE 2 - SOUTH
 HUNTLEE**

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- LEGEND**
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 - Branxton MSD amended (20180308)
 - Local Government boundary
 - Large Lot sites
 - Indictive parks/open space/riparian

Note:
 Drawing adapted from plan supplied by Huntlee Pty Ltd
 (Drawn by Daly Smith, Dwg No. 20406, Sheet 1 of 1, Issue 13, Dated 17/10/2023)
 RT577 Plan of Workings Sheet 2 of 3, Bottom Seam

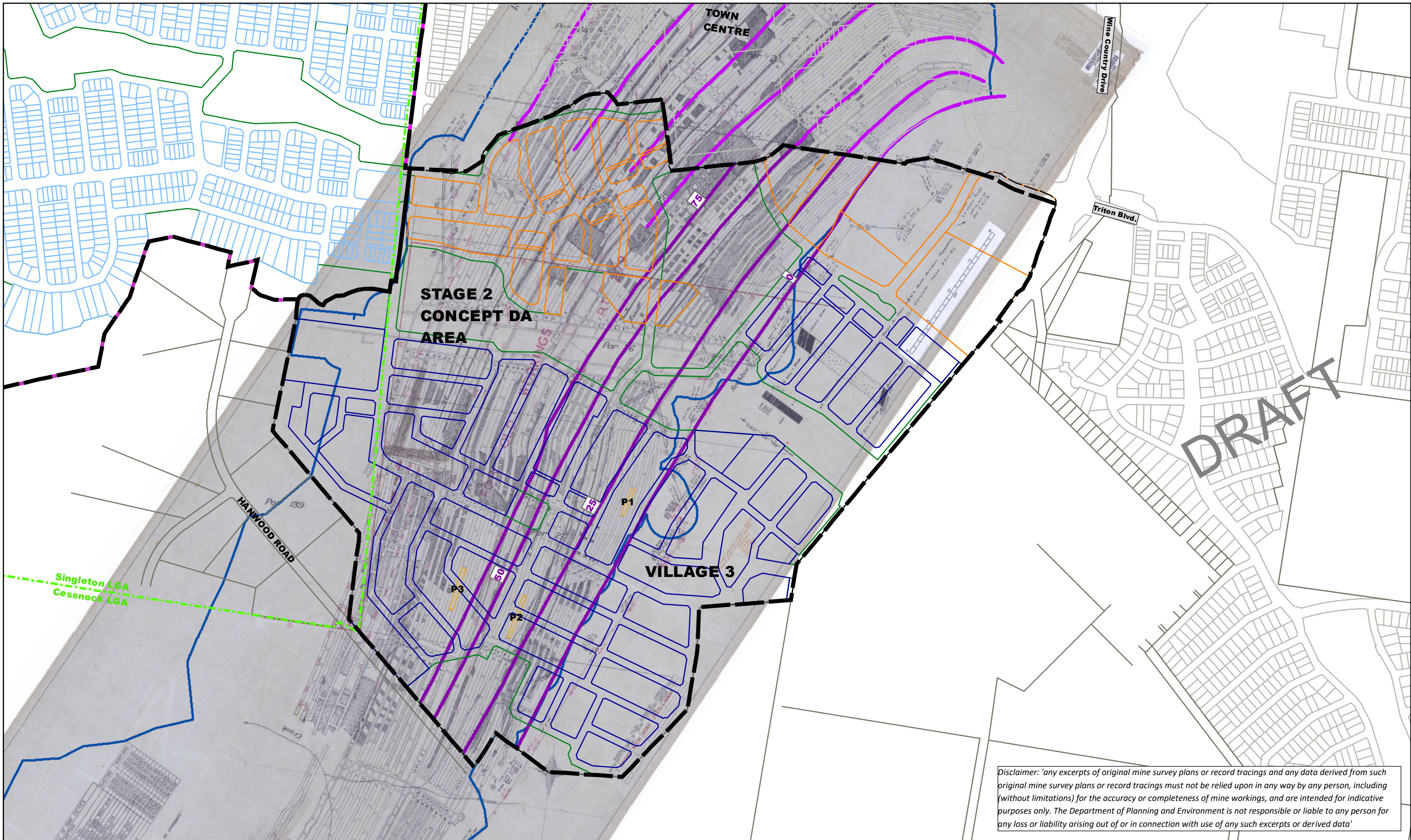


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**MINE OVERLAY PLAN
 BOTTOM SEAM
 STAGE 2 - SOUTH
 HUNTLEE**

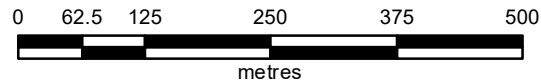
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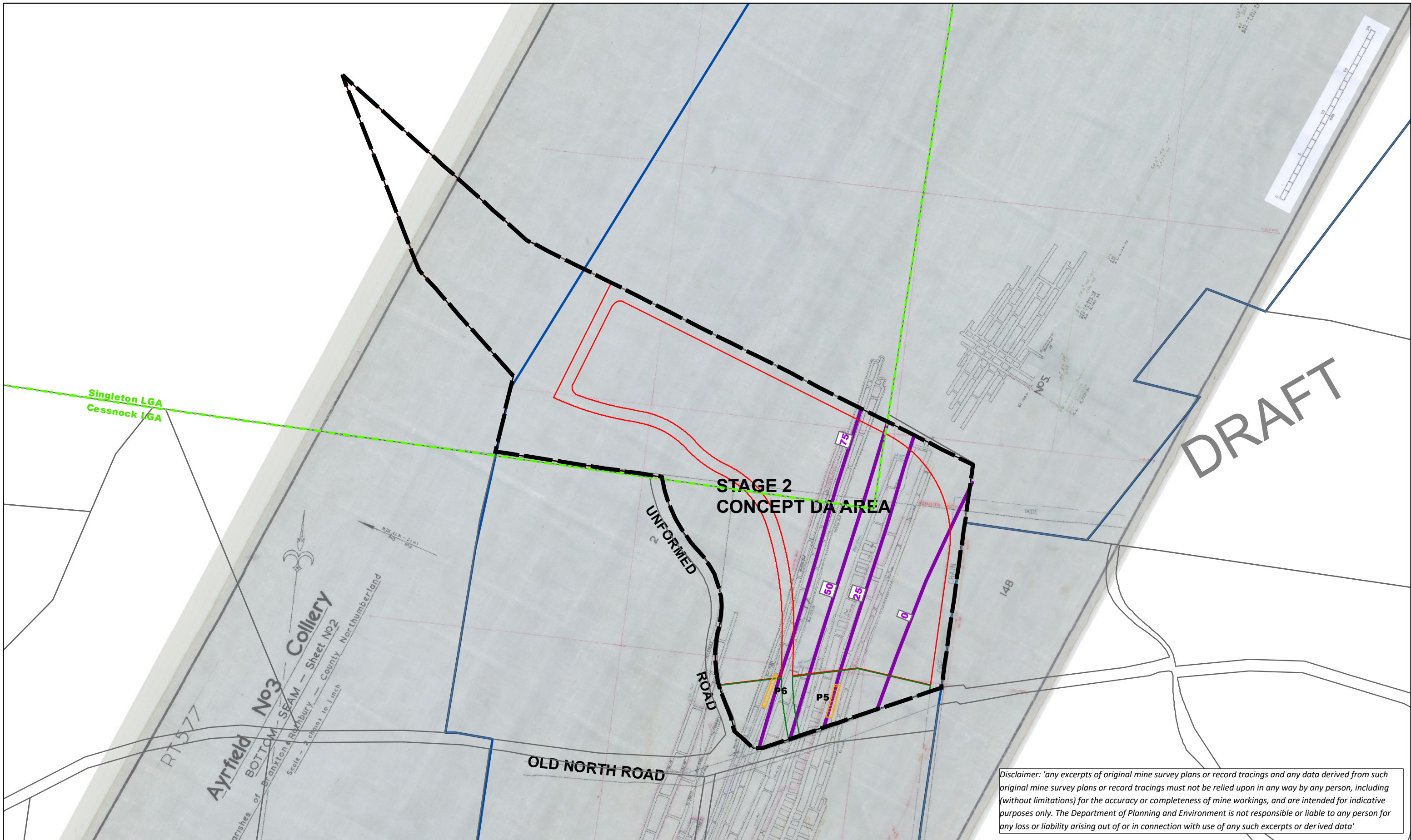
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 - Pillars
 - Isopachs Stage 2 2023
 - Isopachs Stage 1
 - Village 2
 - Village 3
 - Town Centre
 - Indictive parks/open space/riparian

Note:
 Drawing adapted from plan supplied by Huntlee Pty Ltd
 (Drawn by Daly Smith, Dwg No. 20406, Sheet 1 of 1, Issue 13, Dated 17/10/2023)
 RT436 Plan of Workings Sheet 1 of 2, Middle Seam



**DEPTH OF COVER PLAN
 MIDDLE SEAM
 STAGE 2 - NORTH
 WINE COUNTRY DRIVE
 HUNTLEE**

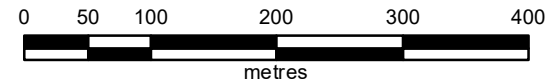
CLIENT	Huntlee Pty Ltd	RCA Ref	16890-201/2
DRAWN BY	MA	SCALE	1:7,500 (A3)
APPROVED BY	MA	DATE	20/11/2023
		DRAWING No	6
		REV	1
		OFFICE	NEWCASTLE



LEGEND

- Stage 2 DA boundary (concept and detailed areas)
- Large Lot sites
- Pillars bottom seam
- Local Government boundary
- Branxton MSD amended (20180308)
- Isopachs_Stage 2 South
- Indictive parks/open space/riparian

Note:
Drawing adapted from plan supplied by Huntlee Pty Ltd
(Drawn by Daly Smith, Dwg No. 20406, Sheet 1 of 1, Issue 13, Dated 17/10/2023)
RT577 Plan of Workings Sheet 2 of 3, Bottom Seam



**DEPTH OF COVER PLAN
BOTTOM SEAM
STAGE 2 - SOUTH
HUNTLEE**

CLIENT	Huntlee Pty Ltd	RCA Ref	16890-201/2
DRAWN BY	MA	SCALE	1:6,000 (A3)
APPROVED BY	MA	DATE	20/11/2023
DRAWING No	7	REV	1
OFFICE	NEWCASTLE		

Appendix B

SA NSW Advice

Department of Planning and Environment
VIA: NSW Planning Portal

Re: Agency Consultation for SEARs – SSD-54836993

To Whom it May Concern,

LOT/DP: 11, 12 & 13/-/1137569, 2/-/1211767, 3 & 4/-/813163, 158/-/1259859, 146/-/1233016, 240/-/1105591, 231/-/879198.

ADDRESS: Huntlee New Town - Stage 2

Thank you for your referral dated 17 February 2023 providing Subsidence Advisory NSW with the opportunity to provide input on environmental assessment requirements pertaining to State Significant Development SSD-54836993.

It is understood that the applicant is proposing to redevelop land for urban development at Huntlee New Town Stage 2.

Some of the lots identified in Table 3 of the Scoping Report by Ethos Urban are within a declared Mine Subsidence District and are undermined by historic abandoned workings in two coal seams.

These workings present varying subsidence risks to development and will require geotechnical investigation in accordance with the requirements of Subsidence Advisory's assessment policies. Some of the undermined areas would likely require remediation prior to any surface development. Other areas may require building controls to manage the risk of subsidence.

Ongoing consultation with Subsidence Advisory NSW is required as project development progresses. Future subdivision or surface development will require approval from Subsidence Advisory.

If you would like more information, please contact me on (02) 4908 4300 or subsidedevelopment@customerservice.nsw.gov.au.

Kind Regards



Melanie Fityus
Senior Risk Engineer

Appendix C

Pillar Stability Calculations

Pillar No.	Depth of Cover, H (m)	Unit Weight of Overburden, γ (kN/m ³)	Seam Thickness (m)	Height of Workings, h (m)	Pillar Width, w (m)	Pillar Length (m)	Angle Between Pillar Sides (°)	Heading Width (m)	Cut-Through Width (m)	Pillar Width along Ribline, w ₁ (m)	Pillar Length along Ribline, w ₂ (m)	Width to Height Ratio, R (w/h)	Pillar Area (m ²)	Tributary Area (m ²)	Extraction Ratio (%)	$\frac{2w_2}{w_1 + w_2}$	Θ	Effective Width, w _{eff} (m)	Total Pillar Stress (Mpa)	Total Pillar Load (MN)	Pillar Strength (Mpa)	Pillar Load Capacity (MN)	Factor of Safety	Probability of Failure	Comments
P1	20	24.9	2.5	2.5	8	64	90	5	2.5	8.0	64.0	3.2	512.0	864.5	40.8	1.778	1.04	8.31	0.84	430.5	11.73	6005.8	13.95	<1.0E-06	Middle Seam
P2	35	24.9	2.5	2.5	8	99	90	7.5	2.5	8.0	99.0	3.2	792.0	1573.3	49.7	1.850	1.04	8.34	1.73	1371.1	11.75	9302.9	6.79	<1.0E-06	Middle Seam
P3	90	24.9	2.5	2.5	10	95	90	7	3	10.0	95.0	4.0	950.0	1666.0	43.0	1.810	1.22	12.19	3.93	3733.5	14.26	13543.7	3.63	<1.0E-06	Middle Seam
P4	40	24.9	2.5	2.5	6	35	90	7	3	6.0	35.0	2.4	210.0	494.0	57.5	1.707	1.00	6.00	2.34	492.0	9.93	2086.0	4.24	<1.0E-06	Bottom Seam
P5	25	24.9	2.5	2.5	11	58	90	7	4	11.0	58.0	4.4	638.0	1116.0	42.8	1.681	1.27	14.02	1.09	694.7	15.31	9769.1	14.06	<1.0E-06	Bottom Seam
P6	80	24.9	2.5	2.5	7	61	90	4	2	7.0	61.0	2.8	427.0	693.0	38.4	1.794	1.00	7.00	3.23	1380.5	10.75	4588.4	3.32	<1.0E-06	Bottom Seam