MINE SUBSIDENCE ASSESSMENT

Regrowth Kurri Kurri, Precinct 1A

Prepared for Loxford Project Management Pty Ltd

Prepared by RCA Australia

RCA ref 15924-201/2

February 2022

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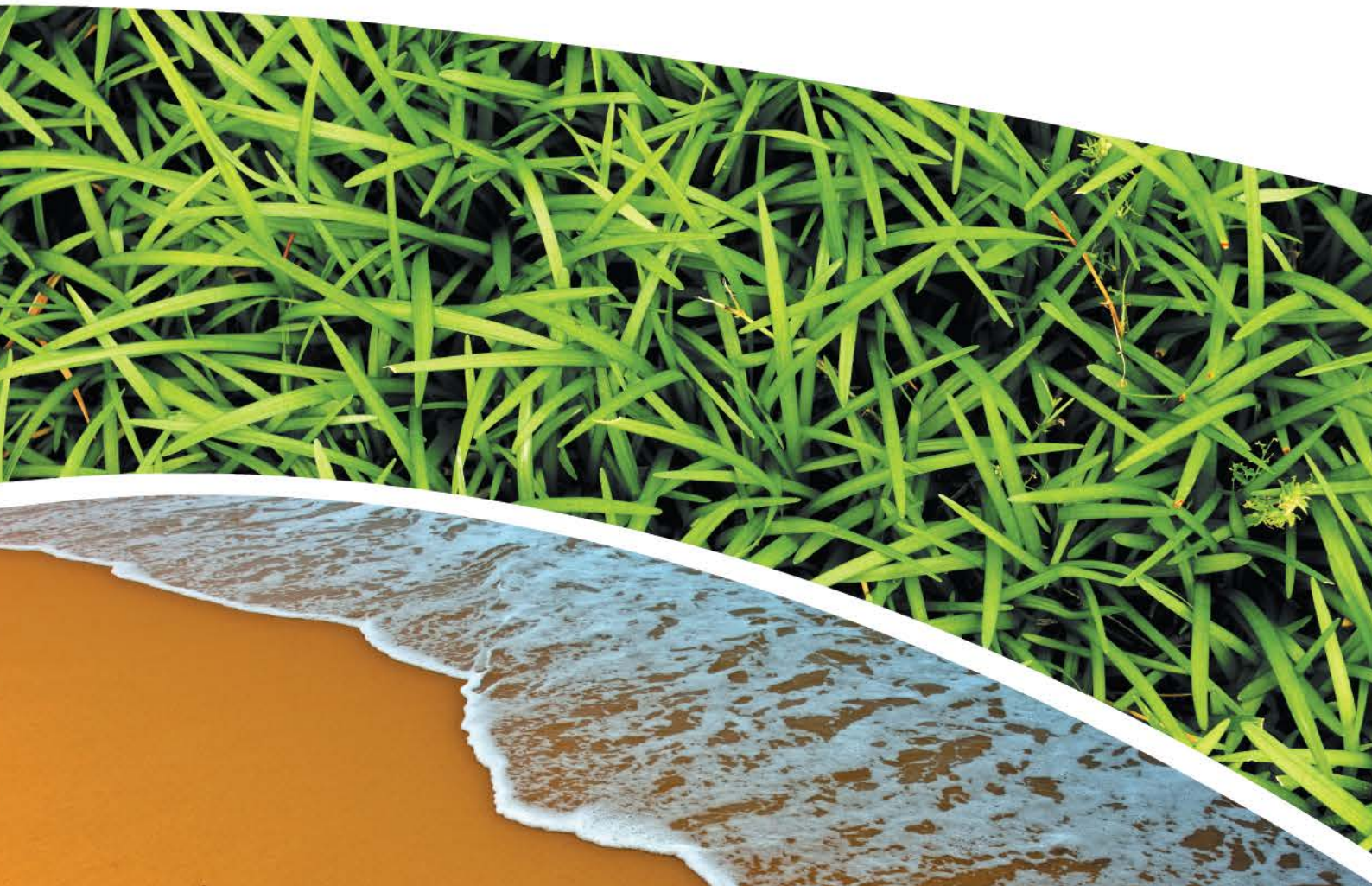

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RCA ref 15924-101/2

21 February 2022

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MINE SUBSIDENCE ASSESSMENT

REGROWTH KURRI KURRI, PRECINCT 1A

1 INTRODUCTION

This report describes a mine subsidence assessment carried out for Loxford Project Management Pty Ltd on the proposed residential subdivision located at Gillieston Heights.

This work was commissioned by Mr Jeffrey Bretag of McCloy Group on 3 December 2021 (email).

Based on plans provided by Loxford Project Management Pty Ltd and discussions with Jeffrey Bretag it is understood that Regrowth Kurri Kurri comprises a multistage mixed-use development comprising residential, commercial and industrial development of former Hydro Aluminium Kurri Kurri land. The subject of this report is Precinct 1A of Precinct 1 of the proposed residential subdivision. The Precinct 1A development includes 344 residential lots, 3 residual lots and 7 public reserve lots, internal roads and construction of detention basins.

Data provided to RCA Australia in relation to the project comprised:

- 239554-SSK-004-A 2018 -12 -20 – Analysis and Survey of Mine Workings Plans prepared by ADW Johnson
- 239835(2)-DA-003 -A – Regrowth, Kurri Kurri Precinct 1 Mine Subsidence Constraints Plan prepared by ADW Johnson

- Report by Newcastle Geotech – August 2013 - Geotechnical Assessment of Mine Subsidence Constraints Proposed Development Cessnock Road Loxford, Ref [1]
- Hydro Kurri Kurri Rezoning Zoning Plan
- Regrowth Kurri Kurri Masterplan
- Dwg Ref: 240289 Lot Plan Uncontrolled Copy B, Dated 28.01.2022 prepared by ADW Johnson

This report has been prepared to support the DA application for proposed Precinct 1A of Precinct 1 of the proposed Kurri Kurri Regrowth development.

2 BACKGROUND

2.1 REGROWTH KURRI KURRI DEVELOPMENT

Regrowth Kurri Kurri comprises 1900 hectares of Hydro Aluminium land of which around 180 hectares are proposed to be rezoned for residential development. Precinct 1 of the proposed residential land lies west of Cessnock Road between Gillieston Heights and Heddon Greta on a property originally named Wangara. Part of the proposed residential development site lies within the West Maitland Mine Subsidence District and is undermined by abandoned coal workings in two seams of the Greta coal measures. **Drawing 1** provides a site plan of Precinct 1, which consists of Precincts 1A and 1B, identifying site features and the West Maitland Mine Subsidence District boundaries. With reference to **Drawing 1** it is noted that a small part of the western side of proposed Precinct 1A lies within the West Maitland Mine Subsidence District while a large area of Precinct 1B lies within the West Maitland Mine Subsidence District.

2.2 MINE WORKINGS

A geotechnical assessment of mine subsidence constraints affecting the site was undertaken by Newcastle Geotech in 2013 (Ref [1]). Reference to that report is recommended for a detailed background on the mine workings. That assessment found that the site was subject to mining in the period from the late 1800's to the early 1900's. The mined seams at the site dip steeply (up to 57° based on the record traces (RT)) and are mined at relatively shallow depth (up to about 180m) and consequently affect a relatively narrow band of the site. Detailed site surface mapping described in Ref [1] identified a range of subsidence features within this narrow band along with the outcrop of the two seams. The location of these features is included on **Drawings 2-4**. RCA Australia undertook an inspection of the site in December 2021 confirming the presence and nature of the mapped surface features. Relevant features of the mines at the site are:

- Two seams were mined under the site. The Greta Top Seam is about 6-7.5m thick with conglomerate rock interburden of up to 10m over the Greta Bottom seam which is about 3m thick. Worked thickness of coal based on mine history was 3-3.5m in the Top Seam and 2.4-2.7m in the Bottom Seam.

- Both seams were mined by bord and pillar methods with areas of first workings and second working (pillar removal) present at this site.

- Maximum depth of the workings under the development site is of the order 150-180m.

- There are historical records of subsidence events at the site over the shallower workings. Evidence of some of these subsidence events remain visible at the site.

- There is a history of spontaneous combustion in the Collieries at the site.

Mine overlay plans for the Greta Top Seam and Bottom Seam have been prepared by RCA Australia using RT's of the mine workings obtained from Planning NSW. **Drawings 2 and 3** present mine overlay plans for the Top and Bottom Seams, respectively. Based on a seam dip of the order of 55°, approximate contours of depth of cover (0m, 100m and 200m) are included on **Drawings 2 and 3** to the Top and Bottom seams respectively. **Drawing 4** presents a mine overlay plan that includes Top and Bottom Seam workings based on an alternative RT (RT228). The position of the sub crop line (0m depth of cover) has been selected at this stage based on observed outcrop locations in the rail cutting along with tunnel locations on the RT's.

Drawing 2 is based on RT422 and RT353. The Top Seam workings of the East Greta Colliery represented on RT422 only affect about 50m of the northern side of the site. These workings are visible as faint grey lines on **Drawing 2**. The Top Seam workings of the Glenmore Colliery represented on RT353 are more widespread beneath the site. RT353 includes some workings in the Bottom and Top Seams. It is noted that the representation of the workings on RT353 is questionable and appears to be based on the survey of the workings in the plane of the seam rather than from a vertical perspective. The steep dip of the seam would have made survey and accurate representation of the workings very difficult. Based on **Drawing 2** it is concluded that workings in the Top Seam beneath the site are limited to 3 bords across the dip with cross hatching of the two rows of pillars indicating they were removed. The workings in the top seam are likely limited to depths less than about 50m, thus affecting a limited width of the site.

Drawing 3 is based on RT423 which represents to Bottom Seam workings of the East Greta Colliery. The workings are more widespread beneath the site and comprise 12-14 bords with a similar number of pillars. Widespread pillar removal is indicated under the site in the Bottom Seam. Based on **Drawing 3** the Bottom Seam workings appear to affect a width of about 120m of the site progressing to about 150-180m depth. There is an area near the northern site boundary where some first workings are shown to progress over a greater extent and to a greater depth.

Drawing 4 is based on RT228 which represents Top and Bottom Seam workings of Glen Main Colliery. RT228 also includes areas of second workings in the Bottom Seam of the East Greta Colliery that are also represented on RT423 and shown in **Drawing 3**. RT228 indicates workings of relatively small extent within two areas of the development site with the workings progressing to a maximum depth of about 75m over a 50-60m width of the site. RT228 shows three areas of surface falls each of which lie over bottom seam workings of the East Greta Colliery. Reference to **Drawing 4** indicates that the surface falls align with surveyed surface subsidence features at the site.

The workings in both seams and all relevant collieries are highly irregular, nonsystematic and in a very steeply dipping seam. The workings are not considered to be amenable to typical pillar stability calculations. Equally, the steep nature of the workings makes assessment of meaningful subsidence parameters problematic.

2.3 POTENTIAL SUBSIDENCE

Two seams have been mined beneath the site with worked seam thickness of 2-3m in each seam. Top Seam workings extent is limited while the Bottom Seam workings are more extensive. Reference to **Drawings 2, 3 & 4** indicates that:

- The depth Top Seam under Precinct 1A is in excess of 200m.
- The Top Seam has not been mined to depths greater than about 100m and the Bottom Seam is the only seam mined at depths greater than 100m

As indicated in Ref [1] and identified on **Drawings 2, 3 & 4** evidence of subsidence at the site includes:

- Identification on RT's. RT 288 shows three areas of surface falls each of which lie over bottom seam workings of the East Greta Colliery. Reference to **Drawing 4** indicates that the surface falls align with surveyed surface subsidence features at the site. These features are assumed to be caused by pillar collapse and/or pillar removal and suggest trough subsidence of up to about 2m may have occurred. The depth of cover in the areas of the falls is assessed to be in a range up to about 80m.
- Numerous subsidence features logged at the surface as identified in Ref [1] and positioned on **Drawings 2, 3 & 4.** The features are primarily in the shallow (less than about 50m cover zone) with one possibly at about 100m of cover.
- Well documented history at this 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 at the Precinct 1 site of:

- Pothole formation in the area of depth of cover to about 50m depth to the roof of the relevant mined seam.
- Trough subsidence in areas with depth of cover greater than 50m.

In areas with workings over 100m cover there is no evidence of mine subsidence at the surface. With reference to **Drawing 3** the second worked panel of pillars below 100m depth of cover in the bottom seam is about 50-60m in width making the worked panel of pillars subcritical (ie less than is required to allow full surface subsidence to develop) and it is concluded that there is low risk of significant subsidence occurring at the surface at depths of cover over 100m.

2.4 INDICATIVE SUBSIDENCE PARAMETERS FOR PRECINCT 1A

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. As mentioned previously the steep nature of the workings makes assessment of meaningful subsidence parameters difficult.

Indicative estimates of trough subsidence have been made using the empirical subsidence model for the Newcastle Coalfield presented by Holla (1987) (Ref [2]). The components of ground movement that are of significance include subsidence, tilt and strain. These components are illustrated in **Figure 1** and the variation of the ground movement components is illustrated in **Figure 2**. 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 3**. 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. Nonetheless it is considered that subsidence data assessed by this method will be conservative for the site geometry and site conditions.

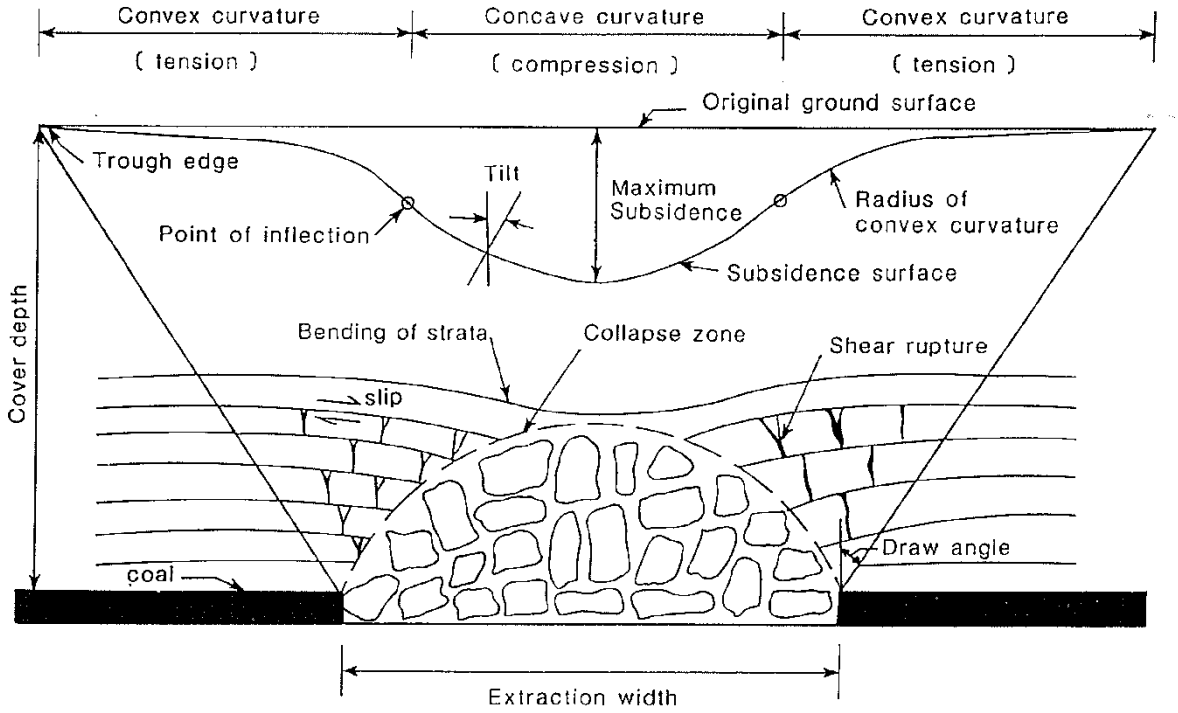

Figure 1 *Components of Trough Subsidence (Holla, 1987)*

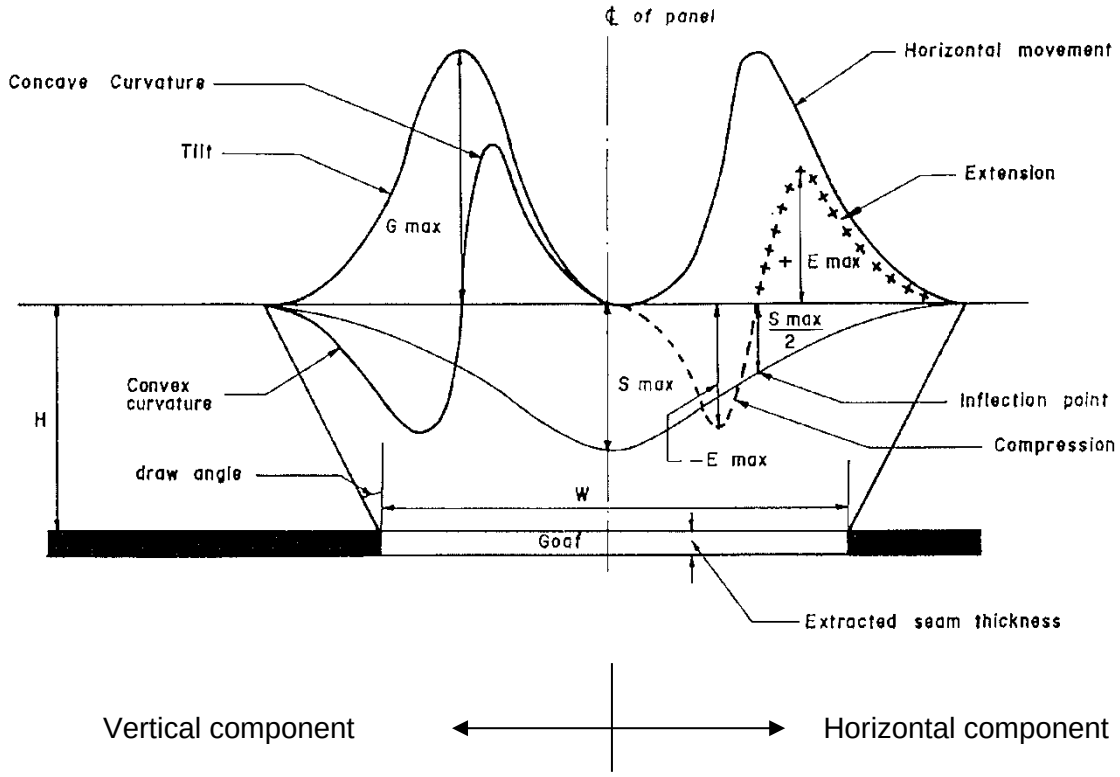

Figure 2 *Characteristics of Trough Subsidence (Holla, 1987)*

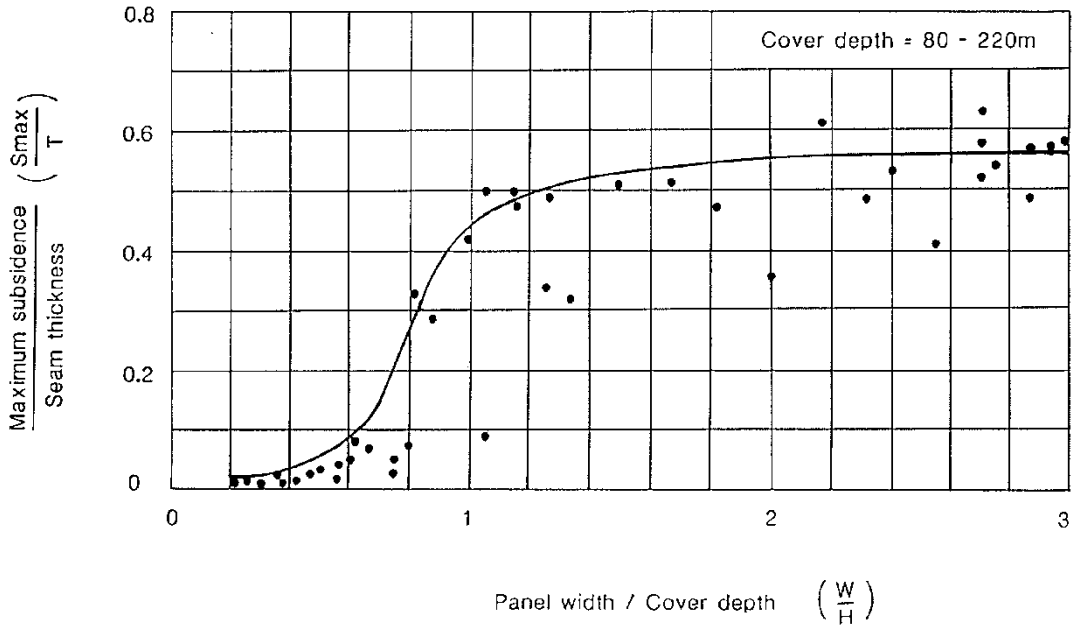

Figure 3 *Relationship between Maximum Subsidence and W/H (Holla, 1987)*

Strains and tilts are a function of S_{max} and H. For critical conditions (wide panel widths eg, W/H>1.5) (Ref [2]) suggests the following relationships for estimating maximum ground movement parameters:

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

The model shown in **Figure 3** 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 x 0.5 x pillar height. For full Bottom Seam thickness of 2.5m this would equate to worst case subsidence of about 0.7m. As previously noted the second worked panels of pillars below 100m depth of cover in the Bottom Seam are about 50-60m in width making the worked panel of pillars subcritical (ie less than is required to allow full surface subsidence to develop) and it is concluded that there is low risk of the worst case subsidence listed above developing in the areas with over 100m of cover.

Indicative subsidence parameters calculated based on the Ref [2] empirical model for mine affected areas at over 200mm of cover are listed in **Table 1**. Separate consideration for areas with less than 100m over cover will be relevant to Precinct 1B and investigation is currently underway in these areas and will be considered separated.

With reference to **Figure 2** it is noted that trough subsidence may give rise to subsidence outside the area of mining. This area of influence is defined by the angle of draw and for the Hunter Valley coalfield this is often taken to be about 1H:2V. Angle of draw affects are considered in the mine subsidence zones considered below.

Table 1 *Indicative Empirical Subsidence Estimates*

Depth of Mine Workings (m)	Subsidence (m)	Strain +/- (mm/m)	Tilt (mm/m)	Curvature (km)
>100	0.25	1	3	15

3 APPROVAL POLICY

3.1 SUBSIDENCE ADVISORY NSW APPROVAL FRAMEWORK

SA NSW has set 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 Precinct 1 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 will be 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 that follows reference is made to the relevant SA NSW assessment policy:

- Subdivision Assessment Policy, Version number: 1, Date: Friday, May 25, 2018

It is assumed that the policies of the Subdivision Assessment Policy will apply to Precinct 1A.

3.2 SUBSIDENCE ADVISORY NSW ASSESSMENT PROCEDURES

3.2.1 POTHOLE SUBSIDENCE

Not relevant to Precinct 1A where depth of cover precludes any risk of pothole subsidence.

3.2.2 TROUGH SUBSIDENCE

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

1. The assessed level of geotechnical uncertainty (uncertainty factor)

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 uncertainty factor is assessed by RCA Australia to be **HIGH**.

Based on a high uncertainty factor and with reference to Table C2 of the subdivision assessment guidelines approval conditions are likely to be : Subdivision works must be designed to be "safe, serviceable and readily repairable" given the estimated subsidence impact parameters.

It is noted that the SA NSW Subdivision Policy indicates that approval conditions will generally require that all subdivision infrastructure be designed to accommodate the estimated subsidence impact as far as practicable and that all buried services should be located for ease of repair if required.

4 RECOMMENDATIONS

4.1 SUBSIDENCE RESTRICTIONS

Mine subsidence conditions are the site are relatively complex. It is recommended that plans for development and improvements within the 0-100m depth of cover zone be avoided. It is understood that future plans for the site limit development within the 0-100m depth of cover zone to one or two road crossings. Remedial works within this zone are likely to be required to make the zone safe for passive uses. As previously mentioned, investigation in this area is underway and will be reported separately as part of future development applications.

Based on guidelines provided in the SA NSW Subdivision Assessment Policy it is suggested that either:

- Proposed Precinct 1A development should be designed to allow for estimated subsidence impacts, or

- Subsidence impacts should be mitigated by suitable means such as grouting.

SA NSW will assess applications for development 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 and data provided in this report it is considered that the approval conditions for Precinct 1A will include allowance for design for subsidence parameters of the order of those listed in **Table 2**.

Table 2 *Indicative Design Subsidence Parameters for Precinct 1A*

Depth of Cover (m)	**"safe, serviceable and readily repairable"**		
	Strain +/- (mm/m)	Tilt (mm/m)	Curvature (km)
100-edge of zone of influence[1]	1	3	15
Outside zone of influence	No restriction	No restriction	No restriction

Notes:

1 Based on the current SA NSW Policy Framework it is considered that SA NSW Guideline 2 may be applied to residential development with greater than 100m depth of cover to workings and within the zone of influence.

Drawing 5 provides approximate zones of depth of cover across the site that design parameters are likely to apply to including the zone of influence.

The Drawings indicate that the entire Precinct 1A area lies over depths of cover to the Top and Bottom Seams of over 200m and almost entirely outside the area of mine workings. As indicated on **Drawing 5** two areas of Precinct 1A lie within the zone of influence while the majority of Precinct 1A lies outside the zone of influence.

Based on the SA NSW Subdivision Policy it is noted that approval conditions will also likely require subdivision infrastructure (assumed to be infrastructure other than buildings) to be designed to accommodate estimated subsidence impacts as far as practicable and that all buried services should be located for ease of repair if required. Any infrastructure (eg. roads) with less than 50m 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.

4.2 FURTHER INVESTIGATION

It is recommended that boreholes be drilled at the site to assess the findings of this desktop assessment. A series of boreholes is suggested where the proposed roads cross the 0-100m cover zone area.

5 LIMITATIONS

This report has been prepared for Loxford Project Management 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 Loxford Project Management 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 Loxford Project Management 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.

Yours faithfully
RCA AUSTRALIA

Mark Allman
Principal Geotechnical Engineer

REFERENCES

[1] Geotechnical Assessment of Mine Subsidence Constraints Proposed Development Cessnock Road Loxford, Newcastle Geotech (2013).

[2] Holla, L (1987) Surface Subsidence Prediction in the Newcastle Coalfield, Department of Mineral Resources.

Appendix A

Drawings

LEGEND

Proposed Precinct 1 boundaries

Maitland West Mine Subsidence District

Note: Aerial image taken from Nearmap, 6 August 2021
(used in accordance with commercial licence)
Proposed development drawing supplied by Loxford Project Management Pty Ltd
(Drawn by ADW Johnson,
Dwg Ref: 240289 Lot Plan Uncontrolled Copy B, Dated 28.01.2022)

0 40 80 160 240 320
metres

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REGROWTH KURRI KURRI PRECINCT 1A SITE PLAN

CLIENT	Loxford Project Management Pty Ltd			RCA Ref	15924-201/2		
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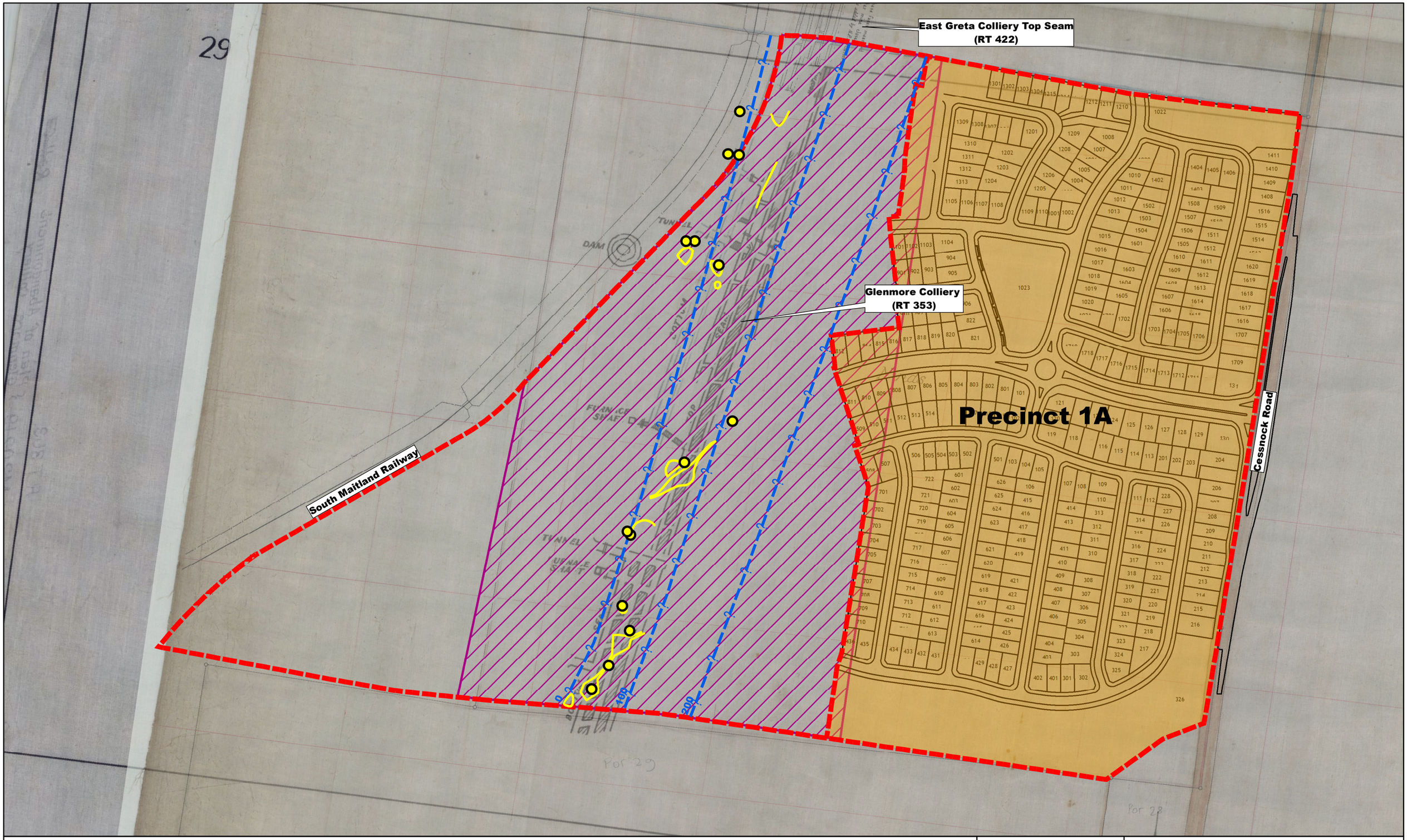
APPROVED BY	MA	DATE	21/12/2021	OFFICE	NEWCASTLE		



LEGEND

- Proposed Precint 1 boundaries
- Maitland West Mine Subsidence District
- Approximate isopachs of depth of cover to top seam
- Surface subsidence features (Ref [1])
- Surface depressions by survey (Ref [1])

Note: RT 353 Plan of Abandonment Sheet 1 Top and Bottom Seam and
RT 422 Plan of Abandonment Sheet 1 Top Seam
obtain from Department of Planning, Environmental Resources and Geoscience
Proposed development drawing supplied by Loxford Project Management Pty Ltd
(Drawn by ADW Johnson,
Dwg Ref: 240289 Lot Plan Uncontrolled Copy B, Dated 28.01.2022)

0 40 80 160 240 320
metres

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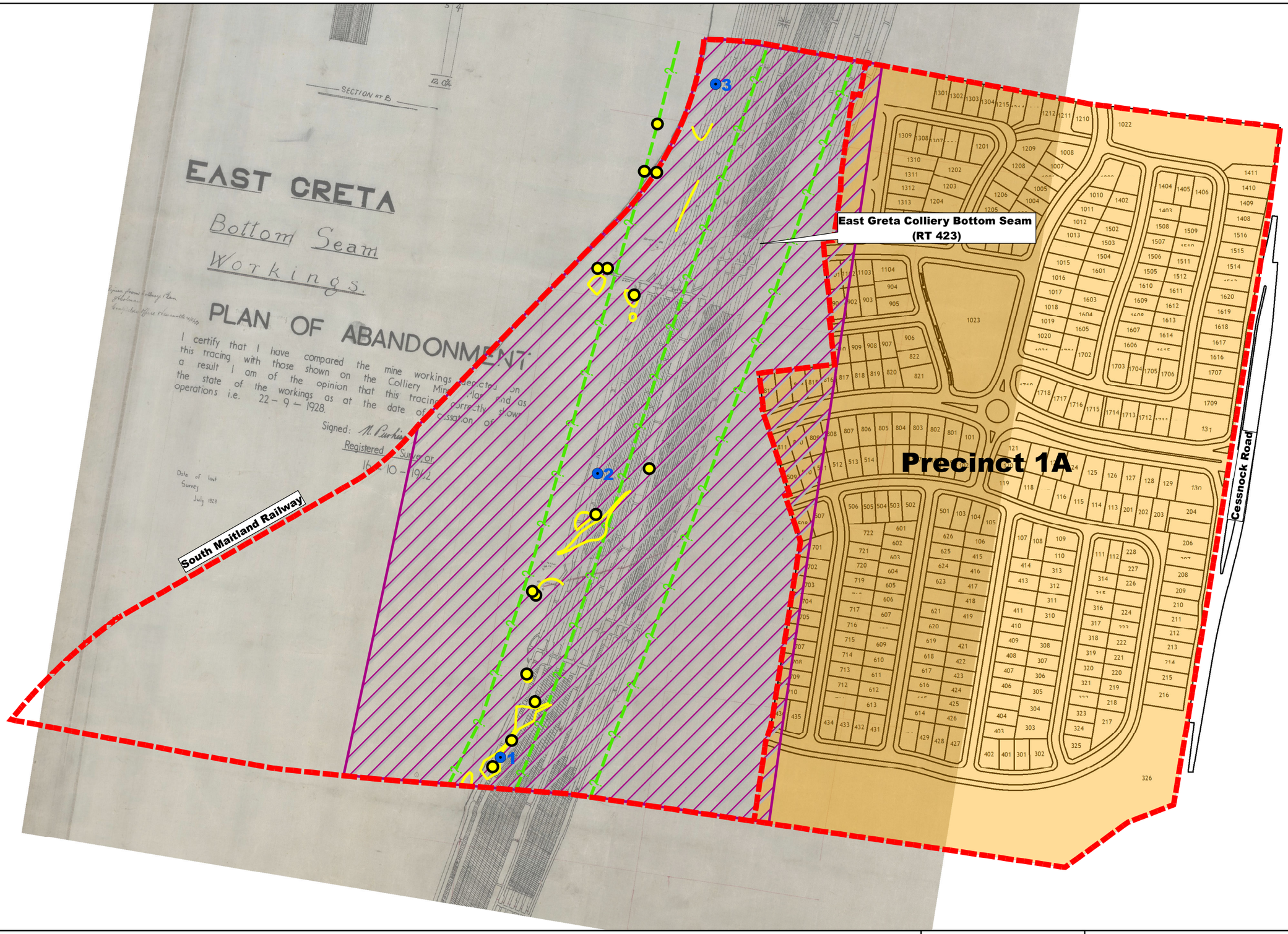
REGROWTH KURRI KURRI
PRECINCT 1A
MINE OVERLAY PLAN
GRETA TOP SEAM

CLIENT	Loxford Project Management Pty Ltd			RCA Ref	15924-201/2
DRAWN BY	MA	SCALE	1:4,000 (A3)	DRAWING No 2	REV 1
APPROVED BY	MA	DATE	21/02/2022	OFFICE	NEWCASTLE



LEGEND

- Proposed Precint 1 boundaries
- Maitland West Mine Subsidence District
- Approximate isopachs of depth of cover to bottom seam
- Surface subsidence features (Ref [1])
- Surface depressions by survey (Ref [1])

Note: RT 423 Plan of Abandonment 1 Sheet Bottom Seam
obtain from Department of Planning, Environmental Resources and Geoscience
Proposed development drawing supplied by Loxford Project Management Pty Ltd
(Drawn by ADW Johnson,
Dwg Ref: 240289 Lot Plan Uncontrolled Copy B, Dated 28.01.2022)

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metres

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REGROWTH KURRI KURRI
PRECINCT 1A
MINE OVERLAY PLAN
GRETA BOTTOM SEAM

CLIENT	Loxford Project Management Pty Ltd			RCA Ref	15924-201/2
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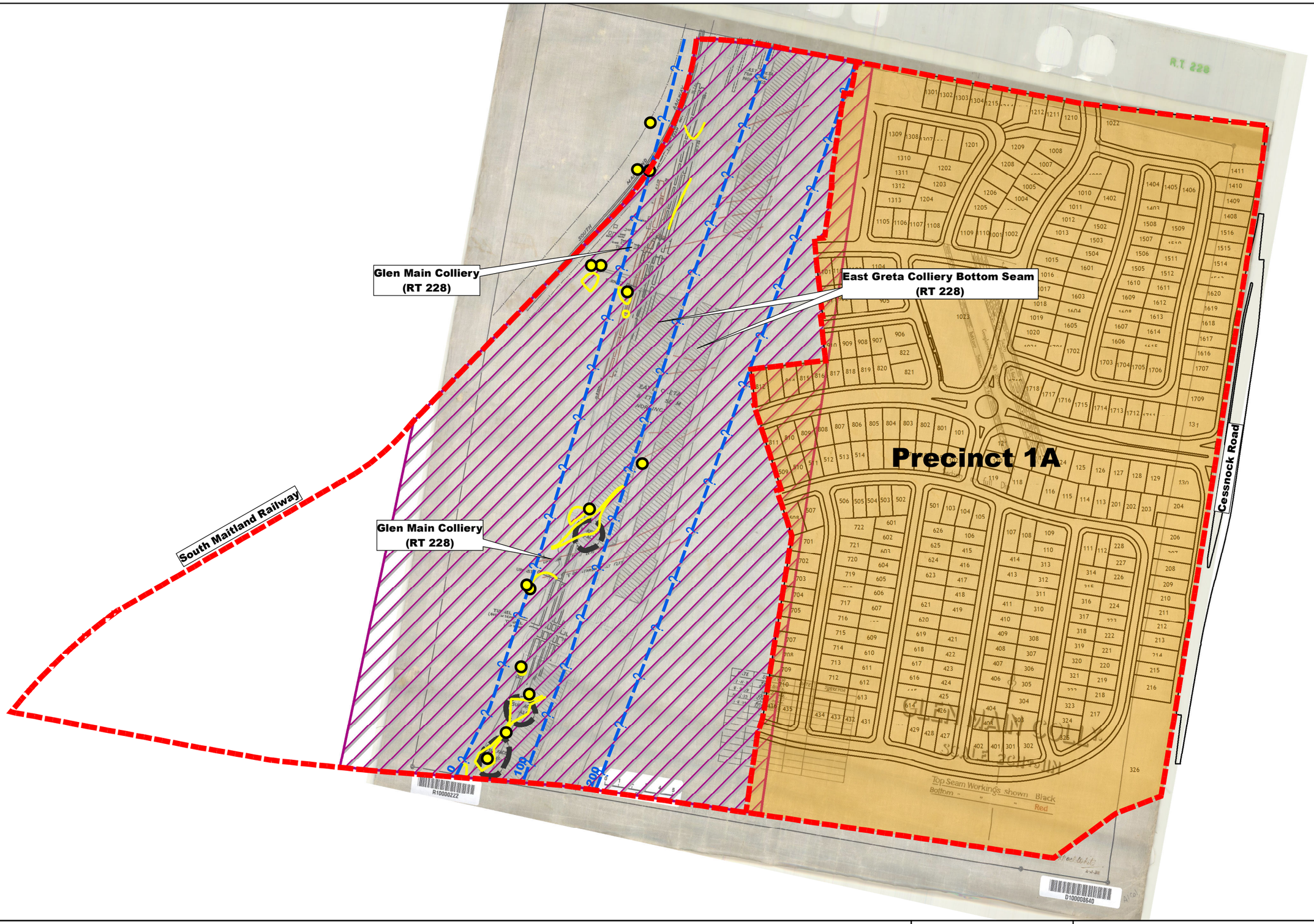

LEGEND

- Proposed Precint 1 boundaries
- Maitland West Mine Subsidence District
- Approximate isopachs of depth of cover to top seam
- Surface subsidence features (Ref [1])
- Surface depressions by survey (Ref [1])
- Surface falls (RT 228)

Note:RT 228 Plan of Workingst 1 Sheet
obtain from Department of Planning, Environmental Resources and Geoscience
Proposed development drawing supplied by Loxford Project Management Pty Ltd
(Drawn by ADW Johnson,
Dwg Ref: 240289 Lot Plan Uncontrolled Copy B, Dated 28.01.2022)

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REGROWTH KURRI KURRI
PRECINCT 1A
MINE OVERLAY PLAN
GRETA TOP AND BOTTOM SEAM
(ALTERNATE RT)

CLIENT	Loxford Project Management Pty Ltd			RCA Ref	15924-201/2
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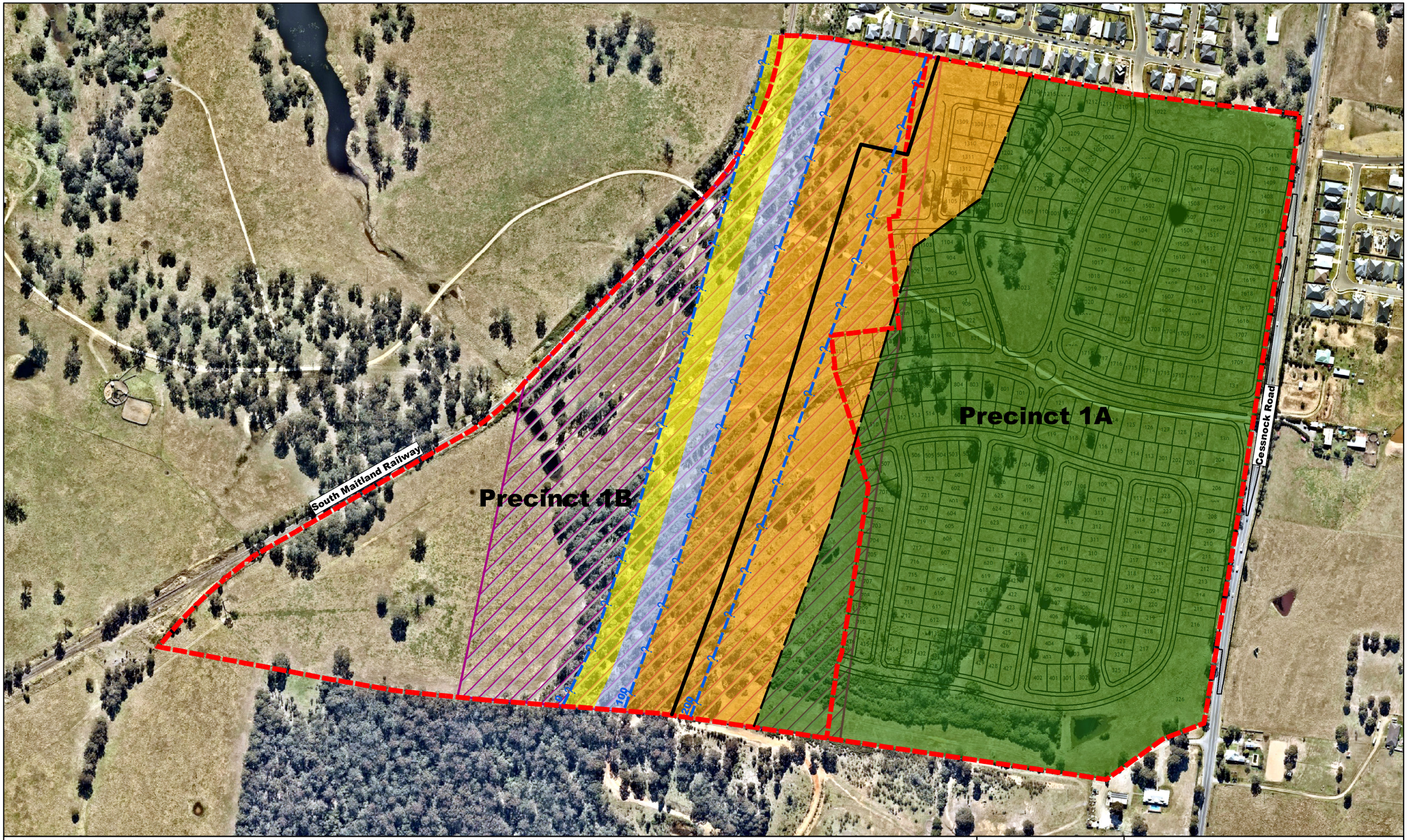

LEGEND

- Proposed Precinct 1 boundaries
- Maitland West Mine Subsidence District
- Approximate isopachs of depth of cover to top seam
- Zone of influence of mine workings
- Deepest extent of mine workings

Mine Subsidence Zone

- 0 - 50m
- 50 - 100m
- 100 - limit of zone of influence
- Outside zone of influence

Note: Aerial image taken from Nearmap, 6 August 2021
(used in accordance with commercial licence)
Proposed development drawing supplied by Loxford Project Management Pty Ltd
(Drawn by ADW Johnson,
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RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

REGROWTH KURRI KURRI PRECINCT 1A MINE SUBSIDENCE ZONES

CLIENT	Loxford Project Management Pty Ltd			RCA Ref	15924-201/2
DRAWN BY	MA	SCALE	1:4,000 (A3)	DRAWING No 5	REV 1
APPROVED BY	MA	DATE	21/02/2022	OFFICE	NEWCASTLE