Centennial Coal
Angus Place

Attachment 1:

Subsidence Assesment Longwall 980

Angus Place Colliery

October 2013

Ditton Geotechnical Services Pty Ltd
82 Roslyn Avenue Charlestown NSW 2290
PO Box 5100 Kahibah NSW 2290

28 October, 2013

Natalie Conroy
Environmental Coordinator
Centennial Angus Place Colliery Pty Ltd
PO Box 42
WALLERAWANG NSW 2845

Report No. ANP-001/5

Dear Natalie,

Subject: Subsidence Assessment on the Proposed Modification to Longwall 980, Centennial Angus Place Colliery, Lidsdale

1.0 Introduction

As requested by Centennial Angus Place Colliery (Angus Place), Ditton Geotechnical Services Pty Ltd (DgS) has completed a subsidence assessment on the proposed changes to Longwall 980 for inclusion in an Environmental Assessment Modification submission to the Department of Planning and Infrastructure (DP&I). This report will also support an application to the Department of Trade and Investment, Regional Infrastructure and Services – Division of Resources and Energy (DTIRIS) to vary the approved Longwalls 930 – 980 Subsidence Management Plan (SMP).

The modification to the proposed longwall panel geometry includes:

- The extension of LW980 by 43.4 m into the barrier pillar towards the west at an extraction height up to 3.425m.

It is possible that some sections of the proposed extension area will not be mined above 3.25m where roof bolts have been installed in access headings. For the purposes of worst-case subsidence assessment, it has been assumed that the increased mining height will be extracted across all of the extension area.

The proposed modification to the original mining layout that was presented in the development consent is shown in **Figure 1**.

2.0 Background

Angus Place received a development consent for the extraction of Longwalls 920 to 980 from the Department of Planning in 2006 under the provisions of Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

Angus Place subsequently received approval to modify PA 06_0021 (Mod 1) in August 2011 from the DP&I (former Department of Planning). The changes included approval for the development and extraction of two additional longwall panels (LWs 900W and 910).

3.0 Scope of Work

This report has been prepared to include the following scope of work:

- A summary of the maximum subsidence effects resulting from the previous mining layout as outlined in the Subsidence Prediction and Impact Assessment Review of LWs 920 to 980 at the Centennial Angus Place Colliery, Lidsdale (**DgS, 2010**).

- Predicted cumulative subsidence effect contours resulting from the previous mining layout and proposed extension to LW980. This assessment also considers the increased extraction height from 3.25 m to 3.425 m between 10CT to 2CT. This variation to the mining layout was approved by DTIRIS on 4 October 2013 following an application by Angus Place to vary the approved SMP.

- A summary of the maximum predicted subsidence impacts above LW980 resulting from the previous mining layout and proposed extension to LW980.

- An assessment of the stability of the first workings and reduced width barrier pillars in the vicinity of the proposed extension following extraction of LW980.

Reference has been made to the original subsidence predictions for LW980 (**DgS, 2010**) and the end of panel report review for LWs 920 to 970 (**DgS, 2013**) for the purposes of this assessment.

4.0 Mining Geometry

Details of the proposed mine workings geometry and modifications are summarised below:

- The currently approved longwall 980 has a void width of 277 m with a depth of cover ranging from 300 m to 380 m. The existing and proposed panel geometries indicate critical panel width/cover depth ratios ranging from 0.72 to 0.98; see **Figure 2**.
- LW 980 is currently being extracted outbye towards the west at a mining height of 3.425 m between 10 C/T and 2 C/T, as approved by the SMP Variation. The previous mining height was 3.25 m.
- The proposed panel extension of 43.4 m between 2 C/T to 1 C/T and the barrier pillar may also be extracted at the increased mining height away from the existing access heading within the extension area. The existing barrier width will be reduced from 100.2 m to a width of 56.8 m.
- This assessment has conservatively modelled worst case subsidence by assuming that the entire are will be extracted at a mining height of 3.425 m.
- The main headings pillars and reduced width barrier pillars are likely to be subject to increased abutment loading (and therefore increased subsidence) after the modified LWs 980 and 900W panels are completed.
- There are four rows of main headings pillars to the west of the reduced width barrier pillar for LW980. The pillars are 35 m wide with lengths ranging from 58 m to 104 m.
- The width and height of the existing roadways are 4.8 m and 3.25 m respectively.

5.0 Surface Features

The modified longwall panel area will be extracted below the Newnes State Forest, which is largely vegetated by eucalypt tree species and shrubs. The terrain is gently undulated with broad crested gullies draining towards the north, north east and southwest. Ground slopes are generally < 10^o; see **Figures 1** to **3**.

There are no existing surface developments within the Design Angle of Draw (AoD) of 26.5^o from the proposed longwall extraction limit modification.

There are no sensitive features such as cliff lines > 20 m in height, rock features between 5 m and 20 m height, watercourses or Aboriginal Heritage Sites, or endangered ecological communities (EEC's) under the *Threatened Species Conservation Act 1995* within an AoD distance of 26.5^o (0.5 times the cover depth) of the proposed panel modification.

6.0 Geology

The surface lithology consists of a shallow residual or alluvial sandy soil cover to a depth 1 m to 5 m overlying highly weathered sandstones of the Burralow Formation with low to very low strength (UCS <20 MPa). Massive, high strength sandstone units of the Narrabeen Group's Banks Wall and Burra-Moko Head Formations exist between depths of 50 m to 200 m and are likely to reduce subsidence due to 'bridging' or natural 'arching' behaviour.

The strata below the massive sandstone units consist of thinly bedded sandstone and siltstone of the Narrabeen Groups' Caley Formation, which exists immediately above the Permian Illawarra Coal Measures. The measures include the 10 m thick Katoomba / Little Riverdale Seams, interbedded sandstone, coal, shale and mudstone of low to moderate strength and the Lidsdale/Lithgow Seams.

Known regional geological structures within the Angus Place Holding consists of normal, reverse and strike slip faulting associated with the Wolgan River and Kangaroo Creek Lineaments.

The structures associated with the lineaments are mid-angled to sub-vertical (i.e. dip angles range from 35^o to 80^o) and oriented on a NNE, NNW and NW strike, see **Figure 4**. The normal and reverse fault throws range from 0.1 m to 1.0 m and the strike - slip faults have displacements of several metres.

The location, categorisation and likely influence of the structures on the overburden and subsidence above the proposed LW980 modification area has been broadly assessed in **Palaris, 2013** and summarised in **Section 7.1**.

7.0 Maximum Subsidence Effect Predictions

7.1 Geological Structure Effects on Subsidence Predictions

The influence of geological structure on predicted subsidence for LW980 was assessed in **DgS, 2010** and based on measured subsidence effects above LWs 920 to 950.

Palaris, 2013 and **DgS, 2011** has established that there are four types (Type 1 to 4) of geological structure within the Angus Place Holding that appear to have had some to no effect on subsidence measurement. A summary of each structure type and its effect on subsidence development is presented below:

- In-seam mapping and surface interpretation work indicates several Major Type 1 faults associated with East Wolgan, Narrow and Kangaroo Creeks. These faults are associated with the Wolgan River and Kangaroo Creek Lineaments and have incised valleys and plateau areas. Subsidence monitoring indicates that there have been subsidence increases above the incised valley sections of up to 1 m. Increased tilt and compressive strains have also occurred in the valleys.

- Type 2 faulting is similar to Type 1, however, it is not as persistent as Type 1 structure with only limited surface expression (e.g. single sided valleys or steep slopes). Subsidence increase potential above Type 2 structure is unknown at this stage as they have not yet been undermined by any Angus Place longwalls.

- Minor Type 3 faulting commonly exists at seam level but show no surface expression across the mining area (e.g. mildly undulating terrain and plateau areas). Subsidence monitoring indicates that there have been no subsidence effect increases above the Type 3 structure areas.

- Type 4 structures are basement structures only, which, despite being common, do not have structural features at the Lithgow Seam level or have expression at the surface. No surface subsidence changes have occurred above Type 4 structure.

Reference to **Palaris, 2013** indicates that the major (Type 1) fault structure associated with Kangaroo Creek terminates within LW980, however this is not associated with the proposed LW980 extension; see **Figure 4**.

7.2 Predicted Maximum Subsidence Effects

The maximum subsidence effects for the proposed modification to LW980 have been predicted based on reference to **ACARP, 2003** and the same methodology described in **DgS, 2010**.

The area of proposed modification to LW980 is considered to be outside the fault affected zones (see **Figure 5**) and within a broad valley associated with the upper reaches of Kangaroo Creek (see **Figure 3**). The predicted subsidence effects are therefore unlikely to be affected by the faulting or valley bulging phenomena. It is considered that the overburden above the proposed LW980 modification area is likely to have 'high' subsidence reduction potential due to the massive strata of the Banks Wall and Burra-Moko sandstone units.

The predicted maximum final subsidence effects for the proposed LW980 extension has been presented in **Table 1** together with the current predictions for the 3.25 m mining height.

Table 1 - Maximum Subsidence Effect Predictions for the LW980 Modification

LW#	Mining Height (m)	Cover Depth (m)	Subsidence S_{max} (m)	Tilt T_{max} (mm/m)	Tensile Strain (mm/m)	Compressive Strain (mm/m)	Surface Cracking width (mm)	CL Angle of draw (°)
980 Extended	3.25	310	0.07 - 0.1	0.5 - 2	0.5 - 1	nil	<50	21.9
	3.425	310	0.1 - 0.2	2 - 6	1.0 - 1.5	nil	<50	22.2
Change	**0.175**	**nil**	**0.03 - 0.1**	**1.5 - 4**	**<0.5**	**nil**	**nil**	**0.3**

The cumulative subsidence effects associated with the increased mining height of 3.425m between 10 CT and 2 CT, as approved by the SMP Variation, have also been considered in this assessment and are presented in **Table 2**.

Table 2 - Maximum Subsidence Effect Predictions for Increased Extraction Height in LW980 (10CT to 2CT)

LW#	Mining Height (m)	Cover Depth (m)	Subsidence S_{max} (m)	Tilt T_{max} (mm/m)	Tensile Strain (mm/m)	Compressive Strain (mm/m)	Surface Cracking width (mm)	CL Angle of draw (°)
980* 10 - 2CT	3.25	310	0.86 - 1.20	6 - 9	2.8 - 4.2	3.5 - 5.3	<50	21.9
	3.425	310	0.90 - 1.25	6 - 9	2.9 - 4.4	3.7 - 5.5	<50	22.2
Change	**0.175**	**nil**	**0.040 - 0.050**	**nil**	**<0.2**	**<0.2**	**nil**	**0.3**

* - Subsidence effect predictions for the 3.25 m mining height presented in *Table 9* of **DgS, 2010**.

The proposed 5% increase in mining height indicates only minor changes to the previously assessed values in **DgS, 2010**. The previously predicted subsidence in the extension area will increase between 0.03 m and 0.1 m, with tilt increasing by 1.5 mm/m to 4 mm/m. Tensile and compressive strains will increase by 0.5 mm/m to 1 mm/m.

The predicted impacts due to the proposed modifications remain unchanged.

7.3 Predicted Subsidence Contour Effects

Based on the calibrated SDPS® model presented in **DgS, 2010**, predictions of cumulative worst-case subsidence contours for the approved and modified LWs 920 to 980 mining layout are shown in **Figure 6a**. The net subsidence contours due to the modified longwall 980 are shown in **Figure 6b**.

Associated subsidence effect contours of principal tilt and horizontal strain have been subsequently derived using the calculus module provided in Surfer8® and the worst-case subsidence contours. The outcomes are shown in **Figures 7** and **8** respectively.

The modified subsidence contours indicate a minor increase of 50 mm of subsidence between 10 - 2 CTs. The subsidence effect contours due to the modified layout have moved a distance of ~43 m to the north, which is similar to the proposed panel extension length. Subsidence effect contours also indicate a slight increase in magnitude to the east of 10 CT.

The subsidence effect increases in the extension area are expected to be lower than the maximum predicted values estimated for the approved mining area (see **Section 7.2**). The impact of the changes to the subsidence effect contours are discussed in **Section 9**.

8.0 Pillar Stability Assessment

8.1 Modified Barrier Pillars and Existing Main Headings

The proposed extension to LW980 will decrease the width of the barrier pillar between the existing main headings pillars from 100 m to 57 m. The locations of the pillars are shown in **Figure 9**.

Based on a cover depth of 310 m and reference to **Peng and Chiang, 1984**, the barrier pillars and first workings pillars within a distance of 90 m from the limits of extraction are likely to be affected by the abutment loads due to the proposed extension of LW980; see **Figure 10**.

The magnitude of the single abutment loading and the potential for future pillar instability is assessed in the following sections.

8.2 Pillar Loading

The estimate of the total stress acting on the proposed barrier and existing main headings pillars has been based on the single abutment loading conditions and the abutment angle concept described in **ACARP, 1998a**. The total stress acting on the barrier pillar after mining of LW980 may be estimated as follows:

σ_b = barrier pillar load/area = $(P_1+RA)/w_1l_1$

σ_{FW} = mains pillar load/area = $(P_2+(1-R)A)/w_2l_2$

where:

$P_{1,2}$ = full tributary area load of column of rock above the pillars;

= $(l_i+ r)(w_i + r).\rho.g.H$;

A = total abutment load acting on the finishing end rib of the longwall in MN/m,

$= (l+r)\rho g(0.5W'H - W'^2/8\tan\phi)$ (for sub-critical panel widths) or

$= (l+r)(\rho g H^2 \tan\phi)/2$ (for super-critical panel widths);

w = pillar width

l = pillar length

r = roadway width.

ρ = unit weight of overburden 0.025 MPa/m

ϕ = abutment angle (normally 21º adopted for cover depths < 370 m at Angus Place)

H = depth of cover = 310 m;

W' = effective panel width (rib to rib distance minus the roadway width). *Note: A panel is deemed sub-critical when W'/2 < Htanϕ.*

R = Proportion of abutment load acting on barrier pillars;

$= 1 - [(D-w-r)/D]^3$ (where D = distance (m) that load distribution will extend from goaf edge according to **Peng & Chiang, 1984**: D = 5.13√H = 90 m)

$= 1 - [(90 - 57 - 4.8)/90]^3$

= 0.97

1-R = Proportion of abutment load acting on first row of main headings pillars adjacent to the barrier.

= 1 - 0.97 = 0.03

8.3 Pillar Strength

The strength of the pillars in the Lithgow Seam has been estimated based on the empirical formulae presented **ACARP, 1998b** and currently widely used in the Australian Coal Industry.

The pillar strength formulae is based on a non-linear power law, which assumes that for a Factor of Safety (FoS) of 1, the pillar panel will have a Probability of Failure (PoF) of 50%. The database includes 'failed' and 'un-failed' pillar panels from the South African and Australian coal industries. The pillars in the data base were all located within super-critical width panels and were all considered to have been subject to full tributary area (FTA) loading conditions.

The design service load for the barrier pillar will be significantly higher than the FTA loading scenario with only a small proportion of the abutment load (3%) likely to be transferred to the first row of adjacent main headings pillars.

As presented in **ACARP, 1998b** the FoS of the barrier and main headings pillars were based on the strength formula for 'squat' pillars with w/h ratios > 5 as follows:

$$S = 27.63\Theta^{0.51}(0.29((w/5h)^{2.5} - 1) + 1)/(w^{0.22}h^{0.11})$$

where:

h = pillar height;

Θ = a dimensionless 'aspect ratio' factor or w/h ratio in this case.

The pillar width/height ratio is also a very important factor that indicates the post-yield behaviour of the pillars when they are overloaded. The width to height ratio of the pillars in the database ranges from 0.87 to 12 with the failed pillar panels having a w/h range between 0.87 and 8.16. Pillars with w/h ratios < 3 are considered most likely to 'strain-soften' and result in rapid failure and pillar runs, whereas w/h ratios > 5 are more likely to 'strain-harden' and fail slowly or 'squeeze'.

These types of post-yield behaviour have been discussed in **ACARP, 2005** and demonstrated in **Figure 11** for various in-situ observations and laboratory experiments.

8.4 Pillar Stability Assessment Results

The FoS for the barrier and first workings pillars was calculated by dividing the pillar strength, S, with the pillar stress, σ. The results of the stability analysis for the proposed pillars are presented in **Table 3**.

Table 3 - Predicted FoS for Barrier Pillars and Main Headings Pillars

Type	Pillar Dimensions (w x l x h) (m)	Pillar Strength (MPa)	Pillar Stress (MPa)	Pillar FoS	Pillar w/h Ratio
Barriers	56.8 x 164.4 x 3.25	89.59	16.74	5.35	10.8
	56.8 x 57.6 x 3.25	73.45	17.62	4.17	10.8
Mains	35.2 x 104.3 x 3.25	36.93	9.62	3.84	10.8
	35.2 x 95.3 x 3.25	36.43	9.66	3.74	17.5
	35.2 x 57.6 x 3.25	33.58	9.97	3.37	17.5

The likelihood of chain pillar instability occurring in the proposed mine workings has been assessed based on reference to probability of failure correlations presented in *Table 12* in **ACARP, 1998b**; see **Figure 12**.

The probability of failure when pillar FoS > 2.11 is < 1 in 1,000,000 for the proposed pillars.

It is assessed that the potential for long-term instability of the proposed pillars is 'very unlikely' due to their high FoS under service loads and 'squat' geometry, which will provide a high degree of natural stability should the pillar ribs deteriorate. The high pillar width/height ratio (>10) will also provide adequate support to the immediate roof strata if pillars are formed beneath geological structure.

The stability of the roof and floor strata under service loading should also be considered in the long-term subsidence assessment.

8.5 Bearing Capacity of Roof and Floor Strata

The bearing capacity of the roof/floor strata and chain pillar strength was firstly checked before appropriate rock mass Young's Modulii values were assigned for subsidence prediction under the assessed loading conditions.
Reference to **Pells *et al*, 1998** indicates that the bearing capacity of sedimentary rock under shallow footing type loading conditions is 3 to 5 times its UCS strength. Based on the estimated minimum UCS of 15 MPa in the immediate coal roof strata, the general bearing capacity is estimated to range between 45 and 75 MPa.

Considering the predicted average pillar service stress values from 9.6 to 17.6 MPa, an overall FoS against average roof and floor bearing failure is > 2.5 for the pillar width geometry proposed, and likely to be within the elastic behaviour range for these materials (i.e. the average pillar roof stress is < 40% of the strata strength).

9.0 Predicted Subsidence Impacts and Environmental Consequences

9.1 Previously Approved Subsidence Impacts

The previous assessment of the worst-case impacts and environmental consequences due to the predicted subsidence effects for LWs 920 to 980 were presented in **DgS, 2010** and are summarised below:

- Minor surface cracking and shearing within tensile and compressive strain zones above the extracted panels. The cracks were estimated to range in width from 1 mm to 20 mm where deep soil profiles exist.

  Worst-case scenarios indicated by the predictions, suggest that where surface rock exposures exist, local strain concentrations could result in tapered vertical cracks of up to 90 mm width near tensile strain peaks or low angled shearing in compressive strain zones.

  An increase or decrease of surface gradients of up to 0.3^o (0.5%) along ephemeral watercourses or gullies that exist above the proposed longwall panels. There is also the potential for a minor increase in erosion and sedimentation along creek beds after several storm events or until a new equilibrium is reached.

- Gully stormwater or groundwater seepage flows may be re-routed to below-surface pathways and re-surface down-stream of cracked areas where shallow surface rock is present. The temporary loss of surface water flows is unlikely to occur where deep alluvial soil profiles exist. Creek bed sediment is likely to infill any surface cracking during storm events.

- Ponding depths of < 0.1 m may develop along creeks and flatter areas above the proposed longwalls. Any increases of existing ponded areas or development of new ponds are likely to be in-channel and unlikely to cause significant impact to the existing environmental conditions.

- Direct hydraulic connection from the surface to the mine workings due to sub-surface fracturing is considered 'very unlikely'. Continuous fracturing is not expected to develop above massive sandstone units of the Narrabeen Formation, which exist between 110 m and 250 m above the workings.

- Based on shallow piezometer and borehole extensometer monitoring results from the neighbouring Springvale Mine, in-direct or discontinuous sub-surface fracturing is 'very unlikely' to interact with surface cracks or effect the near surface groundwater regime.

  The presence of 'plastic' shale beds and the Mount York Claystone unit, which exists between the massive Narrabeen Group sandstone units, is understood to provide significant protection from permanent drainage of surface aquifers through surface and subsurface fracture / joint interconnection.

The Constrained and Elastic Zones in the spanning overburden however, will have the greatest effect on reducing upper sub-surface aquifer losses to the Fractured Zone above the extracted longwall panels. The groundwater losses are expected to be limited to magnitudes that are lower than surface recharge levels.

The forest access tracks above the proposed panels are managed by the Forestry Corporation of NSW (FCNSW). These tracks are accessible to the public. The tracks are likely to be affected by vertical cracking or low angle compressive shearing. The typical crack widths are estimated to range between 1 mm and 20 mm where the tracks pass through the tensile and compressive strain zones above each longwall panel. Worst-case crack widths of up to 90 mm across the tracks may occur if surface rock exists near tensile strain peaks. A worst case assessment predicts that approximately 50 m to 100 m of the road above each longwall may be impacted by cracking.

There are no access tracks above the proposed LW980 modification area.

9.2 Review of Predicted v. Measured Subsidence Effects for LWs 920 to 970

As a component of the Longwalls 900W and 910 Integrated SMP/Extraction Plan being prepared by Angus Place and to satisfy the requirements of Schedule 3, Condition 3C(e) of PA 06_0021 (Mod 1), DgS has recently undertaken a review of the subsidence prediction as outlined in the subsidence assessment for LWs 900W and 910 (**DgS, 2013**). This review is required to incorporate *"any relevant information obtained"* since approval of PA 06_0021 (Mod 1). Mod 1 was approved in August 2011 and since this time Angus Place has completed the secondary extraction of LWs 960 and 970.

The outcome of the subsidence prediction versus measurement review is that the methodology used to include the effects of geological structure and surface topography appears to give a conservative, but reliable suite of 'smooth profile' and discontinuous subsidence effect predictions.

What is also clear from the subsidence review is that while subsidence beneath the Kangaroo Creek and East Wolgan Creek lineaments has not been increased, tilt, curvature and strain increases have still occurred due to discontinuous strata behaviour such as buckling and cracking around the valleys. The predictions for tilt and strain around valleys should therefore be based on 'fault-affected' values rather than non-fault affected ones. The predicted tilt values for plateaus were recommended to be increased by 50% in valleys based on measured results to-date.

It is also apparent that higher subsidence and strains were observed above Narrow Creek due to LW 940 than those associated with Kangaroo Creek (above LW 970), despite LW 940's reduced panel width of 260 m. As the terrain is steeper above Narrow Creek compared to Kangaroo Creek, it is still considered reasonable to distinguish between incised and broad valleys when estimating subsidence effects and their impact.

The above outcomes are considered to be associated with surface topography and geological structure conditions that do not exist above the proposed modification to LW980.

9.3 Environmental Consequence Review for LWs 920 to 970

The observed impacts to-date are summarised on **Figure 4** and detailed in the relevant End of Panel (EoP) Subsidence Assessment Reports and **DgS, 2013**. The review has not identified any impacts in excess of the environmental consequences defined as ‘minor impact’ in the Project Approval.

9.4 Predicted Impacts due to the Proposed Amendments to LW980

Based on the negligible increases to the predicted subsidence effects for LW980 and ‘minor’ impacts observed to-date above LWs 920 to 970, it is assessed that the impacts due to the proposed modification to LW980 are expected to remain within the predicted range of environmental consequences outlined in **DgS, 2010**.

10.0 Survey Monitoring Recommendations

It is recommended that an additional centreline be installed as shown in **Figure 13** to measure the subsidence effect profiles within the modification area after the extraction of LW 980, to (i) review the predictions and impacts for end of panel report and (ii) to assess the performance of the existing main headings pillars and reduced width barrier pillar.

For and on behalf of
Ditton Geotechnical Services Pty Ltd

Steven Ditton
Principal Engineer

Attachments:

Figures 1 to 13

References:

ACARP, 1998a. **ACARP Project No. C6036, Chain Pillar Design (Calibration of ALPS)**. Collwell, M. Collwell Geotechnical Services Pty Ltd.

ACARP, 1998b, **ACARP Project No. C5024, Establishing the Strength of Rectangular and Irregular Pillars**. Galvin, J.M., Hebblewhite, B.K., Salamon, M.D.G., Lin, B.B.

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Palaris, 2013. **Geological Structure Zones in Angus Place and Springvale Mine Extension Areas**. Palaris Report No. CEY1504-01 (January 2013).

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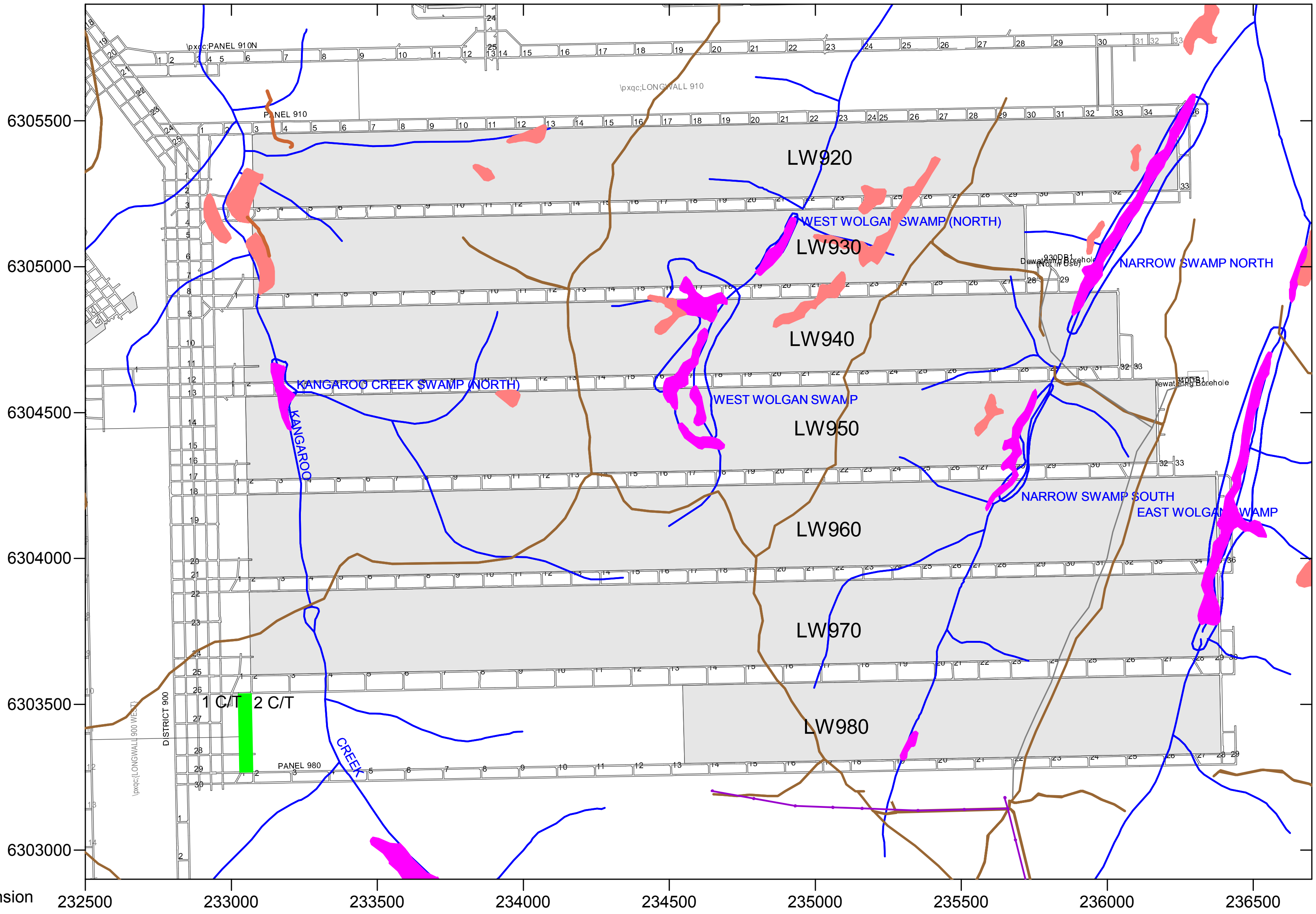
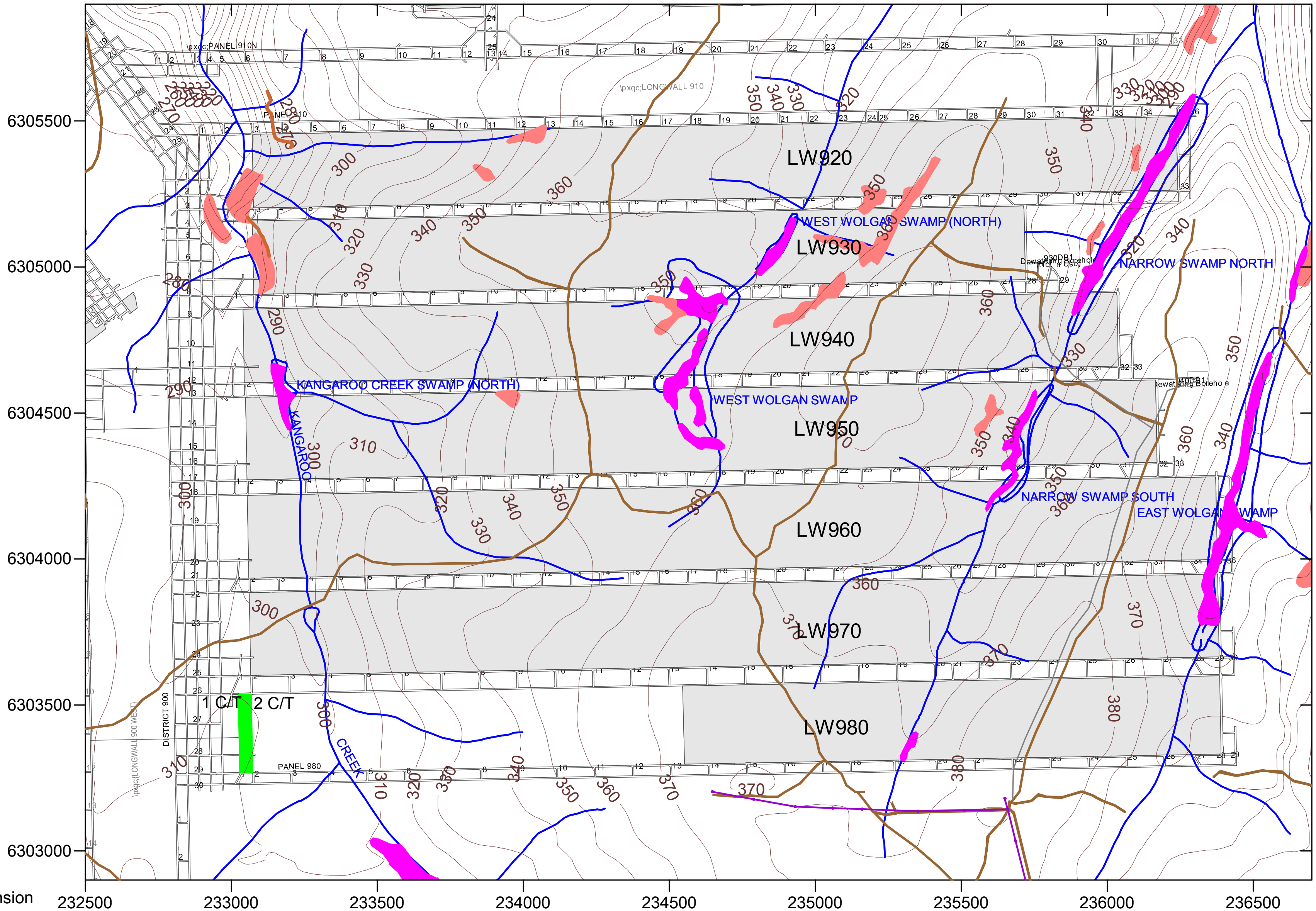


Key:

- Access Roads (unsealed)
- Watercourses
- Shrub Swamps
- Hanging swamps
- Cliff lines (>20 m high)
- Rock Features (5-20 m High)
- Proposed LW980 Panel Extension
- Current Mine Workings
- Completed Longwalls

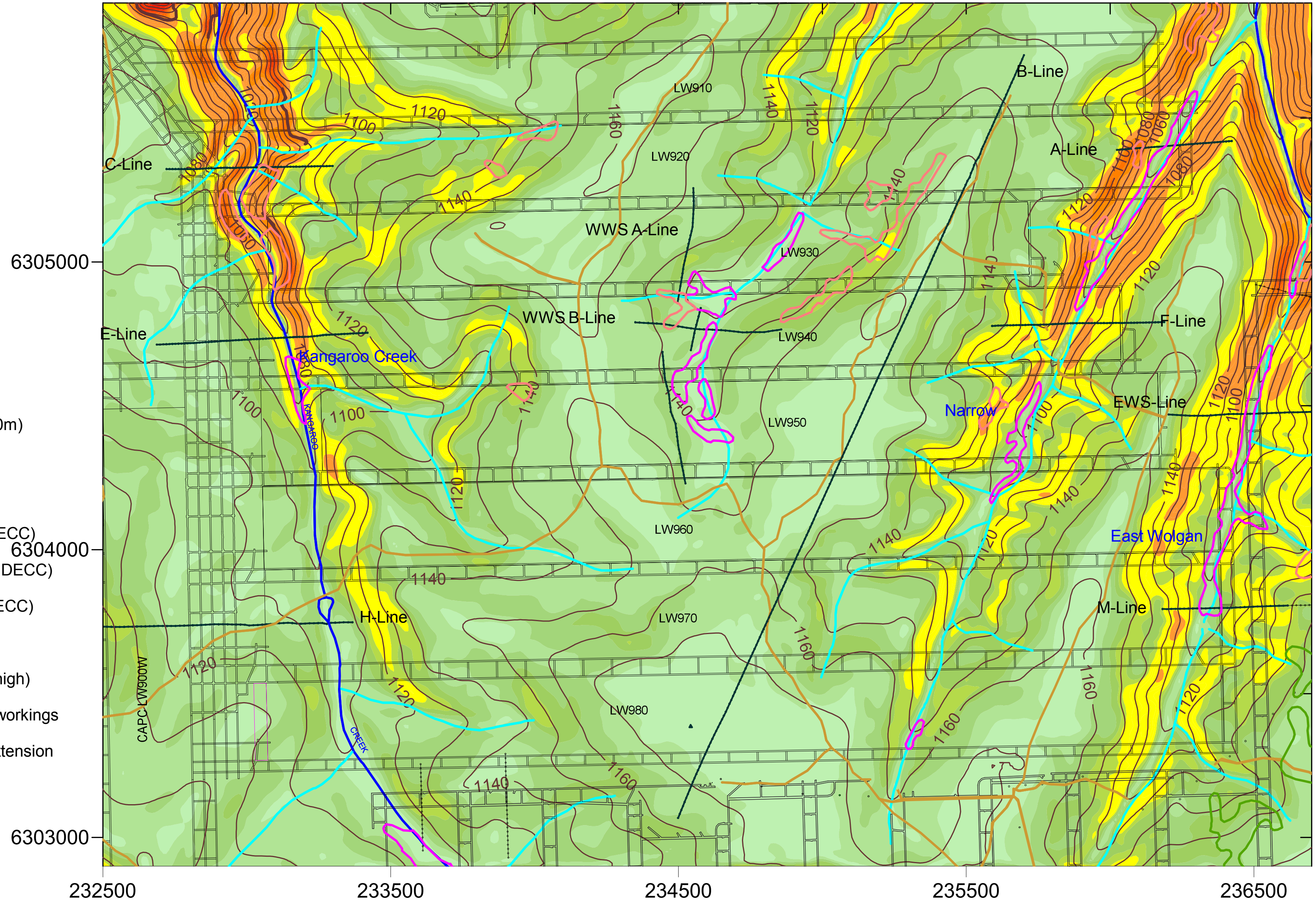
DgS	Engineer: S.Ditton	Client:	Centennial Angus Place ANP-001/5
	Drawn: S.Ditton	Title:	Proposed Extension to LW980 with Surface Features
	Date: 15.10.13		
Ditton Geotechnical Services Pty Ltd		Scale:	1:20,000 — Figure No: 1



Key:

- Access Roads (unsealed)
- Watercourses
- Shrub Swamps
- Hanging swamps
- Cliff lines (>20 m high)
- Rock Features (5-20 m High)
- Proposed LW980 Panel Extension
- Cover Depth Contours (m)
- Current Mine Workings
- Completed Longwalls

DgS Ditton Geotechnical Services Pty Ltd	Engineer: S.Ditton	Client:	Centennial Angus Place ANP-001/5	
	Drawn: S.Ditton			
	Date: 15.10.13	Title:	Proposed Extension to LW980 with Surface Features and Cover Depth Contours	
		Scale:	1:20,000	Figure No: 2



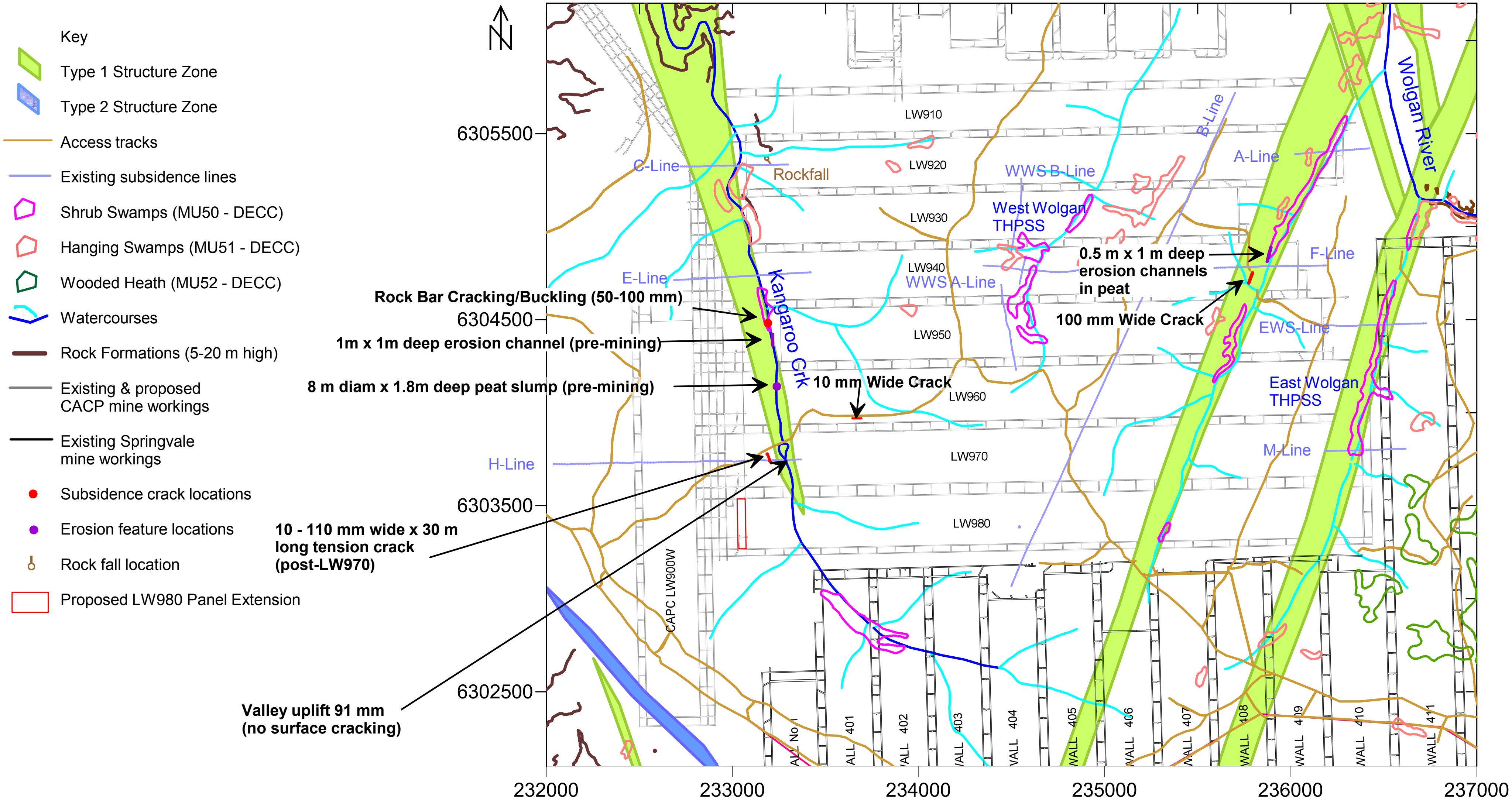
Key

- Surface Level Contours (10m)
- Access Tracks
- Existing Subsidence Lines
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Wooded Heath (MU52 - DECC)
- Watercourses
- Rock Formations (5-20 m high)
- Existing & proposed mine workings
- Proposed LW980 Panel Extension

Surface Gradient (degrees)

48 44 40 36 32 28 24 20 16 12 8 4 0

DgS Ditton Geotechnical Services Pty Ltd			Client:	Centennial Angus Place ANP-001/5		
	Engineer:	S.Ditton	Title:	Proposed LW980 Extension with Surface Level Contours, Gradients, and Surface Features above LWs 920 to 980		
	Drawn:	S.Ditton				
	Date:	15.10.13	Scale:	1:25,000	Figure No:	3

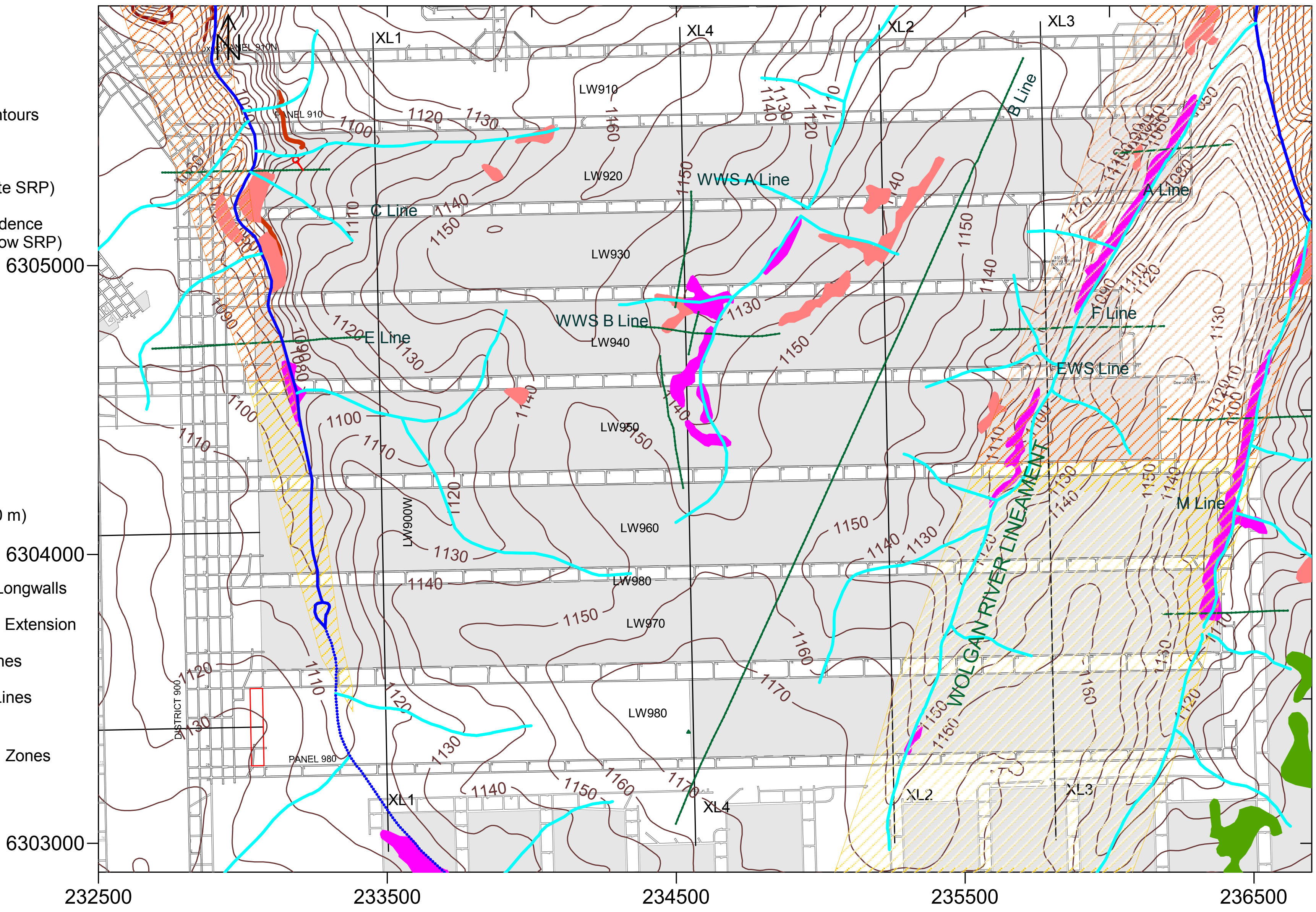


DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-001/5
	Drawn:	S.Ditton		
	Date:	15.10.13	Title:	Proposed LW980 Panel Extension and Observed Impacts due to LWs 920 to 970
	Ditton Geotechnical Services Pty Ltd		Scale:	1:25,000
			Figure No:	4

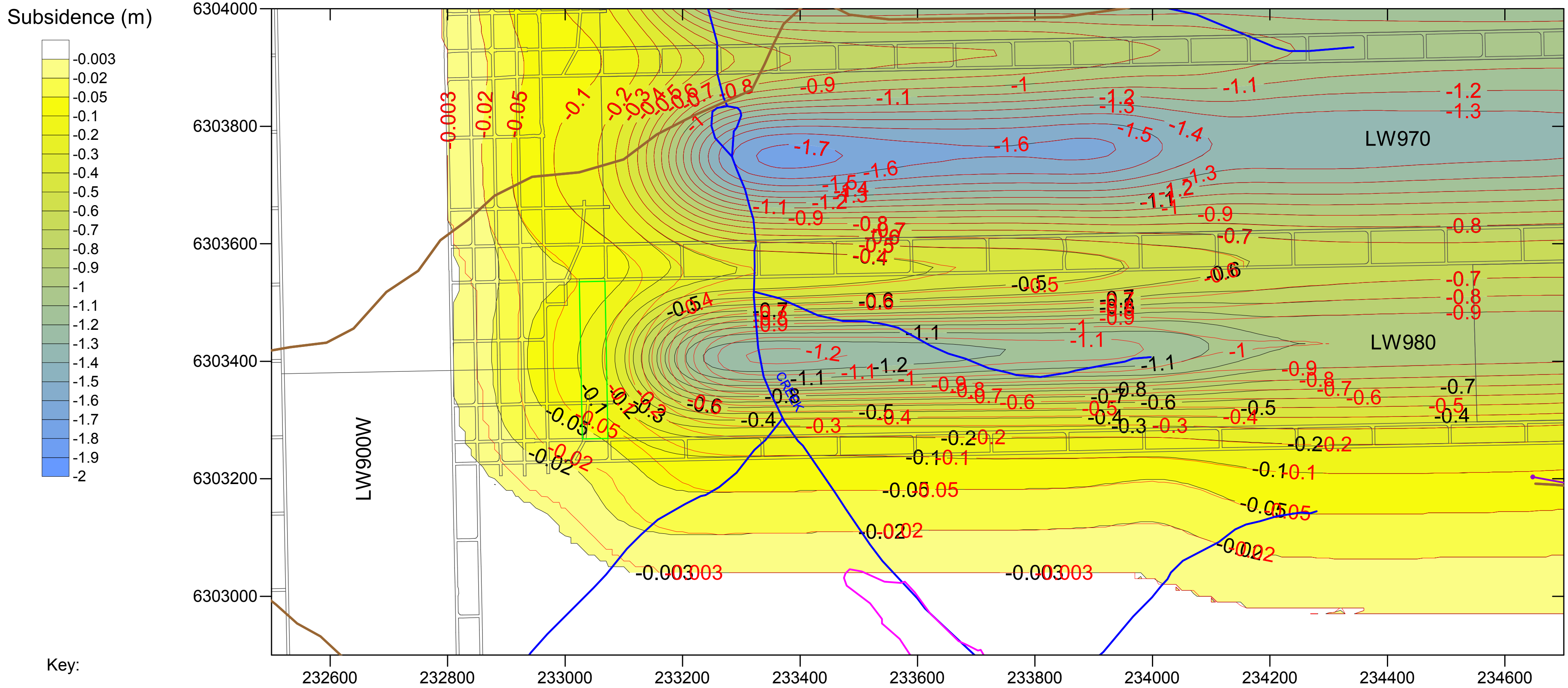
Key:

- 1140 — 10 m Surface Level Contours (AHD)
- Low Subsidence Effect Increase Zone (Moderate SRP)
- Moderate to High Subsidence Effect Increase Zone (Low SRP)
- Watercourses
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Wooded Heath (MU52 - DECC)
- Cliff lines (>20 m high)
- Rock Formations (5 - 20 m)
- Extracted Longwalls
- Approved Unextracted Longwalls
- Proposed LW980 Panel Extension
- Installed Subsidence Lines
- Subsidence prediction Lines

Note: All areas outside of PSEI Zones assumed to have High SRP.



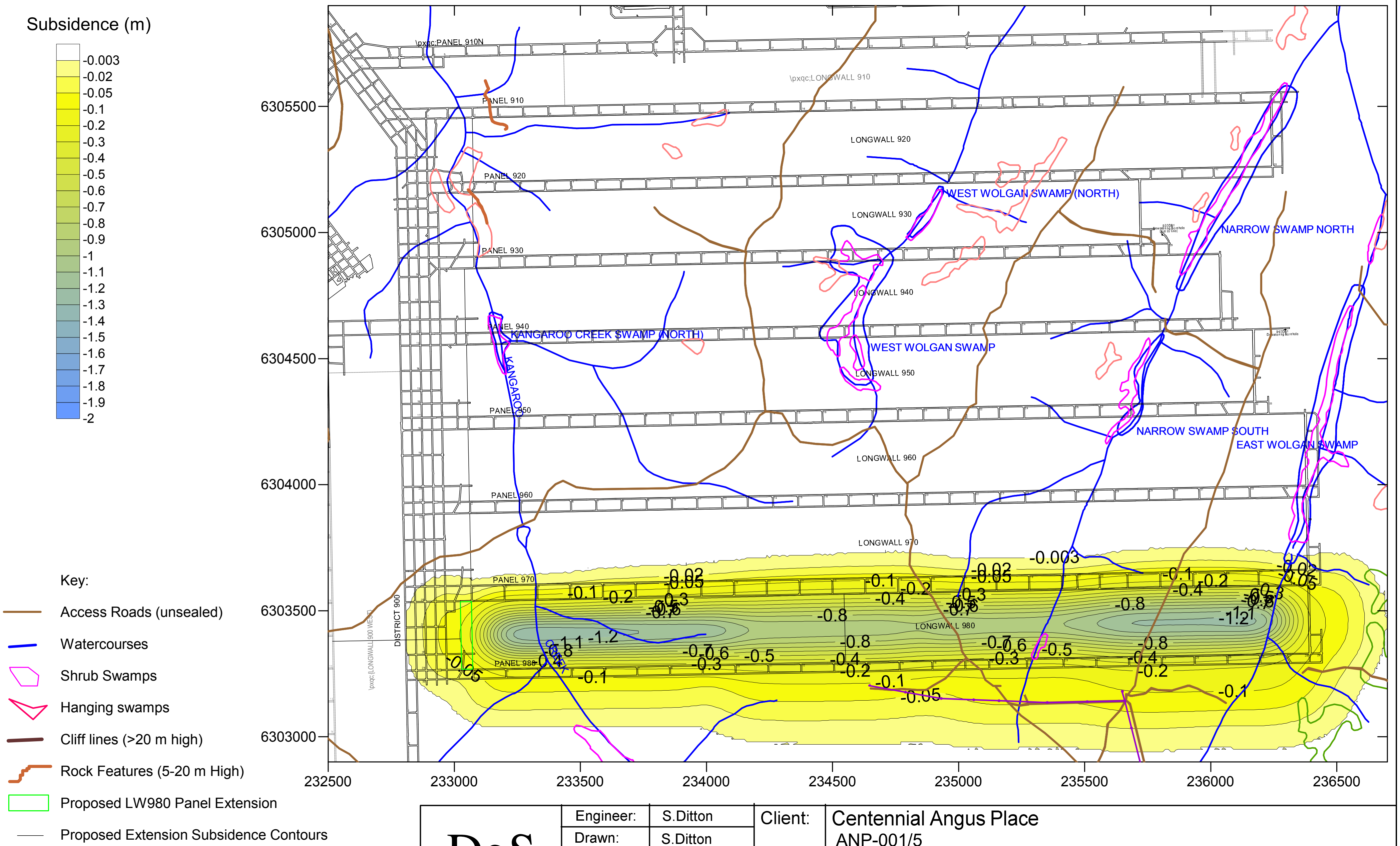
DgS	Engineer:	S.Ditton	Client: Centennial Angus Place ANP-001/5
	Drawn:	S.Ditton	
	Date:	15.10.13	Title: Interpreted Potential Subsidence Effect Increase (PSEI) Zones above the Approved SMP Mining Layout for LWs 920 to 980 and the Proposed LW980 Extension Area
Ditton Geotechnical Services Pty Ltd			Scale: 1:30,000 — Figure No: 5



Key:

- Access Roads (unsealed)
- Watercourses
- Shrub Swamps
- Hanging swamps
- Cliff lines (>20 m high)
- Rock Features (5-20 m High)
- Proposed LW980 Extension Area
- Predicted Subsidence Contours for Approved Layout
- Proposed Extension Subsidence Contours

DgS Ditton Geotechnical Services Pty Ltd	Engineer: S.Ditton Drawn: S.Ditton Date: 15.10.13	Client:	Centennial Angus Place ANP-001/5
		Title:	Predicted Worst-case Subsidence Contours for LWs 920 to 980 with LW980 Extended 43.4 m West
		Scale:	1:10,000 — Figure No: 6a



Engineer:	S.Ditton
Drawn:	S.Ditton
Date:	15.10.13

DgS

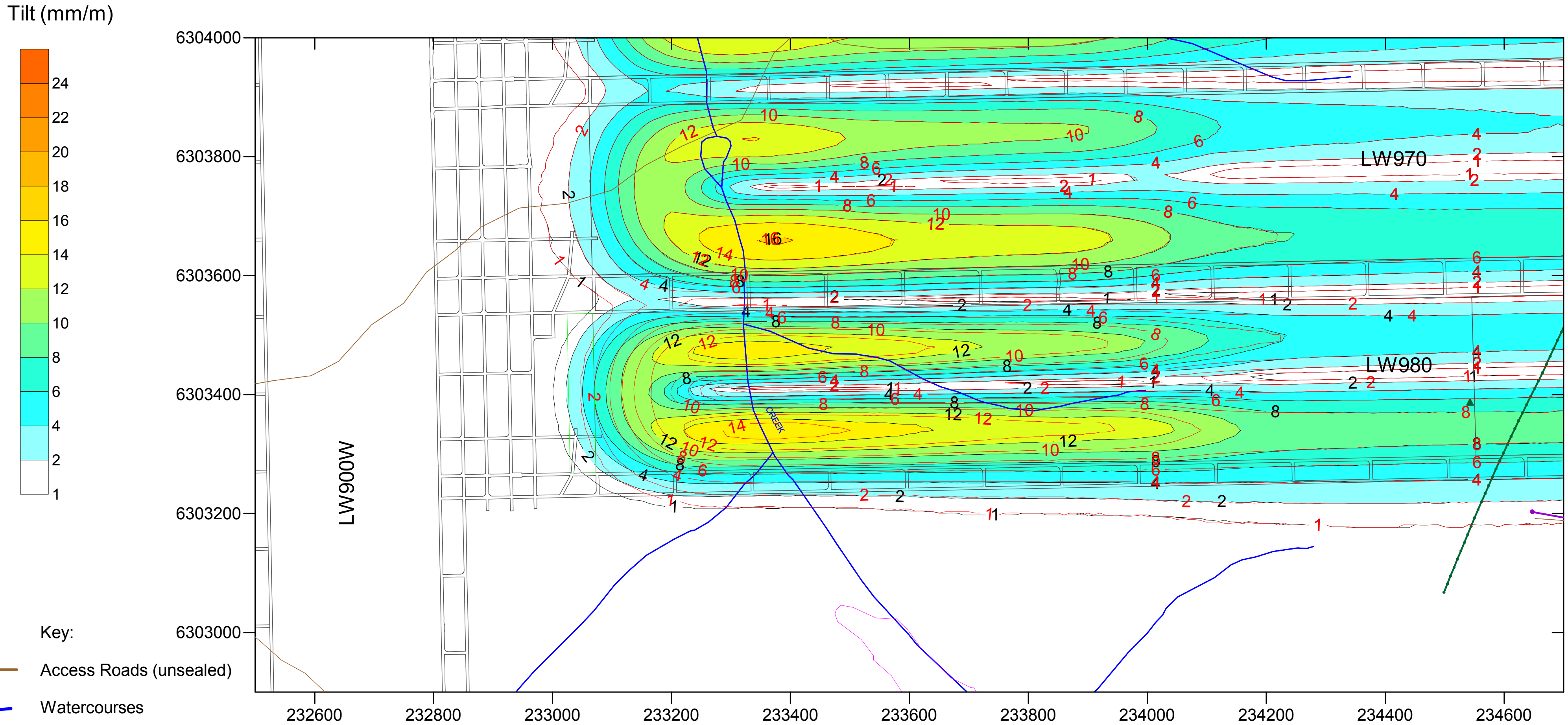
Ditton Geotechnical Services Pty Ltd

Client: Centennial Angus Place
ANP-001/5

Title: Predicted Worst-case Net Subsidence Contours for the Proposed LW980 Panel Extended 43.4 m to the West

Scale: 1:20,000

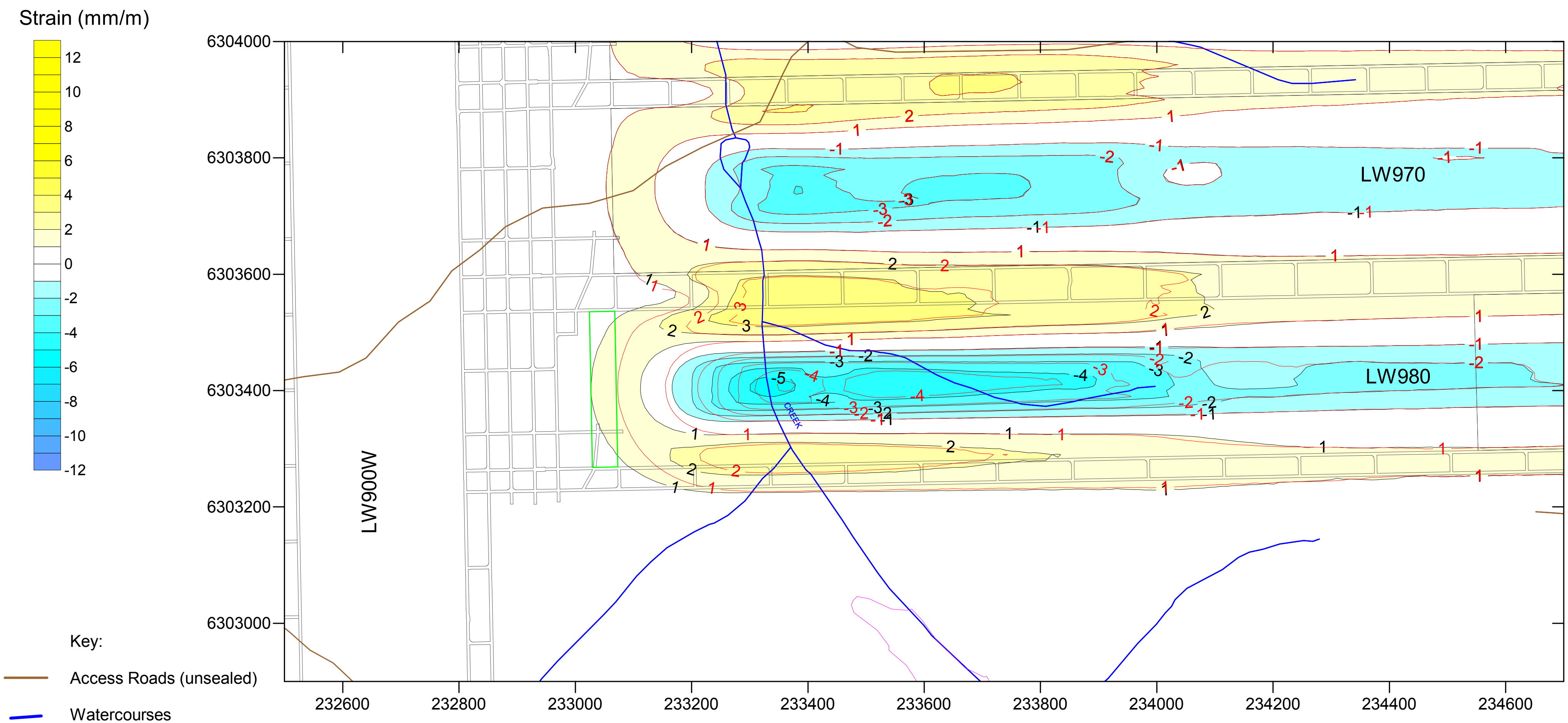
Figure No: 6b



Key:

- Access Roads (unsealed)
- Watercourses
- Shrub Swamps
- Hanging swamps
- Cliff lines (>20 m high)
- Rock Features (5-20 m High)
- Proposed LW980 Extension Area
- Predicted Subsidence Contours for Approved Layout
- Proposed Extension Subsidence Contours

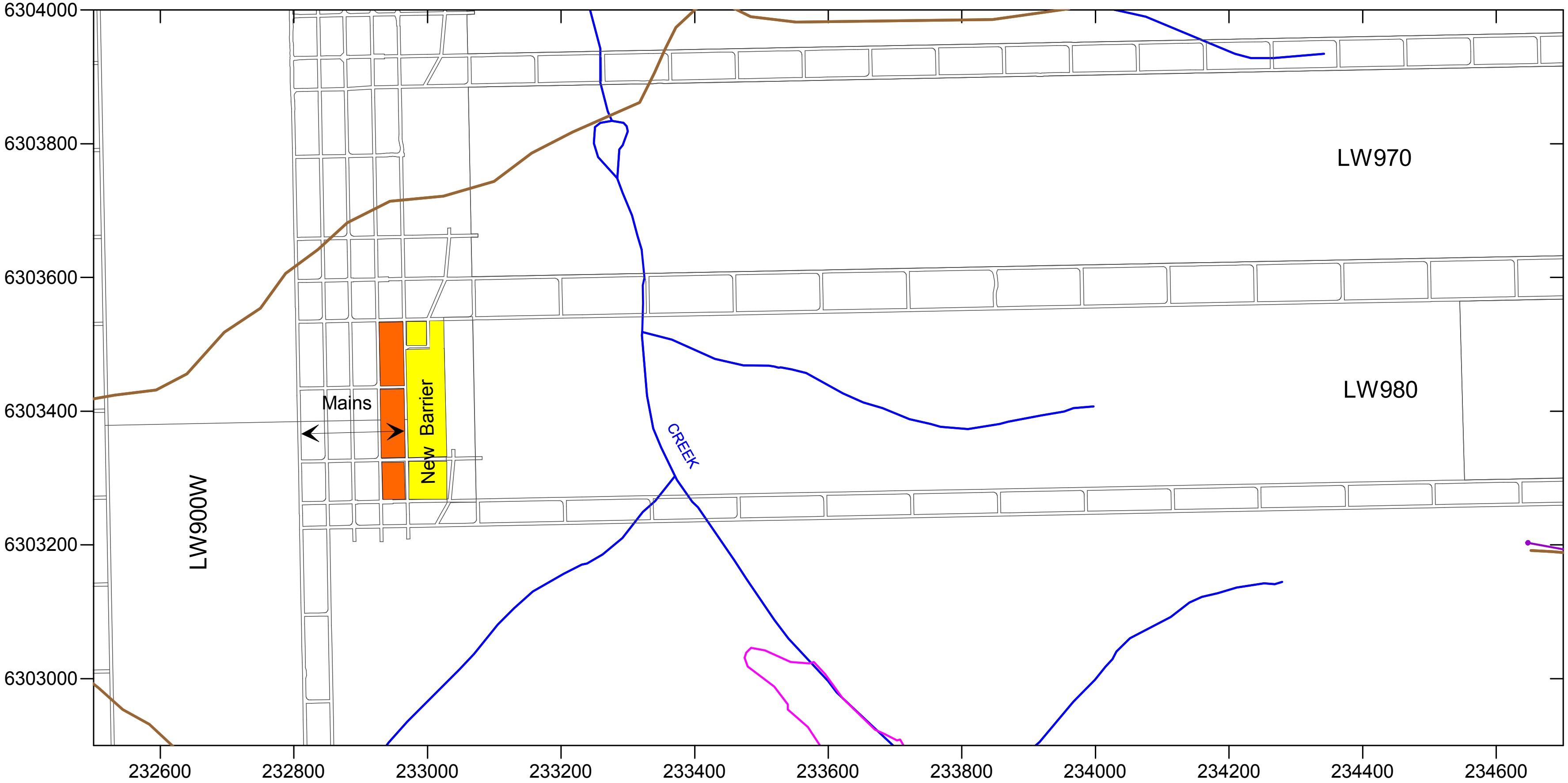
DgS Ditton Geotechnical Services Pty Ltd	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-001/5
	Drawn:	S.Ditton	Title:	Predicted Principle Tilt Contours above the Modified Mining Layout for LWs 920 to 980 with LW980 Extended 43.4 m West
	Date:	15.10.13	Scale:	1:20,000
			Figure No:	7



Key:

- Access Roads (unsealed)
- Watercourses
- Shrub Swamps
- Hanging swamps
- Cliff lines (>20 m high)
- Rock Features (5-20 m High)
- Proposed LW980 Extension Area
- Predicted Subsidence Contours for Approved Layout
- Proposed Extension Subsidence Contours

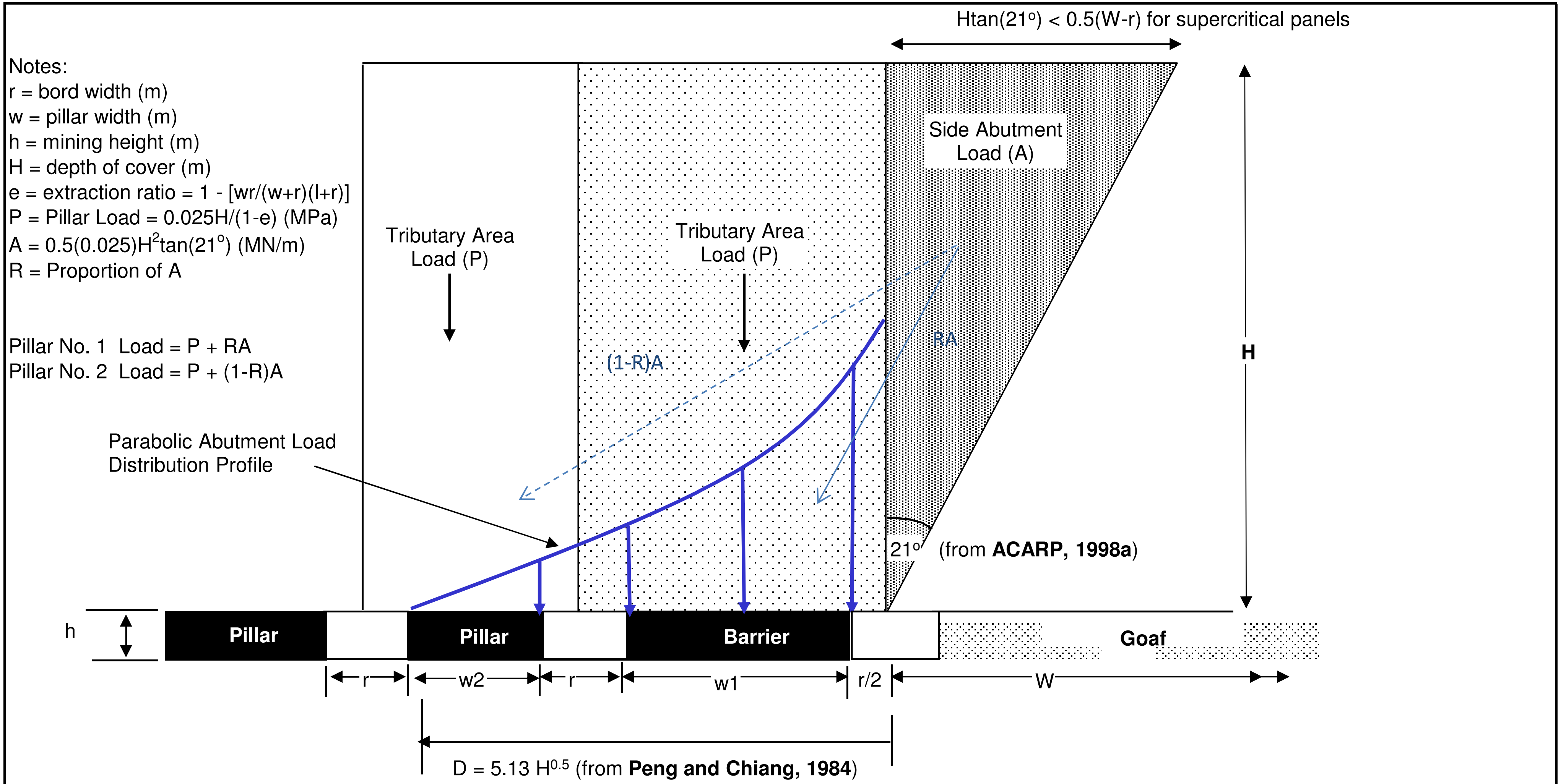
DgS Ditton Geotechnical Services Pty Ltd	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-001/5		
	Drawn:	S.Ditton	Title:	Predicted Principle Horizontal Strain Contours above the Approved SMP Mining Layout for CAPCs LWs 920 to 980 with LW980 Extended 43.4 m West		
	Date:	15.10.13	Scale:	1:20,000	Figure No:	8



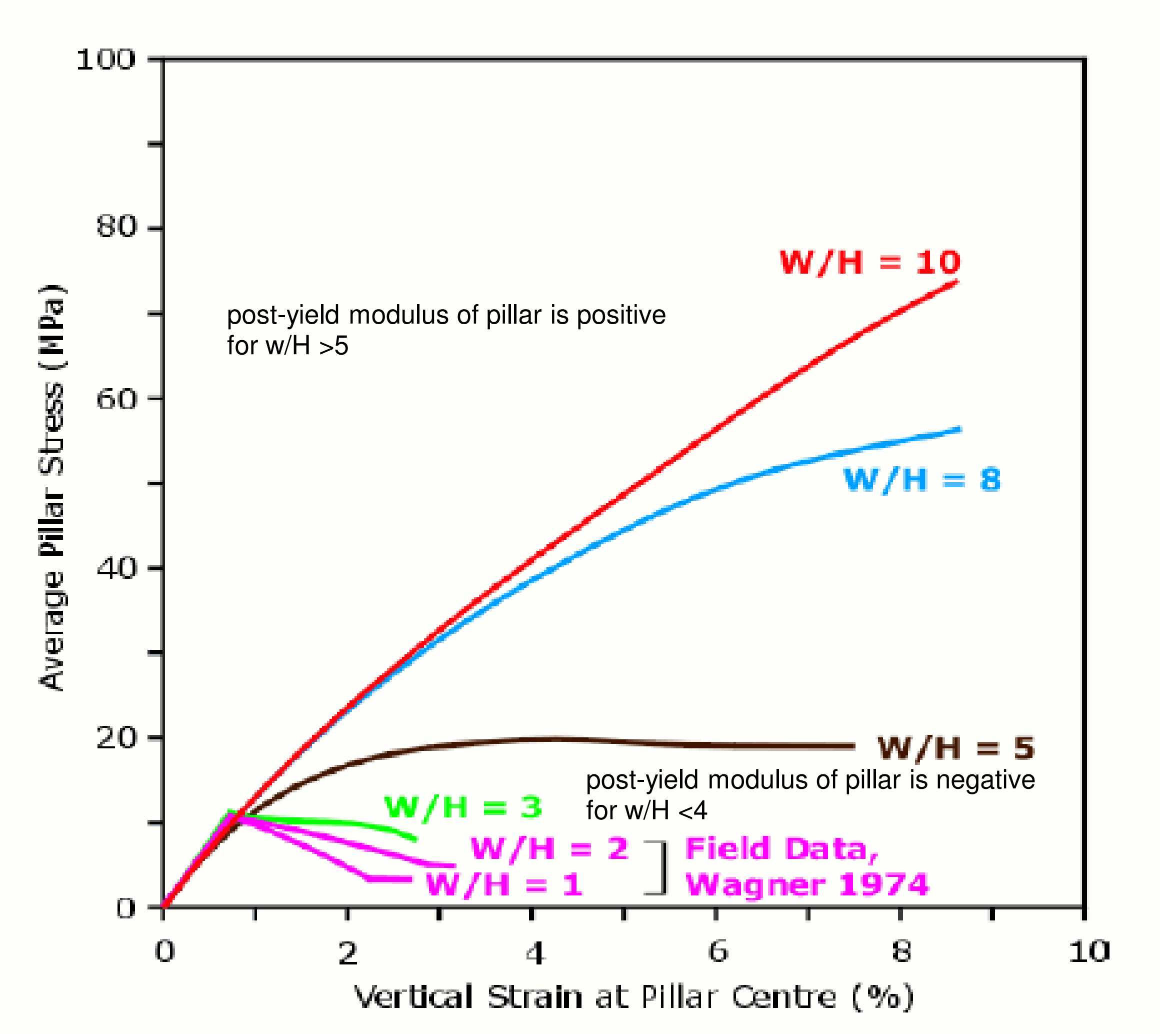
Key:

- Access Roads (unsealed)
- Watercourses
- Shrub Swamps
- Hanging swamps
- Cliff lines (>20 m high)
- Rock Features (5-20 m High)
- Proposed LW980 Barrier Pillars
- Existing Main Headings Pillars within LW980 Abutment Loading Range

DgS	Engineer: S.Ditton	Client:	Centennial Angus Place ANP-001/5
	Drawn: S.Ditton	Title:	Proposed Barrier Pillar for LW 980 with Existing Main Headings Pillars
	Date: 15.10.13		
	Ditton Geotechnical Services Pty Ltd	Scale:	1:10,000 — Figure No: 9

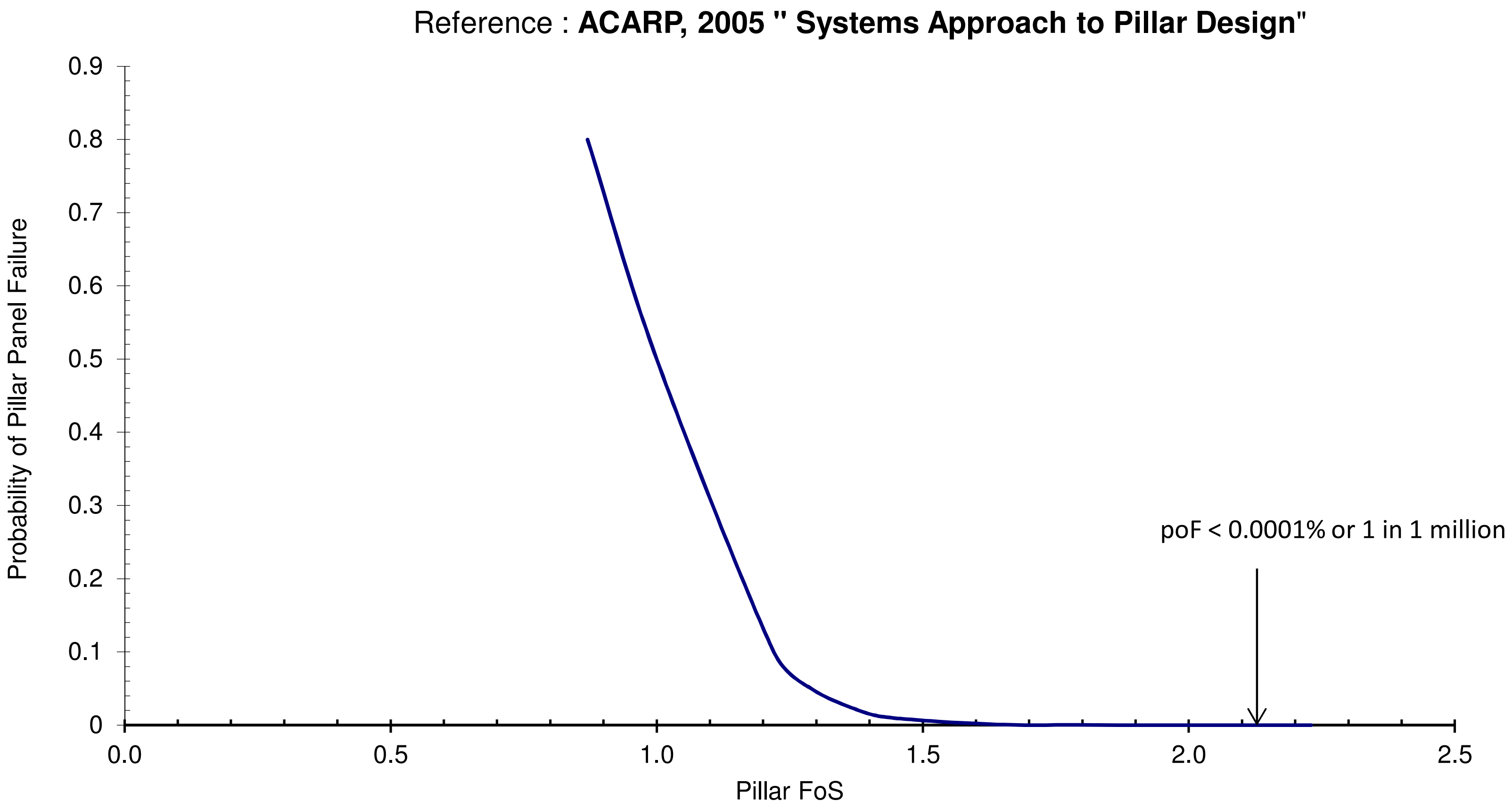


DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-001/5
	Drawn:	S.Ditton		
	Date:	15.10.13	Title:	Analytical Model for Calculating Single Abutment Loads Acting on Maingate Pillars Adjacent to a Longwall Panel
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS — Figure No: 10

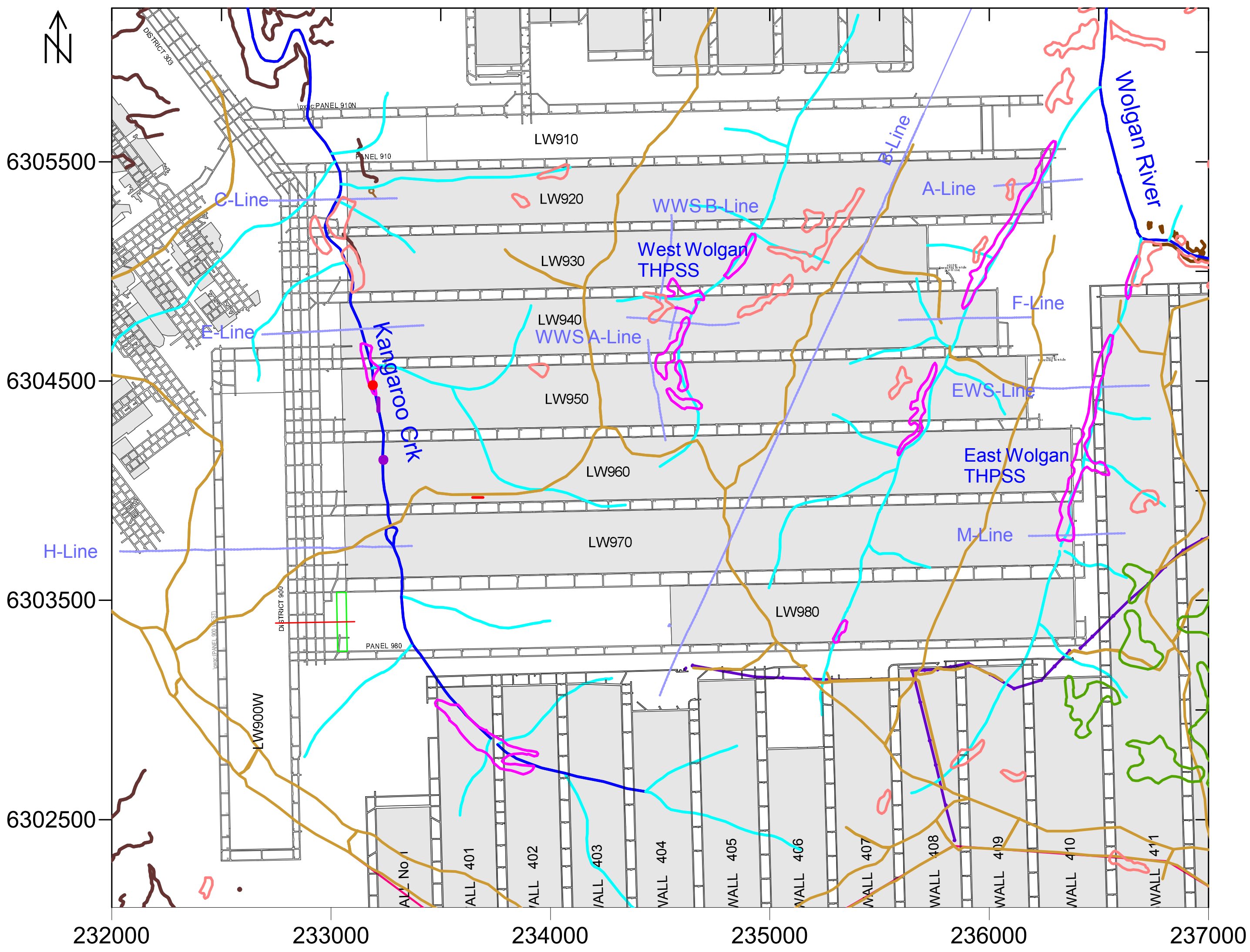


Ref: ACARP, 2005

DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place		
	Drawn:	S.Ditton		ANP-001/5		
	Date:	15.10.13	Title:	In-situ Pillar Stress v. Strain Behaviour for a Range of Pillar Width/Height Ratios		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	11



DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-001/5	
	Drawn:	S.Ditton			
	Date:	15.10.13	Title:	Probability of Pillar Panel Failure v. Pillar Factor of Safety under Design Loading	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 12



Key

- Access tracks
- Existing subsidence monitoring lines
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Wooded Heath (MU52 - DECC)
- Watercourses
- Rock Formations (5-20 m high)
- Existing & proposed mine workings
- Existing Springvale mine workings
- Proposed Panel Extension Areas
- Extracted Longwalls
- Proposed Survey Line

DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-001/5
	Drawn:	S.Ditton		
	Date:	1.10.13	Title:	Proposed Subsidence Monitoring Line for LW980 Modification Area
Ditton Geotechnical Services Pty Ltd			Scale:	1:25,000 — Figure No: 13