Centennial Coal

Angus Place

Attachment 2:

Subsidence Assesment Longwall 900W

Angus Place Colliery

October 2013

Ditton Geotechnical Services Pty Ltd
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28 October, 2013

Natalie Conroy
Environmental Coordinator
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Report No. ANP-002/8

Dear Natalie,

Subject: Subsidence Assessment on the Proposed Modification to Longwall 900W, 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 900W for inclusion in an Environmental Assessment Modification submission to the Department of Planning and Infrastructure (DP&I).

The modification to the proposed longwall panel geometry includes:

- The extension of LW900W by 104.8 m into the barrier pillar towards the north 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**.

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2.0 Background

Angus Place received approval to modify PA 06_0021 (Mod 1) in August 2011 from the Department of Planning and Infrastructure (DP&I) under the provisions of Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The changes included approval for the development and extraction of two additional longwall panels (LWs 900W and 910).

3.0 Scope of Work

Angus Place is currently preparing the Longwalls 900W and 910 Integrated Subsidence Management Plan (SMP)/Extraction Plan for submission to the DP&I and the Department of Trade and Investment, Regional Infrastructure and Services – Division of Resources and Energy. This application is seeking approval to undertake secondary extraction within the currently approved Longwalls 900W and 910. As a component of this application, DgS has completed a Subsidence Assessment Review for the Longwalls 900W and 910 Integrated SMP/Extraction Plan, Centennial Angus Place Colliery (**DgS, 2013a**). This assessment has been prepared to consider *"any relevant information obtained"* since approval of PA 06_0021 (Mod 1) including the increased extraction height in the currently approved LW 900W (20CT to 3CT) from 3.25m to 3.425m.

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

- A summary of the maximum predicted subsidence effects and impacts above LW900W resulting from the proposed 104.8 m extension to LW900W between 3 CT and 1 CT. The mining height is likely to range between 3.25 m and 3.425 m.

- A summary of the maximum predicted subsidence effects and impacts resulting from the previous mining layout as outlined in **DgS, 2013a**, including the increased extraction height from 3.25 m to 3.425 m between 20CT to 3CT.

- Predicted net and cumulative subsidence effect contours resulting from the proposed mining layouts and proposed extension to LW900W. *Note: This assessment has conservatively modelled worst case subsidence by assuming that the entire extension area will be extracted at a mining height of 3.425 m.*

- An assessment of the stability of the first workings and reduced width barrier pillars in the vicinity of the proposed extension to LW 900W and following extraction of the modified LW980 mining layout; see **Figure 1** (refer to **DgS, 2013b**).

4.0 Mining Geometry

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

- The currently approved longwall 900W has a void width of 293 m and a length of 2.087 km. The depth of cover to the Lithgow Seam ranges from 300 m to 320 m. The existing and proposed panel geometries indicate critical panel width/cover depth ratios ranging from 0.92 to 0.98; see **Figure 2**.

- As outlined in the Longwalls 900W and 910 Integrated SMP/Extraction Plan, Angus Place propose to undertake extraction of the currently approved LW 900W (between 20 CT and 3 CT)at a mining height of 3.425 m.

- The proposed panel extension of 104.8 m between 3 CT to 1 CT for LW900W represents a similar reduction in barrier pillar width from 145.8 m to 41.0 m. The barrier pillars will have lengths of 58 m and 220 m.

- The pillar may also be extracted at the increased mining height of 3.425 m away from the existing access headings within the extension area. An average pillar height of 3.34 m has therefore been assumed in this assessment.

- There is one row of main headings pillars to the north of the reduced width barrier pillar for LW900W. The pillars are 51.4 m wide with lengths ranging from 58 m to 116 m. The main headings pillars and reduced width barrier pillars are likely to be subject to increased abutment loading after the modified 900W panel is completed.

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 and north east. 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 also no sensitive natural features such as cliff lines > 20 m in height, rock features between 5 m and 20 m height, Aboriginal Heritage Sites, endangered ecological communities (EECs Species Act) within an AoD distance of 26.5^{o} (0.5 times the cover depth) of the proposed panel modification.

There is one first order tributary of Kangaroo Creek located above the proposed LW900W extension area; see **Figure 1**. Potential subsidence effects to this first order tributary were assessed in the Angus Place Colliery 75W Modification Surface Water Assessment (**GHD, 2010**).

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 LW900W was assessed in **DgS, 2010** and based on measured subsidence effects above LWs 920 to 950. **DgS, 2013a** reviewed the influence of geological structures on predicted subsidence for LW900W based on measured subsidence effects above LWs 960 and 970.

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 there are no geological structures associated with the proposed LW900W extension area; see **Figure 4**.

7.2 Predicted Maximum Subsidence Effects

The maximum subsidence effects for the proposed modification to LW900W have been predicted based on reference to **ACARP, 2003** and the same methodology described in **DgS, 2010**.

The area of proposed modification to LW900W is considered to be outside the fault affected zones (see **Figure 5**) and within a broad valley (see **Figure 3**). The predicted subsidence effects are therefore unlikely to be affected by the faulting or significant valley bulging

phenomena. It is considered that the overburden above the proposed LW900W 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 due to the proposed LW900W extension are presented in **Table 1**.

Table 1 - Maximum Subsidence Effect Predictions for the Proposed Modifications to LW900W

Location	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)
900W^ Extended	**3.25**	295	0.15 - 0.04	2.5 - 0	3.2 - 0.5	0	<50
	3.425	295	0.80 - 0.15	13 - 2.5	3.5 - 2.5	0 - 1	<50
Change	**0.175**	**-**	**0.65 - 0.11**	**10.5 - 2.5**	**0.3 - 2.0**	**<1**	**nil**

^ - Predictions based on subsidence effect contours presented in **Section 7.3**.

The cumulative subsidence effects associated with the increased mining height of 3.425 m within the currently approved LW900W (20CT to 3CT), as assessed in **DgS, 2013a**, have also been considered in this assessment and are presented in **Table 2**.

Table 2 – Maximum Subsidence Effect Prediction for Increased Extraction Height in LW900W (20CT to 3CT)

Location	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)
900W* 20 - 3 CT	3.25	310	0.98 - 1.31	7 - 10	2.9 - 4.3	3.6 - 5.4	<50
	3.425	310	1.03 - 1.38	7 - 11	3.0 - 4.5	3.8 - 5.7	<50
Change	**0.175**	**-**	**0.06 - 0.08**	**<1**	**<0.2**	**<0.3**	**nil**

* - Subsidence effect predictions for the approved mining layout and 3.25 m mining height presented in *Table 7* of **DgS, 2010**.

The proposed 5% increase in mining height within the currently approved LW900W (20CT to 3CT) indicates only minor changes to the previously assessed subsidence values presented in **DgS, 2010**.

The previously predicted subsidence in the extension area will increase between 0.11 m and 0.65 m with tilt increasing from 2.5 mm/m to 13 mm/m. Tensile and compressive strains will also increase by 1 to 2 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 900W and 980 mining

layout are shown in **Figure 6a**. The net subsidence contours due to the modified longwall 900W 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 an increase of 60 mm to 80 mm in maximum subsidence between 20 CT and 3 CT, resulting for the increased extraction height to 3.425 m as assessed in **DgS, 2013a**. The subsidence effect contours due to the modified layout have moved a distance of ~100 m to the north, which is similar to the proposed panel extension length. 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 LW900W will decrease the width of the barrier pillar to the north from 145.8 m to 41.0 m. The proposed extension to LW980 will decrease the width of the barrier pillar between the existing main headings pillars to the west from 100 m to 57 m.

The locations of the affected pillars to the east and north of LW 900W are shown in **Figure 9**.

Based on a cover depth of 295 m and 310 m, **Peng and Chiang, 1984** estimates the abutment loads due to the extraction of LW900W are likely to affect the barrier pillars and/or the first workings pillars within a distance of 87 m and 90 m from the limits of extraction respectively; 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 and first workings pillars after mining of LW980 and 900W 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

= $(l+r)(\rho gH^2\tan\phi)/2$ (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 21° adopted for cover depths < 370 m at Angus Place)

H = depth of cover = 295 m to 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 or W/H <0.77 for $\phi = 21^o$.*

R = Proportion of abutment load acting on first row of pillars next to the goaf;

$= 1 - [(D-w-r)/D]^3$ (where D = distance (m) that load distribution will extend from goaf edge according to **Peng & Chiang**, **1984**: $D = 5.13\sqrt{H}$ = 87 to 90 m)

$= 1 - [(90 - 35 - 4.8)/90]^3$

= 0.83 for H=310 m; w=35 m, and

= 0.89 for H=290 m; w=41 m.

1-R = Proportion of abutment load acting on next row(s) of pillars adjacent to the barrier.

= 1 - 0.83 = 0.17 for H=310 m; w=35 m, and

= 1 - 0.89 = 0.11 for H=290 m; w=41 m.

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' due to greater pillar core confinement.

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.

The potential of pre-mature pillar failure should be considered where moisture sensitive mudstones and claystones can significantly reduce the lateral confinement that can be developed or mobilised in the roof, floor and pillar itself. It is understood that the immediate coal roof and floor conditions have not caused a reduction in pillar strength at Angus Place to-date.

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
Pillars to the East of LW900W*					
Barriers	56.8 x 164.4 x 3.34	84.00	16.74	5.02	10.8
	56.8 x 57.6 x 3.34	68.87	17.62	3.91	10.8
Mains	35.2 x 104.3 x 3.25	36.93	20.55	1.80	10.8
	35.2 x 95.3 x 3.25	36.49	20.66	1.77	17.0
	35.2 x 57.6 x 3.25	33.58	21.28	1.58	17.0
Pillars to the North of LW900W					
Barriers	41.0 x 58.2 x 3.34	40.00	18.27	2.19	12.3
	41 x 219.7 x 3.34	48.11	17.25	2.79	12.3
Mains	51.4 x 58.2 x 3.25	61.66	9.52	6.48	15.8
	51.4 x 99.5 x 3.25	68.96	9.21	7.48	15.8
	51.4 x 115.9 x 3.25	70.67	9.16	7.72	15.8

* - Abutment loads are due to LWs 980 and 900W

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 to the north of LW900W. The probability of failure when pillar FoS > 1.6 is < 1 in 10,000 for the proposed pillars to the east of LW900W.

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 9.2 to 21.3 MPa, an overall FoS against average roof and floor bearing failure is > 2 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 < 50% 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 LW 900W were presented in **DgS, 2010** and are summarised below:

- Minor surface cracking and shearing may develop within tensile and compressive strain zones above the extracted panels and range in width between 1 mm to 20 mm based on the observed cracking over LWs 920 to 950. Localised cracking of up to 90 mm wide is possible where near surface competent bed rock is exposed near the predicted strain peaks.
  It is however considered unlikely that the cracks will occur as a single crack where deep soil or weathered surface rock exists, and likely to consist of several smaller width ones.

- Repairs may be required to some of the wider and deeper cracks in the vicinity of roads and public access areas. Should the worst case scenario eventuate, some remediation of dry creek beds may also be necessary in consultation with relevant stakeholders and government agencies.

  There are no access tracks above the proposed LW900W extension area.

- Cliffs and rock formations are also located outside the Design AoD of 26.5^{o} from the ends of the proposed 900W and very unlikely to be impacted by tilting or strain.

- The increase or decrease of surface gradients of up to 0.5^{o} (1%) along ephemeral watercourses or gullies that exist above the proposed longwall panels. There is the potential for minor increases in erosion and sedimentation along creek beds after several storm events or until a new equilibrium is reached. This should be monitored both pre and post mining. There has been no erosion impact noted above the previously extracted Angus Place longwalls however.

- 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 and creek bed sediment is expected to infill surface cracks after several storm events.

- 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 and 250 m above the workings.

- Based on shallow piezometer monitoring results above LWs 920 to 950, 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 protection from permanent drainage of surface aquifers through surface and subsurface fracture / joint interconnection.

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, 2013a**). 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 LW900W.

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, 2013a**. 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 LW900W

Based on the increased area of predicted subsidence effects for LW900W and 'minor' impacts observed to-date above LWs 920 to 970, it is assessed that the impacts due to the proposed modification to LW900W are expected to remain within the predicted range of environmental consequences outlined in **DgS, 2010**.

10.0 Survey Monitoring Recommendations

It is not considered necessary to install a finishing point centreline to measure subsidence effects within the LW900W extension area due to the lack of sensitive surface features within the area.

For and on behalf of
Ditton Geotechnical Services Pty Ltd

Steven Ditton
Principal Engineer

Attachments:

Figures 1 to 13

References:

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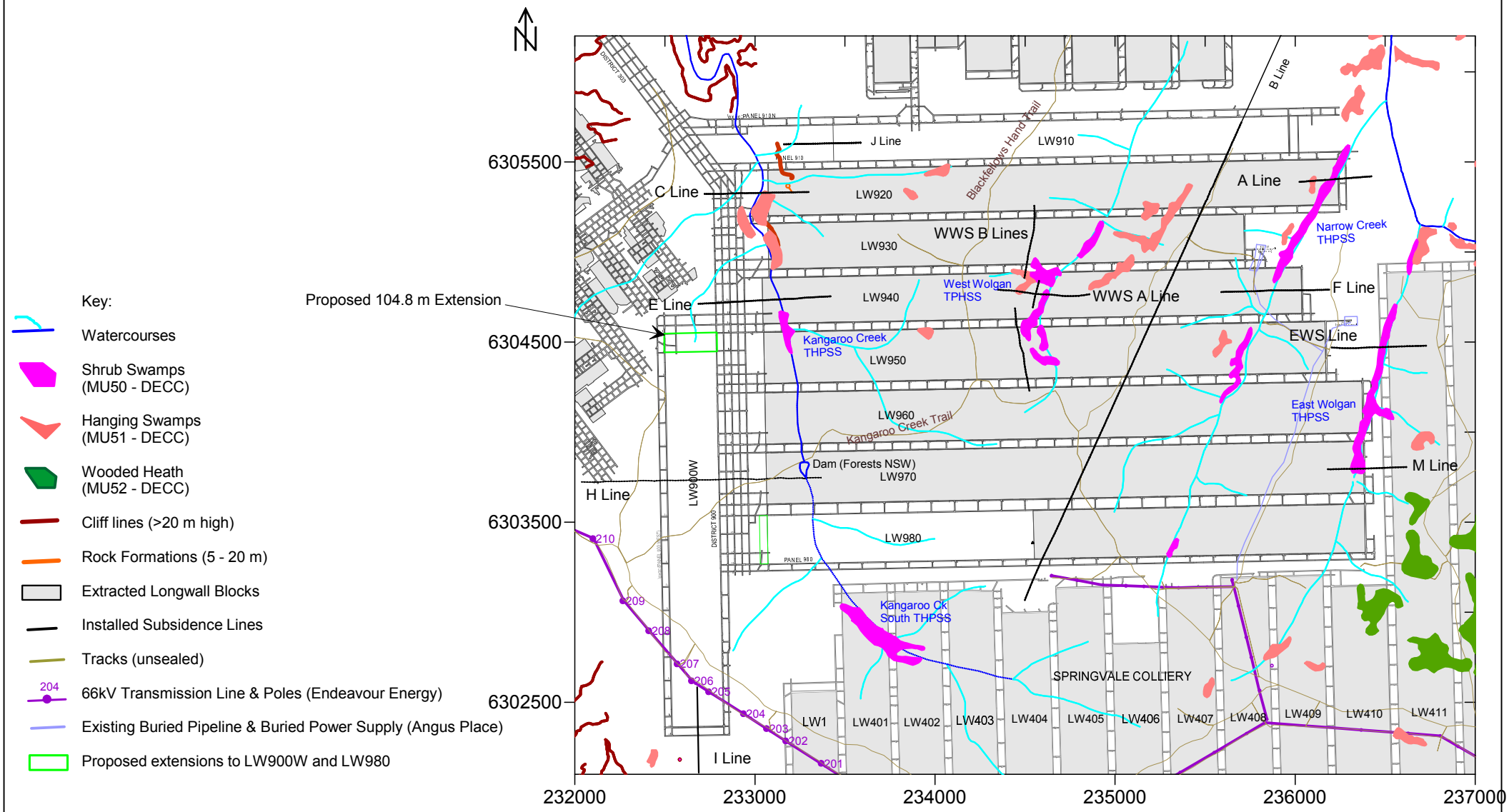
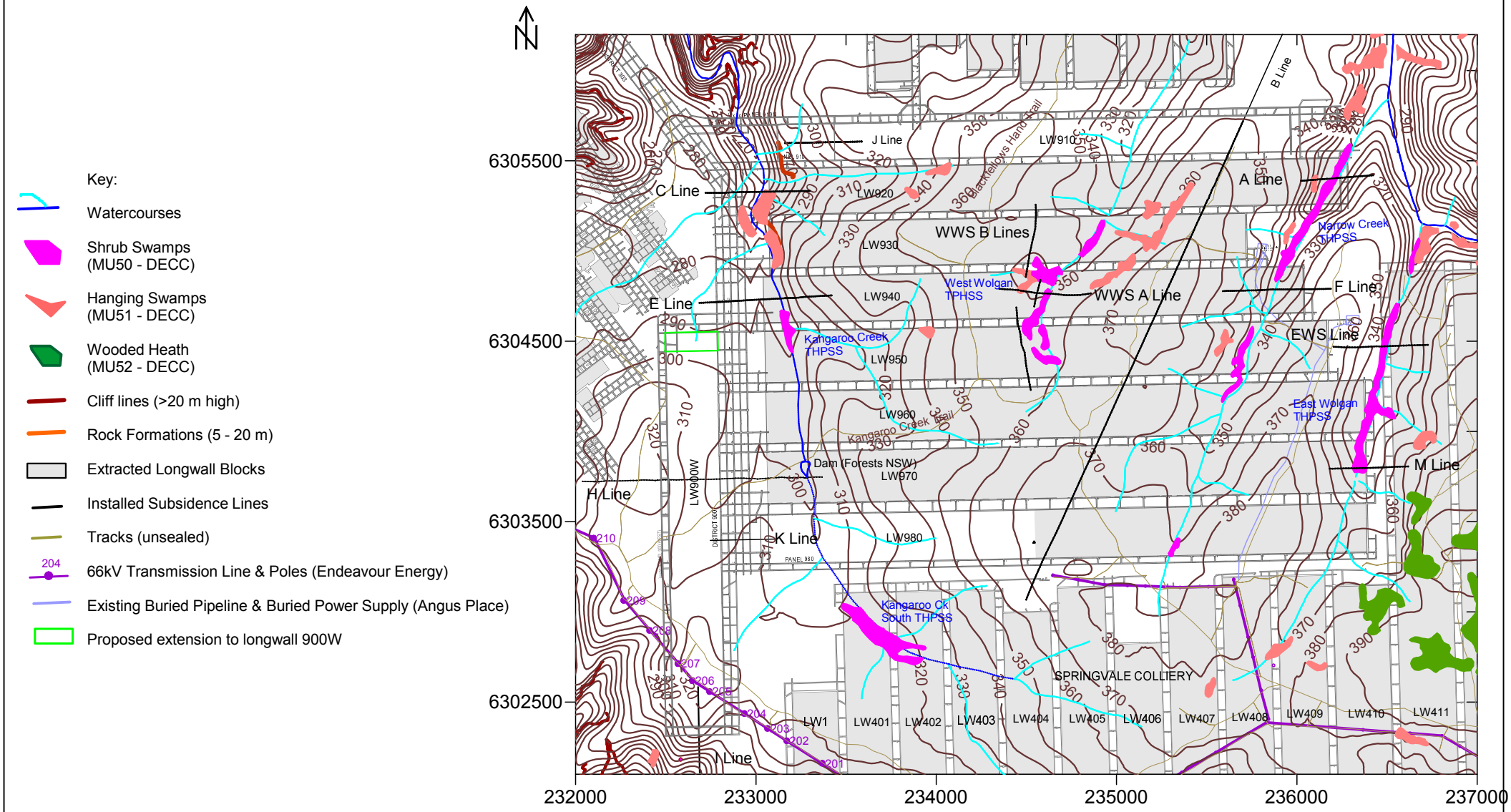
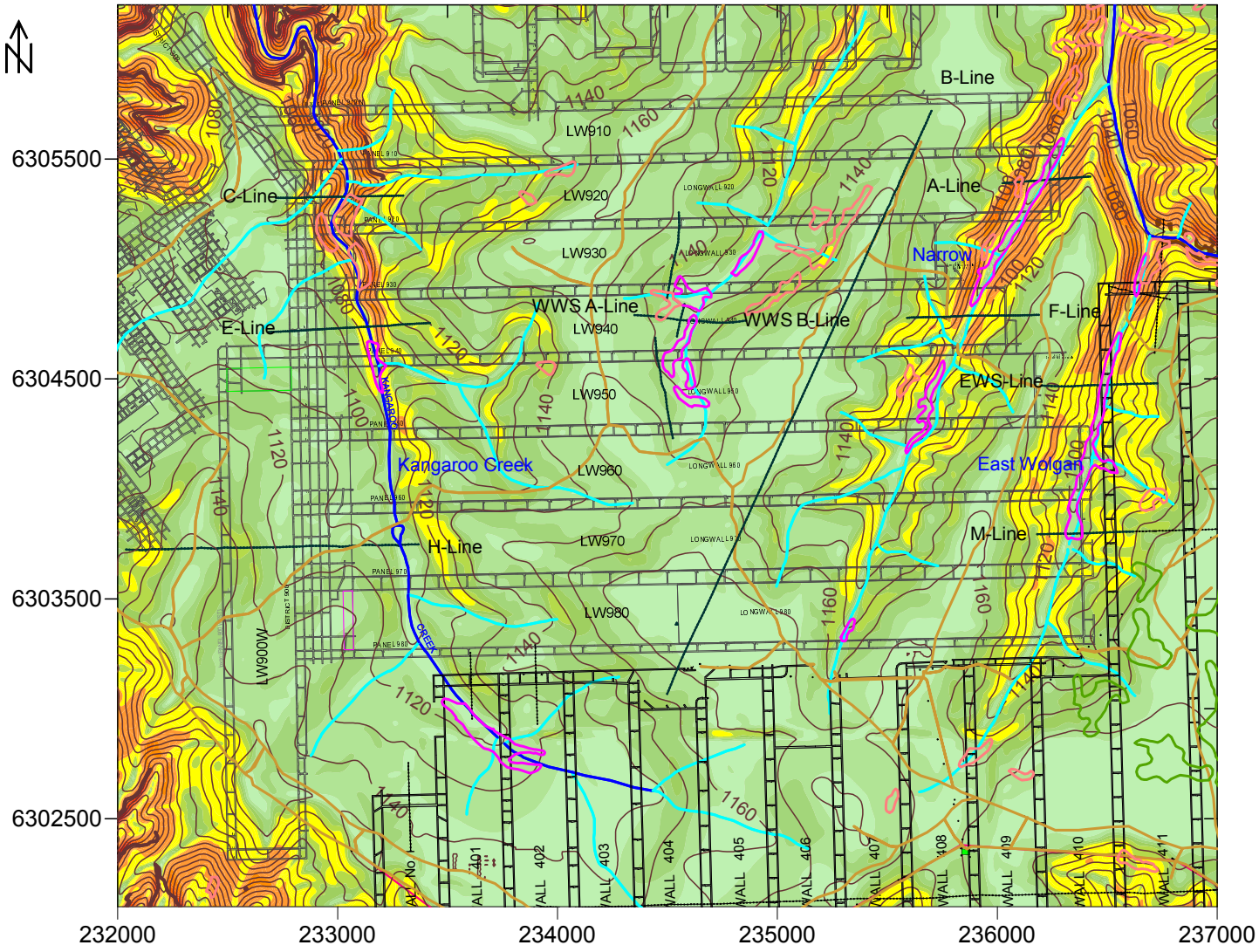


DgS	Engineer: S.Ditton	Client:	Centennial Angus Place ANP-002/8
	Drawn: S.Ditton	Title:	Proposed Extension to LW 900W with Surface Features
	Date: 15.10.13		
Ditton Geotechnical Services Pty Ltd		Scale:	1:30,000 (A4) Figure No: 1



DgS	Engineer:	S.Ditton	Client: Centennial Angus Place ANP-002/8
	Drawn:	S.Ditton	
	Date:	15.10.13	Title: Proposed Extension to LW 900W with Surface Features and Cover Depth Contours
Ditton Geotechnical Services Pty Ltd			Scale: 1:30,000 (A4) 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 Extension to LW 900W

Surface Gradient (degrees)

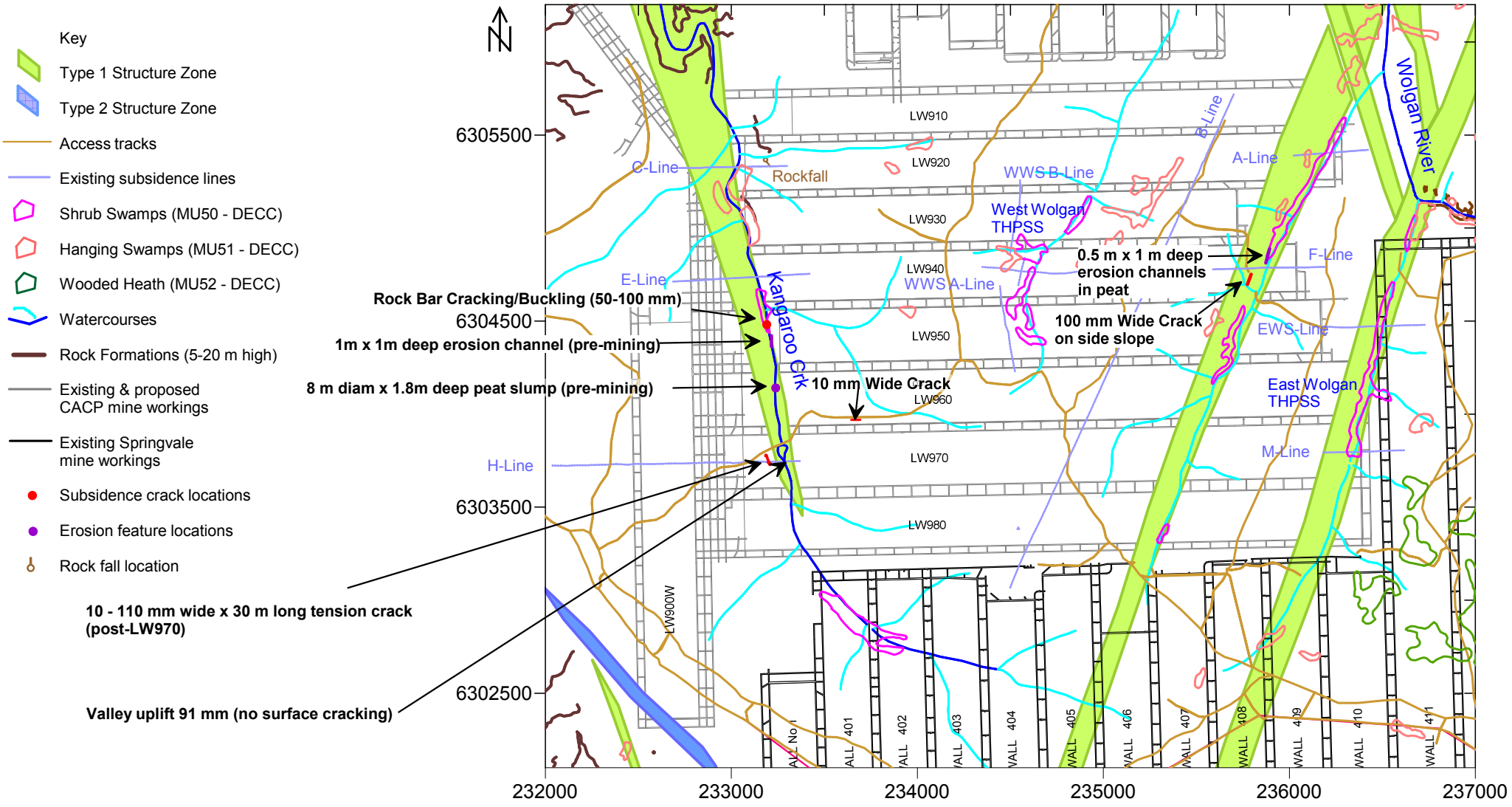
48 44 40 36 32 28 24 20 16 12 8 4 0

DgS

Ditton Geotechnical Services Pty Ltd

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

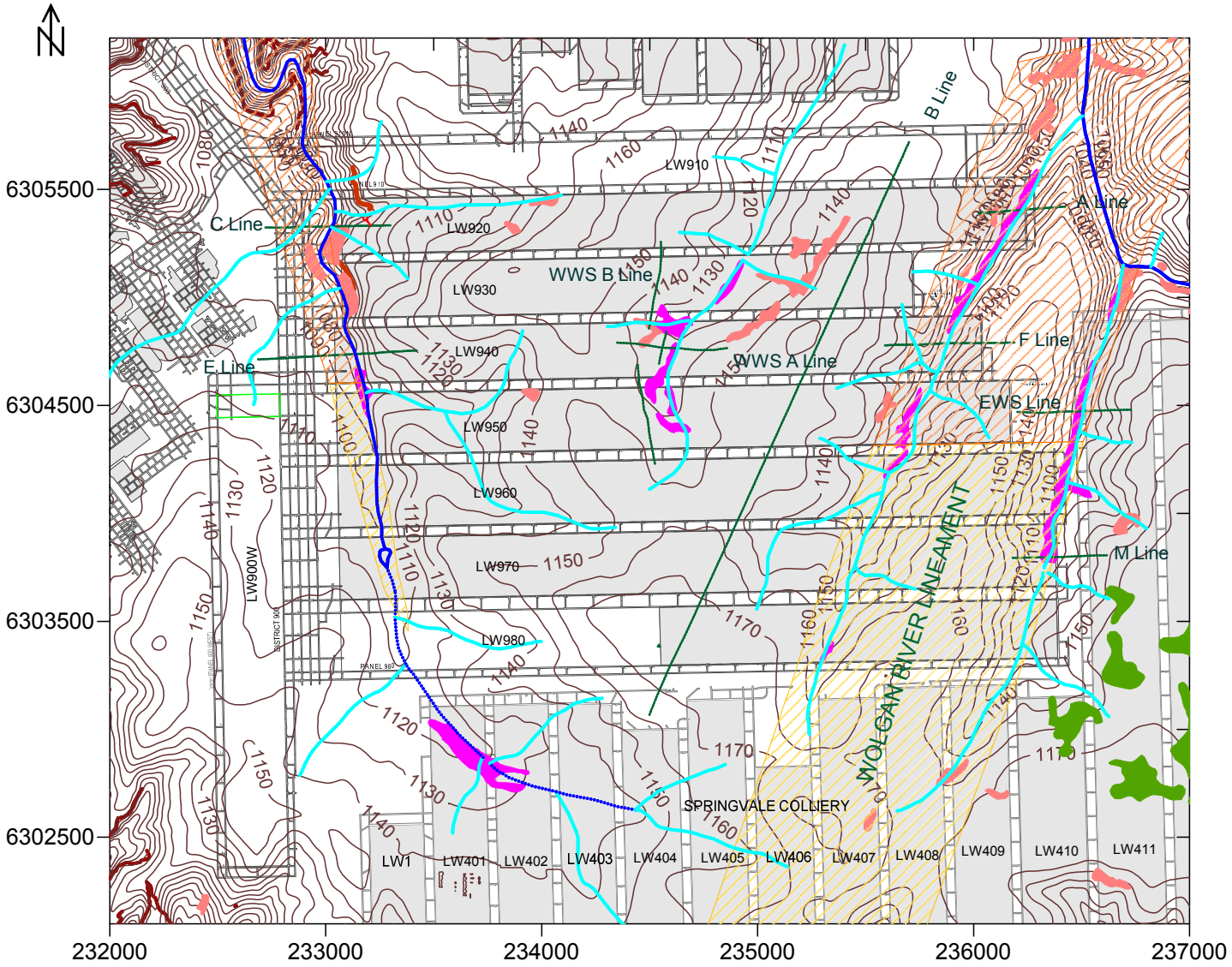
Client:	Centennial Angus Place ANP-002/8		
Title:	Surface Level Contours, Gradients and Surface Features above LWs 900W		
Scale:	1:30,000	Figure No:	3



DgS Ditton Geotechnical Services Pty Ltd	Engineer: S.Ditton	Client:	Centennial Angus Place ANP-002/8
	Drawn: S.Ditton	Title:	Geological Structure and Observed Impacts due to LWs 920 to 970
	Date: 01.10.13	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 Extension to LW900W
- Installed Subsidence Lines



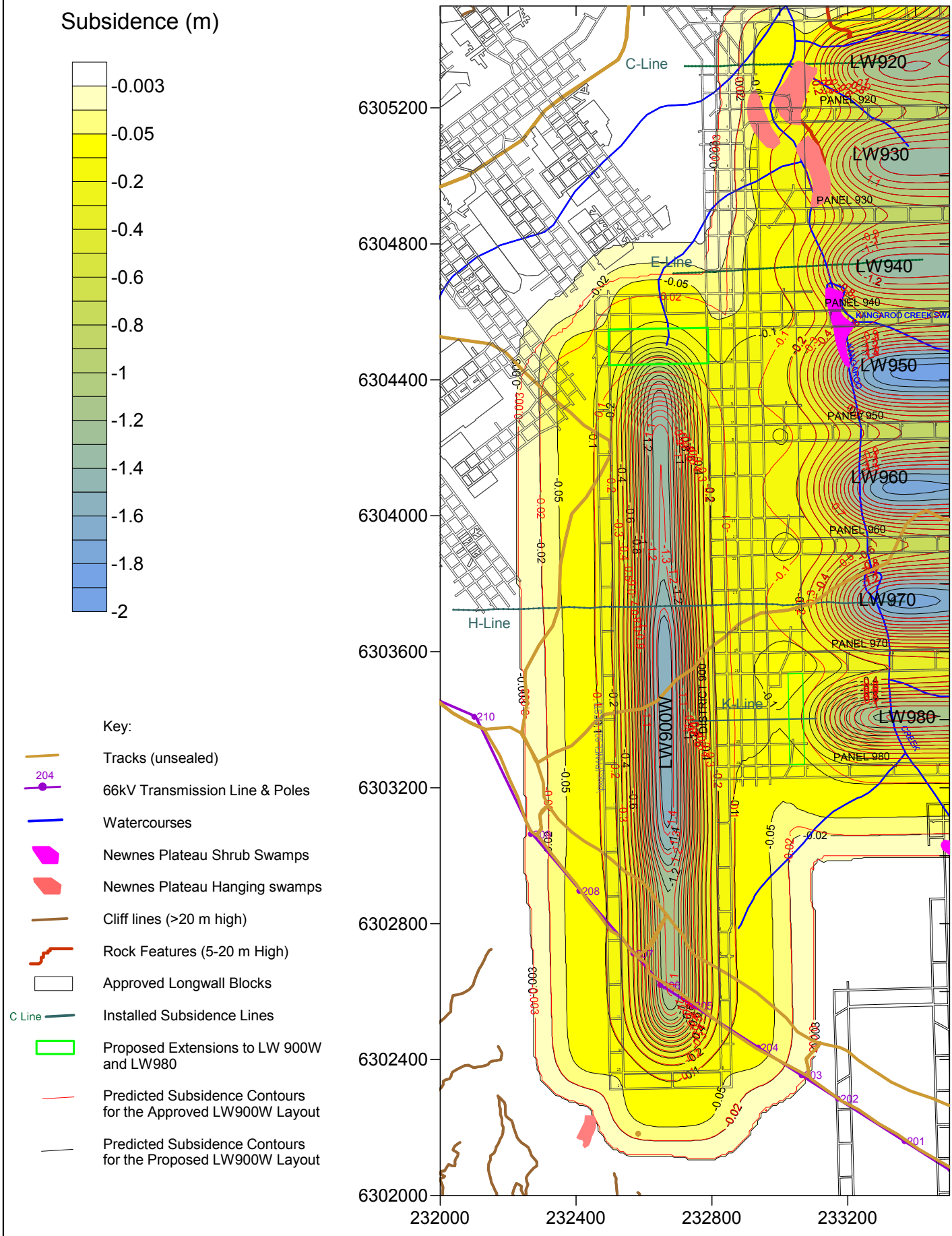
Note: All areas outside of PSEI Zones assumed to have High SRP.

DgS

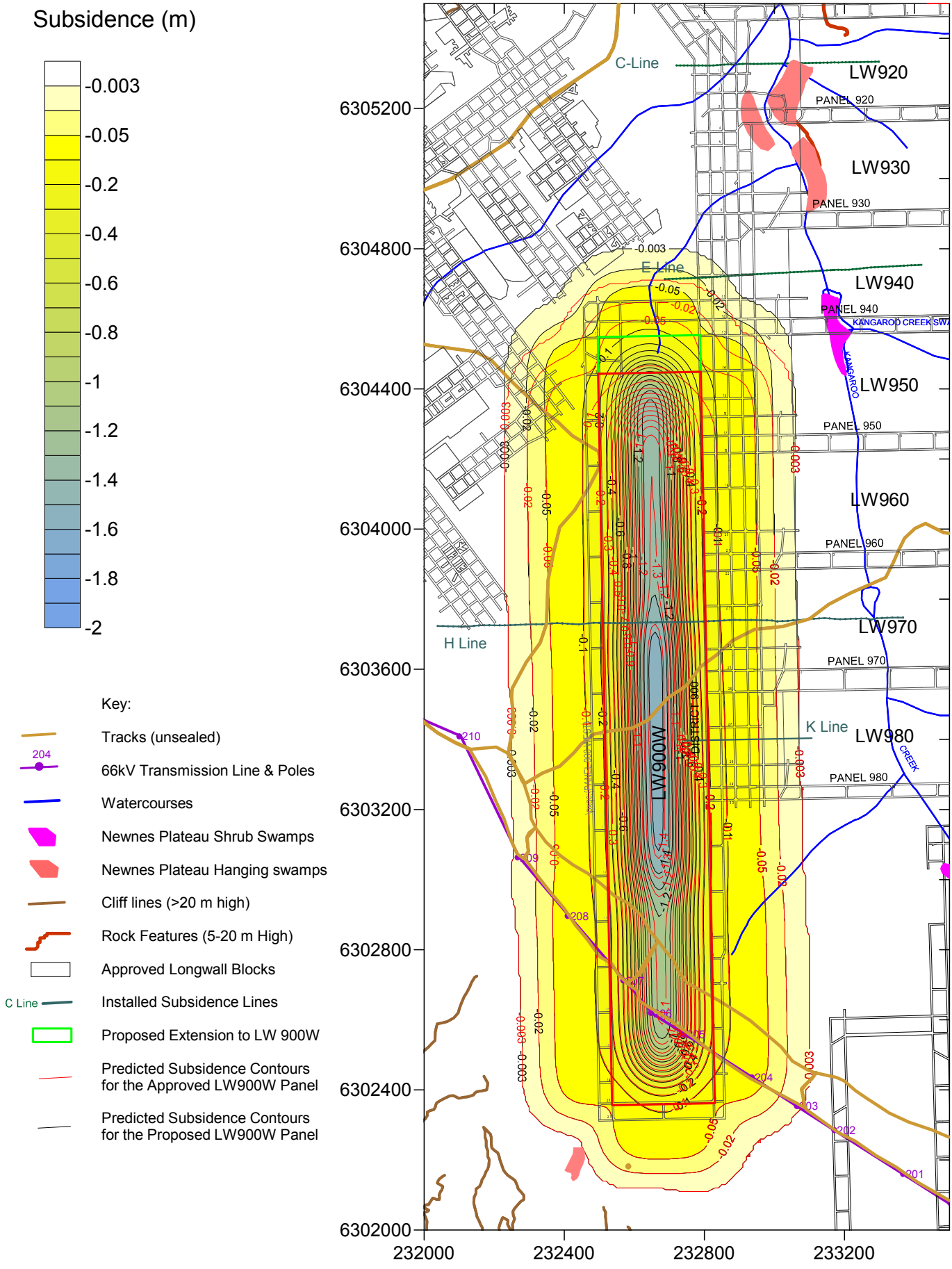
Ditton Geotechnical Services Pty Ltd

Engineer:	S.Ditton
Drawn:	S.Ditton
Date:	28.02.13

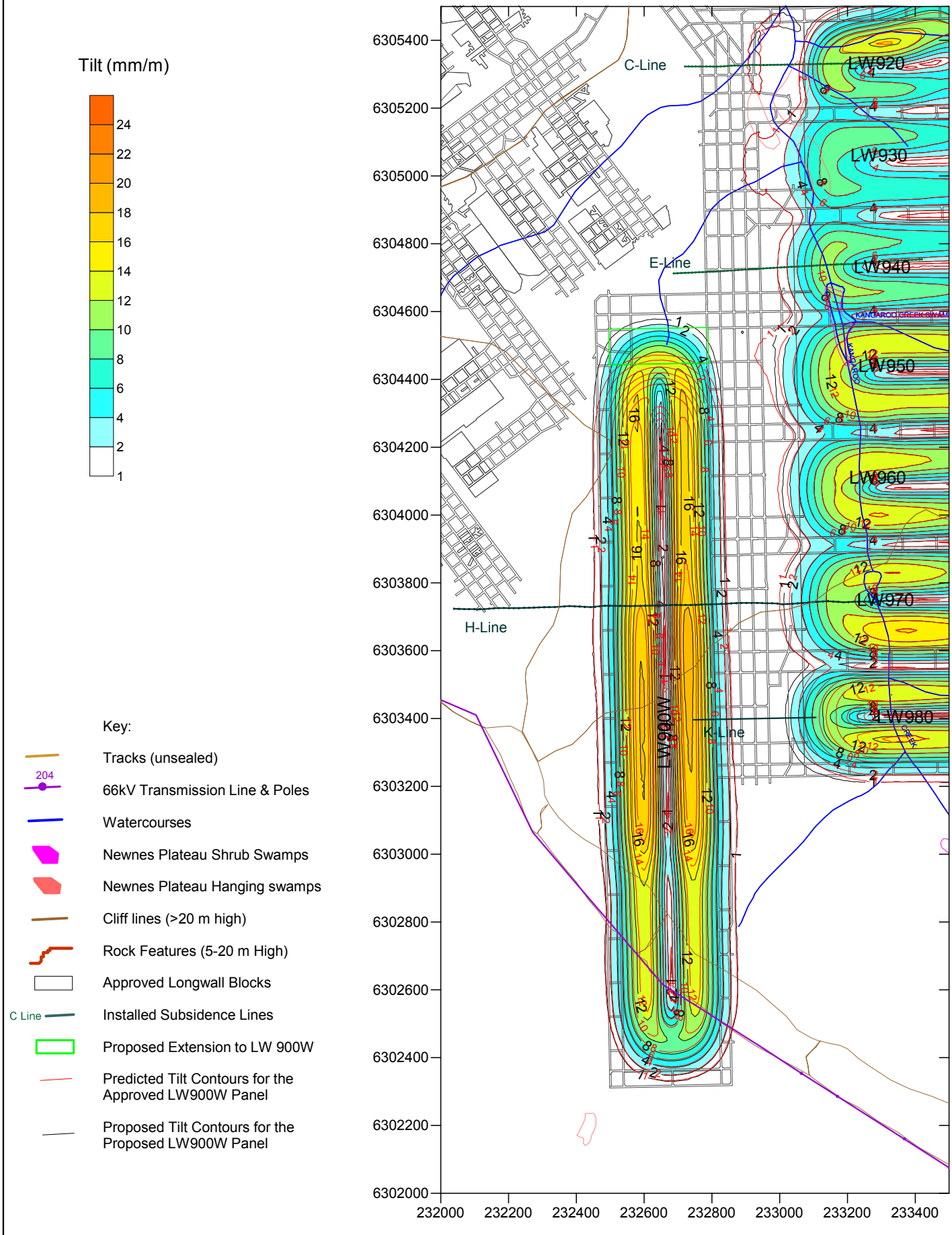
Client:	Centennial Angus Place ANP-002/7
Title:	Interpreted Potential Subsidence Effect Increase (PSEI) Zones above the Approved Mining Layout and the Proposed Extension to LW 900W
Scale:	1:30,000
Figure No:	5



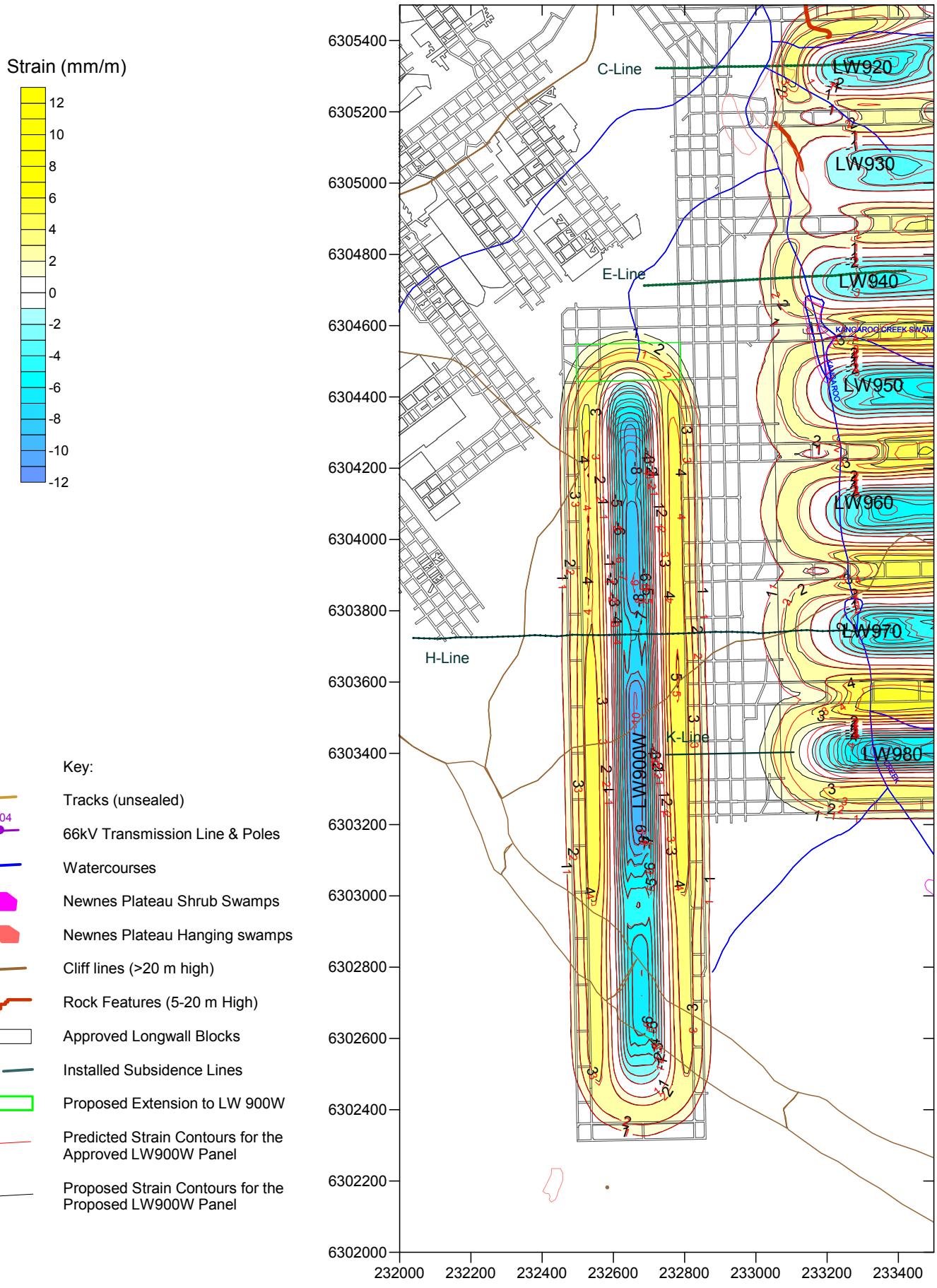
DgS	Engineer:	S.Ditton	Client:	Angus Place ANP-002/8	
	Drawn:	S.Ditton			
	Date:	24.10.13	Title:	Predicted Cumulative Subsidence Contours for the Proposed Modifications to LWs 900W to 980	
Ditton Geotechnical Services Pty Ltd			Scale:	1:1,500	Figure No: 6a



DgS	Engineer:	S.Ditton	Client:	Angus Place ANP-002/8	
	Drawn:	S.Ditton			
	Date:	24.10.13	Title:	Proposed Longwall 900W with it's Finishing Point located 104.8 m to the North and Predicted Net Subsidence Contours	
Ditton Geotechnical Services Pty Ltd			Scale:	1:1,500	Figure No: 6b



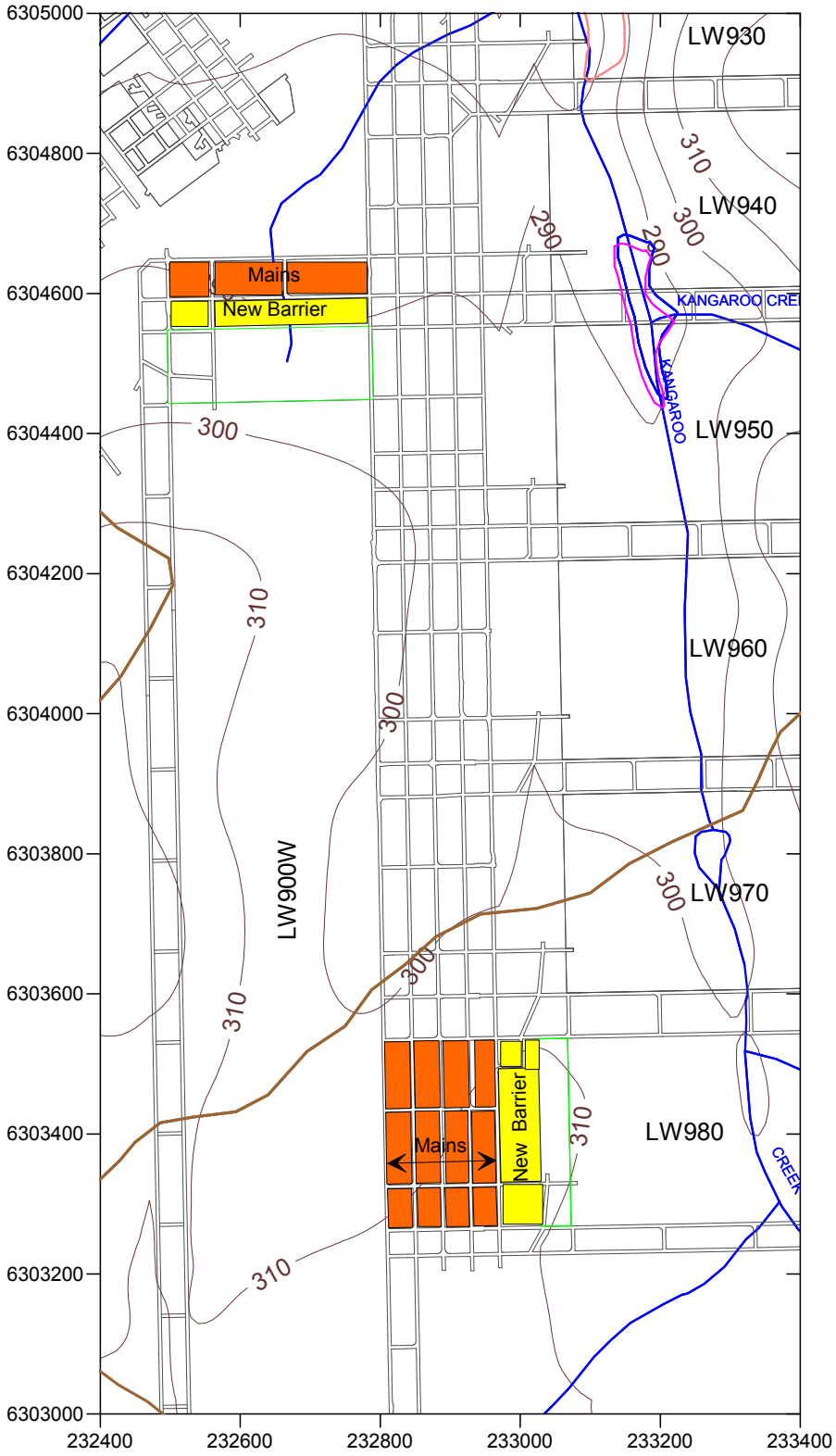
DgS	Engineer:	S.Ditton	Client:	Angus Place ANP-002/8	
	Drawn:	S.Ditton			
	Date:	24.10.13	Title:	Predicted Cumulative Tilt Contours with the Proposed Modifications to LWs 900W and 980 Included	
	Ditton Geotechnical Services Pty Ltd		Scale:	1:1,500	Figure No: 7



Key:

- Tracks (unsealed)
- 204 — 66kV Transmission Line & Poles
- Watercourses
- Newnes Plateau Shrub Swamps
- Newnes Plateau Hanging swamps
- Cliff lines (>20 m high)
- Rock Features (5-20 m High)
- Approved Longwall Blocks
- C Line — Installed Subsidence Lines
- Proposed Extension to LW 900W
- Predicted Strain Contours for the Approved LW900W Panel
- Proposed Strain Contours for the Proposed LW900W Panel

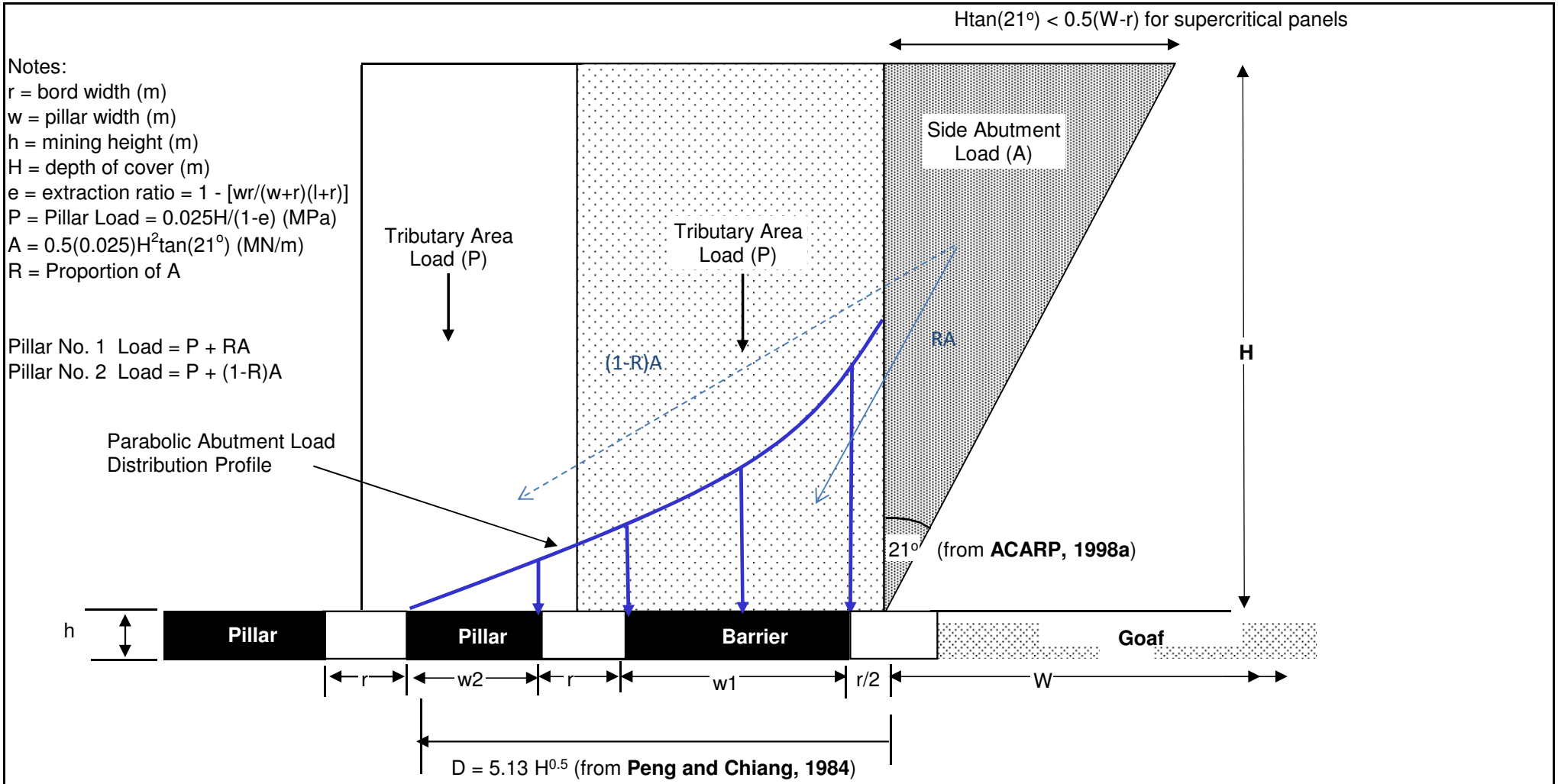
DgS	Engineer:	S.Ditton	Client:	Angus Place ANP-002/8	
	Drawn:	S.Ditton			
	Date:	24.10.13	Title:	Predicted Cumulative Horizontal Strain Contours for the Proposed Modifications to LWs 900W to 980	
	Ditton Geotechnical Services Pty Ltd		Scale:	1:1,500	Figure No: 8



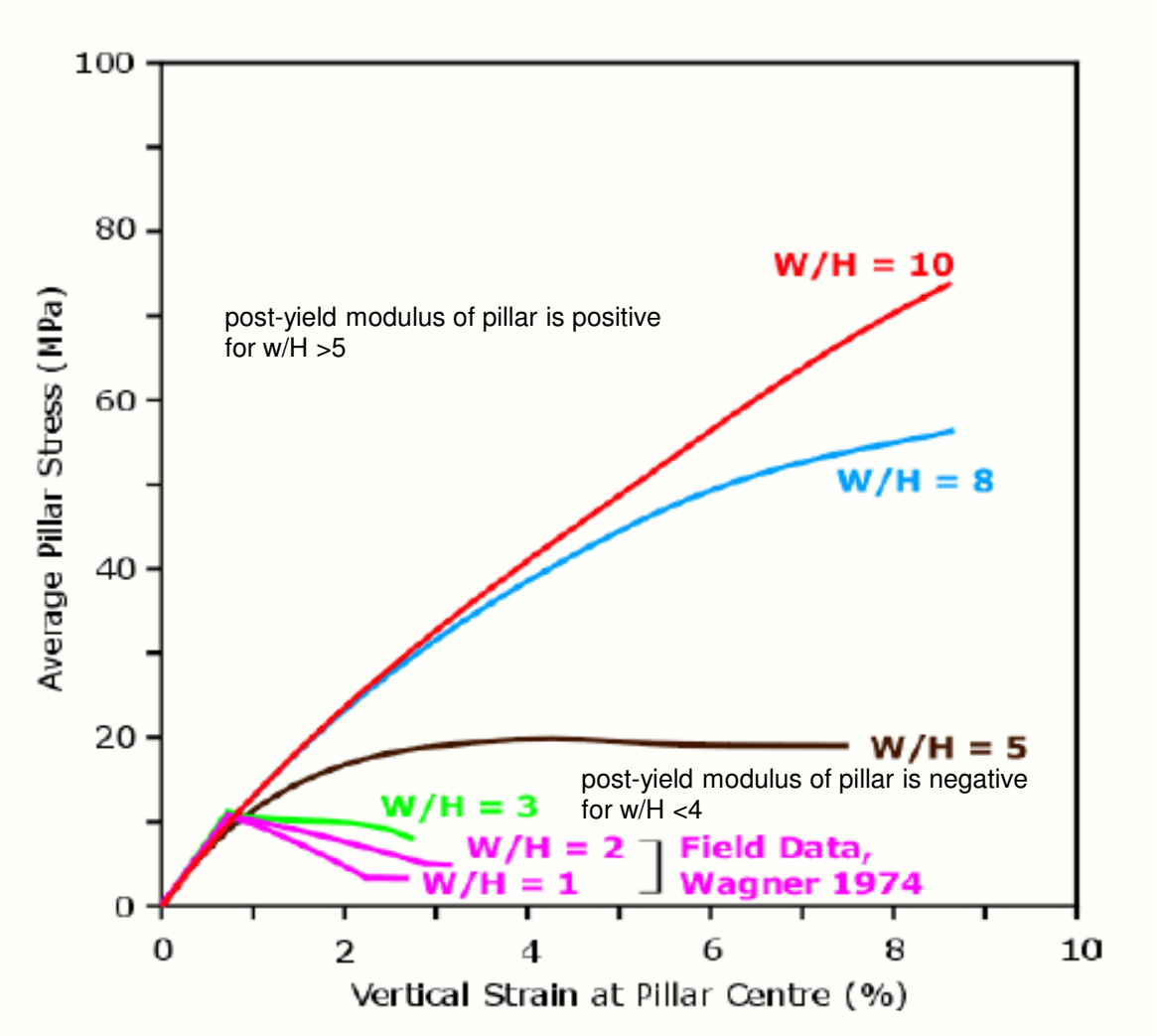
Key:

- Cover Depth (m)
- Access Roads (unsealed)
- Watercourses
- Shrub Swamps
- Hanging swamps
- Proposed Barrier Pillars
- Existing Main Headings Pillars within Longwall Abutment Loading Range
- Proposed Longwall Extensions

DgS	Engineer: S.Ditton	Client:	Angus Place ANP-002/8
	Drawn: S.Ditton		
	Date: 24.10.13	Title:	Proposed Barrier Pillars for LW 900W and 980 with Existing Main Headings Pillars
	Ditton Geotechnical Services Pty Ltd	Scale:	1:1,500 — Figure No: 9



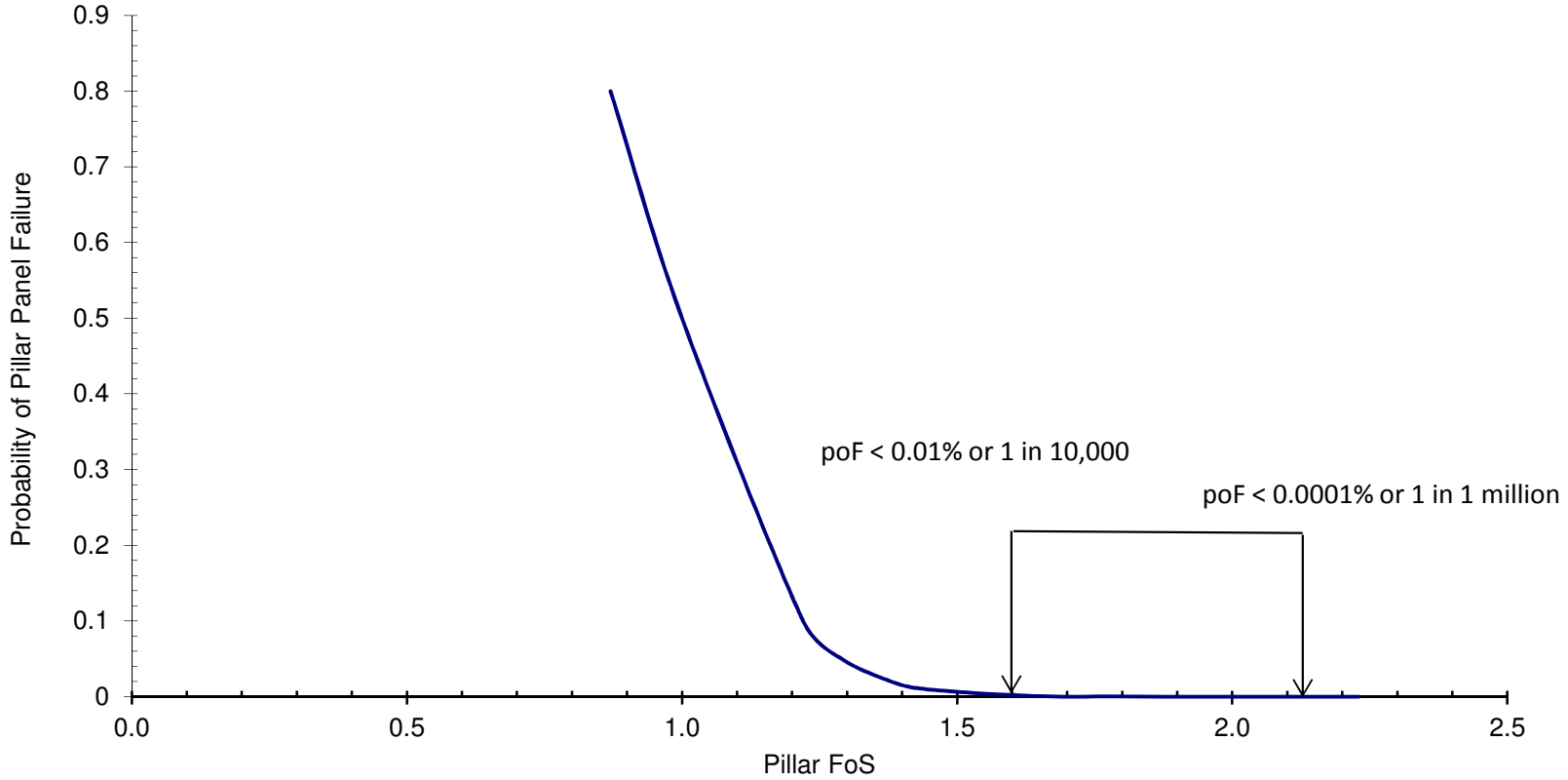
DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-002/8	
	Drawn:	S.Ditton			
	Date:	21.10.13	Title:	Analytical Model for Calculating Single Abutment Loads Acting on Maingate Pillars Adjacent to a Longwall Panel	
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No: 10



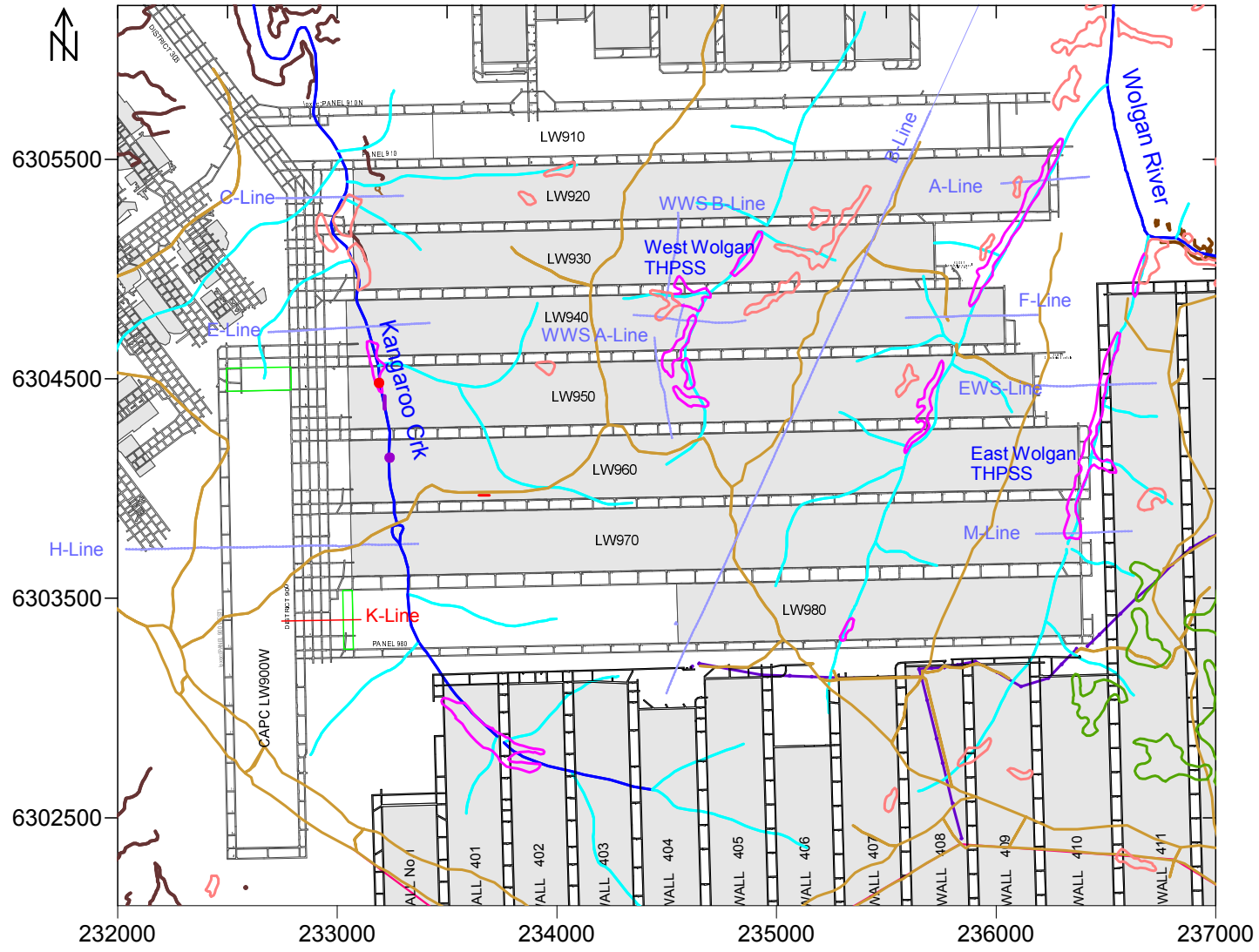
Ref: ACARP, 2005

DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place	
	Drawn:	S.Ditton		ANP-002/8	
	Date:	21.10.13	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

Reference : **ACARP, 2005 " Systems Approach to Pillar Design"**



DgS	Engineer:	S.Ditton	Client:	Centennial Angus Place ANP-002/8	
	Drawn:	S.Ditton			
	Date:	21.10.13	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 (already installed)

DgS

Ditton Geotechnical Services Pty Ltd

Engineer:	S.Ditton
Drawn:	S.Ditton
Date:	21.10.13

Client:	Centennial Angus Place ANP-002/8
Title:	Proposed Subsidence Monitoring Line for LW900W Modification Areas
Scale:	1:25,000
Figure No:	13