REPORT TO

Peabody Energy Ltd

on the

Updated Feasibility Level Geotechnical Study for Codrilla

Date: 23rd March, 2012
Project No: 001047
Report No: IMC1397

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1 INTRODUCTION

At the request Macarthur Coal (MCC), IMC Mining Group Pty Ltd (IMC) completed the analytical geotechnical work that was considered necessary prior to implementation of mining. A significant focus of geotechnical assessment was on the boxut - low wall areas. A kinematic analysis was completed to assess structural patterns across the site and an examination was made of the principal geotechnical hazards as they relate to mining.

1.1 Feasibility Study Assessment

The previous assessment presented a feasibility level geotechnical evaluation of the for the Codrilla site, in terms of the geotechnical data analysed, which characterised overburden and interburden conditions, and presented the details of generic slope stability analysis (Ref 2). However the assessment was not based around a finalised mine plan. In this case, the design recommendations presented were generic in nature and required review and validation against the proposed mine layout, particularly in relation to low wall and boxcut locations.

1.2 Scope of Work

The proposed scope of works was completed as follows:

1. Field program to investigate potential box cut locations, including geotechnical log development in WellCAD and field data reductions;
2. Refinement and confirmation of slope designs based on the current mine plan and geology model;
3. Interpretation of the structural model in relation to the box cut and low wall location;
4. Completion of acoustic scanner interpretation and kinematic analysis, including the development of a geological structure database;
5. Refinement of recommendations on ex-pit and in-pit dumping, potential risks to proposed mining method, and trafficability; and
6. Assessment of ex-pit spoil material for rehabilitation purposes. This involved evaluating the sandstone unit below the VU seam as a potential cover material for the spoil dump and also the dispersive nature of the spoil.

2 LOCATION OF SITE

The Codrilla Prospect is situated in the northern part of EPC 676, which is located astride the Fitzroy Developmental Road (Beef Road) about 25km south of the intersection with the Peak Downs Highway. Figure 2-1 shows the location of the Codrilla Prospect with respect to nearby coal mines and tenements.

The topography is essentially flat, with an elevation between RL180 in the north-west and RL160 in the south, averaging approximately RL170. The only watercourse traversing the Codrilla area is the ephemeral Devlin Creek.

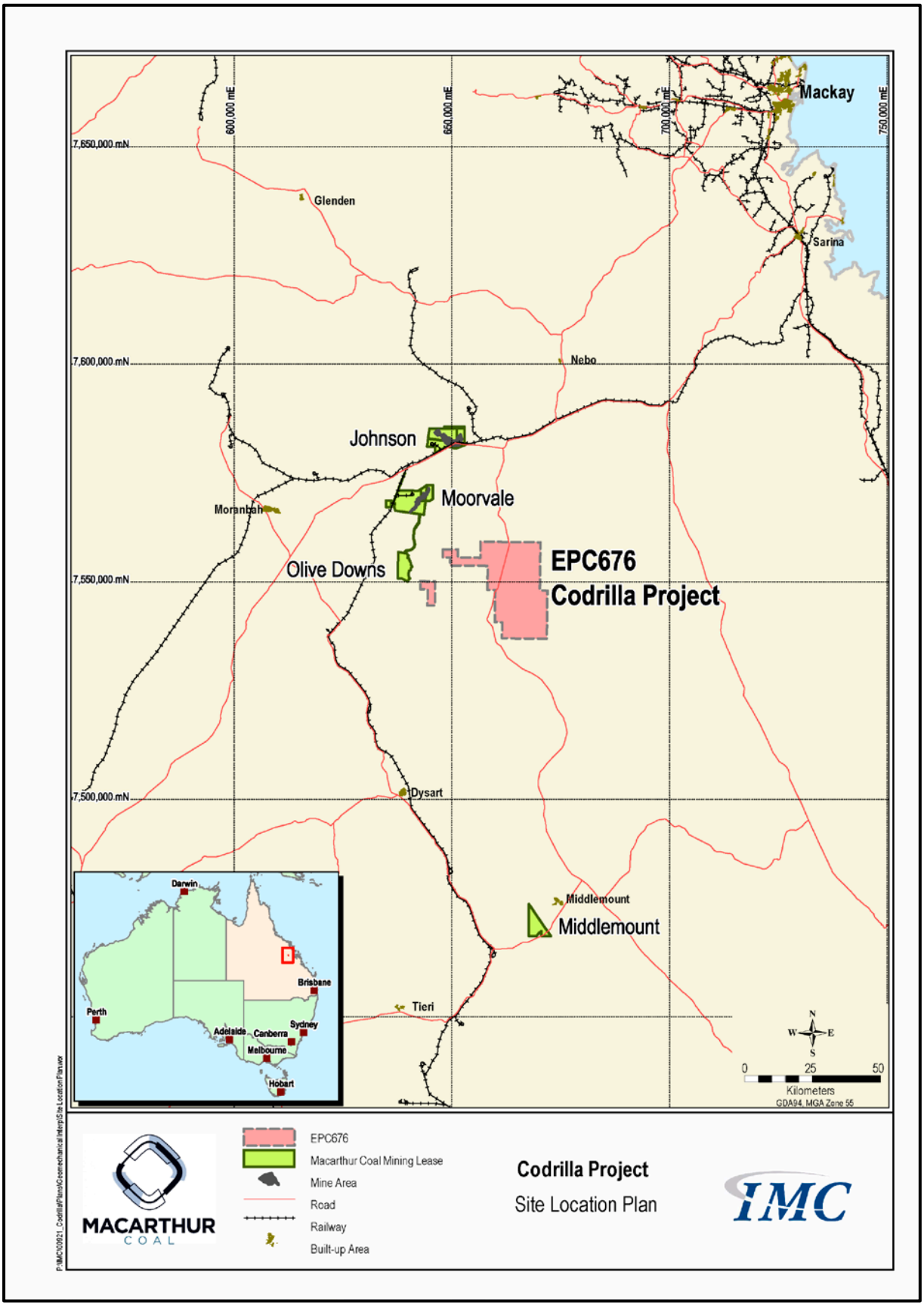

Figure 2-1: Site Location Plan

3 DRILLING PROGRAM

A programme of four fully cored geotechnical boreholes was carried out during August and September, 2011 under the supervision of MCC, with oversight from IMC. The locations of these holes, CX3106FC, CX3115FC, CX3122FC and CX3127FC are shown in Figure 3-1. These holes were cored from close to ground level, to enable engineering geological logs to be compiled for the soft overburden strata and coal seams, and to provide samples for geomechanical testing. The locations were determined to provide further coverage of the proposed low wall areas, following on from the 2009 study.

Coring was HQ giving nominally 63mm diameter core. Engineering logs for these holes are provided in Appendix A.

The acoustic televiewer was also completed on several holes as part of the routine geophysical program.

A significant drilling program was completed by MCC during 2011; however some of the data was not available at the time of report completion for incorporation into the report. It was also noted that the 2011 drilling program focused on coverage of the central portion and LOX areas for each pit.

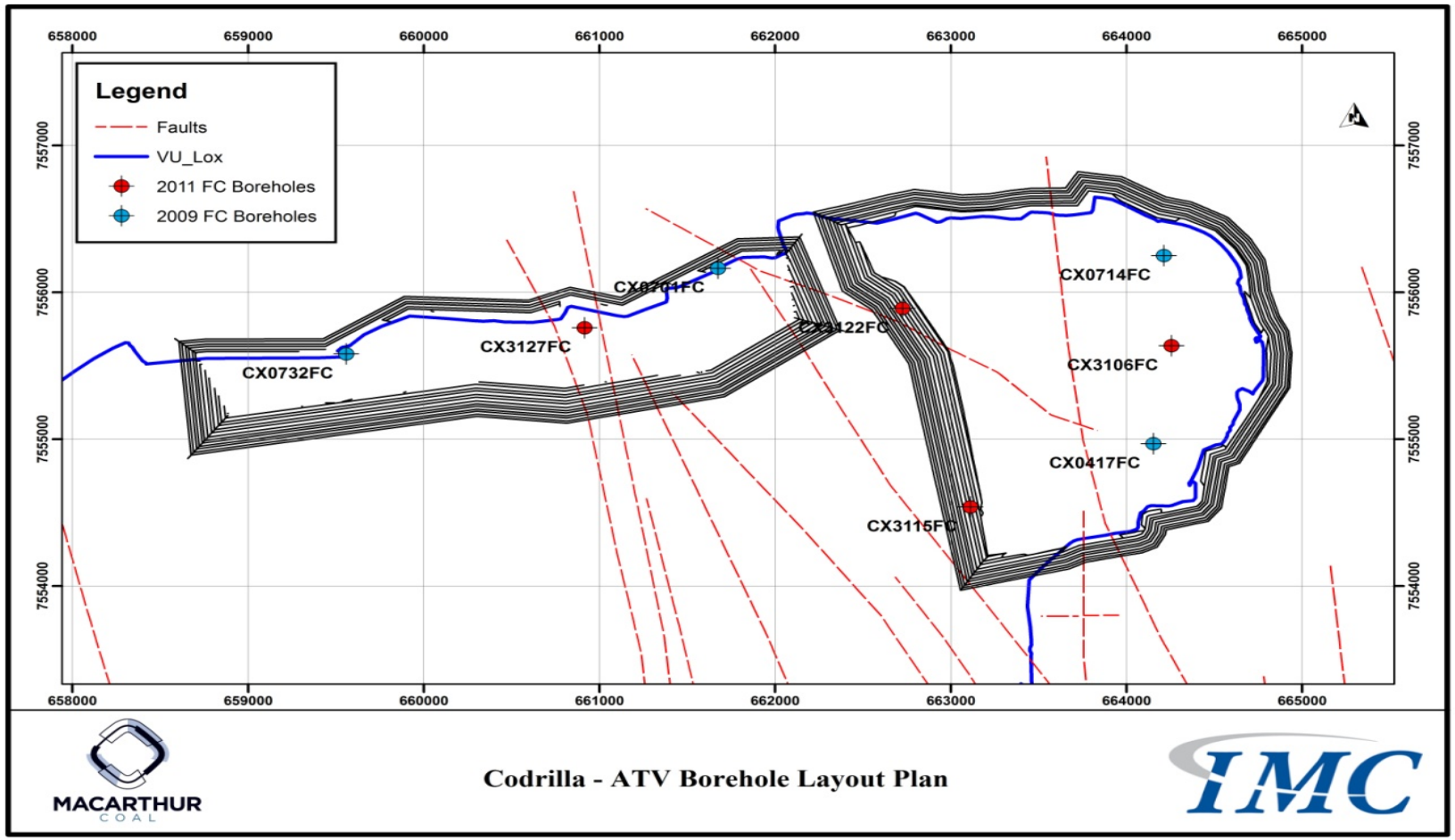

Figure 3-1: Fully Geotechnical Borehole Plan

4 LABORATORY PROGRAM

For this study, the laboratory program focused on improving the reliability of material properties used for slope stability modeling, as part of the previous phase of work. This was achieved by targeting specific soft overburden units (Tertiary and weathered Permian) for sampling and testing.

In addition to this, a separate program of testing was conducted on samples recovered from the soft overburden units and the sandstone unit below the VU seam, which was aimed at assessing the dispersive characteristics of the soft overburden and sandstone as a potential spoil cover material. The results of the testing are presented separately in Section 13.

Similar to the previous study, disturbed and undisturbed samples were taken from the four fully cored boreholes for geomechanical testing. All samples were preserved and dispatched to the laboratory in accordance with nominated procedures.

Routine soil classification (Atterberg limits), shrinkage, slake durability, unconfined compressive strength (UCS) were conducted on overburden, roof and floor samples by Cardno (Ullman & Nolan Technical Services Pty Ltd) at their Mackay laboratory. Triaxial testing was carried out by Trilab Pty Ltd in Brisbane. Young's modulus and Poisson's ration testing was not conducted as part of this laboratory program. Recommendations for roof and floor testing were not included as part of IMC's mandate.

4.1 Laboratory Results

4.1.1 Soft Overburden Units

Soil classification testing indicated the soft overburden to comprise primarily silty or sandy clay or clayey silt of low to intermediate plasticity, with minor occurrences of high plasticity clay. The results are summarised in Table 4-1.

Triaxial testing was conducted on selected samples of soft overburden and one sample of the Yarrabee Tuff to determine shear strength values. These comprised back-saturated, consolidated multistage tests with pore water pressure measurement. A further sample of the Yarrabee Tuff was tested by direct shear. Shear strength parameters derived from these tests indicate significant variability in the shear strength of material at the site. These are also dependent on the nature of the material tested. In this case, soft clayey materials and more competent, highly weathered rock would show variability in shear strength. The results are presented in Table 4-2.

Direct shear testing was carried out on comminuted core to provide an indication of run-of-mine spoil strength during the Feasibility Study. Core from CX0701FC was sent to Australian Soil Testing Pty Ltd where a 1m section from 15.5m to 16.5m was selected as being reasonably representative of the soft overburden. This was broken up manually to pass 6.7mm, and placed in a 100mm shear box under light compaction. Tests were made on a dry (as received) basis and after saturation.

The dry test results were not uniform, showing a drop-off of shear strength above 300 kPa with strength picking up again around 500 kPa. Examination of the test material suggested that below 300 kPa the material remained intact, but from 300 to 500 kPa the particle shape became flattened and lenticular, facilitating shearing.

Above 500 kPa the material became compressed into a more solid mass with much less void space. All the test curves showed a progressive increase in shear strength rather than a more traditional peak value. The 'failure' value was accordingly taken as approximately 10% strain, which tended to correspond to a leveling off in vertical compression (that is, zero volume change). These results are also summarised in Table 4-3.

Results of individual laboratory tests are presented in Appendix B.

4.1.2 Roof and Floor

Unconfined Compressive Strength (UCS) tests were conducted on rock samples from target coal seam roof and floor with slake durability tests on the latter. This mainly focused on the Leichardt and Vermont Upper seams.

Uniaxial compressive strength (UCS) testing indicated the roof units for all seams to be low strength, averaging approximately 10MPa. The predominant roof material was laminite.

Similarly, UCS testing indicated the floor units to be low strength, averaging approximately 8MPa. Floor units generally comprised mudstone, laminite and siltstone, with the occasional occurrence of sandstone.

The UCS and slake durability results are summarised in Table 4-3.

Results of individual laboratory tests are presented in Appendix B.

4.1.3 Spoil Cover Assessment Results

Specific testing requirements completed for the spoil cover assessment included:

- Emerson Class - conducted to assess the dispersive nature of the material, essentially with respect to rehabilitation of spoil and where the overburden (particularly the Tertiary clay) contained slake susceptible clay or mudstone;
- Atterberg Limits - determines the liquid and plastic limits of clayey materials, which is useful indicator of reactivity. An example of a reactive soil would be volcanically derived clay;
- Slake Durability - indicates of rock degradability, which measures changes in rock properties due to chemical and mechanical breakdown; and
- UCS - the unconfined compressive strength of the material.

A discussion of the results of the testing is presented in Section 13.

The results of the Emerson Class testing are summarised in Table 4-4 below, with the UCS, slake durability and Atterberg Limits testing included in Table 4-1 and Table 4-3.

Table 4-1: Soil Classification Tests

Borehole	Depth From (m)	Depth To (m)	Unit	Description	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Linear Shrinkage (%)	Class
CX0417FC	12.33		2	cream to orange with black slightly sandy clay	43	25	18	11.0	CI
CX0417FC	16.20		2	cream to orange with black slightly sandy clay	38	12	26	13.0	CI
CX0417FC	26.50		3	yellow grey & red-brown silty clay with f-c sand	38	15	23		CI
CX0701FC	9.48		2	orange buff slightly sandy clay	50	31	20	8.5	MI
CX0701FC	20.70		2	grey red-brown silty clay	44	12	28		CI
CX0701FC	38.55		3	grey orange very sandy clay	32	22	10	9.0	CL
CX0714FC	16.00		2	orange grey sandy clay (m-c sand)	45	24	21	14.0	CI
CX0714FC	24.00		3	orange grey sandy clay (m-c sand)	32	18	14	9.0	CL
CX0714FC	34.92		3	grey red-brown silty clay with f-c sand	35	13	22		CL/CI
CX0714FC	42.80		4	grey red clay	51	26	25	13.5	CH
CX0714FC	50.13		4	cream red clay	48	30	18	11.0	MI
CX0714FC	64.00		5	grey orange laminated clay	54	35	20	13.5	MH
CX0714FC	111.88		YT	yellow to cream tuff	43	19	24	8.0	CI
CX0732FC	20.19		3	grey yellow-brown silty clay with f-m sand	26	15	11		CL
CX0732FC	31.53		3	grey red-brown silty clay	62	17	45		CH
CX0732FC	56.75		YT	brown tuff	47	23	24		CI
CX3106FC	9.24	9.48	2	Silty sand - f-m grained	33	15	18	11.0	SC
CX3106FC	14.00	14.20	2	Sandy clay, reddish grey	43	20	23	12.5	
CX3106FC	57.95	58.25	3	HW claystone, reddish grey	35	20	15	6.5	
CX3115FC	10.00	10.30	2	XW claystone, sandy, reddish grey	44	14	30	15	CI
CX3115FC	15.48	15.68	3	XW claystone, sandy, grey	46	15	31	15.5	CI
CX3115FC	55.00	55.20	3	HW claystone, reddish grey	44	19	25	12.0	CI
CX3115FC	69.19	69.39	4	HW clayey sandstone, yellow brown	39	22	17	8.5	SC
CX3122FC	10.00	10.20	2	XW claystone, reddish grey	26	18	8	2.5	SC
CX3122FC	24.24	24.44	3	XW claystone, grey brown	37	19	18	8.5	CI
CX3127FC	10.30	10.50	2	XW claystone, sandy, reddish grey	44	13	31	14.5	CI
CX3127FC	36.04	36.24	3	XW claystone, sandy, reddish brown	56	24	32	14.0	
CX3127FC	44.63	44.85	4	HW siltstone, clayey, grey brown	65	28	37	19.0	CH

orange highlighted cells indicate 2011 test results

Table 4-2: Shear Strength Test Results

Borehole	Depth From (m)	Depth To (m)	Horizon	Lithology	Test Type	Moisture (%)	Density (t/m^3)	Cohesion (kPa)	Friction (ϕ)
CX0417FC	26.50		Unit 3	silty clay with f-c sand	triaxial	17.2	2.28	24	29.0
CX0417FC2	125.54		YT	tuff	direct shear			11	38.5
CX0701FC	20.70		Unit 2	silty clay	triaxial	16.2	2.20	70	13.0
CX0714FC	34.92		Unit 3	clay with f-c sand	triaxial	12.4	2.26	65	33.0
CX0732FC	20.19		Unit 3	silty clay with f-m sand	triaxial	14.9	2.23	58	29.0
CX0732FC	56.75		YT	tuff	triaxial	18.3	2.15	70	29.5
CX0701FC	15.5	16.5	Unit 2	reconstituted (spoil)	direct shear dry	15.6	1.47 (bulk)	0	40.0
CX0701FC	15.5	16.5	Unit 2	reconstituted (spoil)	direct shear saturated	15.6	1.47 (bulk)	0	29.0
CX3106FC	9.48	9.78	Unit 2	silty sand	triaxial	13.8	2.19	35.5	30.8
CX3106FC	62.33	62.61	Unit 4	MW siltstone	triaxial	13.3	2.00	**262.1****	29.9
CX3115FC	11.44	11.77	Unit 2	XW claystone	triaxial	15.4	2.18	32.6	30.7
CX3115FC	74.89	75.19	Unit 4	HW sandstone	triaxial	6.8	2.56	Specimen failed Stage 1	
CX3122FC	5.12	5.45	Unit 1b	XW claystone	triaxial	15.6	2.13	37.0	22.5
CX3127FC	8.77	9.05	Unit 2	XW claystone	triaxial	12.3	2.25	**120.0****	22.5
CX3127FC	41.60	41.90	Unit 4	HW siltstone	triaxial	21.1	2.09	71.5	18.0

orange highlighted cells indicates 2011 test results;
** indicates low reliability value

Table 4-3: Strength and Durability Tests

Borehole	Depth From (m)	Depth To (m)	Horizon	Lithology	UCS (MPa)	Moisture (%)	Density (t/m^3)	Slake (%)	Modulus (GPa)	Poisson's Ratio
CX0417FC	78.39		Unit 5	siltstone	9.5	5.6	2.44			
CX0417FC2	104.32		LL3-VU interburden	sandstone	25.4	3.5	2.73		6.22	0.23
CX0417FC2	108.97		LL3-VU interburden	carb siltstone	8.3	5.6	2.42			
CX0417FC2	126.18		VU floor FL1	siltstone				85.6		
CX0417FC2	126.32		VU floor FL1	siltstone	9.0	3.9	2.50			
CX0701FC	58.10		VU sub-floor FL2	mudstone (sw)				21.1		
CX0701FC	58.74		VU sub-floor FL2	mudstone (mw)	2.0	14.2	2.21			
CX0701FC	61.62		VU sub-floor FL3	sandstone (mw)	2.7	9.6	2.34			
CX0714FC	78.88		Unit 5 (LL2 floor)	mudstone				17.1		
CX0714FC	111.99		VU floor FL1	siltstone				96.3		
CX0732FC	58.95		VU floor FL1	mudstone				29.4		
CX0732FC	61.73		VU sub-floor FL3	sandstone (mw)	2.3	9.5	2.32			
CX3106FC*	**189.37**	**189.60**						**95.6**		
CX3106FC*	**191.70**	**192.01**		**Sandstone**	**20.2**	**1.1**	**2.72**			
CX3115FC	82.76	83.06		Sandstone	9.3	3.7	2.52			
CX3115FC	84.37	84.66		Sandstone	4.1	8.2	2.42	3.1		
CX3115FC	116.03	116.23	LL2 Roof	Siltstone	11.6	4.2	2.46			
CX3115FC	119.6	119.86	LL2 Floor	Siltstone	1.5	2.4	2.55	96.5		
CX3115FC	153.21	153.48	VU Roof	Siltstone	45.5	2.3	2.54			
CX3115FC	161.94	162.26	VU Floor	Siltstone	4.3	2.9	2.36	91.3		
CX3115FC*	**169.5**	**169.72**		**Sandstone**	**65.7**	**1.6**	**2.59**	**96.8**		
CX3118CR	113.54	113.81	LL2 Roof	XM	8.0	6.6	2.36			
CX3118CR	117.15	117.47	LL2 Floor	XM-Sandstone	5.2	6.1	2.53	14.9		
CX3118C	143.85	144.06	VUS Roof	XM	12.0	3.9	2.523			
CX3118C	155.51	155.79	VU Floor	Mudstone	13.9	5.0	2.436	71.8		
CX3119C	139.76	140.07	Interburden	Mudstone	23.8	2.0	2.731			
CX3119C	140.66	140.93	Interburden	XM	5.1	5.5	2.388	16.6		

orange highlighted cells indicates 2011 test results; *** indicates spoil suitability assessment**

Table 4-3: Strength and Durability Tests - Continued

Borehole	Depth From (m)	Depth To (m)	Horizon	Lithology	UCS (MPa)	Moisture (%)	Density (t/m^3)	Slake (%)	Modulus (GPa)	Poisson's Ratio
CX3119C	141.03	141.31	LL2 Roof	XM	6.2	5.0	2.400			
CX3119C	143.88	144.14	LL2 Floor	Siltstone				44.5		
CX3119C	173.77	174.07	VU Roof	Sandstone	34.1	2.4	2.644			
CX3119C	182.03	182.3	VU Floor	Siltstone/Mudstone	16.8	3.5	2.505	69.6		
CX3122FC	78.04	78.84	LU Roof	Siltstone	1.1	10.2	2.352			
CX3122FC	80.69	80.99	LU Floor	Siltstone	1.7	13.1	2.206	3.5		
CX3122FC	99.13	99.4	LL1 Roof	Sandstone	13.0	3.6	2.545			
CX3122FC	101.57	101.87	LL1 Floor	Sandstone	6.4	4.0	2.502	92.5		
CX3122FC	136.87	137.18	LL2 Roof	Siltstone/Mudstone	9.9	3.3	2.515			
CX3122FC	142.59	142.85	LL2 Floor	Siltstone	2.9	6.1	2.377	44.7		
CX3122FC	165.73	165.96	VU Roof	Siltstone	14.4	2.6	2.528			
CX3122FC*	**175.00**	**175.27**	**VU Floor**	**Siltstone**	**16.5**	**3.9**	**2.481**	**86.1**		
CX3123C	147.61	147.91	VU Floor	XM/Mudstone	9.3	4.1	2.49			
CX3123C	156.36	156.66	VU Floor	XM	12.1	4.1	2.447	70.1		
CX3124C	155.20	155.47	VUF Roof	XM						
CX3124C	166.24	166.50	VUF Floor	Mudstone	11.3	4.7	2.403	74.5		
CX3124C	167.42	167.68	LL3 Roof	XM						
CX3124C	171.5	171.80	LL3 Floor	XM	1.9	3.6	2.427	65.3		
CX3124C	194.45	194.73	VUF (2) Roof	XM	7.8	3.7	2.483			
CX3124C	197.79	198.07	VUF (2)Floor	XM				82.3		
CX3124C	198.35	198.60	VU Roof	XM	8.2	3.9	2.523			
CX3124C	207.77	208.09	VU Floor	YTB (TU)	4.9	6.4	2.398	31.0		
CX3127FC	72.64	72.98	VU Roof	XL	2.2	9.8	2.319			
CX3127FC	82.42	82.71	VU Floor	XM	2.2	10.8	2.275	11.2		
CX3127FC	84.93	85.15		Sandstone	18.9	3.0	2.51			

orange highlighted cells indicates 2011 test results; *** indicates spoil suitability assessment**

Table 4-3: Strength and Durability Tests - Continued

Borehole	Depth From (m)	Depth To (m)	Horizon	Lithology	UCS (MPa)	Moisture (%)	Density (t/m^3)	Slake (%)	Modulus (GPa)	Poisson's Ratio
CX3127FC*	**99.00**	**99.21**		**Sandstone**	**22.7**	**1.8**	**2.53**	**95.4**		
CX3129C	63.51	63.73	VU Roof	XL						
CX3129C	73.29	73.59	VL Floor	Mudstone	4.0	10.1	2.306	41.5		
CX3132C	85.63	85.93		XM	0.7	8.5	2.276			
CX3132C	88.90	89.20		XM	0.2	11.3	2.168	30.1		
CX3132C	110.23	110.46		Siltstone	12.3	3.8	2.546			
CX3132C	122.25	122.5		Siltstone	2	5.8	2.409	50.8		

orange highlighted cells indicates 2011 test results; *** indicates spoil suitability assessment**

Table 4-4: Emerson Class Results

Borehole No.	Depth From	Depth To	Sample No.	Emerson No.	Comment
CX3106FC	14.00	14.20	165753	5	Unlikely to be sodic
CX3106FC	55.00	55.20	165765	6	Not sodic
CX3122FC	21.00	21.24	6224	4	May be sodic
CX3122FC	69.04	69.24	6239	7	No Dispersion

orange highlighted cells indicates 2011 test results

5 GEOLOGY INTERPRETATION

5.1 Deposit Geology

Figure 5-1 shows the stratigraphical succession. The main target seam is the Vermont Upper (VU) at the base of the Permian Rangal Coal Measures. This has a typical thickness of about 7.5m over the main part of the site however this reduces to about 4.5m in the south.

Other seams within the Rangal Coal Measures with mining potential include the various splits of the Leichardt Seam, the LU, LL1 and LL2 seams. Another minor seam, the LL3 occurs in places below the LL2 Seam, and may represent a split off the VU Seam. This is typically present in the southern area where the VU Seam has a reduced thickness. The Leichardt Seams are generally between 1m to 2m thick, but can be over 3m thick in places. A feature of the Codrilla deposit is the wide variation in thickness of the upper seams and of the interburden distance between them.

The Rangal Coal Measures (RCM) is approximately 110m thick and comprises fine lithic sandstone, siltstone and mudstone. The base of the RCM is marked by the Yarrabee Tuff, which is a widespread and easily recognised marker band. The underlying Fort Cooper Coal Measures strata are predominantly sandstone with banded coal seams. The VL1 Seam is a thin stony seam immediately below the Yarrabee Tuff; the VL2 is thicker, from 2.5m to 4.0m on average but is also stony. Neither of these seams is currently included in the mine plan.

The Rangal Coal Measures are overlain by the barren Rewan Group which comprises sandstone, siltstone and mudstone with a characteristic greenish-grey colour. These would only be present in the overburden where the depth of mining exceeds the present 100m or so.

The top of the Permian strata are deeply weathered, with the base of weathering between 50m and 100m below ground surface. The Permian weathering thickness is interpreted to be between 20m and 50m thick, which is greater than usual, and includes a major proportion of highly to completely weathered material in the form of sandy claystone. The overlying Tertiary is for the most part sandy or silty clay of similar characteristics to the weathered Permian, and is interpreted to be 40m thick on average with range between 25m and 65m. The thick Tertiary and deep weathering appears to be a unique feature of the Codrilla Deposit.

Typical cross sections showing the disposition of the seams for the western and southern parts of the mining area are presented in Figure 5-2 and Figure 5-3.

Isopachs of VU Seam thickness is presented in Figure 5-4. The VU Seam has an average thickness of approximately 6.30m across the site, with a median thickness of approximately 7.0m. Thickness ranges from 1.0m in borehole CX1110, to 10.1m in borehole CX0729.

5.2 Geological Structure and Seam Dip

The Codrilla Prospect is located on the eastern flank of the Coxendean Sub-basin, a separate eastern extension of the Bowen Basin. The coal measures strata have a regional north-south strike with a dip to the west, however just north of the Codrilla Prospect the strike has been disrupted by deformation around the dome of the Bundara Intrusive Complex, causing a sharp swing to a westerly strike direction.

As a consequence the strata at Codrilla form a syncline with a south-west axis with seam dips of the order of 10° around the nose of the syncline, flattening out at depth. South of the nose the strike is south with dips up to 15°, whilst on the north side the strike is due west with dips increasing towards the west and reaching up to 20°.

Figure 5-5 shows structure contours on the base of the VU Seam, which represents the mining floor.

The contours in Figure 5-5 are based on the borehole intersections and are thus limited in confidence by the number of available boreholes. It is apparent that they can only give a general indication of the disposition of the VU Seam, particularly on the limbs of the syncline where the contours are typically based on only two in-line values. Seam dips as recorded from cored boreholes vary from 20° to 30°, sometimes with variations within the borehole.

Seam dips recorded from cored boreholes are noted in Table 5-1. In general terms these fit with the structure contours from the geological model, with dips up to 25° along the western limb and dips from 20° to 10° around the nose. However, there are divergences such dips of 30° or 40° on the western limb where the contours indicate an average of 19°, and cases of significant variation within single boreholes. It is thus apparent that seam dip can be more variable at a local level than indicated by the contours.

Depth of cover varies along the lox line from 60m to 65m along the western limb and 75m along the southern limb, but increases to 90m plus around the nose of the syncline. The depth of cover contours for the VU Seam is shown in Figure 5-6, together with the interpreted subcrop (LOX) line.

5.2.1 Faults

The current fault interpretation is shown in Figure 5-6. This is based on interpretation of the structure contours and the 2D seismic survey. It shows a series of north to north-northwest striking normal faults forming a horst and graben complex across the nose of the syncline. The original interpretation of the 2D seismic traverse (676-02-03) suggests the faults are steep reverse faults with displacements in the order of 8m to 12m. Interpretation of recently procured 2D seismic data indicated a wide structurally disturbed zone in the east pit. A discussion of this is presented in Section 10.9.

In addition to the fault interpretation discussed above, there are a number of anomalous structural features apparent in individual boreholes, such as missing seams, or seam repeats and over thrusting in the VU Seam. Anomalous geological structure identified from borehole interpretation is presented in Table 5-1. This was only completed for the 2009 data at this stage. The location of these boreholes is shown in Figure 5-7.

Missing seams generally indicate the presence of normal faults. Four instances of missing minor seams were noted, in CX0739, CX0418, CX0749 and 1910, none of which lie on interpreted fault lines. However, the thickness variation in the minor seams between boreholes is significant and the level of confidence in the correlation is therefore not high. This may be due to insufficient boreholes to confirm the natural variation or it may indicate that the deposit is more structurally disturbed than the model indicates. The top of the VU Seam appears to have been faulted out in CX0419.

Seam repeats or anomalous increases in thickness are usually indicative of thrusting or reverse faulting arising from compression during the latest tectonic phase of the Bowen Basin. Thrusts are generally of low to moderate angle and of relatively small vertical displacement, and as such, they are virtually impossible to detect from structural interpretation or seismic survey. They are normally only detected from borehole interceptions where coal seams are affected.

Seam repeats were noted in CX0419 (VU), CX0700 (LL1), CX0720 (LL2), CX0735 (VU), CX0742 (YT) and CX1917 (VU) and a thrust was noted within the VU Seam in CX0729. The over thrust VU Seam in CX0735 was not replicated in the re-drill CX0735C4.

Given the incidence of thrusting note above, it can be concluded that thrusting and local perturbation in the VU Seam could be widespread, particularly if there is interaction with the postulated normal faults causing reverse displacement and buckling against them.

Table 5-1: Anomalous Borehole Structure

Borehole	Feature	Horizon	Dip
CX0417C		LL2 boc	2^0
CX0417C		LL3 toc	20^0
CX0417C		LL3 boc	5^0
CX0417FC		LL1	4^0
CX0417FC		LL2	5^0 - 30^0
CX0417FC2		VU	5^0 - 10^0
CX0418	VU fault zone (thrust)		
CX0418	VL2 missing		
CX0419	top VU faulted out		
CX0700	LL1 fault repeat		
CX0700	LL2 overthrust		
CX0700	fault zone 130.5m		
CX0700	VU top repeat?		
CX0701C4		VU	10^0, 20^0, 25^0
CX0701C4		VL1 boc	15^0
CX0701FC		VU	20^0
CX0703C4		LU	10^0
CX0703C4		VL1 subfloor	8^0
CX0707C4		LL2	10^0
CX0707C4		VU toc	3^0
CX0708C4		LL2	3^0
CX0708C4		VU toc	2^0
CX0708C4		VL1 boc	4^0
CX0714C4		LL2	13^0
CX0714C4		VU	5^0 - 10^0
CX0720	LL2 repeat		
CX0720C	LL2 thrust repeat	LL2	4^0
CX0721	GI reduced thickness		
CX0727C4		LL2 toc	4^0
CX0729	fault zone in VU 92.0-94.0		
CX0729C4	VU sheared, faulted	VU toc	10^0
CX0732FC		VU	25^0
CX0735	VU fault repeat		
CX0739	LL2 missing		
CX0742	YT repeat?		
CX0743		LL2 boc	10^0
CX0749	LL3 missing		

5.2.2 Intrusions

From the available data, there was no direct evidence from borehole intersections of igneous intrusion at Codrilla, with the only suggestion of intrusive activity being a reference to coked coal in the LL3 Seam. However, given the presence of a major intrusive body to the north, some dykes emanating from this could be expected to transect the deposit.

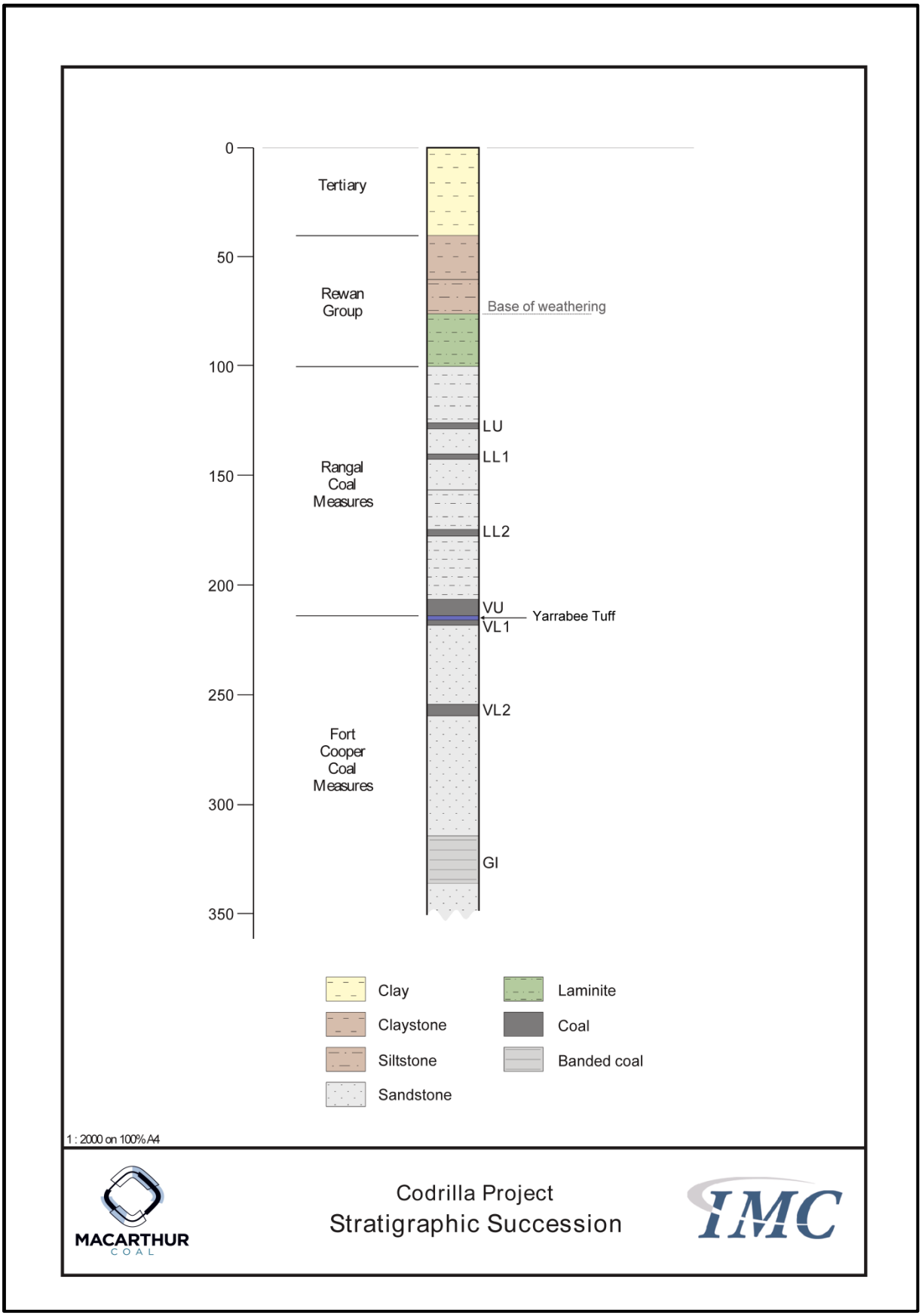

Figure 5-1: Generalised Stratigraphic Section

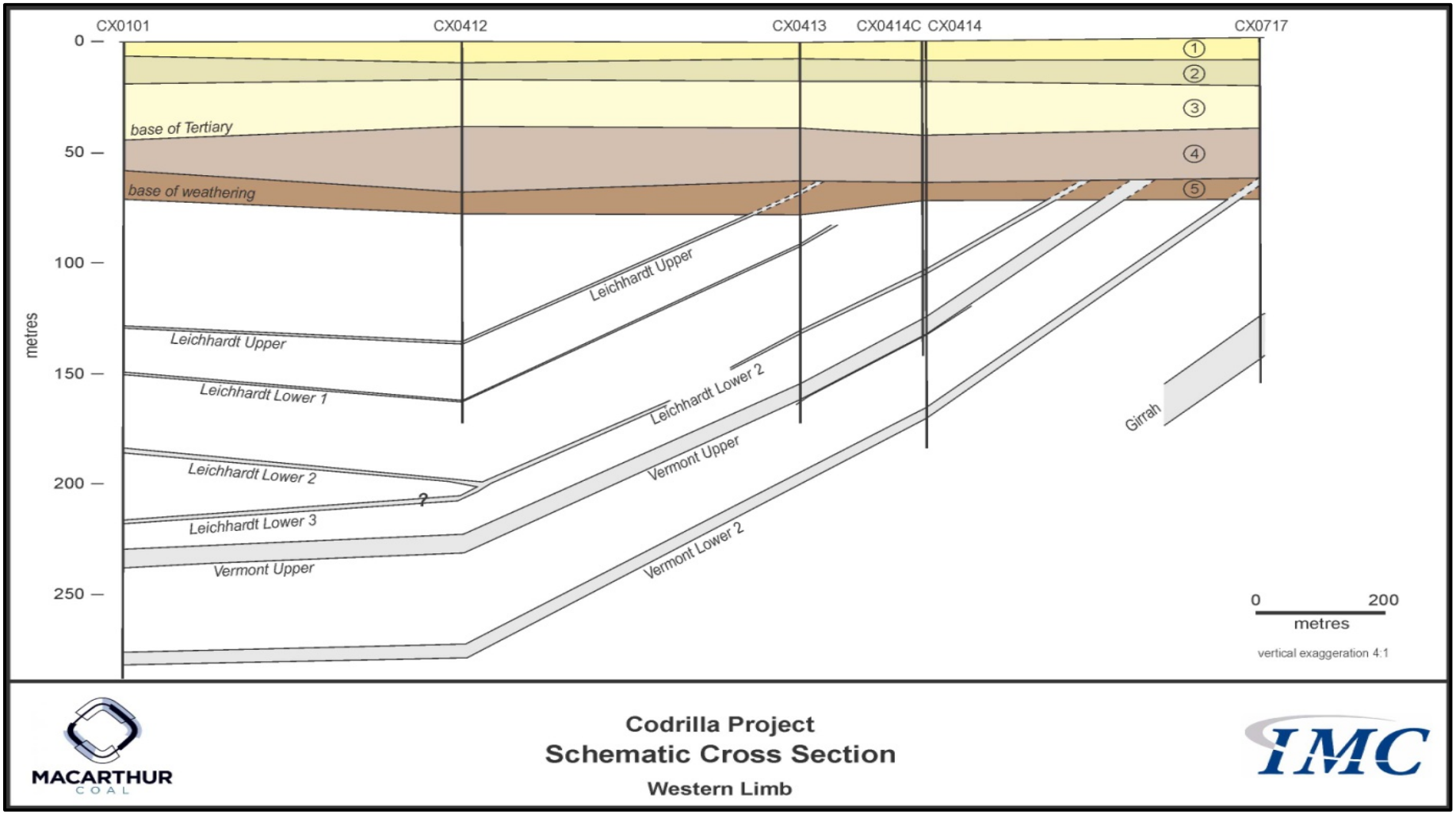

Figure 5-2: Geology Cross Section – Western Limb

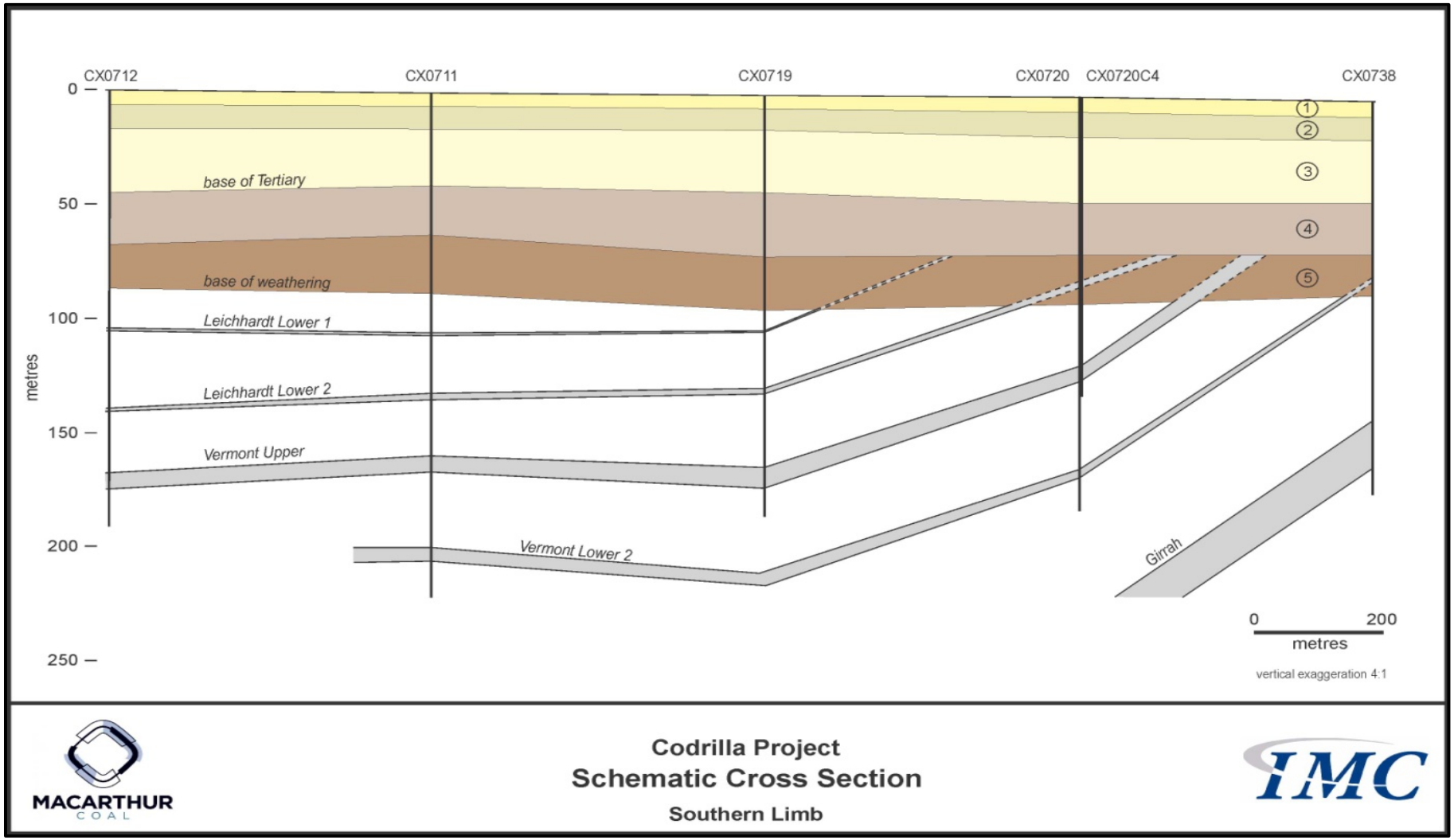

Figure 5-3: Geology Cross Section – Southern Limb

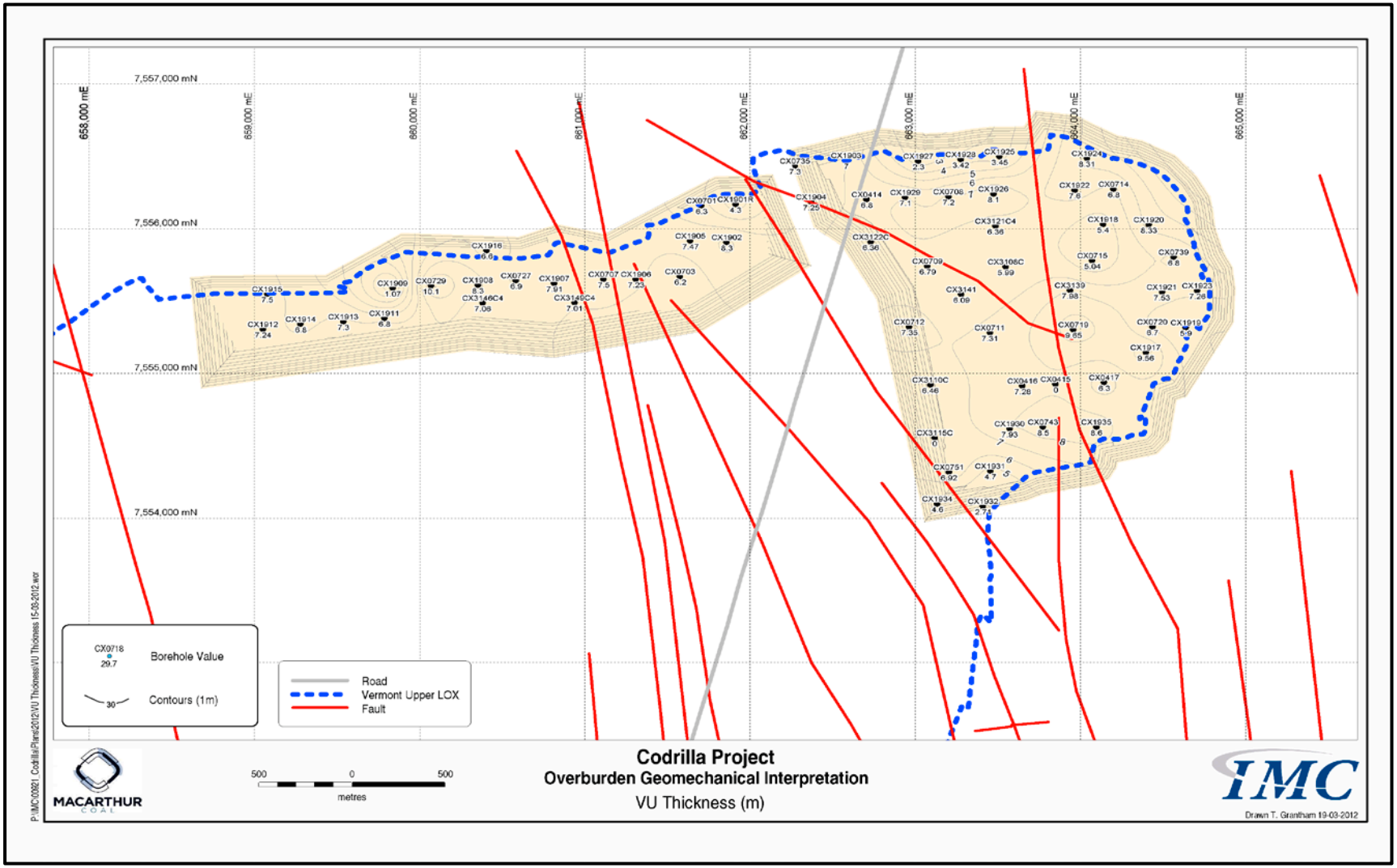

Figure 5-4: VU Seam Thickness

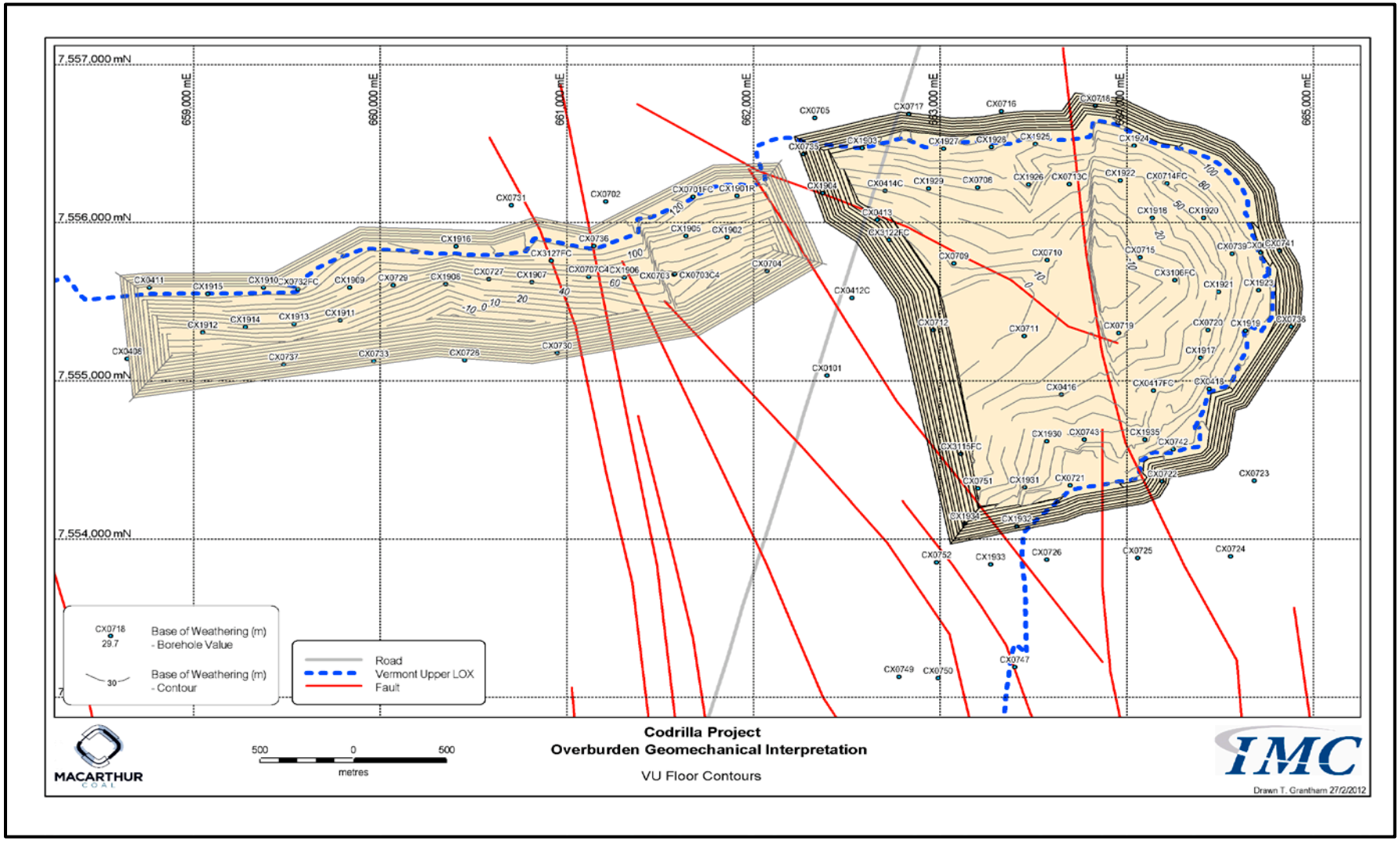

Figure 5-5: VU Seam Structure

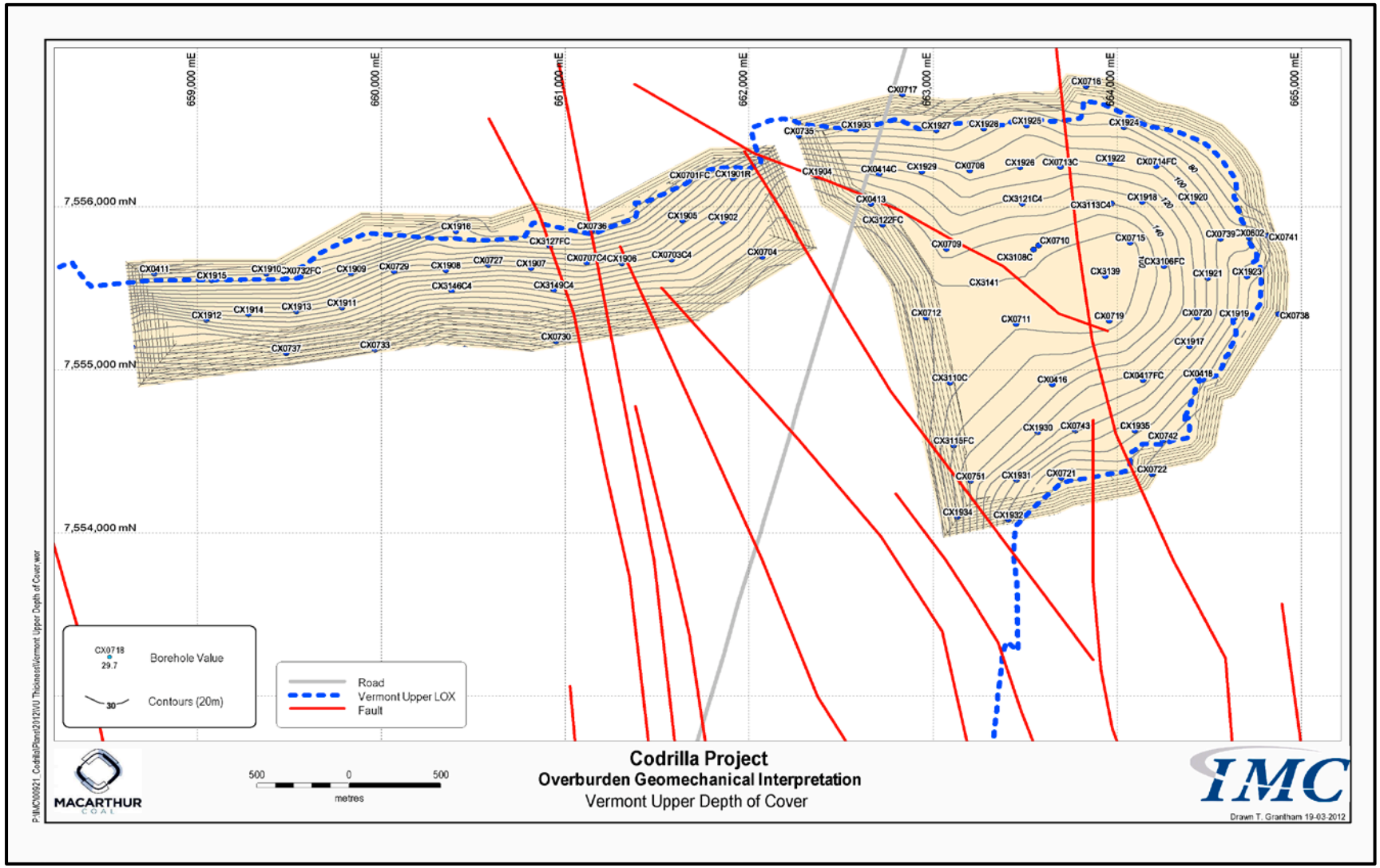

Figure 5-6: VU Depth of Cover

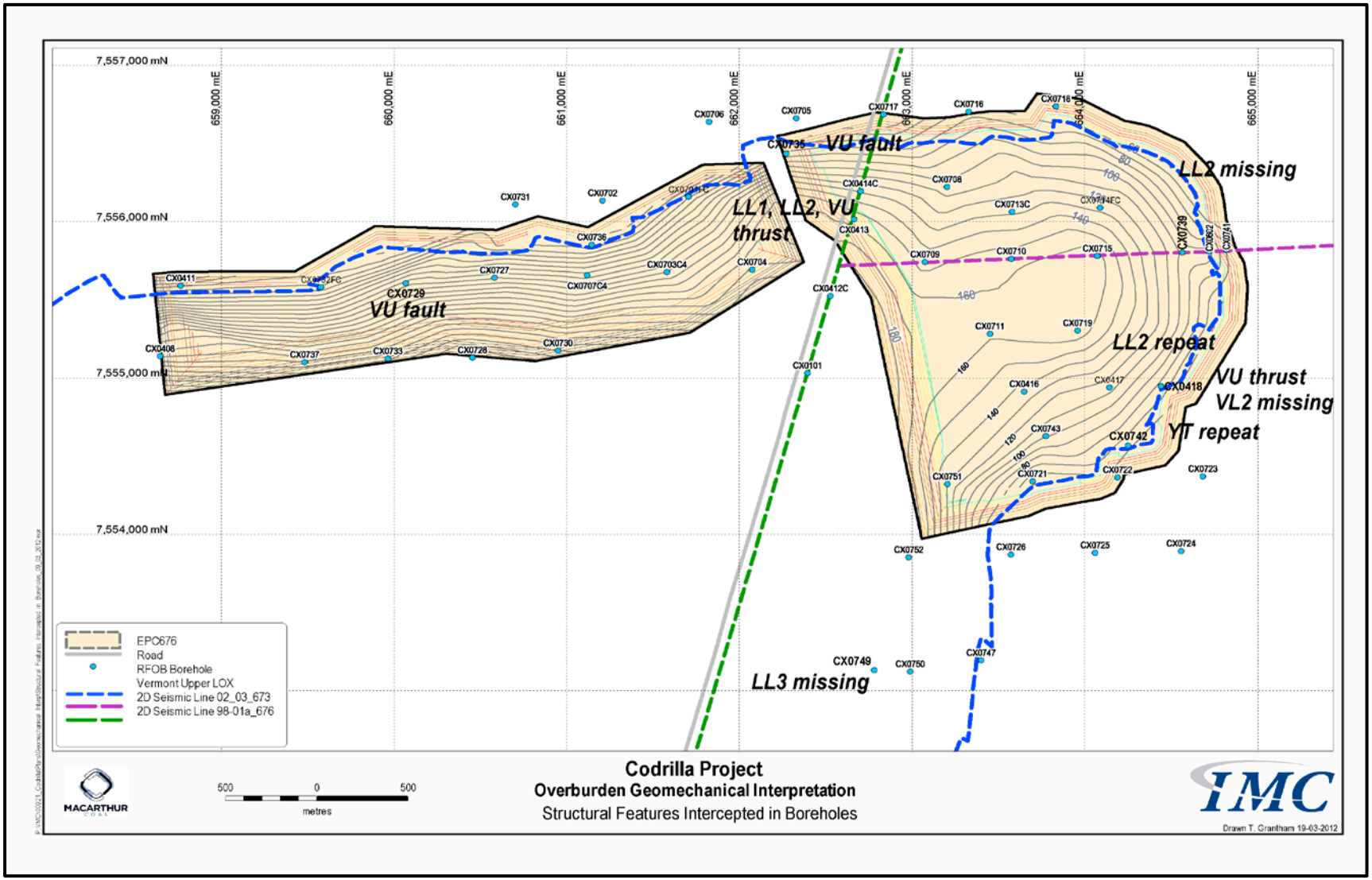

Figure 5-7: Geological Structure – Borehole Intercepts

6 OVERBURDEN, INTERBURDEN AND FLOOR CONDITIONS

6.1 Overburden

The four fully cored geotechnical boreholes during the 2011 field program were drilled to provide a detailed engineering description of the overburden material, as well as provide samples for testing. The results were incorporated with the 2009 drilling program, in which four fully cored boreholes were completed.

Overburden, in the context of this section, refers to material down to the VU Seam at subcrop, and hence is restricted to the Tertiary and weathered Permian layers. These are essentially horizontally disposed as indicated on the cross sections presented in Section 5 (Figure 5-2 and Figure 5-3).

A synopsis of the eight fully cored boreholes (2009 and 2011 fully cored programs) is presented in Figure 6-1. This shows a summary of the main litho types down to the base of weathering. This shows the overburden sequence interpreted into five geomechanical units.

The main component of the overburden is silty or sandy clay or claystone, orange grey in the upper part and pale grey with red or red-brown mottling in the lower part. Also included in the latter are weathered ironstone bands and in some places dark brown to black clay horizons. Gravel layers were recorded in several boreholes, generally at the Tertiary/Permian contact.

Also marked on Figure 6-1 is the depth at which joints are first apparent and bedding becomes discernable. There is no indication of bedding or joints above these levels.

The overburden sequence was interpreted into five geomechanical units, which are indicated in Figure 6-1 and are summarised below in Table 6-1.

Table 6-1 : Summary of Overburden Units

Unit	Horizon	Gamma Count Av.	Min Thickness (m)	Max Thickness (m)	Average Thickness (m)	Material	Nature	Condition	Age
1	Superficials	60	4.2	10.2	7	Clayey sand	Unconsolidated	Loose	Quaternary
2	Laterised Zone	80	6.7		11	Orange-grey sandy clay	Completely weathered	Stiff	Tertiary
3	Tertiary Clay	60	8.5	39.2	22	Pale grey, orange-grey, red-grey sandy clay	Completely weathered	Very Stiff	Tertiary
4	Weathered Permian Claystone	75	7	30	18	Orange-brown, orange-grey sandy claystone	Highly to Completely weathered	Very Weak	Permian
5	Weathered Permian Rock	80	7.2	33.3	17	Siltstone with sandstone etc	Moderately to Slightly weathered	Weak	Permian

These units were essentially based on interpretation of the geophysical logs as it was not possible to define or correlate horizons between boreholes from lithological descriptions alone. In this case, only the 2009 data was used for interpretation as the results from the recent drilling campaign were not available at the time of report completion. The interpretation from the 2009 program was considered to provide adequate coverage across the site to allow reasonable interpretation.

The interpreted units were discernable, but not readily definable, from the core logs and even less definable from chip logs. Geophysical logs from the cored holes and all available chip holes were accordingly examined and interpreted, primarily using the gamma log.

Interpreting Tertiary or weathered Permian from gamma logs alone is notoriously difficult and generally unreliable, however, it was noted that the logs showed responses that could be reasonably well correlated between boreholes, and these were used to identify and define the overburden units described above in conjunction with chip descriptions.

Table 6-1 above shows the average gamma response for each unit; however the range of values tends to be extensive and overlapping. Although the average values can be used for a general guide, the main point of correlation is the contrast between the units which is typically quite sharp.

The base of weathering was determined systematically from the density log as the depth at which the density reached a value of 2.5. This did not necessarily coincide with the geological description but in the majority of cases was a fairly close match.

The overburden units were intended to represent distinct geomechanical horizons. Horizon names were ascribed to the overburden units as shown in Table 6-1 for ease of use without necessarily being definitive in the stratigraphic sense.

This approach was adopted partly because the interpretation of the Tertiary at Codrilla is contentious. The previous view was that the Tertiary was relatively thin and that the Permian weathering was particularly deep – the deep weathering was considered to be a characteristic unique to Codrilla.

There is reason to question this – weathering, being a product of atmospheric exposure, is a broad regional scale feature unlikely to show significant variation in depth locally in similar rock types. At Codrilla the variation is considerable, ranging from 50m to 100m in a distance of 3km. It is difficult to justify how this could occur almost entirely within Permian strata of a similar nature.

Elsewhere in the Bowen Basin the Permian weathering layer beneath the Tertiary is typically about 20m thick, increasing to 40m in places. Total depth of weathering is thus typically 20m plus the Tertiary, which itself can be quite thick depending on the pre-Tertiary topography. The latter is known to be rugged in places with thick Tertiary infilling of valleys. The expectation for Codrilla would thus be 50m to 60m of Tertiary with 20m to 30m of Permian weathering.

The material cored in Unit 3 is at first glance typical of Tertiary clay in coloration, which is pale grey with red mottling and weathered ironstone bands and staining, although it differs in being sandier and of lower plasticity than the usual Tertiary clay. It was also devoid of bedding, which is another typical diagnostic for differentiating between Tertiary and Permian; jointing was also almost nonexistent.

Gravel, or gravelly clay, was noted in Unit 3 in a number of boreholes in a zone along the northern flank of the deposit from CX0408 to CX0739. The gravel horizon typically occurs within Unit 3 at a depth of between 25m and 30m. In some cases it deeper, around 37m and at the eastern limit it is between 53m and 59m. These deeper levels appear to coincide with the base of Unit 3.

Gravel layers up to 2m thick were intersected in CX0714FC, CX0417FC and CX3106FC, as indicated in Figure 5-1, at a depth of between approximately 48m and 58m. Sample recovered from the gravel layers showed medium to coarse gravel comprising a mixture of sub-angular to sub-rounded dark coloured fine grained igneous rock and angular fragments of vein quartz in a clayey matrix. The angularity indicates a local source; that is a non transported deposit, atypical of Permian clastic material. Also included was a fragment of petrified wood, which means the gravel deposit has to be post Permian lithification. The unavoidable conclusion is that this horizon represents a basal Tertiary deposit in this borehole.

Sand and gravel was noted in Unit 4 in boreholes CX0602, CX0738 and CX0741, which are the easternmost boreholes around the nose of the syncline. As sandstone is the predominant lithology in the strata below the VU and as these holes are located east of the VU subcrop, it is considered that in these cases, the loose sand and fine gravel most likely represents the residual effects of leaching out the matrix from Permian sandstones in the weathering zone.

Unit 1 – Superficials: This represents the layer of unconsolidated surface deposits. Descriptions of this material are variable, from clay to sand, but it would appear that sand or clayey sand is the predominant material. The base of the unit is frequently well defined lithologically, with a contrast between sand and clay.

Unit 1 is essentially unconsolidated, loose and non plastic. It has an average thickness of 7m with variation between 4m and 10m.

Unit 2 – Laterised Zone: This is a clay layer that is consistently identifiable on the gamma log with a higher average count than the underlying Unit 3 material. It is not readily discernable as a separate unit in the lithological logs and the base is not apparent visually in the fully cored boreholes, although there is a persistent contrast on the gamma logs which has been taken to mark the base of the unit. It is believed that Unit 2 represents near-surface oxidation or laterisation and weathering of the Tertiary clay.

A number of boreholes along the northern flank recorded a 1m to 4m thickness of dark brown to black claystone, sometimes carbonaceous within Unit 2, generally at a depth of between 6m and 14m. In two of the fully cored holes this horizon was described as orange grey or cream sandy clay interbedded with black coal, the latter being completely weathered to clay. A discrete horizon of dark coloured carbonaceous-looking clay at a particular level is not untypical of the Tertiary, and probably represents a former pond deposit. A point of note is that this horizon has been erroneously correlated with one or other of the Rangal coal seams in the database, which could lead to potential distortion in the seam structure contours.

The material comprising Unit 2 is generally described as orange grey, brown grey or yellow grey sandy clay. In engineering terms it is categorised as stiff clay of intermediate plasticity. Test results were consistent giving an average liquid limit of 44% and an average plasticity index of 23%. Only one triaxial test was made on Unit 2 material and this indicated cohesion of 70 kPa with a 13° friction angle.

There are no records of caprock in Unit 2 but there is indication of some ferruginous material in places.

The thickness of Unit 2 is quite consistent with an average of 11m and a range from 7m to 15m.

Unit 3 – Tertiary Clay: This horizon has a fairly uniform gamma response with an overall average count of 80, although in more detail up to three different layers can be differentiated and correlated. Descriptions of this horizon are variable but predominantly record pale grey to cream with orange, red or red-brown mottling, which is typical colouring for Tertiary clay, however the composition is given as sandy claystone, siltstone or clayey sandstone rather than the pure claystone of the Tertiary from elsewhere. The high sand content is thus unusual and seems to be a characteristic of the Codrilla area.

Weathered ironstone bands or nodules are also present in the unit, together with gravel horizons as described above. In some cases the gravel can be taken as marking the base of the unit, but elsewhere the demarcation of the base is less obvious and more subjective to interpret. Identification of the Tertiary/Permian boundary is difficult at the best of times, particularly where there is Tertiary clay overlying fine grained Permian rock that has been completely weathered to clay. Even in fully cored boreholes the boundary cannot be resolved in these cases to within +2m.

This is also the case with the fully cored holes at Codrilla. Borehole CX0714FC and CX3106FC both recorded basal gravel layers, and CX0417FC showed a colour change from the diagnostic mottled red and grey to orange and grey close to the interpreted level, but CX0701FC, CX0732FC, CX3115FC, CX3122FC and CX3127FC showed no differentiation. Given the subjective nature of the interpretation and the possible variations, it is suggested that the base of Unit 3 can be taken as a first estimate only for the base of Tertiary.

Unit 3 can be summarised as a very stiff sandy clay or very weak sandy claystone, of low to intermediate plasticity. Test results were reasonably consistent for the most part, giving an average liquid limit of 33% and an average plasticity index of 16%. One sample gave values of 62% and 45% respectively for liquid limit and plasticity index, more indicative of the high plasticity that normally typifies the Tertiary clay. Triaxial tests indicated an average cohesion of 49 kPa with a 300 friction angle.

The thickness of Unit 3 is not uniform but varies between 8.5m to 39.8m, the thickness presumably being governed by variations in the pre Tertiary topography. Figure 6-2 shows the depth to the base of Unit 3, that is the presumed base of Tertiary. This shows the Tertiary to be generally between 30m and 40m thick with a 60m deep channel running south-southeast across the nose of the syncline.

Unit 4 – Weathered Permian Clay: This represents the highly to completely weathered upper section of the Permian weathering zone. The thickness of the unit was picked from a uniform gamma log –indicative of clay – and the chip descriptions, but the base of the unit is subjective. The material is very weak sandy claystone or clayey sandstone for the most part, weathered to the consistency of very stiff to hard clay.

The colours are generally orange grey to orange brown without the red or weathered ironstone of Unit 3. In some cases coal seams have been identified within the unit.

One traditional diagnostic for differentiating between the Tertiary and the weathered Permian is the lack of any bedding in the former. In the lack of other evidence, the onset of discernable bedding is normally taken the start of the Permian. As can be seen in Figure 6-1, the onset of bedding observed in the cored boreholes occurs at or within Unit 4.

Tests on Unit 4 samples were consistent showing borderline intermediate to high plasticity, with an average liquid limit of 51% and an average plasticity index of 21%.

Unit 4 has an average thickness of 17.7m with a range from 7.0m to 30.0m. There appears to be a trend in the thickness with thinner values, between 10m and 15m, along the western limb and values between 20m and 25m elsewhere, however there are individual variations.

Unit 5 – Weathered Permian Rock: This unit represents the lower part of the weathering zone down to the base of weathering but for the most part comprises with rock in the highly to moderately weathered category. A main feature of this unit is that the bedding is well developed together with any intraformational shear planes. The base of Unit 5, as mentioned above was picked systematically from the density log but is in close agreement with the estimate from chip and core logging.

Unit 5 has a variable thickness, from 7.2m to 33.3m with an overall average of 17.2m. In general there is a similar trend to Unit 4 with thinner values along the western limb and thicker values in the nose of the syncline. Individual variations are possibly due to the difficulty in picking the base of Unit 4 or 5.

Figure 6-3 shows the depth to the base of Unit 5, which is effectively the base of weathering. This shows a similar pattern to the Tertiary thickness contour plot (Figure 6-2) with a deep channel running south-southeast across the nose of the syncline reaching a maximum depth of 98.2m. Away from the channel the depth of weathering is generally between 60m and 75m.

Isopachs of the difference between the base of Unit 3 and the base of Unit 5, which represents the depth of the Permian weathering zone are presented in Figure 6-4. This shows a thickness of between 25m and 35m on the western limb and 35m to 45m elsewhere. The overall average for the Permian weathering values is 35m; the maximum was 52.7m in CX0719 located in the channel area. CX0652 had an anomalously low value at 18.8m as indicated from the lithology and density logs but the caliper suggests that consistently stronger strata is not recorded until 66.8m, which would give a weathering thickness of 31.6m.

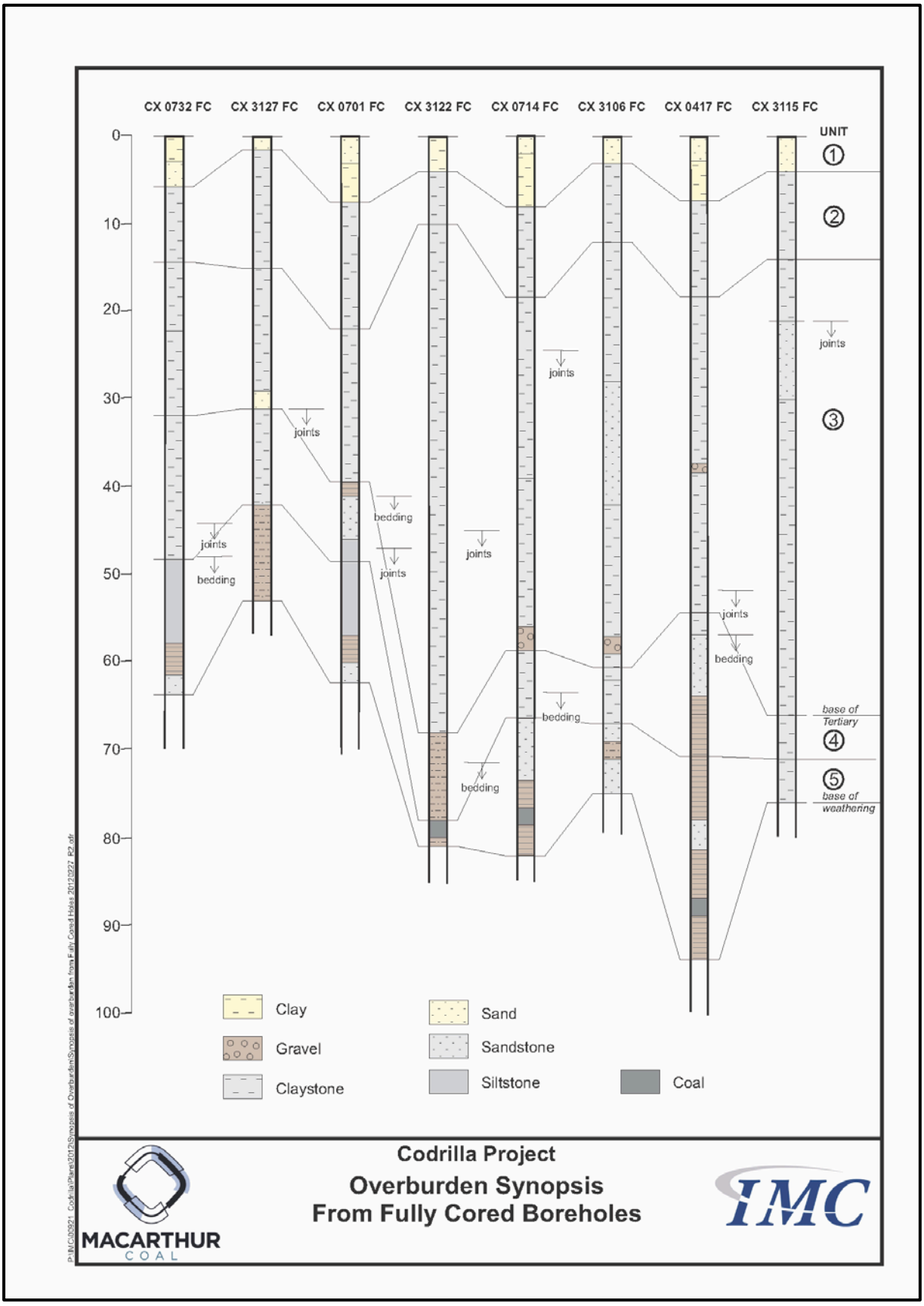

Figure 6-1 : Synopsis of Overburden from Fully Cored Boreholes

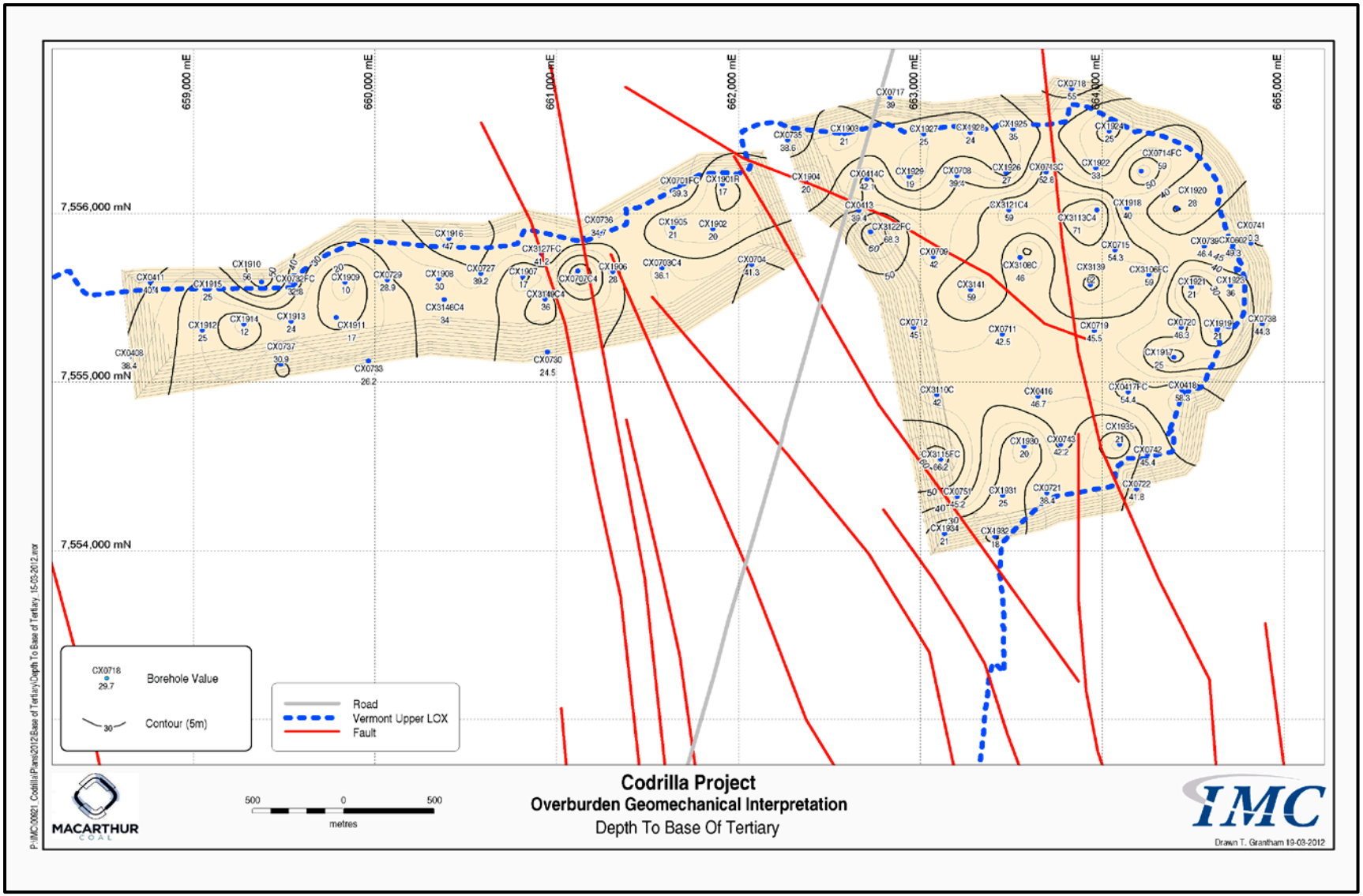

Figure 6-2: Depth to Base of Tertiary

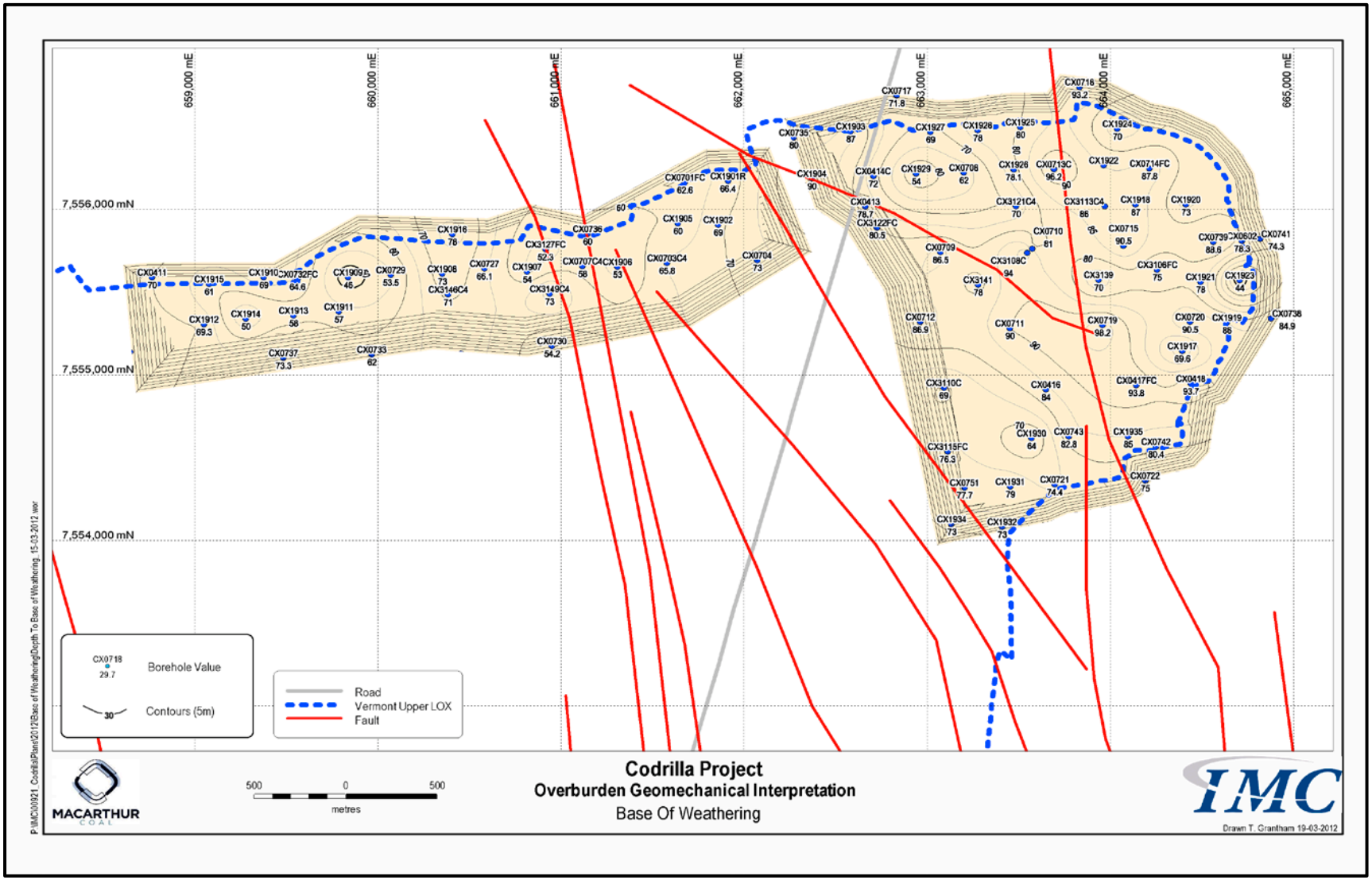

Figure 6-3: Depth to Base of Weathering

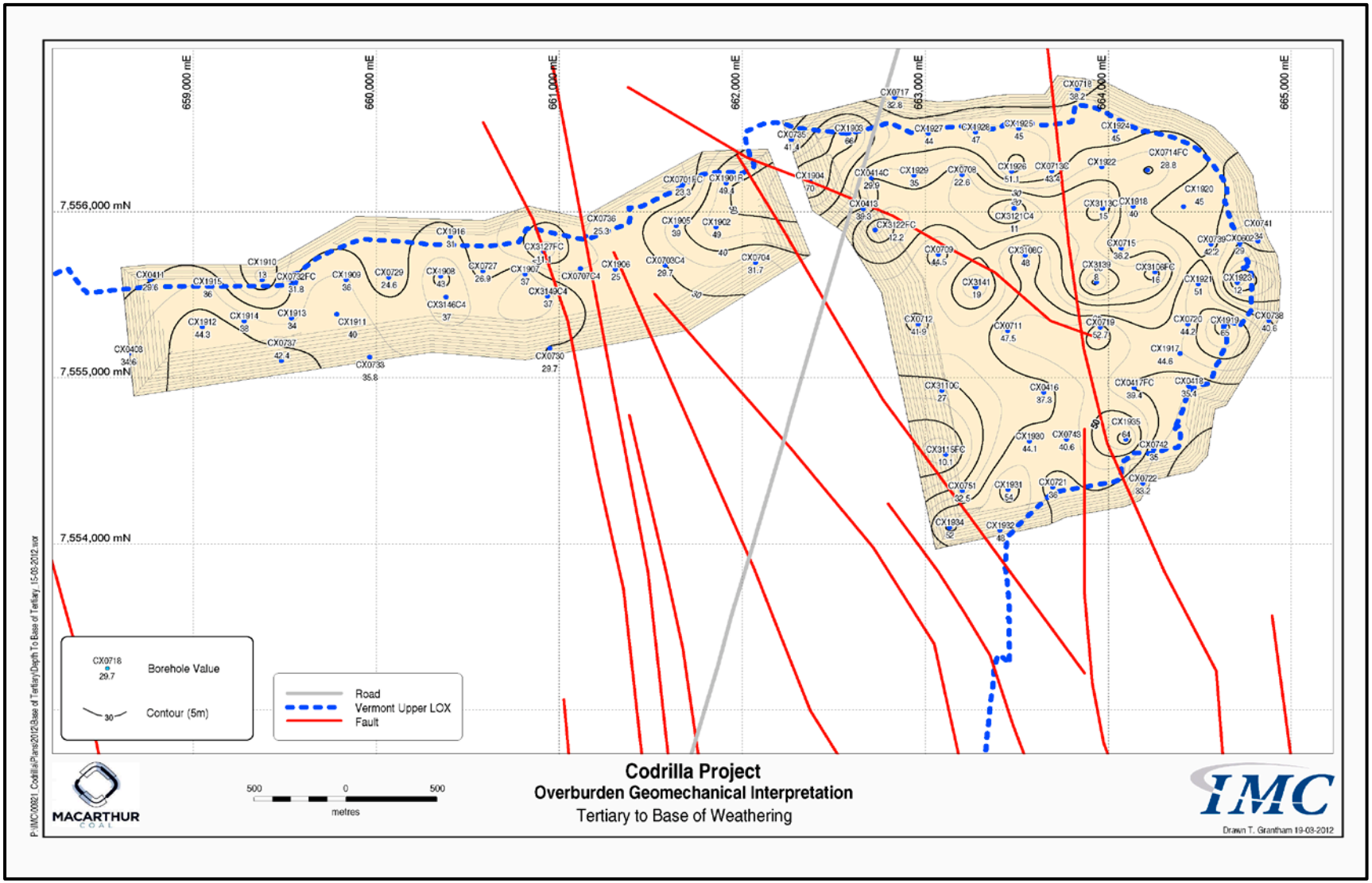

Figure 6-4: Tertiary to Base of Weathering

6.2 Interburden

Interburden in this section refers to all rock material below the base of weathering, even though it is still technically overburden, in order to differentiate it from the soft overburden described in the preceding section. As can be seen in Figure 5-2 and Figure 5-3 from Section 5, the rock interburden is dipping hence the stratigraphic content varies with depth, as opposed to the soft overburden which is essentially horizontally disposed.

The interburden strata above the VU Seam are mostly fine grained, either siltstone or laminite (thinly interbedded fine sandstone and siltstone), except for the upper part of the LL1 to LL2 Seam interval, where fine to medium laminated sandstone are present. Below the VU the strata are predominantly laminated fine to medium sandstone. No bodies of massive sandstone have been identified in the interburden sequence.

Representative interburden sections showing the coal seams and the intervals between are presented in Figure 6-1.

The LU and LL1 Seam are quite consistent with an average thickness of 1.1m each, with a range from 0.55m to 1.60m. The interval between them is 14.5m on average with a range generally between 7m and 20m, with one extreme value of 29.8m. The interburden is mostly laminite with fine to medium sandstone predominating where the interval is thicker. Being the highest seam in the sequence, the LU was only intercepted in the deeper holes so that data points are more limited (24% of boreholes).

The LL2 Seam is more variable, with a thickness generally between 1.0m and 2.5m, with a maximum thickness of 5.84m in CX0700, which is clearly anomalous and may be due to tectonic rather than geological thickening. The LL1 Seam to LL2 Seam interval is 36m on average with a range from 25.1m to 53.4m. Descriptions of the interburden include siltstone, laminite, fine sandstone and fine to medium sandstone. From the logs, there is a general indication that the upper part is sandstone and the lower part finer grained, possibly sandstone or laminite.

The LL2 Seam to VU Seam interval is fairly consistent with an average thickness of 27m. Lithological descriptions of this interval range from siltstone, through laminite to sandstone, but the majority would tend to favour laminite as the major component.

The LL3 Seam is generally not present within the mining area.

At the time of report completion, there was no systematic data on rock strength available, other than one full sonic log through the interburden in CX0101 and some sonic coverage in the fully cored boreholes. The sonic log can be used to provide an estimate of rock strength, which is normally based on a site specific UCS-sonic relationship. A specific formula has not been developed for Codrilla; however a first approximation can be derived from the downhole sonic velocity logs using the Capcoal standard formula for German Creek Mines, which is applicable to the Rangal Coal Measures:

$$UCS = 3330e^{-0.0499t}$$

where UCS is the unconfined compressive strength in MPa and t is the sonic transit time in µsec/ft.

This gives the following estimates from the CX0101 log as shown in Table 6-2.

Table 6-2: Estimated Interburden Strength

Interval	Lithology	Sonic Velocity (m/sec)	Transit Time (µsec/ft)	UCS (MPa)
above LU	siltstone	4000	76	74.3
LU - LL1	sandstone fm	3900	78	67.4
LL1 - LL2	sandstone fm	4000	76	74.3
	siltstone	3600	85	48.7
LL2 - LL3	siltstone	3100	98	24.6
	sandstone	3500	87	43.2
LL3 - VU	sandstone f	3300	92	33.2

Borehole CX101 is a deep hole so that all units are below the base of weathering, the value for the uppermost part starting at a depth of 105m. The table indicates that the upper overburden down to the LL2 Seam is strong with an average UCS of about 77 MPa, which is suspected to be an over-estimate. Below that the interburden strata, both sandstone and siltstone, are moderately strong, in the 25 to 50 MPa range.

Several tests were made on samples from the weathered zone (Unit 5) and these gave UCS values from 2.0 to 9.5 MPa. Two samples of unweathered rock from the deepest fully cored borehole, CX0417FC2, gave UCS values of 8.3 and 25.4 respectively for siltstone and sandstone.

6.3 Floor Conditions

The VU Seam is the principal target seam and will form the mining floor in the opencut pit. Consequently the VU Seam floor has been examined in some detail. The overlying lessser seams would be mined as transient parting operations and hence floor conditions for individual upper seams have not been addressed. The floor sequence for the VU Seam is illustrated in the representative section shown in Figure 6-6.

The Yarrabee Tuff (YT) forms the base of the VU Seam mining. The YT is a pale brown fine tuff, the upper part of which is usually re-worked with carbonaceous material. The upper part is frequently identified as a separate lithological unit in the borehole logs but in the context of this report the YT refers to the full or composite thickness of tuffaceous material. The YT section has an average thickness of 0.5m with a range from 0.2m to 0.8m.

The nature of the YT is normally quite variable, ranging from hard and brittle to soft and puggy, generally with a high slaking potential. It is also known to contain slickensided discontinuities or polished bedding partings. Soil classification tests indicated clay of intermediate plasticity.

The YT is underlain by the 0.5m thick VL1 Seam. This is a dirty coal with tuff bands and is not normally considered to be economic for mining. The VL1 Seam varies in thickness up to 1.0m and in some cases thins out altogether. It is usually associated with bedding plane shearing on the tuff bands.

A sequence of three geomechanical units of increasing strength and competence were interpreted in the stone floor below the VL1 Seam. These units have been termed FL1, FL2 and FL3 as indicated in Figure 6-6. The interpretation was based on the gamma log and lithological descriptions and all available logs were examined and interpreted.

Unit FL1 is the immediate floor and is typically a weak to moderately weak carbonaceous mudstone or siltstone, sometimes with coal bands. The top may be transitional from the stony coal of the VL1 Seam. It is relatively thin ranging from 0.2m to 1.0m.

Unit FL1 grades down into the laminated siltstone of Unit FL2, which has a highly variable thickness ranging from 0.7m to 6.2m. The indication from the sonic log in CX0101 is that the strength of this unit increases from top to base.

Below this is a more massive and consistent medium sandstone that constitutes Unit FL3. In fully penetrating boreholes this sandstone is some 25m to 40m and virtually makes up the entire VL1 Seam to VL2 Seam interval.

Interpretation of the sonic log for CX0101 gives the following estimate of strength for the floor units as shown in Table 6-3.

Table 6-3 : Estimated Floor Unit Strength

Interval	Lithology	Sonic Velocity (m/sec)	Transit Time (µsec/ft)	UCS (MPa)
FL1	carb siltstone	2900	105	17.6
FL2	siltstone	3200	95	28.7
FL3	sandstone fm	4200	73	89.1

These should be taken as top of the range strength estimates for unweathered rock. The sonic strengths from CX0714FC were 3.3 MPa for FL1, 7.6 MPa for FL2 and 28.7 MPa for FL3; CX0732FC gave a sonic strength of 33.2 MPa for FL3.

Laboratory testing on floor samples indicated a UCS value of 9.9 MPa for Unit FL1; with an average slake durability of 75.7%, ranging from 29.4% to 96.3%. Other tests were on weathered samples and these showed a reduction in strength to around 2.5 MPa for all three floor units, with a corresponding reduction in durability to 22.5% on average.

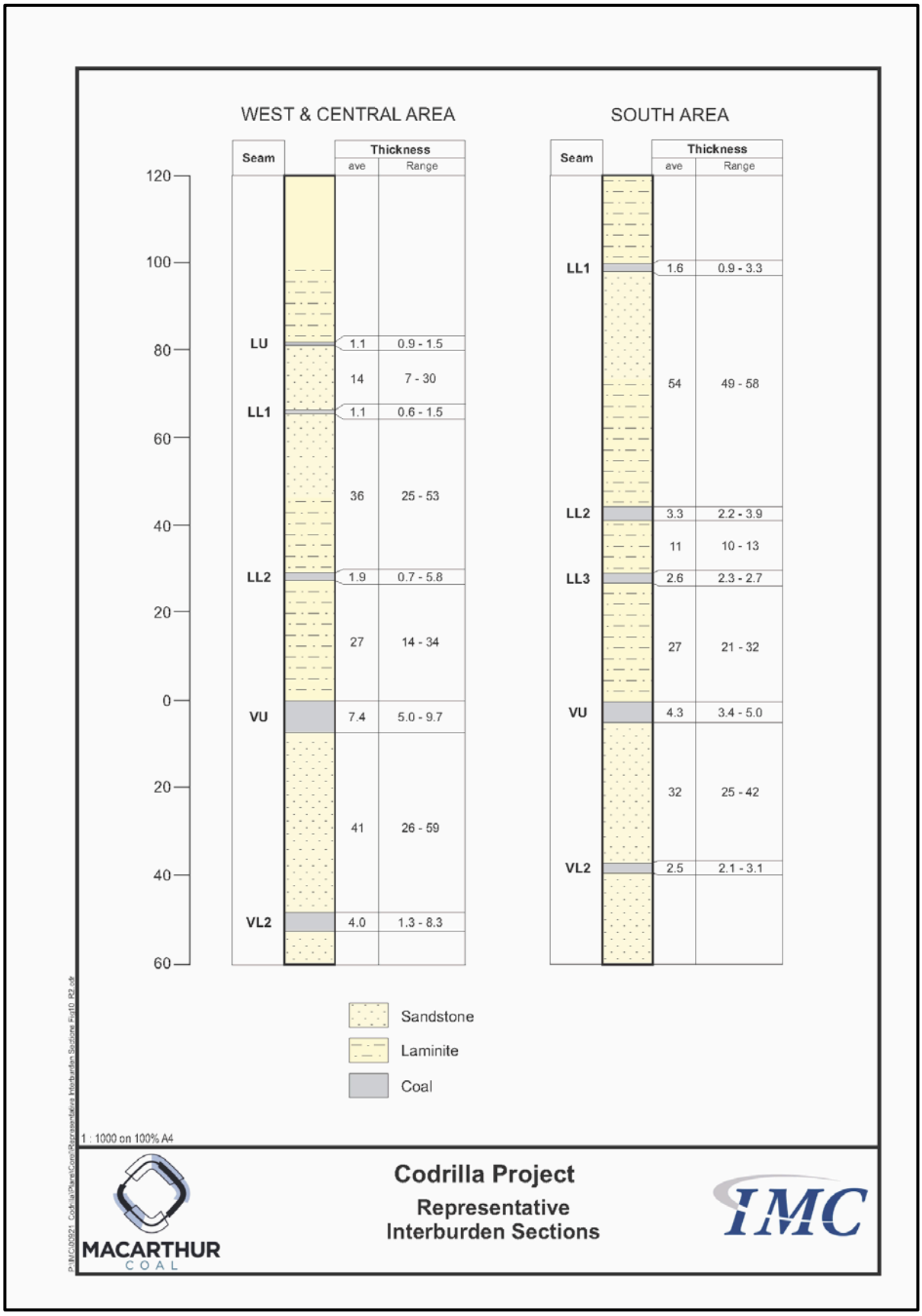

Figure 6-5: Representative Interburden Sections

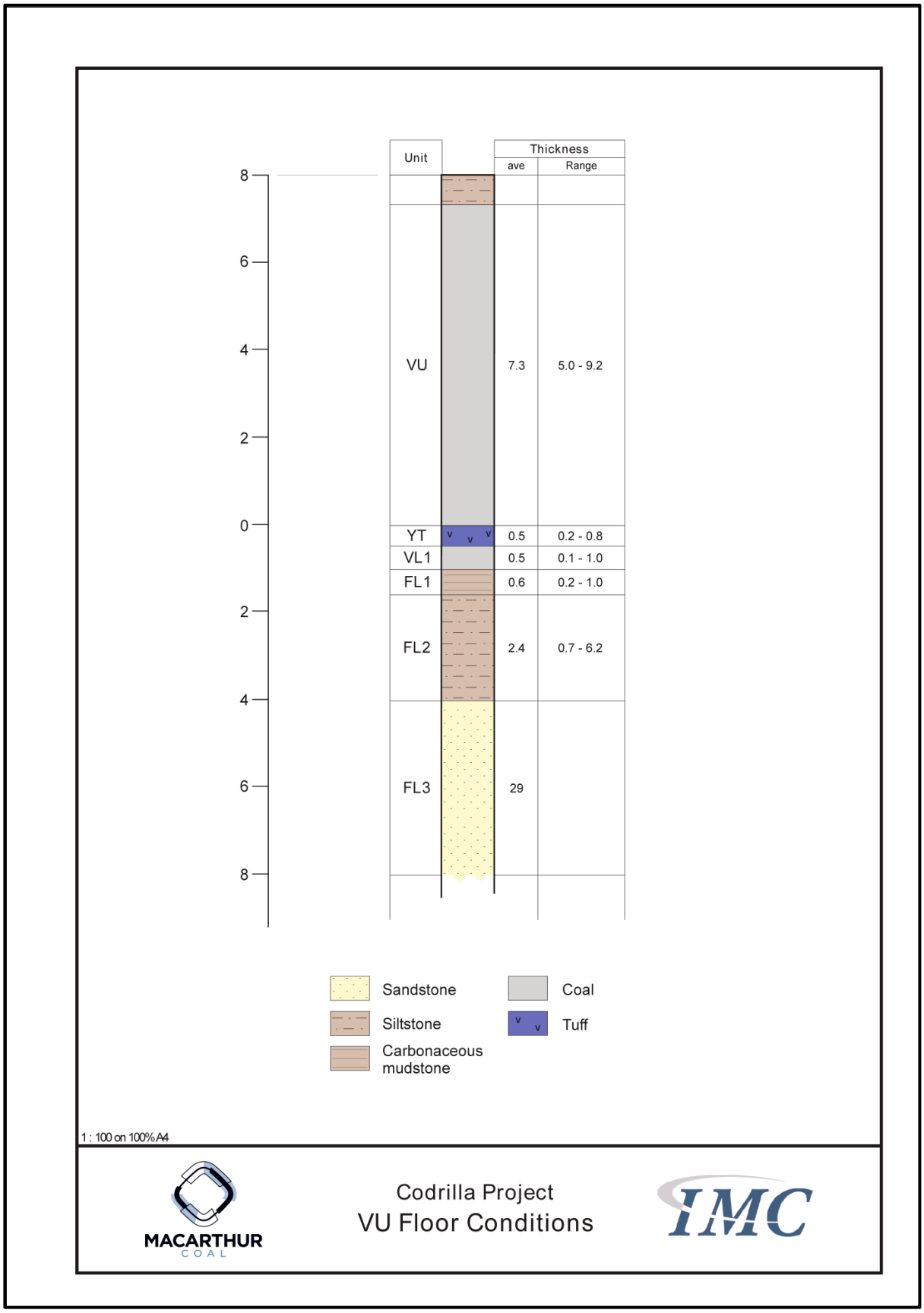

Figure 6-6: VU Floor Conditions

7 HYDROGEOLOGY

No further groundwater evaluation was made for the deeper formations as part of this assessment.

A pebble conglomerate layer was identified at the base of the Tertiary clay. This unit comprised an intermediate plasticity clayey gravel, with sub-rounded to rounded clasts. Whilst not continuous across the site, the material was identified in several boreholes. The unit may represent a high energy flowing paleo-channel, and may form a system of discontinuous confined aquifers or semi-confined aquifer lenses.

From a mining perspective, where this unit is encountered, the potential for groundwater emissions is possible and would require further assessment to evaluate the potential pit inflows, but also there is the potential for the material to undercut the lower benches should the material be partially saturated.

8 ACOUSTIC SCANNER INTERPRETATION (ATV) AND PROCESS

8.1 ATV Interpretation Process

WellCAD files were provided by Weatherford, and number of steps was required to interpret discontinuities within the borehole sidewall. These are summarised as follows:

1) Following the application of Quality Control processes and conversions, discontinuities were interpreted as "picks" through sinusoid positioning and shaping on structural projection logs using WellCAD software features. The categories used for interpretation are as defined by discrete allocated colours in WellCAD. It should be noted that these features are interpreted as they appear, in magnetic north and representing an apparent dip;

2) On completion of the interpretation for each relevant strata section, structure logs are converted from apparent to true dip, with a further stage involving conversion from magnetic to true north through rotation of the structure logs by +9°;

3) The structure legend shown in Figure 8-1 was used to identify discontinuity types as defined by colour and shape;

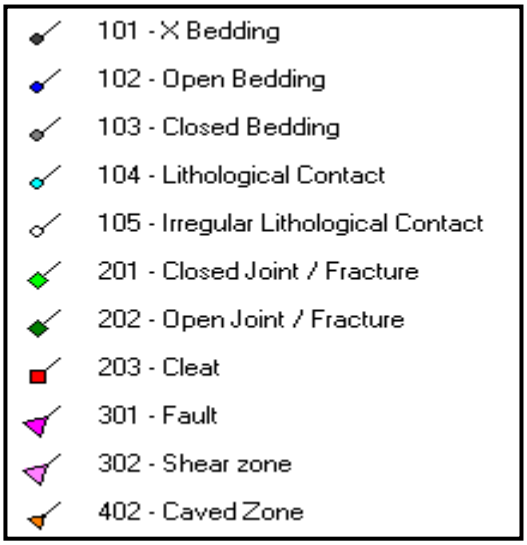

Figure 8-1: IMC Structure Dictionary

4) Borehole breakout is generally determined through assessment of both amplitude and travel time. The borehole image is presented in magnetic north and the borehole breakout interpretation (value) therefore requires rotation by +9° to obtain the breakout relative to True North. The Principal Major Horizontal Stress orientation (σ^{H1}) is interpreted in all cases at 90° to the borehole breakout; and

5) Compositing of interpreted structures into a database format and the production of stereonet plots, including pole projection diagrams and rose plots. This was particularly useful for bedding, joint and cleat orientations, and also the general analysis of discontinuity trends in the context of mining impacts.

8.2 Site Overview

The acoustic scanner (ATV) interpretation was completed to establish background structural patterns across the site, which would be an important component for the kinematic analysis. A total of five boreholes from the East Pit were available for ATV interpretation. A plan showing the ATV borehole locations are presented in Figure 8-2. No ATV information was available for the West Pit at this stage.

8.3 Limitations

The limitations of interpreting geological structures using the ATV method are that it provides no indication of the persistence of the structure/discontinuity. The only method that can be employed to fully understand structural persistence is by routine geotechnical mapping during operations and incorporation of this information into a database. This can then identify the structures which may have the potential to lead to slope instability. Similarly, information pertaining to the planarity of the discontinuities or groundwater interaction, which may increase the potential for geotechnical hazards, is not known either. During core logging, faults may be identified by surfaces with movement features such as slickensides, gouge infill or zones of brecciation. Cross referencing against core was not completed as part of this assessment.

On this basis, the information procured from the ATV interpretation should be used only for preliminary planning purposes and confirmed by core logging and routine bench scale face mapping and assessment during operations.

A number of boreholes had only partial ATV data for interpretation. The ATV sondes are only operational in a borehole fluid, usually water. Table 8-1 shows the depth interval for each borehole available for interpretation.

Table 8-1 : Depth Intervals for Interpretation Based On Available Boreholes

Borehole No.	From (m)	To (m)
CX0711C	83.4	164.3
CX3106FCR	80.0	180.2
CX3108C	95.2	161.0
CX3109C	73.8	115.3
CX3115FC	78.0	171.0

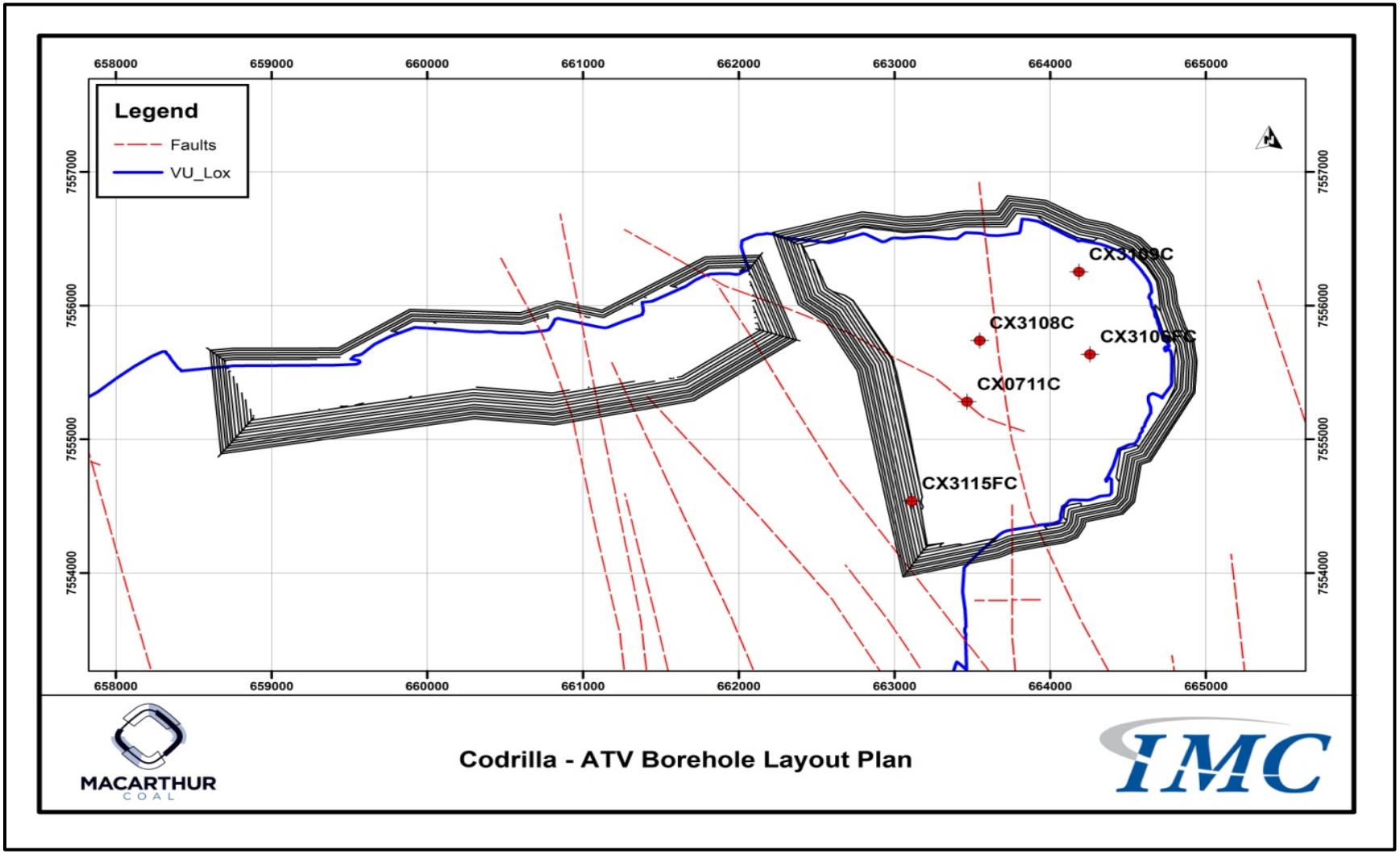

Figure 8-2: ATV Borehole Location Plan

8.4 Classification of Discontinuities

In the context of this assessment, it was considered sensible to limit interpretation to structures that were important from a geotechnical perspective and could be tied in, to some extent, with interpreted features from geotechnical logging.

For the interpretation the classification of discontinuities were simplified into 4 main categories:

- **Bedding**: Generally low angle 0° - 25° features representing either a closed bedding or open plane. These discontinuity picks are represented by solid grey or dark blue lines illustrated in Figure 8-3;
- **Lithological Contacts**: Distinct contact between two major lithology types usually representing a plane of weakness. These discontinuity picks are represented by solid cyan coloured lines as illustrated in Figure 8-3;
- **Joints:** Classified as discontinuities at increased angles relative to bedding partings which are presumed to be continuous across the hole, with no indication that the feature is open, but still represents a weakness plane. As mentioned in Section 8.3, it is difficult to differentiate between joints and tightly bound faults by ATV interpretation; therefore these definitions were grouped collectively as "joints". The joints can either be closed or open and are represented by solid light and dark green lines as illustrated in Figure 8-4; and
- **Fault/Shear Zones:** This is a general description which represents possible structural anomalies that can be interpreted by a caliper deflection, decrease in density and an increase in gamma response associated with possible clay infilling. This feature was often observed at coal/rock interfaces, and may also be associated with shearing/faulting along weaker coal/rock contacts or within weak strata. Interpreted shear/fault zones could also be identified where intervals of high joint/defect density (joint swarm) are observed (green sinusoids). These discontinuity picks are represented by hatched pink regions as illustrated in Figure 8-4.

Coal cleat was not examined as part of this investigation.

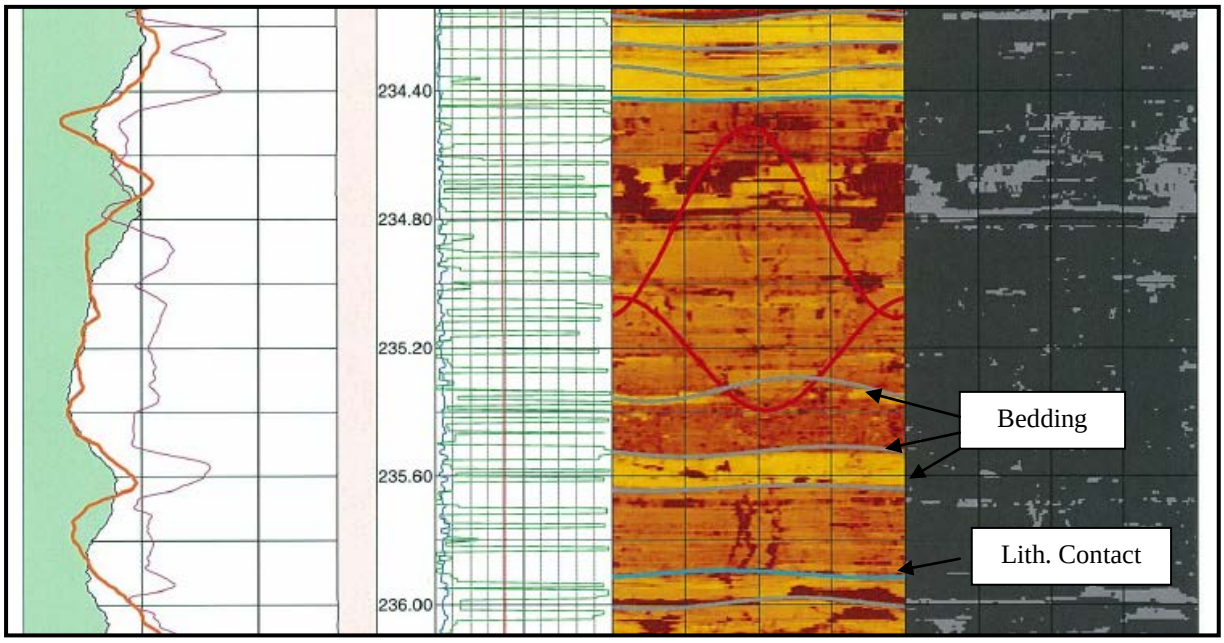

Figure 8-3 : Example of Bedding and Lithological Contact

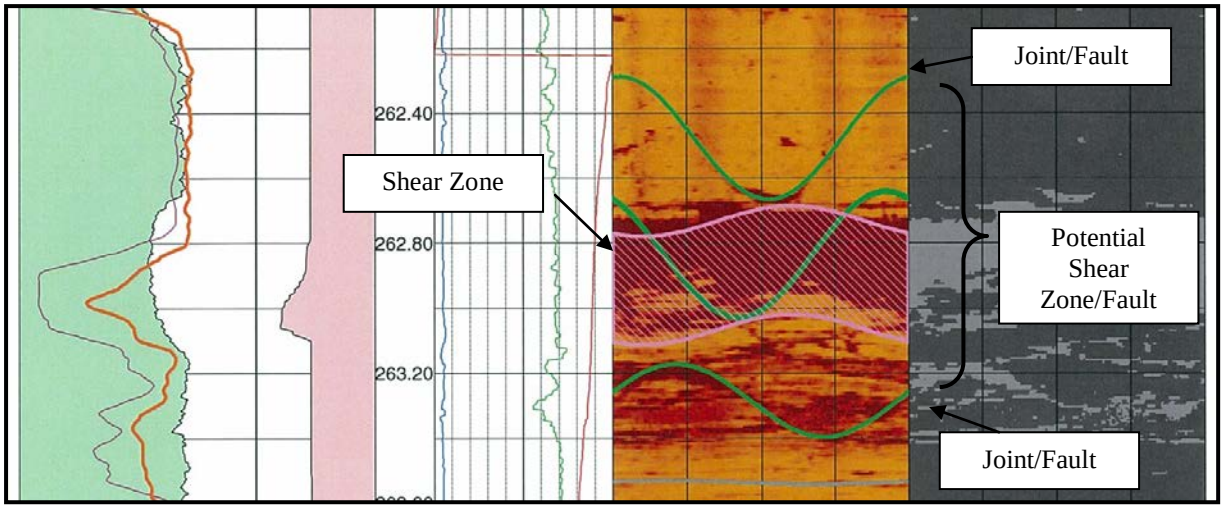

Figure 8-4 : Example of Possible Caved Zone, Shear Zone and Joints

8.5 Considerations for Mine Planning

The potential geotechnical impact of each discontinuity type during operations is controlled by its orientation relative to the pit face. In this context, IMC have broadly defined features based on the following dip categories:

- **Very low angle features** – 0 to 19^0, usually bedding and sheared lithological contacts or caved strata;
- **Low angle features** – 20^0 to 44^0, typically cross bedding structures, bedding influenced by proximal faulting or low angle joints, faults or shears;
- **Moderate angle features** – 45^0 to 69^0, typically joints, faults or shears; and
- **High angle features** – 70^0 to 90^0, typically joints, faults or shears.

The above structure types (Section 8.3) are presented as a series of pole projection diagrams, which allow preferred orientation "clusters" or "sets" to be established relative to true north. This method of presentation allows a mean vector to be applied, giving an average dip and dip direction for the set of structures. This is discussed further in Section 8.5.2.

Structure categories are presented as lower hemisphere equal angle circular plots where the orientation (dip and azimuth) of each feature is represented by a single point (or pole) on the diagram.

8.5.1 In-situ Stress Orientation

In this case, borehole breakout was not observed due to the shallow nature of the deposit; however the inferred principal in-situ stress direction from other Bowen Basin coal deposits in the vicinity of Middlemount/Dysart would be northeast - southwest.

8.5.2 Pole Projection Diagrams

Pole projection diagrams were used to identify the orientation (relative to true north) and dip magnitude (relative to horizontal) of interpreted discontinuities. An example of a pole contours illustrating joint orientation is shown in Figure 8-5.

An interpretation of the general orientations of interpreted sets of features, for each pole projection diagram, is provided for each ATV borehole across the Codrilla project area.

Where there are a high density of structure picks interpreted in a region of a pole projection plot, these are referred to as the "major" set. These can be identified when the contouring function is applied. Where there are additional clusters of interpreted structures, represented by a lower density of picks, these are referred to as "minor" sets or clusters. Each cluster set is determined by a set window which calculates the mean orientation for the set.

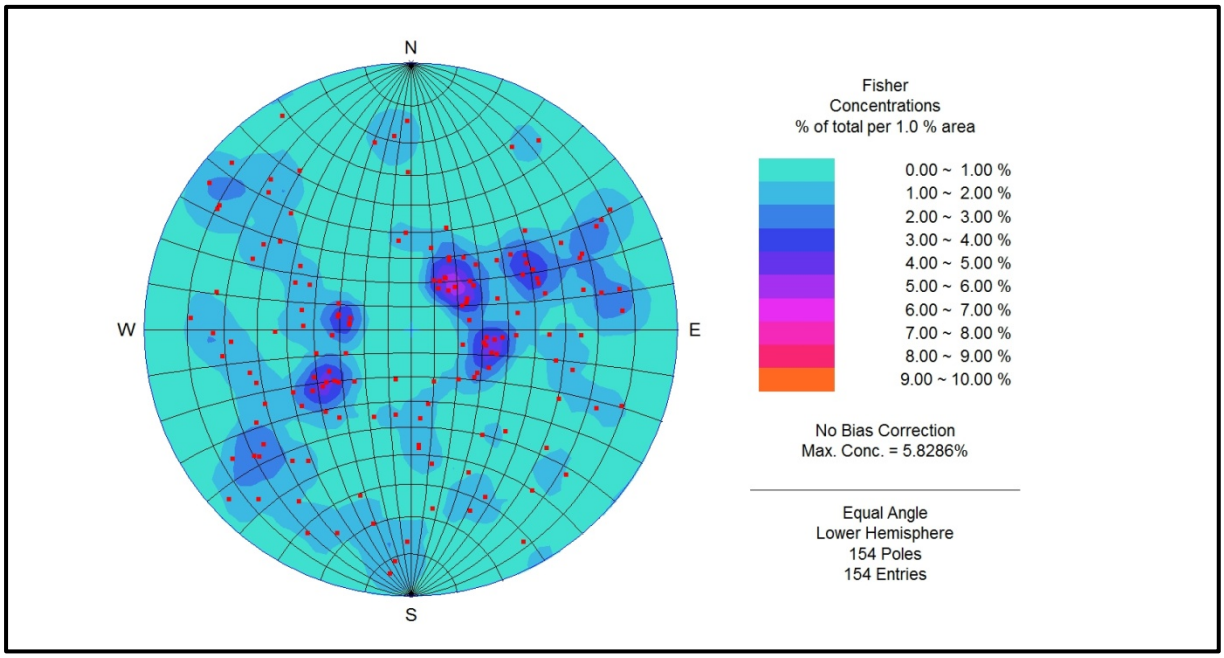

Figure 8-5: Example IMC Interpreted Pole Contours for Joints

8.5.3 Rose Diagrams

Rose diagrams are used to present a directional representation of structures and the frequency of each class in terms of "strike". An example of a rose plot is shown below in Figure 8-6. The rose diagrams allow sets or clusters of planes to be more sharply grouped and visually defined, and often allows for better determination of dominant structure sets, particularly when there is significant structural variability. Rose diagrams are often more intuitive as a means of presenting data, and are particularly suitable for vertical and sub-vertical data sets.

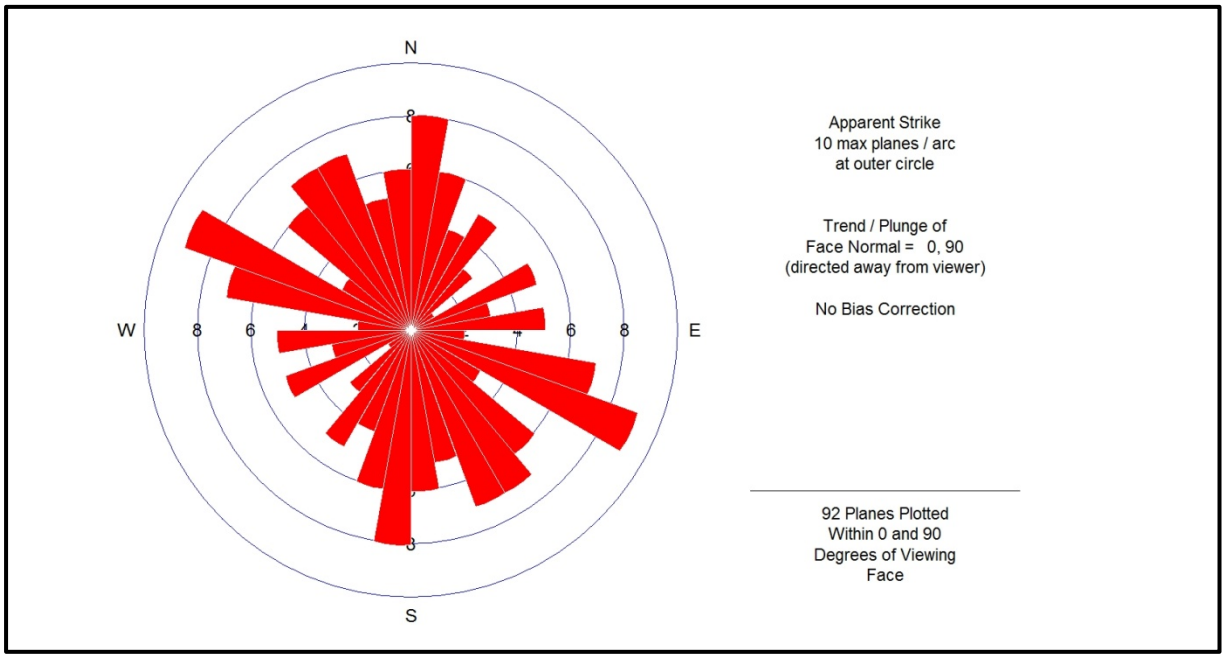

Figure 8-6: Example IMC Interpreted Strike Rose Diagram for Joints

8.5.4 Dip-Azimuth Rose Diagrams

Rose dip-azimuth plots are similar to strike rose plots; however, each "petal" corresponds to the count of planes having their azimuth fall within a particular interval. An example of a dip-azimuth rose diagram is show below in Figure 8-7. These plots are used in this report for bedding, as they give a more intuitive indication of the "downhill" direction for mine planning purposes.

Note that counts of bedding discontinuities for the defined intervals are represented by "open bedding" (category 102) and "closed bedding" (category 103).

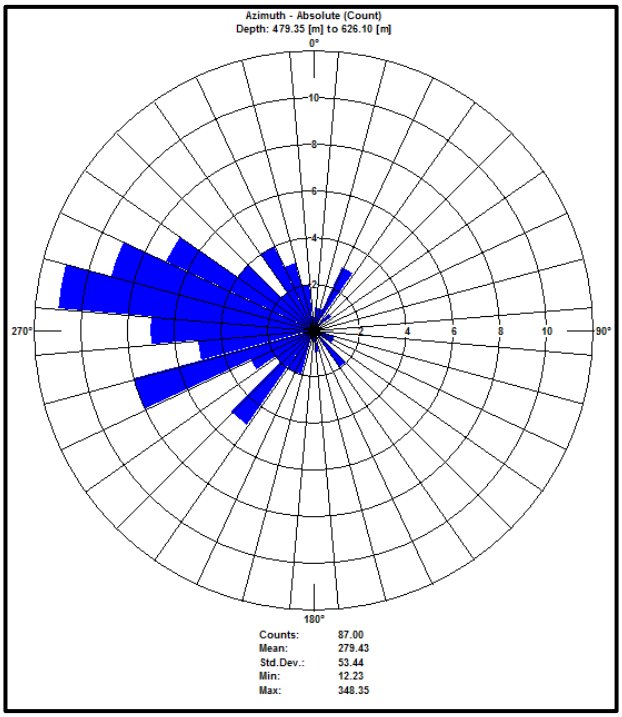

Figure 8-7: Example IMC Dip-Azimuth Rose Diagram for Bedding

8.6 Analysis of Joints

Joints were frequently observed throughout the rock mass, mainly in siltstone and interbedded units. Some of the sandstone units were observed to be massive therefore did not contain discontinuities or defects. At this stage there was no information collected which described the characteristics of the joints, such as planarity and roughness of the joint surfaces.

Table 8-2 presents an analysis of joint planes recorded from the ATV interpretation.

Table 8-2: Recorded Joint Dip Angles

Dip Angle Category (^{0})	Count	Percentage (%)
20 - 39	54	34
40 - 59	36	23
60 - 79	53	34
80 - 90	14	9
Total	157	100

The above table shows the predominant joint dips to be > 40^0, however a significant proportion of joints were recorded at < 40^0. The median dip angle for all joints recorded was approximately 54^0.

Figure 8-2 presents a joint angle frequency histogram, which shows two possible joint categories; one low angle and one moderate to high angle population.

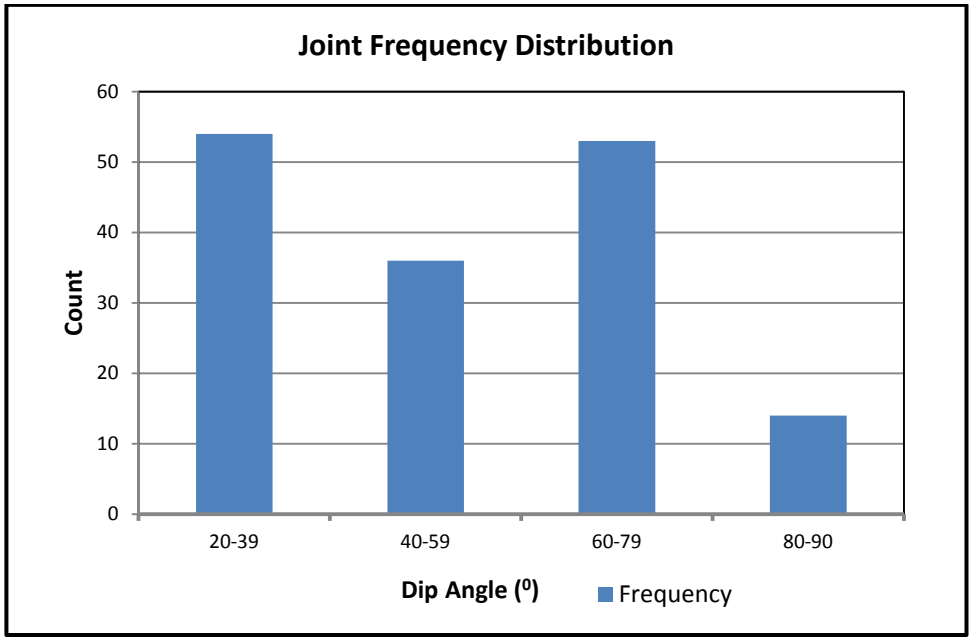

Figure 8-8: Joint Dip Angle Frequency – Codrilla Site

Figure 8-9 and Figure 8-10 shows the pole contours and rose diagram, respectively, for recorded joints across the Codrilla site, where five distinct joint sets were interpreted. The dip and azimuth for each joint set is summarised in Table 8-3.

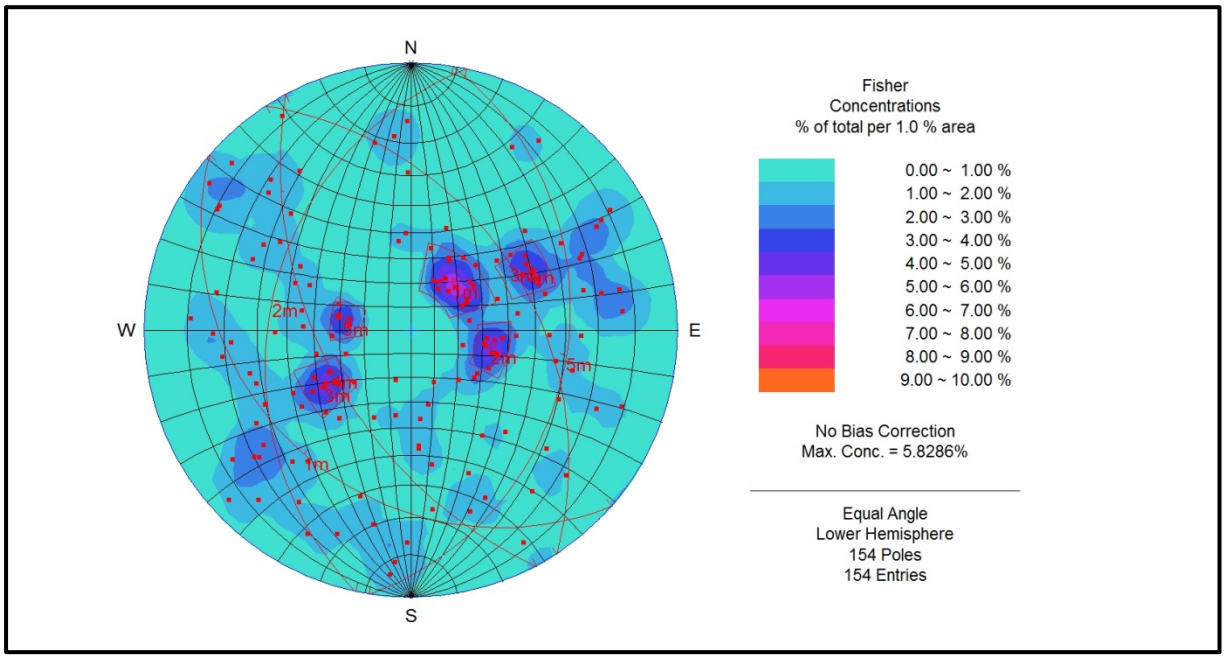

Figure 8-9: Pole Contours for Interpreted Joints – Codrilla Site

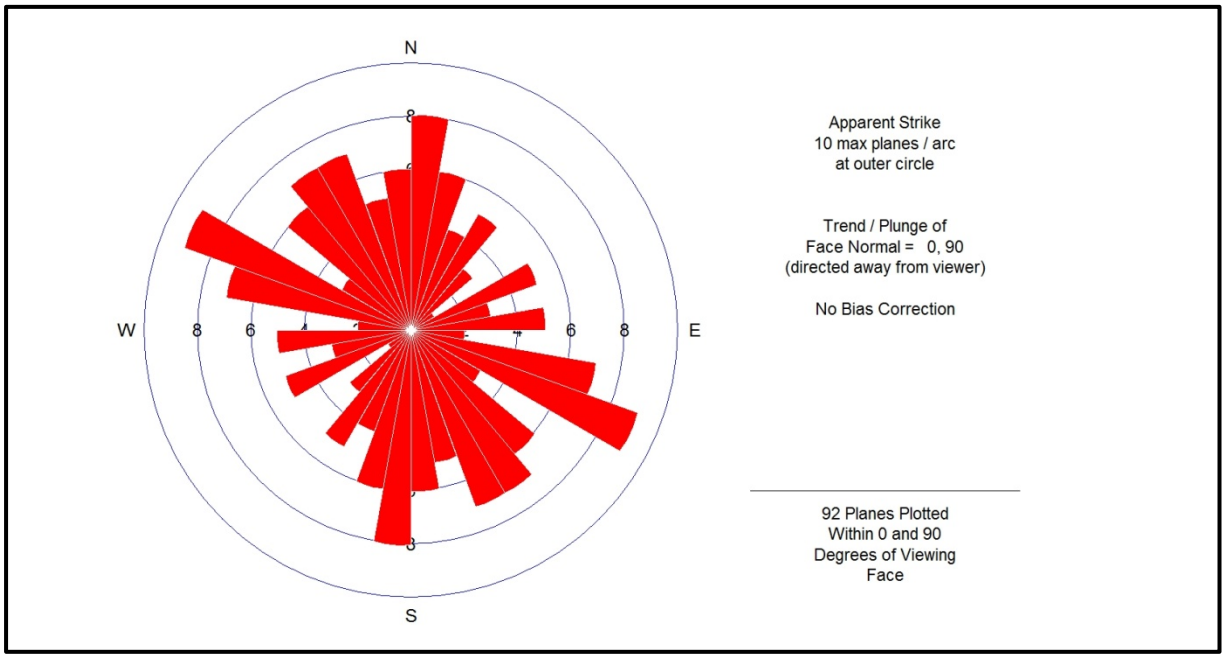

Figure 8-10: Rose Diagram for Interpreted Joints – Codrilla Site

Table 8-3: Mean Joint Set Orientation - Codrilla Site

Set	Mean Dip (^{0})	Mean Dip Direction
1	27	221
2	34	282
3	42	057
4	53	242
5	29	099

Figure 8-11 presents a site plan showing the stereonets of the major joint sets interpreted from each borehole. An analysis of joints for each borehole is presented in Section 8.7.

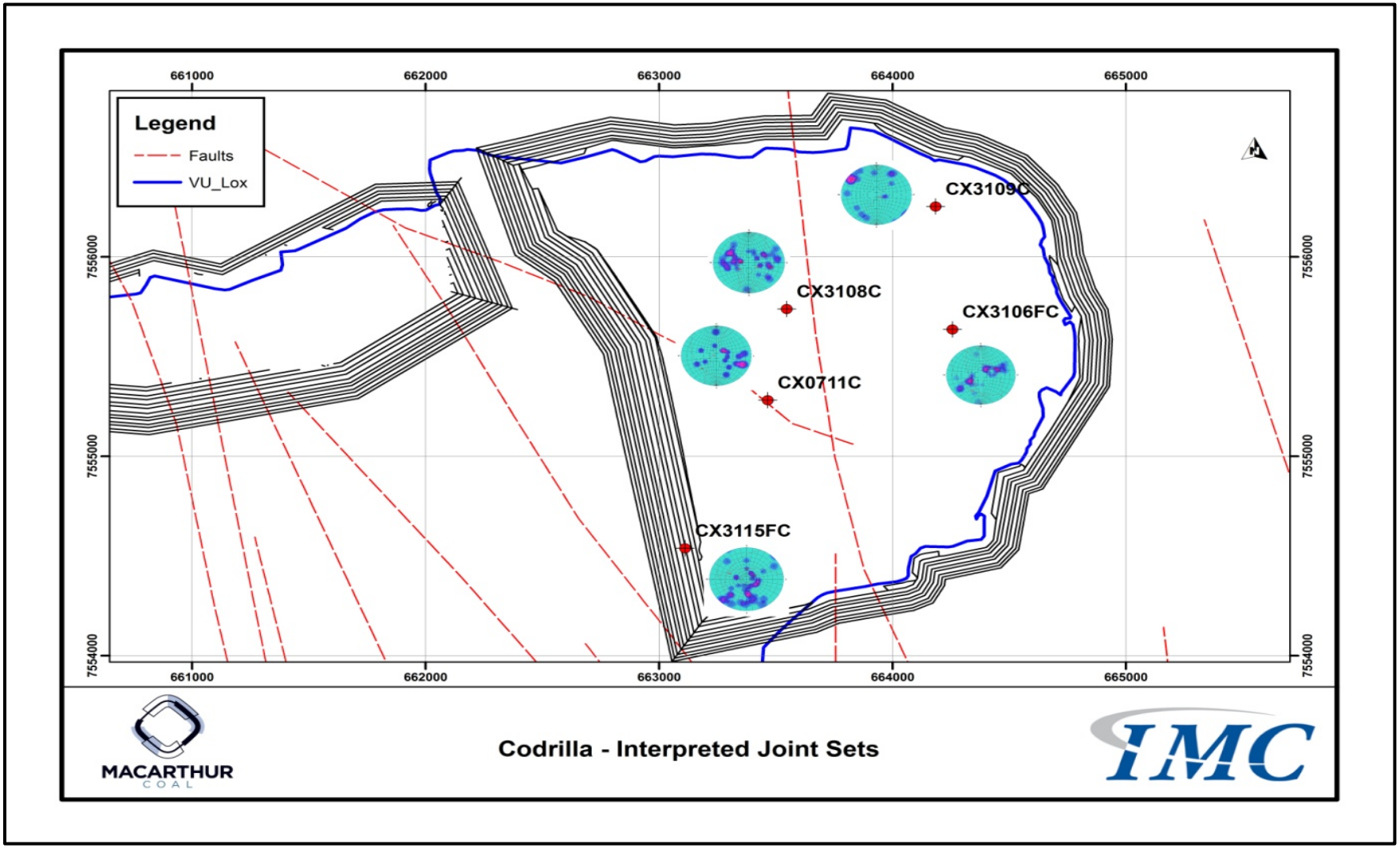

Figure 8-11: Interpreted Joint Sets – Stereonet Layout Plan

8.7 Interpreted Joints – Borehole Analysis

8.7.1 CX0711C – Joints

Borehole CX0711C showed two major joint/defect sets with azimuths toward the west-northwest and southwest, respectively. The southwest dipping set represents a low angle joint set, whilst the northwest dipping set represents a angle angle joint set.

Table 8-4 summarises the main joint set orientations. Figure 8-12 and Figure 8-13 present the pole contour and rose diagrams for borehole CX0711C joints.

Table 8-4: Mean Joint Set Orientation – CX0711C

Set	Dip (^{0})	Dip Direction
1	77	291
2	29	229

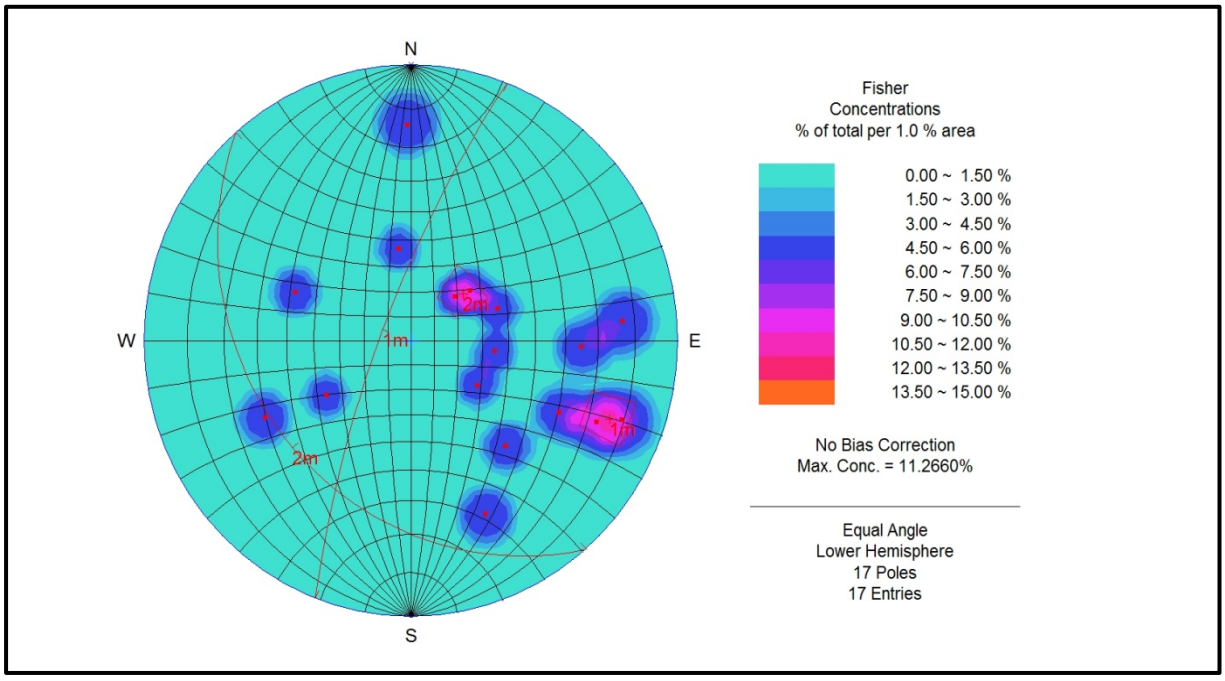

Figure 8-12: Pole Contours for Interpreted Joints – CX0711C

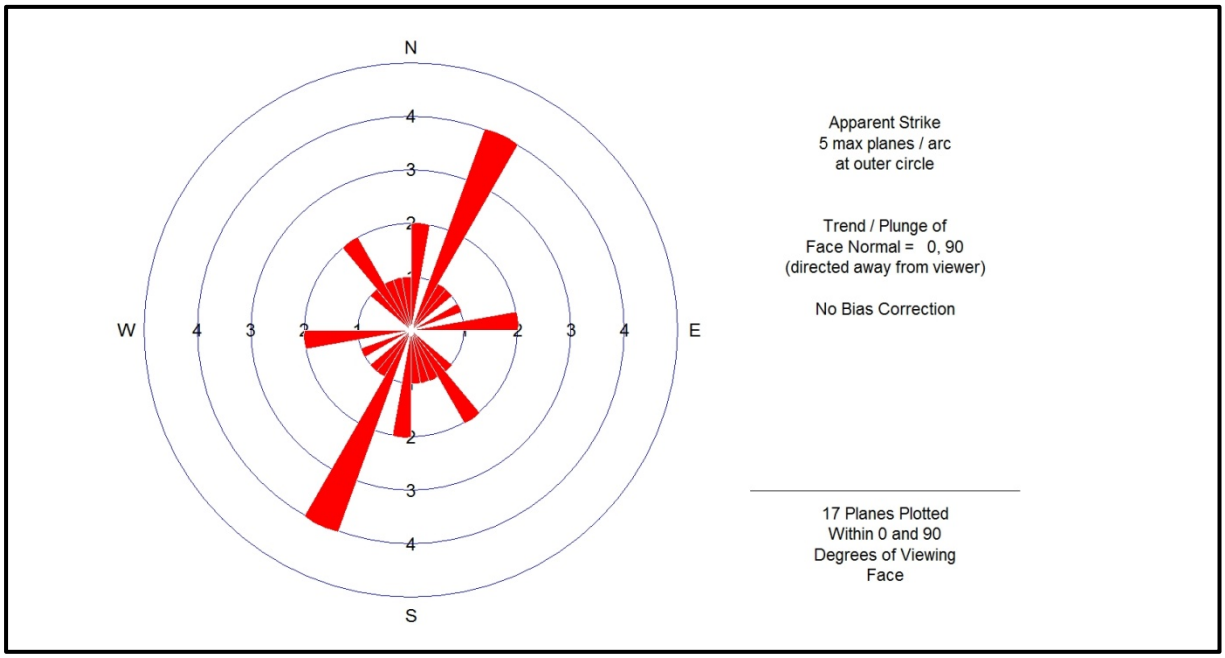

Figure 8-13: Rose Diagram for Interpreted Joints – CX0711C

8.7.2 CX3106FC – Joints

Borehole CX3106FC showed three major low to moderate angle joint sets with azimuths toward the south-southwest, northeast and southwest, respectively.

Table 8-5 summarises the main joint set orientations. Figure 8-14 and Figure 8-15 present the pole contour and rose diagrams for borehole CX3106FC joints.

Table 8-5: Mean Joint Set Orientations – CX3106FC

Set	Dip (^{0})	Dip Direction
1	29	212
2	41	055
3	53	248

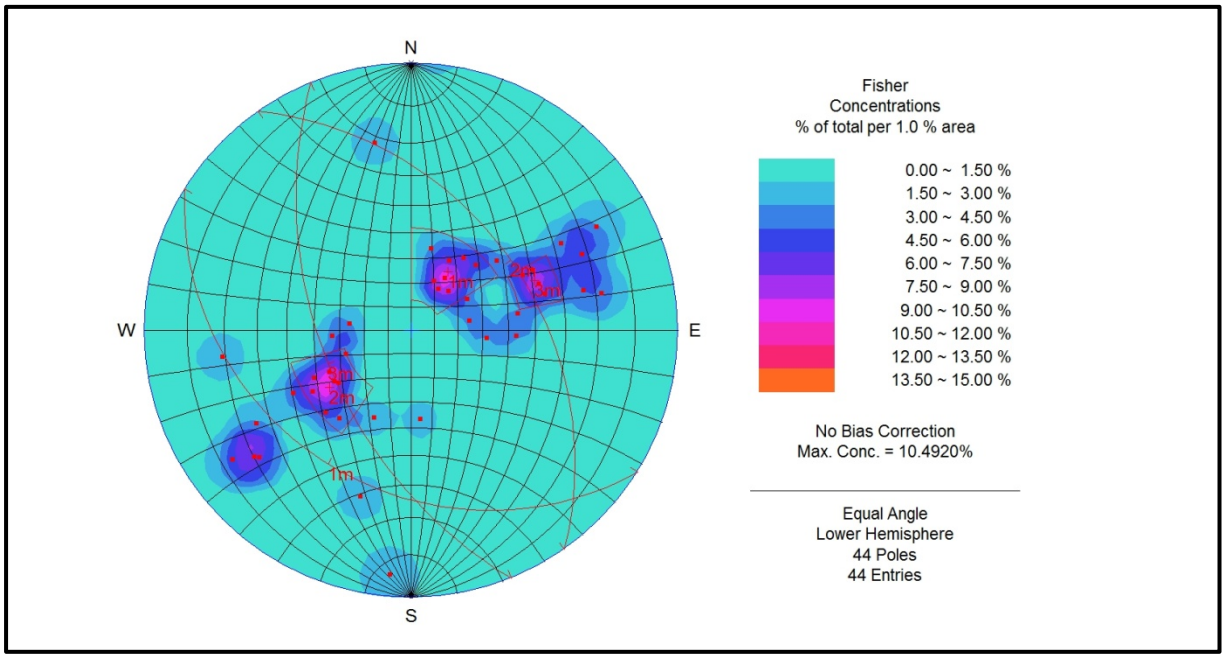

Figure 8-14: Pole Contours for Interpreted Joints – CX3106FCR

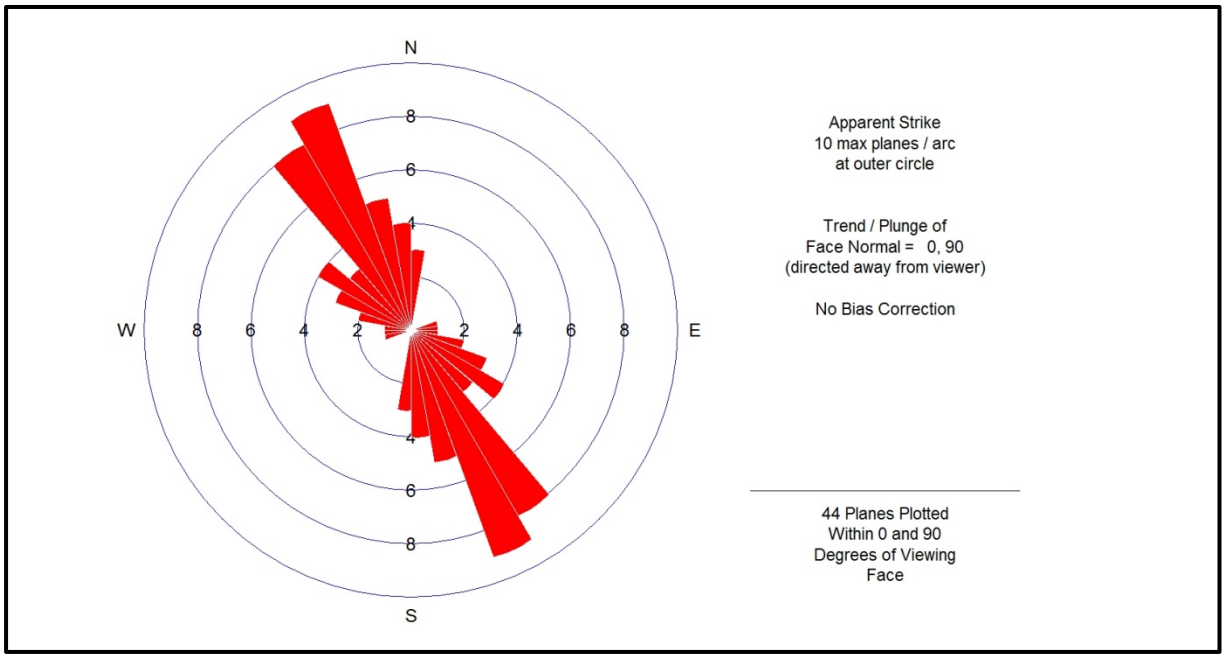

Figure 8-15: Rose Diagram for Interpreted Joints – CX3106FCR

8.7.3 CX3108C – Joints

Borehole CX3108C showed four low to moderate angle joint sets with azimuths toward the southwest, west-northwest, east-southeast and southeast, respectively.

Table 8-6 summarises the main joint set orientations. Figure 8-16 and Figure 8-17 presents the pole contour and rose diagrams for borehole CX3108C joints.

Table 8-6: Mean Joint Set Orientation – CX3108C

Set	Dip (^{0})	Dip Direction
1	52	239
2	59	280
3	28	103
4	64	119

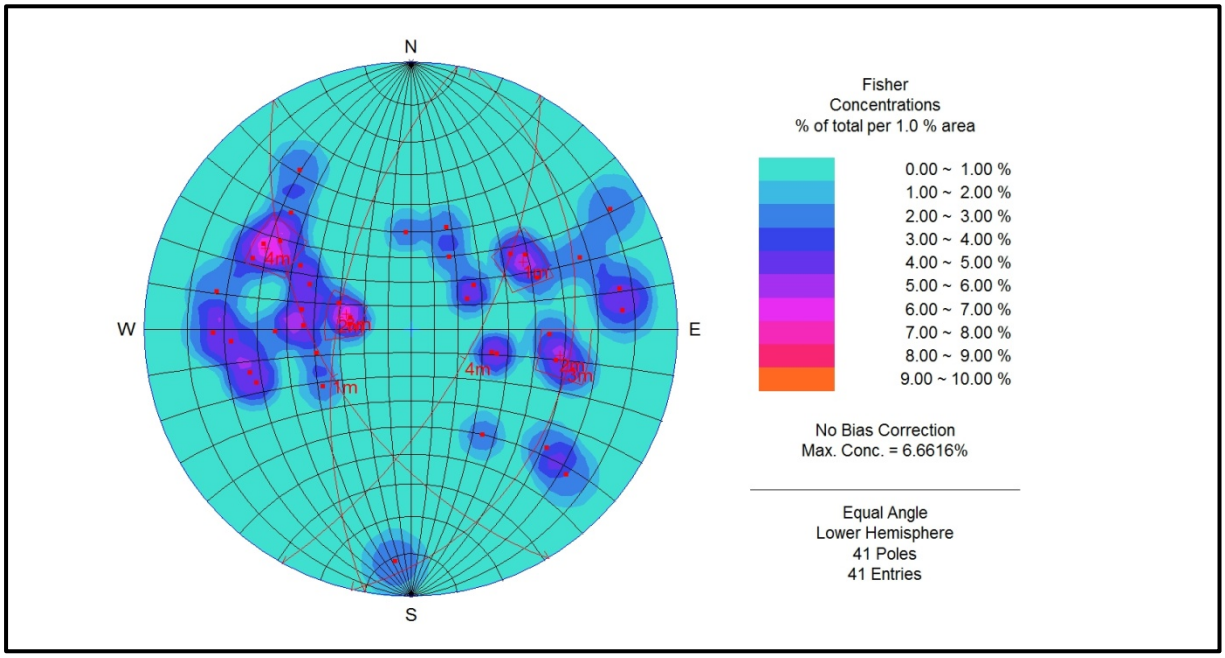

Figure 8-16: Pole Contours for Interpreted Joints – CX3108C

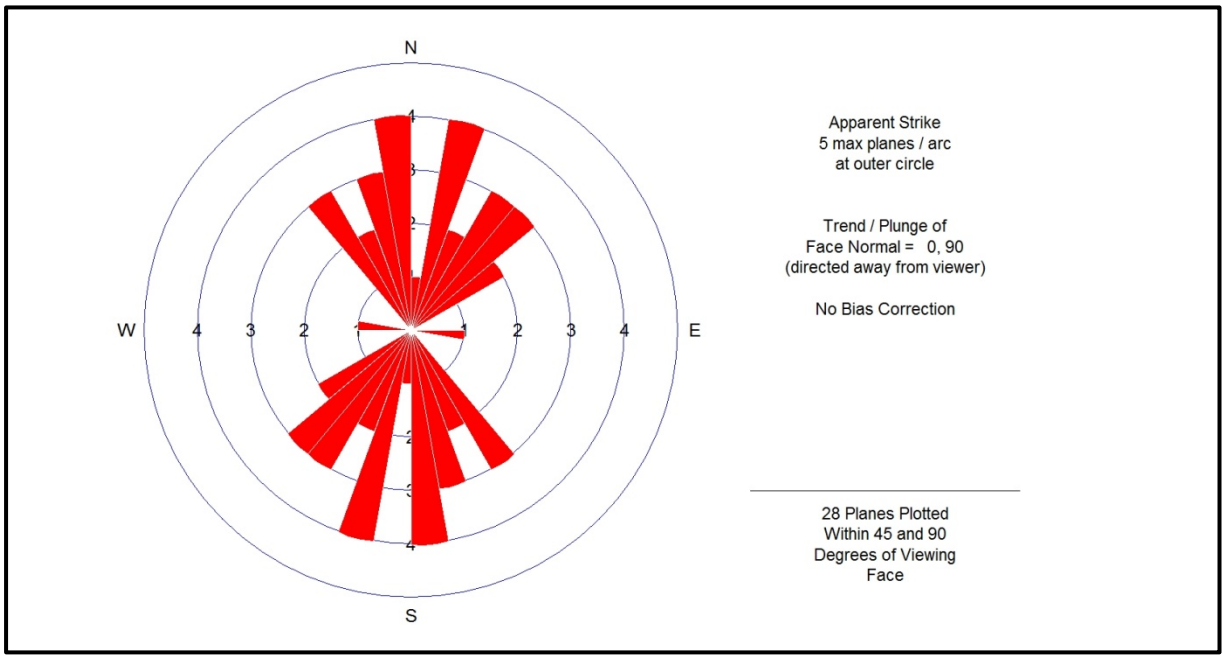

Figure 8-17: Rose Diagram for Interpreted Joints – CX3108C

8.7.4 CX3109C – Joints

Borehole CX3109C showed a high angle joint set with azimuths toward the southeast.

Table 8-7 summarises the main joint set orientations. Figure 8-18 and Figure 8-19 presents the pole contour and rose diagrams for borehole CX3109C joints.

Table 8-7: Mean Joint Set Orientation – CX3109C

Set	Dip (^{0})	Dip Direction
1	81	128

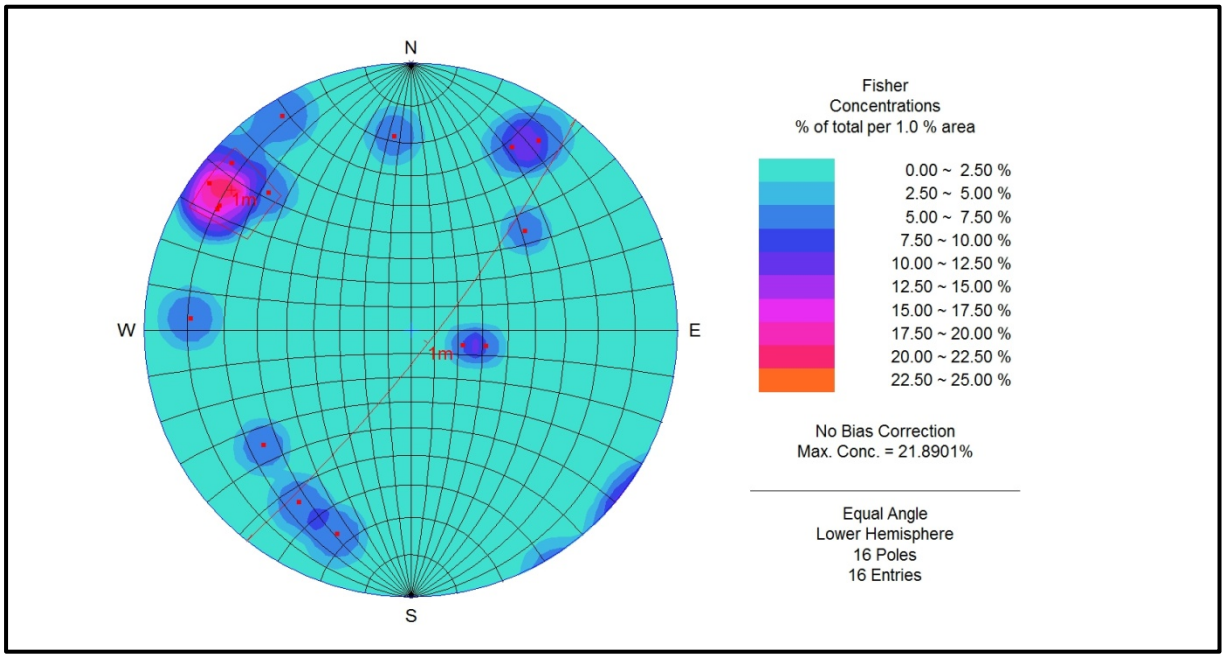

Figure 8-18: Pole Contours for Interpreted Joints – CX3109C

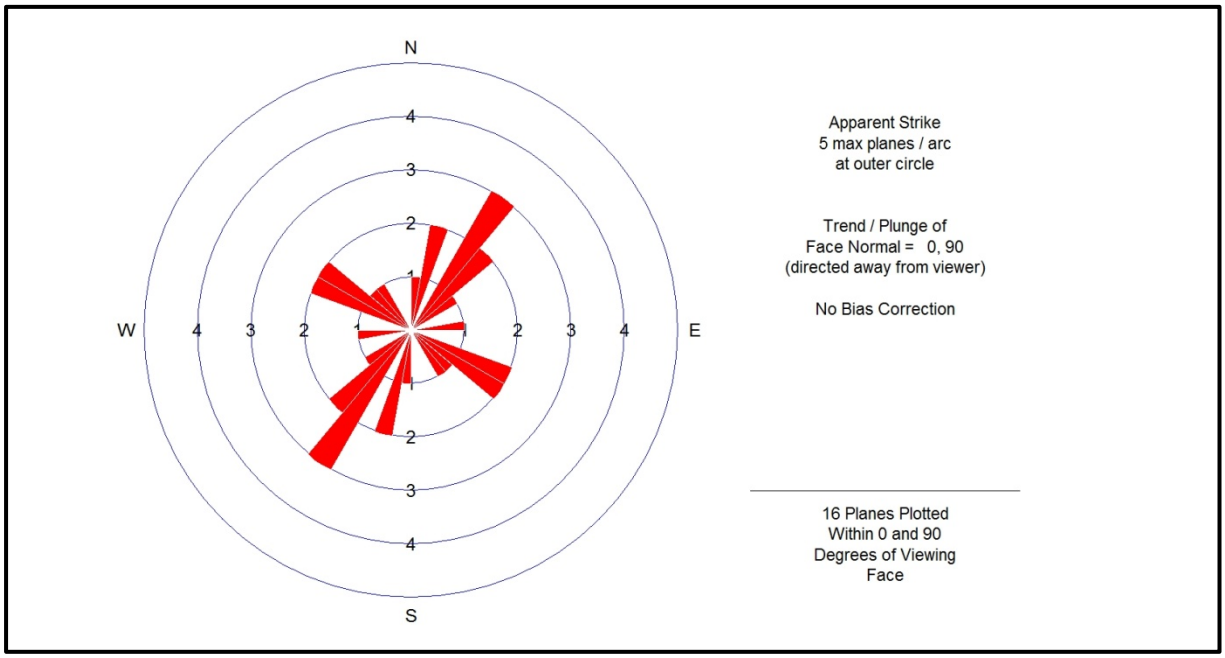

Figure 8-19: Rose Diagram for Interpreted Joints – CX3109C

8.7.5 CX3115FC – Joints

Borehole CX3115FC showed three moderate angle joint sets with azimuths towards the southwest, west-northwest and north, respectively.

Table 8-8 summarises the main joint set orientations. Figure 8-20 and Figure 8-21 presents the pole contour and rose diagrams for borehole CX3115FC joints.

Table 8-8: Mean Joint Set Orientation – CX3115FC

Set	Dip (^{0})	Dip Direction
1	24	229
2	34	289
3	50	354

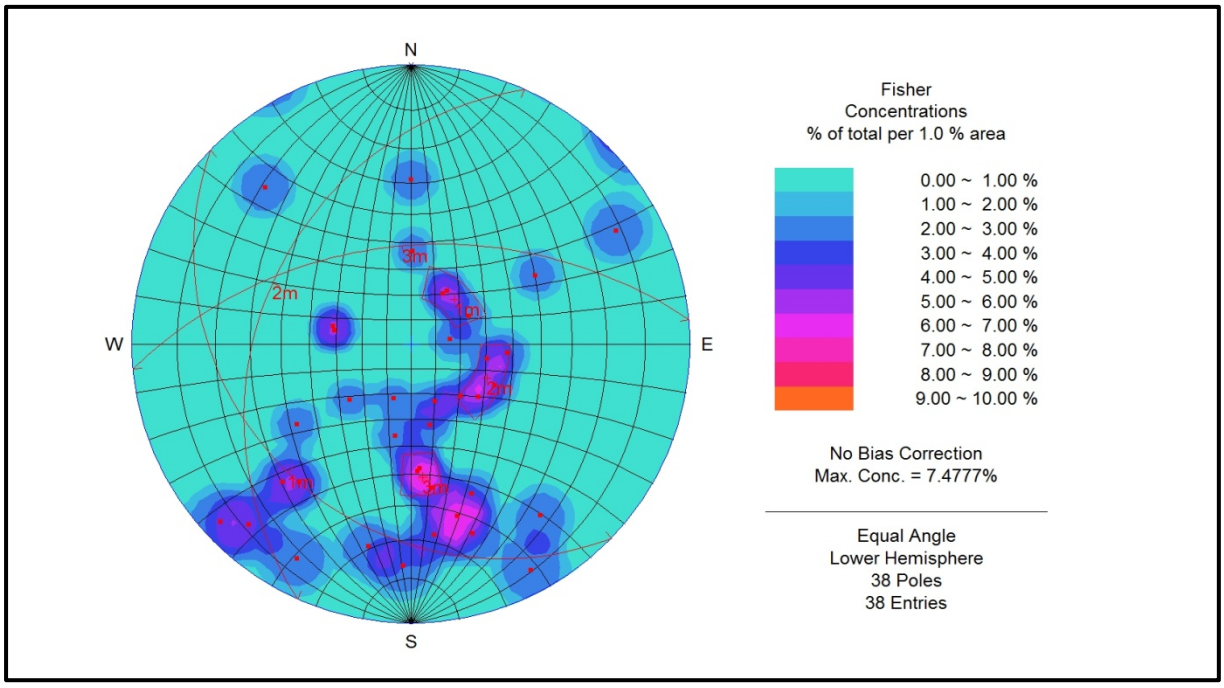

Figure 8-20: Pole Contours for Interpreted Joints – CX3115FC

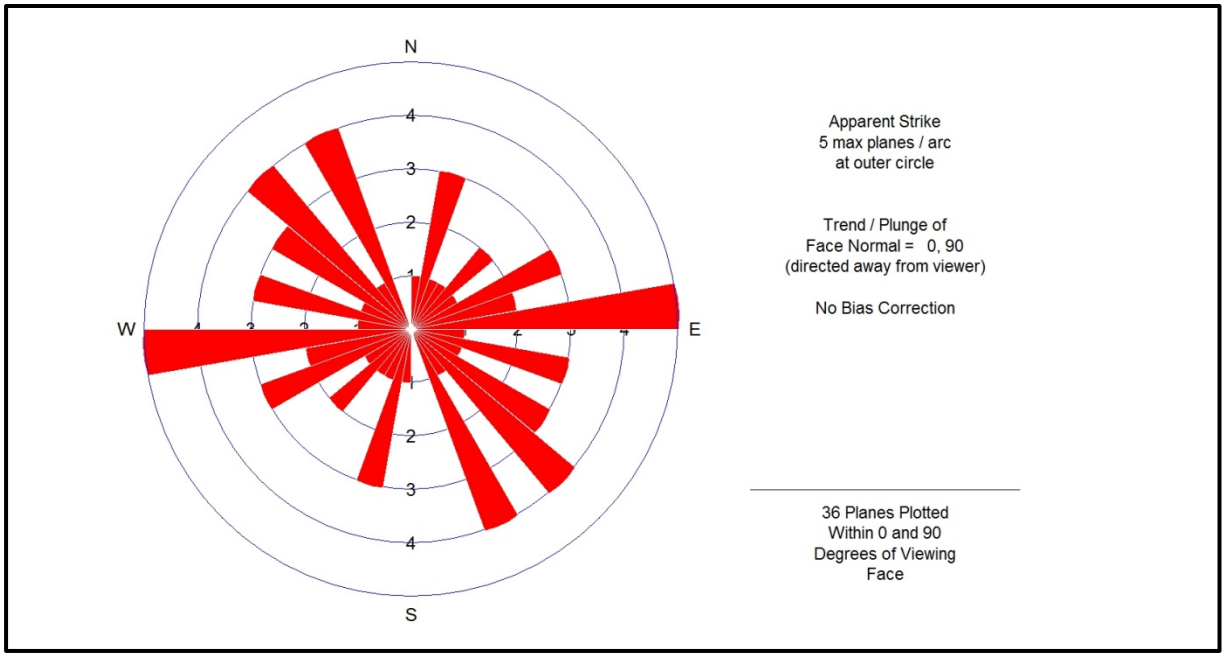

Figure 8-21: Rose Diagram for Interpreted Joints – CX3115FC

8.8 Analysis of Bedding

Interpreted bedding for all available boreholes showed some variability in azimuth. This observed variability may be a result of the influence of localised faults or shear zones, which tend to steepen the dip of the bedding planes. A more reliable method of obtaining the overall site bedding trends is to examine the target seam floor structure.

From the stereographic analysis, it was possible to ascertain a low confidence site wide azimuth trend. However, more localised trends were observed on a borehole by borehole basis, which is presented in Section 8.9.

Figure 8-22 presents an analysis of bedding dip angles recorded from the ATV interpretation. A total of 84% of the bedding surfaces interpreted dip at ≤ 19^0, with 56% dipping at ≤ 14^0. It must be noted that these dip angles are the site average and are not weighted with respect to geological structures or discretised according to interburden unit. The table below shows the majority of bedding dips to be < 19^0, with median dip angle for all interpreted bedding of approximately 12^0.

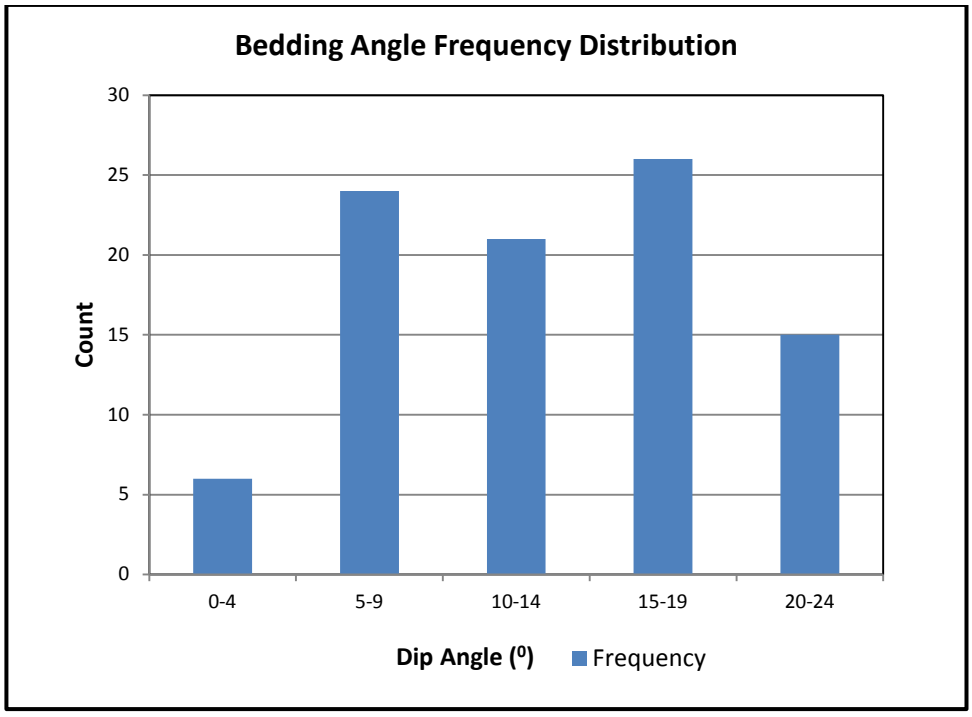

Figure 8-22: Bedding Angle Frequency Distribution – Codrilla Site

Table 8-9: Recorded Bedding Dip Angles

Dip Angle Category (^{0})	Count	Percentage (%)
0 - 4	6	7
5 - 9	24	26
10 -14	21	23
15 - 19	26	28
20 - 24	15	16
Total	92	100

Figure 8-23 and Figure 8-24 presents a pole contour plot and rose diagram for bedding structures across the Codrilla site.

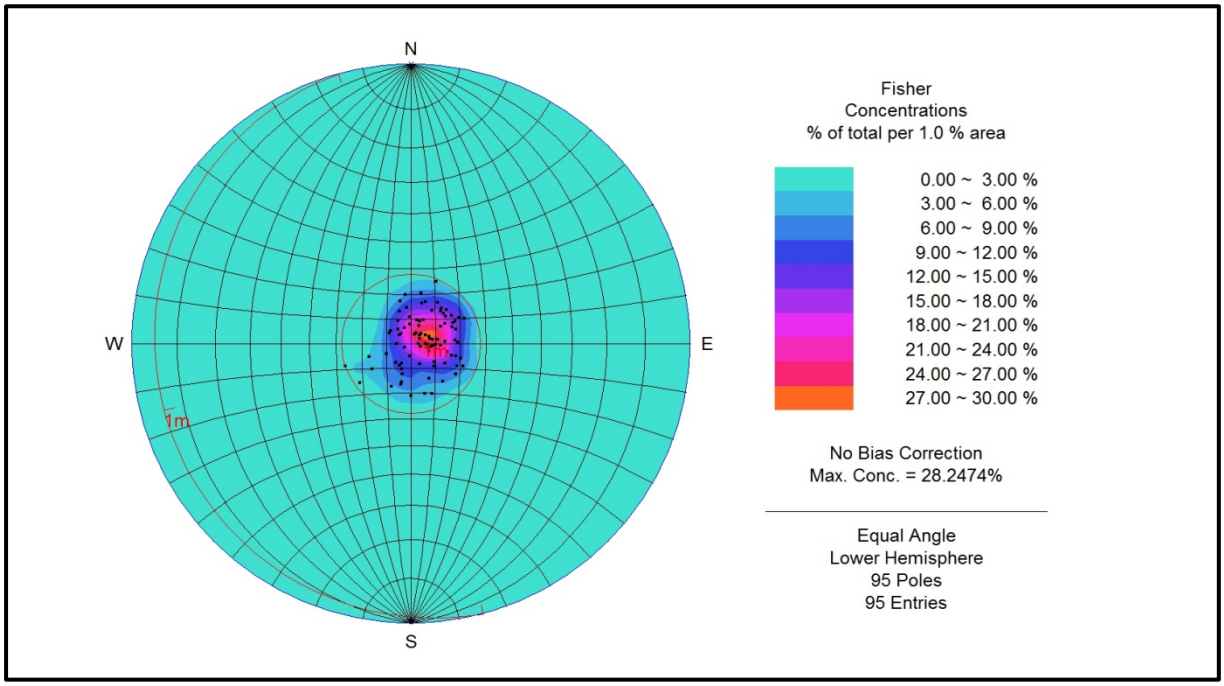

Figure 8-23: Pole Contours for Interpreted Bedding – Codrilla Site

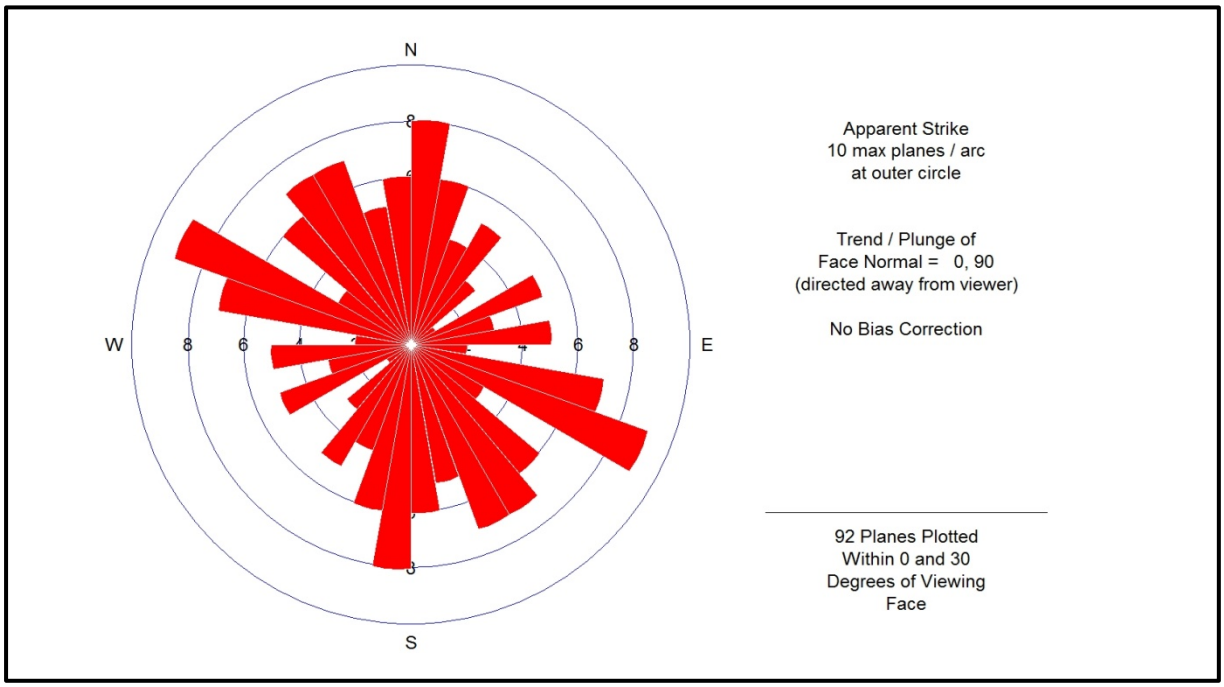

Figure 8-24: Rose Diagram for Interpreted Bedding – Codrilla Site

8.9 Interpreted Bedding – All Boreholes

8.9.1 CX0711C – Bedding

Figure 8-25 presents the bedding azimuth rose diagram for the CX0711C. The diagram shows an azimuth trend towards the west-northwest.

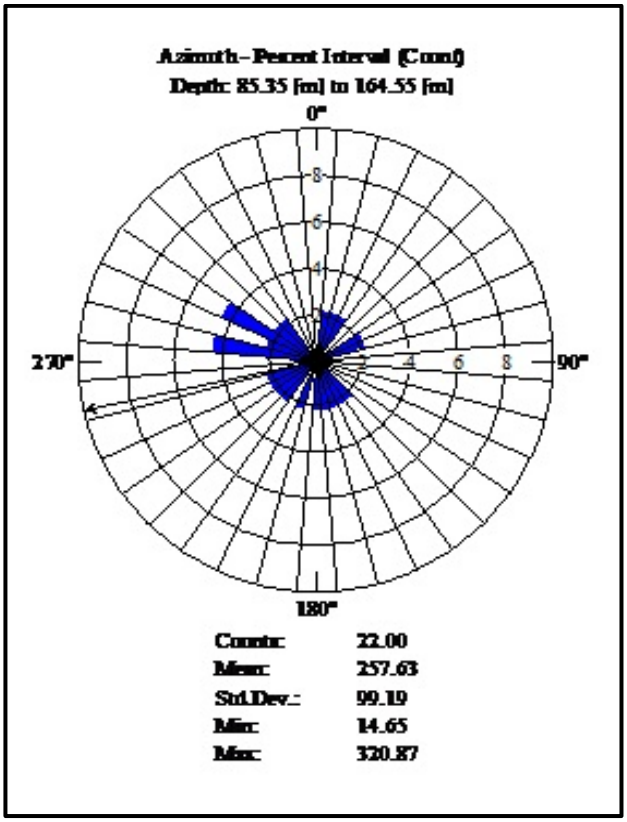

Figure 8-25: Bedding Dip Azimuth Rose Diagram – CX0711C

8.9.2 CX3106FC – Bedding

Figure 8-26 presents the bedding azimuth rose diagram for the CX3106FC. The diagram shows an azimuth trend towards the west-southwest.

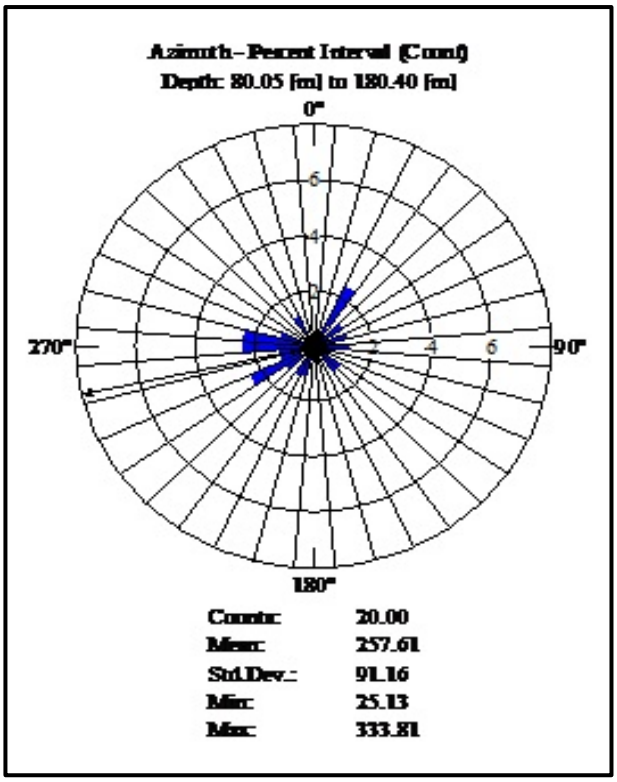

Figure 8-26: Bedding Dip Azimuth Rose Diagram – CX3106FC

8.9.3 CX3108C – Bedding

Figure 8-27 presents the bedding azimuth rose diagram for the CX3108FC. The diagram shows an azimuth trend towards the west.

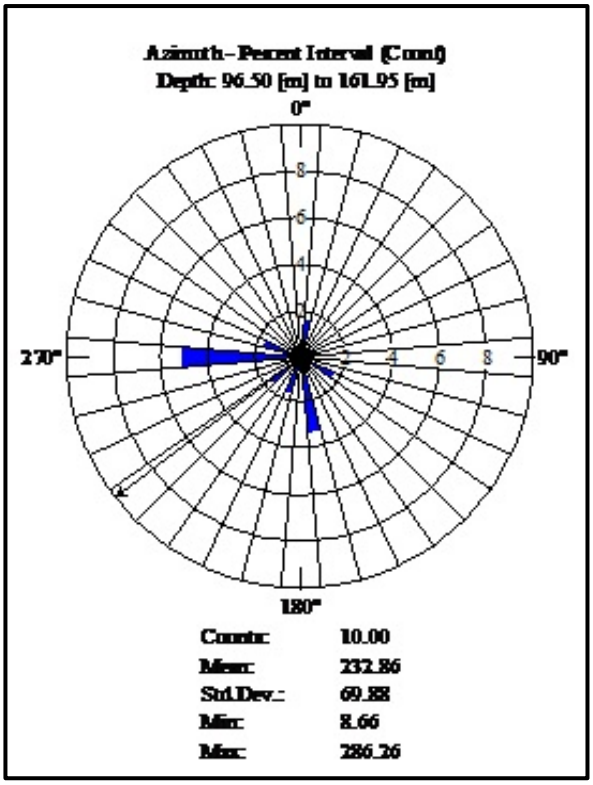

Figure 8-27: Bedding Dip Azimuth Rose Diagram – CX3108FC

8.9.4 CX3109C – Bedding

Figure 8-28 presents the bedding azimuth rose diagram for the CX3109FC. The diagram shows an azimuth trend towards the south southwest (SSW).

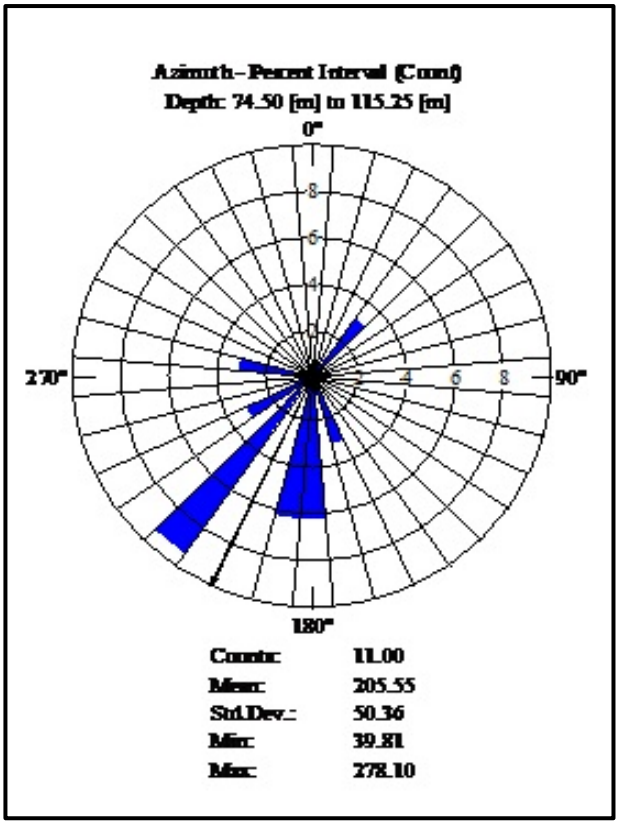

Figure 8-28: Bedding Dip Azimuth Rose Diagram – CX3109FC

8.9.5 CX3115C – Bedding

Figure 8-29 presents the bedding azimuth rose diagram for the CX3115FC. The diagram shows an azimuth trend towards the west southwest (WSW).

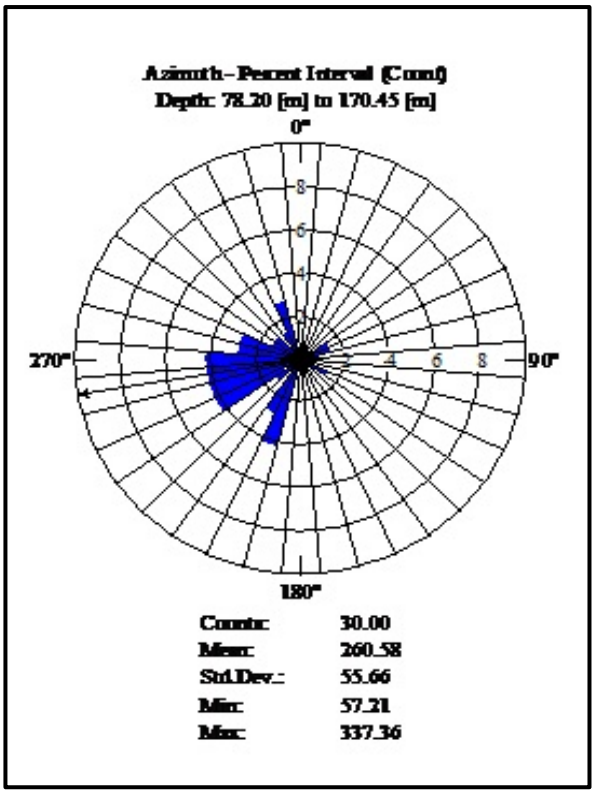

Figure 8-29: Bedding Dip Azimuth Rose Diagram – CX3115FC

9 PRELIMINARY KINEMATIC ANALYSIS

An evaluation of structural interactions for nominated interim and final highwall positions, northern and southern end walls and low wall positions was conducted to identify potential bench scale stability issues. This was achieved using the Rocscience DIPS V5.1 software to interpret the structural data obtained from the ATV interpretation.

The analysis presented was designed to test the applicability of the proposed pre-split bench angles, and to examine the potential failure mechanisms that may exist for fresh rock slopes designed at 65°. On this basis, the kinematic analysis was only conducted for fresh Permian materials, where failure would be controlled by adverse block configurations and geometries relative to the pit face.

The following failure mechanisms were examined as part of the kinematic analysis:

- Planar failures; and
- Wedge failures.

Toppling failure was not considered as part of the kinematic analysis due to it being a relatively uncommon occurrence in the Bowen Basin.

Based on the limited amount of acoustic scanner data, the kinematic analysis presented is considered only indicative at this stage, and is also limited to the East Pit, given that no ATV information was available for the West Pit. A further constraint was that most of the ATV boreholes were not located in proximity to the final pit slopes; therefore some undisclosed variations in the presented analysis could be expected.

It is important to note, that whilst the kinematic analysis produces a statistical likelihood of a “set” of joints or discontinuities contributing to potential instability, failure is the result of individual, or the interaction of individual discontinuities. Although the interpretation of discontinuity sets is considered to have a low reliability at this stage, joints sets that are shown to daylight on the pit face are likely to have a greater chance of failure, than random joints. It is recommended that additional ATV information be procured during more detailed phases of work to improve the reliability of joint/discontinuity set interpretations.

For the purposes of analysis, kinematic scenarios were evaluated for several positions along the low wall, endwalls and for an interim and final highwall position for the East Pit. These are presented in Figure 9-1.

Table 9-1 below presents seven pit slope azimuth cases, using available borehole data for the highwall, end wall and low wall.

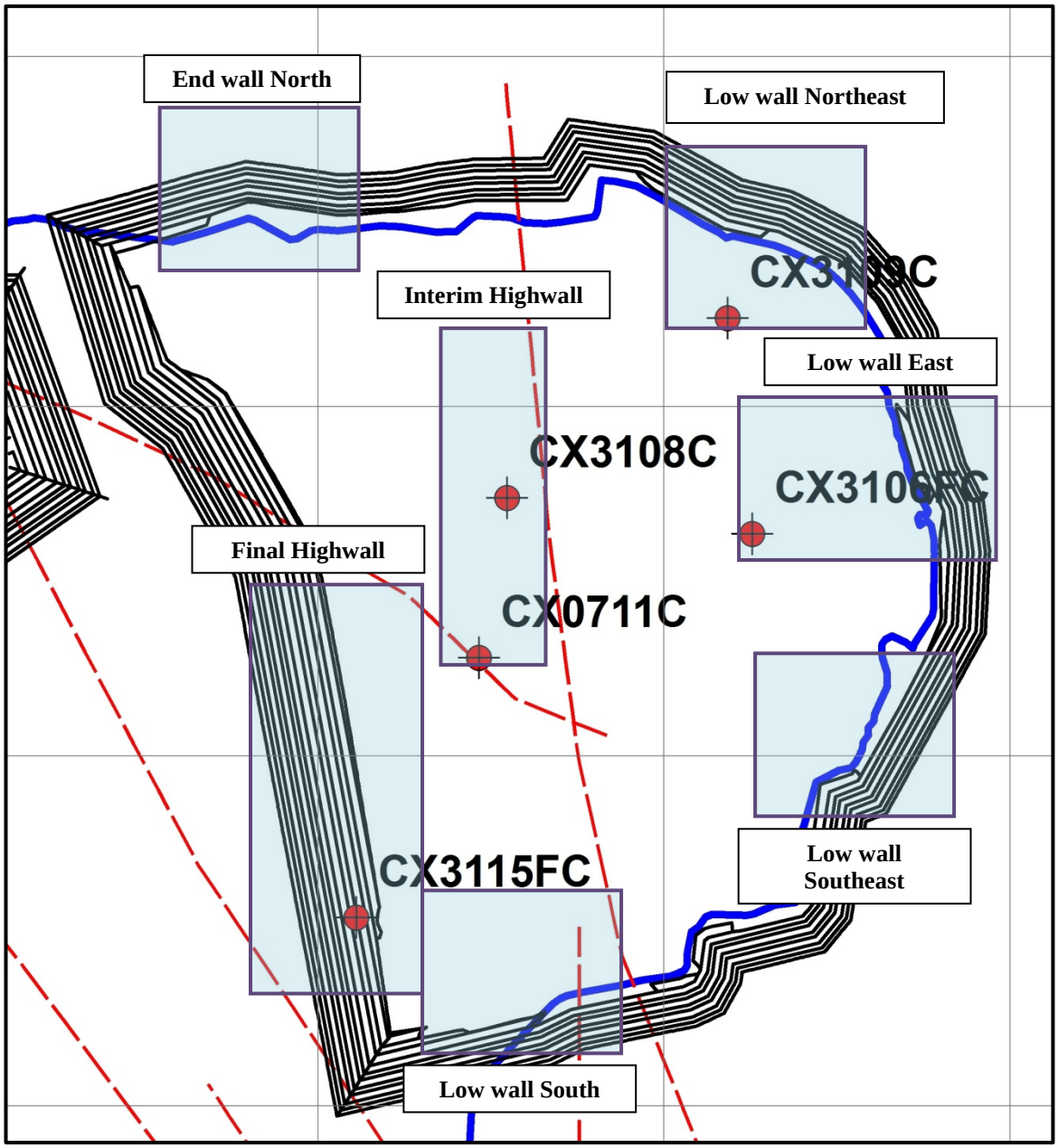

Figure 9-1: Pit Locations for Kinematic Scenarios

Table 9-1: Pit Slope Azimuth Cases

Case	Relevant Borehole	Approx. Bench Angle (^{o})	Approx. Wall Azimuth(^{o})
Final Highwall	CX3115C	65	080
Interim Highwall	CX3108C & CX0711C	65	080
Endwall - North	CX3108FC	65	165
Endwall - South	CX3115FC	65	345
Lowwall - East	CX3106FC	65	265
Low wall - Northeast	CX3109C	65	235
Low wall - Southeast	CX3106FC	65	315

These failure mechanisms were assessed by plotting the pit wall dip and azimuth on a stereonet, using those measurements presented in the above.

Pit wall daylight envelopes were also plotted, along with the friction cone which is essentially an assumed friction angle of the structure (joints, bedding etc) planes.

An example of planar, wedge and block slippage failure mechanisms from a stereographic analysis is presented in Figure 9-2 to Figure 9-3.

For planar failure analysis, structure poles that plot outside of the friction cone, but within the daylight envelope (orange highlighted region), are considered to be kinematically free to move. Structure poles that plot inside the friction cone generally indicate that planar failure would be unlikely due to frictional resistance.

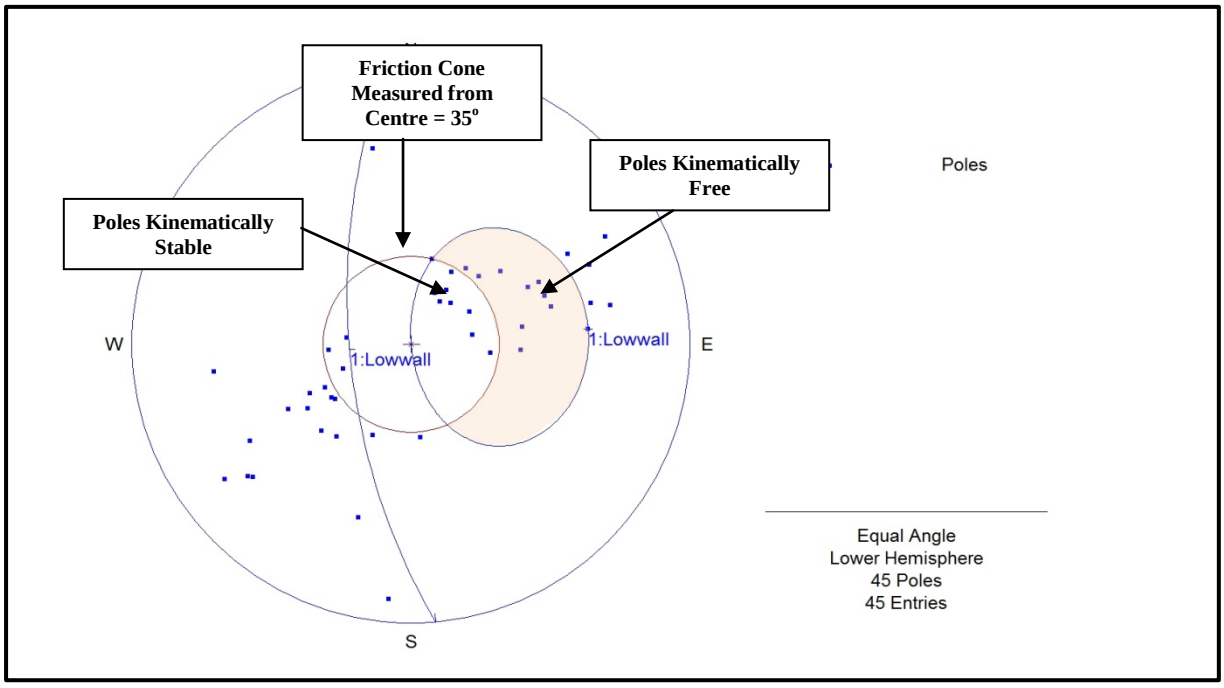

Figure 9-2: Planar Failure Kinematic Scenario Example

Similarly, for wedge failure analysis, the intersection of structure planes which daylight on the pit face, inside the friction cone, are kinematically free to move.

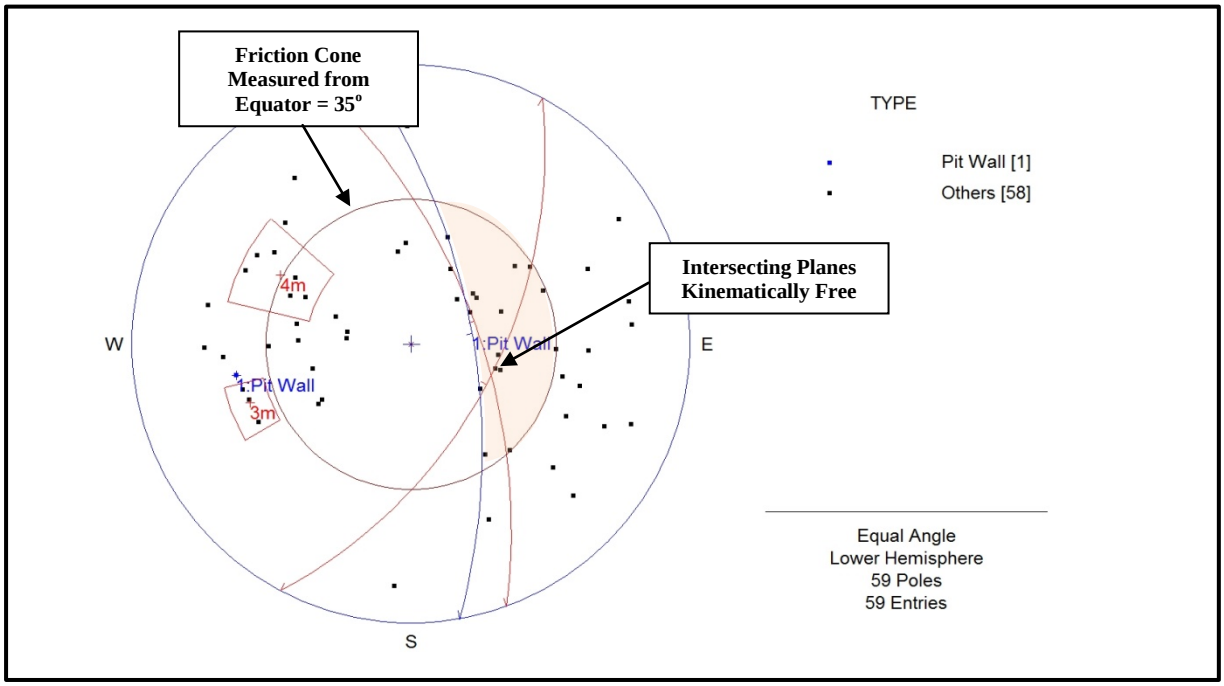

Figure 9-3: Wedge Failure Kinematic Scenario Example

9.1 Assumptions

The following assumptions were made for the analysis of discontinuities:

- Friction angle of joint planes assumed to be approximately 35°;
- Friction angle of Yarrabee Tuff (YT) assumed to be approximately 20^{0};
- Friction cone for wedge configurations measured from the equator of the stereonet; therefore 55° used for planes; and
- Joint planes are pervasive and continuous throughout the rock mass.

9.2 Indicative Planar Failure Mechanisms

9.2.1 Final and Interim Highwall

Figure 9-4 and Figure 9-5 show the stereographic analyses for the final and interim highwall positions, respectively. The analyses indicate the following joint sets for each case:

- Three main joints sets for the final highwall; and
- Four main joint sets for the interim highwall.

The final highwall case showed the joint sets were unlikely to form planar failure configurations, based on the available data; however the interim highwall case indicated that of the four main joint sets measured two could have the potential to form planar failure configurations.

For both cases, the analyses show the possibility for planar configurations from random joint orientations; however based on the limitations of the dataset, these are not considered to be statistically relevant at this stage.

In addition to this, potential wedge configurations were also identified for the interim highwall case, which will be discussed in Section 9.3.

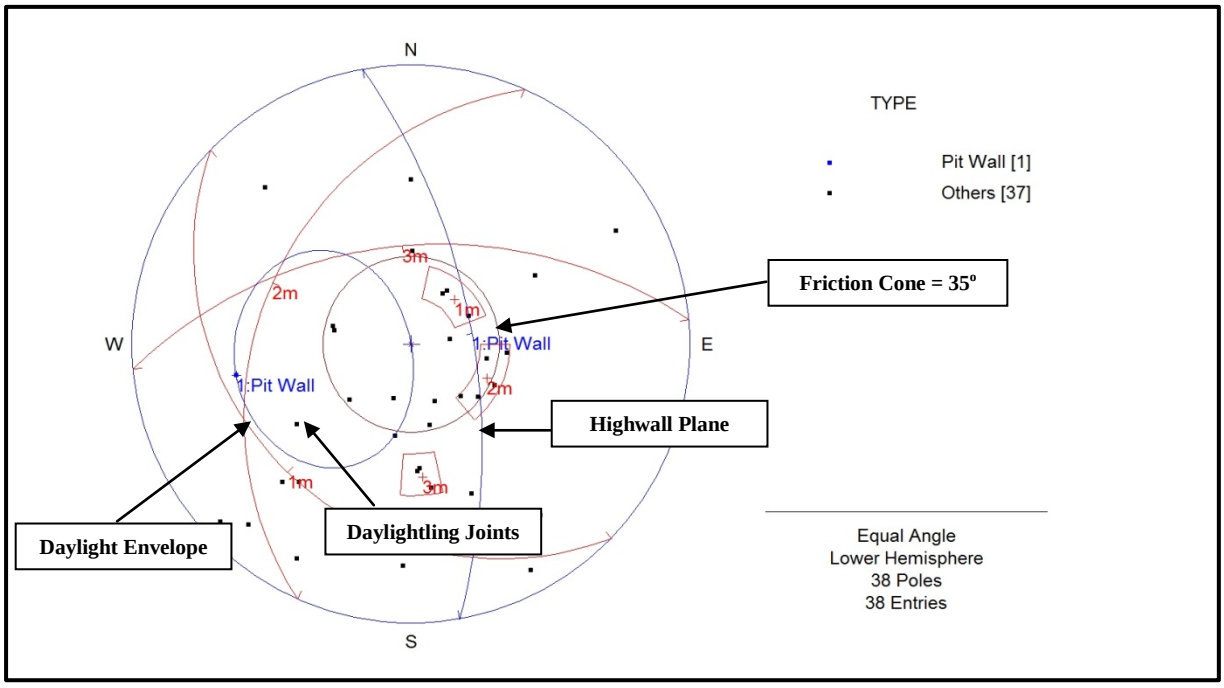

Figure 9-4: Planar Kinematic Scenario – Final Highwall

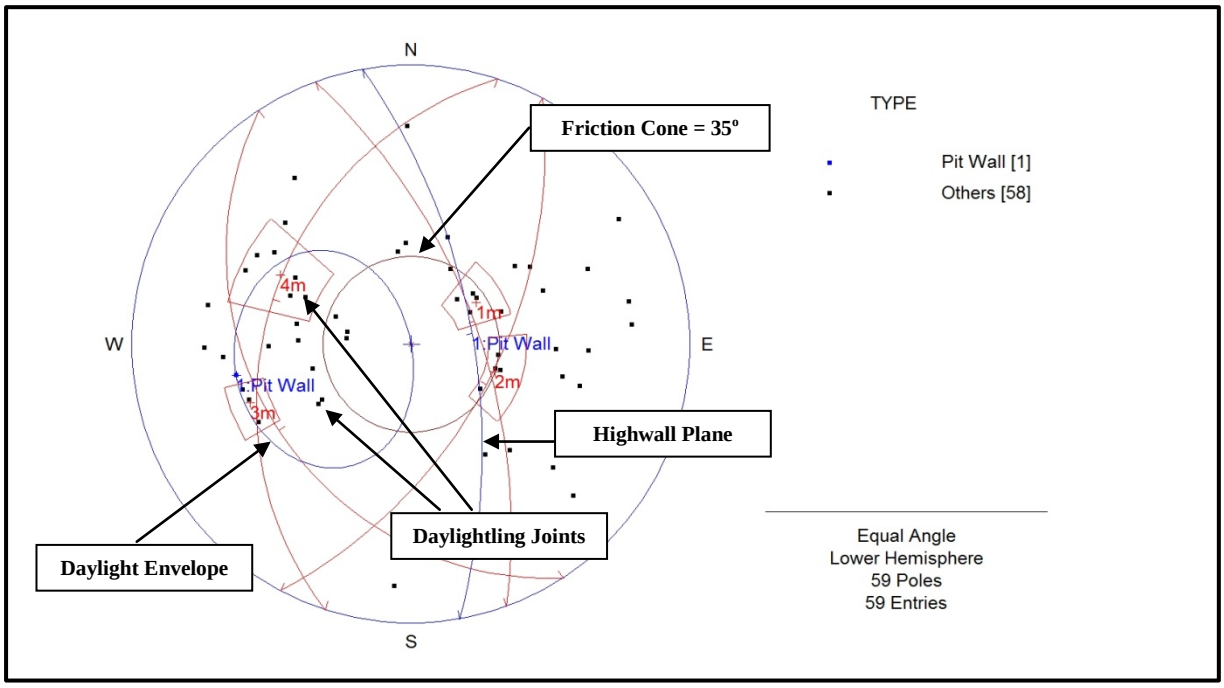

Figure 9-5: Planar Kinematic Scenario – Interim Highwall

9.2.2 Endwall North and South

Figure 9-6 and Figure 9-7 show the stereographic analyses for the endwall north and endwall south cases, respectively. The analyses indicated the following joints sets for each case:

- Four main joint sets for endwall north; and
- Three main joints sets for endwall south.

The endwall north case showed that joint sets were unlikely to form planar failure configurations, based on the available data; however the endwall south case indicated that one of the joint sets could have the potential to form planar failure configurations. The endwall south case also shows two joint sets located inside the friction cone. This indicates that the dip of the joints is lower than the frictional forces required for displacement under dry conditions, therefore would be kinematically stable.

Similar to the highwall cases, the analyses showed the possibility for planar configurations from random joint orientations; however based on the limitations of the dataset, these are not considered to be statistically relevant at this stage.

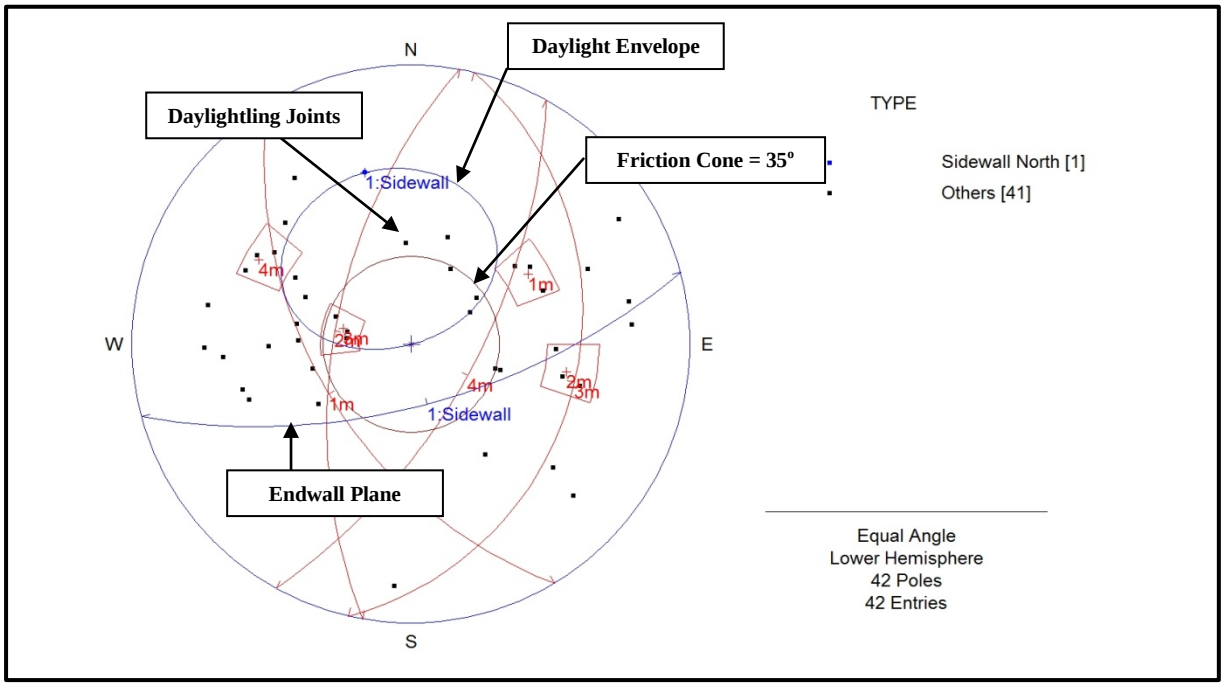

Figure 9-6: Planar Kinematic Scenario – Endwall North

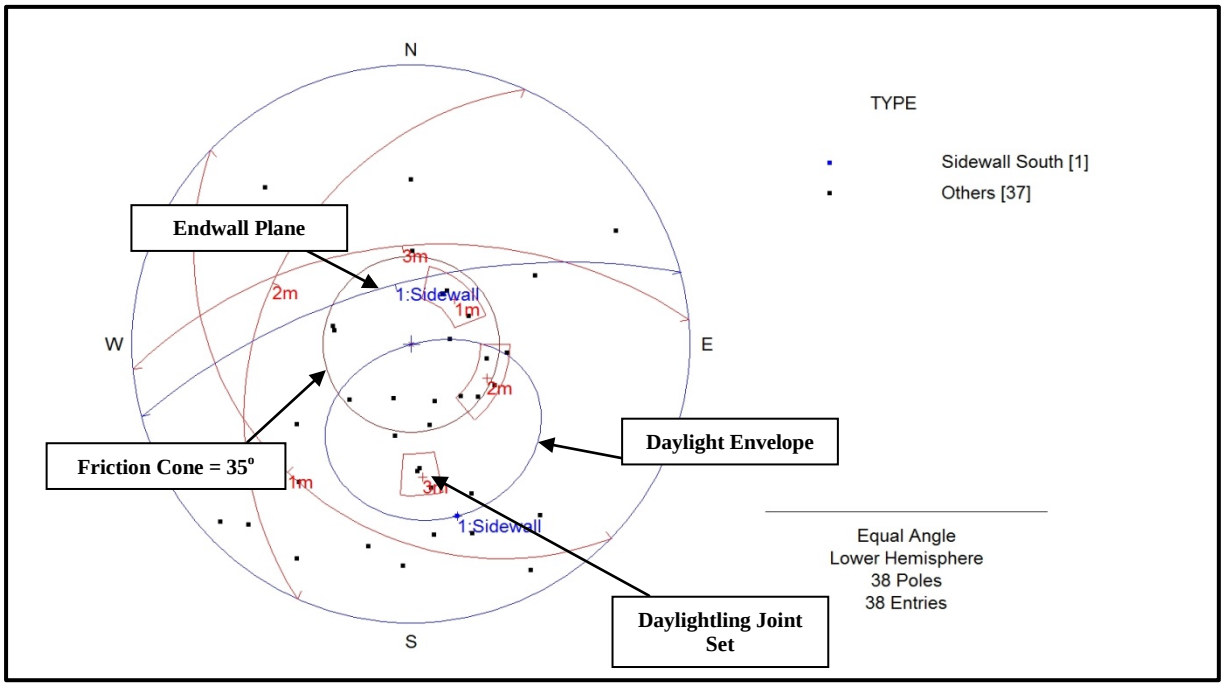

Figure 9-7: Planar Kinematic Scenario – Endwall South

9.2.3 Low wall East

Figure 9-8 shows the stereographic analyses for the low wall east case. The analyses indicated the following joints sets for each case:

- Three main joint sets for low wall east.

The low wall east case showed that one joint set could have the potential to form planar failure configurations, with also the possibility of random joint configurations.

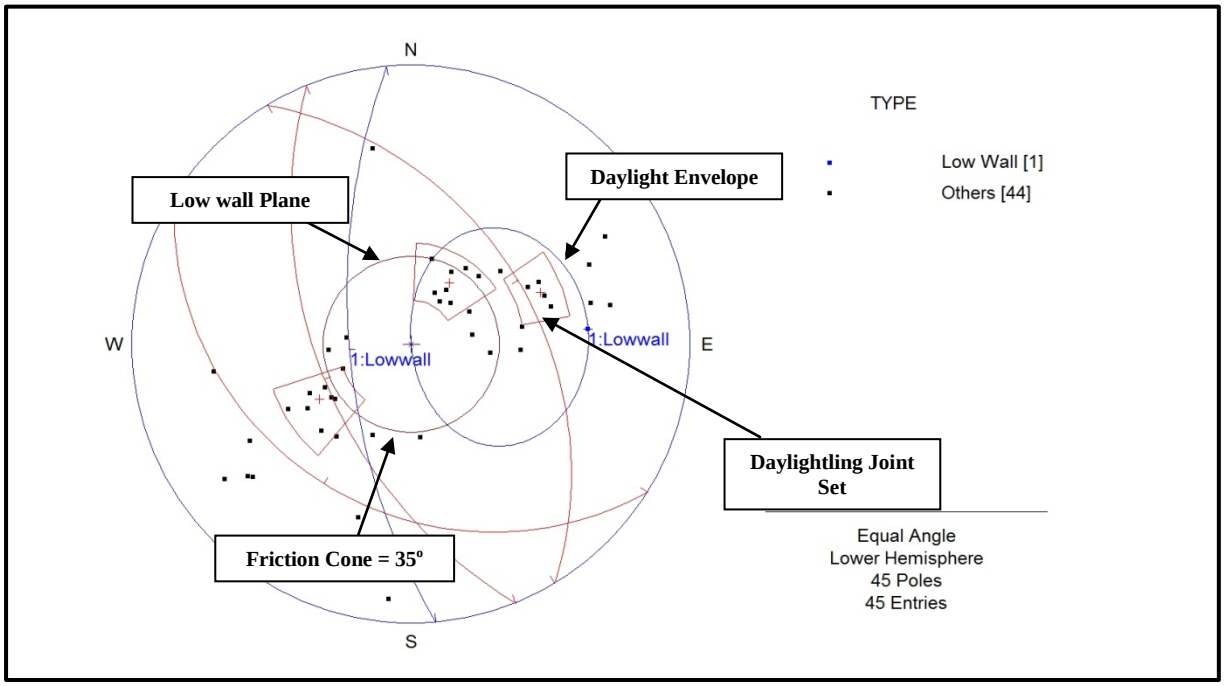

Figure 9-8: Planar Kinematic Scenario – Low wall East

9.2.4 Low wall North-East and South-East

Figure 9-9 and Figure 9-10 show the stereographic analyses for the low wall north-east and low wall south-east cases, respectively. The analyses indicated the following joints sets for each case:

- One main joint sets for low wall north-east; and
- Three main joints sets for low wall south-east.

Both cases showed that interpreted joint sets were unlikely to form planar failure configurations, based on the available data; however the analyses showed the possibility for planar configurations from random joint orientations for the low wall south-east case.

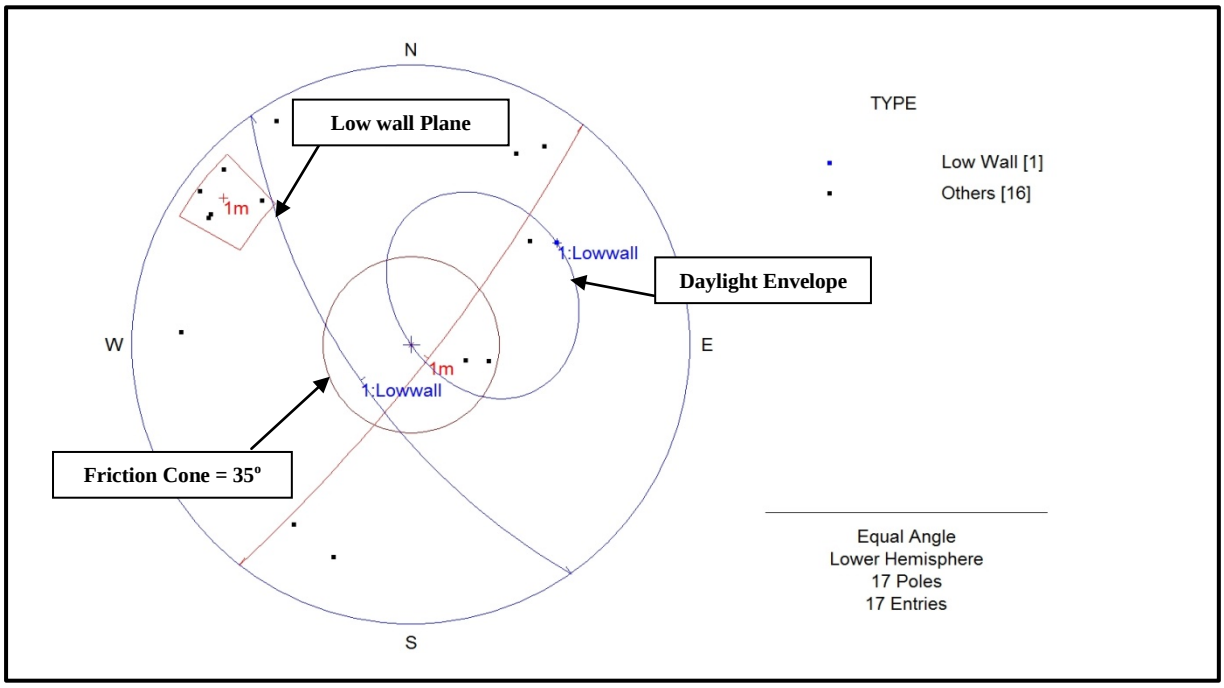

Figure 9-9: Planar Kinematic Scenario – Low wall North-East

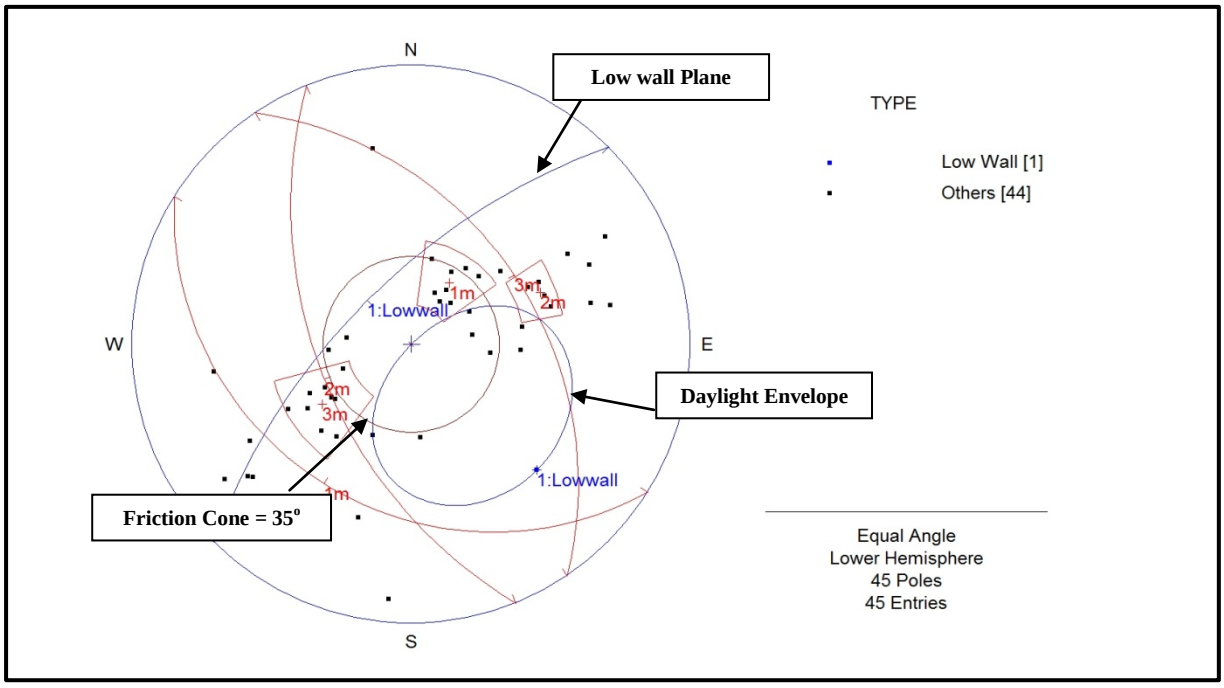

Figure 9-10: Planar Kinematic Scenario – Low wall South-East

9.3 Indicative Wedge Failure Mechanisms

9.3.1 Final and Interim Highwall

Figure 9-11 shows the final highwall case does not indicate the potential for significant wedge configurations at this stage, with only two random joint poles showing steep intersections.

The interim highwall case did however indicate the potential for wedge configurations for the interpreted joint sets, as shown in Figure 9-12.

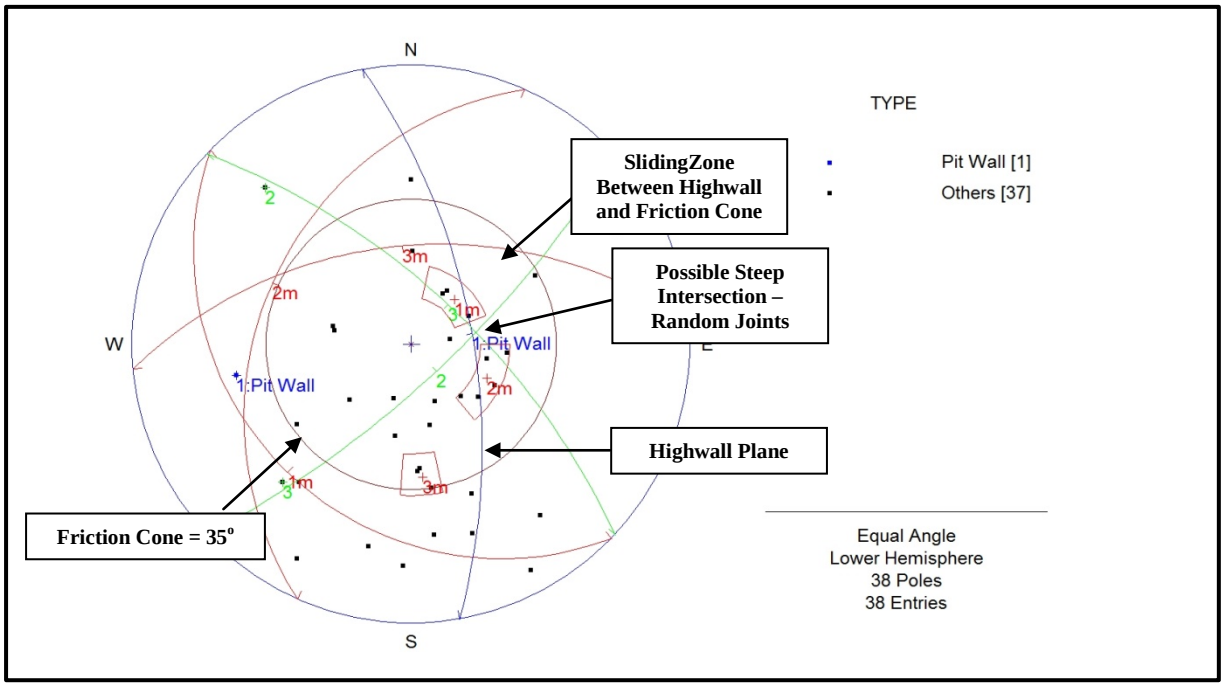

Figure 9-11: Wedge Kinematic Scenario – Final Highwall

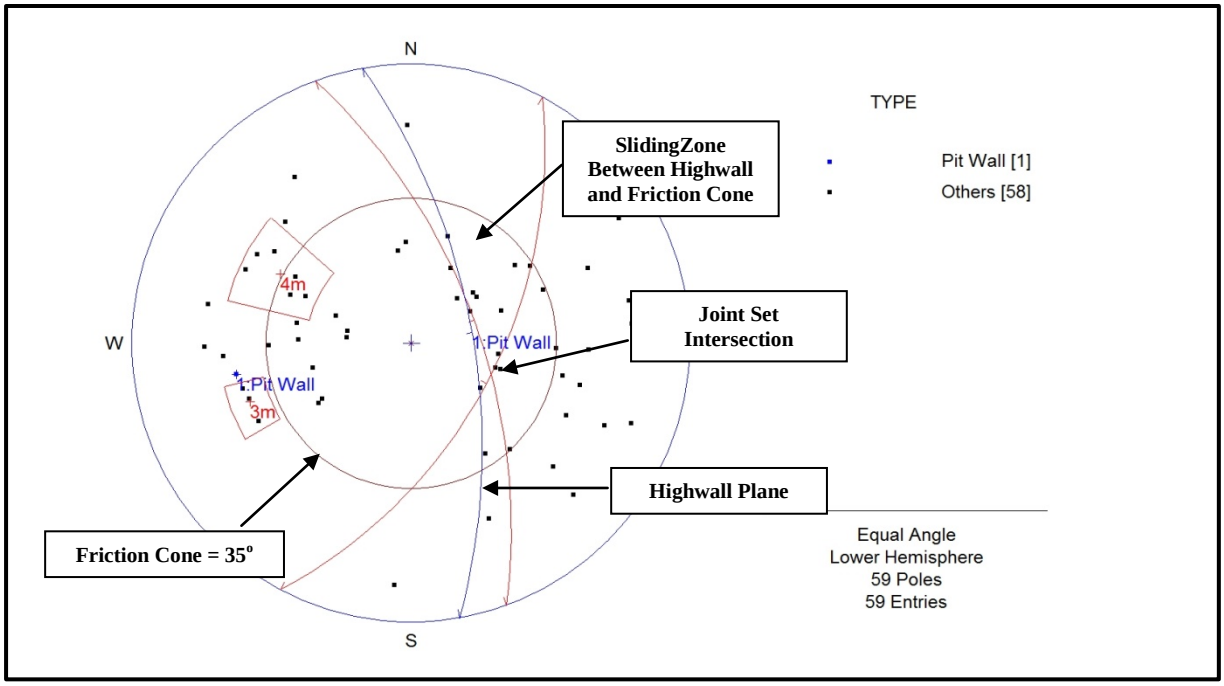

Figure 9-12: Wedge Kinematic Scenario – Interim Highwall

9.3.2 Endwall North and South

Figure 9-13 shows the endwall north case and indicates the potential for kinematically unstable wedge configurations; however the intersection plotted marginally close to the frictional limits. Wedge failure, in this case, may be dependent on the characteristics of the joint surfaces.

Similarly, the endwall south case also indicated the potential for wedge configurations; however these intersections were marginally outside of the friction cone, as shown in Figure 9-14.

Both cases would need to be evaluated further for this type of failure mechanism.

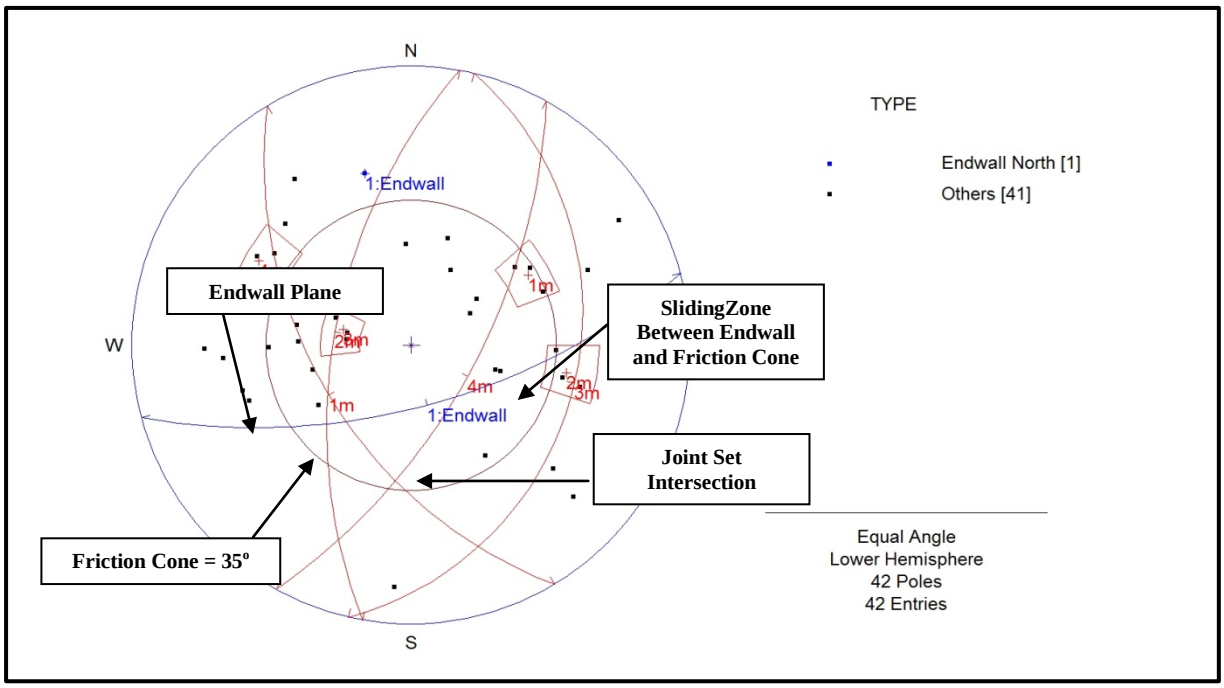

Figure 9-13: Wedge Kinematic Scenario – Endwall North

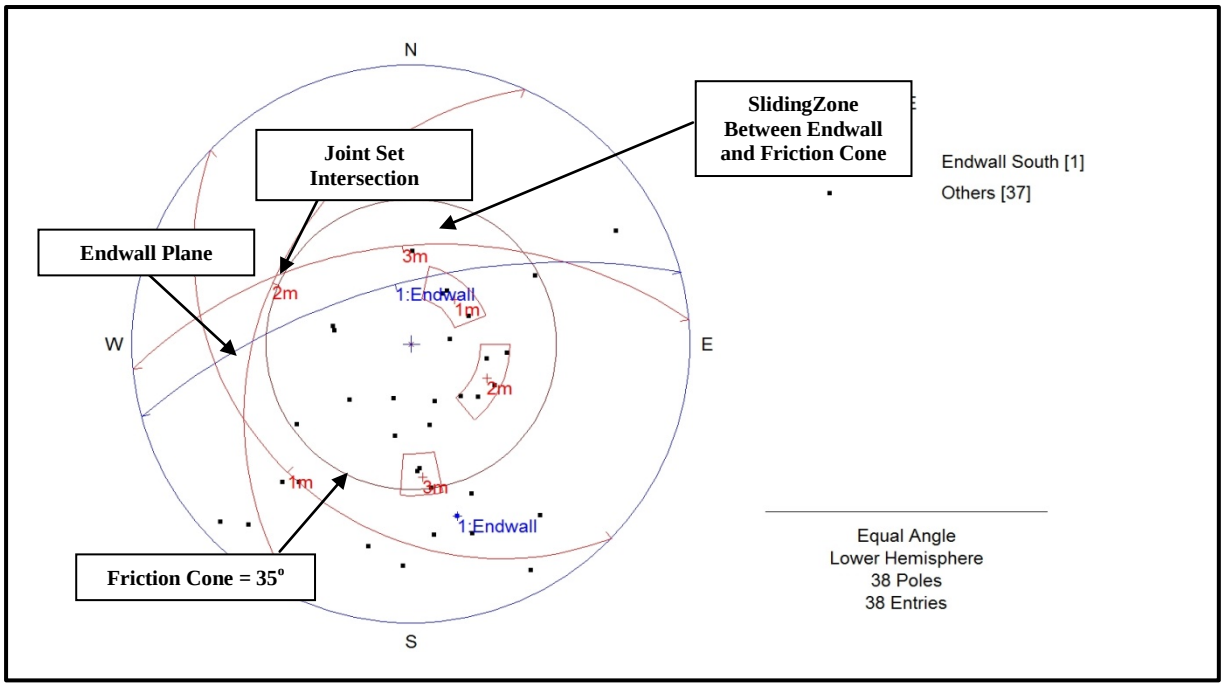

Figure 9-14: Wedge Kinematic Scenario – Endwall South

9.3.3 Low wall East

Figure 9-15 shows the low wall east case does not indicate the potential for wedge configurations. In this case, the interpreted joint set intersections do not daylight on the low wall face. An evaluation of random joint intersections did not indicate the likelihood of this occurring.

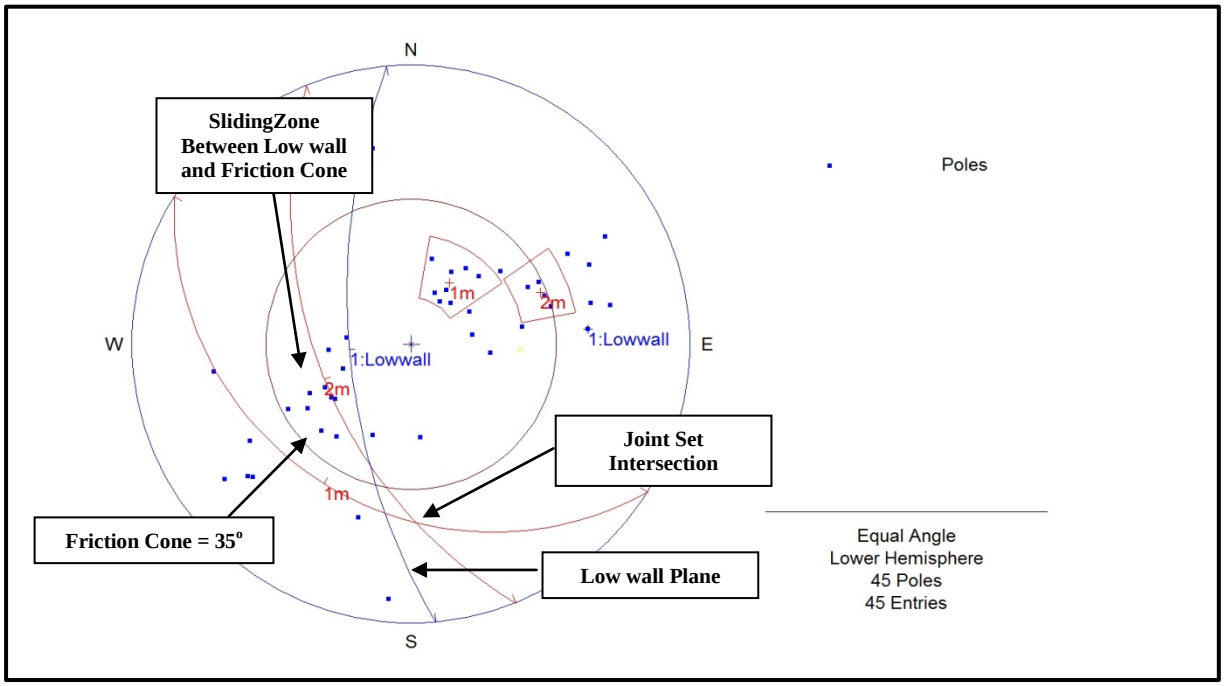

Figure 9-15: Wedge Kinematic Scenario – Low wall East

9.3.4 Low wall North-East and South-East

Figure 9-16 showed the low wall case did not indicate the potential for wedge configurations. In this case, the interpreted joint set intersections do not daylight on the low wall face. An evaluation of random joint intersections did not indicate the likelihood of this occurring.

The low wall southeast case showed comparatively few joint planes therefore the reliability of the dataset is very low. In this case, only one joint set was interpreted, therefore wedge configurations would be unlikely to form, as shown in Figure 9-17.

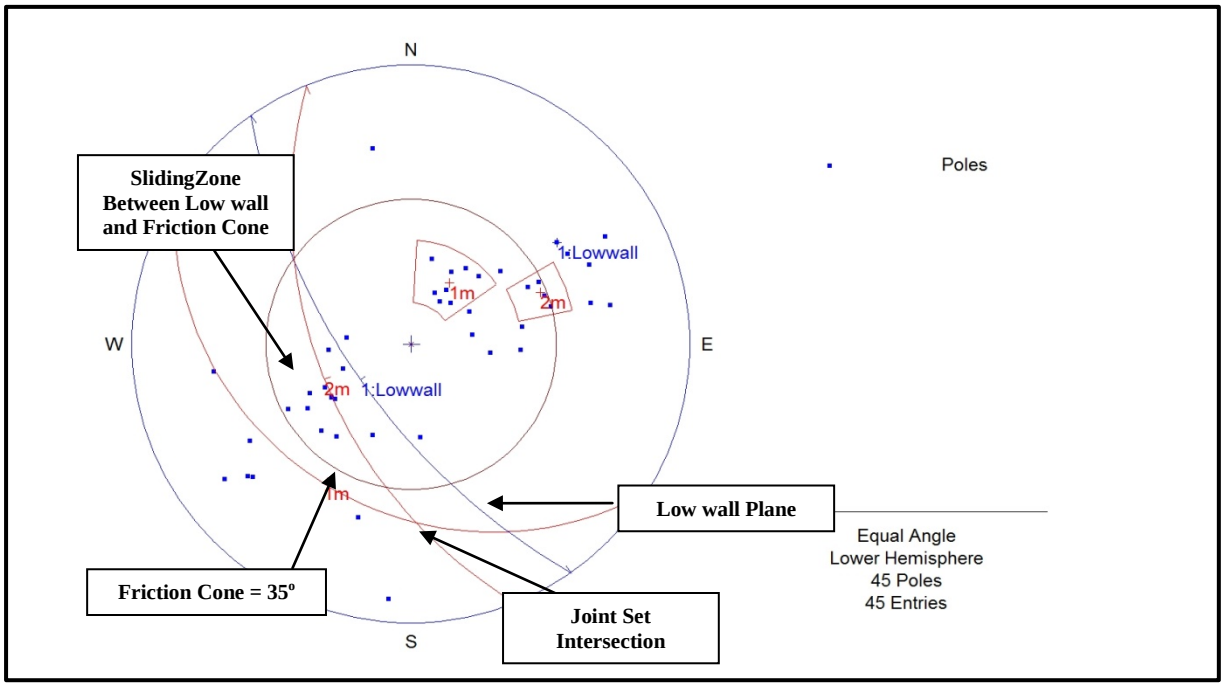

Figure 9-16: Wedge Kinematic Scenario – Low wall North-East

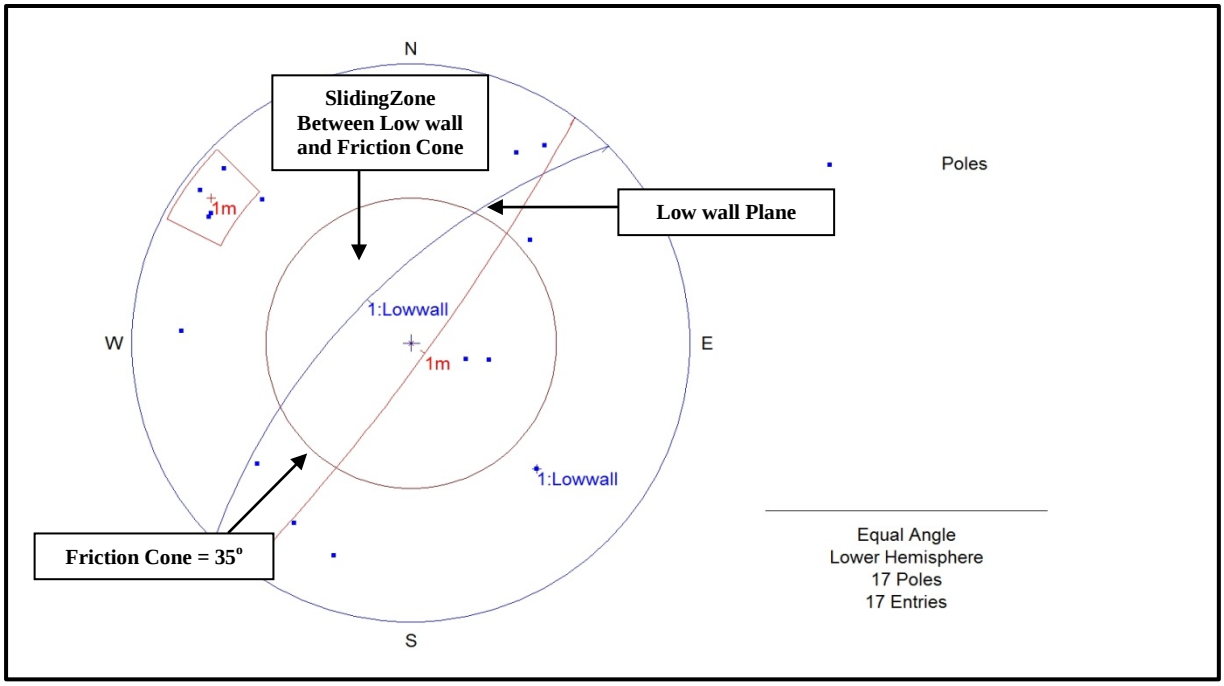

Figure 9-17: Wedge Kinematic Scenario – Low wall South-East

9.4 Kinematic Analysis Discussion and Summary

For the Codrilla deposit, the strength and quality of the rock fabric is too high to permit mass slope failure by shearing through the body of the material, hence failure is a function of the characteristics of discontinuities present in the rock mass. From

the kinematic analysis, it is evident that localised failure configurations can be created from combinations of joints or the disposition of the joint relative to the slope face, however assessing failure scale is difficult using kinematic techniques.

The scale of structural failures can be classified into main three categories:

- Small to medium scale failures from joint planar intersections; and
- Small to medium scale failures from adverse joint combinations or wedges.

Small scale rockfall configurations are common where joint planes are non pervasive and tend to be confined to discrete beds. These types of failures are an inevitable hazard in rock slopes and cannot be entirely eliminated.

Larger scale wedge configurations can develop when the joint planes are more pervasive and daylight in the slope face. Daylighting joints or joint intersections could create a potential for high angle rock failure conditions.

A more common occurrence would be where pervasive joint planes intersect the bench at a small oblique angle of less than approximately 20^0. This tends to create a potential asymmetric planar wedge condition. The wedge would fail if there were conjugate joints (not necessary pervasive) that would link up to form the second separation plane or, since the wedge would be cantilevering laterally, where tensile failure breaks the cantilever effect. The wedge failure mechanism geometry is illustrated in Figure 9-18.

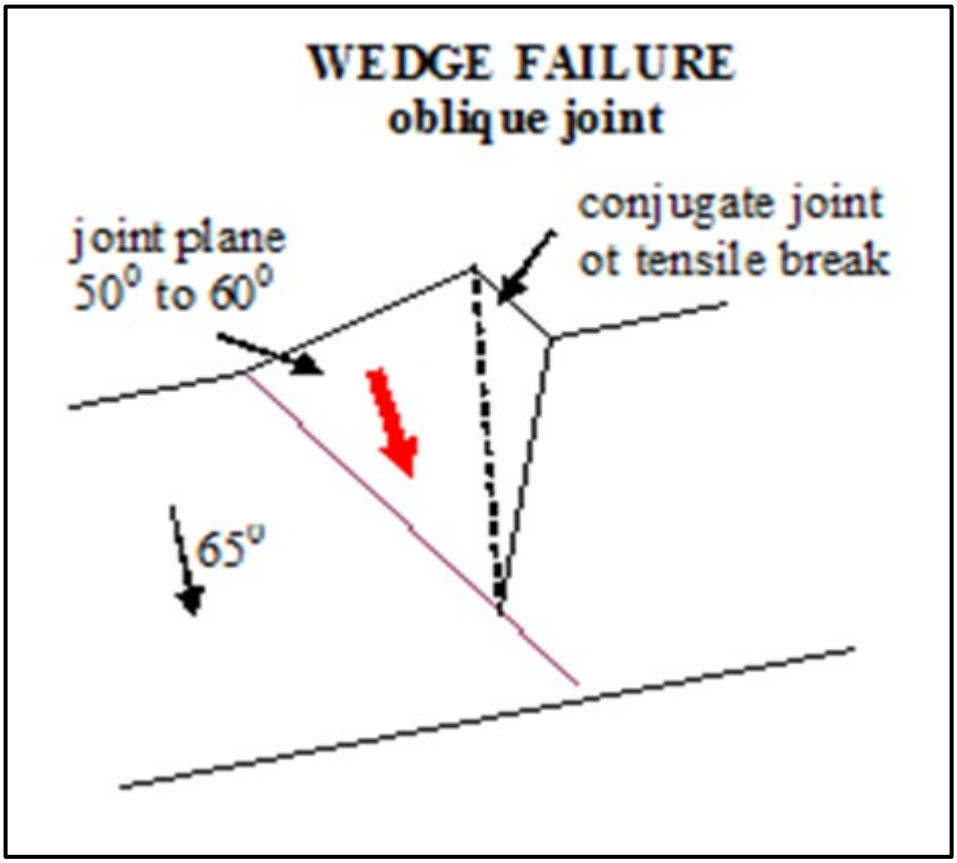

Figure 9-18: Wedge Failure Mechanism Geometry

The structural data analysed from the ATV outputs does not contain information on the pervasiveness of the joint planes throughout the rock mass. The interaction of joint planes that are persistent at the metre scale would have a higher probability of forming larger blocks, which would have a greater chance of movement under gravity. This characteristic is typically a key driver for slope instability. For the analysis presented, it was assumed that the joint planes were pervasive throughout the rock mass.

If the joint planes were oriented parallel to the slope, there would be a possibility of planar slip along the joint plane. In these conditions, the attitude of the wall would be governed by the joint angle, as the wall would fail back to the joint plane. This situation is more likely to occur where the highwall is approaching a major structure oriented parallel to the face, such as those identified in the 2D seismics. The planar failure mechanism geometry is illustrated in Figure 9-19.

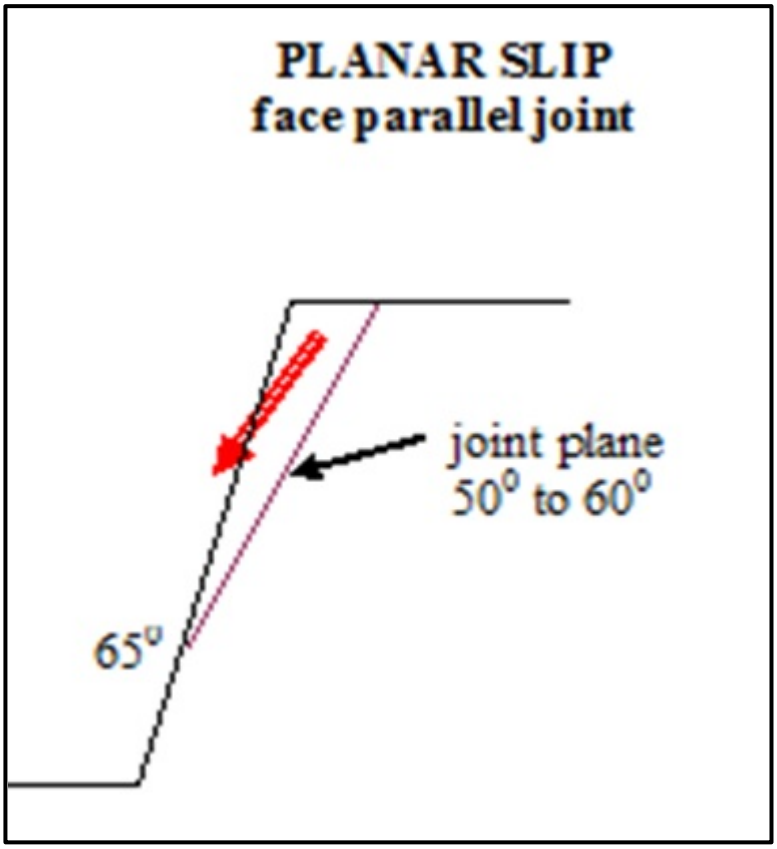

Figure 9-19: Planar Failure Mechanism Geometry

Generally, both failure mechanisms would not prejudice the overall stability of the slope, but could induce bench scale failure, as well as constituting a major hazard to mining operations beneath the wall. The likelihood of major rockfalls of this type would depend on the pervasiveness of the joints that would require joint planes in excess of approximately 10m in extent, as well as discontinuity orientations to within 20^0 of the wall.

Table 9-2 below presents a summary of failure mechanisms and the specific mode of failure for each pit wall case.

Table 9-2: Potential Failure Mechanisms for Pit Slope Cases

Case	Planar Configurations		Wedge Configurations	
	Joint Set	Random Joints	Joint Set	Random Joints
Final Highwall		√		√
Interim Highwall	√		√	
Endwall - North		√	√	
Endwall - South	√			√
Low wall - East	√	√		
Low wall – North-East		√		
Low wall – South-East		√		

This shows that there is a distinct likelihood that both planar, wedge and block slippage failure mechanisms could be mobilised from interpreted joint sets and random joint combinations on the slope faces for the East Pit. In this case, failure mechanisms mobilised from joint sets are more likely to occur than the random intersections.

In light of the findings presented, it is strongly recommended that further ATV work be conducted to improve the reliability of structural patterns across the site. In addition to this, monitoring of rock exposures is recommended to highlight those areas of the pit which may be susceptible to the different failure mechanisms.

10 CUT SLOPE STABILITY

10.1 Material Properties

Material properties were derived mainly from geotechnical testing, with the exception of the Yarrabee Tuff which was estimated from other projects and local experience. Table 10-1 summarises the strength parameters for each of the overburden geomechanical units identified.

Table 10-1 : Shear Strength Values for Analysis

Horizon	Density (kN/m^3)	Cohesion (kPa)	Friction Angle (ϕ)	Source
Unit 1	21.3	37	22.5^0	Single Measurement
Unit 2	22.1	46	23.4^0	Average of Measured
Unit 3	22.6	49	30.3^0	Average of Measured
Unit 4	23.1	72	24^0	Average of Measured
Unit 5	23.5	75	30^0	Estimate
YT - Low		15	15^0	Lake Lindsay Residual
YT - High		1	24.5^0	Middlemount Average
Spoil		30	34^0	Measured from Composite Cuttings
Base Spoil	Clay	0	29^0	Measured from Composite Cuttings
Base Spoil	Weak Rock	0	23^0	Capcoal Value for Fine Spoil

Triaxial shear testing on samples collected from Unit 2 to Unit 4 produced some variable results for cohesion and friction angle; therefore, average values were used for analysis. The selection criteria of appropriate strength parameter values for Unit 2 to Unit 4 are as follows:

- The elimination of unreliable data by selecting appropriate Mohr circle combinations from triaxial shear test results;
- The exclusion of outlier values and the use of engineering judgment for value selection – for example, the laboratory results indicated cohesion values for Unit 2 samples tested of 120 kPa. In this case, a 50% reduction was assumed to account for site variability; and
- Similarly, samples tested from Unit 4 samples indicated cohesion values > 260 kPa. In this case, a cohesion value of 75 kPa was assumed to account for site variability and also for applicability in limit equilibrium modeling.

Direct shear testing was conducted on two samples recovered from the Yarrabee Tuff (YT) and recorded friction angles of 38.5° and 29.5°, and cohesion values of 11 kPa and 70 kPa, respectively. These results were considered to be high in comparison to average shear strength values across the Bowen Basin.

The nature of the YT is known to be quite variable, from brittle to puggy, sometimes with slickensided partings, however the worst case for stability is where there has been bedding plane shearing, producing a pervasive smooth or slickensided planar surface, with a relatively low shear strength. In this case, the residual shear strength value taken from Lake Lindsay was used for analysis to represent the low strength case, and a high strength case recorded from Middlemount (Table 10-1).

10.2 Generic Design Criteria

The generic design criteria have not changed from the original proposed for the feasibility study. For the geotechnical conditions expected at Codrilla, the basic design criteria are presented below in Table 10-2.

Table 10-2: Generic Design Criteria

Material	Bench Height (m)	Slope Angle (°)	Berm Width (m)
Unit 1, 2, 3 & 4	20	45	10
Unit 5	Variable	55	15
Fresh Rock	40 - 45	65	15

The generally accepted minimum Factor of Stability (FOS) for mine slope design, is 1.2 (Ref 3), where the FOS in the context of limiting equilibrium slope stability analyses is defined as the ratio of resisting forces to disturbing forces for any given slope failure configuration.

10.3 Generic Slope Design

The Codrilla deposit is characterised by a thick cover of soft overburden comprising Tertiary and weathered Permian that is predominantly sandy clay or claystone. The nature of this material means that soft slope batters are required down to at least the base of Unit 4. The underlying fresh rock is generally moderately strong to strong, but is likely to contain structural discontinuities and associated defects and could be subject to significant in situ stresses from the deep excavation level.

Taking these factors into consideration, a generic slope design was adopted based on operating practice in other opencut mines in the Bowen Basin. This is illustrated in Figure 10-1.

Slopes through the clay layers down to the base of Unit 4 were designed at 45° batter angle with 20m high benches and 10m wide berms. The ground level is generally flat at approximately RL180; therefore benches are designed on levels RL160, RL140 and RL120. The batter angle for the bottom bench through the weathered Permian strata of Unit 5 is increased to 55°. The design is intended to give an overall slope angle of approximately 35° down to the BOW.

The height of the bottom bench through Unit 5 will vary according to the location of the BOW, but for analytical purposes the average Unit 5 thickness of 15m is used, with a 15m berm at rockhead. The 10m intermediate berms are designed to have sufficient width to catch any accumulation of material from slumping or partial collapse of the bench due to erosion or slumping of horizons of loose or water-bearing sand.

A conservative batter angle is advised for rock benches, at least for planning purposes, because of the high potential for defect driven instability, and the

possibility of stress-induced movement affecting the integrity of the rock mass. Rock batters in this case would be limited to 65°. Based on the current pit design, a 15m berm is allowed for at rockhead (base of Unit 5) to allow for any defect-driven instability, such as fault bounded wedge failures or planar failures that would otherwise undercut the soft overburden and potentially precipitate major slope failure.

Multiple pass mining of the intermediate seams will influence the height of benches in the rock slopes; therefore actual slope configurations will be variable, however, a maximum bench height of 40m is specified. This is also dependent on the proposed mining method. Generally, a maximum bench height of 40m is preferable for operations from a safety perspective however a 45m bench height would be more appropriate for dragline mining (refer Figure 10-1). At this stage MCC have not indicated a preferred mining method.

The generic design for the soft overburden was tested using the Galena code for circular slip failure. Multiple analyses were performed using the Bishop Simplified method to establish the least stable slip surface within the constraints. The shear strength parameters used for the analyses, where possible were updated from the Feasibility Study (Table 10-1). Dry conditions were presumed given the predominantly clay sequence and lack of aquifers. At this stage, the soft overburden units were modeled as horizontally disposed.

10.4 Generic Design Results and Discussion

The slip circle configurations are illustrated in Figure 10-2. The toe of the failure was taken at the toe of the bench and the most critical slip circle in each case had a backscarp 5m back from the crest (mid-berm).

The results of the slope stability analyses are summarised below in Table 10-3.

The results of individual analyses are presented in Appendix C.

Table 10-3 : Factors of Stability for Circular Slip Failure

Bench	Material	Factor of Stability (FOS)
Bench 1	Units 1, 2 & 3	1.47
Bench 2	Unit 3	1.67
Bench 3	Unit 4	1.92
Bench 1+2	Units 1, 2 & 3	1.54
Bench 2+3	Units 3 & 4	1.55
Bench 1+2+3	Units 1, 2, 3 & 4	1.34

Using parameters updated from the Feasibility Study, these were still considered to be conservative; however the results indicate that mass slope failure would be unlikely.

Based on the results of the slope stability modeling, it is concluded that the proposed bench configurations for the generic design provides an adequate degree of stability against mass failure of the Tertiary and weathered Permian clays. This part of the design, down to the base of Unit 5, is applicable to all slopes. The full generic design including the weathered Permian rock (Unit 5) and fresh Permian rock is applicable to all highwall and endwall slopes not subject to structural disturbance, and where there is not an adverse dip in the face (refer Figure 10-1). The design however is not applicable to boxcut - low walls.

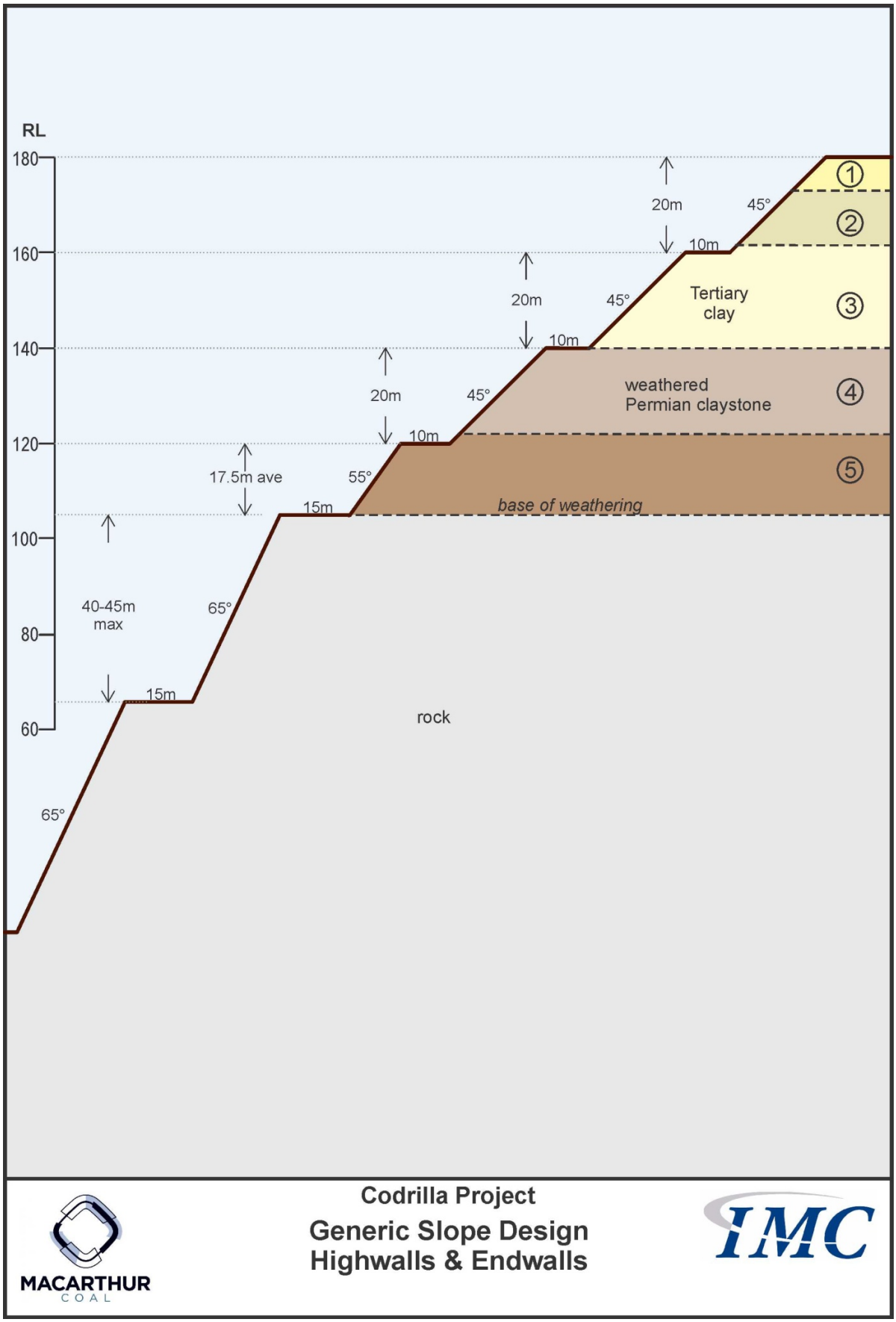

Figure 10-1: Generic Slope Design

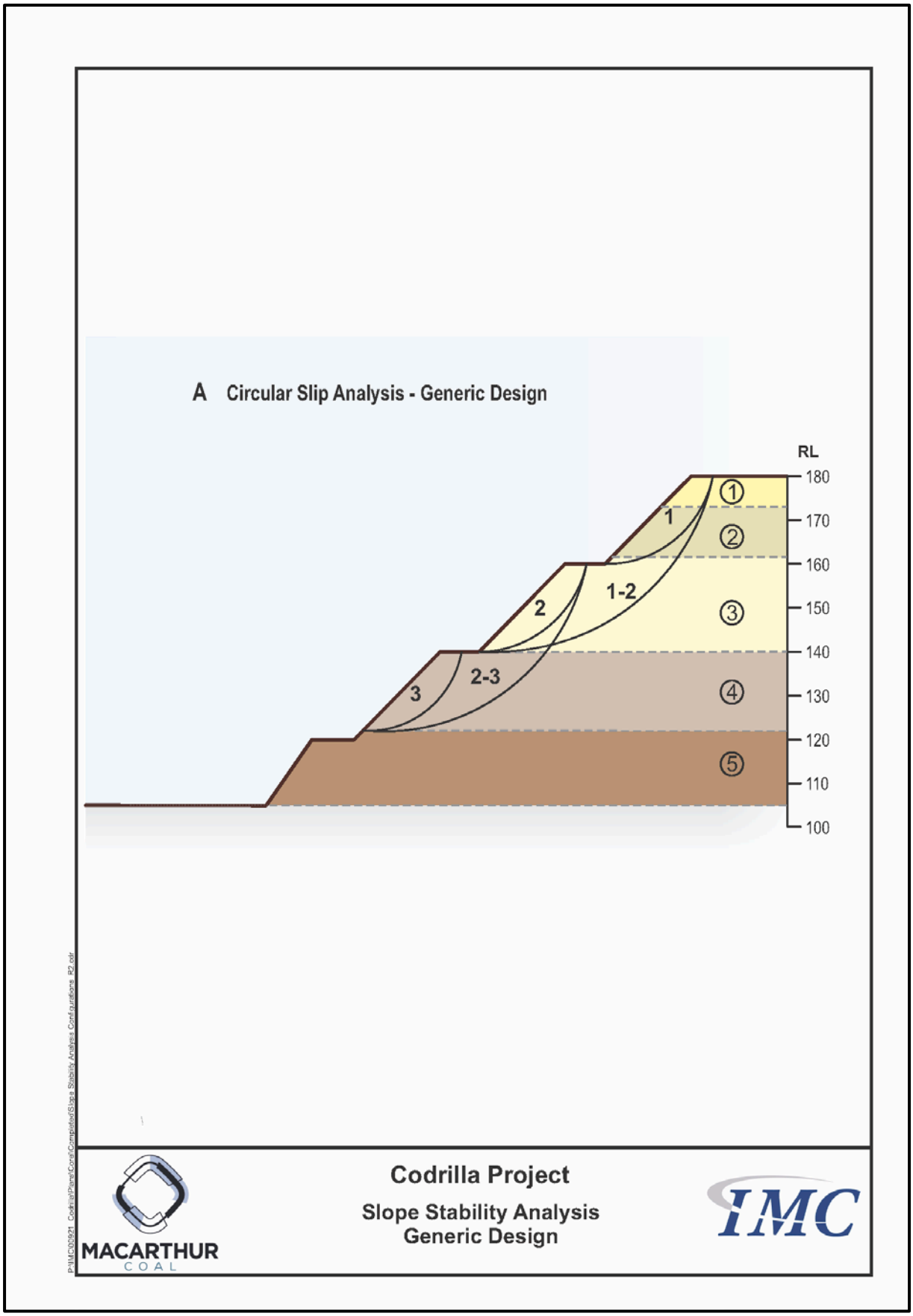

Figure 10-2: Generic Slope Stability Analysis

10.5 Summary of Previous Numerical Modelling

For the Feasibility Study, finite element analysis using Phase2 software was completed as part of a general analysis.

As the potential depth of mining could be up to 200m, insitu and mining induced stress could have an impact on the stability of the rock slopes. A finite element analysis, using the Phase2 code, was accordingly carried out to gauge the effect of stress on the wall design. The model used was as per the generic design (total wall height 165m) with the addition of horizontally disposed rock overburden units covering the VU Seam to LU Seam interval.

Figure 10-3 shows the slope model used for the numerical analysis; the overburden layers are horizontal, as the dip does not materially affect the stress distribution. Rock mass properties used in the model are summarised in Table 10-4.

Table 10-4 : Rock Mass Properties for Numerical Modelling

Unit	Lithology	Sonic Velocity (m/sec)	Density (t/m^3)	Intact UCS (MPa)	In situ UCS (MPa)	E (MPa)	ν	Φ (°)	C (kPa)	T (kPa)
1	Superficials		2.0		0	10	0.33	30	0	0
2	Laterised zone		2.2		0.08	16	0.33	25	25	0
3	Tertiary clay		2.25		0.17	34	0.33	30	50	0
4	Weathered Permian claystone		2.25		0.5	120	0.3	30	0.14	0.04
5	Weathered Permian rock		2.35		1	250	0.3	30	0.29	0.08
6	Siltstone 1	4000	2.5	30	17	5500	0.25	40	4	1.4
7	LU Seam		1.6	10	5.6	2240	0.3	40	1.3	0.45
8	Sandstone 1	3900	2.5	30	17	5500	0.25	40	4	1.4
9	LL1 Seam		1.6	10	5.6	2240	0.3	40	1.3	0.45
10	Sandstone 2	4000	2.5	30	17	5500	0.25	40	4	1.4
11	Siltstone 2	3600	2.5	25	14	4500	0.25	37	3.5	1.1
12	LL2 Seam		1.6	10	5.6	2240	0.3	40	1.3	0.45
13	Siltstone 3	3300	2.5	20	11	3500	0.25	35	2.9	0.9
14	VU Seam		1.6	10	5.6	2240	0.3	40	1.3	0.45
15	YT/VL1/FL1		2.0	6	3.4	1360	0.3	30	1	0.3
16	FL2 (siltstone)	3200	2.5	20	11	3500	0.25	35	2.9	0.9
17	FL3 (sandstone)	4200	2.5	30	17	5500	0.25	40	4	1.4

The upper coal seams have been modelled as interfaces (joints) but the VU Seam has been included as a discrete layer. The weak floor beneath the VU Seam has been modeled as a composite unit consisting of the Yarrabee Tuff, VL1 Seam and Unit FL1, with the top of the Yarrabee Tuff as an interface. Interface properties are listed in Table 10-5 below. The analysis is essentially elastic deformation but allowing the interfaces to fail. A hydrostatic stress field was assumed, in this case, as it represented the simplest modeling case, with the least variables.

Table 10-5 : Joint Material Properties

Interface	Normal stiffness (MPa/m)	Shear stiffness (MPa/m)	Joint cohesion (MPa)	Joint friction angle (°)	Joint Tensile strength (MPa)
Coal seam	15000	6000	0.8	30	0.2
Yarrabee Tuff	10000	4000	0.5	25	0.1

Figure 10-4 shows the stress distribution for the major principal mining induced stress. The stress reaches about 2 MPa towards the bottom of the slope, with a higher concentration up to 5 MPa in the immediate floor at the toe.

Figure 10-5 shows the strength factor, that is, the ratio of rock strength to stress. The modelling results indicated that there was no failure of the rock strata, but the strength factor was less than 1.25 at the toe, and the YT interface was failing.

In practical terms, for a jointed rock mass the strength factor plot would suggest that some degree of local failure could become manifest towards the base of the wall where the maximum wall height exceeds about 160m. This could result in blocks falling out and undercutting the wall but would not necessarily lead to mass instability. As the mining is a multi-seam operation, the pit will be terraced such that the full height would only apply to the final highwall and a small section of the endwalls.

The model shows that low strength bedding planes or intraformational shear planes (and no doubt any structural discontinuities such as thrust planes) would fail at 160m wall height. In the case of adversely dipping beds or structure, block movement out of the wall would probably occur, which could present a risk of larger scale failure.

The analysis presented did not incorporate the in-situ stress field, since the tectonic setting at Codrilla is known to be complex (as outlined in previous sections), therefore the typical Bowen Basin setting may not apply. Now that the final highwall locations are known, it may be appropriate to consider a more detailed numerical modeling approach based on actual geology, within which potential variations in the stress field could be tested, using specific kinematic scenarios.

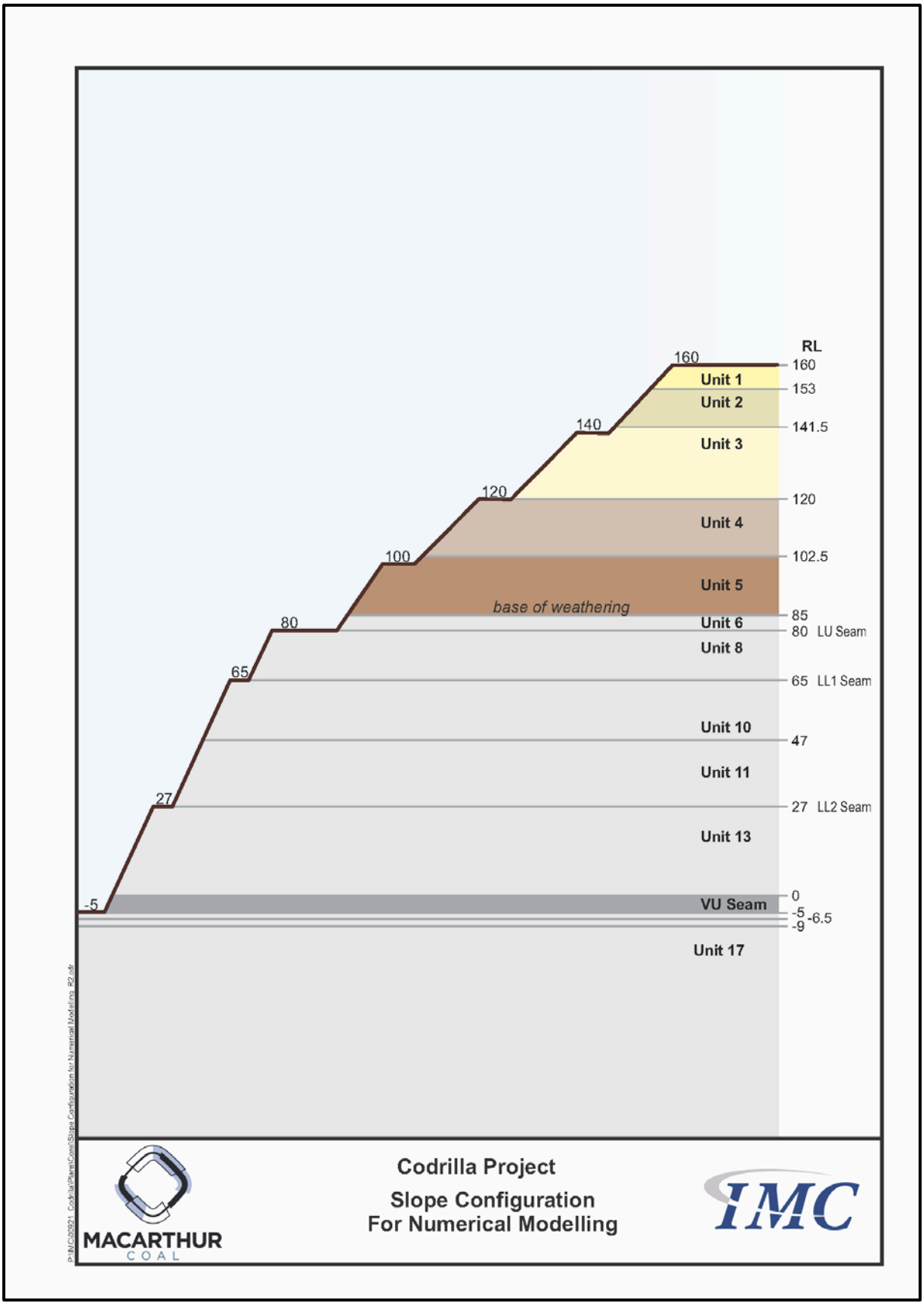

Figure 10-3: Slope Configuration for Numerical Modelling

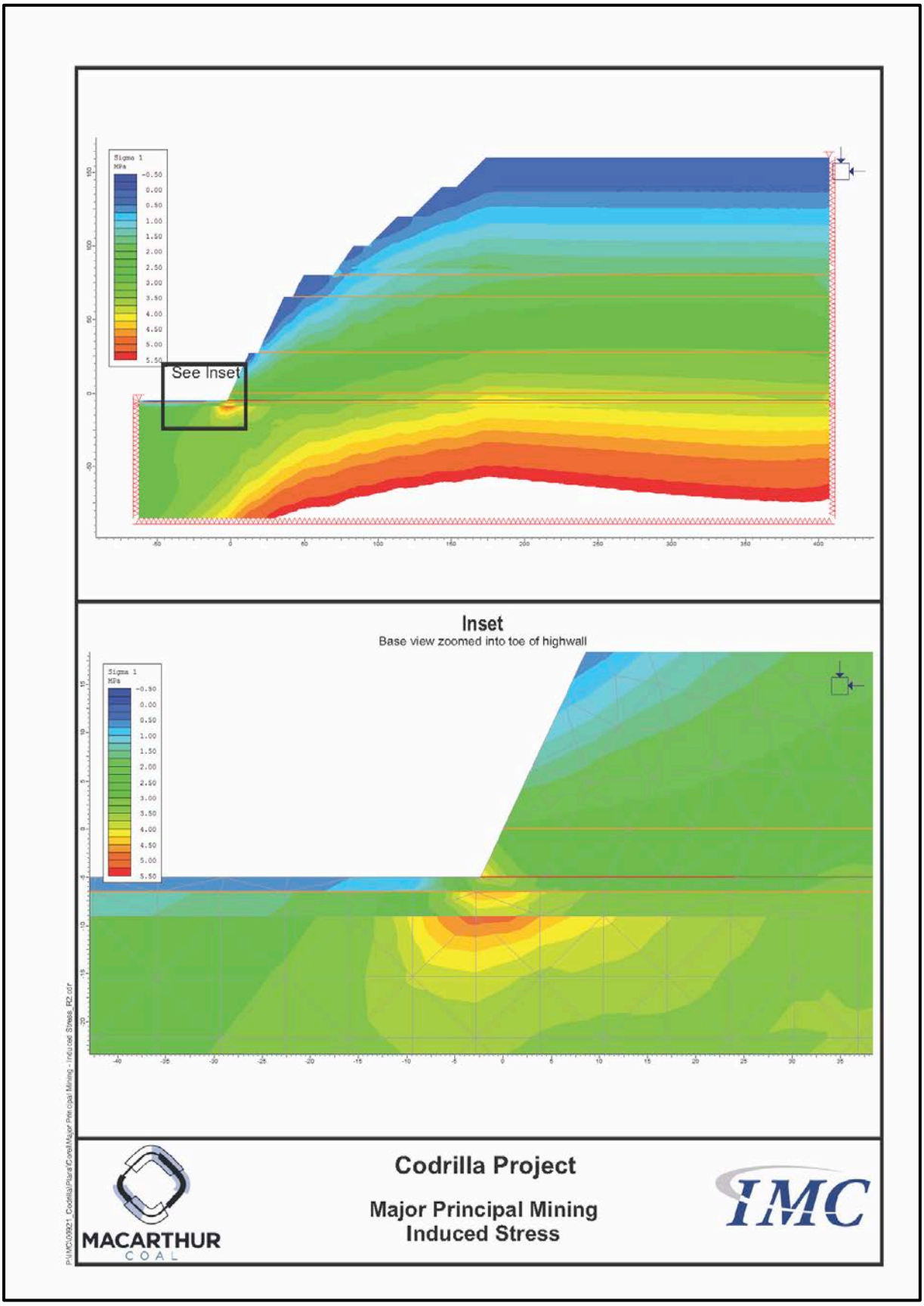

Figure 10-4: Stress Distribution

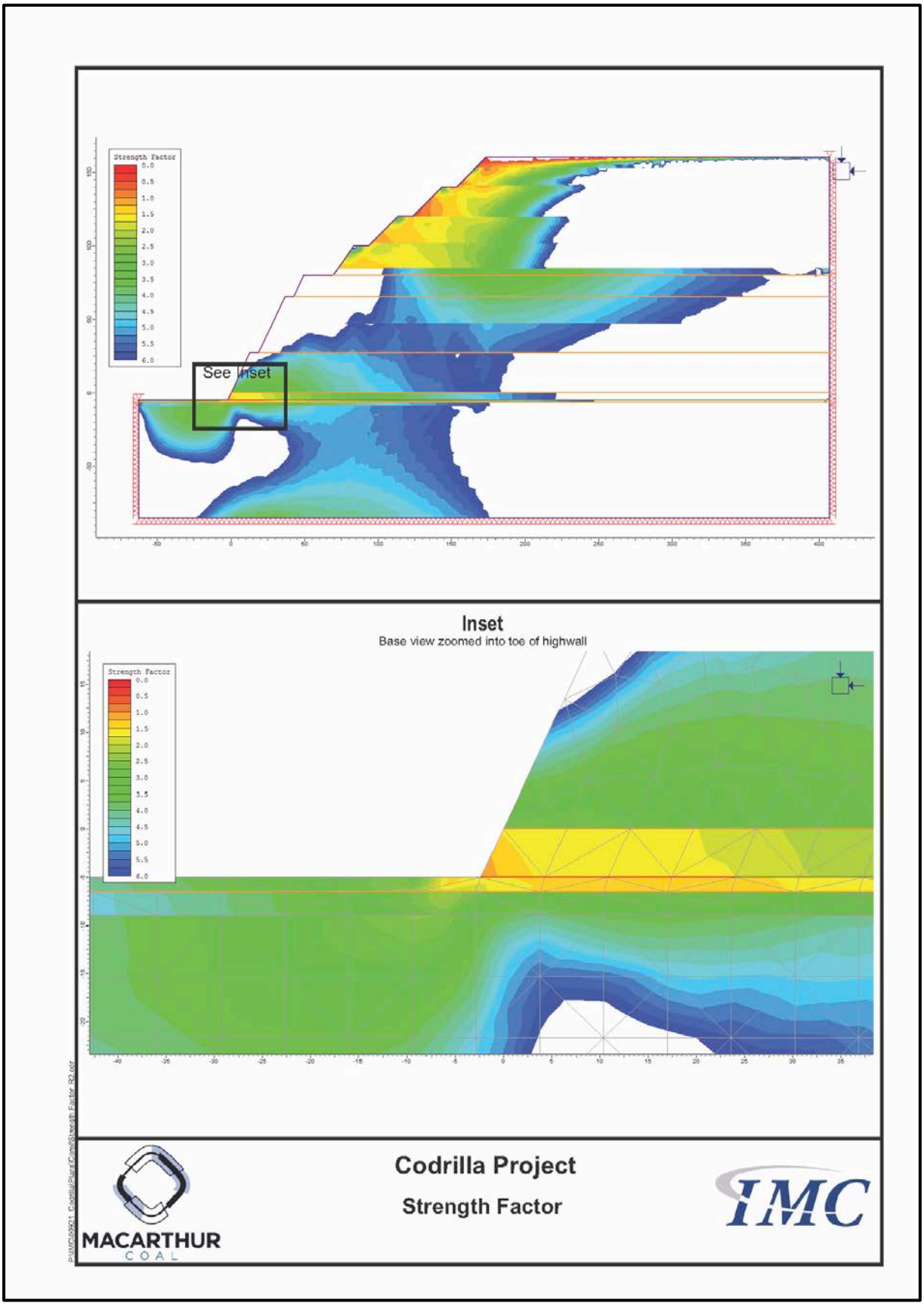

Figure 10-5: Strength Factor

10.6 Box Cut – Low Wall Stability Analysis

Boxcut - Low wall stability is a function of geometrical constraints resulting from a combination of the dip, the depth of the low wall, and the thickness of the Tertiary, as well as the material strength.

The LOX line (subcrop) for the VU Seam was divided into zones of similar geometry for analysis, from which slope designs have been generated. This should be satisfactory for general planning purposes, but it should be noted that there are variations within the zones, which could necessitate local adjustment to the design at a more detailed level of mine planning.

A total of 11 low wall zones were generated to represent the different stability zones around the pit. This included 4 sections from the West Pit and 7 sections from the East Pit. Figure 10-6 presents the low wall zone locations used for stability analysis.

The Tertiary clay (Unit 3) was identified as being a major driver of instability, due to the low shear strength. The thickness of Unit 3 Tertiary clay, depth to BOW and floor dips for each section are summarised in Table 10-6.

Sections which represented the best and worst case stability zone scenarios were selected from each pit from the low wall and endwall zones. In most cases there were similarities between stability zones, in terms of floor dip and overburden thickness, therefore a representative case was chosen for zones of similar characteristics in each case. The generic slope design was applied for all cases.

At this stage, a representative highwall case was not analysed as the possibility of block slippage was considered to be very low due back a back dip, however further discussion on highwall geotechnical hazards is presented in Section 10.9.

Analyses were carried out to examine the stability with respect to a full height failure configuration. In addition to this, lower height analyses were conducted where the failure surface for a full height failure was deemed to be unrealistic, due to the geometry of the VU floor. In this case, a failure surface through to a lower bench was examined.

Table 10-6: Low Wall Stability Zones

Section	Unit 3 Thickness (m)	Base of Weathering (m)	VU Seam Dip	Location
Zone A	40	70	14.0°	West Pit
Zone B	33	65	10.3°	
Zone C	31	53	17.6°	
Zone D	39	63	11.3°	
Zone E	39	72	12.6°	East Pit
Zone F	37	72	5.5°	
Zone G	57	90	16.2°	
Zone H	41	69	10.3°	
Zone I	44	78	11.3°	
Zone J	38	74	6.0°	
Zone K	45	78	10.3°	

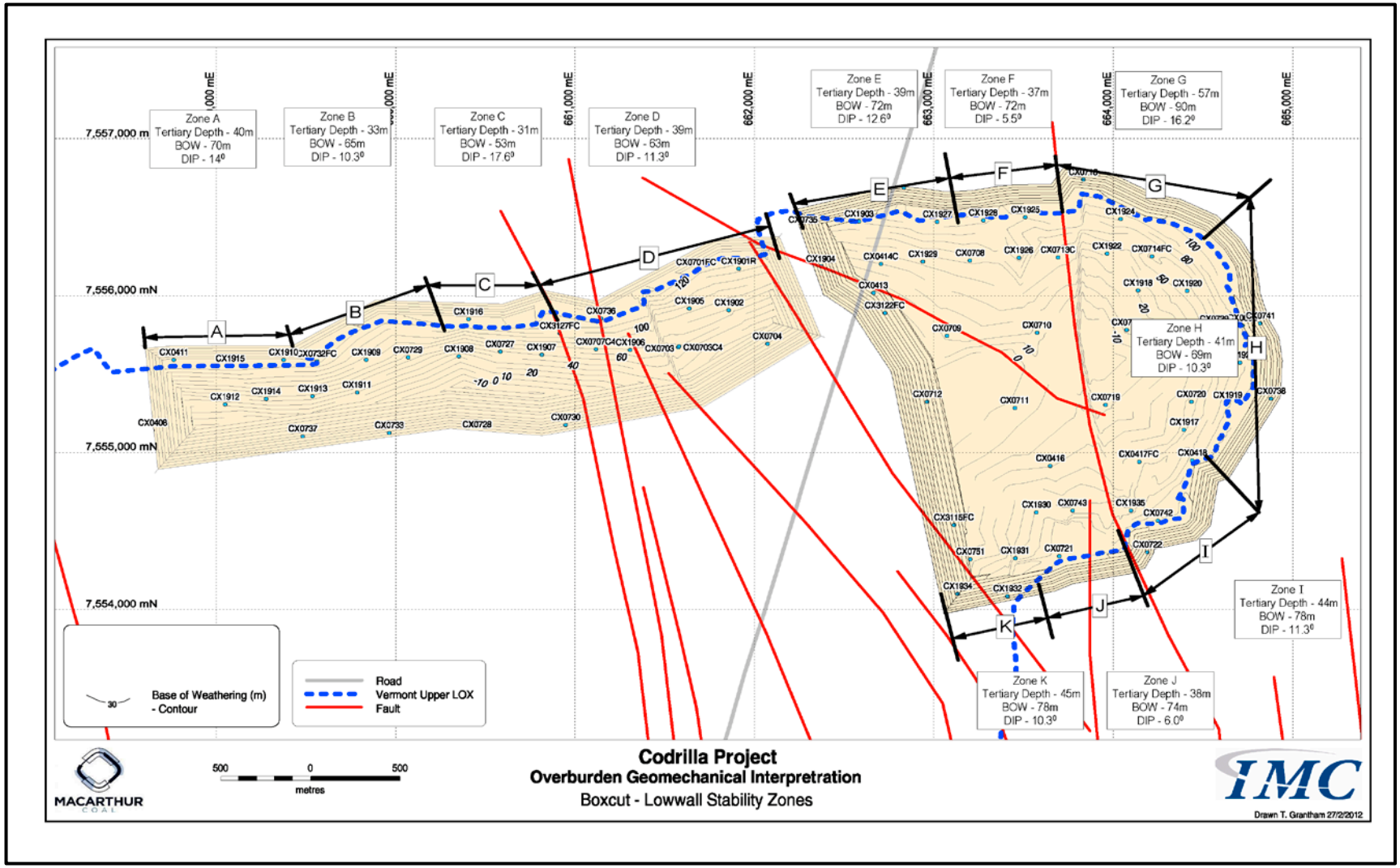

Figure 10-6: Lowwall Stability Zones – West and East Pit

10.7 Modelling Cases

Representative cross sections were compiled for each of the zones, based on the generic model, and a potential composite failure surface was estimated. This was based on a planar section from the toe to the intersection of the extrapolated YT with the base of Unit 4, and a quasi-circular section up to the crest at the point where a rising 60° line met the slope surface. Figure 10-7 shows the non-circular failure surfaces for used in the analysis for each case.

For this study, a total of 7 low wall stability cases were examined, as shown in Table 10-7. Each section was then analysed using the Galena code for Sarma's method for both high and low basal strength cases.

Table 10-7: West and East Pit Low wall Stability Zones for Analysis

Pit	Low wall Stability Zone
West Pit	Zone A
	Zone B
	Zone C
East Pit	Zone E
	Zone F
	Zone G
	Zone I

Zones A to C, and G and I represent low wall profiles in the West Pit and East Pit, respectively, whilst Section E and F represent the end wall profiles in the East Pit. The end wall location on the eastern end of the West Pit will be dictated by the major fault which at this stage has not been defined sufficiently to allow a representative geological section to be established. It is possible that the end wall profile will be formed in solid ground to the west of the fault. It should also be noted that there are variations within the zones, which could necessitate local adjustment to the design at a more detailed level of mine planning.

For all profiles, a high and low YT shear strength case was modeled, as shown in Table 10-1.

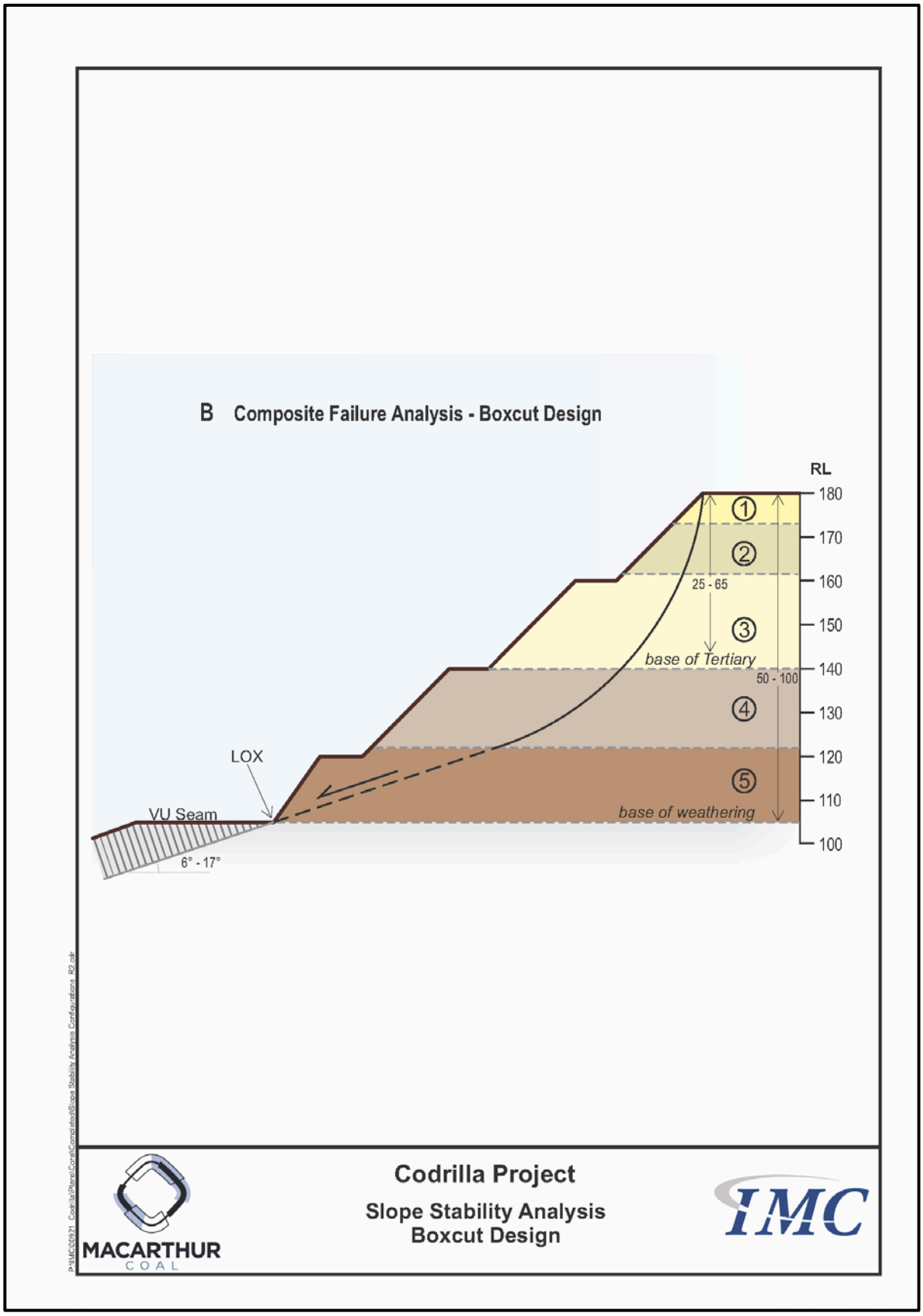

Figure 10-7: Low Wall Slope Stability Analysis

10.8 Boxcut – Low Wall Stability Analysis Results

Table 10-8 below summarises the results of the stability analysis.

Table 10-8: Factors of Stability for Circular Slip Failure

Stability Zone	Dip Angle (°)	FoS Upper Shear Strength	FoS Lower Shear Strength
Zone A – Full Height	14.0	**1.09**	**1.00**
Zone B – Full Height	10.3	1.26	**0.98**
Zone C – Full Height	17.6	**1.16**	**1.14**
Zone C – RL 150 Bench	17.6	**1.17**	**1.09**
Zone D – Full Height	11.3	1.21	**0.96**
Zone E – Full Height	12.6	**1.12**	**1.01**
Zone F – Full Height	5.5	2.22	1.57
Zone G – Full Height	16.2	**1.05**	**0.93**
Zone I – Full Height	11.3	1.19	**0.94**

orange highlight indicates FoS < 1.2

The results indicate that under a low strength scenario all zones would present an unstable configuration for the generic slope design, with FoS less than 1.2, except for Zone F in which the critical floor dip was not exceeded, thus presenting a stable configuration. For the high strength scenario the results indicate an acceptable FoS for the shallower dip Zones B, D, F and I, with FoS less than 1.2 for the remainder. Allowing for variation in shear strength and the probability that the low strength value would apply at least in part, it is clear that some design modification would be required to ensure there is an adequate level of stability.

There is a possibility that intermediate height failures would also show a less than adequate FoS but these have not been examined as it is the full height case that will ultimately be applicable.

The available options for mitigating the risk of systematic slope failure include:

- Setting back toe up-dip of lox line (dummy boxcut); and
- Excavating below Unit 4 in 60m bays and backfill (toe buttress).

In the first option, the potential for major failure can be designed out by geometric changes that remove the planar slip surface from beneath the main part of the slope. This can be achieved by shifting the low wall toe up-dip and creating a dummy boxcut up-dip of the LOX line, as indicated in Figure 10-8.

A 35m toe shift would eliminate the potential for a composite slip failure in Zone C. It would not eliminate the potential for failure but would restrict the potential failure

to the third bench (Unit 4 bench) in Zone A, which may be an acceptable risk. However, a 35m shift plus a 15m berm at the base of Unit 4 would eliminate the potential for a composite slip failure in Zone A. Zone F would not require any shift in the toe position.

The geometry for Zones B, D, E, G and I is such that a 50m - 65m wide dummy boxcut would be needed to restrict failure potential, which would most likely render it financially non viable.

The second option, which was evaluated as part of the Feasibility Study, is to minimise the instability risk by limiting the exposed width of the low wall. This could be achieved by excavating the low wall in bays of limited width, approximately 50m to 60m, backfilling each with overburden from the adjacent bay. In this case the overburden could be stripped down to the base of Unit 4, or thereabouts – strictly speaking to the first onset of bedding planes in the weathered Permian – with excavation in 60m wide bays down to the VU Seam.

This would leave a spoil buttress against the low wall to counteract any subsequent slippage on the residual section of bedding, as illustrated in Figure 10-9. There should be no need to excavate up-dip of the LOX line, so that although the method is not efficient in operation, it at least delivers coal unlike the dummy boxcut approach.

The efficacy of this option was tested as part of the Feasibility Study using a spreadsheet version of the modified Bishop method of slices. The slope geometry was as per the illustration in Figure 10-9, with a 60m wide buttress to the height of the bottom bench, with a 35° batter. The standard Capcoal shear strength value for fine spoil was used for the base of the buttress (see Table 10-1 showing shear strengths in Section 10.1), assuming Permian rock spoil would be used for this purpose. The analyses were for dry conditions with the same composite failure path as used before.

The results of modeling, for the low strength YT scenario, were FoS varying from 0.96 to 1.25. They indicate that although the buttress approach improved the level of stability for short term design; however the FoS values were less than acceptable for the medium term, which suggests that the buttress would not be satisfactory for a fully-opened length of low wall.

There is also a high probability of random instability from undetected structural disturbances or seam rolls. In general terms, the main fault direction is north-south and the seismic interpretation suggests associated thrusting or compression folding rising to the east. With this configuration, locally steep dip components would be perpendicular to the northern and southern low walls and thus would not constitute a stability hazard, however, on the east low wall the dip planes would be adversely oriented with respect to the low wall, and would thus present a significant stability hazard where they daylight out of the low wall.

Slope failure in these cases would take the form of block slippage down the thrust planes, which is likely to result in full slope failure. Even if the initial slippage is only partial height, it could result in undercutting the upper benches and lead to full scale slope failure.

Some local modification to highwall orientation may be required in faulted areas, to accommodate adverse combinations of fault and joint planes. This would typically involve rebating the highwall to sufficient depth to remove potentially unstable

masses. As the exact nature and disposition of the fault planes will not be known with sufficient certainty beforehand, design changes will probably have to be made as and when conditions are exposed during mining.

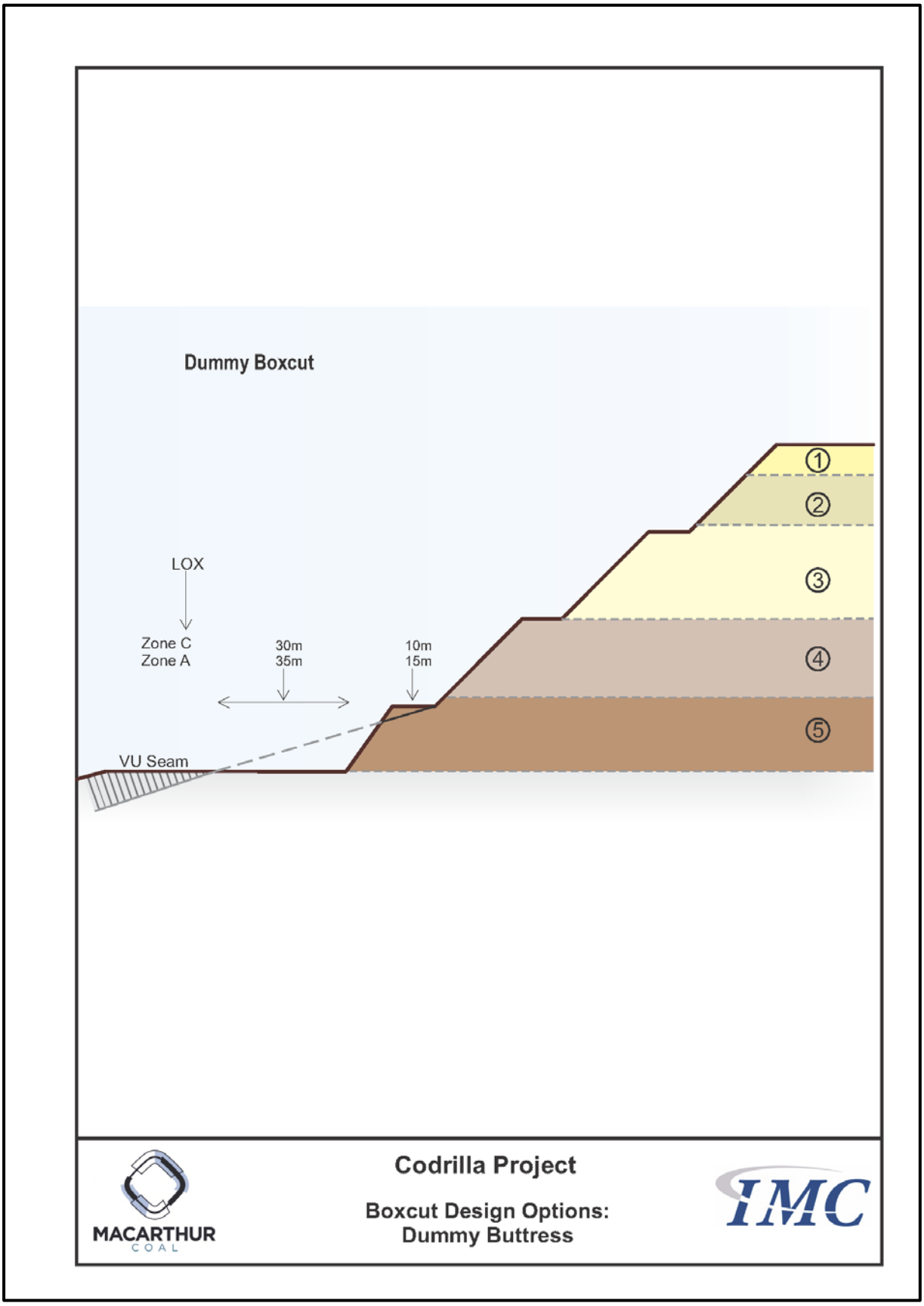

Figure 10-8: Boxcut Design Option – Dummy Boxcut

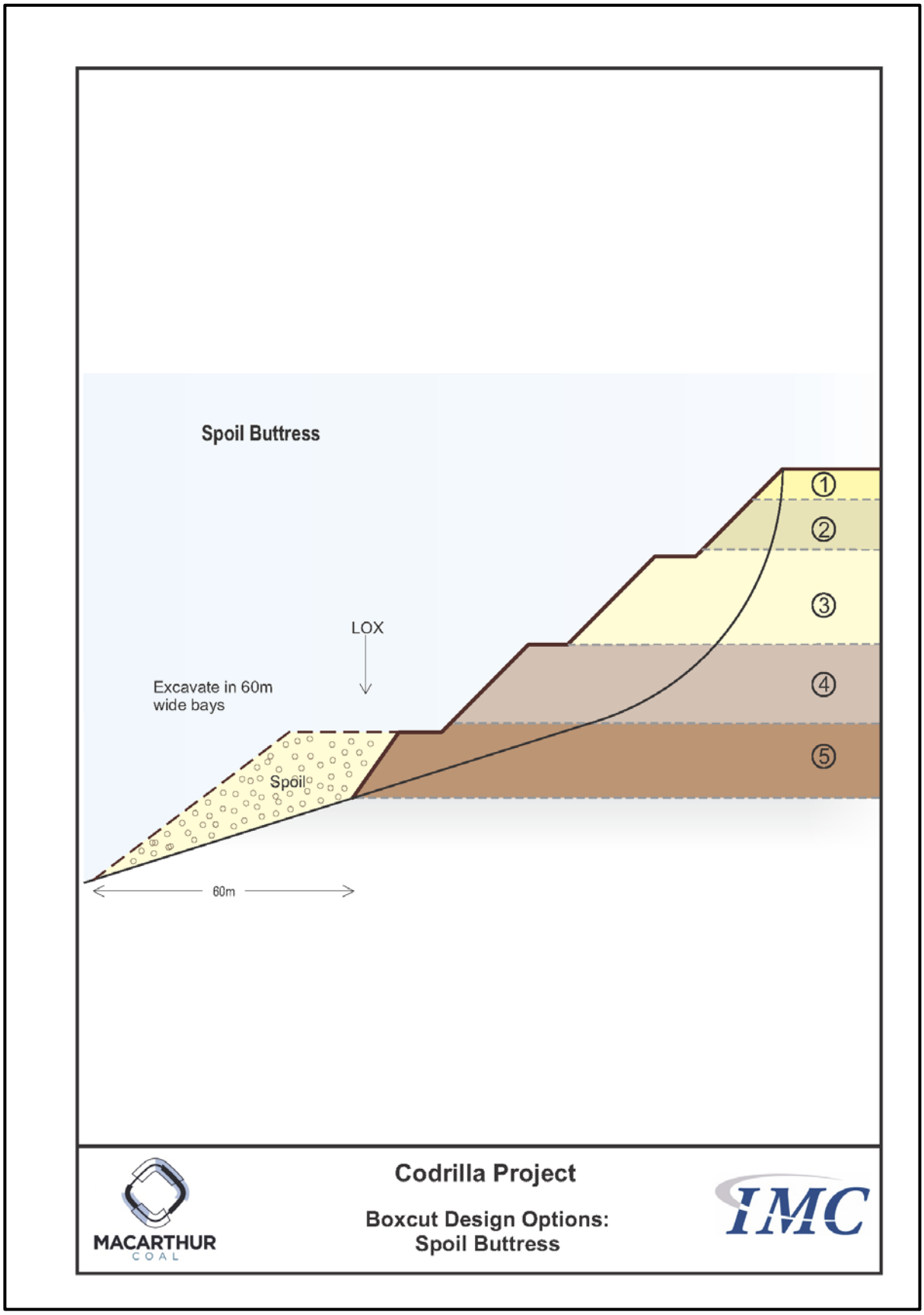

Figure 10-9: Boxcut Design Option – Spoil Buttress

10.9 Fault/Structural Interactions on Pit Walls – Principal Hazards and Controls

10.9.1 Bench Scale Hazards

The kinematic analysis showed the potential for planar and wedge configurations, which may lead to bench scale failures. As mentioned previously, these types of small to medium scale failures could be common occurrence during operations. Adequate controls would need to be implemented to sufficiently mitigate operational risks. These controls could include the following:

- Sufficient berm widths to contain gravity induced failures;
- Bench face scaling (where possible) to remove loose materials; and
- Pre-split blasting of the face to reduce back-break, which tends to reduce dilatancy of the discontinuities, and by imposing of a 10m exclusion zone at the foot of the wall. The recommended 65^0 bench angle through rock benches is typically the maximum lay-back for angled pre-split drilling.

10.9.2 Large Scale Hazards

The structural model supplied by MCC indicates there are several major faults identified at the Codrilla site (refer Figure 10-6). The north - south striking faults in the East Pit would have the potential to cause significant instability on interim highwall positions of the East Pit if the mining direction was from east to west.

Another oblique fault was observed to intersect the east pit final highwall, although the angle of intersection between the fault and highwall is greater than 20° and may be less likely to impact on stability.

There was a significant fault zone also observed in the West Pit; however the faults appear to intersect the highwall and low wall sub-perpendicular. The mining impacts of this would be relatively low, however regular monitoring is recommended.

It should be noted that there is some discrepancy between the information presented in the structural model compared to that from the 2D seismic. The 2D seismic supplied by MCC indicates a wide, structurally disturbed zone associated with the large scale faulting within the East Pit. From a geotechnical perspective, these fault zones have the potential to generate significant instability for the interim highwall positions. Figure 10-10 shows the 2D seismic section through the East Pit.

The 2D seismic also shows the faults to be variably oriented. In this case, mobilisation of several failure mechanisms could be possible, which would further increase the likelihood of instability. The 2D seismic output is presented in Figure 10-11. At this stage, there is limited information which systematically defines the characteristics of the large fault zone in the East Pit. The 2D seismic generally provides a good method to define the presence of structures and give an indication of overall displacement; however it usually contains insufficient detail for operational planning. It is recommended the 2D seismic information be incorporated into the current geological model.

Floor dip is not normally of major concern for typical highwalls; however given the identified disturbance zones it is possible for floor dip reversals in any of the walls. This may be evaluated by assessing the target seam floor structure. Adverse floor dips/floor dip reversals generally occur in the vicinity of major faults, where the

strata deform in response to the fault movement and increase in dip towards the fault. These can occur over very short distances (between boreholes) and may be undetected during ground investigations. In the event of adverse dip, there would be a need for further analysis to evaluate the impacts on wall stability. At this stage, no information was available in order to assess floor dip reversals.

An assessment of the VU floor contours indicated variable floor dips along the low wall sections of the East and West Pits. Generally, the risk of mass block slippage on the floor increases where the dip exceeds approximately 8°. In this case, floor generated instability for the pit wall is considered unlikely, except in the case of the south-west facing sidewall, where the dip rises to the fault.

In this case, larger scale block slippage mechanisms could be mobilised, which have the potential to impact significantly on the operations and the safety of personnel. This type of failure mechanism involves a combination of high angle joint planes and basal slippage on adversely dipping beds or intraformational shear planes that are at increasing dip beneath the slope, as illustrated in Figure 10-12. In this case, the Yarrabee Tuff is considered to be the slippage plane, which is characteristically low strength, and would daylight on the pit face. The LL2 seam floor also indicated evidence of intraformational shearing. Due to the steeper inclination, adverse gravitational forces would be generated which, in conjunction with the removal of confining forces associated with excavation, allows the bench to move forward, resulting in the opening up any face-parallel joints.

Surface run-off down the face can enter the joint and reduce the cohesion of the bedding plane, which may encourage block slippage out of the face, particularly from the lower part of the bench. The scale of this type of failure is typically small, from small rock falls to large blocks ($\geq 10m^3$).

In cases of major pervasive joints or fault planes behind the wall, storm run-off can enter and generate hydrostatic pressure. Pore pressure uplift could also be generated beneath the block, further reducing the resistance to sliding. These forces may be great enough to disrupt the whole bench (refer Figure 10-12).

10.9.3 Monitoring and Stability Controls

Monitoring of the highwall slope is generally recommended in order to provide adequate response to large scale instability. In this case, radar techniques are particularly useful and are employed widely.

Where a highwall stability problem develops, various stability controls can be implemented to manage the operational risks. These are presented as follows:

- Locate interim highwalls either behind face parallel major structure so that the fault is mined out;
- Use photogrammetry techniques to map joint sets, which can be used to develop highwall hazard plans;
- Establish a suitable standoff distance from the fault and leave a buttress of intact rock in front of the fault;
- Management of storm water run-off to avoid flows entering joint or fault planes, or mining induced cracks on benches;

- Change in mining method to enable better stability control and flexibility through the fault zones. This may include slope stabilisation using the soft wall method (cut wall to 45^0 through faulted zones), which has proved to be an effective control in managing highwall instability at other mines; and
- Change in mining sequence to approach the faulted area from more favourable directions.

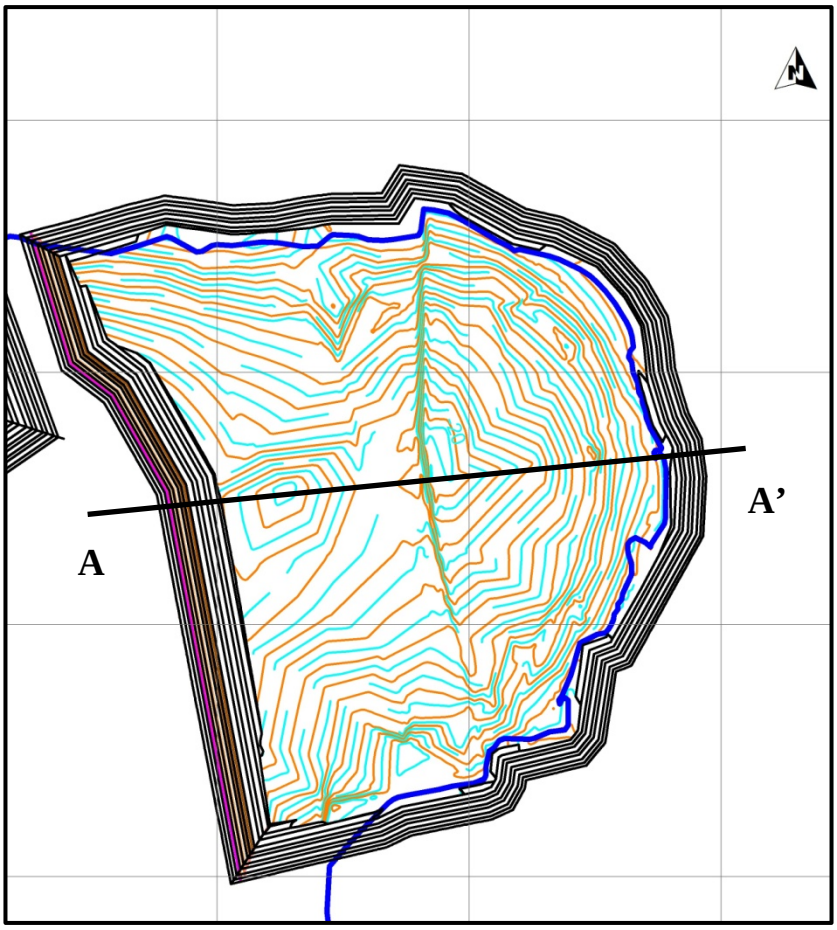

Figure 10-10: Approximate 2D Seismic Line - East Pit

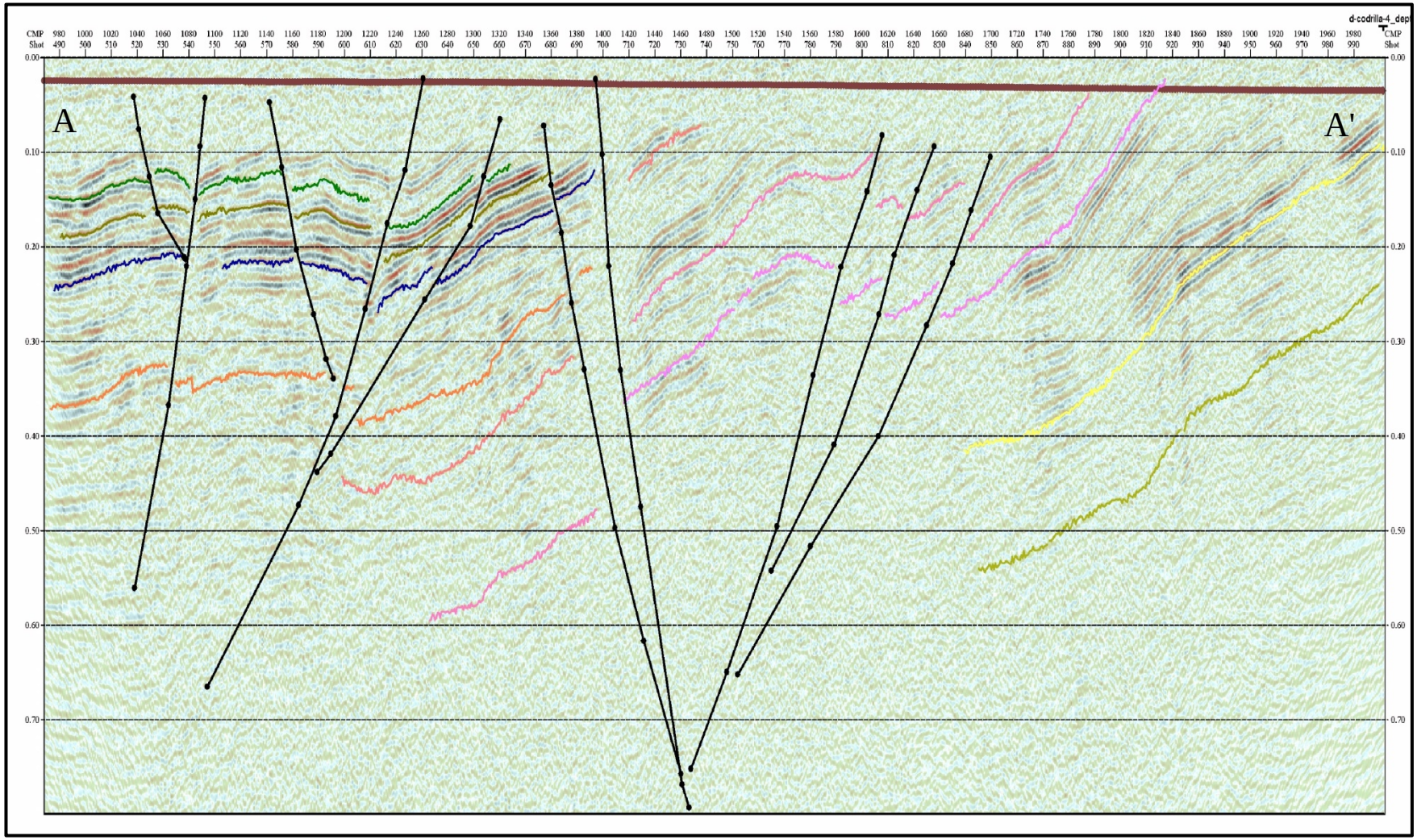

Figure 10-11: 2D Seismic Section – East Pit

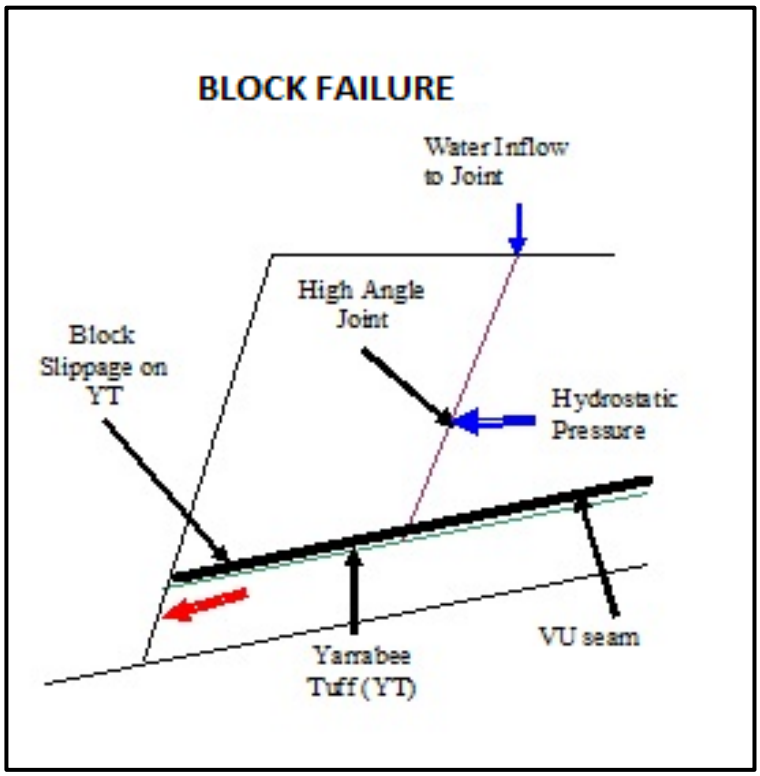

Figure 10-12: Block Slippage Failure Geometry

11 SPOIL STABILITY

11.1 Ex-Pit Spoil Dumps

Boxcut spoil will be dumped externally on flat natural ground, with batters formed by end-dumping at the angle of repose, which is presumed to be 35°. A dump height of 80m was adopted for analytical purposes, with 20m lifts and 8m berms, giving an overall slope angle of 30°.

Testing of a comminuted core sample of Unit 2 overburden indicated a peak dry shear strength of c = 0 kPa, ϕ = 40°. This friction angle is significantly higher than the standard spoil values derived by BMA and Capcoal for design purposes. Inspection of the test data showed that this value was a good fit to the data at lower normal loading, up to 300 kPa, whereas taking account of the higher test loading, up to 550 kPa, a better fit was given by c = 30 kPa, ϕ = 34°. As the dump height would give loadings in excess of 550 kPa, this value was adopted for analysis.

Slope stability analyses were made for circular slip failure using the Galena code for the Bishop simplified method for a full height failure, as illustrated in Figure 11-1A. The most critical slip surface ran from a location 10m back from the crest, and emerged 10m in front of the toe, passing through the natural ground (Unit 1 material). The analysis indicated a FoS = 1.61 for dry conditions, and a FoS = 1.42 for a phreatic surface up to 20m above natural ground within the dump. The latter is a very conservative condition as the bulk of the spoil is likely to be more or less impermeable clay. The Galena output is presented in Appendix D.

The results indicate that instability in benched external spoil dumps with angle of repose batters is not going to be an issue. Note that in consideration of ex pit dumps that there may be a need to establish a flatter final batter at say 1 in 3.5 grade for rehabilitation. A minimum 20m stand-off distance from the wall crest should be allowed for to avoid any undercutting of the spoil in the event of localised failures through the in-situ slope beneath. The stand-off would need to be increased to 50m for Low wall Zone K, where the slope geometry indicates a potential major failure path could occur approximately 42m back from the crest.

11.2 In-Pit Spoil Dumps

For conventional strike mining, with down-dip strips to an advancing highwall, dumping of spoil up-dip of the working area can create a risk of spoil failure through slippage on the floor of the dump. This risk typically becomes elevated where the dip exceeds approximately 8°.

In-pit spoil failure is typically bi-planar, as illustrated in Figure 11-1B, with translational slippage along the floor of the pit with a backscarp formed by shearing through the spoil at a steep angle. This configuration was analysed using the Galena code for Sarma's method. The backscarp was taken at 63°, which is fairly typical for spoil failures, emerging at the crest line. The as-measured strength of c = 30 kPa, ϕ = 34° was used for shearing through the body of the spoil. A benched dump profile was modeled, based on 20m lifts, 8m berms and a 35° angle of repose.

Basal slippage can occur along the base of spoil, where the material is typically subject to wetting and slaking or in the floor itself if there are weak or sheared horizons. The Capcoal residual value for fine spoil of c = 0 kPa, ϕ = 23° was used

for the basal spoil strength case and the standard Lake Lindsay value for the VL1 horizon of c = 10 kPa, ϕ = 20° was used for shearing through the floor. Analyses were made for dry conditions.

Analyses were made for a series of dip angles from 10° to 16°, for a dump height of 100m. The results are tabulated below in Table 11-1.

Results of individual analyses are presented in Appendix D.

Table 11-1 : Factors of Stability - In-Pit Spoil Failure

Dip	FoS spoil base	FoS weak floor	FoS YT low
10^0	1.37	1.27	**1.07**
12^0	1.33	1.24	**1.04**
14^0	1.22	**1.14**	**0.95**
16^0	**1.16**	**1.08**	**0.90**

orange highlight indicates FoS < 1.2

The results of the analyses indicate that up-dip spoil dumps would be acceptable on floor dips of up to about 14.5° for slippage on the base of spoil. The FoS are somewhat less for failure through the floor, suggesting an upper dip angle constraint of about 13° in general. This would effectively preclude the option for up-dip spoiling in low wall zones A, C and G.

The FoS values presented in Table 11-1 are only applicable if there is no weakness in the floor, such as a continuous sheared or slickensided horizon or intraformational shear plane. When the analyses were run for basal slippage on the YT using the low strength case of c = 15 kPa, ϕ = 15°, which is a typical value for bedding plane shear, the FoS were all less than acceptable. This means that floor treatment would be required in all cases to disrupt any potential shear planes, including the YT itself, the VL1 seam and associated thin tuff bands, and the immediate floor below the VL1 seam.

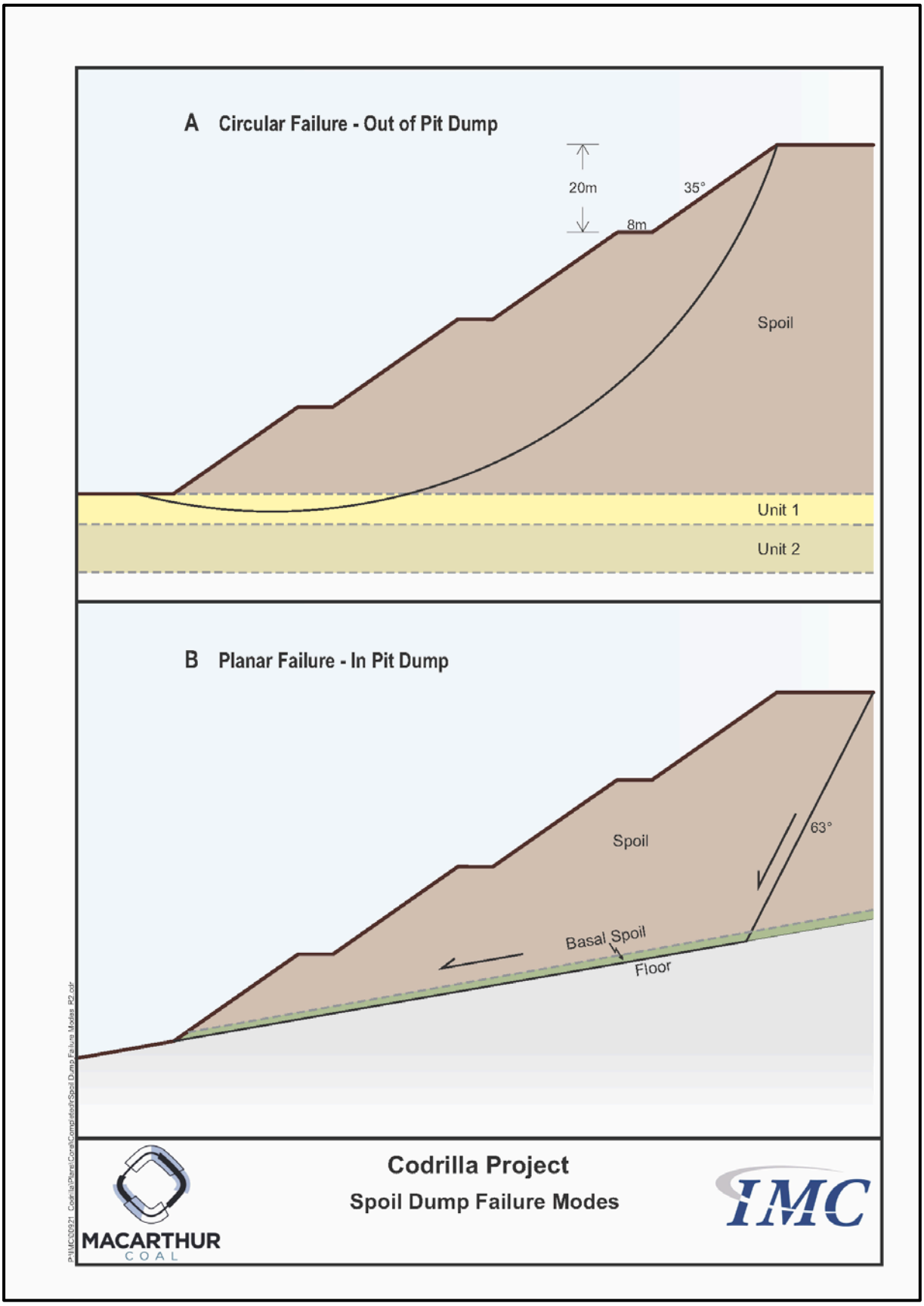

Figure 11-1: Spoil Dump Failure Modes

12 MINING CONDITIONS

12.1 Excavatability

The superficial surface layer, with an average thickness of 7m, is unconsolidated, and comprises mostly clayey sand or sand. This layer is clearly free dig. There are no references to caprock or other hard material, either at the surface or within the underlying clays; although there are cases of ferruginous material in the laterised zone (Unit 2) which may be somewhat harder than the clay.

The Tertiary, which is taken to extend to the base of Unit 3, is composed of stiff to very stiff sandy clay or clayey sand. It can be considered as free dig material for excavation, however due to the homogeneity and compactness of the material, some degree of light blasting may be advantageous to improve the efficiency of the excavators and to reduce equipment damage. However, Tertiary clay is not particularly amenable to blasting and 'belling' of blast holes is not uncommon.

Unit 4 in the overburden sequence, which is equated to completely weathered Permian, is similar to the Tertiary but more compact, being essentially a very weak sandy claystone or clayey sandstone. This, and the upper part of the underlying weathered Permian rock strata in Unit 5, would theoretically be free dig material for large hydraulic excavators, but in practice would normally require light blasting.

Apart from some loose sand at the surface, the soft overburden appears to be largely homogeneous clay of low to medium plasticity, so that blast hole instability should not be an issue. There were no reports of significant hole instability in the exploration drilling. Gravel layers were noted in a number of boreholes within or at the base of Unit 3 which are likely to be loose and could cause some caving in blast hole sides. Similarly at deeper levels within Unit 4 there are records of loose sand where the sandstone strata have been completely weathered and leached, and these horizons could also cause possible caving.

The rock below the weathered zone appears to be typical fine grained coal measure strata, moderately weak to moderately strong. No bodies of massive sandstone were identified in the interburden sequence above the VU Seam. There is very little measured data regarding the physical properties of the overburden rock material, as most boreholes were not cored and did not have sonic velocity logs for estimating rock strength. The following parameters as shown in Table 12-1 are based on the one full sonic log through the interburden in CX0101.

Table 12-1 : Estimated Interburden Blast Parameters

UCS (MPa)	10 -50
Modulus (GPa)	2.5 - 11.5
Poisson's ratio	0.2 - 0.3
Tensile strength (MPa)	1 - 5
Density (t/m^3)	2.4 - 2.6
Sonic velocity (m/sec)	2000 - 4000

The VU Seam would normally be blasted, particularly if mining is to be carried out using wheeled loaders, but the coal could probably be dug unblasted by hydraulic excavator.

12.2 Traffickability

Tertiary clay of any sort is likely to become untraffickable when wet, even though the clays at Codrilla are sandier and less plastic than typical Tertiary. This would impact on ramps down to rockhead as well as to the general overburden stripping fleet. The Permian clays in Unit 4 would be similar. A dark brown to black claystone has been noted in Unit 2 places, generally at a depth of between 6m and 14m. Horizons of black clay, representing pond deposition in the Tertiary, have been found to be soft and highly troublesome for trafficking at other mines.

Little information is available on the detailed nature of the floor for the upper seams, but the borehole data indicates variable conditions ranging from soft carbonaceous mudstone to hard sandstone. It would appear that conditions will be reasonable for trafficking except in those cases where the floor is mudstone and water is accumulating.

The mining floor for the VU Seam will be the Yarrabee Tuff. This is highly variable in nature, varying from brittle to puggy and is highly slake susceptible in places. It is generally considered to be unsuitable for trafficking, and is usually removed by bulldozing into rills. Note in this connection that it normally needs to be rilled in any case before dumping spoil to avoid leaving a potential basal slip horizon. The poor quality VL1 Seam is normally left to form the trafficking surface.

Floor treatment will be required for spoil dumped on the VU Seam floor where there is an outward dip of more than 5°, to disrupt potential shear planes or thin weak tuffaceous clay bands associated with the VL1 Seam and any weakness in immediate mudstone floor. The potential weak floor sequence below the YT is from 0.7m to 1.5m thick. It is suggested that the floor should be disrupted by blasting to a depth of approximately 4m prior to any up-dip spoil dumping.

12.3 Groundwater

There are no known major aquifers and the overburden is largely clay which is more or less impermeable; however there are occasional references to water make in exploration boreholes, none of which would indicate anything more than a minor aquifer.

The only likely emissions of groundwater in the upper soft overburden could be from the gravel layers or lenses, although there is no specific reference to this from the exploration drilling. Any exposed gravel layers are likely to be free-draining and of limited volume and in excavation would be drained to sumps. There is also a possibility of blast holes making water from the gravel. The other potential source of groundwater in the overburden is the sand or sandstone towards the bottom of the weathered zone.

The coal seams can typically constitute minor aquifers, particularly the thick VU Seam and would be expected to make some amount of water when exposed in the pit. Localised higher flows could be expected from the fault zones within the coal seams where the fracturing provides the flow path and storage.

The general conclusion is that the pit would be relatively dry with only nuisance water emissions from the aforementioned sources. The normal method of control

would be to drain surface water into sumps, in order to avoid accumulation in trafficked areas.

13 SPOIL COVER SUITABILITY – ENVIRONMENTAL CONSIDERATIONS

As part of MCC's environmental obligations, spoil dumps are required to be rehabilitated in accordance with relevant legislation.

The intent of rehabilitation is to effectively mitigate the physical and chemical degradation of the spoil dumps, but also to control any potential polluting sources.

Generally, there are several physical and chemical characteristics which are important to ascertain when rehabilitating mine spoil. These include:

- Acid generating potential;
- Dispersion potential and salinity; and
- Erosion potential.

An assessment was conducted to ascertain basic physical and chemical properties of the spoil material and the suitability of the competent sandstone unit as a spoil cover material.

Section 4 presented the laboratory results as part of the assessment to determine some basic physical and chemical characteristics of the Tertiary clay spoil and the suitability of a higher competency sandstone unit, below the VU Seam, as a spoil cover. For this study however, only limited chemical and physical index testing was conducted, which could be considered a screening process for evaluation during more detailed studies.

It is recommended that further studies be undertaken to understand the distribution of soils across the site that would require adequate management in order successfully rehabilitate.

13.1 Acid Generating Potential

The generation of acidic conditions is primarily a result of the oxidation of sulphide minerals within the either a soil lattice or rock matrix. The potential impacts of acid generation are often extensive; therefore materials of this nature would require management from the outset (Ref 4).

Strategies for managing the impacts of potential acid generation include:

- Minimising material oxidation via water and oxygen contact;
- Introducing neutralising agents, such as carbonates;
- Preventing discharge of acidic runoff from within the spoil dump; and
- Treatment of runoff and seepage water prior to discharge.

13.2 Dispersion Potential and Salinity (Dispersivity)

Soil dispersion is generally controlled by the exchangeable sodium content of the soil, where even small concentrations of exchangeable sodium can have a significant influence on dispersion potential (Ref 1). In this case, the dispersion mechanism only requires the presence of water, therefore the modification of the landform has limited affect on the success of the rehabilitation (Ref 4).

Often soils with a significant concentration of exchangeable sodium are also unsuitable for vegetation growth due high salinity. This is another critical factor in controlling soil dispersion.

Strategies for managing the impacts of dispersion and salinity include:

- Application of a cover material to prevent seepage contact and to provide a suitable growth medium for the establishment of vegetation; and
- Addition of reagents to displace sodium cations.

The results of the limited testing indicate some dispersive variability for the soft overburden samples tested, although the tests suggest that material dispersion is unlikely.

13.3 Erosion Potential

Where chemical stability is unlikely to be the key driver of spoil degradation, other physical properties, such as swelling potential, would still warrant the placement of a suitable covering.

In this case, clayey materials with high liquid limits tend to swell significantly upon exposure to moisture resulting in a reduction in cohesion and shear strength. These materials would be susceptible to further physical degradation and would require a protective rock cover to reduce this likelihood.

Strategies for managing erosion potential include:

- Reducing the slopes and catchment areas;
- Application of a cover material and the establishment of vegetation.

13.4 Rock Cover Suitability – VU Sandstone

The sandstone unit below the VU seam was evaluated as a potential soil cover material. Material strength testing indicated some variability in UCS, ranging from 16.5 MPa to 65.7 MPa. Inspection of the UCS test results in Section 4 (Table 4-3) indicated the low strength values were the result of failure along pre-defined surfaces, and therefore a representative UCS value are likely to be moderate to high strength.

Slake durability testing indicated the sandstone material to have a low slake potential, which also an important material property when selecting a suitable cover material.

The testing indicates the material to have suitable physical properties for use a spoil cover, however further test work would be required in order to evaluate the materials acid generating potential.

14 REFERENCES

1. Hazelton, P.A & Murphy, B.W (2007). **"Interpreting Soil Test Results: What Do All The Numbers Mean?"** New South Wales Department of Natural Resources.
2. Ward, B and Hanson C (2009). **"Codrilla Project Opencut Feasibility Study – Geotechnical Report"**, IMC Mining Solutions Pty Ltd.
3. Read, J and Stacey, P (2009). **"Guidelines for Open Pit Slope Design"**. CSIRO Publishing.
4. Henderson, S (Minserve) et al (2008). **"Specification of Overburden for Use as Cover Spoil"**. ACARP Project C14042

APPENDIX A – Geotechnical Logs

GEOTECHNICAL DRILLHOLE LOG

DRILLHOLE: CX3106FC

PROJECT: CODRILLA

E: 664257, N:7555636, RL:173.4

COMP DEPTH: 75.00m

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
0.0			Clayey SAND (SC), medium dense, medium to coarse grained, brown (Quaternary).						
1.0			Clayey SAND (SC), medium dense, medium to coarse grained, grey (Tertiary).						
2.0									
3.0			CLAYSTONE (XW), extremely low strength, pinkish-red brown, mottled, weathered to silty clay (CH) in parts.						
4.0									
5.0									
6.0									
7.0									
8.0									
9.0									

Depth 1:50	Samples	Litho	Description	Weathering					
				RS	XW	HW	MW	SW	FR
10.0									
11.0									
12.0									
13.0									
14.0									
15.0									
16.0									
17.0									
18.0									
19.0									
20.0									
21.0									
22.0									
23.0									

Depth 1:50	Samples	Litho	Description	Weathering					
				RS	XW	HW	MW	SW	FR
24.0									
25.0									
26.0									
27.0									
28.0			SILTSTONE (HW), extremely low strength, grey-brown, fine grained, with fine grained SAND thoughout.						
29.0			SANDSTONE (HW), very low strength, fine grained, brown grey, with (CH) in matrix, Fe staining in places, minor fracturing observed.						
30.0									
31.0									
32.0									
33.0									
34.0									
35.0									
36.0									

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
37.0									
38.0									
39.0									
40.0									
41.0									
42.0			CLAYSTONE (HW), very low strength, reddish grey, mottled, some fine grained sand lenses, weathered to silty to sandy clay (CH) in parts, minor microfractures observed.						
43.0									
44.0									
45.0									
46.0									
47.0									
48.0									
49.0			SANDSTONE (HW), very low strength, grey brown, fine grained, with (CH) in matrix.						

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
50.0									
51.0			CLAYSTONE (HW), very low strength, reddish grey, mottled, some fine grained sand lenses, weathered to silty to sandy clay (CH) in parts, Fe staining.						
52.0									
53.0									
54.0									
55.0									
56.0									
57.0			PEBBLE CONGLOMERATE (HW), dense, pebbles with fine to coarse GRAVEL and SAND, white, with high plasticity CLAY matrix.						
58.0									
59.0									
60.0			CLAYSTONE (HW), very low strength, pinkish-red brown, mottled, some fine grained sand lenses, weathered to silty to sandy clay (CH) in parts, Fe staining thoughout (Permian), fractures.						
61.0									
62.0			SILTSTONE (MW), very low strength, grey-brown, fine grained, with fine grained SAND thoughout, fractures.						

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
63.0									
64.0			SANDSTONE (MW), very low strength, orange-brown, fine grained, finely laminated, weakly cemented, fractures.						
65.0									
66.0									
67.0			SILTSTONE (MW), very low strength, grey-brown, fine grained, with fine grained SAND thoughout, fractures.						
68.0									
69.0			SANDSTONE (SW), low strength, orange-brown, fine grained, finely laminated, fractures.						
70.0									
71.0									
72.0			SILTSTONE (FR), low strength, grey-brown, fine grained, with fine grained SAND thoughout.						
73.0									
74.0									
75.0			EOH @ 75m - Base of Weathering						

GEOTECHNICAL DRILLHOLE LOG

DRILLHOLE: CX3115FC

PROJECT: CODRILLA

E: 663112, N:7554538, RL:174.9

COMP DEPTH: 76.30m

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
0.0			Clayey SAND (SC), medium dense, loose, medium to coarse grained, brown (Quaternary) - Residual Soil.						
1.0									
2.0									
3.0									
4.0									
5.0			CLAYSTONE (XW), extremely low strength, pinkish-red grey, mottled, sandy, weathered to silty clay (CH) in parts.						
6.0									
7.0			SANDSTONE (HW), very low strength, very fine grained, red grey, with (CH) in matrix.						
8.0									
9.0									
			CLAYSTONE (HW), extremely low strength, grey brown, mottled, sandy, weathered to silty clay (CH) in parts.						

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
10.0									
11.0									
12.0									
13.0									
14.0									
15.0									
16.0									
17.0									
18.0									
19.0									
20.0									
21.0									
22.0			SANDSTONE (HW), very low strength, very fine grained, red grey, with (CH) in matrix.						
23.0									

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
24.0									
25.0									
26.0									
27.0									
28.0			CLAYSTONE (HW-MW), very low strength, red grey brown to yellow grey, mottled, sandy, weathered to silty clay and clayey sand (CH) & (SC) in parts.						
29.0									
30.0									
31.0									
32.0									
33.0									
34.0									
35.0									
36.0									

Depth 1:50	Samples	Litho	Description	Weathering					
				RS	XW	HW	MW	SW	FR
37.0									
38.0									
39.0									
40.0									
41.0									
42.0									
43.0									
44.0									
45.0									
46.0									
47.0									
48.0									
49.0									

Depth 1:50	Samples	Litho	Description	Weathering					
				RS	XW	HW	MW	SW	FR
50.0									
51.0									
52.0									
53.0									
54.0									
55.0									
56.0									
57.0									
58.0									
59.0									
60.0									
61.0									
62.0									

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
63.0									
64.0									
65.0									
66.0									
67.0			SANDSTONE (HW), very low strength, very fine grained, light grey to brown grey, with (CH) in matrix, thin CLAYSTONE bands.						
68.0									
69.0									
70.0									
71.0									
72.0									
73.0									
74.0									
75.0									

Depth 1:50	Samples	Litho	Description	Weathering RS	XW	HW	MW	SW	FR
76.0									
			EOH @ 76.3m - BASE OF WEATHERING						
77.0									
78.0									
79.0									
80.0									
81.0									

GEOTECHNICAL DRILLHOLE LOG

DRILLHOLE: CX3122FC

PROJECT: CODRILLA

E: 662726, N:7555890, RL:175.6

COMP DEPTH: 80.47m

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
0.0			Clayey SAND (SC), medium dense, medium grained, brown to grey (Quaternary / Tertiary) - Aluvials.						
1.0									
2.0									
3.0									
4.0			CLAYSTONE (XW), extremely low strength, red grey, mottled, sandy, weathered to silty clay (CH) in parts, Fe staining in places.						
5.0									
6.0									
7.0									
8.0									
9.0									

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
10.0			SANDSTONE (HW), very low strength, fine grained, red grey, clayey, Fe staining in places.						
11.0									
12.0									
13.0									
			CLAYSTONE (HW-MW), very low strength, grey brown, mottled, sandy, Fe staining in places, fractures.						
14.0									
15.0									
16.0									
17.0									
18.0									
19.0									
20.0									
21.0									
22.0									

Depth 1:50	Sample	Lithology	Description	Weathering					
				RS	XW	HW	MW	SW	FR
23.0									
24.0									
25.0									
26.0									
27.0									
28.0									
29.0									
30.0									
31.0									
32.0									
33.0									
34.0									
35.0									

Depth 1:50	Sample	Lithology	Description	Weathering					
				RS	XW	HW	MW	SW	FR
36.0									
37.0									
38.0									
39.0									
40.0									
41.0									
42.0									
43.0									
44.0									
45.0									
46.0									
47.0									
48.0									

Depth 1:50	Sample	Lithology	Description	Weathering					
				RS	XW	HW	MW	SW	FR
49.0									
50.0									
51.0									
52.0									
53.0									
54.0									
55.0									
56.0									
57.0									
58.0									
59.0									
60.0									
61.0									

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
62.0									
63.0									
64.0									
65.0									
66.0									
67.0									
68.0									
			SILTSTONE / SANDSTONE (MW-SW), interbedded, very low strength, brown grey, clayey, fractures.						
69.0									
70.0									
71.0									
72.0									
73.0									
74.0									
75.0									

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
75.0									
76.0									
77.0									
78.0			WEATHERED COAL (SW), Leichardt Lower 1 Seam, very low strength, black.						
			SILTSTONE / SANDSTONE (SW), very low strength, grey, carbonaceous in places.						
79.0									
80.0									
			EOH @ 80.47m - Base of Weathering						
81.0									

GEOTECHNICAL DRILLHOLE LOG

DRILLHOLE: CX3127FC

PROJECT: CODRILLA

E: 660916, N:7555759, RL:180.3

COMP DEPTH: 52.89m

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
0.0			SAND (SC), medium dense, fine to medium grained, brown red (Quaternary / Tertiary) - Aluvials.						
1.0									
2.0			CLAYSTONE (XW), extremely low strength, grey red, mottled, sandy, weathered to silty clay (CH) in parts, Fe staining in places.						
3.0									
4.0									
5.0									
			CLAYSTONE (XW-HW), very low strength, grey red, mottled, sandy, weathered to silty clay (CH) in parts, Fe staining in places, fractures.						
6.0									
7.0									
8.0									
9.0									

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
10.0									
11.0									
12.0									
13.0									
14.0									
15.0									
16.0									
17.0									
18.0									
19.0									
20.0									
21.0									
22.0			CLAYSTONE / SANDSTONE (XW-HW), very low strength, grey brown, mottled, sandy, Fe staining in places.						

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
23.0									
24.0									
25.0									
26.0									
27.0									
28.0									
29.0									
30.0									
31.0			CLAYSTONE (HW), very low strength, white red, sandy in places, Fe staining in places, fractures.						
32.0									
33.0									
34.0									
35.0									

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
36.0									
37.0									
38.0									
39.0									
40.0									
41.0									
42.0			SILTSTONE (MW-SW), very low strength, brown grey, carbonaceous in places, fractures.						
43.0									
44.0									
45.0									
46.0									
47.0									
48.0									

Depth 1:50	Sample	Lithology	Description	Weathering RS	XW	HW	MW	SW	FR
49.0									
50.0									
51.0									
52.0									
53.0			EOH @ 52.89m - Base of Weathering						
54.0									
55.0									
56.0									
57.0									
58.0									
59.0									
60.0									
61.0									

APPENDIX B – Laboratory Test Results

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091158 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	2/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165752	**Depth (m):**	9.48-9.78

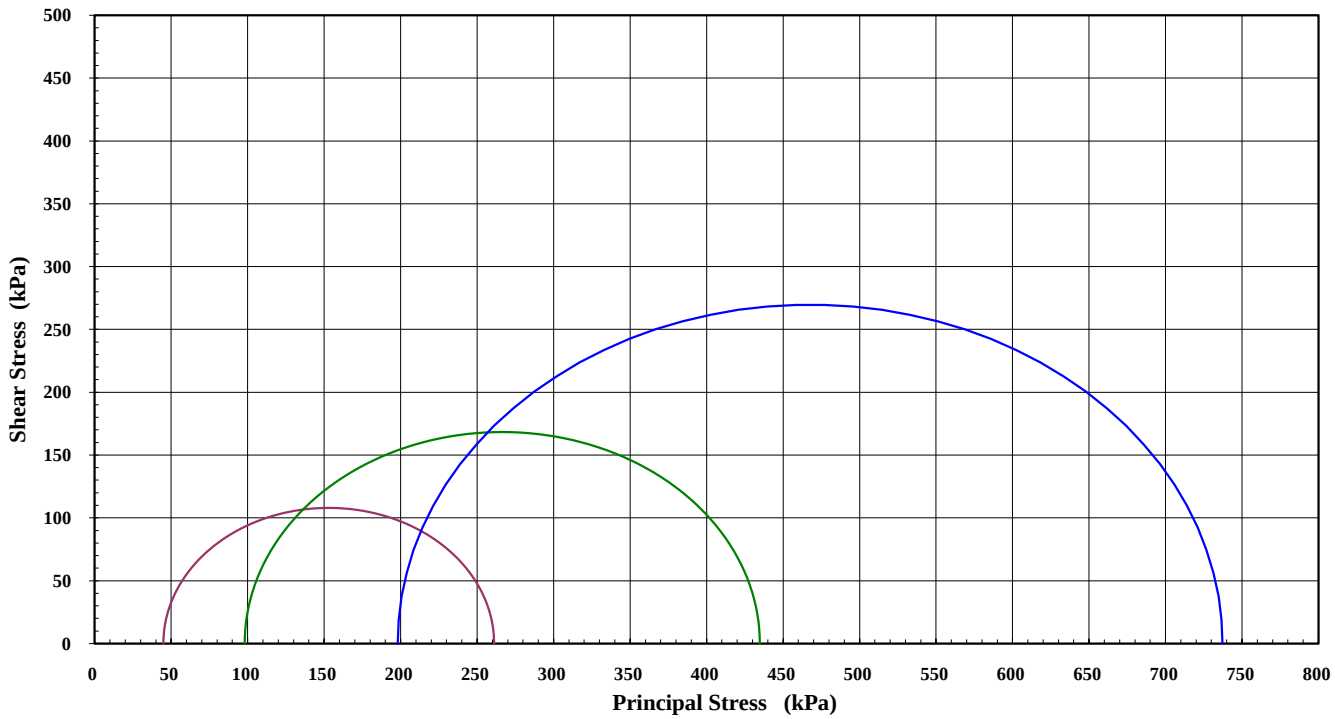
Description: SILTY SAND - grey & yellow

SAMPLE & TEST DETAILS

Initial Height:	127.7	mm	Initial Moisture Content:	12.3	%	Rate of Strain:	0.005	%/min
Initial Diameter:	60.2	mm	Final Moisture Content:	13.8	%	B Response:	97	%
L/D Ratio:	2.1 : 1		Wet Density:	2.19	t/m^3			
			Dry Density:	1.95	t/m^3			

Failure Criteria: Peak Principal Stress Ratio

Mohr Circle Diagram



	1 to 2	2 to 3	1 to 3
Interpretation between stages :			
Cohesion C' (kPa) :	31.3	39.8	35.5
Angle of Shear Resistance Φ' (Degrees) :	32.2	30.2	30.8

Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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Authorised Signatory
J. Russell

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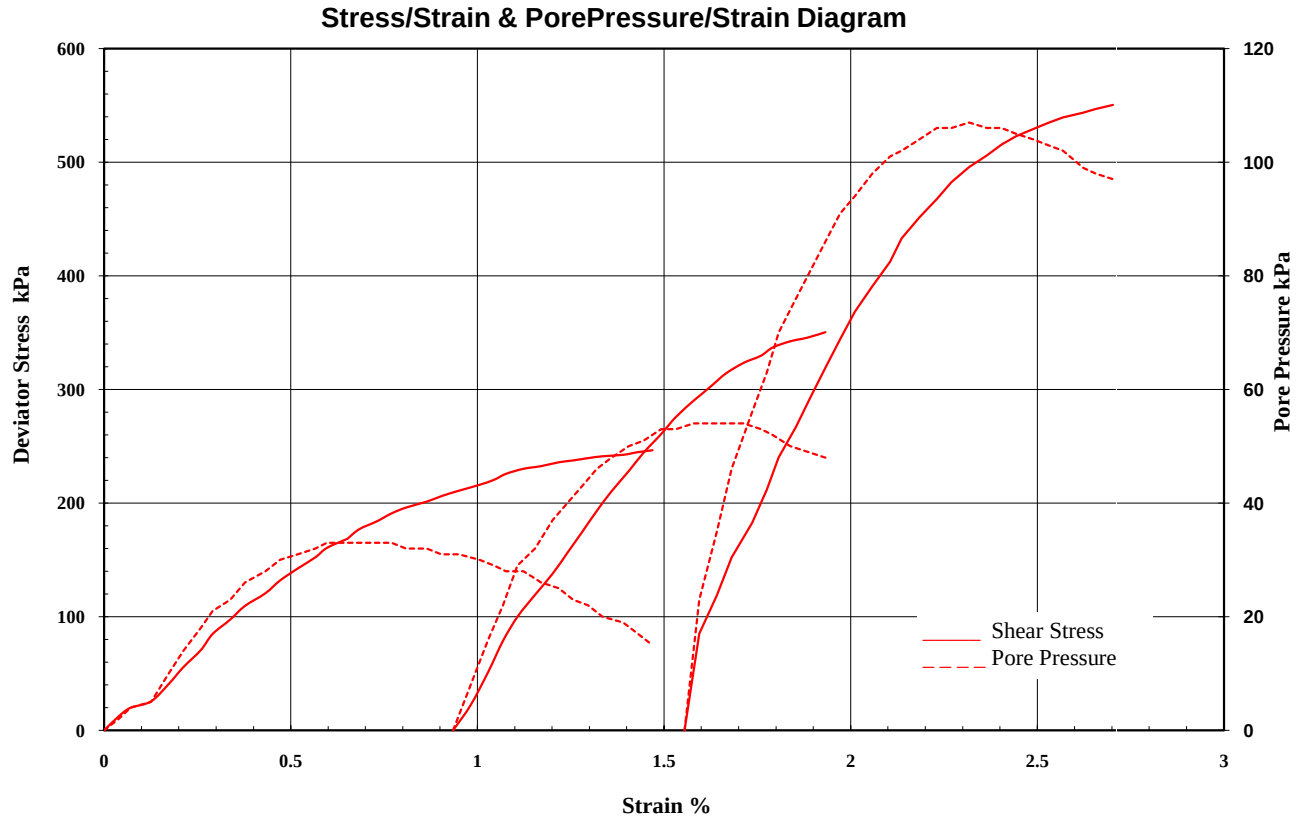
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091158 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	2/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165752	**Depth (m):**	9.48-9.78

Description: SILTY SAND - grey & yellow



FAILURE DETAILS

Confining Pressure	Back Pressure	Initial Pore	Failure Pore	Principal Effective Stresses σ'_1	σ'_3	σ'_1 / σ'_3	Deviator Stress	Strain
582 kPa	507 kPa	507 kPa	535 kPa	261 kPa	45 kPa	5.800	216 kPa	1.01 %
656 kPa	506 kPa	506 kPa	558 kPa	435 kPa	98 kPa	4.437	337 kPa	1.79 %
807 kPa	507 kPa	507 kPa	609 kPa	737 kPa	198 kPa	3.724	539 kPa	2.57 %

Sample Type: Single Individual Undisturbed Specimen
Remarks: Tested as Received
Sample/s supplied by the client
Note: Graph not to scale

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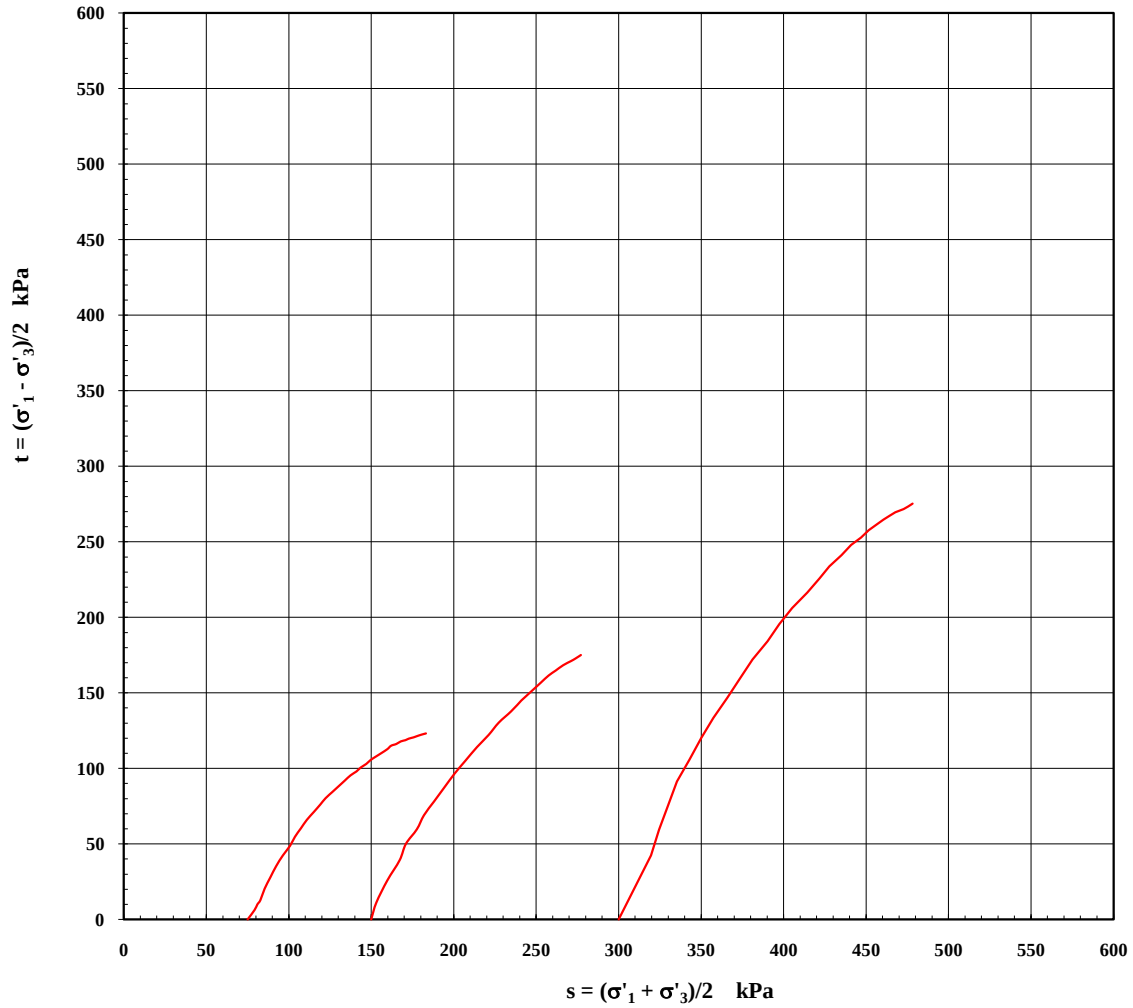
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091158 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	2/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165752	**Depth (m):**	9.48-9.78

Description: SILTY SAND - grey & yellow

MIT Method - Effective Stress Path



Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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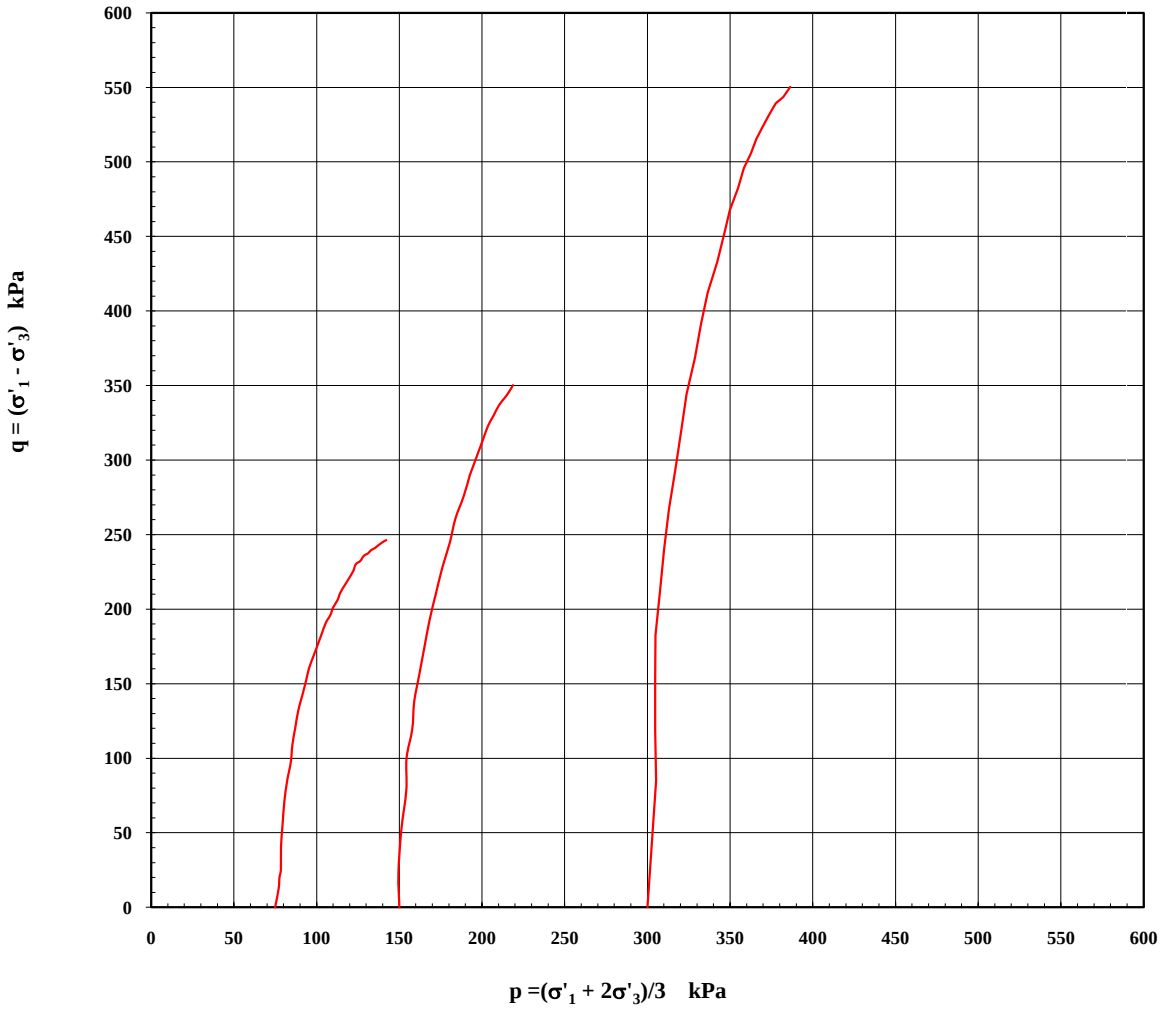
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091158 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	2/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165752	**Depth (m):**	9.48-9.78

Description: SILTY SAND - grey & yellow

Cambridge Method - Effective Stress Path



Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091158 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	2/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165752	**Depth (m):**	9.48-9.78
Description:	SILTY SAND - grey & yellow		

Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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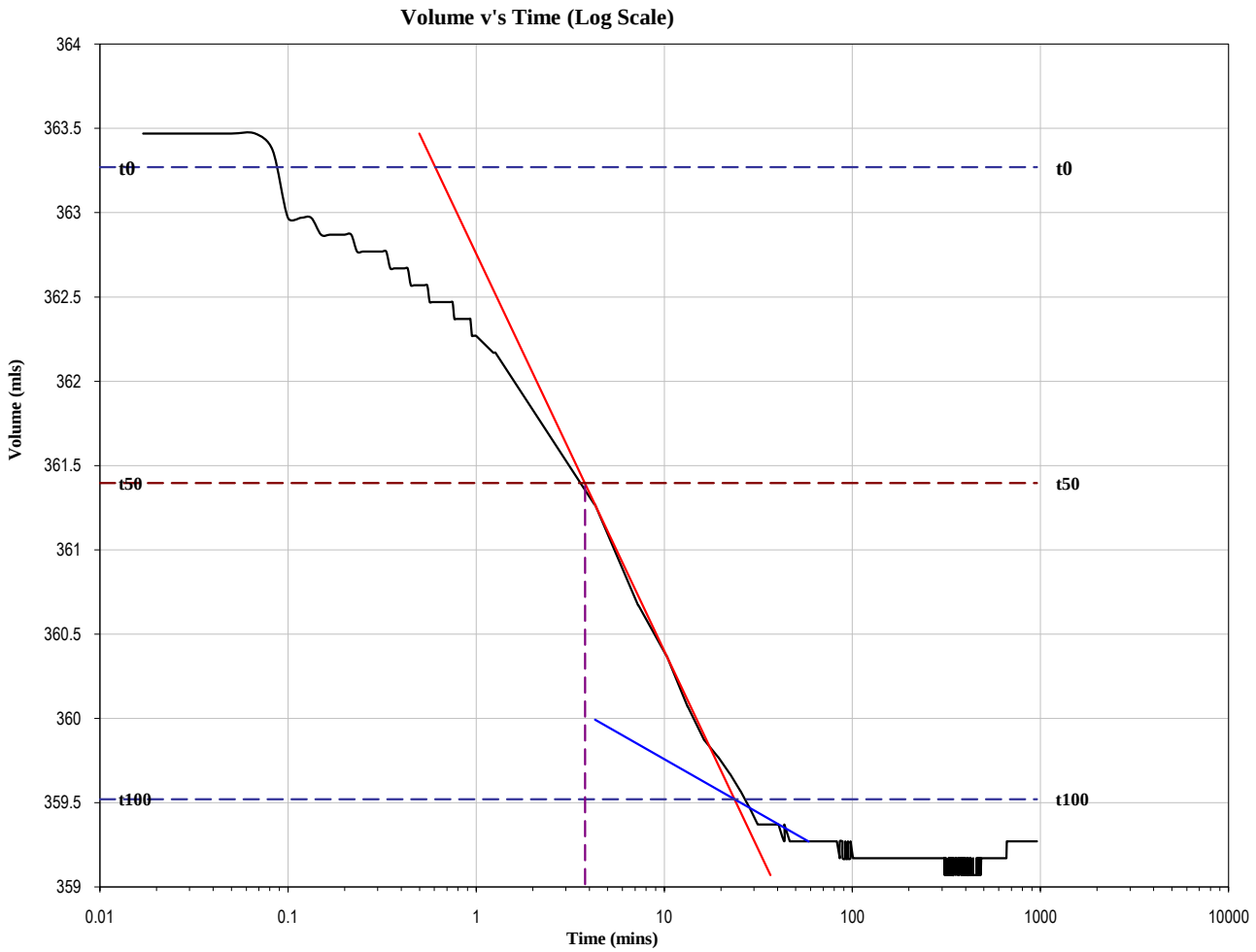
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091158 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	2/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165752	**Depth (m):**	9.48-9.78

Description: SILTY SAND - grey & yellow



Cv:	**3.33**	**m^2/year**
Mv:	**0.145**	**m^2/MN**
k:	**1.50E-10**	**m/s**

Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091159 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	3/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165770	**Depth (m):**	62.33-62.61

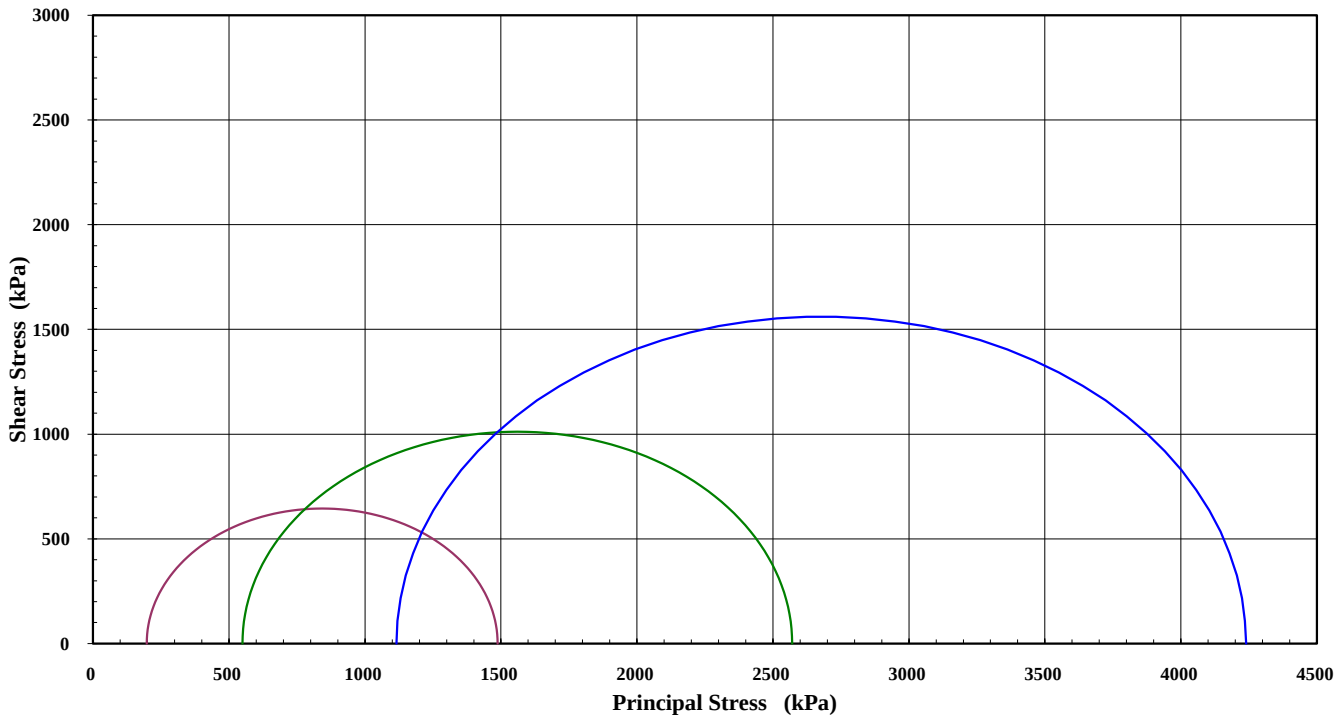
Description: SILTSTONE - yellow-brown

SAMPLE & TEST DETAILS

Initial Height:	135.0	mm	Initial Moisture Content:	13.2	%	Rate of Strain:	0.005	%/min
Initial Diameter:	60.0	mm	Final Moisture Content:	13.3	%	B Response:	97	%
L/D Ratio:	2.3 : 1		Wet Density:	2.27	t/m^3			
			Dry Density:	2.00	t/m^3			

Failure Criteria: Peak Principal Stress Ratio

Mohr Circle Diagram



	1 to 2	2 to 3	1 to 3
Interpretation between stages :			
Cohesion C' (kPa) :	249.1	278.6	262.1
Angle of Shear Resistance Φ' (Degrees) :	30.7	29.5	29.9

Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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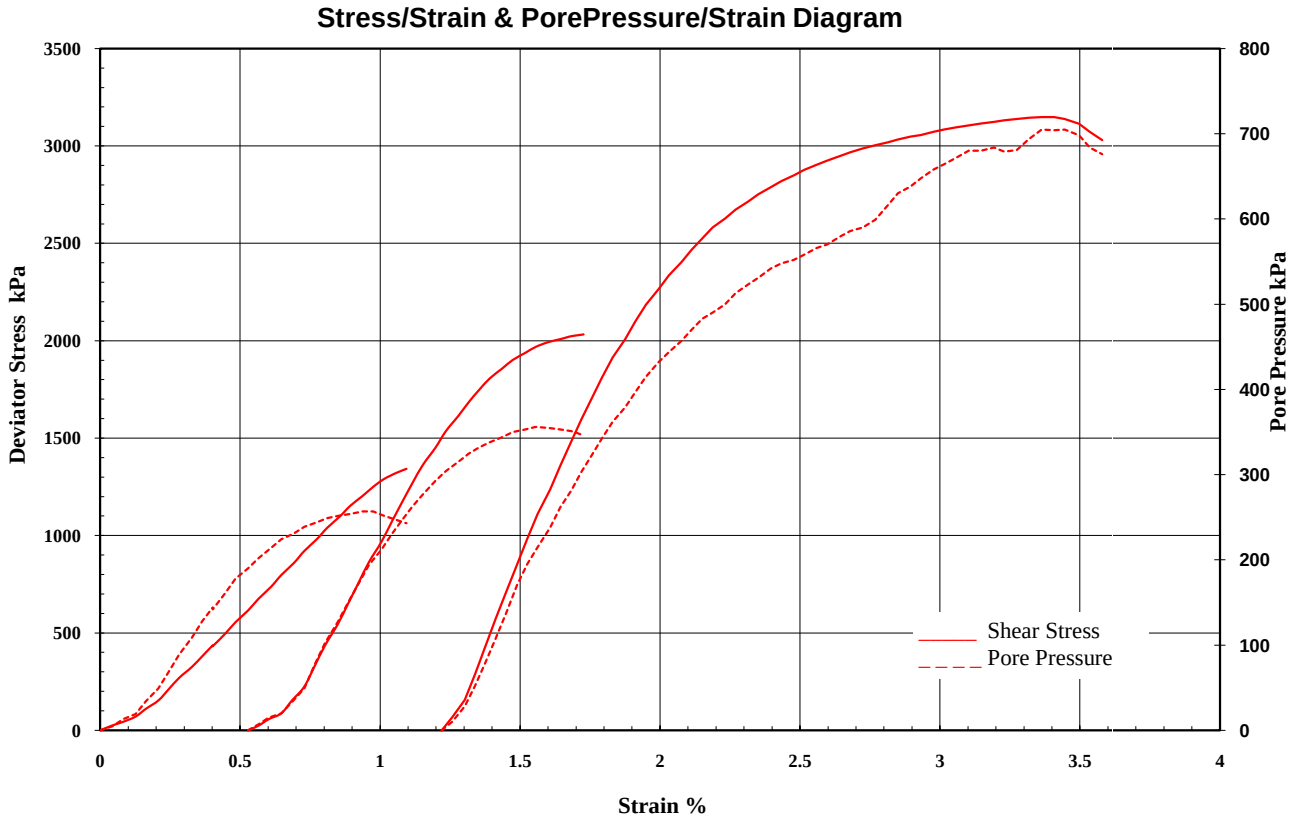
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091159 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	3/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165770	**Depth (m):**	62.33-62.61

Description: SILTSTONE - yellow-brown



FAILURE DETAILS

Confining Pressure	Back Pressure	Initial Pore	Failure Pore	Principal Effective Stresses σ'_1	σ'_3	σ'_1 / σ'_3	Deviator Stress	Strain
763 kPa	313 kPa	317 kPa	569 kPa	1487 kPa	198 kPa	7.511	1289 kPa	1.01 %
1213 kPa	313 kPa	317 kPa	668 kPa	2571 kPa	549 kPa	4.683	2022 kPa	1.68 %
2111 kPa	311 kPa	311 kPa	1016 kPa	4240 kPa	1116 kPa	3.799	3124 kPa	3.19 %

Sample Type: Single Individual Undisturbed Specimen Remarks: Tested as Received

Sample/s supplied by the client Note: Graph not to scale

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James Russell
J. Russell

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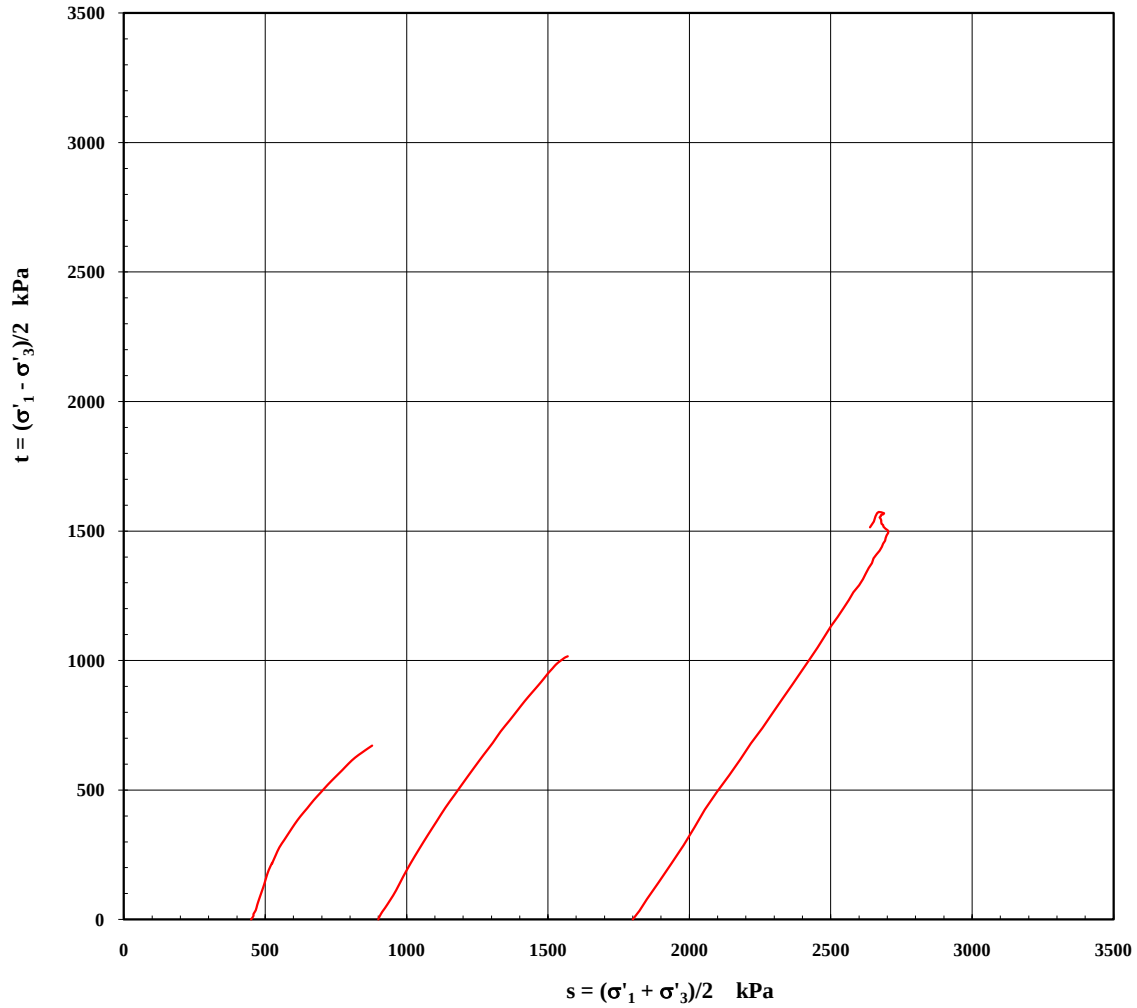
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091159 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	3/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165770	**Depth (m):**	62.33-62.61

Description: SILTSTONE - yellow-brown

MIT Method - Effective Stress Path



Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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Authorised Signatory
J. Russell

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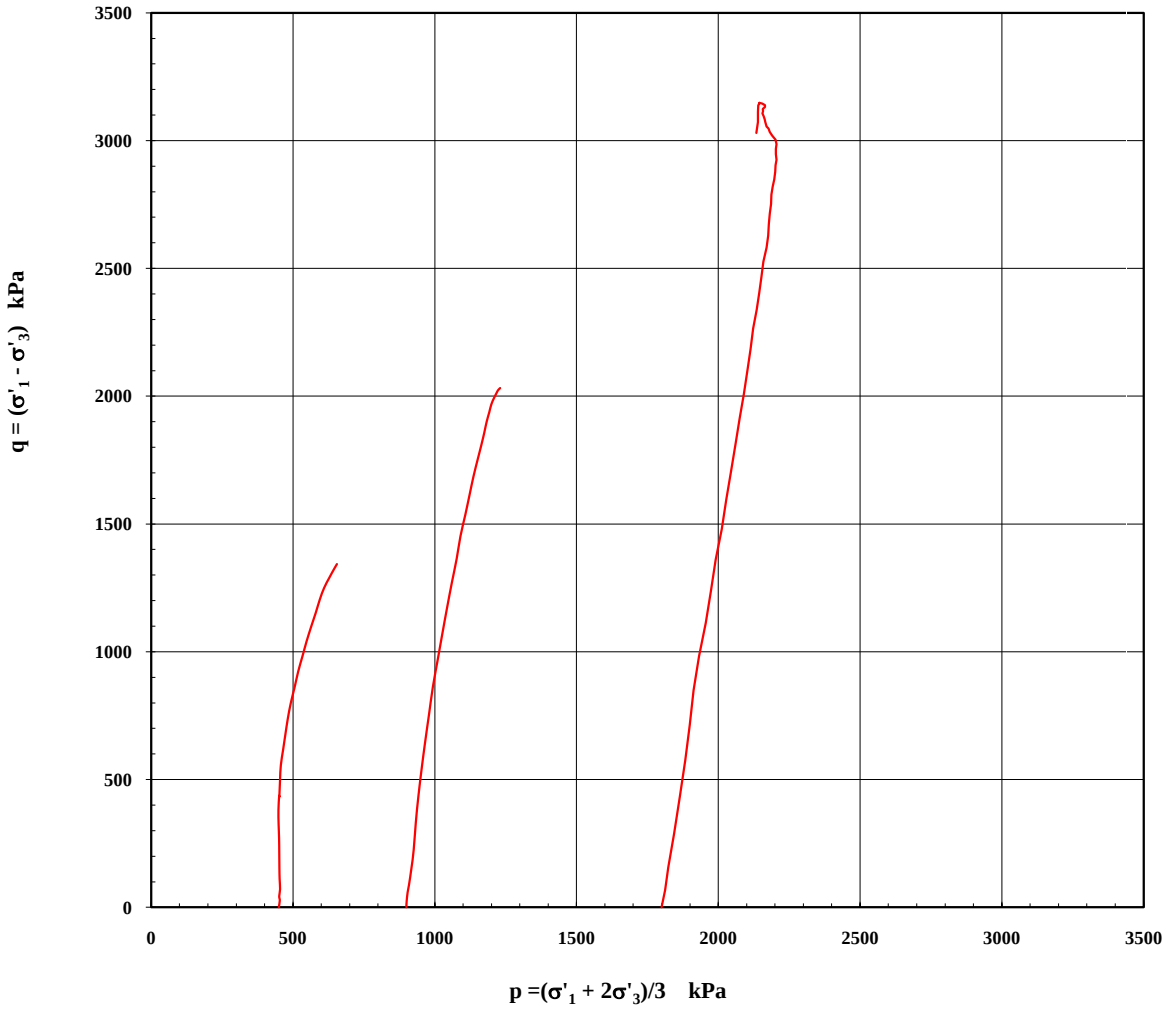
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091159 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	3/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165770	**Depth (m):**	62.33-62.61

Description: SILTSTONE - yellow-brown

Cambridge Method - Effective Stress Path



Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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Authorised Signatory

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J. Russell

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091159 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	3/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165770	**Depth (m):**	62.33-62.61
Description:	SILTSTONE - yellow-brown		

Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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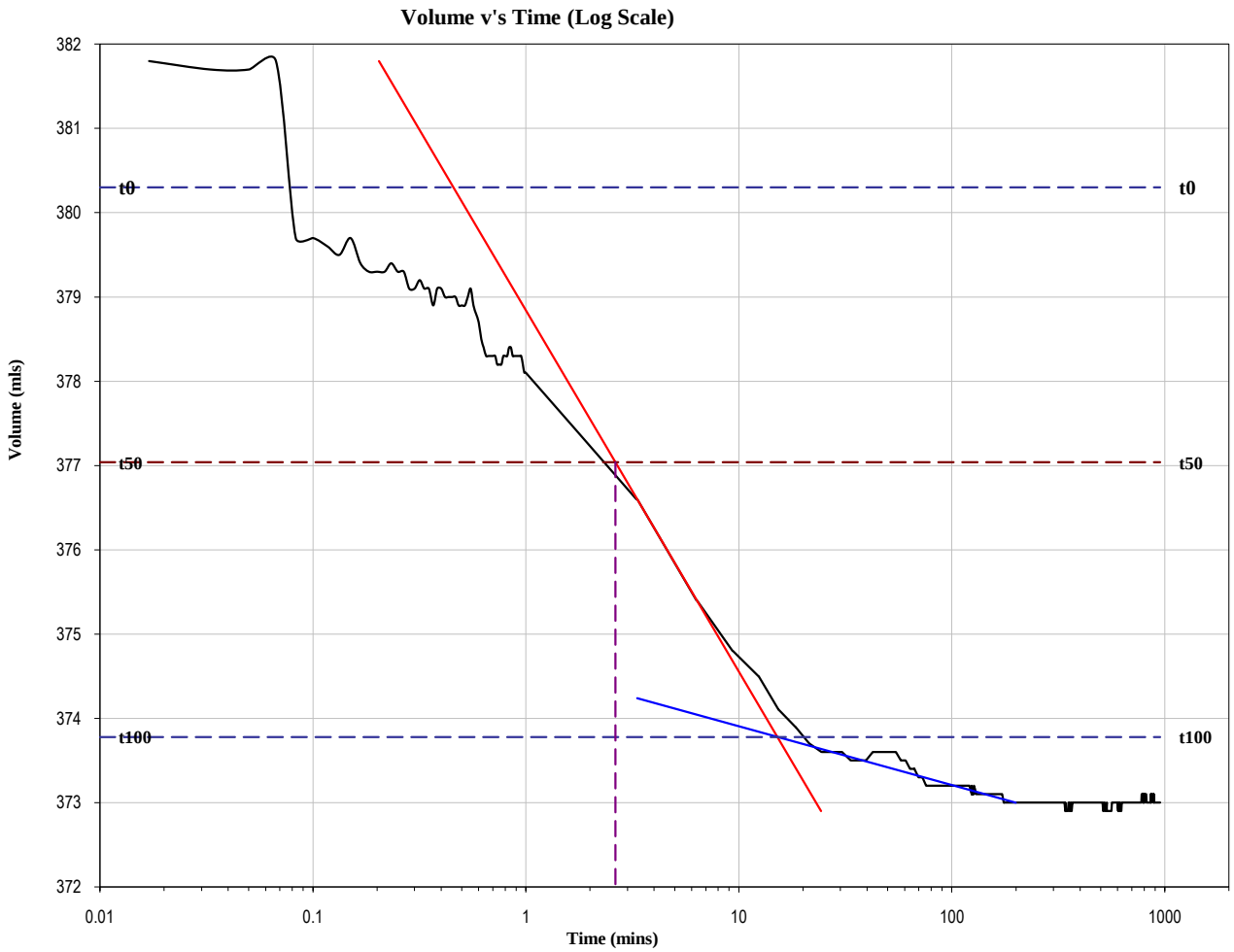
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Macarthur Coal (C&M Management) Pty Ltd	**Report No.:**	11091159 - CU
Project:	"Codrilla Project" EPC676	**Test Date:**	3/11/2011
		Report Date:	9/11/2011
Client Id.:	CX3106FC / 165770	**Depth (m):**	62.33-62.61

Description: SILTSTONE - yellow-brown



Cv:	**4.61**	**m^2/year**
Mv:	**0.046**	**m^2/MN**
k:	**6.60E-11**	**m/s**

Sample Type:	Single Individual Undisturbed Specimen	Remarks:	Tested as Received
Sample/s supplied by the client		Note: Graph not to scale	

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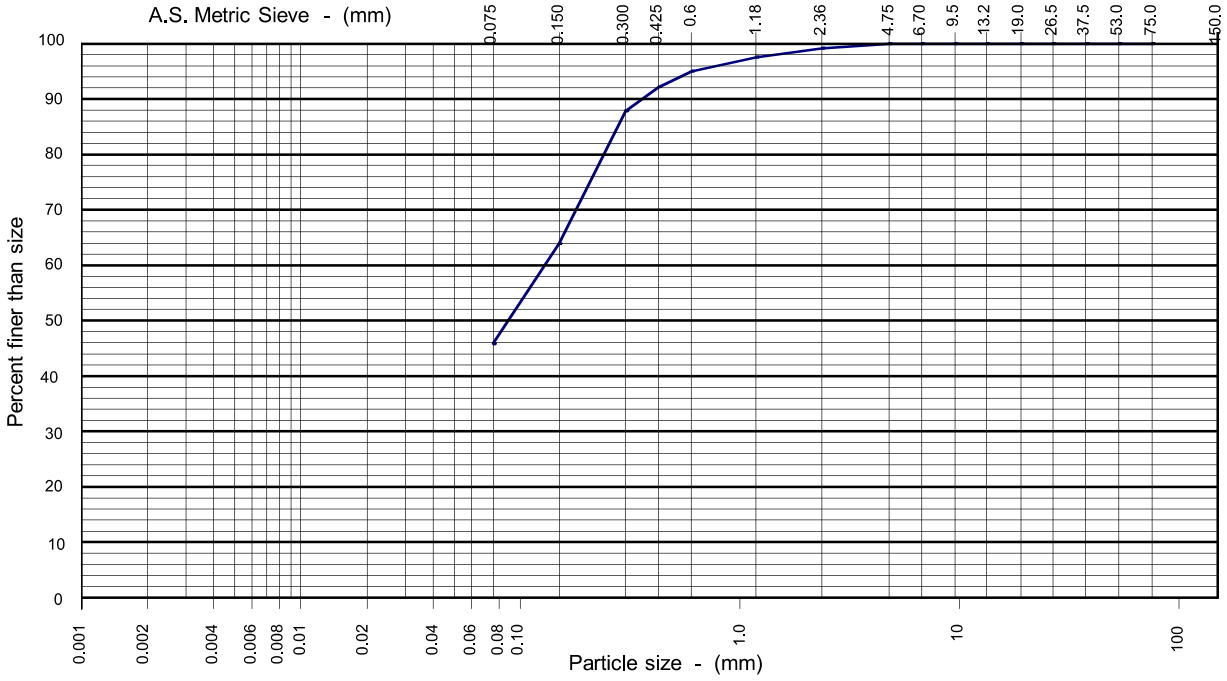
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-3979AB
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 9.24-9.48m(Uncorrected)	**TESTED BY:**	MW,LH	**DATE:**	5-6.10.11
MATERIAL:	Clayey Sand	**CHECKED BY:**	KR	**DATE:**	6.10.11
TEST PROCEDURES:	AS 1289.3.1.1, 3.2.1, 3.3.1, 3.4.1, 3.6.1	**CLIENT REF:**	CX3106FC-165751		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
46				28	21	4	1	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0	100		
9.5	100		
4.75	100		
2.36	99		
1.18	98		
0.600	95		
0.425	92		
0.300	88		
0.150	64		
0.075	46		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
33	15	18	11.0	-

Classification: **Clayey Sand;** fine to coarse grained

(SC)

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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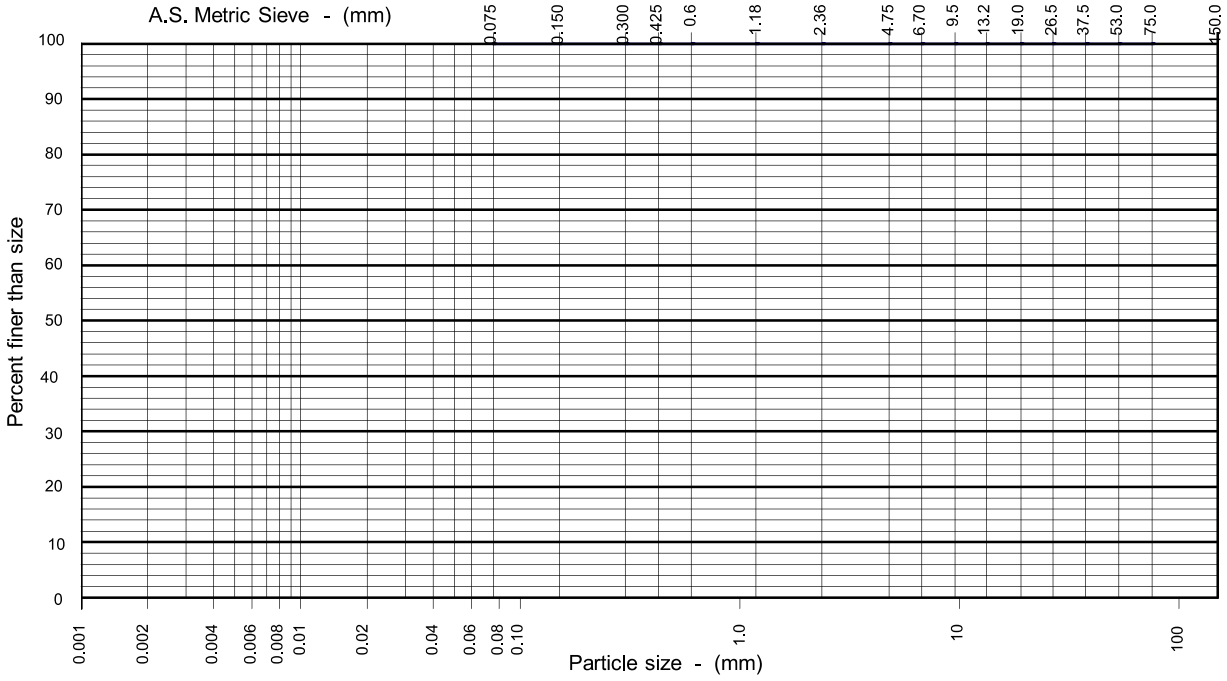
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-3980AB
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 14.00-14.20m(Uncorrected)	**TESTED BY:**	MW,TL	**DATE:**	7-11.10.11
MATERIAL:	XW Claystone	**CHECKED BY:**	KR	**DATE:**	13.10.11
TEST PROCEDURES:	AS 1289.3.1.1, 3.2.1, 3.3.1, 3.4.1, 3.8.1	**CLIENT REF:**	CX3106FC-165753		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
				0	0	0	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5			
4.75			
2.36			
1.18			
0.600			
0.425			
0.300			
0.150			
0.075			

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
43	20	23	12.5	-

Classification:

Emerson Class No.: 5 Type of Water: Distilled Temperature of Water: 23ºC

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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Certificate No. 11-3980A

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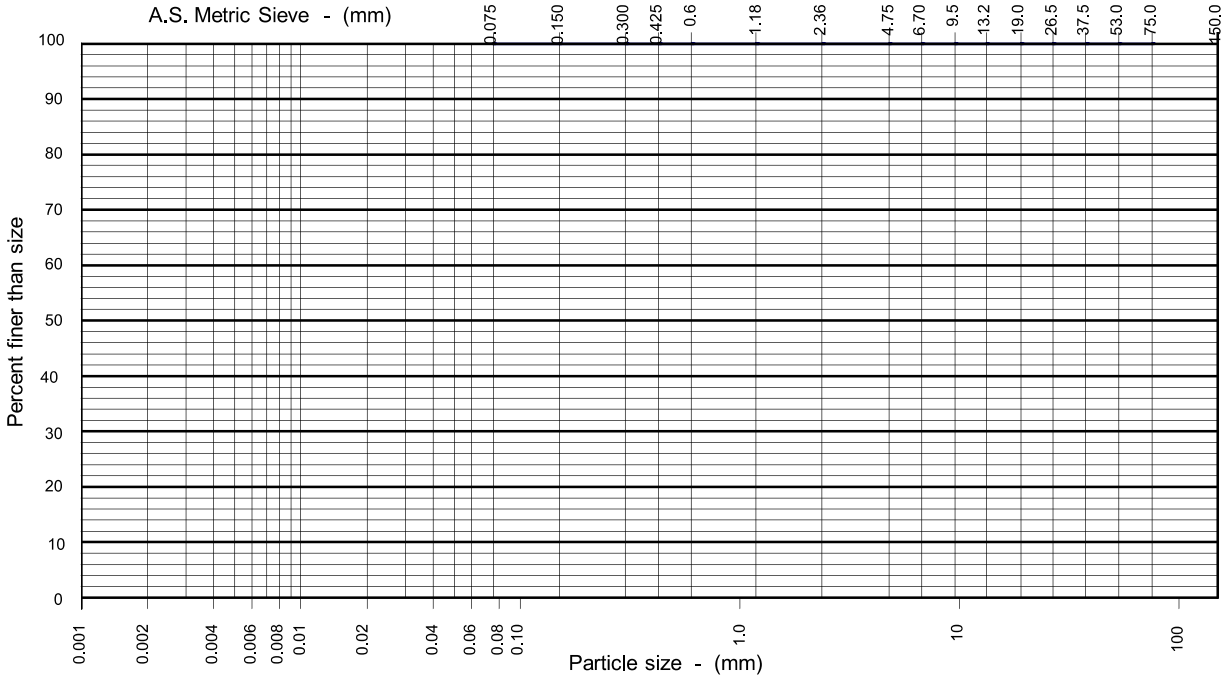
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-3981AB
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 55.00-55.20m(Uncorrected)	**TESTED BY:**	MW,TL	**DATE:**	6-7.10.11
MATERIAL:	HW Claystone	**CHECKED BY:**	KR	**DATE:**	10.10.11
TEST PROCEDURES:	AS 1289.3.1.1, 3.2.1, 3.3.1, 3.4.1, 3.8.1	**CLIENT REF:**	CX3106FC-165765		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
				0	0	0	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5			
4.75			
2.36			
1.18			
0.600			
0.425			
0.300			
0.150			
0.075			

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
30	15	15	8.0	-

Classification:

Emerson Class No.: 6 Type of Water: Distilled Temperature of Water: 23ºC

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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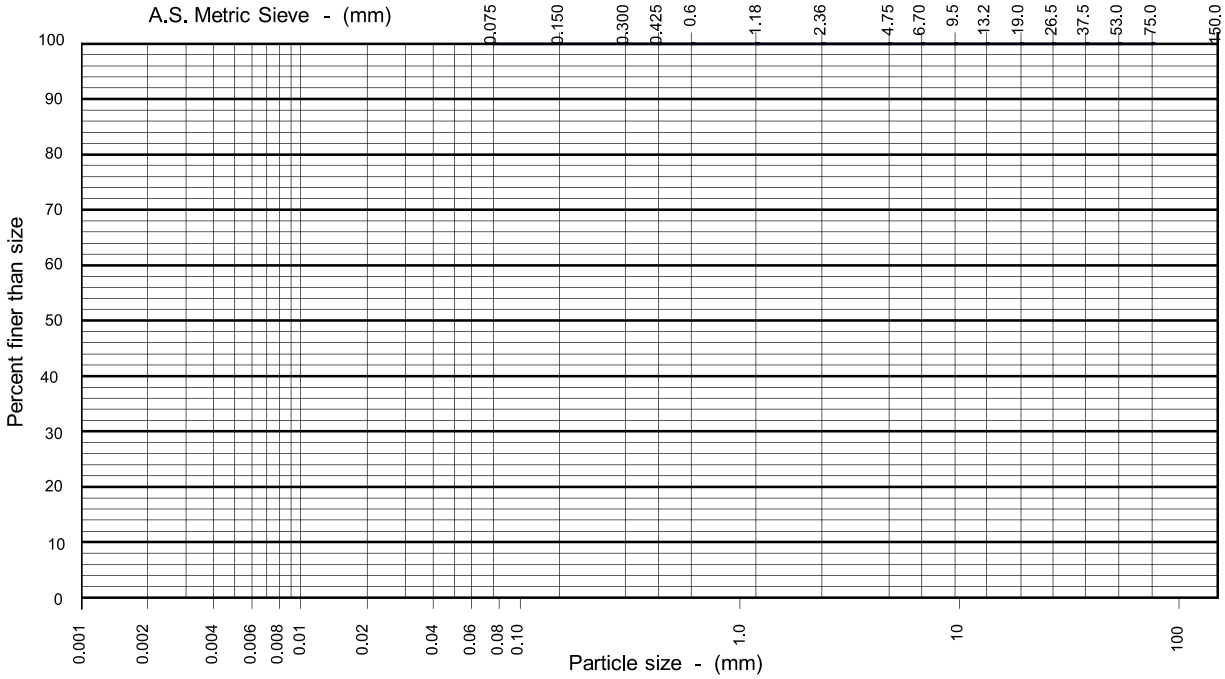
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-3982A
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 57.95-58.25m(Uncorrected)	**TESTED BY:**	MW	**DATE:**	11.10.11
MATERIAL:	HW Conglomerate	**CHECKED BY:**	KR	**DATE:**	13.10.11
TEST PROCEDURES:	AS 1289.3.1.1, 3.2.1, 3.3.1, 3.4.1	**CLIENT REF:**	CX3106FC-165766		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
				0	0	0	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5			
4.75			
2.36			
1.18			
0.600			
0.425			
0.300			
0.150			
0.075			

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
35	20	15	6.5	-

Classification:

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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Certificate No. 11-3982A

Date of Issue 13.10.11

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REPORT ON SLAKE DURABILITY TEST

Sheet 1 of 1 | Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	Refer below
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	29-Sep-11
TEST PROCEDURE:	AS 4133.3.4	**CHECKED BY:**	AW	**CHECK DATE:**	08-Oct-11

Lab Ref No	Borehole	Client Ref	Uncorrected Depth From (m)	Uncorrected Depth To (m)	Slake Durability Index (First Cycle) %	Slake Durability Index (Second Cycle) %	Appearance of Fragments Retained in the drum	Appearance of Fragments Passing the drum
11-3983A	CX3106FC	165785	189.37	189.60	96.5	95.6	Rock lumps still intact	Sandy silt

Temperature of slaking fluid: 23 °C

Slaking fluid used: Potable

Variations from standard: Nil

Signature: _____ Date: 08-Oct-11

Andrew Williams

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REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-3984A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	01-Oct-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	08-Oct-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3106FC
Client sample number	165787
Uncorrected Depth from (m)	191.70
Uncorrected Depth to (m)	192.01
Stratigraphic horizon	
Orientation of core axis	Vertical
Lithological description	FR Sandstone
Mass of sample (g)	1200.8
Average sample diameter (mm)	61.0
Diameter variation > 0.3mm?	No
Average height (mm)	151
Length / Diameter ratio	2.5
Cross sectional area (mm^2)	2922
Uniaxial Comp. Strength (MPa)	**20.2**
Number of specimens in sample	1
Moisture content (%)	1.1
Density at as received moisture content (t/m^3)	2.721
Loading rate (N/min)	12500
Time to failure (min)	4.42
Max. applied load (kN)	59.1
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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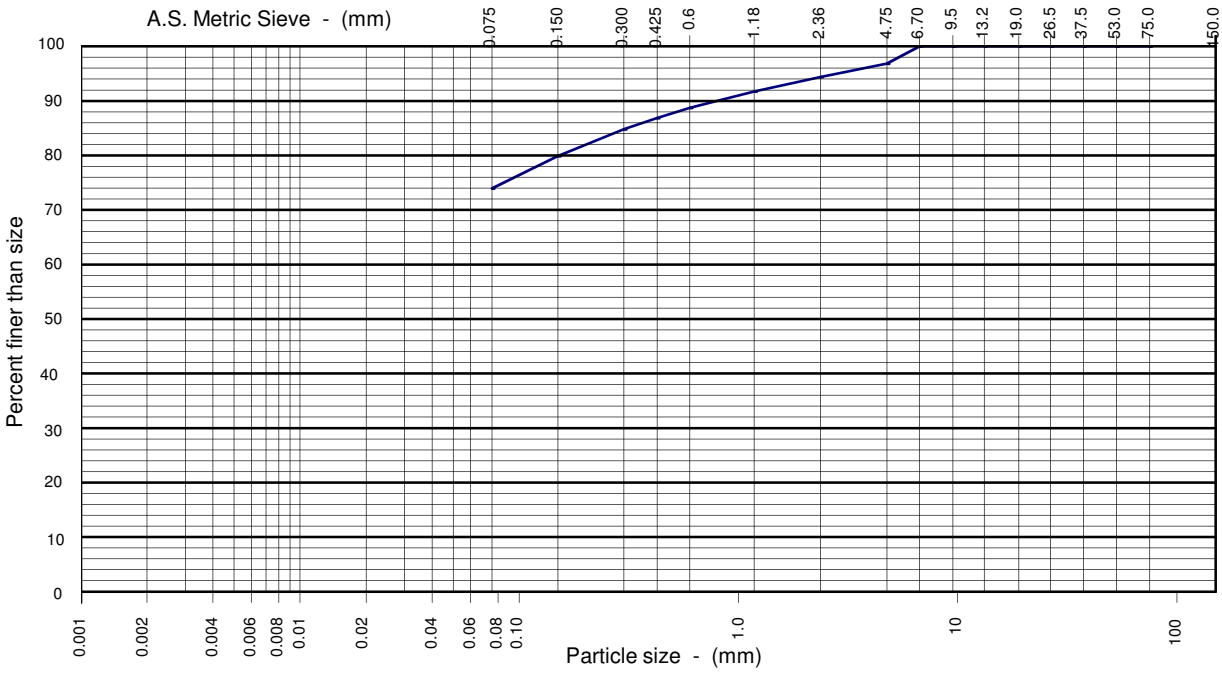
REPORT ON SOIL CLASSIFICATION

 Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-5338ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 10.00-10.30m	**TESTED BY:**	TL, BS	**DATE:**	3-4.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	5.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1	**CLIENT REF:**	CX3115FC-933		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
74				8	7	5	4	2	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5	100		
4.75	97		
2.36	94		
1.18	92		
0.600	89		
0.425	87		
0.300	85		
0.150	80		
0.075	74		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
44	14	30	15.0	-

Classification: **Sandy Clay;** sand is fine to coarse grained

(CI)

Emerson Class No.: 4 Type of Water: Distilled Temp. Of Water: 24ºC

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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Accredited No. 910

Certificate No. 11-5338A

Date of Issue 5.1.12

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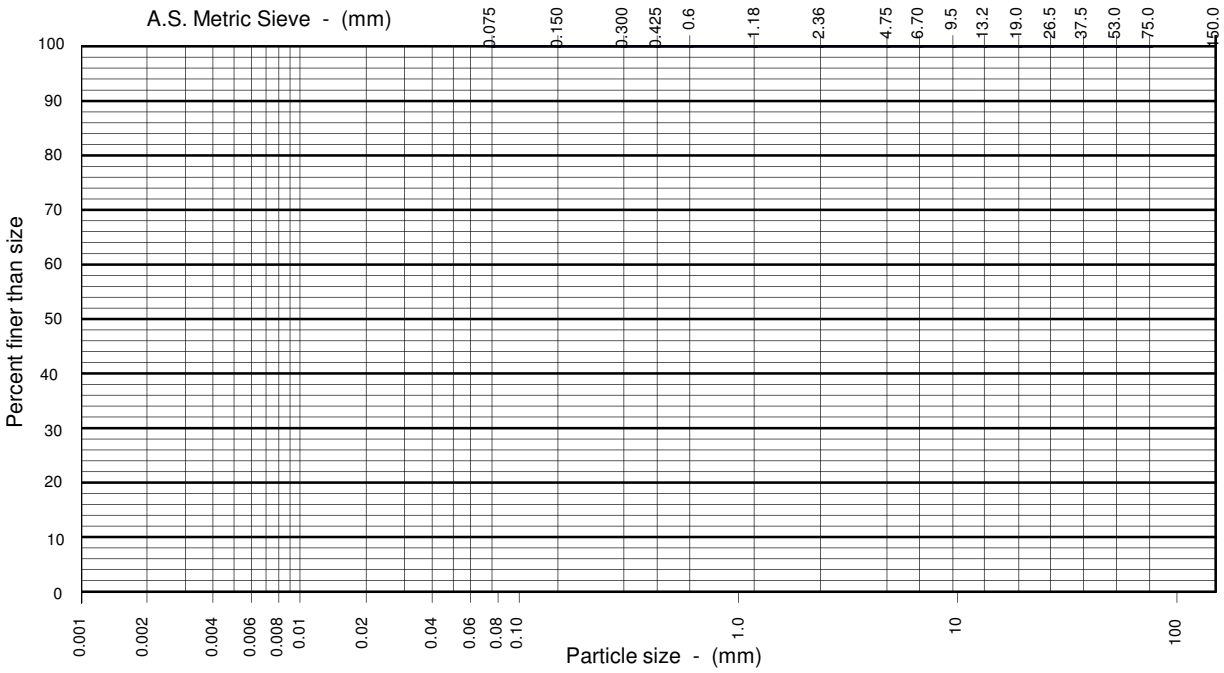
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**			11-5339AB
PROJECT:	Codrilla			**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 15.00-15.68m			**TESTED BY:**	TL, BS	**DATE:**	3-4.1.12
MATERIAL:	Extremely Weathered Claystone			**CHECKED BY:**	CC	**DATE:**	5.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.8.1			**CLIENT REF:**	CX3115FC-935		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
150.0				46	15	31	15.5	-
75.0								
37.5								
19.0								
9.5								
4.75								
2.36								
1.18								
0.600								
0.425								
0.300								
0.150								
0.075								

Classification:

Emerson Class No.: 4 Type of Water: Distilled Temp. Of Water: 24ºC

Sampled in Accordance with AS 1289.1.2.1 (6.5.4)

Preparation History of Atterberg Limits

Sample : ~~Natural~~/Air Dried/~~Oven~~

Sieved: ~~Wet~~/dry

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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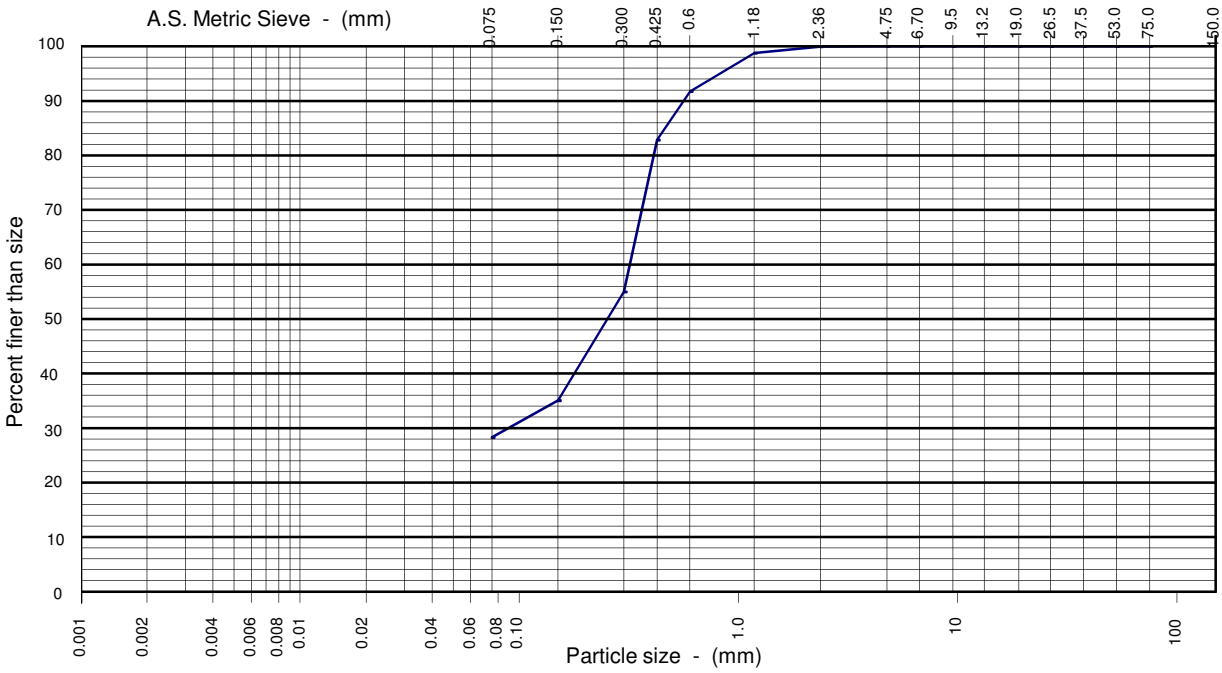
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-5341ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 69.19-69.39m	**TESTED BY:**	LH, BS	**DATE:**	3-5.1.12
MATERIAL:	Highly Weathered Sandstone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1	**CLIENT REF:**	CX3115FC-952		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
28				15	49	8	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5			
4.75			
2.36	100		
1.18	99		
0.600	92		
0.425	83		
0.300	55		
0.150	35		
0.075	28		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
39	22	17	8.5	-

Classification: **Clayey Sand;** fine to coarse grained

(CI)

Emerson Class No.: 4 Type of Water: Distilled Temp. Of Water: 24ºC

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No. 910

Certificate No. 11-5341A

Date of Issue 6.1.12

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Authorised Signatory ..... N. J. Richardson

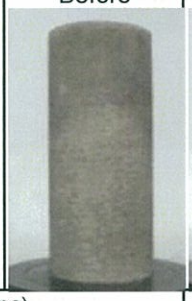
CARDNO ULLMAN & NOLAN GEOTECHNIC PTY LTD

71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4895A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	29-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	05-Dec-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3115FC
Client sample number		GT01
Depth from (m)		82.76
Depth to (m)		83.06
Stratigraphic horizon		LL1 Roof
Orientation of core axis		Vertical
Lithological description		Sandstone
Mass of sample (g)		1140.4
Average sample diameter (mm)		61.0
Diameter variation > 0.3mm?		No
Average height (mm)		155
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2922
Uniaxial Comp. Strength (MPa)		**9.3**
Number of specimens in sample		1
Moisture content (%)		3.7
Density at as received moisture content (t/m^3)		2.518
Loading rate (N/min)		5000
Time to failure (min)		5.25
Max. applied load (kN)		27.1
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard:

Young's Modulus method: N/A

Poisson's Ratio method: N/A

NATA

Accredited No. 910
Certificate No. 11-4895A
Date of Issue 05-Dec-11

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Authorised Signatory

Andrew Williams

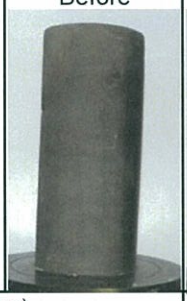
CARDNO ULLMAN & NOLAN GEOTECHNIC PTY LTD

71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4896A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	29-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	05-Dec-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3115FC
Client sample number		GT02
Depth from (m)		84.37
Depth to (m)		84.66
Stratigraphic horizon		LL1 Floor
Orientation of core axis		Vertical
Lithological description		Sandstone
Mass of sample (g)		1058.0
Average sample diameter (mm)		60.7
Diameter variation > 0.3mm?		No
Average height (mm)		151
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2894
Uniaxial Comp. Strength (MPa)		**4.1**
Number of specimens in sample		1
Moisture content (%)		8.2
Density at as received moisture content (t/m^3)		2.421
Loading rate (N/min)		5000
Time to failure (min)		2.24
Max. applied load (kN)		11.9
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

NATA

Accredited No.	910
Certificate No.	11-4896A
Date of Issue	05-Dec-11

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Andrew Williams

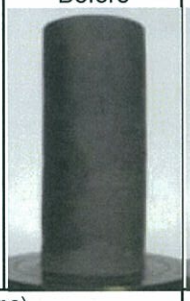
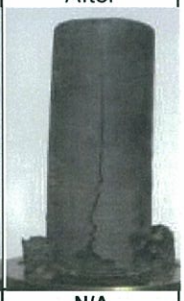
CARDNO ULLMAN & NOLAN GEOTECHNIC PTY LTD

71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4897A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	29-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	05-Dec-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3115FC
Client sample number		GT03
Depth from (m)		116.03
Depth to (m)		116.23
Stratigraphic horizon		LL2 Roof
Orientation of core axis		Vertical
Lithological description		XL
Mass of sample (g)		1084.4
Average sample diameter (mm)		60.8
Diameter variation > 0.3mm?		Yes
Average height (mm)		152
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2903
Uniaxial Comp. Strength (MPa)		**11.6**
Number of specimens in sample		1
Moisture content (%)		4.2
Density at as received moisture content (t/m^3)		2.457
Loading rate (N/min)		5000
Time to failure (min)		6.43
Max. applied load (kN)		33.6
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard:

Young's Modulus method: N/A

Poisson's Ratio method: N/A

NATA

Accredited No.	910
Certificate No.	11-4897A
Date of Issue	05-Dec-11

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Andrew Williams

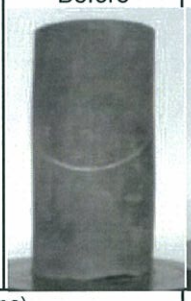
CARDNO ULLMAN & NOLAN GEOTECHNIC PTY LTD

71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4898A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	01-Dec-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	05-Dec-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3115FC
Client sample number		GT04
Depth from (m)		119.60
Depth to (m)		119.86
Stratigraphic horizon		LL2 Floor
Orientation of core axis		Vertical
Lithological description		Siltstone
Mass of sample (g)		967.4
Average sample diameter (mm)		60.7
Diameter variation > 0.3mm?		No
Average height (mm)		131
Length / Diameter ratio		2.2
Cross sectional area (mm^2)		2894
Uniaxial Comp. Strength (MPa)		**1.5**
Number of specimens in sample		1
Moisture content (%)		2.4
Density at as received moisture content (t/m^3)		2.552
Loading rate (N/min)		5000
Time to failure (min)		0.90
Max. applied load (kN)		4.4
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Had a natural crack along a lamination that was glued prior to test.
Height to diameter ratio less than 2.5 due to core structural features.
Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Certificate No.	11-4898A
Date of Issue	05-Dec-11

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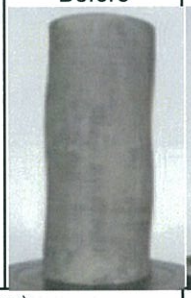
71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4899A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	30-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	05-Dec-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3115FC
Client sample number		GT05
Depth from (m)		153.21
Depth to (m)		153.48
Stratigraphic horizon		VU Roof
Orientation of core axis		Vertical
Lithological description		Siltstone
Mass of sample (g)		1131.0
Average sample diameter (mm)		60.6
Diameter variation > 0.3mm?		Yes
Average height (mm)		154
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2884
Uniaxial Comp. Strength (MPa)		**45.5**
Number of specimens in sample		1
Moisture content (%)		2.3
Density at as received moisture content (t/m^3)		2.546
Loading rate (N/min)		12500
Time to failure (min)		10.30
Max. applied load (kN)		131.1
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard:

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Certificate No. 11-4899A
Date of Issue 05-Dec-11

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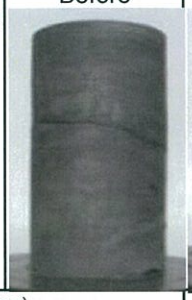
REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4900A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	30-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	05-Dec-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3115FC
Client sample number		GT06
Depth from (m)		161.94
Depth to (m)		162.26
Stratigraphic horizon		VU Floor
Orientation of core axis		Vertical
Lithological description		XL
Mass of sample (g)		783.4
Average sample diameter (mm)		60.9
Diameter variation > 0.3mm?		No
Average height (mm)		114
Length / Diameter ratio		1.9
Cross sectional area (mm^2)		2913
Uniaxial Comp. Strength (MPa)		**4.3**
Number of specimens in sample		1
Moisture content (%)		2.9
Density at as received moisture content (t/m^3)		2.359
Loading rate (N/min)		5000
Time to failure (min)		2.30
Max. applied load (kN)		12.6
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Had a natural crack along a lamination that was glued prior to test.
Height to diameter ratio less than 2.5 due to core structural features.
Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Certificate No.	11-4900A
Date of Issue	05-Dec-11

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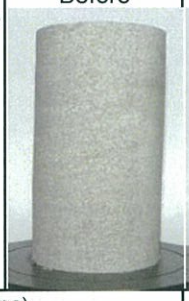
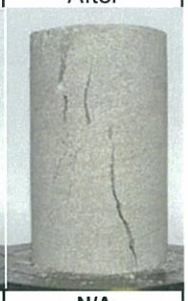
71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	12-0270A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	14-Jan-12
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	16-Jan-12
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3115FC
Client sample number		0958
Depth from (m)		169.50
Depth to (m)		169.72
Stratigraphic horizon		-
Orientation of core axis		Vertical
Lithological description		FR Sandstone
Mass of sample (g)		881.8
Average sample diameter (mm)		60.8
Diameter variation > 0.3mm?		No
Average height (mm)		117
Length / Diameter ratio		1.9
Cross sectional area (mm^2)		2903
Uniaxial Comp. Strength (MPa)		**65.7**
Number of specimens in sample		1
Moisture content (%)		1.6
Density at as received moisture content (t/m^3)		2.596
Loading rate (N/min)		25000
Time to failure (min)		7.37
Max. applied load (kN)		190.7
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Height to diameter ratio less than 2.5 due to core structural features.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

NATA

Accredited No.	910
Certificate No.	12-0270A
Date of Issue	16-Jan-12

This document is issued in accordance with NATA's accreditation requirements

Authorised Signatory

Andrew Williams

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(6/5/09)

CARDNO ULLMAN & NOLAN GEOTECHNIC PTY LTD

71 CONNORS ROAD MACKAY QLD

REPORT ON SLAKE DURABILITY TEST

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	Refer below
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	30/11/2011-14/1/12
TEST PROCEDURE:	AS 4133.3.4	**CHECKED BY:**	AW	**CHECK DATE:**	14-Jan-12

Lab Ref No	Borehole	Client Ref	Depth From (m)	Depth To (m)	Slake Durability Index (First Cycle) %	Slake Durability Index (Second Cycle) %	Appearance of Fragments Retained in the drum	Appearance of Fragments Passing the drum
11-4896B	CX3115FC	GT2	84.37	84.66	82.0	3.1	Rock lumps completely broken down, many small angular particles present	Large quantities of silty material present
11-4898B	CX3115FC	GT4	119.60	119.86	97.1	96.5	Rock lumps completely broken down, many small angular particles present	Gritty material present
11-4900B	CX3115FC	GT6	161.94	162.26	95.2	91.3	Rock lumps completely broken down, many small angular particles present	Large quantities of sandy/silty material present
12-0270B	CX3115FC	0958	169.50	169.72	97.1	96.8	Rock lumps still intact	Fine silt

Temperature of slaking fluid: 23 °C

Slaking fluid used: Potable

Variations from standard: Nil

Signature: Andrew Williams

Date: 14-Jan-12

CARDNO ULLMAN & NOLAN
GEOTECHNIC PTY LTD
71 CONNORS ROAD MACKAY QLD

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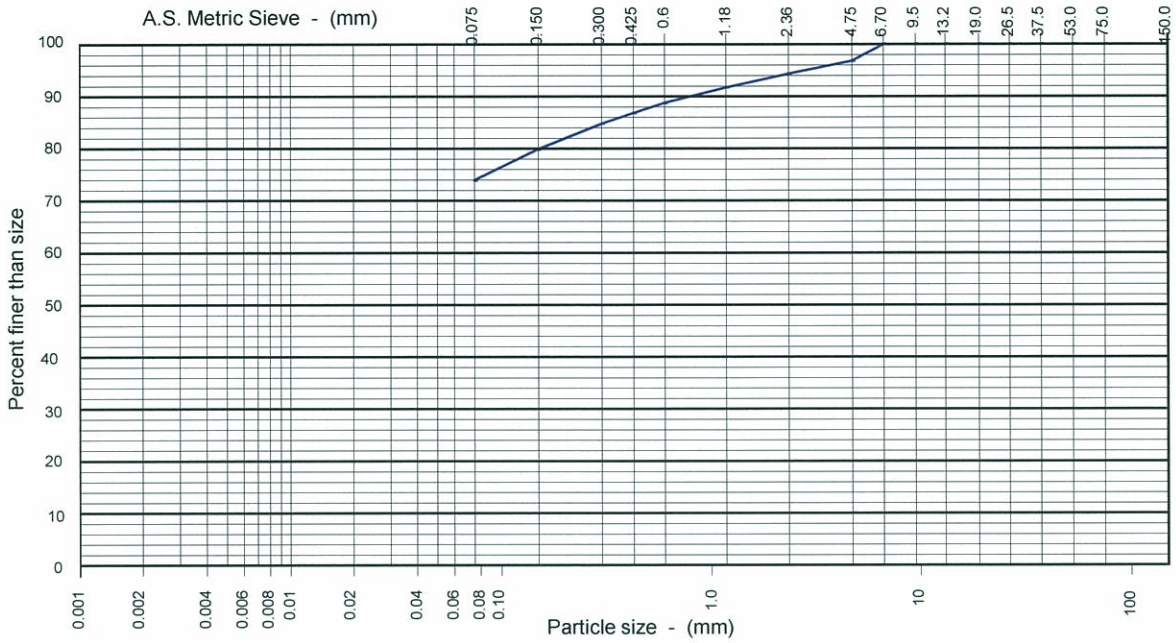
(-/10/10)

REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-5338ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 10.00-10.30m	**TESTED BY:**	TL, BS	**DATE:**	3-4.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	5.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1	**CLIENT REF:**	CX3115FC-933		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
74				8	7	5	4	2	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
150.0				44	14	30	15.0	-
75.0				Classification: **Sandy Clay;** sand is fine to coarse grained				
37.5								(CI)
19.0				Emerson Class No.: 4	Type of Water: Distilled			Temp. Of Water: 24ºC
9.5	100			Sampled in Accordance with AS 1289.1.2.1 (6.5.3)				
4.75	97							
2.36	94							
1.18	92							
0.600	89							
0.425	87							
0.300	85							
0.150	80							
0.075	74							

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No.	910
Certificate No.	11-5338A
Date of Issue	5.1.12

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Authorised Signatory ..... N. J. Richardson

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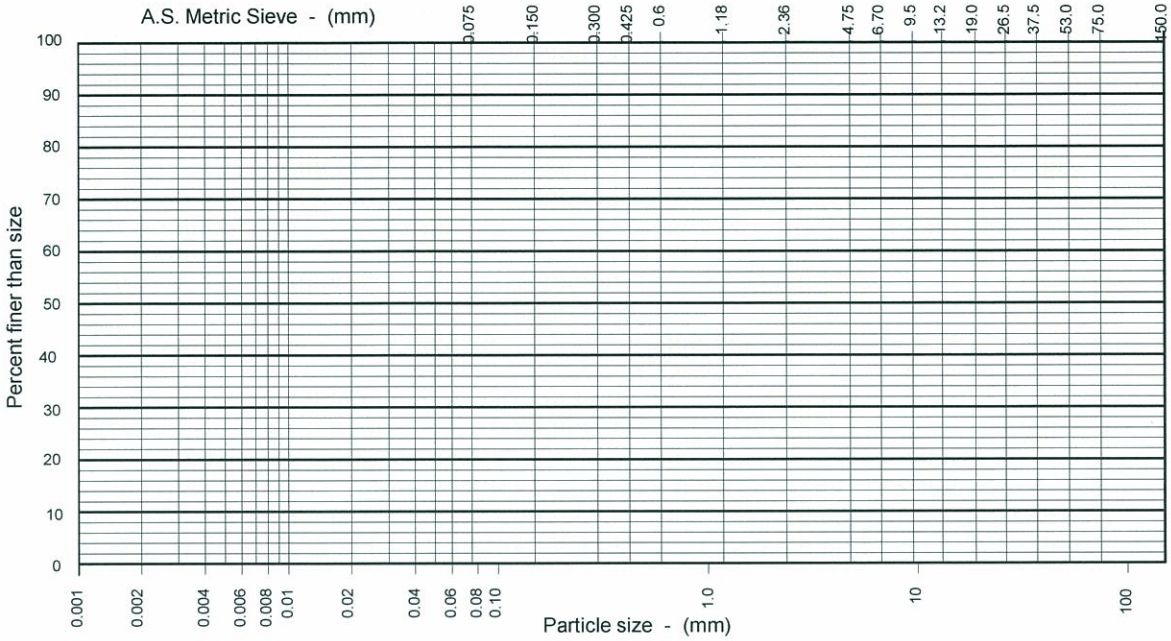
UNGR 1 G
(-/10/10)

REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-5339AB
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 15.00-15.68m	**TESTED BY:**	TL, BS	**DATE:**	3-4.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	5.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.8.1	**CLIENT REF:**	CX3115FC-935		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
150.0				46	15	31	15.5	-
75.0				Classification:				
37.5								
19.0				Emerson Class No.: 4	Type of Water: Distilled		Temp. Of Water: 24°C	
9.5				Sampled in Accordance with AS 1289.1.2.1 (6.5.4)				
4.75				Preparation History of Atterberg Limits				
2.36				Sample : ~~Natural~~/Air Dried/~~Oven~~				
1.18				Sieved: ~~Wet~~/dry				
0.600								
0.425				Linear Shrinkage Data				
0.300				Length of Mould (mm) : 250				
0.150				Sample: -				
0.075								

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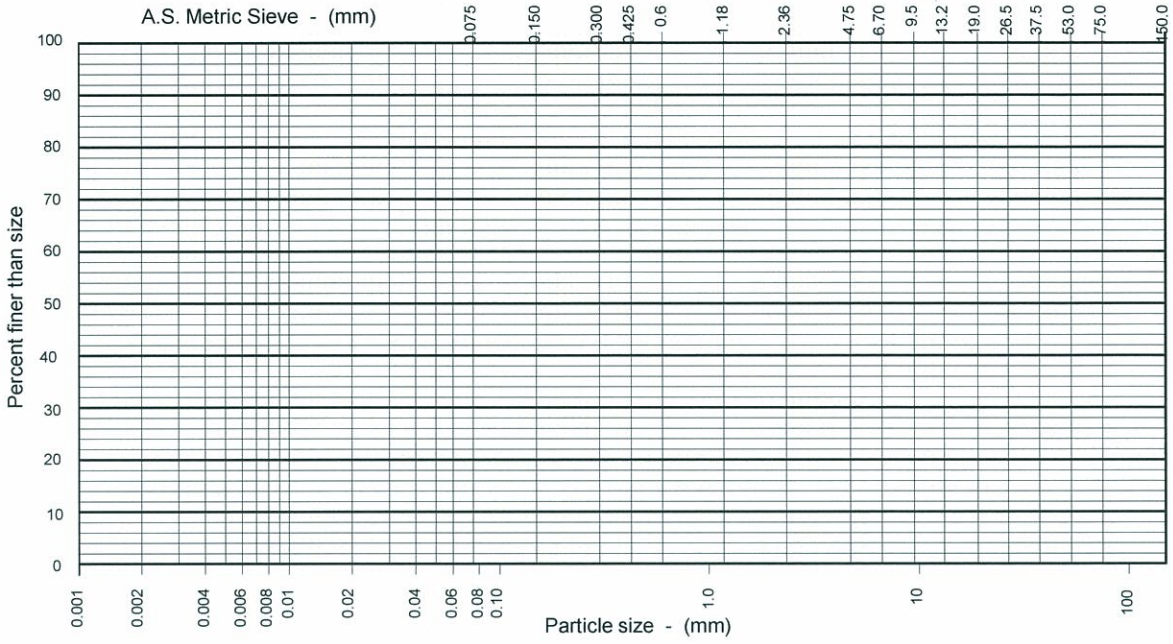
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-5340AB
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 55.00-55.20m	**TESTED BY:**	TL, BS	**DATE:**	3-5.1.12
MATERIAL:	Highly Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.8.1	**CLIENT REF:**	CX3115FC-947		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
150.0				44	19	25	12.0	-
75.0				Classification:				
37.5								
19.0				Emerson Class No.: 4	Type of Water: Distilled			Temp. Of Water: 24°C
9.5				Sampled in Accordance with AS 1289.1.2.1 (6.5.3)				
4.75								
2.36								
1.18								
0.600								
0.425								
0.300								
0.150								
0.075								

Preparation History of Atterberg Limits

Sample : ~~Natural~~/Air Dried/~~Oven~~

Sieved: ~~Wet~~/dry

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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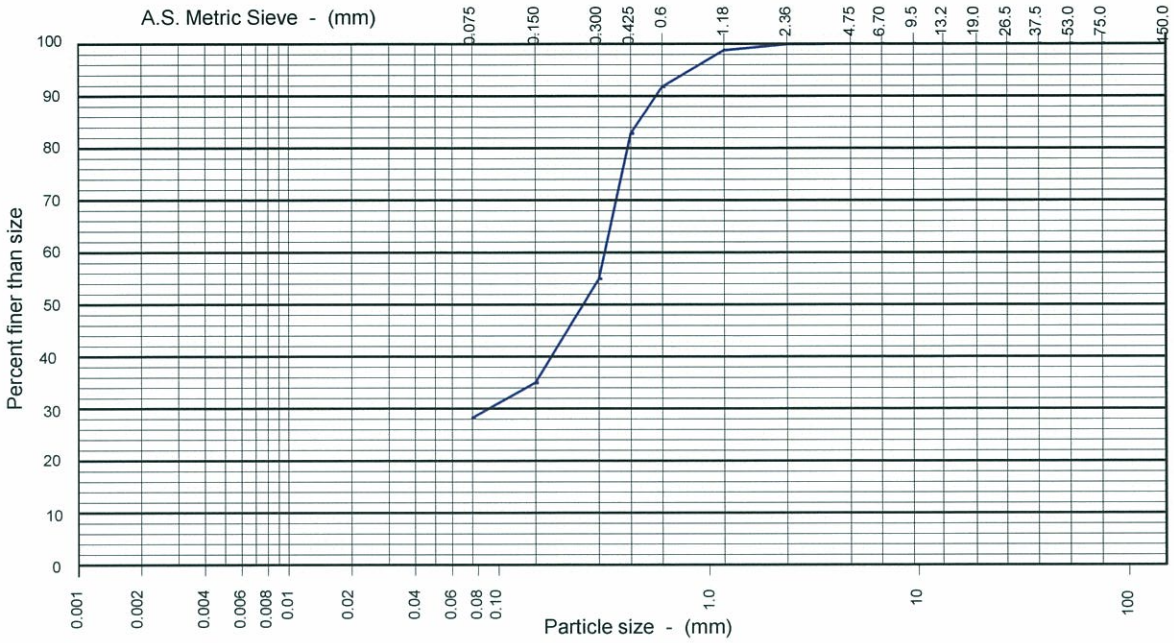
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-5341ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 69.19-69.39m	**TESTED BY:**	LH, BS	**DATE:**	3-5.1.12
MATERIAL:	Highly Weathered Sandstone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1	**CLIENT REF:**	CX3115FC-952		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
28				15	49	8	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
150.0				39	22	17	8.5	-
75.0				Classification: **Clayey Sand;** fine to coarse grained				
37.5								(CI)
19.0				Emerson Class No.: 4	Type of Water: Distilled			Temp. Of Water: 24°C
9.5				Sampled in Accordance with AS 1289.1.2.1 (6.5.3)				
4.75								
2.36	100							
1.18	99							
0.600	92							
0.425	83							
0.300	55							
0.150	35							
0.075	28							

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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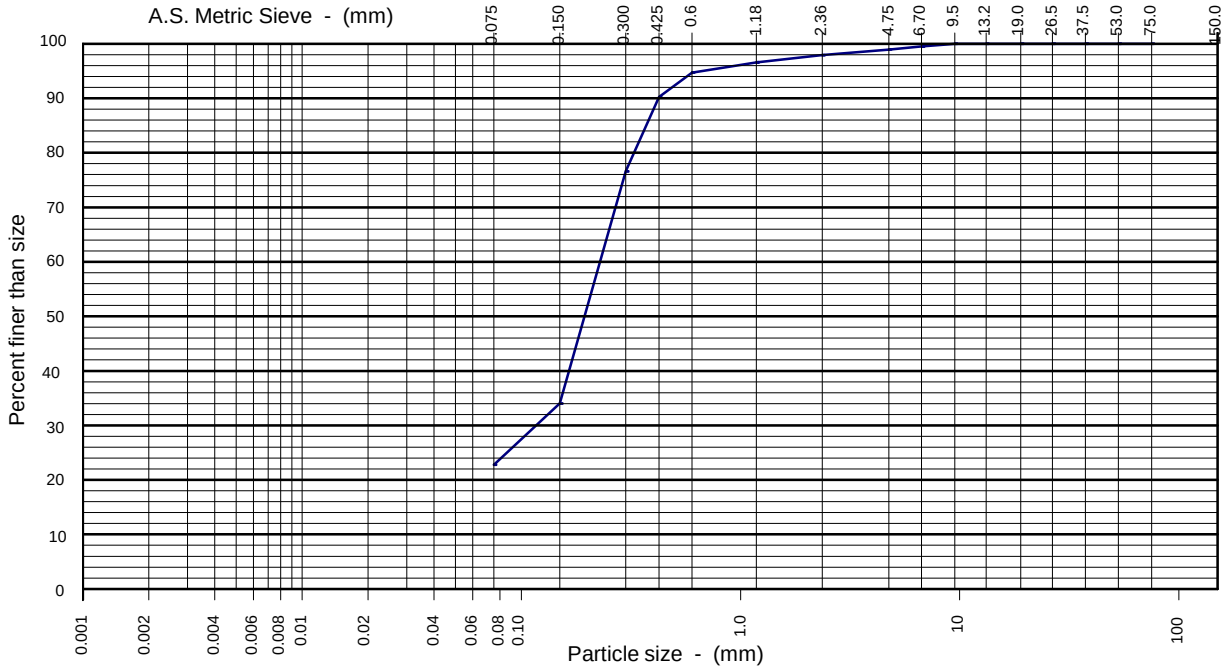
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-4346AB
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 10.00-10.20m	**TESTED BY:**	MW,LH	**DATE:**	2.11.11
MATERIAL:	XW Sandstone	**CHECKED BY:**	KR	**DATE:**	3.11.11
TEST PROCEDURES:	AS 1289.3.1.1, 3.2.1, 3.3.1, 3.4.1, 3.6.1	**CLIENT REF:**	CX3122FC-6221		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
23				29	43	3	1	1	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0	100		
9.5	100		
4.75	99		
2.36	98		
1.18	97		
0.600	95		
0.425	90		
0.300	77		
0.150	34		
0.075	23		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
26	18	8	2.5	-

Classification: **XW Sandstone;** fine to coarse grained

(SC)

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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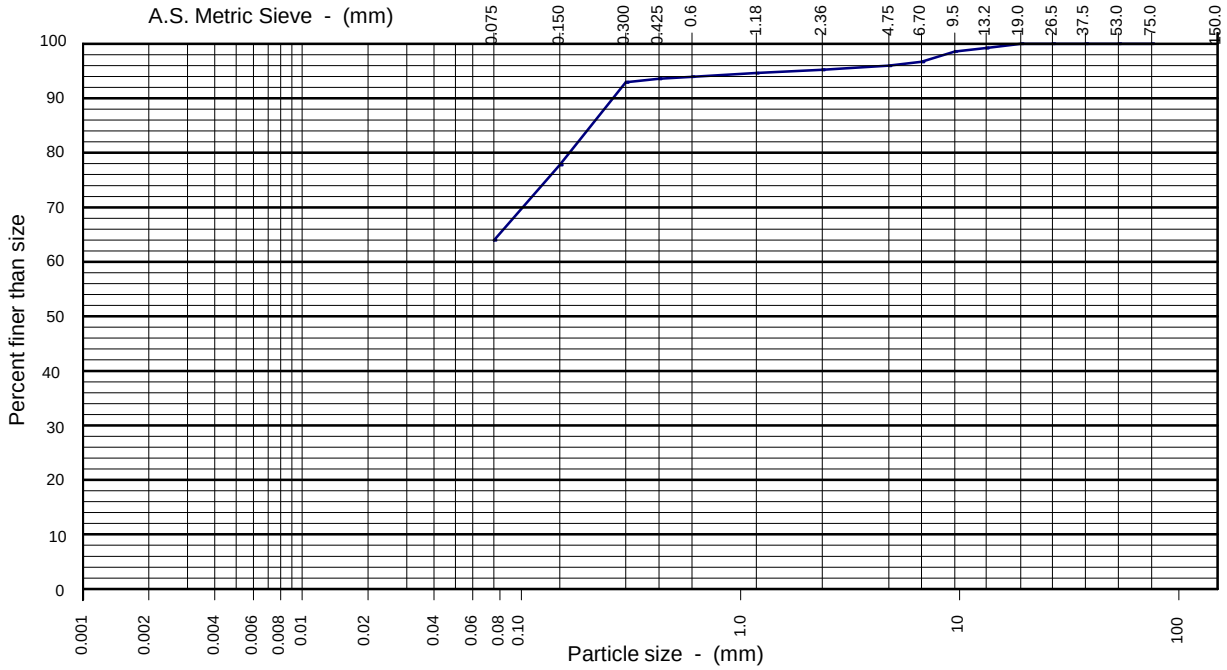
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	11-4348AB
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 24.24-24.44m	**TESTED BY:**	MW,LH	**DATE:**	3-8.11.11
MATERIAL:	HW Claystone	**CHECKED BY:**	KR	**DATE:**	9.11.11
TEST PROCEDURES:	AS 1289.3.1.1, 3.2.1, 3.3.1, 3.4.1, 3.6.1	**CLIENT REF:**	CX3122FC-6225		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
64				20	10	1	2	3	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0	100		
9.5	99		
4.75	96		
2.36	95		
1.18	95		
0.600	94		
0.425	94		
0.300	93		
0.150	78		
0.075	64		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
37	19	18	8.5	-

Classification: **HW Claystone;** sand is fine to coarse grained

(CI)

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 150

Sample: -

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Certificate No.	11-4348A
Date of Issue	9.11.11

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REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4469A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3122FC
Client sample number	GT01
Depth from (m)	78.04
Depth to (m)	78.84
Stratigraphic horizon	LU Roof
Orientation of core axis	Vertical
Lithological description	Siltstone
Mass of sample (g)	601.7
Average sample diameter (mm)	60.5
Diameter variation > 0.3mm?	Yes
Average height (mm)	89
Length / Diameter ratio	1.5
Cross sectional area (mm^2)	2875
Uniaxial Comp. Strength (MPa)	**1.1**
Number of specimens in sample	1
Moisture content (%)	10.2
Density at as received moisture content (t/m^3)	2.352
Loading rate (N/min)	1250
Time to failure (min)	2.32
Max. applied load (kN)	3.1
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Height to diameter ratio less than 2.5 due to core structural features.
Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Certificate No.	11-4469A
Date of Issue	14-Nov-11

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REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4470A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3122FC
Client sample number		GT02
Depth from (m)		80.69
Depth to (m)		80.99
Stratigraphic horizon		LU Floor
Orientation of core axis		Vertical
Lithological description		Siltstone
Mass of sample (g)		954.4
Average sample diameter (mm)		60.4
Diameter variation > 0.3mm?		Yes
Average height (mm)		151
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2865
Uniaxial Comp. Strength (MPa)		**1.7**
Number of specimens in sample		1
Moisture content (%)		13.1
Density at as received moisture content (t/m^3)		2.206
Loading rate (N/min)		1250
Time to failure (min)		3.48
Max. applied load (kN)		4.8
Dominant structural features with respect to core axis	Before	After
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4471A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3122FC
Client sample number	GT03
Depth from (m)	99.13
Depth to (m)	99.40
Stratigraphic horizon	LL1 Roof
Orientation of core axis	Vertical
Lithological description	Sandstone
Mass of sample (g)	1130.7
Average sample diameter (mm)	60.8
Diameter variation > 0.3mm?	No
Average height (mm)	153
Length / Diameter ratio	2.5
Cross sectional area (mm^2)	2903
Uniaxial Comp. Strength (MPa)	**13.0**
Number of specimens in sample	1
Moisture content (%)	3.6
Density at as received moisture content (t/m^3)	2.545
Loading rate (N/min)	5000
Time to failure (min)	7.32
Max. applied load (kN)	37.7
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard:

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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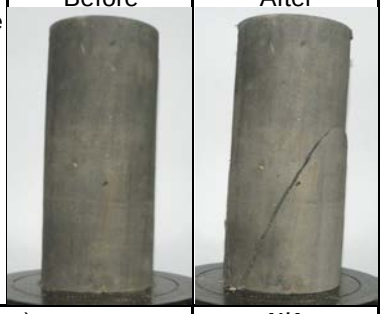
REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4472A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3122FC
Client sample number	GT04
Depth from (m)	101.57
Depth to (m)	101.87
Stratigraphic horizon	LL1 Floor
Orientation of core axis	Vertical
Lithological description	Sandstone
Mass of sample (g)	1104.2
Average sample diameter (mm)	60.8
Diameter variation > 0.3mm?	No
Average height (mm)	152
Length / Diameter ratio	2.5
Cross sectional area (mm^2)	2903
Uniaxial Comp. Strength (MPa)	**6.4**
Number of specimens in sample	1
Moisture content (%)	4.0
Density at as received moisture content (t/m^3)	2.502
Loading rate (N/min)	5000
Time to failure (min)	3.43
Max. applied load (kN)	18.6
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	



Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4473A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3122FC
Client sample number	GT05
Depth from (m)	136.87
Depth to (m)	137.18
Stratigraphic horizon	LL2 Roof
Orientation of core axis	Vertical
Lithological description	Siltstone/ Mudstone
Mass of sample (g)	1080.9
Average sample diameter (mm)	60.6
Diameter variation > 0.3mm?	No
Average height (mm)	149
Length / Diameter ratio	2.5
Cross sectional area (mm^2)	2884
Uniaxial Comp. Strength (MPa)	**9.9**
Number of specimens in sample	1
Moisture content (%)	3.3
Density at as received moisture content (t/m^3)	2.515
Loading rate (N/min)	2500
Time to failure (min)	11.36
Max. applied load (kN)	28.4
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard:

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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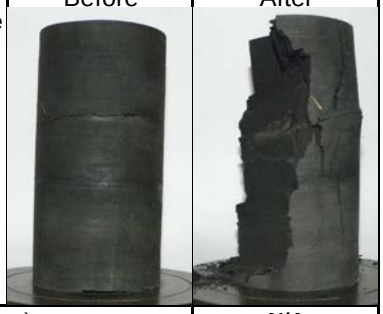
REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4474A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3122FC
Client sample number	GT06
Depth from (m)	142.59
Depth to (m)	142.85
Stratigraphic horizon	LL2 Floor
Orientation of core axis	Vertical
Lithological description	Siltstone
Mass of sample (g)	897.1
Average sample diameter (mm)	60.8
Diameter variation > 0.3mm?	No
Average height (mm)	130
Length / Diameter ratio	2.1
Cross sectional area (mm^2)	2903
Uniaxial Comp. Strength (MPa)	**2.9**
Number of specimens in sample	1
Moisture content (%)	6.1
Density at as received moisture content (t/m^3)	2.377
Loading rate (N/min)	2500
Time to failure (min)	3.24
Max. applied load (kN)	8.5
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	



Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Had a natural crack along a lamination that was glued prior to test.
Height to diameter ratio less than 2.5 due to core structural features.
Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4475A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3122FC
Client sample number	GT07
Depth from (m)	165.73
Depth to (m)	165.96
Stratigraphic horizon	VU Roof
Orientation of core axis	Vertical
Lithological description	Siltstone
Mass of sample (g)	1086.5
Average sample diameter (mm)	60.6
Diameter variation > 0.3mm?	No
Average height (mm)	149
Length / Diameter ratio	2.5
Cross sectional area (mm^2)	2884
Uniaxial Comp. Strength (MPa)	**14.4**
Number of specimens in sample	1
Moisture content (%)	2.6
Density at as received moisture content (t/m^3)	2.528
Loading rate (N/min)	5000
Time to failure (min)	8.18
Max. applied load (kN)	41.5
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard:

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Certificate No.	11-4475A
Date of Issue	14-Nov-11

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Andrew Williams

CARDNO ULLMAN & NOLAN GEOTECHNIC PTY LTD

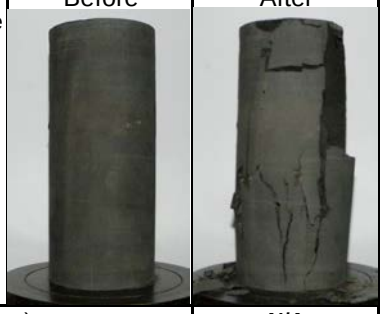
71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4476A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	07-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.	CX3122FC
Client sample number	GT08
Depth from (m)	175.00
Depth to (m)	175.27
Stratigraphic horizon	VU Floor
Orientation of core axis	Vertical
Lithological description	Siltstone
Mass of sample (g)	1094.9
Average sample diameter (mm)	60.6
Diameter variation > 0.3mm?	No
Average height (mm)	153
Length / Diameter ratio	2.5
Cross sectional area (mm^2)	2884
Uniaxial Comp. Strength (MPa)	**16.5**
Number of specimens in sample	1
Moisture content (%)	3.9
Density at as received moisture content (t/m^3)	2.481
Loading rate (N/min)	5000
Time to failure (min)	9.30
Max. applied load (kN)	47.5
Dominant structural features with respect to core axis	Before / After
Secant Young's Modulus (Gpa)	**N/A**
Corrected Poisson's Ratio	**N/A**
Remarks	



Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard:

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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REPORT ON SLAKE DURABILITY TEST

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	Refer below
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	08-Nov-11
TEST PROCEDURE:	AS 4133.3.4	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11

Lab Ref No	Borehole	Client Ref	Depth From (m)	Depth To (m)	Slake Durability Index (First Cycle) %	Slake Durability Index (Second Cycle) %	Appearance of Fragments Retained in the drum	Appearance of Fragments Passing the drum
11-4470B	CX3122FC	GT02	80.69	80.99	61.4	3.5	Rock lumps completely broken down, many small angular particles present	Fine silt
11-4472B	CX3122FC	GT04	101.57	101.87	94.3	92.5	Rock lumps still intact	Fine silt
11-4474B	CX3122FC	GT06	142.59	142.85	91.6	44.7	Rock lumps completely broken down, many small angular particles present	Large quantities of angular, flaky material present
11-4476B	CX3122FC	GT08	175.00	175.27	94.6	86.1	Rock lumps broken down, many small angular particles present	Gritty material present

Temperature of slaking fluid: 23 °C

Slaking fluid used: Potable

Variations from standard: Nil

Signature: _____ Date: 14-Nov-11

Andrew Williams

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71 CONNORS ROAD MACKAY QLD

REPORT ON EMERSON CLASS NUMBER OF A SOIL

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	Refer below
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	LH	**TEST DATE:**	01-Nov-11
TEST PROGRAM:	Emerson Class program	**CHECKED BY:**	CC	**CHECK DATE:**	07-Nov-11
TEST PROCEDURES:	AS 4133.3.8.1				

Borehole.: CX3122FC Sample ID.: 6224

Lab Ref No.: 11-4347A From: 21.00 To: 21.24

Stratigraphic Location:

Soil Description: HW Claystone

Type of Water Used: Distilled

Temperature of Water: 23 °C

Emersion Class Number: 4

Variation to standard: Nil

Borehole.: CX3122FC Sample ID.: 6239

Lab Ref No.: 11-4349A From: 69.04 To: 69.24

Stratigraphic Location:

Soil Description: MW Siltstone

Type of Water Used: Distilled

Temperature of Water: 23 °C

Emersion Class Number: 7

Variation to standard: Nil

Borehole.: Sample ID.:

Lab Ref No.: From: To:

Stratigraphic Location:

Soil Description:

Type of Water Used:

Temperature of Water: °C

Emersion Class Number:

Variation to standard:

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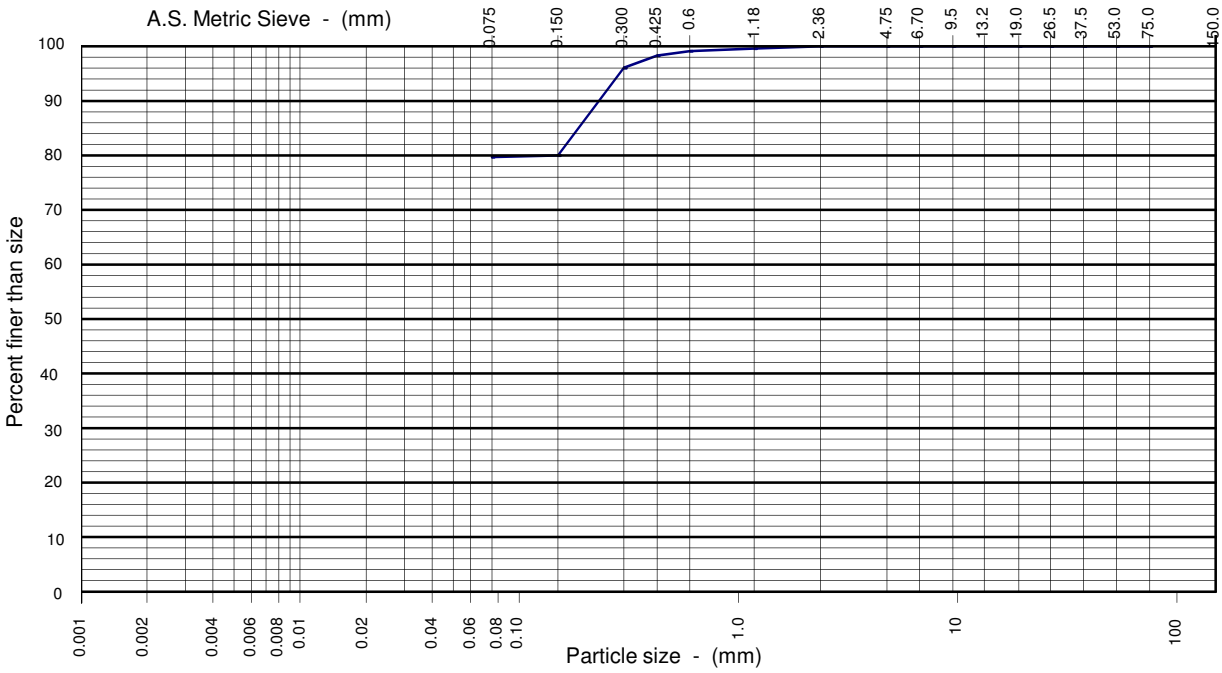
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	12-0012ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 10.30-10.50m	**TESTED BY:**	TL, AR	**DATE:**	5-6.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1	**CLIENT REF:**	CX3127FC-6257		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
80				7	12	1	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
150.0				44	13	31	14.5	-
75.0				Classification: **Sandy Clay;** sand is fine to coarse grained				
37.5								(CI)
19.0								
9.5				Sampled in Accordance with AS 1289.1.2.1 (6.5.3)				
4.75				Preparation History of Atterberg Limits				
2.36				Sample : ~~Natural/Air Dried/Oven~~				
1.18	100			Sieved: ~~Wet/dry~~				
0.600	99							
0.425	98			Linear Shrinkage Data				
0.300	96			Length of Mould (mm) : 250				
0.150	80			Sample: -				
0.075	80							

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REPORT ON EMERSON CLASS NUMBER OF A SOIL

Sheet 1 of 1 Mackay Laboratory

CLIENT:	Macarthur Coal(C.M Management)	**JOB NO.:**	U23209	**LAB REF NO.:**	12-0013A
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC676, Depth 15.14-15.42m	**TESTED BY:**	BS	**DATE:**	4.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	4.1.12
TEST PROCEDURES:	AS 1289.3.8.1	**CLIENT REF:**	CX3127FC-6258		

Soil Description: Extremely Weathered Claystone

Type of Water Used: Distilled

Temperature of Water: 24 °C

Emerson Class Number: 4

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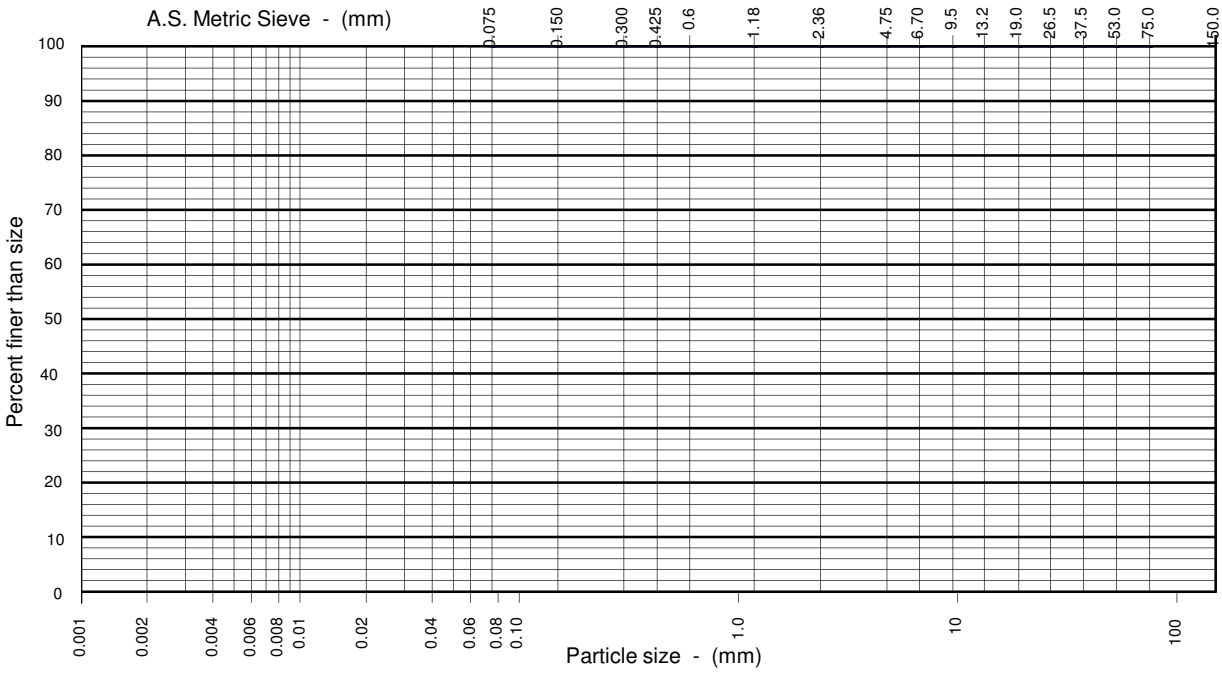
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	12-0014A
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 36.04-36.24m	**TESTED BY:**	TL	**DATE:**	5.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1	**CLIENT REF:**	CX3127FC-6264		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
150.0				56	24	32	14.0	-
75.0				Classification:				
37.5								
19.0								
9.5				Sampled in Accordance with AS 1289.1.2.1 (6.5.3)				
4.75								
2.36								
1.18								
0.600								
0.425								
0.300								
0.150								
0.075								

Preparation History of Atterberg Limits

Sample : ~~Natural~~/Air Dried/~~Oven~~

Sieved: ~~Wet~~/dry

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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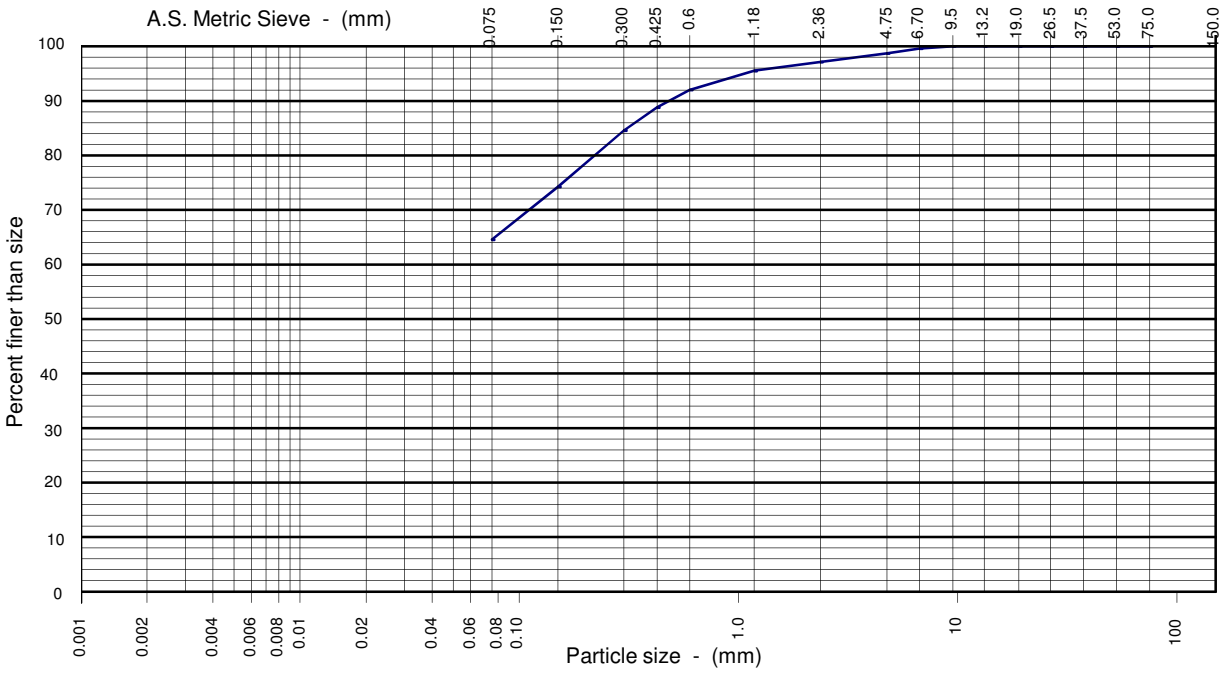
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	12-0015ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 44.63-44.85m	**TESTED BY:**	TL, BS	**DATE:**	4-6.1.12
MATERIAL:	Highly Weathered Siltstone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1	**CLIENT REF:**	CX3127FC-6267		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
65				14	13	5	2	1	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5	100		
4.75	99		
2.36	97		
1.18	96		
0.600	92		
0.425	89		
0.300	85		
0.150	74		
0.075	65		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
65	28	37	19.0	-

Classification: **Sandy Clay;** sand is fine to coarse grained

(CH)

Emerson Class No.: 4 Type of Water: Distilled Temp. Of Water: 24ºC

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

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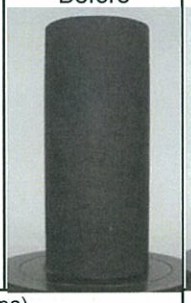
71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4481A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	05-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3127FC
Client sample number		GT01
Depth from (m)		72.64
Depth to (m)		72.98
Stratigraphic horizon		VU Roof
Orientation of core axis		Vertical
Lithological description		XL
Mass of sample (g)		1013.5
Average sample diameter (mm)		60.5
Diameter variation > 0.3mm?		No
Average height (mm)		152
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2875
Uniaxial Comp. Strength (MPa)		**2.2**
Number of specimens in sample		1
Moisture content (%)		9.8
Density at as received moisture content (t/m^3)		2.319
Loading rate (N/min)		2500
Time to failure (min)		2.32
Max. applied load (kN)		6.3
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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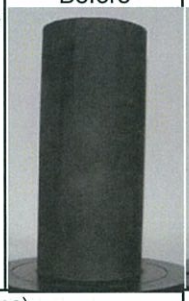
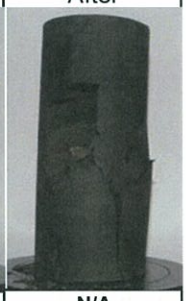
REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	11-4482A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	05-Nov-11
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	14-Nov-11
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3127FC
Client sample number		GT02
Depth from (m)		82.42
Depth to (m)		82.71
Stratigraphic horizon		VU Floor
Orientation of core axis		Vertical
Lithological description		XM
Mass of sample (g)		977.6
Average sample diameter (mm)		60.2
Diameter variation > 0.3mm?		No
Average height (mm)		151
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2846
Uniaxial Comp. Strength (MPa)		**2.2**
Number of specimens in sample		1
Moisture content (%)		10.8
Density at as received moisture content (t/m^3)		2.275
Loading rate (N/min)		2500
Time to failure (min)		2.32
Max. applied load (kN)		6.4
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Date of Issue	14-Nov-11

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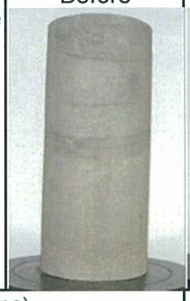
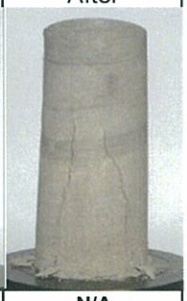
71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	12-0016A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	14-Jan-12
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	16-Jan-12
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3127FC
Client sample number		6294
Depth from (m)		84.93
Depth to (m)		85.15
Stratigraphic horizon		-
Orientation of core axis		Vertical
Lithological description		FR Sandstone
Mass of sample (g)		1080.7
Average sample diameter (mm)		60.2
Diameter variation > 0.3mm?		Yes
Average height (mm)		151
Length / Diameter ratio		2.5
Cross sectional area (mm^2)		2846
Uniaxial Comp. Strength (MPa)		**18.9**
Number of specimens in sample		1
Moisture content (%)		3.0
Density at as received moisture content (t/m^3)		2.514
Loading rate (N/min)		12500
Time to failure (min)		4.18
Max. applied load (kN)		53.7
Dominant structural features with respect to core axis	Before	After
		
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Time to failure less than standard 5 to 15 minutes.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Date of Issue	16-Jan-12

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71 CONNORS ROAD MACKAY QLD

REPORT ON STRENGTH (UCS) TEST FOR ROCK MATERIALS

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	12-0017A
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	14-Jan-12
TEST PROGRAM:	UCS Testing program	**CHECKED BY:**	AW	**CHECK DATE:**	16-Jan-12
TEST PROCEDURES:	Q186 AS 4133.1.1.1				

Borehole No.		CX3127FC
Client sample number		6295
Depth from (m)		99.00
Depth to (m)		99.21
Stratigraphic horizon		-
Orientation of core axis		Vertical
Lithological description		FR Sandstone
Mass of sample (g)		650.7
Average sample diameter (mm)		60.6
Diameter variation > 0.3mm?		No
Average height (mm)		89
Length / Diameter ratio		1.5
Cross sectional area (mm^2)		2884
Uniaxial Comp. Strength (MPa)		**22.7**
Number of specimens in sample		1
Moisture content (%)		1.8
Density at as received moisture content (t/m^3)		2.535
Loading rate (N/min)		12500
Time to failure (min)		5.14
Max. applied load (kN)		65.5
Dominant structural features with respect to core axis	Before	After
Secant Young's Modulus (Gpa)		**N/A**
Corrected Poisson's Ratio		**N/A**
Remarks		

Storage History of specimens: Supplied by client, sealed. Stored at room temperature and humidity and tested at as received moisture content.

Compression machine: Shimadzu U.E.H. -50 S/N 79097

Variations from standard: Height to diameter ratio less than 2.5 due to core structural features.

Young's Modulus method: N/A

Poisson's Ratio method: N/A

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Date of Issue	16-Jan-12

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Authorised Signatory

Andrew Williams

UNGR 18 Ga
(6/5/09)

CARDNO ULLMAN & NOLAN GEOTECHNIC PTY LTD

71 CONNORS ROAD MACKAY QLD

REPORT ON SLAKE DURABILITY TEST

Mackay Laboratory

CLIENT:	Macarthur Coal (C&M Management) Pty Ltd	**JOB NO.:**	U23142	**LAB REF NO:**	Refer below
PROJECT:	Codrilla	**SAMPLED BY:**	Client	**SAMPLE DATE:**	Not supplied
LOCATION:	EPC676	**TESTED BY:**	RD	**TEST DATE:**	5/11/2011-14/1/12
TEST PROCEDURE:	AS 4133.3.4	**CHECKED BY:**	AW	**CHECK DATE:**	14-Jan-12

Lab Ref No	Borehole	Client Ref	Depth From (m)	Depth To (m)	Slake Durability Index (First Cycle) %	Slake Durability Index (Second Cycle) %	Appearance of Fragments Retained in the drum	Appearance of Fragments Passing the drum
11-4482B	CX3127FC	GT02	82.42	82.71	87.3	11.2	Rock lumps completely broken down, many small angular particles present	Large quantities of angular, flaky material present
12-0017B	CX3127FC	6295	99.00	99.21	96.3	95.4	Rock lumps still intact	Fine silt

Temperature of slaking fluid: 23 °C

Slaking fluid used: Potable

Variations from standard: Nil

Signature: _____ Andrew Williams

Date: 14-Jan-12

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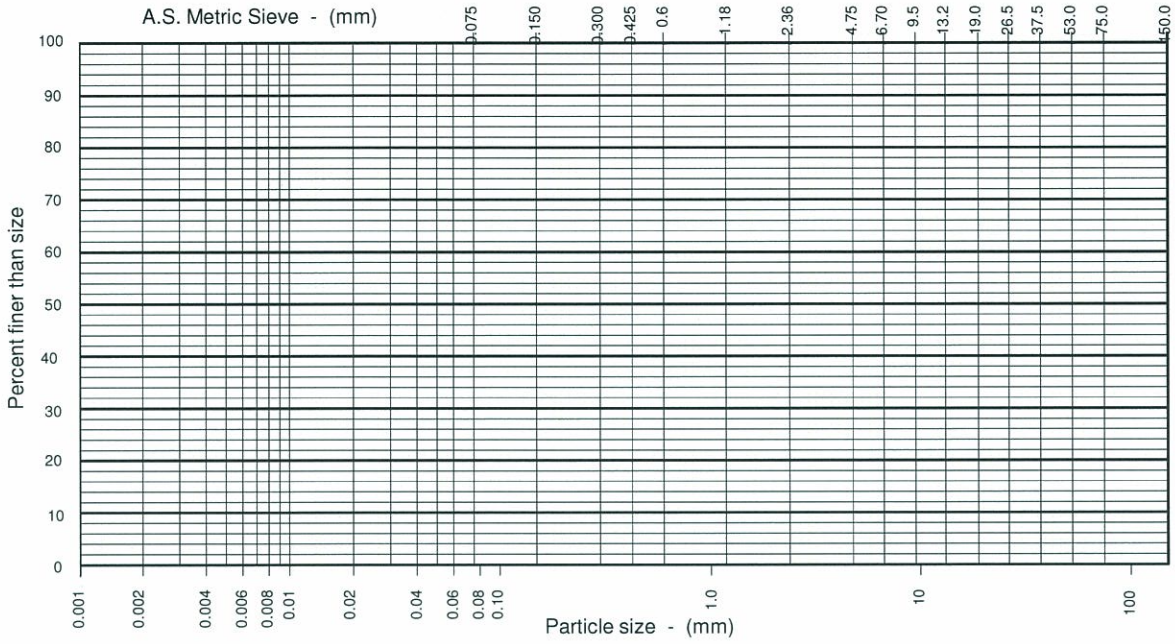
UNGR 1 G
(-/10/10)

REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	12-0014A
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 36.04-36.24m	**TESTED BY:**	TL	**DATE:**	5.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1	**CLIENT REF:**	CX3127FC-6264		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5			
4.75			
2.36			
1.18			
0.600			
0.425			
0.300			
0.150			
0.075			

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
56	24	32	14.0	-

Classification:

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural~~/Air Dried/~~Oven~~

Sieved: ~~Wet~~/dry

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No.	910
Certificate No.	12-0014A
Date of Issue	6.1.12

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(10/10)

REPORT ON EMERSON CLASS NUMBER OF A SOIL

Sheet 1 of 1 | Mackay Laboratory

CLIENT:	Macarthur Coal(C.M Management)	**JOB NO.:**	U23209	**LAB REF NO.:**	12-0013A
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC676, Depth 15.14-15.42m	**TESTED BY:**	BS	**DATE:**	4.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	4.1.12
TEST PROCEDURES:	AS 1289.3.8.1	**CLIENT REF:**	CX3127FC-6258		

Soil Description: Extremely Weathered Claystone

Type of Water Used: Distilled

Temperature of Water: 24 °C

Emerson Class Number: 4

NATA

Accredited No. .910

Certificate No. 12-0013A

Date of Issue 4.1.12

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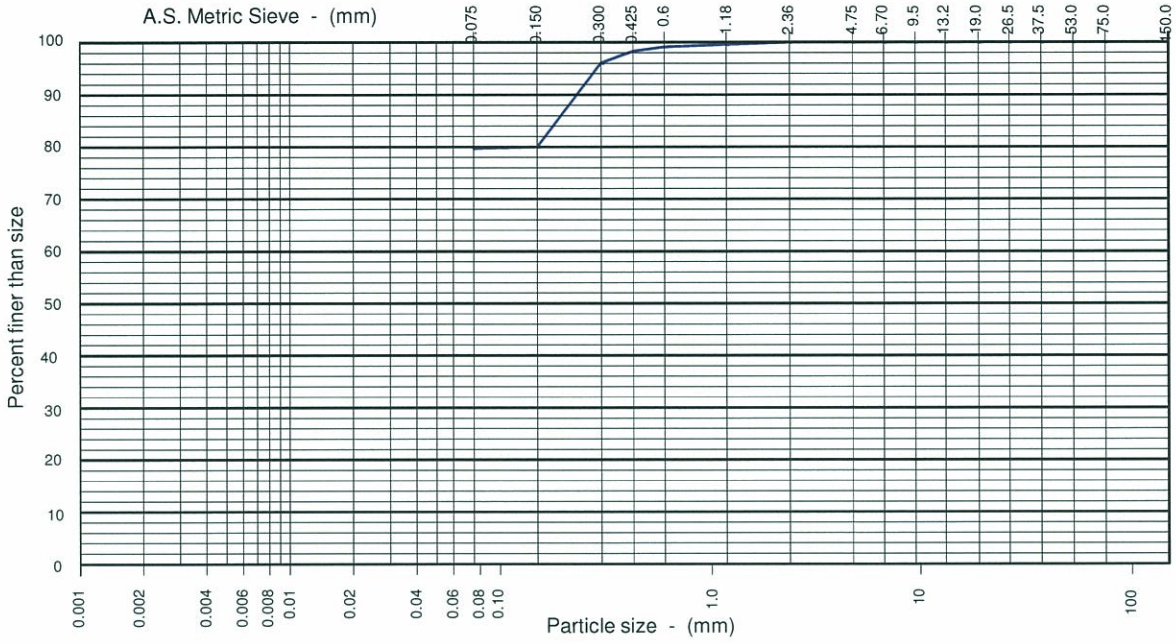
REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	12-0012ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 10.30-10.50m	**TESTED BY:**	TL, AR	**DATE:**	5-6.1.12
MATERIAL:	Extremely Weathered Claystone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1	**CLIENT REF:**	CX3127FC-6257		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
80				7	12	1	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5			
4.75			
2.36			
1.18	100		
0.600	99		
0.425	98		
0.300	96		
0.150	80		
0.075	80		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
44	13	31	14.5	-

Classification: **Sandy Clay;** sand is fine to coarse grained

(CI)

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No.	910
Certificate No.	12-0012A
Date of Issue	6.1.12

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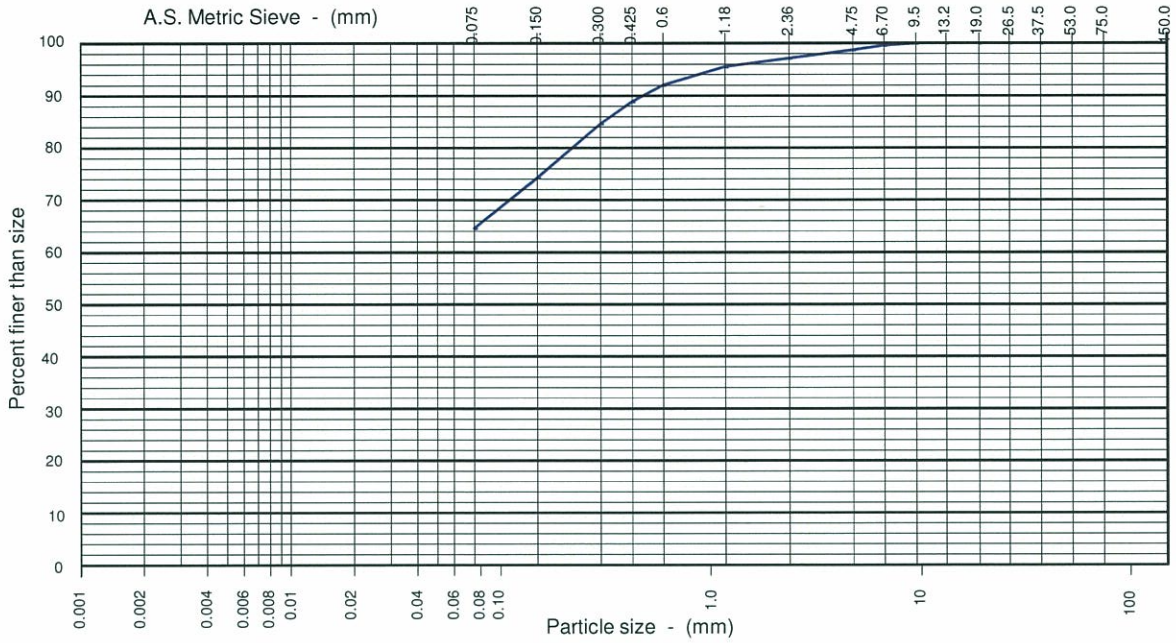
(-/10/10)

REPORT ON SOIL CLASSIFICATION

Mackay Laboratory

CLIENT:	Macarthur Coal (C.M Management)	**JOB NO:**	U23142	**LAB REF NO:**	12-0015ABC
PROJECT:	Codrilla	**SAMPLED BY:**	CLIENT	**DATE:**	Not Supplied
LOCATION:	EPC 676, Depth 44.63-44.85m	**TESTED BY:**	TL, BS	**DATE:**	4-6.1.12
MATERIAL:	Highly Weathered Siltstone	**CHECKED BY:**	CC	**DATE:**	6.1.12
TEST PROCEDURES:	AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1	**CLIENT REF:**	CX3127FC-6267		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
65				14	13	5	2	1	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5	100		
4.75	99		
2.36	97		
1.18	96		
0.600	92		
0.425	89		
0.300	85		
0.150	74		
0.075	65		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
65	28	37	19.0	-

Classification: **Sandy Clay;** sand is fine to coarse grained

(CH)

Emerson Class No.: 4 Type of Water: Distilled Temp. Of Water: 24°C

Sampled in Accordance with AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural/Air Dried/Oven~~

Sieved: ~~Wet/dry~~

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No.	910
Certificate No.	12-0015A
Date of Issue	6.1.12

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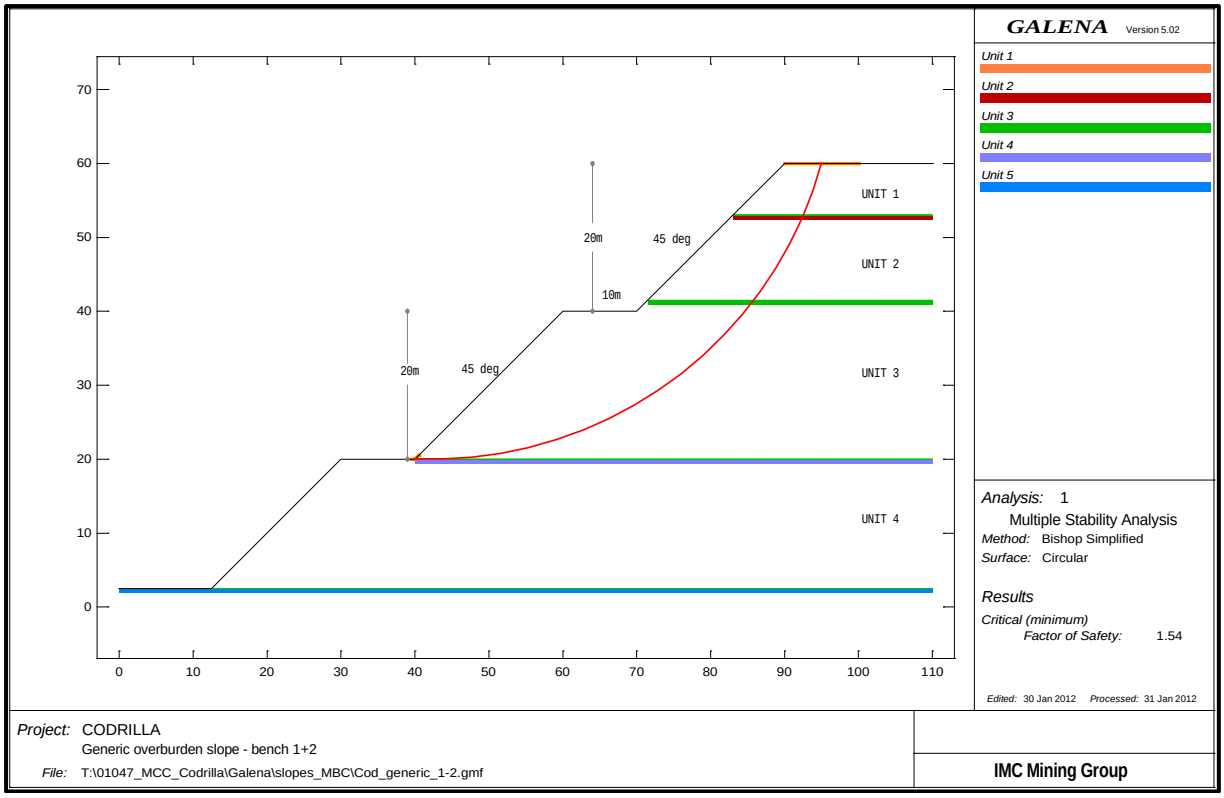
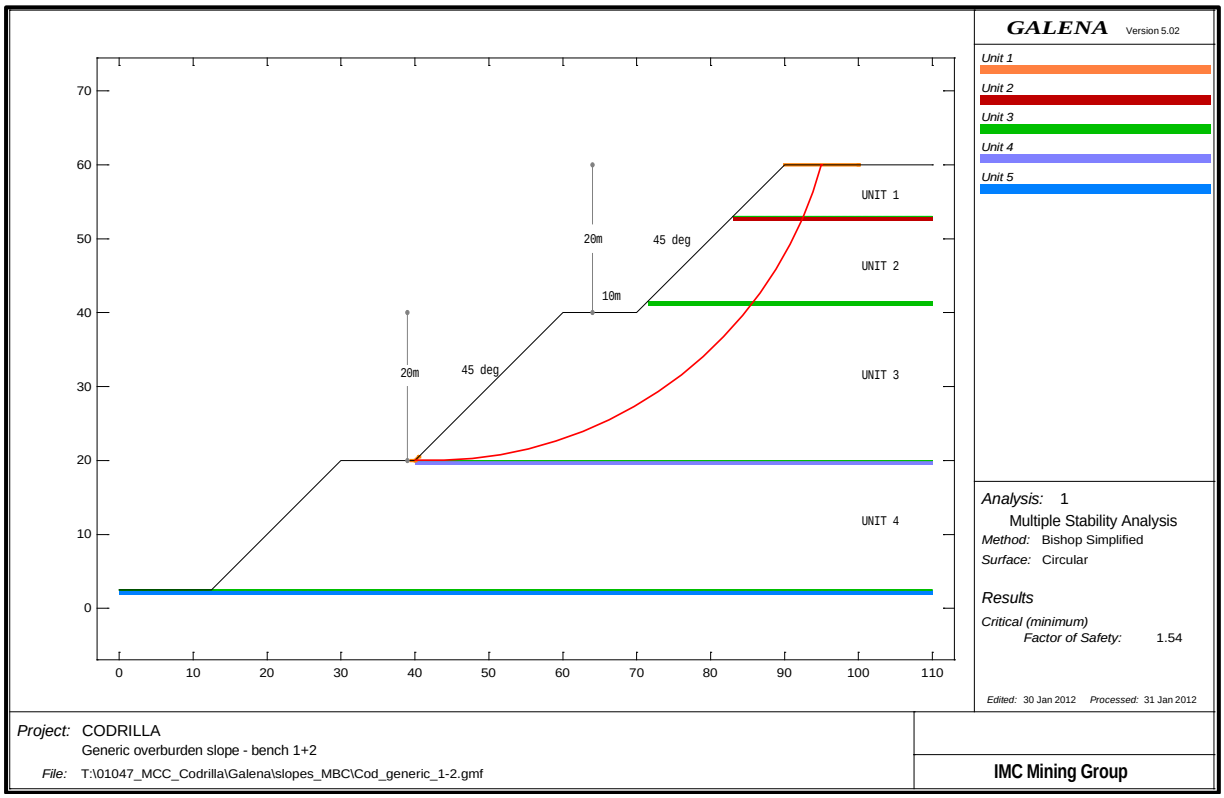
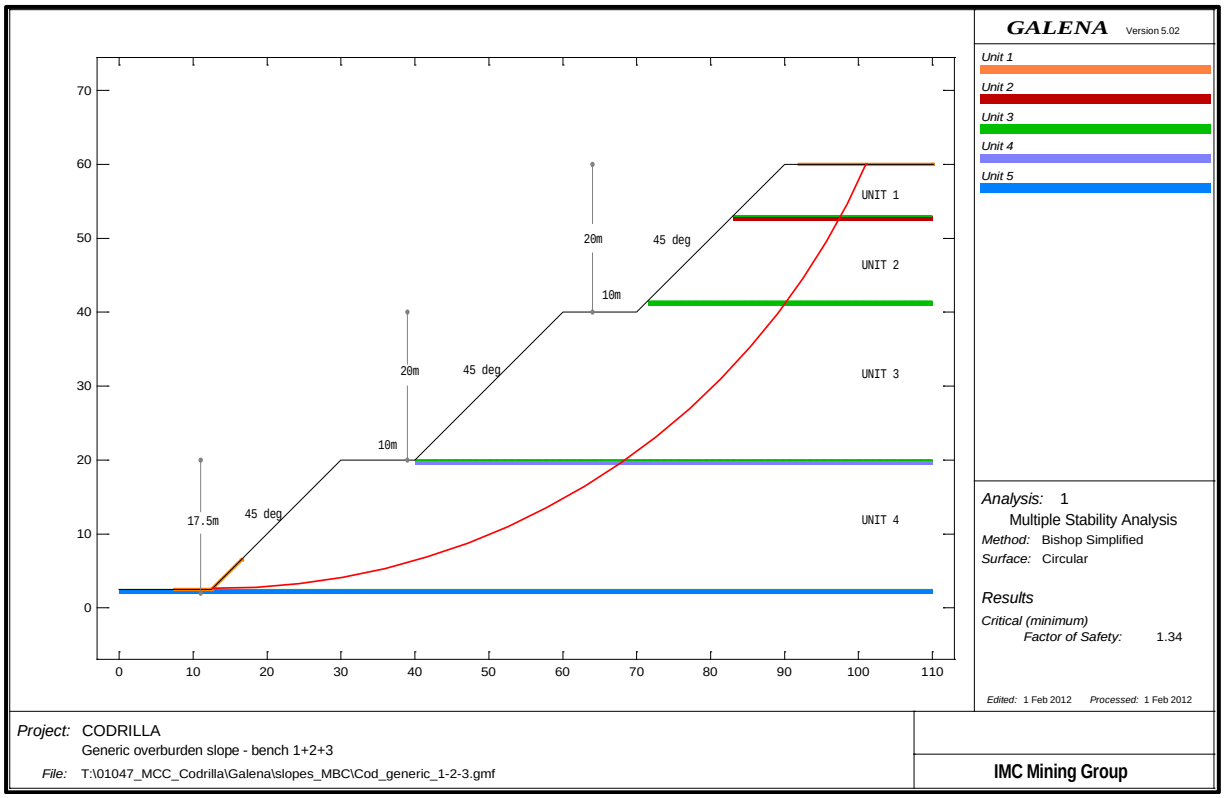
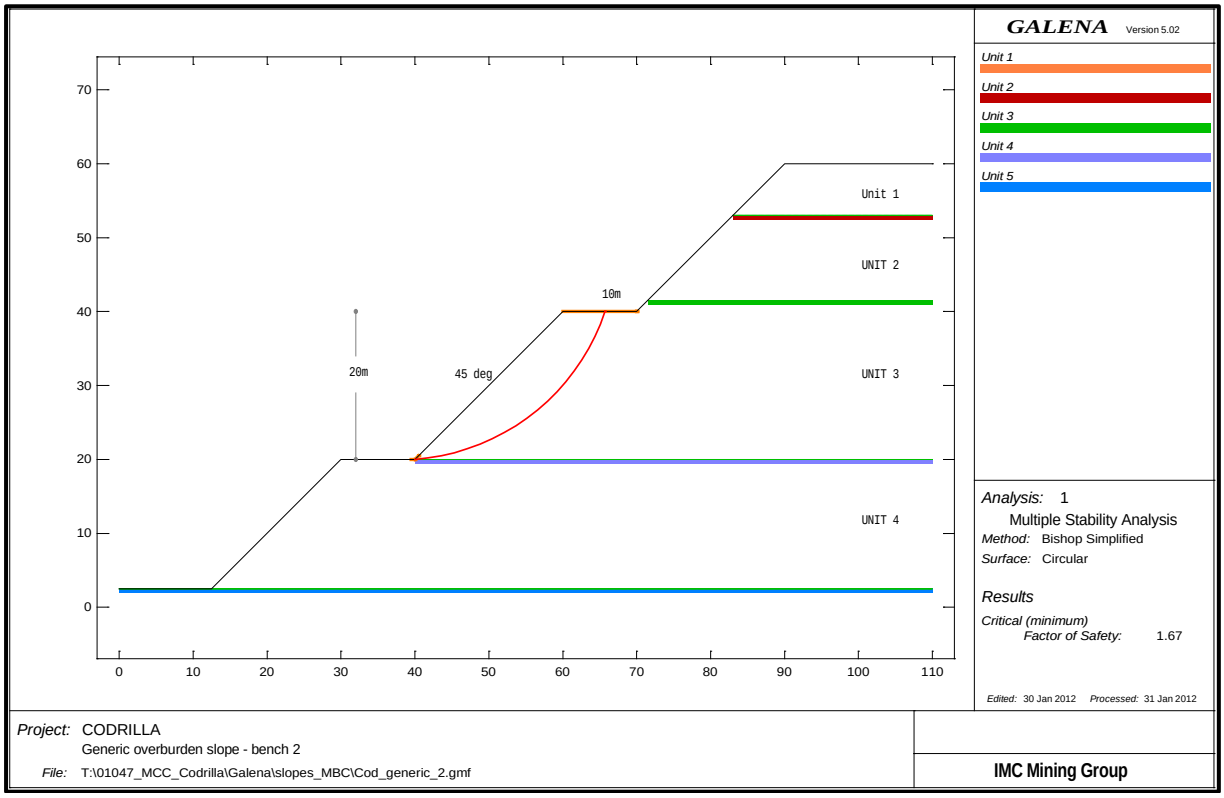
APPENDIX C – Slope Stability Analysis Results

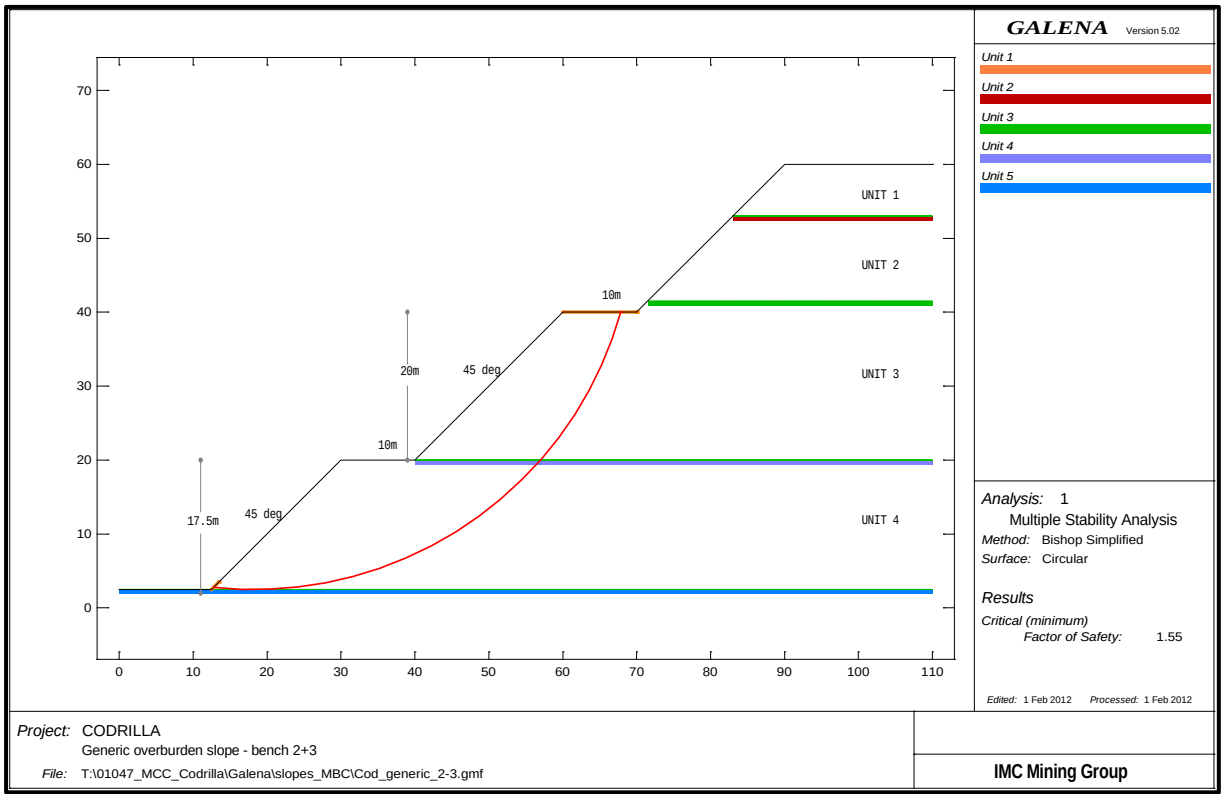
C1 – Generic Slope Stability Analysis Results

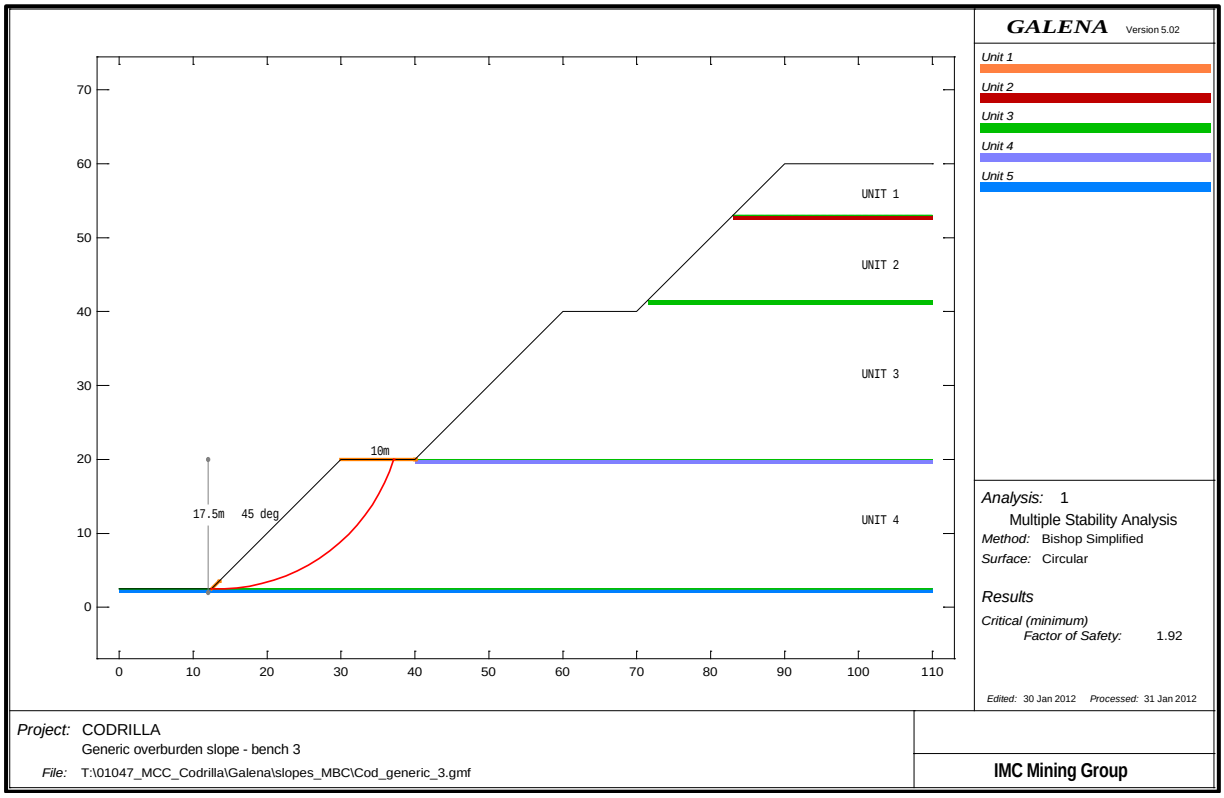




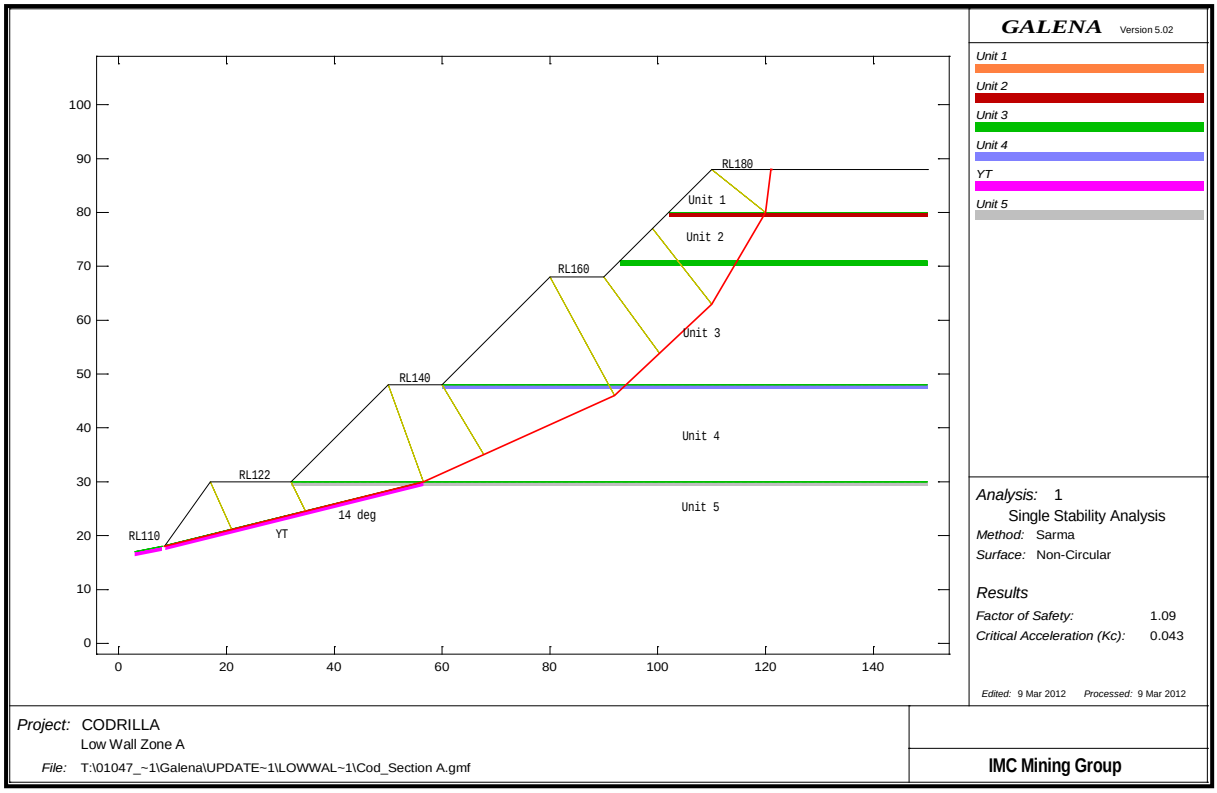

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
UNIT 1
UNIT 2
UNIT 3
UNIT 4
17.5m
45 deg
10m
20m
45 deg
10m
20m
45 deg
Analysis: 1
Multiple Stability Analysis
Method: Bishop Simplified
Surface: Circular
Results
Critical (minimum)
Factor of Safety: 1.34
Edited: 1 Feb 2012 Processed: 1 Feb 2012
Project: CODRILLA
Generic overburden slope - bench 1+2+3
File: T:\01047_MCC_Codrilla\Galena\slopes_MBC\Cod_generic_1-2-3.gmf
IMC Mining Group

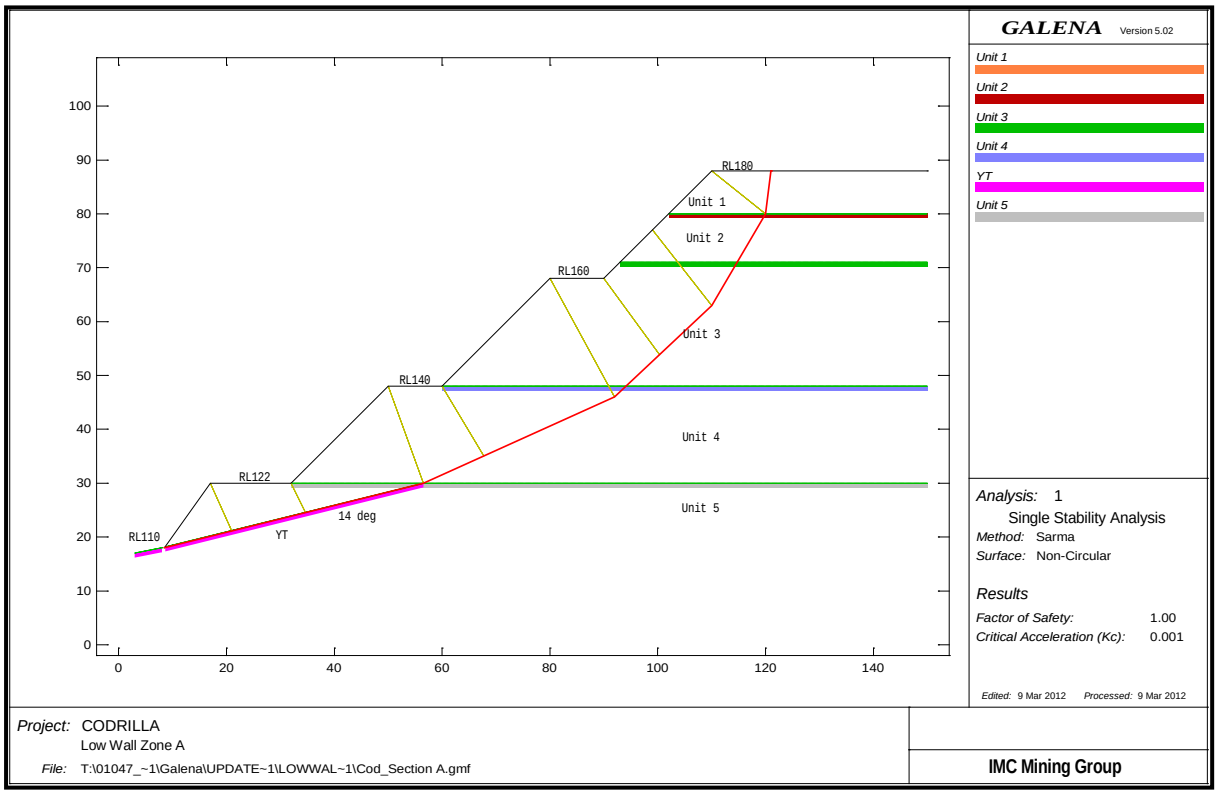

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
Unit 1
UNIT 2
UNIT 3
UNIT 4
10m
20m
45 deg
Analysis: 1
Multiple Stability Analysis
Method: Bishop Simplified
Surface: Circular
Results
Critical (minimum)
Factor of Safety: 1.67
Edited: 30 Jan 2012 Processed: 31 Jan 2012
Project: CODRILLA
Generic overburden slope - bench 2
File: T:\01047_MCC_Codrilla\Galena\slopes_MBC\Cod_generic_2.gmf
IMC Mining Group

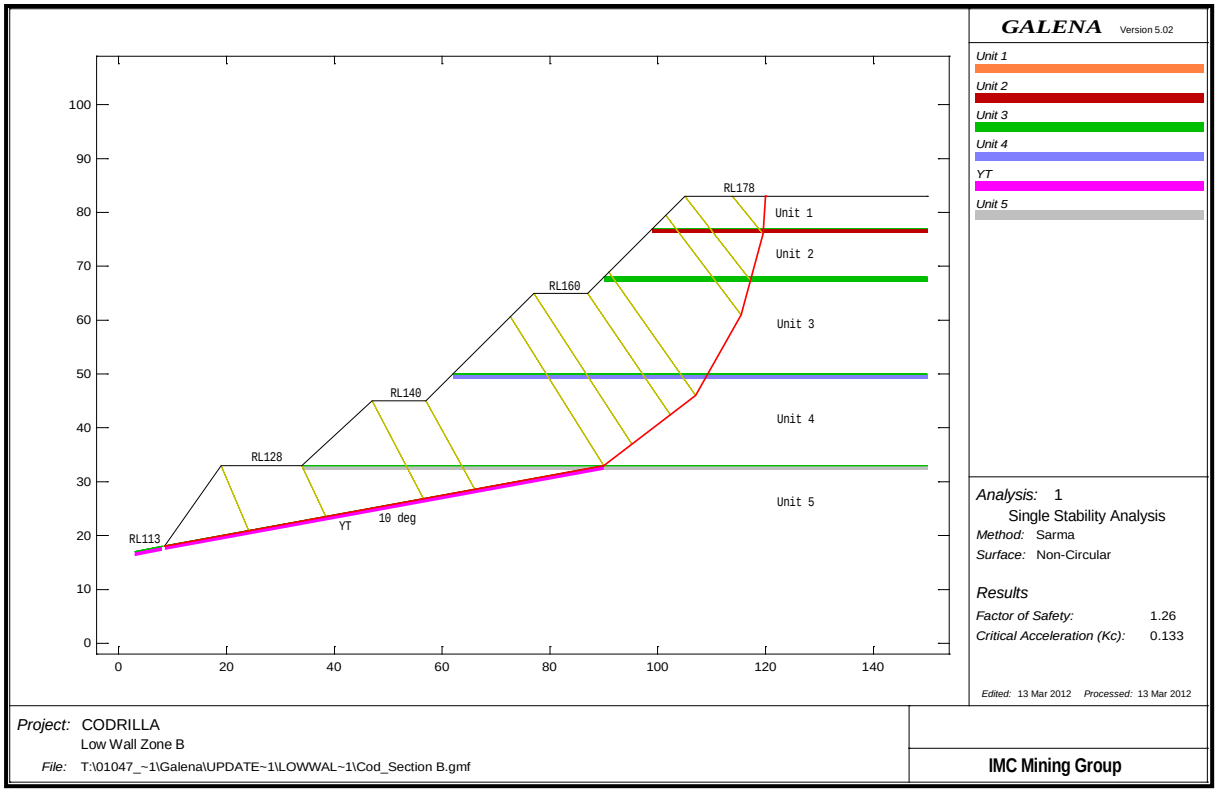

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
UNIT 1
UNIT 2
UNIT 3
UNIT 4
10m
20m
45 deg
10m
17.5m
45 deg
Analysis: 1
Multiple Stability Analysis
Method: Bishop Simplified
Surface: Circular
Results
Critical (minimum)
Factor of Safety: 1.55
Edited: 1 Feb 2012 Processed: 1 Feb 2012
Project: CODRILLA
Generic overburden slope - bench 2+3
File: T:\01047_MCC_Codrilla\Galena\slopes_MBC\Cod_generic_2-3.gmf
IMC Mining Group

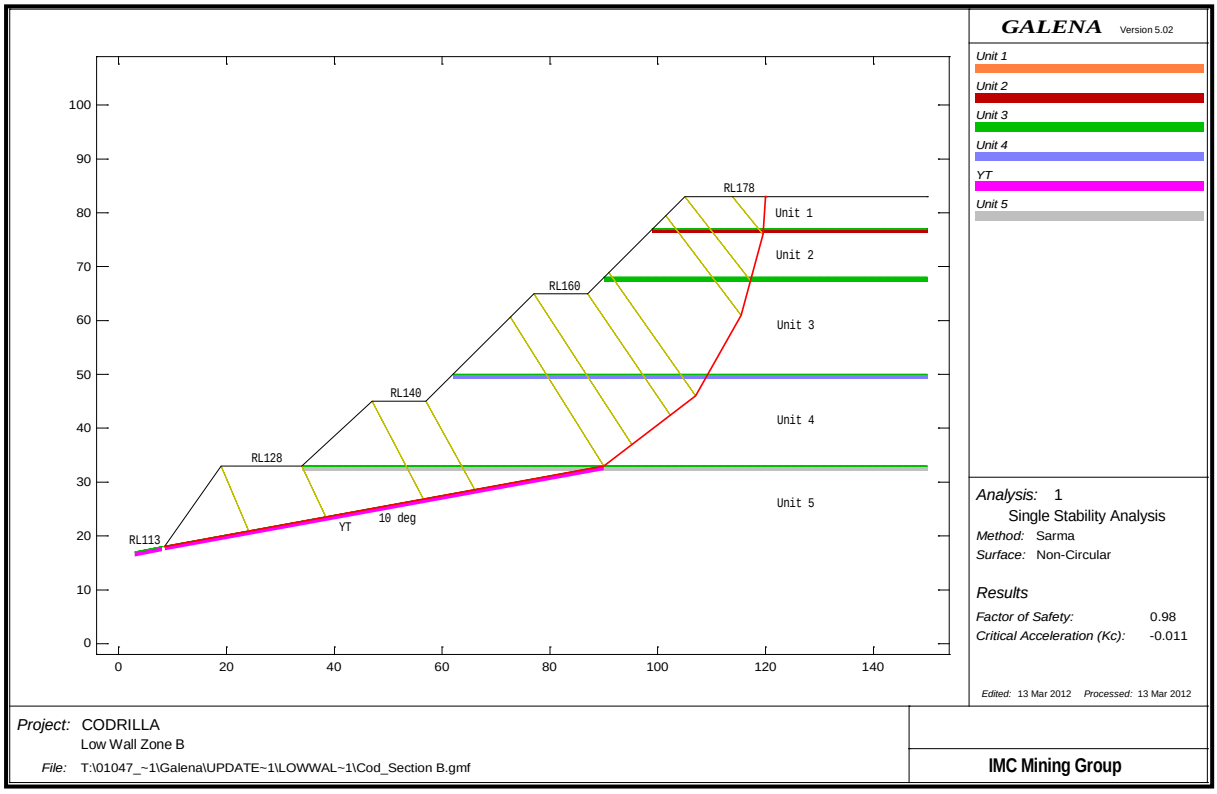

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
UNIT 1
UNIT 2
UNIT 3
UNIT 4
10m
17.5m
45 deg
Analysis: 1
Multiple Stability Analysis
Method: Bishop Simplified
Surface: Circular
Results
Critical (minimum)
Factor of Safety: 1.92
Edited: 30 Jan 2012 Processed: 31 Jan 2012
Project: CODRILLA
Generic overburden slope - bench 3
File: T:\01047_MCC_Codrilla\Galena\slopes_MBC\Cod_generic_3.gmf
IMC Mining Group

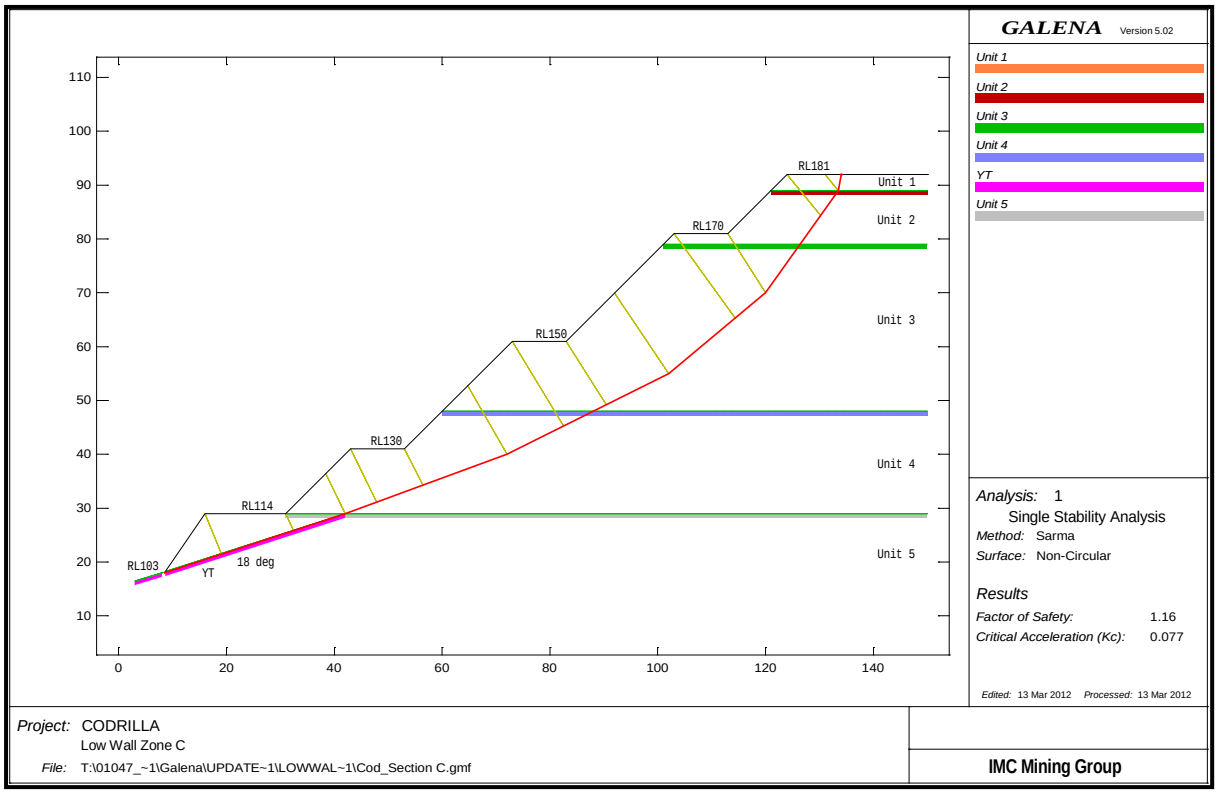
C2 – Low wall Stability Analysis Results

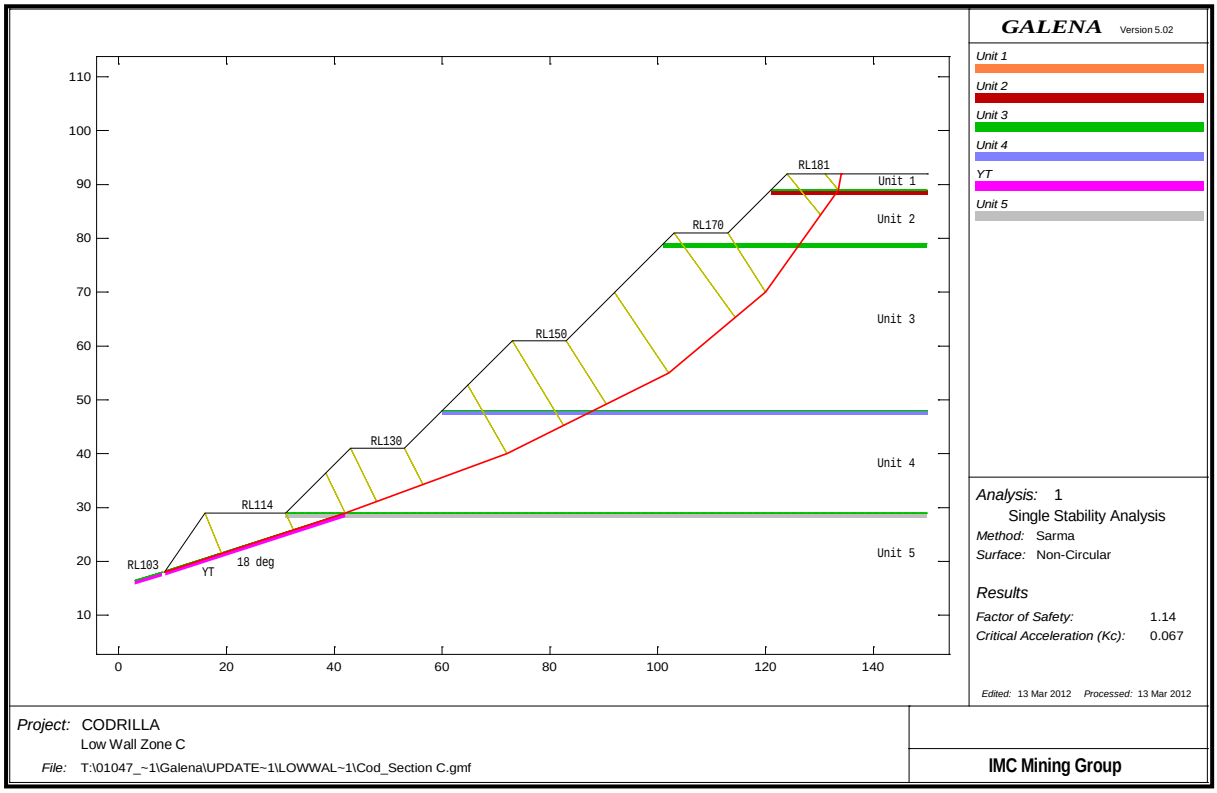


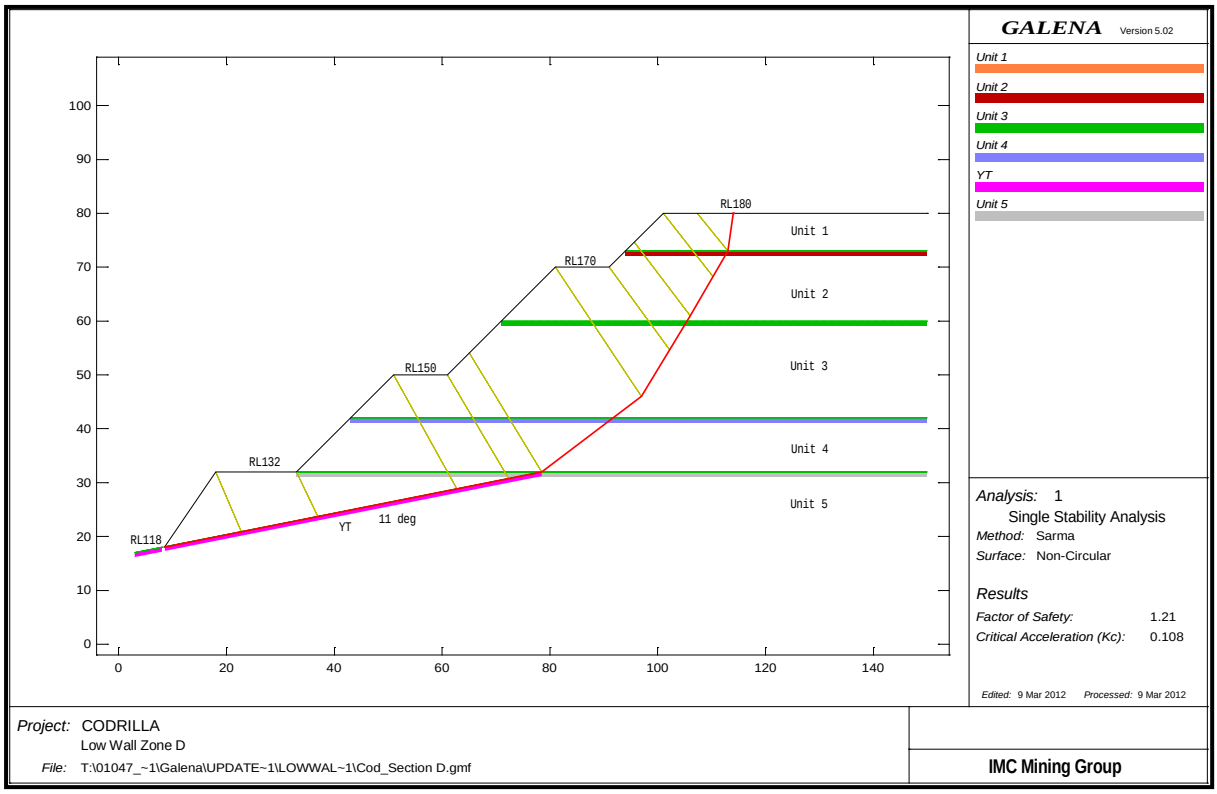


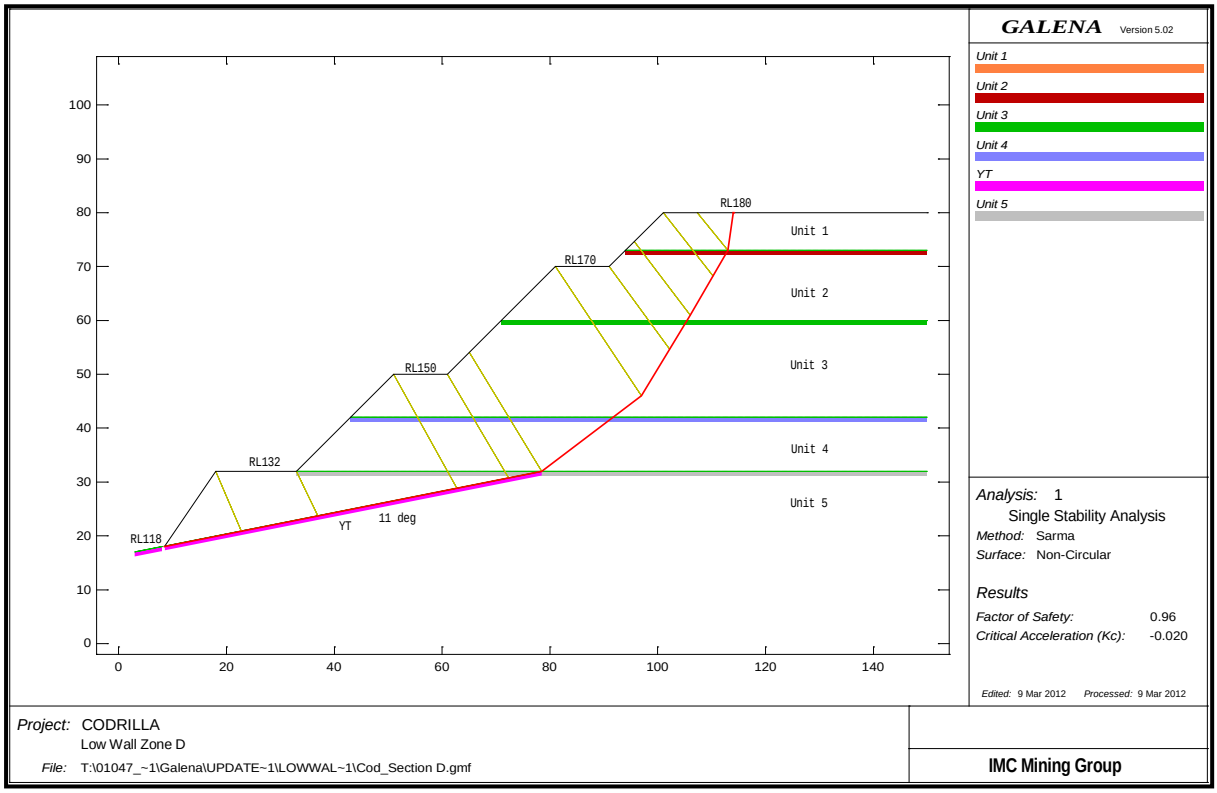

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL178
RL160
RL140
RL128
RL113
YT
10 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.26
Critical Acceleration (Kc): 0.133
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone B
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section B.gmf
IMC Mining Group


GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL178
RL160
RL140
RL128
RL113
YT
10 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 0.98
Critical Acceleration (Kc): -0.011
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone B
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section B.gmf
IMC Mining Group


GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL181
RL170
RL150
RL130
RL114
RL103
18 deg
YT
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.16
Critical Acceleration (Kc): 0.077
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone C
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section C.gmf
IMC Mining Group


GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL181
RL170
RL150
RL130
RL114
RL103
18 deg
YT
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.14
Critical Acceleration (Kc): 0.067
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone C
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section C.gmf
IMC Mining Group


GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL180
RL170
RL150
RL132
RL118
YT
11 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.21
Critical Acceleration (Kc): 0.108
Edited: 9 Mar 2012 Processed: 9 Mar 2012
Project: CODRILLA
Low Wall Zone D
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section D.gmf
IMC Mining Group


GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL180
RL170
RL150
RL132
RL118
YT
11 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 0.96
Critical Acceleration (Kc): -0.020
Edited: 9 Mar 2012 Processed: 9 Mar 2012
Project: CODRILLA
Low Wall Zone D
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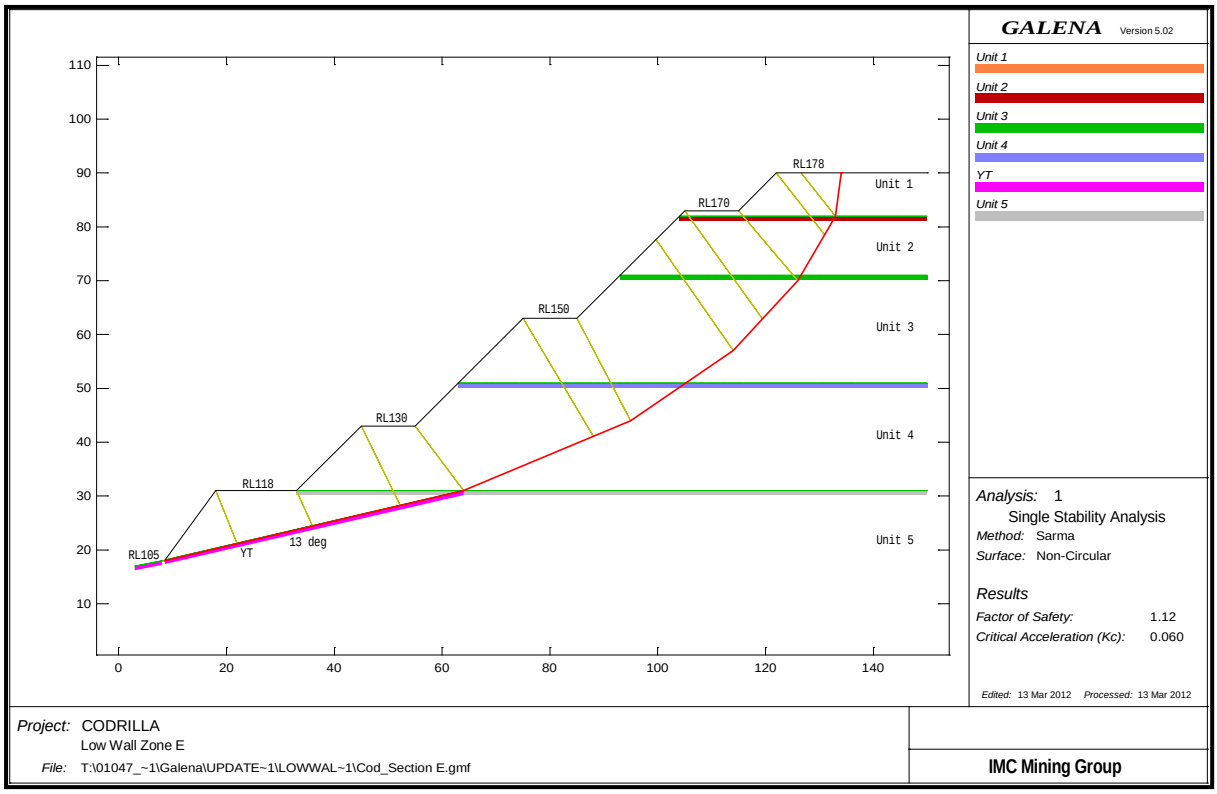
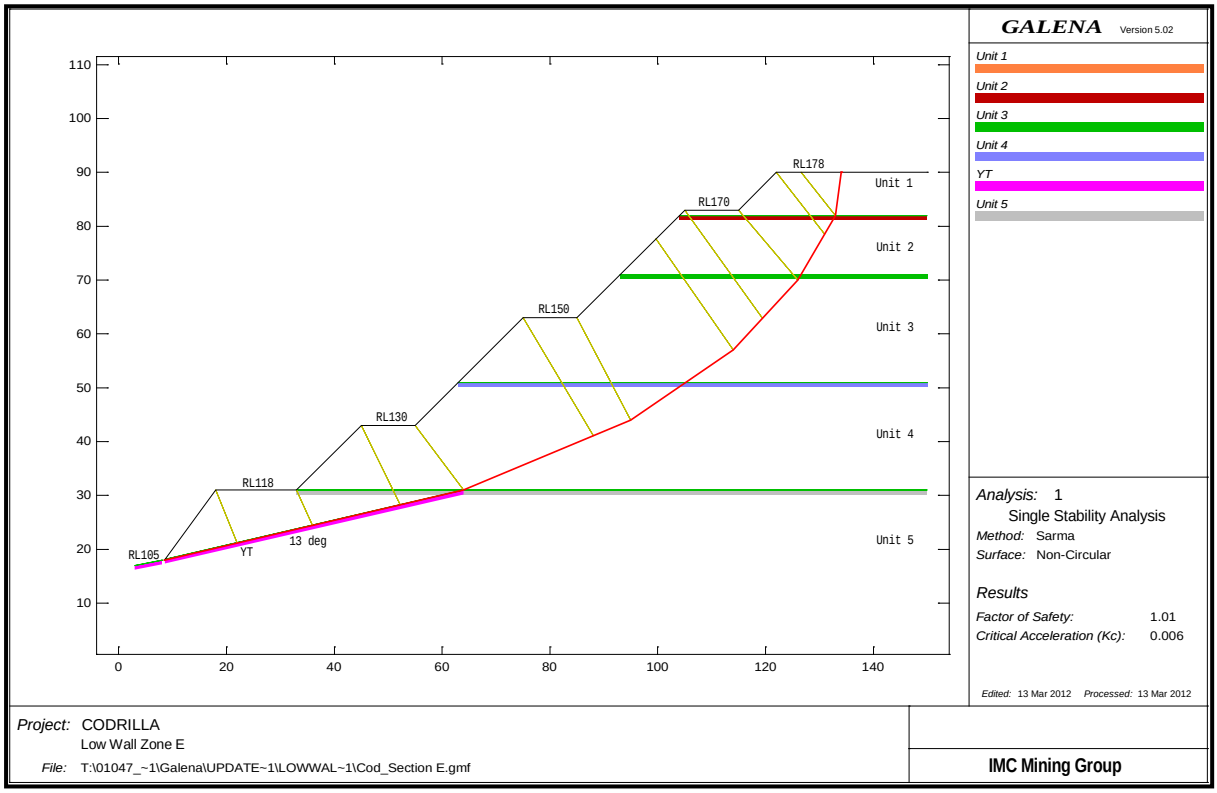
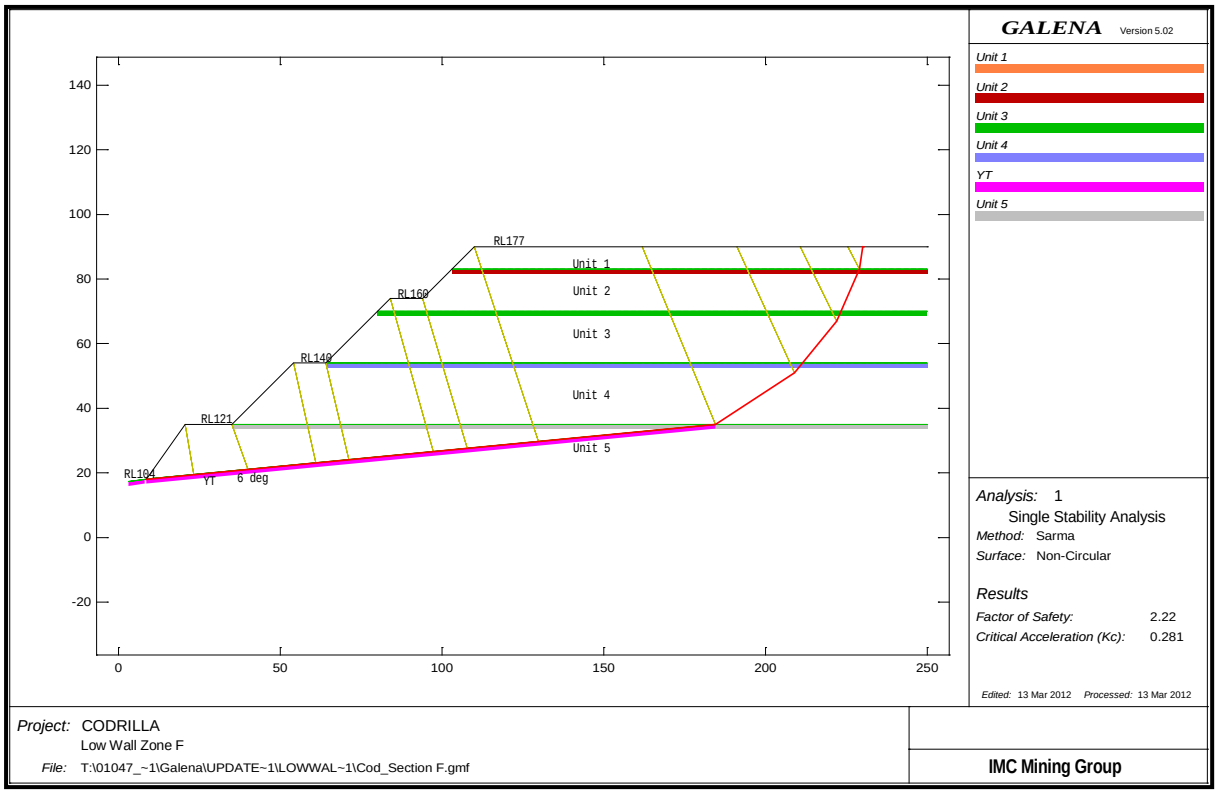
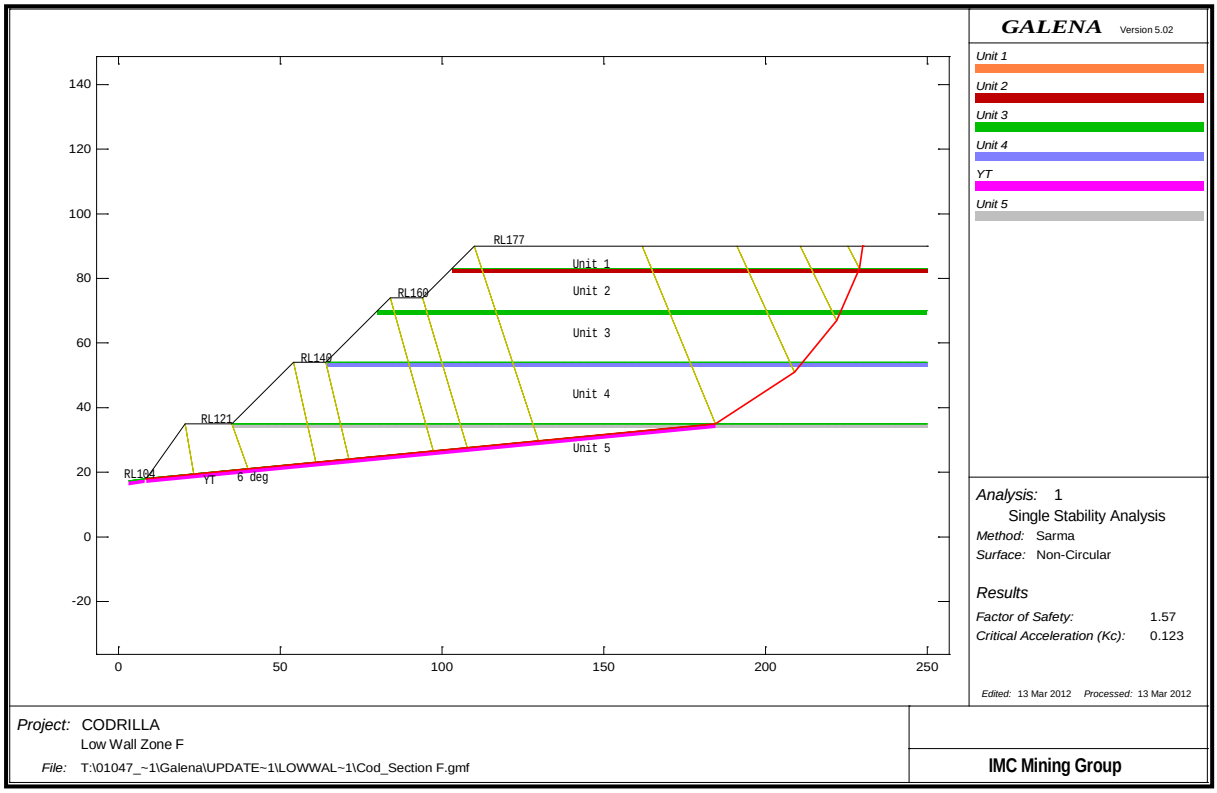
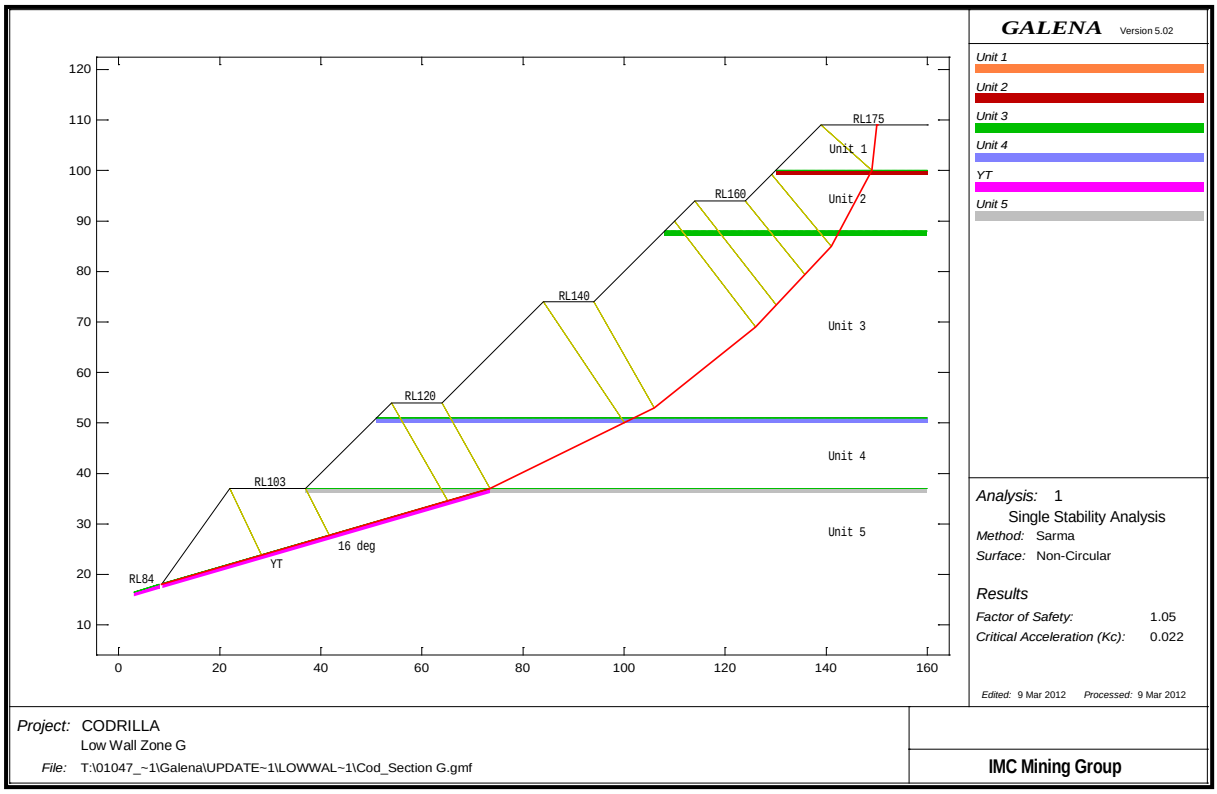
IMC Mining Group

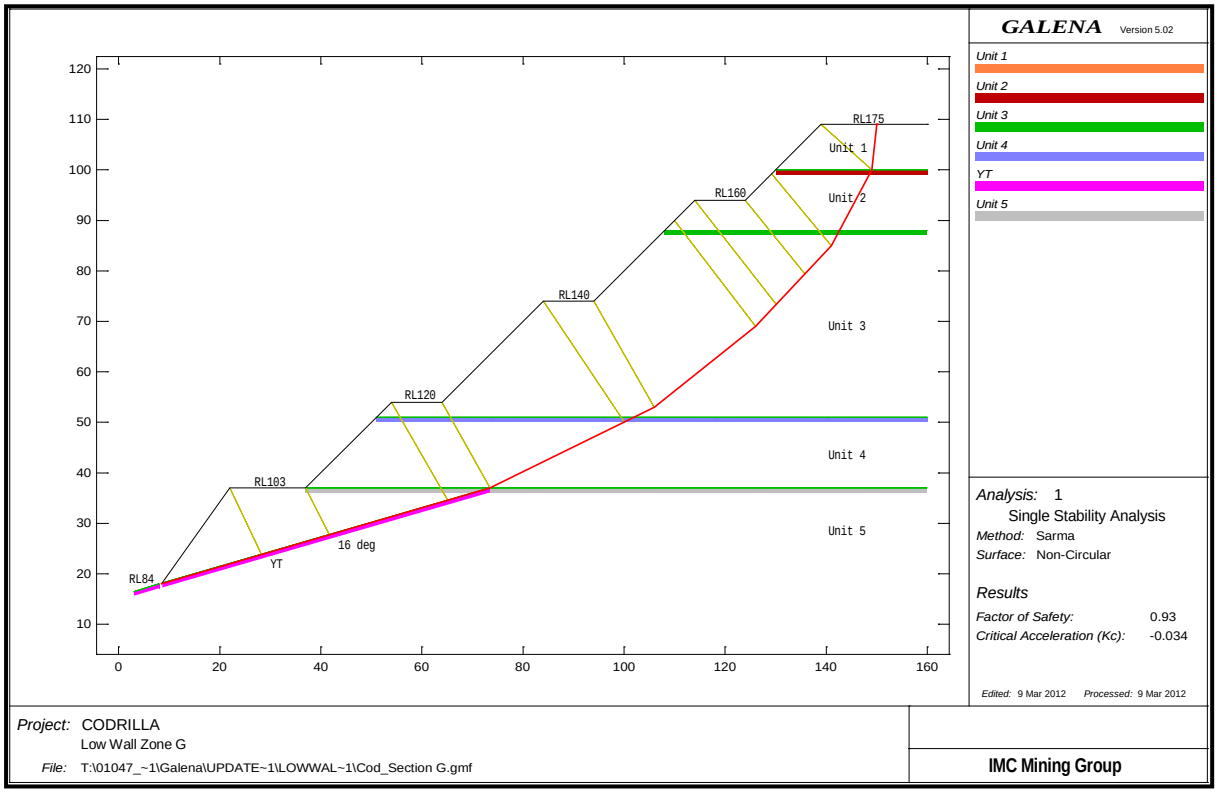

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL178
RL170
RL150
RL130
RL118
RL105
YT
13 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.12
Critical Acceleration (Kc): 0.060
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone E
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section E.gmf
IMC Mining Group

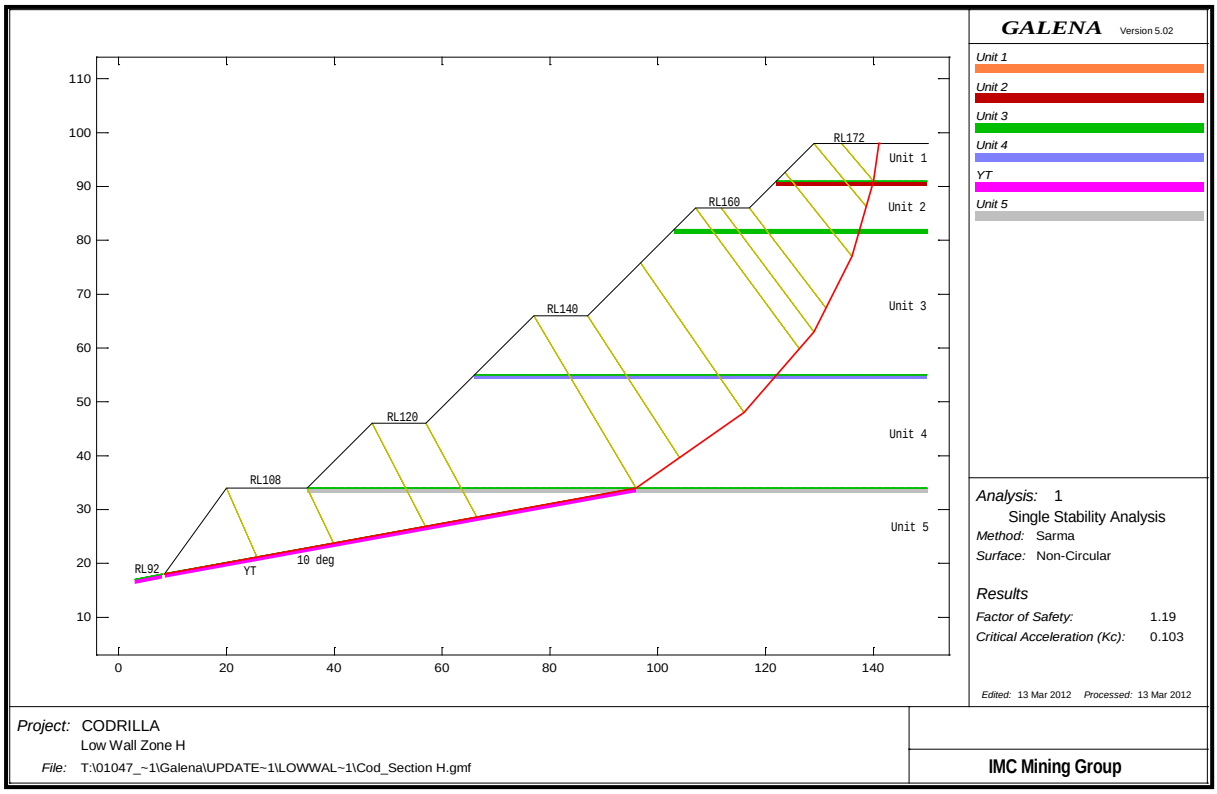

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL178
RL170
RL150
RL130
RL118
RL105
YT
13 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.01
Critical Acceleration (Kc): 0.006
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone E
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section E.gmf
IMC Mining Group

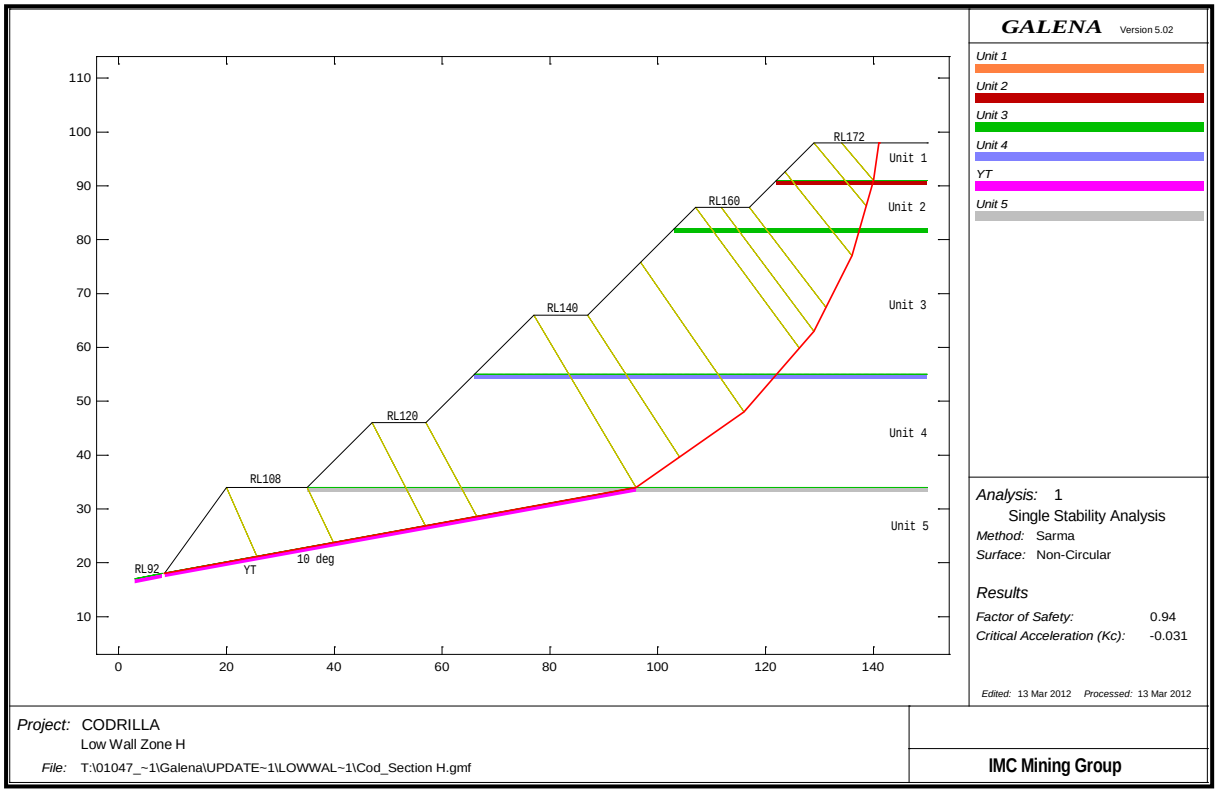

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL177
RL160
RL140
RL121
RL104
YT 6 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 2.22
Critical Acceleration (Kc): 0.281
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone F
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section F.gmf
IMC Mining Group

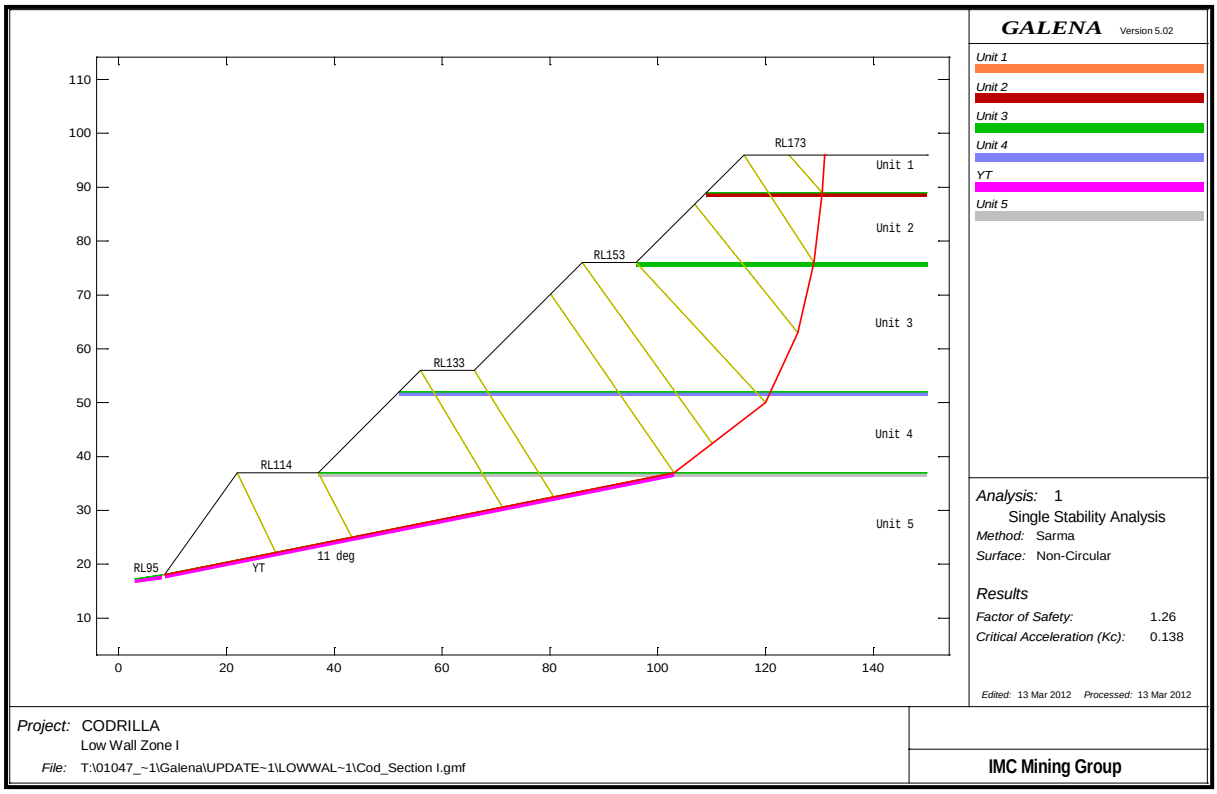

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL177
RL160
RL140
RL121
RL104
YT 6 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.57
Critical Acceleration (Kc): 0.123
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone F
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section F.gmf
IMC Mining Group

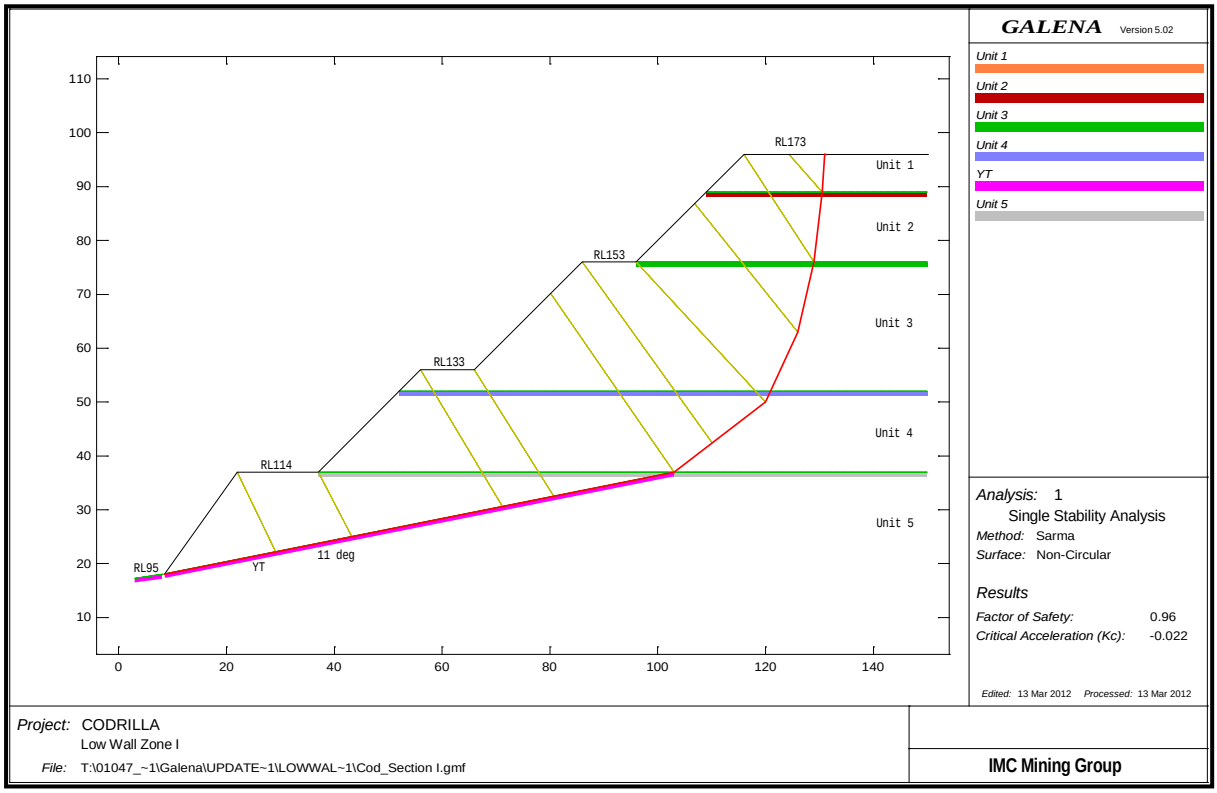

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL175
RL160
RL140
RL120
RL103
RL84
16 deg
YT
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.05
Critical Acceleration (Kc): 0.022
Edited: 9 Mar 2012 Processed: 9 Mar 2012
Project: CODRILLA
Low Wall Zone G
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section G.gmf
IMC Mining Group

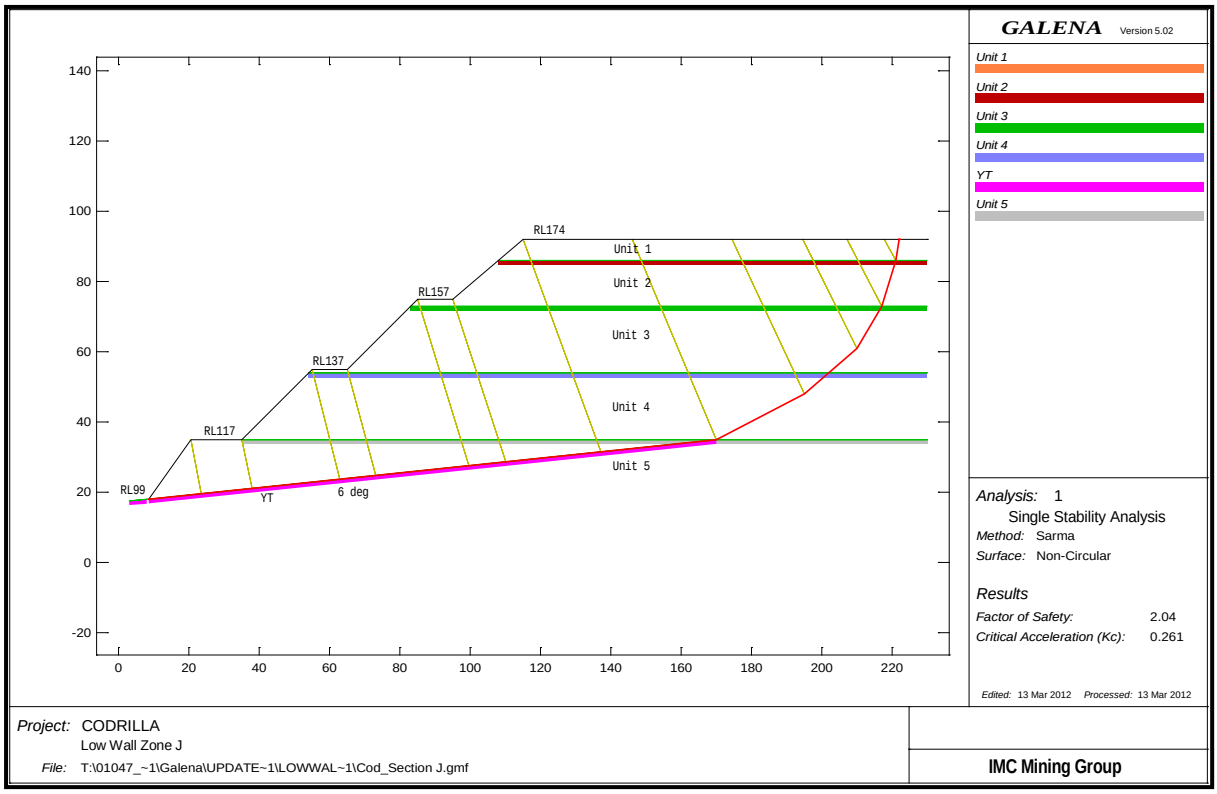

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL175
RL160
RL140
RL120
RL103
RL84
16 deg
YT
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 0.93
Critical Acceleration (Kc): -0.034
Edited: 9 Mar 2012 Processed: 9 Mar 2012
Project: CODRILLA
Low Wall Zone G
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section G.gmf
IMC Mining Group

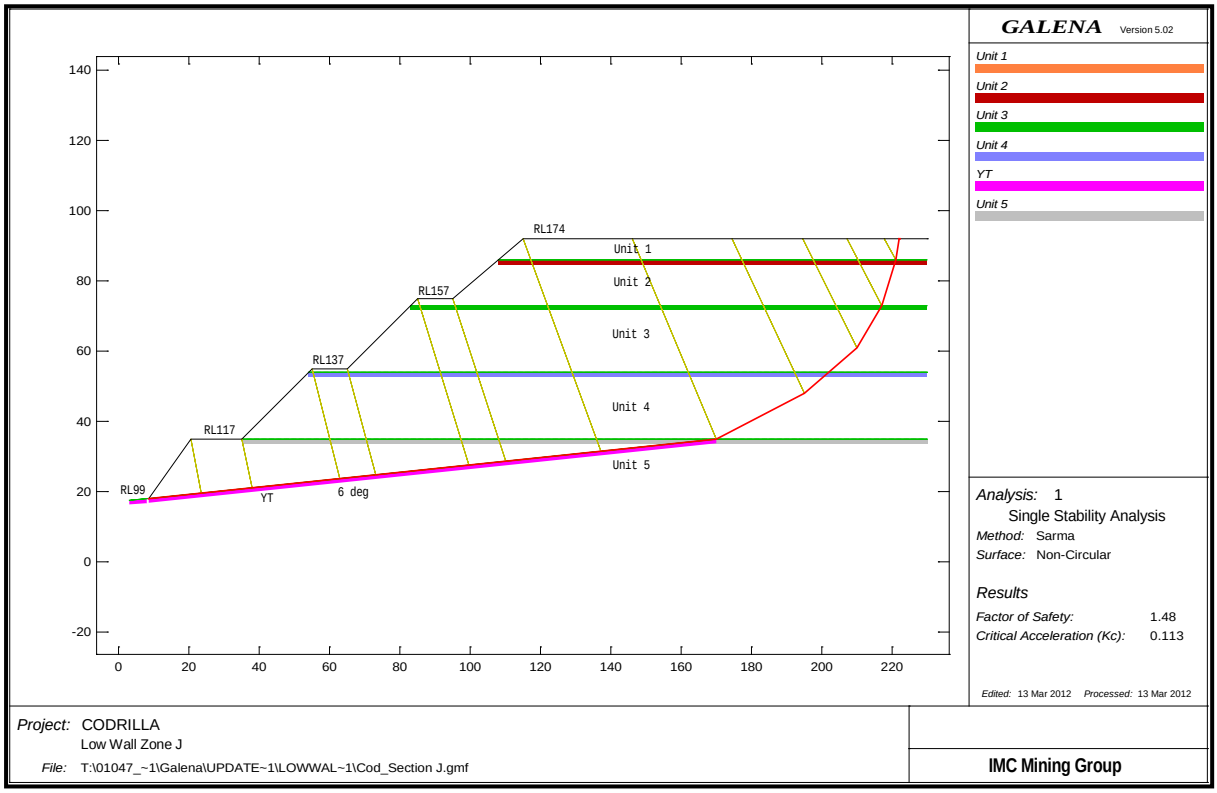

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL172
RL160
RL140
RL120
RL108
RL92
YT
10 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.19
Critical Acceleration (Kc): 0.103
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone H
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section H.gmf
IMC Mining Group

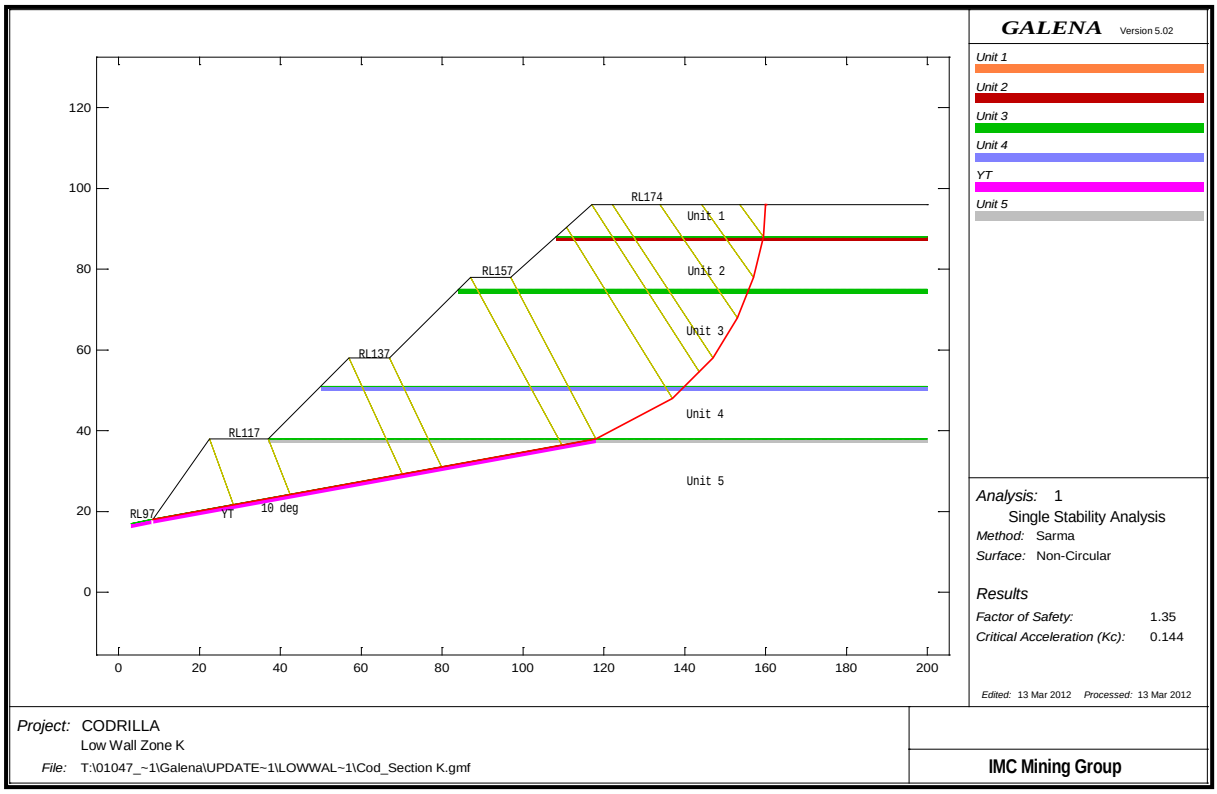

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL172
RL160
RL140
RL120
RL108
RL92
YT
10 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 0.94
Critical Acceleration (Kc): -0.031
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone H
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section H.gmf
IMC Mining Group

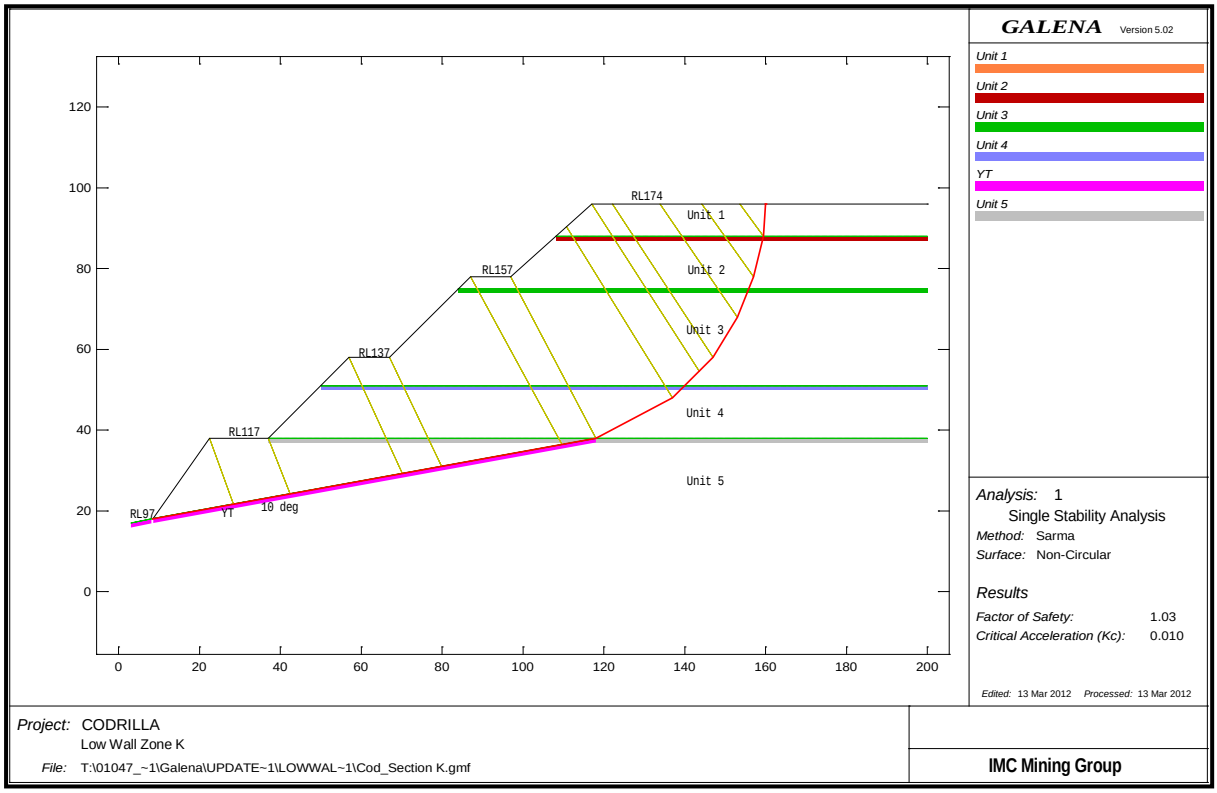

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL173
RL153
RL133
RL114
RL95
YT
11 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.26
Critical Acceleration (Kc): 0.138
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone I
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section I.gmf
IMC Mining Group


GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL173
RL153
RL133
RL114
RL95
YT
11 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 0.96
Critical Acceleration (Kc): -0.022
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone I
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section I.gmf
IMC Mining Group


GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL174
RL157
RL137
RL117
RL99
YT
6 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 2.04
Critical Acceleration (Kc): 0.261
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone J
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section J.gmf
IMC Mining Group

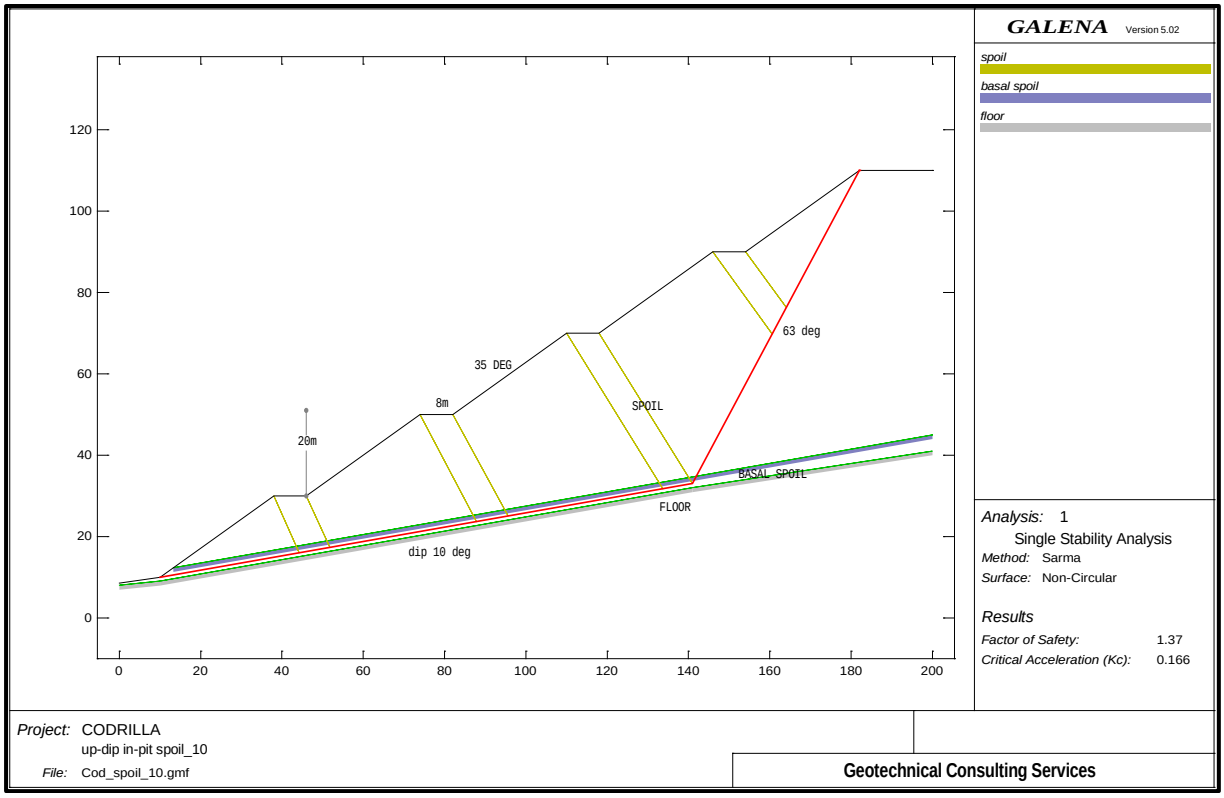

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL174
RL157
RL137
RL117
RL99
YT
6 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.48
Critical Acceleration (Kc): 0.113
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone J
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section J.gmf
IMC Mining Group

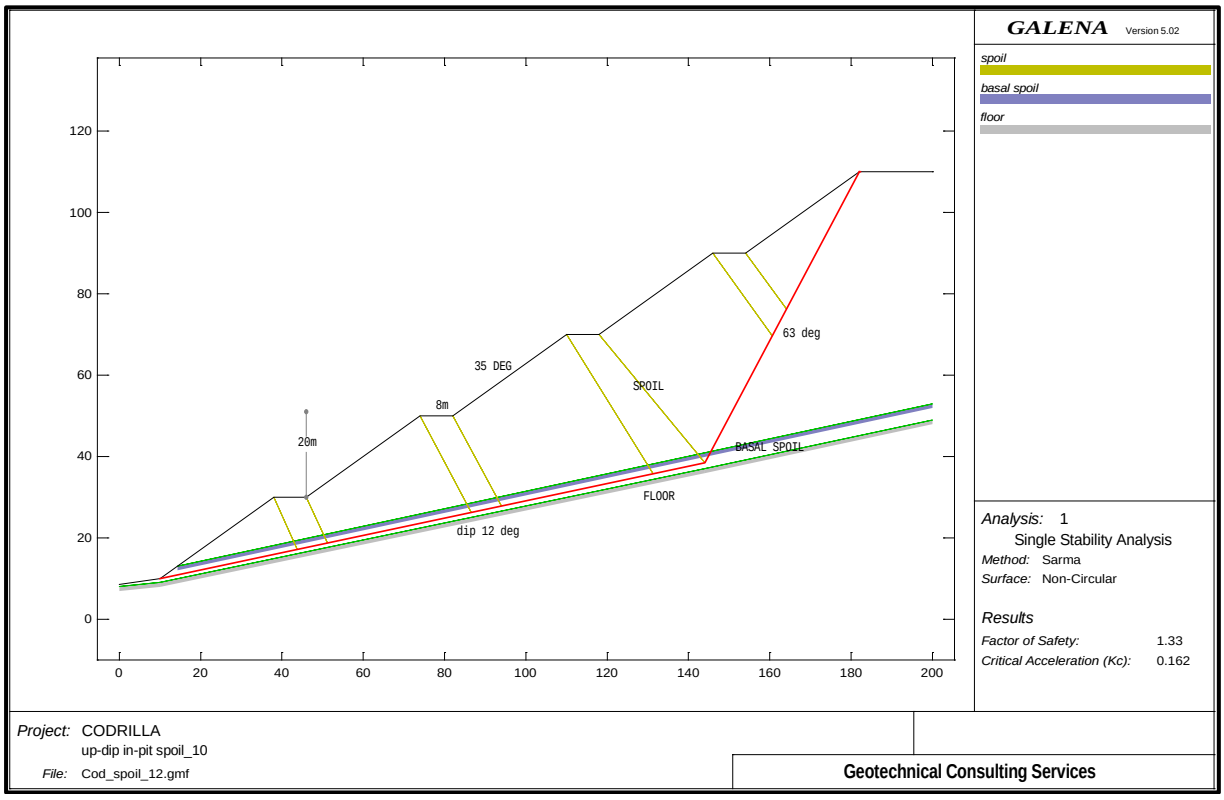

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL174
RL157
RL137
RL117
RL97
YT
10 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.35
Critical Acceleration (Kc): 0.144
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone K
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section K.gmf
IMC Mining Group

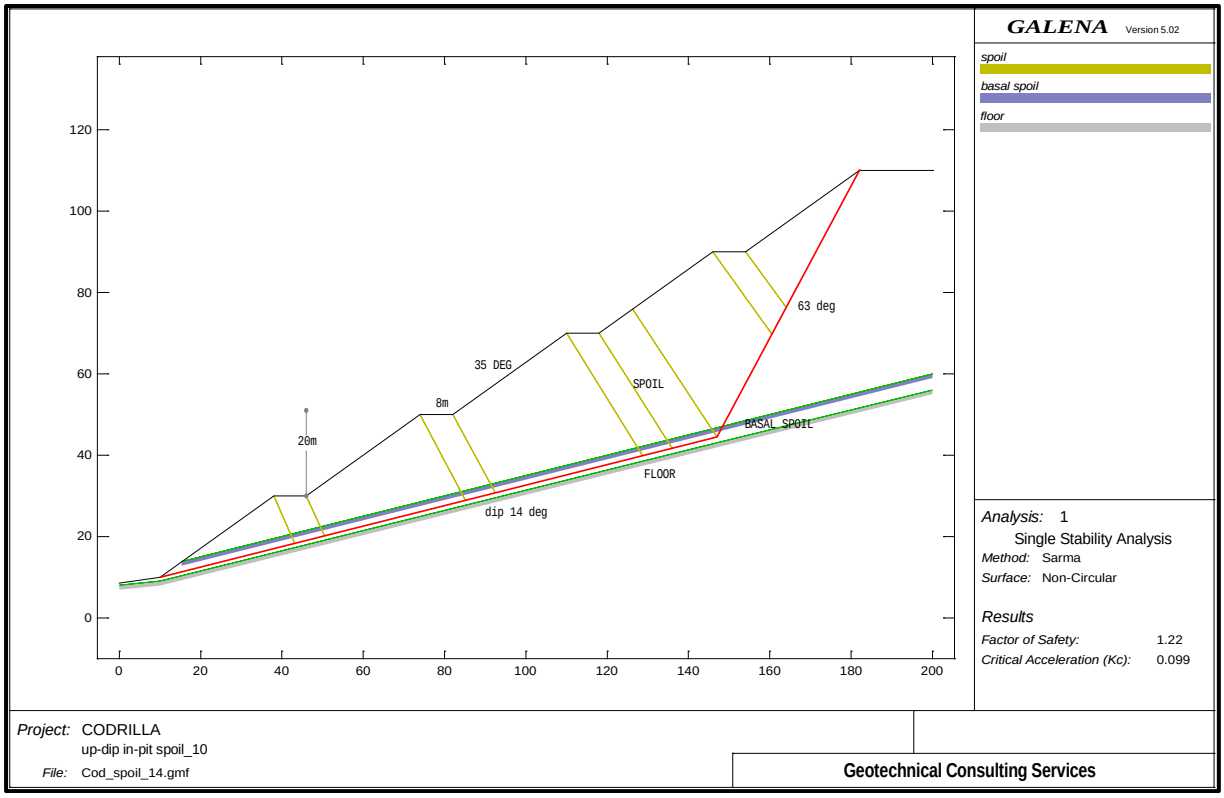

GALENA Version 5.02
Unit 1
Unit 2
Unit 3
Unit 4
YT
Unit 5
RL174
RL157
RL137
RL117
RL97
YT
10 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.03
Critical Acceleration (Kc): 0.010
Edited: 13 Mar 2012 Processed: 13 Mar 2012
Project: CODRILLA
Low Wall Zone K
File: T:\01047_~1\Galena\UPDATE~1\LOWWAL~1\Cod_Section K.gmf
IMC Mining Group

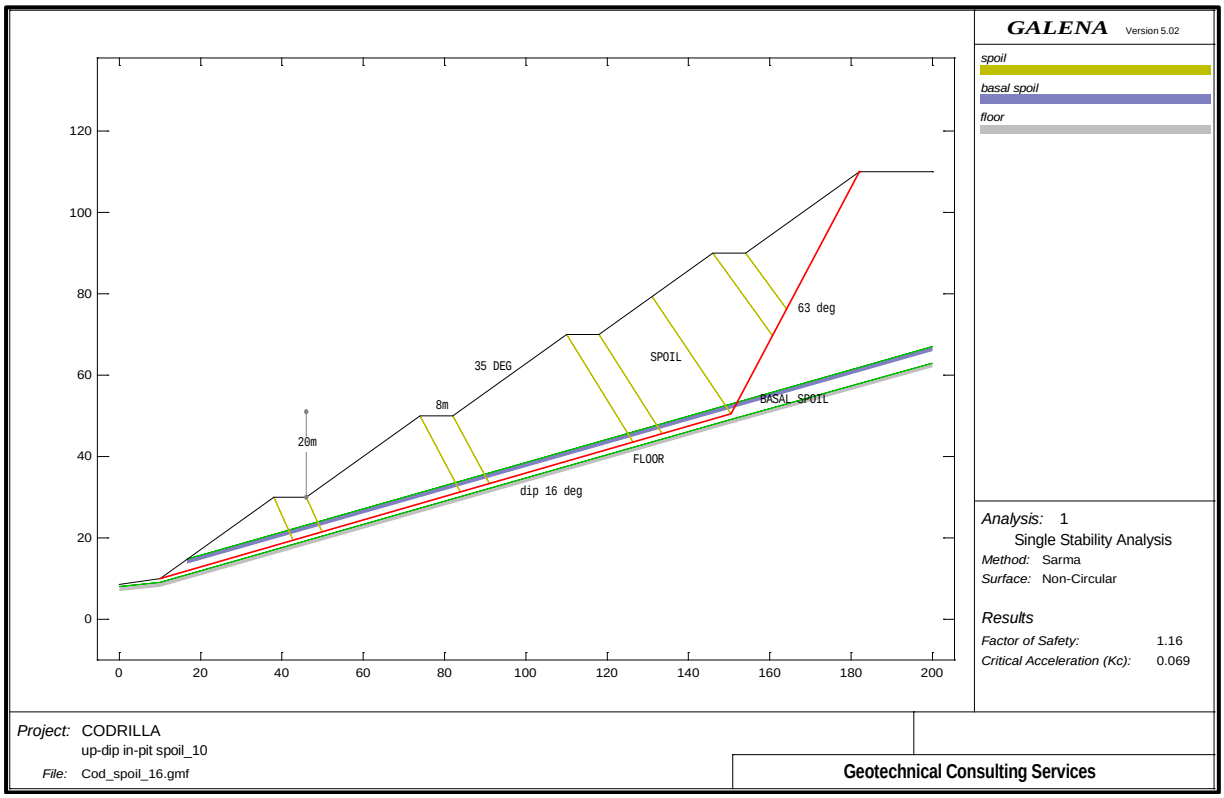
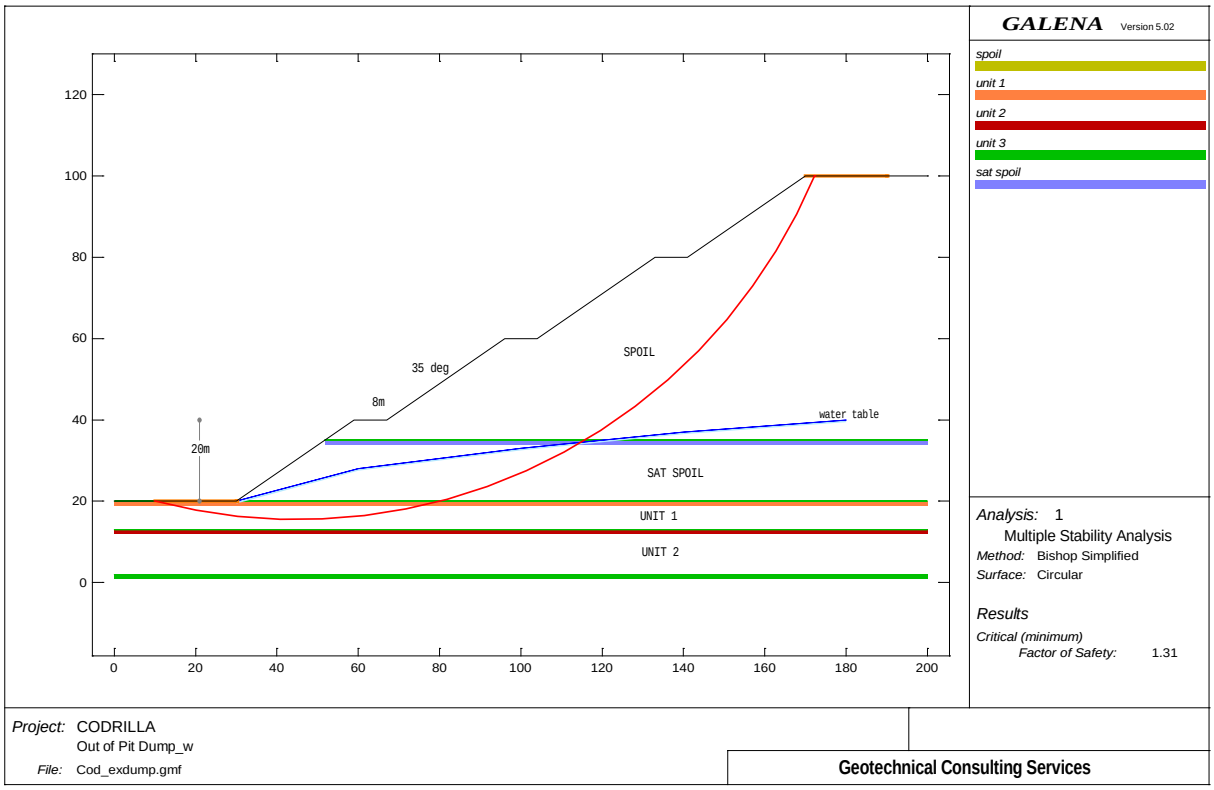
APPENDIX D – Spoil Stability Analysis Results

In-Pit Spoil Stability






GALENA Version 5.02
spoil
basal spoil
floor
63 deg
35 DEG
SPOIL
8m
20m
BASAL SPOIL
FLOOR
dip 14 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.22
Critical Acceleration (Kc): 0.099
Project: CODRILLA
up-dip in-pit spoil_10
File: Cod_spoil_14.gmf
Geotechnical Consulting Services


GALENA Version 5.02
spoil
basal spoil
floor
63 deg
35 DEG
SPOIL
8m
20m
BASAL SPOIL
FLOOR
dip 16 deg
Analysis: 1
Single Stability Analysis
Method: Sarma
Surface: Non-Circular
Results
Factor of Safety: 1.16
Critical Acceleration (Kc): 0.069
Project: CODRILLA
up-dip in-pit spoil_10
File: Cod_spoil_16.gmf
Geotechnical Consulting Services

Ex-Pit Spoil Stability