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Mine	Chain Valley Colliery		
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	David Hill, Tim Chisholm, Wade C	Covey, Chris Armit	
Author(s)			
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Authorised by:		Gary Cambourn	
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1.0 Introduction

1.1 Background

Chain Valley Colliery (CVC) is an underground coal mine located at the Southern end of Lake Macquarie approximately 40km South of Newcastle. Mining at CVC first commenced in 1962 and since then, both primary and secondary coal extraction has occurred in the Wallarah, Great Northern and Fassifern Seams, primarily using Bord and Pillar mining methods.

Of the three mined coal seams, the Wallarah Seam was discontinued in 1997, the Great Northern Seam was discontinued in May 2008 and mining is currently in the Fassifern Seam.

In December 2013, development consent was received from the NSW Department of Planning under Section 89E of the Environmental Planning and Assessment Act 1979 for CVC to continue mining via miniwall mining methods to the North of the previous approval boundary until 31st December 2027. Subsequently modifications in November 2014 (MOD 1) and December 2015 (MOD 2) provided approval of the Link Rd to Mannering Colliery and changes to production limits and panel layout including maximum subsidence. The approved mining boundary extends beyond the Northern boundary of mining lease ML1051 (held by LakeCoal and into lease areas held by Centennial Coal (ML1632 and CCL721). Agreements have been reached between Centennial Coal and Lake Coal allowing CVC to extract within a defined parcel of these lease areas, namely Sub-lease A and Sub-lease B. Both now form part of the Chain Valley Colliery Holding.

This Extraction Plan is related to a small portion of the mining area previously approved by the NSW Department of Planning, located within "Area A". The proposed miniwall panels, S2 and S3, have been designed such that all extraction is located beneath the lake and all secondary extraction is outside of both the High Water Mark Subsidence Barrier (HWMSB) and the Seagrass Protection Barrier zones (Figure 1). The final limits of extraction and mine design requirements for subsidence management were also informed by geotechnical (Strata2, 2018), subsidence estimation and impact studies (MSEC, 2018).

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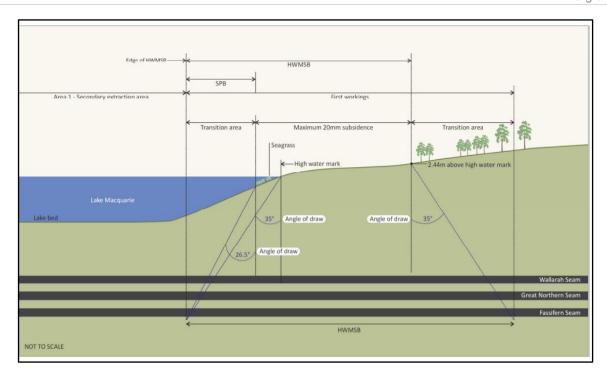


Figure 1- Protection Barrier Schematic

1.2 Scope

Prior to commencement of secondary extraction within the approved Mining Extension 1 project area, the CVC approval conditions (Schedule 4, Condition 7) state that:

"The Applicant shall prepare an Extraction Plan for all second workings on site, to the satisfaction of the Secretary."

As such, this Extraction Plan has been developed in accordance with Schedule 4, Condition 7 of the Development Consent and details proposed subsidence management techniques to be implemented during secondary extraction to ensure that there are no exceedances of the key performance measures identified in the Development Consent.

This extraction plan is limited to S2 and S3 Panels (**Figure 2**) and as such, does not cover the entire Mining Extension 1 approval plan (**Figure 3**). The limited scope of this Extraction Plan aims to:

(i) address short term mine planning requirements in a conservative manner (i.e. by limiting the plan to the two panels) and

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(ii) enable a re-assessment of the remainder of the mining layout for the Northern Mining Area, incorporating the learning outcomes from previous minimal extraction, as well as other learnings and opportunities for layout optimisation.

Whilst current minimal extraction is being undertaken under previous approvals and a current Extraction Plan approval (S1/N1), the extraction of the S2 and S3 Panel will not commence until this document is approved. Subsequent Extraction Plans will be submitted for future mining in the Mining Extension 1 area, but are outside the scope of this document.



Figure 2- S2 and S3 Extraction Plan Locality

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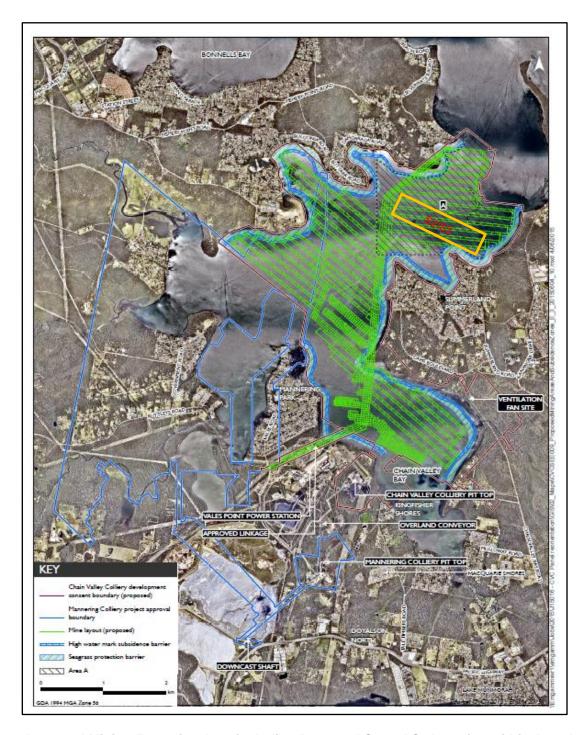


Figure 3- Approved Mining Extension Area including Proposed S2 and S3 Location within Area A

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1.3 Development Consent Conditions

This document has been developed in accordance with Schedule 4 of the site's Development Consent. The associated management plans have been developed in accordance with Schedule 6, Condition 3 of the Approval Conditions and the Guidelines for the Preparation of Extraction Plans. The requirements prescribed in the Approval Conditions relevant to this document are listed in **Table 1**.

Table 1 – Development Consent Conditions

Develo	pment Consent Condition - Condition 7 of Schedule 4	Document Reference
	plicant shall prepare an Extraction Plan for all second workings on site, to the ction of the Secretary. Each Extraction Plan must:	
a)	Be prepared by suitably qualified and experienced persons whose appointment has been endorsed by the Secretary	Section 2.1
b)	Be approved by the Secretary before the Applicant carries out any second workings covered by the plan	Section 1.2
c)	Include detailed plans of existing and proposed first and secondary workings	Appendix 9
	and any associated surface development, including any applicable adaptive management measures	Section 3.4.4
d)	Include detailed performance indicators for each of the performance measures in Tables 8 and 9	Sections 3.3 & 4.0
	In Tables 8 and 9	Appendix 1
e)	Provide revised predictions of the potential subsidence effects, subsidence impacts and environmental consequences of the proposed second workings, incorporating any relevant information obtained since this consent	Section 2.5 and 3.2
f)	Describe the measures that would be implemented to ensure compliance with	Sections 3.4 & 4.0
	the performance measures in Tables 8 and 9, and manage or remediate any impacts and/or environmental consequences	Appendix 1
g)	Include a Built Features Management Plan, which has been prepared in consultation with DRE and the owners of affected public infrastructure, to manage the potential subsidence impacts and/or environmental consequences of the proposed second workings, and which	Section 4
	 Addresses in appropriate detail all items of public infrastructure and other public infrastructure and all classes of other built features 	
	 Has been prepared following appropriate consultation with the owner/s of potentially affected feature/s 	
	 Recommends appropriate remedial measures and includes commitments to mitigate, repair, replace or compensate all predicted impacts on potentially affected built features in a timely manner 	
	Include a Benthic Communities Management Plan, which has been	Section 4
	prepared in consultation with OEH, LMCC, and DPI Fisheries, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on benthic communities, which includes:	Appendix 4

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	 Surveys of the lake bed to enable contours to be produced and changes in depth following subsidence to be accurately measured 	
	Benthic species surveys within the area subject to second workings, as well as control sites outside of the area subject to second workings (at similar depths) to establish baseline data on species number and composition within the communities	
	 A program of ongoing seasonal monitoring of benthic species in both control and impact sites 	
	 Development of a model to predict subsidence impact of increased depth and associated subsidence impacts and effects, including but not limited to light reduction and sediment disturbance, on benthic species number and benthic communities composition, incorporating the monitoring and survey data collected; and 	
	 Updating the model every 2 years using the most recent monitoring and survey data 	
a)	Include a Seagrass Management Plan, which has been prepared in consultation with OEH, LMCC, and DPI Fisheries, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on seagrass beds, and which includes:	Section 4 Appendix 5
	 A program of ongoing monitoring of seagrasses in both control and impact sites 	
	 A program to predict and manage subsidence impacts and environmental consequences to seagrass beds to ensure the performance measures in Table 8 are met 	
b)	Include a Public Safety Management Plan, which has been prepared in consultation with DRE, to ensure public safety	Section 4 Appendix 6
c)	Include a Subsidence Monitoring Program which has been prepared in consultation with DRE, to:	Section 5 Appendix 7
	 Provide data to assist with the management of the risks associated with subsidence 	
	Validates the subsidence predictions	
	 Analyses the relationship between the predicted and resulting subsidence effects and predicted and resulting impacts under the plan and any ensuing environmental consequences 	
	Informs the contingency plan and adaptive management process	
d)	Include a contingency plan that expressly provides for adaptive management	Section 3.4.2
	where monitoring indicates that there has been an exceedance of any performance measures in Tables 8 and 9, or where any such exceedance appears likely	Appendix 1
e)	Include appropriate revisions to the Rehabilitation Management Plan required under Condition 28 of Schedule 3	Section 3.4.3
		Appendix 9
f)	Include a program to collect sufficient baseline data for future Extraction Plans	Section 4

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1.4 Objective

The objective of this Extraction Plan is to provide adequate management techniques to ensure the protection of the overlying land and lake environment from direct and indirect subsidence impacts associated with the extraction of S2 and S3. This objective will be achieved by:

- The implementation of monitoring and management measures to reduce identified subsidence risks to as low as reasonable practicable; and
- Implement a review and audit system as well as proactive management techniques to ensure that the proposed monitoring and management strategies are effectively controlling subsidence risks and allow for mitigation measures to be implemented if required.

2.0 Extraction Plan Development

This extraction plan has been informed by the Statement of Environmental Effects (EMM, 2013 and EMM, 2015), as well as two studies specific to the S2 and S3 Panels, namely:

- an assessment of key geotechnical aspects (Strata2, 2018) and
- subsidence predictions and impact assessments (MSEC, 2018)

Previous studies relating to the subsidence exceedance over Miniwalls 1 to 12 (**DGS Report CHV-002-10b**) and subsidence assessments for the S1 and N1 layout (**DGS Report CHV-002-11a**), have also contributed to the operation's understanding of local subsidence development mechanisms, and the associated required mine design controls for S2 and S3 to maintain subsidence and height of fracturing within currently predicted and approved limits. This has informed risk assessments as to the likelihood of irregular subsidence occurring and what monitoring and subsidence management controls are required. This has culminated in updated subsidence predictions, mine design change recommendations and adaptive management strategies, which have been applied throughout this Extraction Plan.

2.1 Project Team

The project team responsible for the preparation of this Extraction Plan and supporting documents is listed in **Table 2**. In accordance with Schedule 4, Condition 7(a) of the approval conditions, the project team was endorsed by the nominee of the Secretary for the Department of Planning and Environment on 25th February 2019.

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Table 2- Project Team

Name	Company	Technical Area
Wade Covey	LakeCoal Pty Ltd	Environmental management
Chris Armit	LakeCoal Pty Ltd	Environmental, Geotechnical, Mining Engineering
David Hill	Strata2 Pty Ltd	Geotechnical Characterisation, Mine Design, Subsidence Estimation and Management
Tim Chisholm	LakeCoal Pty Ltd	Mine Surveying, Titles Management, Subsidence monitoring and reporting

Specialist consultants have also been utilised to undertake specialist assessments as part of this application. The technical reports resulting from these analyses have been used to formulate and update the relevant management plans by the project team. The project team worked closely with the specialist consultants and corresponded with them throughout the EP development phase and/or whilst developing the attached management plans.

The specialist consultants used are listed in **Table 3**.

Table 3 - Specialist Consultants

Management Plan	Developed By	Associated Specialist Company	Specialist Name	Specialisation/Notes
Extraction Plan Main Document	Wade Covey/Tim Chisholm/Ben Smith (LakeCoal)	Strata2	David Hill	Geotechnical Consultant
Groundwater	Geoterra	Geoterra	Andrew	As S2 and S3 EP area
Management Plan			Dawkins	contained wholly below Lake Macquarie, only relates to groundwater and water bores
Land Management Plan	Not applicable. S2	and S3 EP area co	ntained wholly I	pelow Lake Macquarie
Biodiversity Management Plan	Wade Covey (Lakecoal)	JSA Environmental	Jemma Sargent	Marine Ecology Assessment (including seagrass and benthic community assessment)
Heritage Management Plan	Not applicable. S2 and S3 area contained wholly below Lake Macquarie			

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Management Plan	Developed By	Associated Specialist Company	Specialist Name	Specialisation/Notes	
Built Features Management Plan	Not applicable. S2 and S3 EP area contained wholly below Lake Macquarie. Any further unanticipated requirement for BFMP triggered via Subsidence Management TARP				
Public Safety Management Plan	Wade Covey / Chris Armit (Lakecoal)	NA	NA	As relates to adjacent foreshore area features	
Rehabilitation Management Plan	Wade Covey /Chris Armit (Lakecoal)	NA	NA	As S2 and S3 EP area contained wholly below Lake Macquarie not requiring implementation of rehabilitation. Plan only relevant if impact outside of expected and impact to foreshore occurs	
Subsidence Monitoring Program	Tim Chisholm (LakeCoal)	MSEC	James Barbato	Subsidence predictions based on proposed mine plan	

2.2 Agency Consultation

The Department of Planning and Environment have been consulted at the commencement of Extraction Plan development. The Department of Planning and Environment – Resource Regulator have been consulted via the 2018-2020 Chain Valley and Mannering Mining Operations Plan in section 2.3.3.1 which was approved on 11 September 2018.

2.3 Landholder and Community Consultation

Landholders with registered water bores near Chain Valley Bay were contacted during the environmental assessment. No currently active water bores were identified as requiring management. Similarly, no further impacts to landholders are anticipated from the proposed extraction and thus no further consultation has been required. Landholders along the foreshore areas adjacent miniwall S2 and S3 have been consulted via letter box drops and face and face meetings regarding the development of subsidence monitoring program.

Consultation with the local community is undertaken via the site approved Community Consultative Committee (CCC). The committee meets quarterly and is provided with an operational update on Chain Valley Collieries underground operations. The CCC been provided with regular updates on the

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status of the sites subsidence monitoring and reporting, and the Extraction Plan for the application area.

2.4 Infrastructure Owner Consultation

The only infrastructure identified within the S2 and S3 extraction plan area of impact, relates to a navigational marker located off Summerland Point. The Roads and Maritime Services Project Officer (North Area) has was contacted during the development of the Extraction application for minimals S1 and N1 and referred the matter to the RMS asset team, resulting in no further immediate actions required in regard to management of the markers.

It is noted that the mine plan for the S2 and S3 Panels prepared for this EP Application results in manageable impacts to this marker.

2.5 Subsidence Predictions and Impact Review

The original subsidence assessment (**DGS**, **2015**) completed to support the modification SEE (MOD 2) reviewed available subsidence data as at the time of reporting (Chapter 7). This included updated subsidence data from Miniwalls 1 to 8, along with existing historic subsidence data from surrounding extracted areas. Later subsidence data over Miniwalls 1 to 12 revealed that actual subsidence was approximately 0.37m above the maximum predicted values (**DGS CHV-002-10b**).

It was assessed that time-dependent subsidence associated with chain pillar overloading in soft floor conditions was resulting in subsidence above original predictions (0.78m maximum predicted), with the data and associated analyses indicating that the subsidence is likely to be driven by:

- (i) the increase in span of the Munmorah Conglomerate and subsequent decrease in overburden stiffness, and
- (ii) the increased stress applied to the central chain pillars by the deflecting conglomerate likely to having exceeded the bearing strength of the moisture sensitive claystone floor strata.

These learnings have been incorporated into the S2 and S3 Panel design, in that:

- the plan is limited to two miniwall panels, thereby limiting the overall span created and
- the S2 to S3 inter-panel chain pillar width has been increased from 32.6m to 40m to limit pillar system deformation (**Strata2**, **2018**).

Updated subsidence predictions have been developed for this revised layout based on a combination of empirical and numerical modelling techniques (MSEC, 2018).

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The following surface and subsurface features of significance were identified from the assessments and area inspections within the zone of predicted subsidence (**Figure 4**), or with the potential to be affected by far-field movements as a result of the proposed Fassifern Seam workings. These include:

- Lake Macquarie and its bed sediments;
- Benthic fauna communities on the lake bed
- Seagrass beds
- Groundwater
- The Frying Pan Bay Navigational Marker off Summerland Point, within the Lake
- Jetties

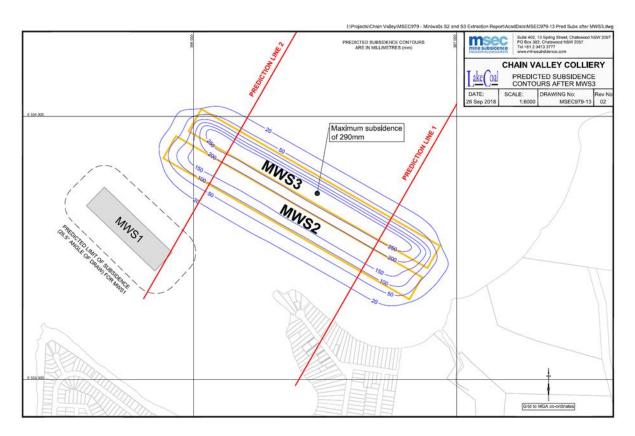


Figure 4: Predicted subsidence contours after S2 and S3

These have all been reassessed in terms of the updated subsidence predictions in **MSEC (2018)**, following a similar process to the previous applications and via the Extraction Plan Risk Assessment (**Appendix 1**).

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Additionally, the following surface and subsurface features are located adjacent to the immediate area of subsidence and as such will be managed, should unexpected changes / impacts occur in association with Fassifern Seam mining in the S2 and S3 Panels:

- Seagrass beds;
- High water mark (RL 0.0m to RL 2.44m AHD) along the lake foreshore
- Residential buildings and other built features adjacent the foreshore
- Moorings

3.0 Overview

3.1 Mine Planning and Design

3.1.1 Area covered by this Extraction Plan

The area adjacent the proposed workings has been extensively mined over the past 60 years, primarily in the overlying Wallarah Seam and, to a lesser extent, the Fassifern Seam (see **Plan 4**, **Appendix 9**). The North Mains first workings access the mining area on the Fassifern Seam, noting that previously extracted miniwall and bord and pillar panels are outside the angle of draw.

The Extraction Plan area consists of 2 minimal panels (S2 and S3) with a surface effect area covering 37ha wholly beneath Lake Macquarie (see **Figure 5**). Panels are aligned in a east-south-east to west-north-west orientation and S2 is planned to be extracted first. This could be changed without impact to subsidence management outcomes.

As all extraction and subsidence impacts from the proposed mining layout are beneath the lake, surface features are limited to the lake floor and the Frying Pan Bay navigational marker. It is not expected that the lake foreshore or surrounding seagrass will be impacted (see **Figure 5**). Mine design has been the primary control to limit impact or prevent predicted subsidence exceedance; thus the application of the High Water and Seagrass barriers, as well as the various mine plan changes indicated below.

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3.1.2 Proposed mine layout

In 2016, the operation unexpectedly encountered large-scale faulting, necessitating alternative mining areas be extracted whilst the Northern Domain could be further explored, mine plans reevaluated and approvals sought. This has contributed to the mine plan variation in this application. Primary considerations in this plan have been:

- Applying the learnings with respect to subsidence due to previous minimal extraction, as outlined in Section 2.5.
- Minimising the likely exposure of both panels to normal faults for safety, productivity and subsidence management purposes.
- Controlling the height of fracturing above the extracted area to meet rockhead thickness constraints.

The location and impact of the proposed mine design is generally consistent with the current State Significant Development Consent (SSD-5465 MOD 2). A summary of the mine design changes, informed by the mining studies and updated subsidence assessments implemented by LakeCoal in the proposed mining area are outlined below.

Table 4: Mine Plan Change

Approved Layout Change	Justification for Modification
Re-orientation of the panels from SE-NW to ESE-WNW	Maximise recovery and improved mining conditions. Increased seagrass protection barrier as a result of increased seagrass which had extended since the last survey.
Increase in S2 to S3 inter-panel chain pillar width from 32.6m to 40.0m (solid)	Limit pillar system deformation and maintain sub-critical overburden caving behaviour.

These modifications are considered generally consistent with the Development Consent and result in an overall reduction in impact, providing an example of adaptive management being applied to extraction within the mining area.

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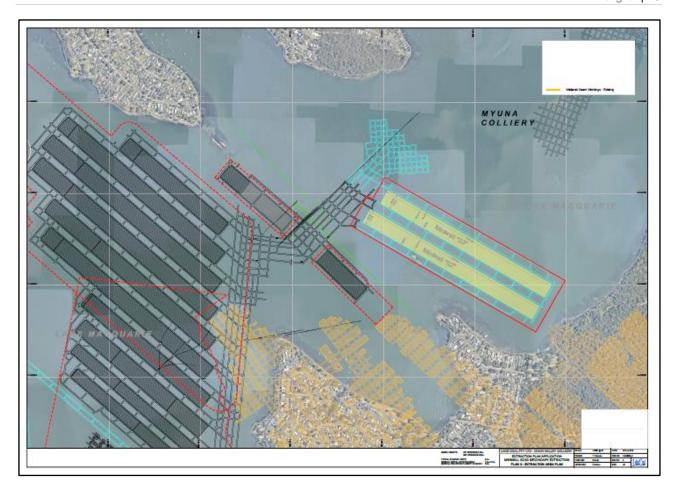


Figure 5- Aerial Photograph with mine plan overlay

3.1.3 Mining Domains (extracted and approved)

The extraction plan area is covered by mining lease/s and the domain areas described below as shown on Figure 6, and referenced in Plan 5, Appendix 9.

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Figure 6- Chain Valley Bay Leases and Land Ownership

Overlying Wallarah Seam Workings

Only previous Wallarah Seam partial extraction workings are associated with the Extraction Plan area these are adjacent to, but not directly above the proposed workings. The closest Wallarah first workings are located approximately 100m south of the starting position of MWS2. The Wallarah Seam workings are some 80m - 85m above the Fassifern Seam, with the interburden consisting of claystone, sandstone, coal seams and thick conglomerate beds. No subsidence or abutment loading interaction would be expected between the Fassifern and Wallarah Seam workings, due to the large barrier pillar.

Existing Chain Valley Colliery First Workings and Extraction

Extraction has occurred in the Fassifern Seam Miniwall's S1 and N1, south-west of the area and covered by a previous Extraction Plan. The first workings currently used to access Chain Valley Colliery and the Extraction Plan application area panels adjoin these extraction areas. No subsidence or abutment loading interaction would be expected between these domains, due to the large barrier pillar and long-term stable (life of mine) main heading pillars.

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Future Chain Valley Mining

It is proposed to limit extraction in the approval area to the two nominated panels (S2 and S3). This is intended to enable the mine to:

- gain additional monitoring data to validate updated subsidence predictions, improve knowledge on the subsidence development mechanisms and controls, as well as
- optimise the future layout.

This provides continuity of operations and minimises the risk of any further exceedance of predicted subsidence.

Accordingly, any further minimal extraction beyond these panels will be subject to a future extraction plan application.

3.1.4 Mining parameters

The proposed mining is via minimal methods with panel widths of 97m (total extracted void) accessed by a combination of:

- twin gateroads separated by 24.6m (solid width) chain pillars in the case of the S2 Tailgate and S3 Maingate and
- twin gateroads separated by 40.0m (solid width) chain pillars in the case of the S2 Maingate.
- single entries in the inbye portions and tailgates (see Plan 1, Appendix 9).

A miniwall is essentially a longwall with a reduced face width. Miniwall methods offer a low operating cost, high production rate and operationally safer alternative to pillar extraction mining methods previously employed at CVC. The reduced panel widths allow for the maintenance of bridging overburden conditions, reducing subsidence and improving face conditions.

The Fassifern Seam in the application area ranges between 4.5m and 4.9m thick, Depth of Cover (including sediment) is between approximately 160m and 180m. It is proposed to extract a maximum of 3.5m on the miniwall and 3.2m in development, leaving coal both on the floor and in the immediate roof. Floor coal provides a protective layer above the underlying claystones, which are highly susceptible to deterioration, if exposed to water and atmosphere. They are also readily broken up by mining equipment, greatly impacting roadway conditions where exposed. The roof coal is of significantly higher ash content and would negatively impact on the saleability of the coal product; left in place, it contributes to improved roadway roof conditions on development.

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Tables 5 to 8 provide a summary of key mining parameters for S2 to S3.

Table 5 - Coal Recovery within the Extraction Plan Area

Total Resource (Extraction Plan area 37.3ha)	3.0Mt
Total Development extraction	0.21Mt
Total Miniwall Extraction	0.97Mt
Total Reserves Extracted	1.18Mt
Percentage Recovery	39%

Table 6 - Miniwall Panel Geometry

Panel	Panel Length	Void Width	Extraction Height	ROM Tonnes
	(m)	(m)	(m)	(Mt)
S2	1075	97	3.5	0.48 Mt
S3	1043	97	3.5	0.49 Mt

Table 7- Fassifern Seam Parameters and Development Roadway Geometry

Panel	Seam Thickness	Depth of Cover	Drivage Width	Drivage Height
	(m)	(m)	(m)	(m)
S2	4.5 – 4.9	166 - 175	5.4	3.2
S3	4.6 – 4.9	164 - 168		

Table 8- Estimated Mining Schedule

Panel	Start Date	End Date	Estimated Duration (months)
S2	June 2019	October 2019	4
\$3	November 2019	March 2020	5

3.1.5 Previous Wallarah Seam workings and multi-seam interactions

The following was concluded in Section 3.5 of MSEC Report 979 (2018):

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- Historic partial extraction workings have been carried out in the panel located south-west of MWS2 and MWS3. The workings comprise 42m wide goafs (i.e. extracted pillars) between 18m by 18m remnant pillars. These historic workings are located 300m from MWS2 at their closest point, i.e. two times the depth of cover from the miniwalls. At this distance, it is very unlikely that the extraction of MWS2 and MWS3 would affect the load on or the stability of these historic workings.
- Historic first workings only have been carried out to the south-east of MWS2 and MWS3 and beneath the foreshore. These historic workings are located outside the 26.5° and 35° angles of draw. It is unlikely that the extraction of MWS2 and MWS3 would affect the load on or the stability of these historic first workings.

3.1.6 Special subsidence management features

Thin beds of claystone in the Fassifern Seam floor have been attributed to increases in floor heave under higher pillars loads associated with the extraction of multiple panels. The potential for increased subsidence effects associated with softening and lateral squeezing of the claystone has been noted and accounted for in the updated analyses. As per the **Strata2 Report CHV-006-Rev1** and **MSEC Report 979**, the limited final pillar stresses and high Stability Factors associated with the S2 and S3 Panel chain pillars are not anticipated to have any adverse or irregular subsidence effects.

Also, as previously noted, the S2 and S3 Panels are offset from the known and inferred faults, which are therefore not anticipated to have any adverse or irregular subsidence effects.

3.2 Subsidence Predictions

Subsidence magnitudes and impacts have previously been estimated for the proposed Life of Mine design for Chain Valley Colliery, including the area associated with this Extraction Plan (DGS, 2015). The methodology used to predict subsidence was originally based on the results of ACARP Project C10023 (ACARP, 2003) as well as a review of subsidence data from previously extracted MWs 1 to 9 at Chain Valley Colliery and nearby Mannering (Wyee) Colliery's LW17 to 23. This information was re-analysed for the MWs 1 to 12 exceedance investigation (DGS Report CHV-002-10b), leading to a revised subsidence assessment for the S1 and N1 Panels (DGS Report CHV-002-11a).

In assessing factors that influence subsidence for this S2 and S3 Panel Extraction Plan, a geotechnical mine design investigation was conducted by Strata2 Consulting (**Strata2**, **2018**). This document was used to inform the MSEC subsidence assessment. These two assessments built on

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the previous learnings with respect to subsidence impacts from previous miniwall extraction at the mine.

Specific consideration was given to:

- · depth of cover,
- rock head cover,
- panel width,
- · chain pillar geometry,
- · extraction height,
- the spanning capabilities of the conglomerate-dominated overburden,
- the properties of the floor (in particular the weak and moisture sensitive claystone units),
- the potential for additional long-term subsidence / creep,
- the location of the proposed extraction outside of both the HWMSB and the Seagrass Protection Barriers.
- the location of the workings with regard to previous workings in the same seam and other seams.

Predicted subsidence effect parameters for S2 and S3 Panels are summarised in Table 9.

Table 9 - Predicted Subsidence Effects (MSEC, 2018)

Panel	Subside	ence (m)	Angle of Draw	Long-Term Tilt & Systematic Strain Maxim (mm/m)		Strain Maxima
	Short-Term	Long-Term		Tilt	Tensile Strain	Compressive Strain
S2	0.1	0.3	<26.5°	6	1	3
S3	0.3	0.3	26.5°	6	1	3

3.2.1 Lakebed fracturing

Ditton (2015) indicated that, based on previous experience at nearby mines, it can be assumed that any surface cracking to the rock head below the lake bed sediments is likely to be minor for the predicted range of surface subsidence magnitudes. Tensile strains were predicted to be up to 1.5 mm/m and maximum crack widths were estimated to be < 20 mm at rock head.

MSEC (2018) arrived at a similar conclusion, with fractures of \leq 10mm at the rock head extending to a depth of up to 3m.

It is likely that any cracks that occur will be naturally 'filled' by lake bed sediments with no impact on the lake bed itself. The strains at the lake bed surface itself will also be more uniformly distributed and are therefore more likely to be absorbed by the plastic nature of the sediments.

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3.2.2 Sub-surface Fracturing

Two main methods have been adopted for estimating the height of sub-surface fracturing, namely:

- i) The model developed by Ditton and Merrick (2014) that has been used successfully for all previous minimal extraction at the mine and
- ii) The model developed by ACARP Project C13013 (SCT, 2008).

These outcomes are addressed below.

3.2.2.1 Ditton and Merrick (2014) Methodology

The Ditton and Merrick approach builds on the work of Whittaker and Reddish (1989) and Forster (1995). Figure 7 illustrates the nomenclature of the sub-surface fracturing model, . The predicted height of connective cracking is termed the "A Horizon" (Whittaker and Reddish) or "Fractured Zone" (Forster).

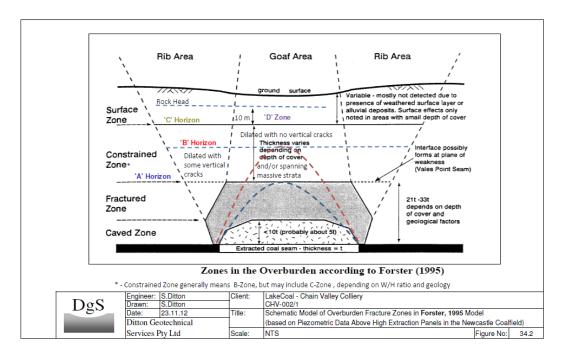


Figure 7- Overburden Fracture Zones (Ditton, 2013)

The **Ditton & Merrick (2014)** model includes the **Forster** data and may be used to assess both sub-critical and supercritical panel geometries, whereas the original **Forster** work focussed on super-critical panels. **DSG Report CHV-002-11a** back analysed sub-critical and supercritical behaviour relating to height of fracturing for previous Wyee and Chain Valley panels and found these models to provide reliable height of fracturing predictions.

The results for an extraction height (T) of 3.5m are summarised in **Table 10**.

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Table 10 - Predicted Heights of Fracturing Above Panels S2 and S3 (Strata2, 2018)

Panel	Effective Cover	Rock	"A Zone" Height Range	Thic below Roo	ned Zone kness k Head (m)
(S=Start) (F=Finish)	Depth (m)	Cover (m)	(Ditton and Merrick, 2014) (m)	Predicted Minimum from Ditton and Merrick (m)	12T Criterion (m)
S2 (S)	172	159	81 - 96	63	42
S2 (F)	170	147	81 - 95	52	42
S3 (S)	168	157	81 - 95	62	42
S3 (F)	166	144	80 - 94	50	42

The mine conducted a detailed geophysical survey of lakebed sediment thickness over the northern mining domain in early 2018, to obtain accurate rock head cover values. This survey has shown that the sediment is often thicker than previously estimated, particularly in the central lake area. In the S2 and S3 Panel area, the **Ditton and Merrick** model indicates that there is sufficient cover to meet a minimum constrained zoned thickness of 12T (**Forster, 1995**). This is considered acceptable given the quality of the data, the absence of major geological structures and the sub-critical nature of the panels. This is consistent with the successful application of the model in the MW1-12, CVB1, S1 and N1 areas, noting that MWs 11 and 12 involve similar depths of cover and haven't experienced any signs of interconnectivity.

3.2.2.2 SCT (2008) Methodology

The SCT approach also builds on the work of Whittaker and Reddish (1989) in that it links inflow experiences to subsidence and systematic tensile strains. Essentially, no issues are expected at strains of <4mm/m and major difficulties are anticipated at strains of >10mm/m (assuming a 'k' value of 0.6). These findings are consistent with those of Whittaker and Reddish, as well as Wardell (1975).

The local Chain Valley / Wyee experience is also consistent with that from elsewhere, with no inflow issues at low strain values. The predicted S2 and S3 Panel subsidence and systematic strain values are at the low end of the database, such that no issues are again anticipated.

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3.2.2.3 Conclusions regarding Sub-Surface Fracturing

The maintenance of a sub-critical panel geometry with subsidence at the low end of the historical range for minimal operations at the mine results in acceptable outcomes in terms of the height of connective fracturing for S2 and S3 Panels.

3.2.3 Potential Environmental Consequences

Based on the level of predicted maximum panel subsidence, tilt and strain values for the miniwall panel layouts, the potential for the following subsidence related impacts and their likely effect on the natural and man-made features within the Site have been assessed in the Statement of Environmental Effects (SEE) (2013 and 2015) and the Extraction Plan Risk Assessment (**Appendix 2**):

- Changes to lake bed level;
- Surface cracking beneath the lake bed;
- Height of sub-surface fracturing above the panels (direct and in-direct hydraulic connection zones) potentially impacting groundwater; and
- Impacts on the foreshore of Lake Macquarie and surrounding natural and manmade features inclusive of public safe risks.

The Extraction Plan risk assessment additionally evaluated overall environmental risk (as it relates to subsidence impact) for the extraction plan area. From this and via application of mine design controls (**Section 3.1.2**) along with monitoring and response management systems (i.e. TARPs), the risk of irregular subsidence impacting the foreshore or sensitive environmental features was considered highly unlikely.

In terms of changes to the lake bed level as a result of subsidence, the resultant impact on Benthic communities, Seagrass communities and wave climate have been assessed within the SEE. A Marine Ecology Impact Assessment was conducted by JSA Environmental as part of the SEE completed by EMM in 2013 and reviewed in 2015 which included the full Extraction Plan area. As part of the previous extraction plan assessment, an aquatic biological survey was conducted including soft bottom benthic communities and seagrass mapping. Ground truthing of the seagrass beds since the original mapping has been utilised along with additional mapping data and satellite imagery to provide the most accurate location of seagrass beds at the time of this application and as such protection barrier offsets for mine design.

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Considering the survey results, the proposed mine plan and the modelled subsidence predictions, JSA Environmental concluded that there would be no more than minor impacts on Benthic Communities and negligible impacts on seagrass levels as a result of the proposed mining. This has been supported through the monitoring results over time. Given the additional mine plan controls since the SEE, these impacts would not be expected to increase. Bathymetric surveys conducted by Astute Surveying have been increased to 6 monthly to validate and update predictions and control effectiveness, including survey prior to any secondary extraction within the application area. The results of the bathymetric surveys will be used to confirm the predicted subsidence levels and the mapping of seagrass levels and benthic communities will be ongoing throughout the period of extraction within the application. This will confirm that subsidence and associated impacts are being maintained within predicted levels.

Leading wave climate experts from the University of New South Wales, Water Research Laboratory concluded that the predicted subsidence will not affect the wave climate sufficiently to have adverse shoreline impacts. Changes to the sea bed level will also have the potential to impact man made features.

In regards to surface cracking beneath the lake bed, as stated above, the strains at the lake bed surface itself are expected to be more uniformly distributed and are therefore more likely to be absorbed by the plastic nature of the sediments. Any cracks are therefore likely be naturally filled by lake sediments with no significant impact on the lake bed itself. The predicted heights of continuous and discontinuous fracturing above the proposed miniwalls are below the logged rock head thickness above the panels, and provide for sufficient constrained zone thickness at the adjusted extraction heights. As such, it is considered very unlikely that hydraulic connection between the lake and the mine workings will occur, or that connection between mining related fractures and the lake will cause significant impacts on the lake. Additional monitoring, including extension of the site's subsidence management TARP, will be put in place to monitor for early signs of unexpected subsidence.

In regard to the surface features, namely the lake foreshore and features surrounding the foreshore, both the HWMSB and the Seagrass Protection Barrier have been closely applied in the mine design process. Routine monitoring and TARPs will still be applied to identify and respond to any unanticipated changes as a result of Fassifern Seam extraction, and further adaptive management and contingency controls will be implemented as required. The risk assessment for the extraction plan area identified the potential impact to navigational markers as a key variable for the extraction plan. At the predicted subsidence levels each is considered easily manageable and will also be done so via the Subsidence Management TARP.

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Table 13- Navigation Marker Predicted Subsidence Parameters

Location / ID	Predicted Subsidence (m)	Predicted Tilt (mm/m)
Frying Pan Bay (Adjacent to S2)	<0.1	1

3.3 Performance Objectives

3.3.1 Development Consent Approval Requirements

Condition 1, Schedule 4 of SSD-5465 states:

"The Applicant shall ensure that vertical subsidence within the High Water Mark Subsidence Barrier and within Seagrass beds is limited to a maximum of 20 millimetres (mm). If at any stage predicted subsidence levels are exceeded within these area, an ecological monitoring program shall be initiated to assess the impacts to ecological communities and threatened species and if appropriate, offsets are to be provided for any impacts detected"

At present there is no expectation that predicted subsidence levels will be exceeded based on actual subsidence monitoring and the recently (2018) updated subsidence predictions. The adopted mine design has been developed to result in no additional subsidence impact due to Fassifern Seam extraction in the High Water barrier or Seagrass. Despite this, a Subsidence Management TARP is to be implemented as outlined in **Section 3.4** of this management plan to deal with unanticipated subsidence monitoring results in a proactive manner should in the unlikely event they occur.

In addition to the above, Condition 2 within Schedule 4 of SSD-5465 also requires that:

"The Applicant shall ensure that the development does not cause any exceedance of the performance measures in Table 8 to the satisfaction of the Secretary."

The relevant subsidence requirements from Table 8 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 14**.

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Table 14 - Performance Measures - Natural & Heritage Features

Biodiversity	
Threatened species or endangered populations	Negligible environmental consequences
Seagrass beds	Negligible environmental consequences including:
	 Negligible changes in size and distribution of seagrass beds;
	Negligible change in the function of seagrass beds; and
	 Negligible change to the composition or distribution of seagrass species within seagrass beds.
Benthic communities	Minor environmental consequences, including minor changes to species composition and/or distribution
Mine Workings	
First Workings under an approved Extraction Plan beneath any feature where performance measures in this table require negligible environmental consequences	To remain long term stable and non-subsiding
Second Workings	To be carried out only in accordance with and approved Extraction Plan.

Notes:

- The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.
- The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.

Fassifern Seam first workings in the Extraction Plan area, are not beneath any feature outlined in **Table 14**. Should a change to first workings necessitate this, the first workings will be designed to be long term stable.

Again a Subsidence Management TARP will be implemented as outlined in **Section 3.4** of this management plan to deal with such matters in a proactive manner should in the unlikely event more than negligible/minor impacts occur. The TARP also includes more detailed performance indicators.

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Condition 4 within Schedule 4 of SSD-5465 also requires that:

"The Applicant shall ensure that the development does not cause any exceedances of the performance measures in Table 9, to the satisfaction of the Secretary.

The relevant subsidence requirements from Table 9 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 15**.

Table 15 – Subsidence Impact Performance Measures – Built Features

Built Features		
Trinity Point Marina Development Other built features	 Always safe Serviceability should be maintained wherever practicable. Loss of serviceability must be fully compensated Damage must be fully compensated 	
Public Safety		
Public Safety	Negligible additional risk	

Notes

- The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in measures in the Built Features Management Plans or Public Safety Management Plan (see Condition 7 below).
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.
- The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.
- Requirement's regarding safety or serviceability do not preclude preventative actions or mitigation being taken prior to or during mining in order to achieve or maintain these outcomes.
- Requirement's under this condition may be met by measures undertaken in accordance with the Mine Subsidence Compensation Act 1961

The extraction plan area is outside any zone that may affect the Trinity Point Marina Development.

Again a Subsidence Management TARP will be implemented as outlined in **Section 3.4** of this management plan to deal with other Built Feature or Public Safety matters in a proactive manner. The TARP also includes more detailed performance indicators.

3.3.2 Other Approval Requirements

Additional to Approvals required under Development Consent SSD-5465, LakeCoal will require the following related approvals or notifications prior to extraction in the area:

• Secondary Extraction High Risk Activity Notification required under Clause 33 (1) of the Work Health and Safety (Mines) Regulations 2014.

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3.4 Subsidence Management Strategies

3.4.1 Mine design elements

Mine design parameters such as panel start and finish position, panel width, chain pillar width and barrier pillar width in conjunction with an assessment of overlying strata, depth of cover and depth of rock head all contribute to the management of vertical subsidence effect and impacts. Whilst, restricting the mine design such that no secondary extraction occurs within the High Water Mark Subsidence Barrier and the Seagrass Protection Barrier to ensure that there are no significant impacts on the foreshore of Lake Macquarie or the seagrass communities in the shallow foreshore areas.

The outcomes of the updated subsidence predictions have further informed the mine design strategies to be undertaken as outlined in **Section 3.1.2**. Adaptive management recommendations have been applied to the final mine design.

3.4.2 Subsidence Monitoring and Management

The overall framework for subsidence monitoring and management of impacts under this Extraction Plan may is described by:



Figure 10- Subsidence Monitoring and Management Framework

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Details as to the respective triggers/performance indicators (including actual measured subsidence and inspections for environmental impact) as they relate to each environmental management function are found in the respective Key Component Plans (**Section 4**). These management plans also include specific information regarding the subsidence monitoring requirements (including baseline monitoring), remediation and adaptive management techniques and contingency plans. All of which are summarised in the Subsidence Management Trigger Action Response Plan (TARP) included in **Appendix 2**. The TARP aims to consolidate all subsidence management requirements into a central focus point, triggering a response or set of responses commensurate with the nature of the measurement or the impact that has been identified.

3.4.3 Remediation strategies

Remediation strategies are incorporated into the Subsidence Management TARP (**Appendix 2**). These also follow the principals outlined in the current Rehabilitation Management Plan (see **Appendix 8**). Mining and associated impacts in the extraction area are identical to that proposed elsewhere in the current MOP and as such, no modifications to the existing Rehabilitation Management Plan are required for the submission of this document.

3.4.4 Adaptive Management Strategy

The CVC Subsidence Management TARP includes a series of triggers and responses to impacts that exceed those predicted. The extensive mining history in and around this area of the lake has greatly improved the ability to predict subsidence levels and developed mine design guidelines to protect against foreshore, seagrass and lake bed impacts. That combined with the recent history at CVC using similarly designed miniwall panels suggests that exceedances of predicted subsidence effects and impacts are unlikely. However, the routine collection of data such as regular bathymetric surveys, foreshore subsidence surveys, ground water assessment, seagrass mapping and benthic community surveys will allow rapid and proactive verification of both initial and final subsidence effects and impacts such that adaptive measures such as mine design changes, increased barrier pillars, widening of protection zones etc can all be undertaken in a timely manner to mitigate against and minimise the impact of these unforeseen exceedances.

3.4.5 Procedures for investigation of incidents

In accordance with Condition 6 Schedule 7 of Development Consent SSD-5465 CVC will notify the Secretary and any other relevant agencies, of any incident or non-compliance or exceedance of

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performance criteria associated with the Extraction Plan performance at the mine complex as soon as practicable after CVC becomes aware of the incident.

Within 7 days of the date of the incident or non-compliance, CVC will provide a detailed report on the incident to the Secretary and any other relevant agencies that have been notified. The incident investigation will follow the CVC incident reporting and investigation policy.

3.4.6 Procedures for quality assurance and review

The results of monitoring undertaken in accordance with this Extraction Plan will be provided on a quarterly basis to the CVC Community Consultative Committee.

Regular review of the Extraction Plan and/or any of the sub-plans is required by SSD-5465. In particular, CVC is required to review, and if necessary revise, the strategies, plans, and programs of this Extraction Plan within 3 months of the submission of an:

- Audit under condition 9 of schedule 6;
- Incident report under condition 7 of schedule 6; and
- Annual Review under condition 4 of schedule 6.

Any revision to the Extraction Plan including component sub-plans must be completed to the satisfaction of the Secretary.

3.4.7 Complaints

Complaints in relation to the management of subsidence will be managed using the established protocols in the CVC Environmental Management System.

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4.0 Key Component Plans

Management of impacts identified via the Subsidence Monitoring Program under this Extraction Plan (Section 5), are commensurate with the nature of the measurement or the impact which has been identified. The Extraction Plan relies on a set of individual management (Key Component) plans to address these impacts to particular environmental or built features within the Extraction Plan Area. As per the Guidelines, six (6) key component plans are to be considered as per Table 16, however following the risk assessment (Appendix 2) for the extraction plan area, particular to S2 and S3 only, LakeCoal has determined that only three (3) key component plans are relevant to this application and as such have been developed as a part of this Extraction Plan. As part of the Extraction Plan application/approval process LakeCoal seeks the Secretary's endorsement/approval that the identified key component plans are not required for this Extraction Plan.

Whilst a Built Features, Land Management Plan and a Heritage Management Plan are specific requirements of the Approval Condition 7 in Schedule 4, the notes below Condition 3 of Schedule 6 in the Approval Conditions state "The Secretary may waive some of these requirements if they are unnecessary or unwarranted for particular management plans", and as such it is considered that these plans are not required.

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Table 16 – Key Component Plan Requirements

	Relevant to S2 and S3	Comments
Groundwater Management Plan	Yes	Ground water extraction and water bore drawdown managed via groundwater management plan which is part of the updated Groundwater Management Plan.
Land Management Plan	No	S2 and S3 are wholly contained below lake Macquarie and as such extraction itself will not have any effect on land management being controlled via the application of the High Water Mark Subsidence Barrier and Mine Design recommendations
Biodiversity Management Plan	Yes	The existing site Biodiversity Management Plan incorporates two separate management plans relevant to S2 and S3 extraction; the Seagrass and Benthic Community Management Plans
Heritage Management Plan	No	S2 and S3 are wholly contained below lake Macquarie and as such extraction itself will not have any effect on Heritage items being controlled via the application of the High Water Mark Subsidence Barrier
Built Features Management Plan	No	S2 and S3 are wholly contained below lake Macquarie and as such extraction itself will not have any effect on built features above the High Water Mark. No features were identified as requiring direct management within the lake area impacted by S2 and S3. Navigation markers will be monitored but are not expected to require any management and thus will be triggered via a TARP for unexpected impact.
Public Safety Management Plan	Yes	Foreshore potentially only impacted due to far field movement near cliffs with very low likelihood of impact resulting in public safety risk increase

Each of the relevant Key Component Plans are located in the Appendices. Below provides a summary of the intent of each and where an existing site management plans is utilised, how it relates to the S2 and S3 Extraction Plan Area.

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Groundwater Management Plan

As it relates to S2 and S3 extraction, the CVC Groundwater Management Plan (contained within the CVC Water Management Plan) covers the risk assessment (**Appendix 1**) identified impacts of regional groundwater drawdown and reduction of private water bore yields. Whilst in both instances due to the existing large extent of depressurisation from historical mining, the impact created via the extraction plan area is considered negligible, controls have been adopted including:

- Continuation of the groundwater monitoring program
- Faults or dykes within the extraction panel are to be assessed case by case as to whether an extraction barrier is required to prevent hydraulic connection.
- Where access is available, monitoring of bore yields, saturated thickness and quality. Where
 additional mining related impact can be proven, an alternative water supply will be provided
 until the bore recovers

The groundwater management plan was updated as part of this extraction plan. Other potential water related impact risks due to extraction are either not applicable due to the extraction being contained wholly below Lake Macquarie, or not relevant due to no risk of impact.

Biodiversity Management Plan

The site Biodiversity Management Plan was reviewed in 2016. As it relates to S2 and S3 extraction, only the Seagrass and Benthic Community Management Plan components are applicable to this Extraction Plan. These are located in **Appendices 5 and 4** respectively. As the Seagrass Management Plan also directly relates to potential biodiversity impact to the only threatened species (sea turtles), this management plan also serves to manage this aspect. Both of these plans have been reviewed and updated as a part of this extraction plan, including the addition of new control and sample monitoring sites. Both of these management plans have been submitted for consultation with the relevant stakeholders as identified in SSD 5465. Evidence of this consultation is provided at the back of each management plan.

Bathymetric surveys, Benthic and Seagrass monitoring as well the review and allocation of new seagrass and benthic monitoring locations will be the primary control to identify if any adaptive management is required as a result of mining. This monitoring is tailored to confirm that negligible changes are being recorded as required by the Consent. If impacts are identified that are outside the mines approved performance criteria LakeCoal will investigate and undertake an assessment of the

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impacts. If the impacts cannot be remediated a suitable offset will be provided in accordance with Condition 3, Schedule 4 of SSD 5465.

Public Safety and Built Features Management Plans

All mining activities within the application area are to occur beneath Lake Macquarie and as such will have no direct impact on surface facilities and infrastructure. One Navigational marker located off Frying Pan Bay (S2) is predicted to have negligible subsidence impacts. Roads and Maritime have been consulted in relation to these and the level of subsidence impact, and have concluded that no direct management will be required and the markers will be able to be monitored as a part of their routine inspections. All proposed secondary extraction is located outside of both the High Water Mark Subsidence Barrier and Seagrass Protection Zone and as such, no adverse impacts are anticipated on the immediate foreshore of Lake Macquarie as a result of Fassifern Seam extraction.

Based on Chain Valley Colliery's approved mine design principles mining is not expected to result in any noticeable impacts along foreshore areas. Despite this, CVC will monitor the foreshore zone for any sign of change and if impacts are observed to be occurring, as a result of mining, a review of public safety measures will be triggered via the Subsidence Management TARP in consultation with the relevant authorities. Actions will be implemented by LakeCoal to reduce the risk to the Public in unlikely circumstance that impacts are identified outside those predicted and approved.

No other immediate increase in public safety risks were identified, associated with any horizontal movement at the foreshore.

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5.0 Subsidence Effects and Environmental Monitoring Program

5.1 Monitoring Program Summary

The proposed Subsidence Monitoring Program is included in **Appendix 7** of this document. Environmental monitoring programs are contained within each of the relevant Key Component Plans. Essentially, subsidence management at CVC is achieved through a combination of mine design and continual monitoring of key subsidence related effects and impacts via the Subsidence Management TARP. Regular and routine monitoring of the foreshore, lake bed, seagrass communities and benthic communities provide a means to verify and validate that predicted subsidence levels are not being exceeded, and that the resultant levels of subsidence are not resulting in excessive impacts beyond those predicted. The mine design can then be adapted and refined as required if exceedances occur or are likely to occur.

Bathymetric surveys of the lake bed and surveys of the foreshore will be used to validate and confirm the predicted vertical subsidence around the miniwall panels. In addition ongoing environmental monitoring in the form of benthic and seagrass community surveys will ensure that the resultant vertical subsidence levels are not resulting in more significant impacts than predicted. **Appendix 4** and 5 contain the mine's Benthic Community and Seagrass Management Plans.

Monitoring of sub-surface fracture heights above some of the miniwall panels would usually be recommended within the mining area to confirm the predictions of potential areas of connective surface cracking. Due to the presence of the lake however, measurement of sub-surface fracture heights above the proposed miniwalls is not recommended due to the risks associated with the drilling from a barge and potential intersection with goafs from barge mounted drilling rigs after mining a given panel. However, monitoring of groundwater inflow rates will be utilised to provide an indirect measure of connectivity between the lake and mine workings.

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Ongoing inspections, monitoring and mapping of the stability of underground workings will continue along with assessment of groundwater monitoring data. In particular, the presence of a fault, dyke or joint shear zone that may have the potential to cause a hydraulic connection between the fracture zones, causing abnormal inflows, will be assessed on a case by case basis.

As stated above, the strains at the lake bed surface itself will also be more uniformly distributed and are therefore more likely to be absorbed by the plastic nature of the sediments. Accordingly, no monitoring or remediation for the potential minor cracking will be required as may be undertaken for land based cracking.

All of these management and monitoring techniques are consolidated in the Subsidence Management TARP (**Appendix 2**). The overall system not only provides an effective means of management of subsidence effects and impacts, but also the collection of appropriate data to inform future extraction plans.

6.0 Plan Implementation

6.1 Reporting Incident Reporting

Refer to **Section 3.4.5** of this document.

Regular Reporting

Regular reporting will be undertaken in accordance with the Approval Conditions and the relevant site environmental management plans. This reporting will be provided to all relevant agencies as well as posted on the mine's website and discussed at the mine operated community consultation committee meetings.

Annual Reporting

As per Condition 4 of Schedule 6, by the end of March each year, or other timing as may be agreed by the Secretary), the mine will review the environmental performance for the previous year and submit this review as an annual report.

This review will include:

(a) Describe the development (including any rehabilitation) that was carried out in the past calendar year, and the development that is proposed to be carried out over the current calendar year;

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- (b) Include a comprehensive review of the monitoring results and complaints records of the development over the past calendar year, which includes a comparison of these results against the:
 - relevant statutory requirements, limits or performance measures/criteria;
 - requirements of any plan or program required under this consent;
 - monitoring results of previous years; and relevant predictions in the EIS;
- (c) Identify any non-compliance over the past calendar year, and describe what actions were (or are being) taken to ensure compliance;
- (d) Identify any trends in the monitoring data over the life of the development;
- (e) Identify any discrepancies between the predicted and actual impacts of the development, and analyse the potential cause of any significant discrepancies; and
- (f) Describe what measures will be implemented over the current financial year to improve the environmental performance of the development.

6.2 Review

Reviews of this document and all other relevant environmental management plans will be undertaken within 3 months of the submission of the annual review and/or incident report or independent audits. If necessary, this review will also include required revisions to the associated plans. If revisions are made, within 4 weeks of the review, the revised plans will be submitted to the Secretary for approval. In addition to routine auditing and reviewing of the environmental management plans, by the end of February 2016 and on a 3 yearly basis after that, the mines' environmental management systems will be independently reviewed by external experts suitably qualified to undertake such a review.

6.3 Responsibilities

Whilst the overall responsibility for the implementation of this extraction plan sits with the Manager of Mining Engineering, various others within the organisational structure have responsibilities under this plan to ensure that it is effectively implemented. **Table 17** outlines the key personnel and their individual responsibilities with regard to the implementation of this plan.

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Table 17 - Roles and Responsibilities

Role	Responsibilities
Manager of Mining Engineering	Provide adequate resources for the activities required under this plan
	Ensure all operations are undertaken in accordance with this plan
	Ensure all mining is undertaken in accordance to approved mine plans
Technical Services Manager	Provide adequate resources for the activities required under this plan
	 Provide technical review and assistance during the development of the extraction plan and its appendices.
	Coordinate technical sub consultants used as part of this extraction plan.
Environment and Community Coordinator	Coordinate and undertake all environmental monitoring required under this document
	Ensure all reporting and monitoring is completed to an appropriate standard and in a timely manner
	 Ensure any discrepancies between actual monitoring results and predicted outcomes are reported to appropriate stakeholders as soon as practicable
	Manage the implementation of all environmental management plans under this document
	Be responsible for all environmental reports, management plans, community consultation and communication with stakeholders and departmental authorities
Mine Surveyor	Preparation of the Subsidence monitoring program
	Coordinate and undertake all subsidence monitoring required under the Subsidence Monitoring Program
	Maintain plans and records of all subsidence monitoring
	 Distribute survey data to the relevant stakeholders within agreed timeframes
	 Report any discrepancies and/or exceedances of actual survey results from expected/predicted data to the E&C Coordinator and Manager of Mining Engineering
	Prepare all subsidence related reporting to an appropriate standard

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7.0 References

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DgS (2015). Subsidence Predictions and General Impact Assessment for the Chain Valley Colliery – Modification 2. Report No. CHV-002/4.

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SCT (2008). **Aquifer Inflow Prediction above Longwall Panels**. End of Grant Report for ACARP Project No. C13013.

Strata2 (2018). **Geotechnical Aspects of S2 and S3 Panel Design**. Report No. CHV-006-Rev1 to Lake Coal.

Whittaker, B.N. and Reddish, D.J. (1989). **Subsidence: Occurrence, Prediction and Control**. Development in Geotechnical Engineering Series, 56, Elsevier Science Publishing.

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WRAC Risk Assessment

Workplace Risk Assessment & Control

RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

Site: Chain Valley Colliery

Date: 25/02/2019

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RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

No:	RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment		
Topic	S2 and S3 Miniwall Extraction F	Plan Risk Assessment	
Venue	CVC Boardroom		
Requested by:	Wade Covey Environment and Community Coordinator	Date: 25/02/2019	Time allowed: ½ day
Facilitator	Wade Covey Environment and Community Coordinator		

Relevant Risk Assessment Documents/Procedures/Safety Alerts/Safety Bulletins

- MSEC (2018) Subsidence Assessment S2/S3 Miniwall panels
- Strata2 Geotechnical Assessment S2/S3 Miniwall panels

Persons participating in Risk Assessment

Name	Position	Years' Experience in Industry	Signature
Chris Almit.	Environmental Mining Grown,	19	Chest.
David Hill	Gestechnical Engineer	39	1300
Lian Krick	Geotzehnical Engineer DENVIORMENTER COORDINATE	7	Carlot
Dode Cover	Environmental Coordinata	13	Marie
	,		
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RISK ASSESSMENT

S2 and S3 Miniwall Extraction Plan Risk Assessment

RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

Purpose

This risk assessment has been conducted to assess and document potential surface and sub-surface subsidence risks associated with mining of Northern Mining Domains (NMD) Miniwall's S2 to S3.

Objectives and Scope

The objectives of this risk assessment are to:

- Identify hazards and assess the risk associated with environmental, public safety and surface built feature impacts from extraction.
- Ensure compliance with the WHS (Mines) Regulation 2014 Clause 67 Subsidence:
 - (1) In complying with clause 9, the mine operator of an underground coal mine must manage risks to health and safety associated with subsidence at the mine.
 - (2) Without limiting subclause (1), the mine operator must ensure that:
 - (a) So far as is reasonably practicable, the rate, method, layout, schedule and sequence of mining operations do not put the health and safety of any person at risk from subsidence, and
 - (b) Monitoring of subsidence is conducted, including monitoring of its effects on relevant surface and subsurface features, and
 - (c) Any investigation of subsidence and any interpretation of subsidence information is carried out only by a competent person, and
 - (d) All subsidence monitoring data is provided to the regulator in the form and at the times required by the regulator, and
 - (e) So far as reasonably practicable, procedures are implemented for the effective consultation, co-operation and co-ordination of action with respect to subsidence between the mine operator and relevant persons conducting any business or undertaking that is, or is likely to be, affected by subsidence.
- Meet (where applicable) the standards for assessing and managing risks of subsidence as outlined in the "Managing Risks of Subsidence Guideline", February 2017.
- Place a particular focus on recently updated subsidence predictions and recommendations for the area including a review of causal factors behind the exceedance of subsidence predictions over the MW 1 to 12 area.
- Identify the existing and potential controls to reduce the risk to a reasonable practicable level.

The scope of the risk assessment focuses on the extraction area defined by a 35 degree angle of draw or to the predicted 20mm subsidence contour of S2 to S3 (see **Figure 1**). The level of monitoring strategy

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required will be commensurate with the assessed level of risk (ie after controls are put in place) or potential consequence. The corresponding residual risk will determine if these controls are sufficiently acceptable.

The list of surface and sub-surface features outlined in Appendix B of the 2003 NSW Department of Mineral Resources Guidelines for Application for Subsidence Management Approvals, along with items outlined in the 2017 Managing Risks of Subsidence Guideline, have been used as a starting reference list of features for assessment. All features on the list were assessed as to whether they exist within the defined extraction plan area. Where a feature is not noted in the WRAC assessment, it has not been identified within the area of interest.



Figure 1- NMD S2 to S3 Extraction Impact area (area of change) due to Fassifern Miniwall Mining

Risk Assessment Process

- 1. Hazard identification
- 2. Identified hazards were evaluated with regard to consequence and then the Likelihood of that consequence outcome was assessed, assuming existing controls to be effectively implemented.
- 3. Risk rankings were derived.

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- 4. Additional controls were proposed where possible for medium and high risks and the hazards were reevaluated to arrive at the residual risk.
- 5. Likelihood and consequence were assessed in accordance AS/NZS ISO 31000:2009 Risk Management Principles and guidelines.
- 6. This risk assessment was conducted in general compliance with MDG1010 and MDG1014.
- 7. As low as reasonably practicable (ALARP) is determined from WHS Act 2011, Section 18.
- 8. Hazardous Manual Tasks should be identified and controlled to a reasonable practicable level of risk using the Risk Assessment Worksheet for Hazardous Manual Tasks Form and actions recorded in this risk assessment.
- 9. Actions and outcomes from the risk assessment are recorded with a due date of action completion and responsible person.
- 10. Risk Assessments are monitored and reviewed as detailed by the LakeCoal Site Work Health and Safety Management System.

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Risk Assessment Checklist based on Hazard / Energy Types

	POTENTIAL HAZARDS				
Energy Type	To People	To Equipment	To Production	To The Environment	
Electrical	Electric ShockBurnsSmoke Inhalation	Unplanned movementFireCircuit Damage	 Supply fails causing shutdown Inadequate supply causing process slowdown 	• Fire	
Mechanical	 Crushed Struck by Moving or Flying Objects Caught Between Moving Objects 	 Collision Breakdown Unplanned Movement Breakages Vibration 	Fails & Causes ShutdownSlows Down Production	Physical DamageFire	
Chemical	 Burns Skin Irritation Ingestion Inhalation (Toxic atmospheres) Explosion (Mixing incompatible) 	FireInternal DamageCorrosion	Causes Delays or Shutdowns (Not enough, wrong type to much)	Spillage (Water contamination, soil contamination, air pollution, vegetation destroyed)	
Pressure (Fluids/Gases)	Fluid InjectionCrushRespiratory Problems	Unplanned MovementPoor PerformanceBreakdown	Equipment Failure Shutdown (No fluids or to much fluids, no gases or to much gases)	Contamination (Dust, fuel/oil, dirty water0	
Radiation	BurnsEye Damage (welding flash)Internal problems		Source fails (Causing delays or shutdown)	Contamination	
Thermal	BurnsHeat ExhaustionFrostbite	Overheating Freezing	Shutdown (Overheating or freezing)		
Biochemical	SprainsStrains		Slowdown due to loss of staff		
Noise/Vibration	Hearing damage	Mechanical damage	Slowdown due to people not accessing area	Community complaints	
Biological	IllnessDisease		Shutdown due to lack of people		
Gravitational	 Falling from Heights Objects falling on Personnel 	RolloverCollapseFailureDamage from fallDamage from	Objects falling causing slowdown or shutdown	Contamination	

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	objects falling	



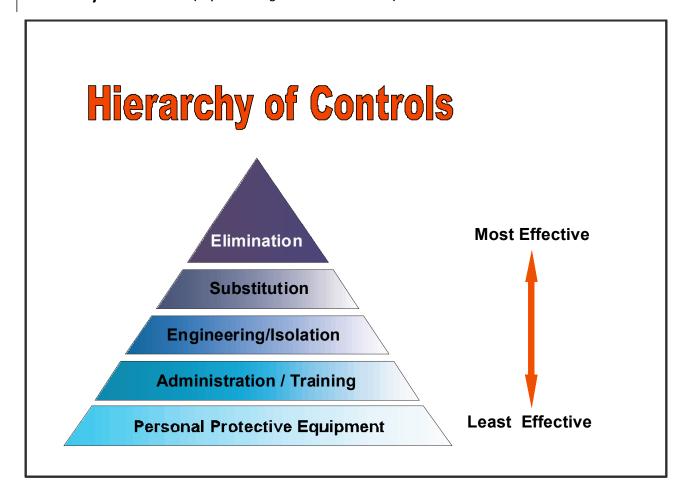
S2 and S3 Miniwall Extraction Plan Risk Assessment

Elimination Substitution Redesign/Enginee		HIERARCHY OF CONTROL o we still have to do this?			- 1		Risk Matrix							
Substitution		we still have to do this?		HIERARCHY OF CONTROL				LIKELIHOOD						
	ls t				Α	Almost certain to happ	en		1 per week	to 1 per month				
Redesign/Enginee		there another way or product?			В	Likely to happen at son	ne point	3	1 per mont	h to 1 per year				
	r Ca	in the equipment or process be modified?			С	Moderate, possible; he	ard of so it might	nappen	1 per year	to 1 per 10 years				
Isolation/Guarding	g Wi	ill guarding or some type of barrier help?			D	Unlikely, not likely to h	appen		1 per 10 ye	ars to 1 per 100 ye	ars			
Administration	Wi	ill a written procedure and/or training help	?		E	Rare, practically impos	sible		Less than 1	per 100 years				
PPE	ls į	personal protective equipment adequate?												
MAXIMUM REASONABLE CONSEQUENCE														
Consequence	E	Injury (I)			E	ENVIRONMENTAL (E)				Loss (L)				
1 - Critical	Со	ould kill, permanently disable	-	Regional environmental impact/ecosystem damage. Impact causing mine or business closure. E.g. Major release off site with long term detrimental effect				Could caus	Could cause very major damage > \$3M					
2 - High	Со	ould cause serious injury (major LTI)		Substantial environmental damage which could result in major financial loss and/or prosecution. E.g. Off-site release resulting in local ecosystem damage Could cause major				cause major damage \$500K - \$3M						
3 - MEDIUM	Со	ould cause typical MTC/LTI		•	_	mage, release immediat on spill. Legal non-compl	•	outside assistanc	e eg. Could caus	Could cause moderate damage \$100K - \$500K				
4 - Low	Co	ould cause first aid injury	Temporary or minor spill	damage,	non-complianc	e with internal environn	nental target, no le	egal breach, eg. Mi	Could caus	Could cause damage \$20K - \$100K				
5 - Insignifican	VT Co	ouldn't cause injury	No detrimental effec	t, low fin	ancial loss, neg	ligible environmental im	pact		Couldn't ca	Couldn't cause damage, or <\$20K damage				
					Risk Scor	e Matrix								
RISK SCORE	Risk	What should I do	?				LIKELIHO	DD						
1 to 3	Critical	STOP WORK Immediate action required management	, inform senior			A- Certain	B - Likely	C - Moderate	D - Unlikely	E - Rare	Least Effective			
4 to 10	High	Risk Assessment required. Action plan r			1 - Critical	1	2	4	7	11	1			
		management attention needed	2 - Hi		2 - High	3	5	8	12	16				
11 to 15	Medium	Specific monitoring of procedures requires responsibility must be specified	ed management		3 - Medium	6	9	13	17	20				
16 to 25	Low	Manage through routine procedures			4 - Low 5 - Insignificant	10 t 15	14 19	18	21	23	Most Effective			

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Hierarchy of Controls (as per WHS Regulations 2011 Clause 36)



HIERARCHY OF CONTROLS	1-6 Descending Order(as per WHS Regulations 2011 Clause 36)			
Elimination	Remove the hazard from the workplace (Re-Design)			
Substitution	Substituting (wholly or partly) the hazard giving rise to the risk with something that gives rise to a lesser risk. (Alternative product / plant)			
Isolation	Isolating the hazard from any person exposed to it. Use barriers to shield or isolate the hazard (Guards on machines, enclosures for noises)			
Engineering controls	Design & install equipment to counteract or lessen the hazard			
Administrative controls	change to a system of work, a process or a procedure to lessen the hazard			
Personal Protective Equipment	ensuring the provision and use of suitable personal protective equipment			

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RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

Hazard Analysis and Risk Assessment

The risk management methodology as described in WHS Act 2011, WHS Regulations 2011, WHS Code of Practice WHS Act 2011, Section 274, Code of Practice —How to Manage Work, Health and Safety Risks 2011, MDG1010 and AS/NZS ISO 31000:2009 is used to identify the various processes and activities at LakeCoal sites.

Risk analyses shall be completed for each activity based on the following matrix. The subsequent risk ranking shall then determine the frequency of re-assessments.

Likelihood	Consequences
A. Almost certain to happen	1. Permanently disable.
B. Like to happen at some point	2. Could cause serious injury (Major LTI)
C. Moderate, possible, heard of so it might happen	3. Could cause Medical Treatment Case/ LTI
D. Unlikely, not likely to happen	4. Could cause First Aid Treatment
E. Rare, practically Impossible	5. Could not cause injury

Likelihood and Consequences are applicable to Table 1 below.

LIKELIHOOD							
		A – Certain	B – Likely	C – Moderate	D – Unlikely	E - Rare	
S C E	1 - Critical	1	2	4	7	11	
CONSEQUENCE	2 - High	3	5	8	12	16	
NSEC	3 - Medium	6	9	13	17	20	
8	4 - Low	10	14	18	21	23	
	5 - Insignificant	15	19	22	24	25	

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RISK ASSESSMENT

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Facts

- Extraction is to occur in the Fassifern seam utilising miniwall extraction methods and solely beneath Lake Macquarie (ie outside the High Water Mark Subsidence Barrier and Seagrass Protection Barrier).
- S2 to S3 extraction depth of cover ranges between an effective depth of 142-165m. The panels are at >35° angle of draw to the foreshore.
- Both miniwalls have a void width of 97m and an inter panel pillar width of 40m.
- No extraction is planned within the High Water Mark Subsidence Barrier (HWMSB) and Seagrass Protection Barrier (SPB)
- Updated predictions for subsidence over the MW1 to 12 area of 720mm were exceeded in the
 MW7 to 10 area with up to 1100mm recorded (a further 150mm of creep movement could be
 expected). The subsidence model has since been reviewed and amended to align with this increase,
 and to gain an understanding of the potential mechanisms behind the increase. This model and
 information has been utilised to develop a mine plan and updated predictions for the NMD such
 that predicted subsidence is planned to remain within the approved 780mm for the domain
 allowing for anticipated longer term creep.
- A detailed subsidence assessment has been undertaken for miniwalls S2 and S3 by Mine Subsidence Engineering Consultants (MSEC). The assessment has indicated that the subsidence results over the miniwalls will result in approximately 290mm of vertical subsidence and 6mm/m tilt. Predicted vertical subsidence at the sea grass beds/moorings and jetties is predicted to be less than 20mm. The expected subsidence at Pelican rock is expected to be in the order of 90mm.
- Strata2 Consulting has undertaken a detailed geotechnical design report for the miniwall layout which has formed the basis for the mine design used in the subsidence assessment.
- LakeCoal has successfully mined Miniwall S1 in the NMD with subsidence monitoring results at the foreshore well within predictions.
- LakeCoal has completed a rock head survey of the NMD which has formed the basis for the key assumptions used in the technical reports.
- The location of the maximum predicted subsidence is located beneath Lake Macquarie within the FAS working footprint (ie outside the foreshore and mapped seagrass areas) **Figure 1**.

Assumptions

 Employees are trained and assessed in relevant contents of the LakeCoal site WHSMS as a minimum.

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- Compliance with the Environmental Protection Act 1994, Environmental Planning and Assessment Act 1979, Work Health and Safety Act 2011 and Work Health and Safety Regulations 2011, Code of Practice –How to Manage Work, Health and Safety Risks 2011, AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines.
- Compliance with the Lake Coal Environmental Management System
- Compliance with the Work Health and Safety Act 2011 and Work Health and Safety Regulations 2011, Code of Practice –How to Manage Work, Health and Safety Risks 2011, AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines.

Monitoring and Review

LakeCoal site monitoring and review processes should encompass all aspects of the risk management process for the purposes of:

- ensuring that controls are effective and efficient in both design and operation;
- obtaining further information to improve risk assessment;
- analyzing and learning lessons from events (including near-misses), changes, trends, successes and failures;
- Identifying emerging risks.

References

- AS/NZS ISO 31000:2009 Risk Management Principles and Guidelines
- MDG1010 Risk Management Handbook for the Mining Industry
- MDG1014 Guideline to reviewing a risk assessment of mine equipment and operations
- Work Health and Safety Act 2011
- Work Health and Safety Regulations 2011
- Codes of Practice –WHS Act 2011, Section 274.
- Work Health and Safety Mines Act 2013
- Work Health and Safety Mines Regulations 2014
- AS/NZS ISO 31000:2009 Risk Management Principles and Guidelines
- MDG1010 Risk Management Handbook for the Mining Industry
- MDG1014 Guideline to reviewing a risk assessment of mine equipment and operations

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- Environmental Protection Act 1994
- Environmental Planning and Assessment Act 1979
- DGS, 2017. Multi-Seam Mining Feasibility Study for the Proposed Miniwalls CVB to CVB4 at Chain Valley Colliery
- EMM, 2015. Chain Valley Colliery- Modification 2- SoEE
- EMM, 2013. Chain Valley Colliery Mining Extension project 1- EIS
- Lake Coal, 2013. Chain Valley Colliery Extraction Plan MW7 to MW12
- NSW DMR, 2003. Guideline for Applications for Subsidence Management Approvals
- NSW DRE Mine Safety, 2017. Guideline Managing Risk of Subsidence
- PHMP 00021- Mannering and Chain Valley Collieries Principal Hazard Management Plans
- Subsidence PHMP Risk Assessment Dated 15/12/16
- Miniwall S1/N1 Extraction Plan and associated Risk Assessment

Definitions

Hazard

Means a situation or thing that has the potential to harm a person. Hazards at work may include: noisy machinery, a moving forklift, chemicals, electricity, working at heights, a repetitive job, bullying and violence at the workplace.(reference Code of Practice –How to Manage Work, Health and Safety Risks 2011)

Hazardous Manual Task

Defined in the WHS Regulations 2011, means a task that requires a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any person, animal or thing involving one or more of the following:

- repetitive or sustained force
- high or sudden force
- repetitive movement
- sustained or awkward posture
- exposure to vibration.

Musculoskeletal disorder

Defined in the WHS Regulations 2011, means an injury to, or a disease of, the musculoskeletal system, whether occurring suddenly or over time. It does not include an injury caused by crushing,

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entrapment (such as fractures and dislocations) or cutting resulting from the mechanical operation of plant.

Risk Assessment

Risk management process applied to a scope of work, overall activities, equipment and machinery to determine how often specified events may occur and the magnitude of their consequence. When applied to a specific and sequential set of job steps/activities this may be referred to as a Job Safety Analysis.

Risk

Is the possibility that harm (death, injury or illness) might occur when exposed to a hazard. (Reference Code of Practice –How to Manage Work, Health and Safety Risks 2011)

Risk control

Means taking action to eliminate health and safety risks so far as is reasonably practicable, and if that is not possible, minimising the risks so far as is reasonably practicable. Eliminating a hazard will also eliminate any risks associated with that hazard. (reference Code of Practice –How to Manage Work, Health and Safety Risks 2011)

WRAC

Workplace Risk Assessment & Control

Subsidence

Movement of the ground surface as a result of readjustments of the overburden due to collapse or failure of underground mine workings and/or compression of remnant pillars

Subsidence Effects

The term used to define the subsidence and differential subsidence parameters (i.e. subsidence, tilt, strain and horizontal displacement) that may or may not have an impact on natural or man-made surface and sub-surface features above a mining area

Subsidence Impacts

The impact that a subsidence effect has on natural or man-made surface and sub-surface features above a mining area

Tilt

The rate of change of subsidence between two points (A and B), measured at set distances apart (usually 10 m).

Strain

The change in horizontal distance between two points at the surface after mining, divided by the premining distance between the points, may be tensile, compressive or shear.

Rock Head

The geological boundary in the overburden between competent rock and unconsolidated sediments and weathered rock

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S2 and S3 Miniwall Extraction Plan Risk Assessment

RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

Abbreviations

ALARP As low as reasonably practicable (ALARP) - determined from WHS Act 2011, Section 18.

CVC Chain Valley Colliery

DISRD Department of Industry, Skills and Regional Development

EMP Environmental Management Plan

FOS Factor of Safety

JSA Job Safety Analysis

LTA less than adequate

LAK LakeCoal

MC Mannering Colliery

MSD Musculoskeletal Disorder

MSMFI Multi-seam Mining Feasibility Investigation

PCP Principle Control Plans

PMHMP Principle Mining Hazard Management Plans

PPE Personal protective Equipment

STD Standard

STF Slip/Trips/Falls

SMP Safety Management Plan

SWP Standard Work Procedure

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S2 and S3 Miniwall Extraction Plan Risk Assessment

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Risk Table

The hazards were analysed and risks derived. The existing control mechanisms were identified prior to establishment of risk. Proposed risk reductions were discussed and agreed and a residual risk determined based on implementation of existing and proposed risk reductions. Consequences assessed through this risk assessment were taken as the reasonable practicable level of risk considering Injury to Personnel as a primary consideration and Environmental Impact and Financial Loss as a secondary consideration as defined in the Risk Assessment Matrix.

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.	Natural Features													
1.1a		Loss of groundwater from aquifers due to subsidence induced fracturing impacts users or dependant ecosystems	 Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) Strata2 Mine Design Report Existing extraction has already influenced groundwater levels (minimal further impact predicted) Avg dewatering volume is within predictions. Ground water assessment (SEE) GWMP Operational water management TARP and underground water make monitoring. 	Е	D	3	17	Update the GWMP for S2/S3 Extraction Plan application Review CVC operational water management TARP to include GWMP review outcomes					E&C Coordinator Mine Surveyor	25/03/19 25/03/19

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S2 and S3 Miniwall Extraction Plan Risk Assessment

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.1b		Abnormal groundwater loss due to extraction of miniwall panels	 Strata2 Mine Design Report Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) S2 and S3 panels designed to exclude direct extraction and indirect interconnection with major fault plane/dip Existing extraction has already influenced groundwater levels (minimal further impact predicted) Avg dewatering volume is within predictions Ground water assessment (SEE) 	Е	D	З	17	Review and update subsidence and water management TARP based on recent NMD experience and GWMP update.					Technical Services Manager	25/03/19

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S2 and S3 Miniwall Extraction Plan Risk Assessment

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.1c		Impact on registered groundwater bores in proximity to extraction effects their ongoing use (GW24575)	·	E	D	4	18	Monitor yields, saturated thickness and quality where access granted Provide alternative water supply until impacted bore recovers where proven to be related to mining impact or as required by the secretary	D	5	22	МОТ		If triggered

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S2 and S3 Miniwall Extraction Plan Risk Assessment

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.2a	,	Increased depth/lakebed cracking resulting in impacts outside predictions	 Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) Geological mapping of known structures incorporated into the mine design and assessed. Detailed subsidence assessment by MSEC. Predictions are significantly less than the EA approved limits. Extensive subsidence model including bathymetric survey Subsidence monitoring program No previous evidence of significant irregularities around geological structures in previous MW areas 	E	D	3	17					ALARP		
1.3a		Increased flooding risk due to subsidence	 HWMSB/Mine Design Report Subsidence assessment (<20mm predicted) Subsidence monitoring program Contingency Plan 	E	E	2	16					ALARP		

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No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.3b	i i	impacted by increased flooding or erosion	 HWMSB/Mine Design Subsidence assessment Subsidence monitoring program including 6 monthly bathymetric surveys 	E	E	3	20	Undertake remediation of any mining affected sections of foreshore in consultation with relevant authorities/landowners.				ALARP	E&C Coordinator	If triggered
1.3c		depth and wave climate result in increased erosion	 HWMSB/Mine Design Low wave height environment (SEE) Subsidence assessment Subsidence monitoring program 	E	E	4	23					ALARP		

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S2 and S3 Miniwall Extraction Plan Risk Assessment

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.4	(Seagrass)	Increased depth from subsidence reduces presence/health of seagrass beds	 Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) Seagrass mapping (no threatened species identified in extraction plan area) Seagrass Management Plan and monitoring program SPB/Mine design report Subsidence assessment (<20mm predicted) Subsidence monitoring program 	Е	D	4	21					ALARP		
1.5	Communities)	Increased depth from subsidence reduces colony numbers/health		E	D	4	21					ALARP		

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S2 and S3 Miniwall Extraction Plan Risk Assessment

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.6	Protected Species (Loggerhead and	Increased depth from subsidence results in reduction in food source (seagrass)	 Seagrass mapping SPB/Mine Design Report Subsidence Assessment (<20mm Predicted) Mobile and no impact predicted to food source 	E	E	5	25					ALARP		
1.7	Slope(Frying Pan Point)	Horizontal movements of cliff face results in rock failure	 Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) Subsidence assessment (MSEC) Subsidence monitoring program HWMSB/Mine Design 	E I	D D	3 2	17 12		(I)E	2	16	NON		
1.8		Change in depth results in public safety risk	 Subsidence assessment (<100mm predicted) No direct undermining of the outcrop or marker Subsidence monitoring program 	ı	E	2	16	RMS to undertake visual monitoring of marker during routine inspections.				ALARP		During Subsidence

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S2 and S3 Miniwall Extraction Plan Risk Assessment

Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
Telecommunication line	Nil. Outside extraction area	•											
		no services located within subsidence affectation area (>20mm). All services located	L	D	3	17		E	3	20			
c Amenities													
Nil		•											
Land and Facilities				•				•					
Nil		•											
	Telecommunication line Services C Amenities Nil Land and Facilities Nil	Telecommunication line Nil. Outside extraction area Services Services not identified within impact area during original SEE impacted by subsidence C Amenities Nil Land and Facilities Nil	Telecommunication line Nil. Outside extraction area Services Services not identified within impact area during original SEE impacted by subsidence C Amenities Nil Land and Facilities Nil Nil Nil Nil Nil Nil Nil Ni	Telecommunication line Nil. Outside extraction area Services Services not identified within impact area during original SEE impacted by subsidence C Amenities Nil Land and Facilities Nil Nil Nil Nil Nil Nil Nil Ni	Telecommunication Nil. Outside extraction area Services Services ost identified within impact area during original SEE impacted by subsidence CAmenities Nil Land and Facilities Nil Nil Outside extraction area Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. Land and Facilities Nil	Telecommunication line Nil. Outside extraction area Services Services ond identified within impact area during original SEE impacted by subsidence C Amenities Nil L D 3 A 3 A 4 A 5 A 6 A 7 A 8 A 8 A 8 A 8 A 8 A 8 A 9 A 9	Telecommunication Nil. Outside extraction area Services Services not identified within impact area during original SEE impacted by subsidence C Amenities Nil Land and Facilities Nil Nil Nil Nil Nil Nil Nil Ni	Telecommunication Nil. Outside extraction area Services Services not identified within impact area during original SEE impacted by subsidence **Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. **Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. **Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. **Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. **Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. **Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located within subsidence affectation area (>20mm). All services located landward from high water mark. **Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landward from high water mark. **Dial before you dig has confirmed no services located landw	Telecommunication Nil. Outside extraction area • Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. • Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. • Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. • Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. • Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. • Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. • Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services located landward from high water mark. • Dial before you dig has confirmed no services	Telecommunication Nil. Outside extraction area	Telecommunication Nil. Outside extraction area extraction impact area during original SEE impacted by subsidence extraction area explainment. All services located within subsidence affectation area explainment. All services located landward from high water mark. Nil Amenities Nil Amenities	Telecommunication Nil. Outside extraction area Nil. Outside Nil. Out	Telecommunication Nil. Outside extraction area

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S2 and S3 Miniwall Extraction Plan Risk Assessment

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5. Indus	trial, Commercial and	Business Establishme	ents											
	Nil													
6. Areas	. Areas of Archaeological and/or Heritage Significance													

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	(adjacent extraction plan area)	foreshore impacted by flooding or erosion increases due to subsidence	 Locations identified (approx.) via AHIMS register No sites located adjacent to mining footprint on AHIMS register Heritage Management Plan (EMP-D-16371) HWMSB (no impact predicted) Subsidence assessment Subsidence monitoring program 	E	E	4	23					ALARP		
7. Items	s of Architectural Sign	ificance												
	Nil													

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S2 and S3 Miniwall Extraction Plan Risk Assessment

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
8. Perm	nanent Survey Control	Marks												
	Marks/Permanent Survey Marks foreshore effected by horizontal/vertical movement Subsidence assessment Subsidence monitoring program For S2 and S3 include in subsidence monitoring program for S2 and S3											15/2/19		
9. Resid	. Residential Establishments													
	Nil		•											

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No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10	10. Other identified items requiring particular assessment													
10.1a	Public Safety	Shallow water buoy (or other markers including sailing markers) within extraction plan area impacted due to subsidence resulting public safety risk	 Subsidence assessment Strata2 Mine Design Report. Marker locations visually assessed and mapped. RMS consulted as part of previous Extraction Plan. 	ı	С	3	13	RMS to undertake visual inspections of markers during subsidence. Keep CCC informed of actions taken in relation to public safety risks	E	3	20	TOW	E&C Coordinator	During mining Quarterly
10.1b		Jetties within extraction plan area impacted due to subsidence	 Subsidence assessment (<20mm predicted) due to mine design principles Consultation program / community notifications Visual assessment undertaken Subsidence monitoring program 	Е	D	4	21	Consultation with affected landholders - send out notification letters Keep CCC informed of actions taken and progress.				ALARP	Mine Surveyor E&C Coordinator	25/03/19 Quarterly

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		Moorings within extraction plan area impacted due to subsidence	 Limited moorings adjacent the EP area MSEC Subsidence assessment Majority of moorings within seagrass boundary (<20mm subsidence). Negligible change Subsidence monitoring program 	E	D	4	21					ALARP		
10.2		results in concerns	 CCC Website Regular meetings with relevant authorities Extraction Plan Guidelines Landowner notifications to be sent out. 	E	С	4	18					ALARP		

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10.3a	(general)	predictions exceeded results in increased impact/community concern/ breach of	 Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) MSEC Subsidence Assessment Extensive subsidence model including bathymetric survey Subsidence monitoring program 	Е	D	3	17	Extend Summerland Point foreshore monitoring where is access granted Organise appropriate land access to conduct monitoring Investigate potential for additional floor and roof cores to be undertaken in the NMD to improve understanding of geological conditions Review mine design and contingency plans/adaptive management measures in each management plan/TARP are adequate	E	3	20	Low	Mine Surveyor Technical Services Manager	25/03/19 25/03/19 25/03/19

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No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
	(general)	Known or unknown geological structures in the workings increases subsidence impact	 Geological database and mapping from old and existing workings Strata2 Mine Design Report Known major structures incorporated into the updated geological and subsidence model All pillars squat pillars thus confinement not reduced by structures Subsidence monitoring to date has not indicated significant variation in areas of geological structure Subsidence monitoring program 	Ε	D	3	17	Faults/dykes to be assessed case by case as to whether extraction barrier required					Technical Services Manager	As required

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S2 and S3 Miniwall Extraction Plan Risk Assessment

RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10.3c		Height of fracturing exceeds predictions leading to impacts on groundwater/ingress into mine workings due to direct hydraulic connectivity with the Lake.	 Sub-critical mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) Lake Bed rock head survey undertaken and used to inform Mine Design and Subsidence Assessment report. Constrained zone thickness is greater than or equal to 12T Strata2 Mine Design Report Experience from inbye end of Miniwall 12 at Chain Valley at similar rock head thickness did not result in increased water make or signs of direct connectivity at higher levels of subsidence MSEC Subsidence Assessment Report No overlying workings in the NMD Geological mapping and site model Subsidence monitoring program Avg dewatering volume is within predictions Ground water assessment (SEE) GWMP Operational water management 	E	D	3	17	Bathymetric survey to be undertaken at the end of S2 and end of S3 panel. Consider the potential for a cored uphole to confirm the geo mechanical properties of the above the workings to confirm mine design assumptions.				ALARP	Mine Surveyor Technical Services Manager	30/10/19



S2 and S3 Miniwall Extraction Plan Risk Assessment

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No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10.3d	Subsidence Risk (consideration of all risks and required controls)	Irregular subsidence due to Failure/yield of pillars or floor resulting in subsidence exceedance /impacts	 Mine design Report (panel width, pillar width and extraction height results in limited subsidence of <290mm) Panels designed to exclude direct extraction and indirect interconnection with major fault plane/dip Only two extraction panels separated by 40m wide pillar. Subsidence assessment Subsidence monitoring program Subsidence management TARP No previous evidence of significant subsidence irregularities around geological structures in previous MW areas 	E L	D D D	2 2 3	12 12 17	Consider taking floor cores along the north mains to determine claystone thickness/properties to confirm consistency with design assumptions. Review Subsidence Management TARP after S2 panel, if greater than normal triggered. Revise predictions and management strategies as required Apply further mine design and contingency plans/adaptive management measures in each management plan based on ongoing monitoring as mining progresses. Bathymetric survey to be undertaken at the end of S2 and end of S3 panel.	(E)D	2	12	Mod	Manager Technical Services Manager Technical Services Manager Mine Surveyor	25/03/19 Post S2 (indicative 1/9/19) As required

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S2 and S3 Miniwall Extraction Plan Risk Assessment

RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

Actions

No	Clause(s) No from RA Tables	for Action timeframe		Comments	Database Action No	Responsible Person signature	
1.		Update the GWMP for S2/S3 Extraction Plan application	E&C Coordinator	28/2/19			
2		Review CVC operational water management TARP to include GWMP review outcomes	Mine Surveyor	31/3/19			
3		Review and update subsidence and water management TARP based on recent NMD experience and GWMP update.	Technical Services Manager	31/4/19			
4		Monitor yields, saturated thickness and quality where access granted Provide alternative water supply until impacted bore recovers where proven to be related to mining impact or as required by the secretary	E&C Coordinator	If Triggered	Only required if triggered.	n/a	
5		Undertake remediation of any mining affected sections of foreshore in consultation with relevant authorities/landowners.	E&C Coordinator	If Triggered	Only required if triggered.	n/a	
6	1.8, 10.1a	RMS to undertake visual monitoring of marker during routine inspections.	•	During Subsidence	To be coordinated by RMS	n/a	
7	8.1	Search for existing State Survey marks and include in subsidence monitoring program for S2 and S3	Mine Surveyor	31/3/19			
8		Keep CCC informed of actions taken in relation to public safety risks	E&C Coordinator	Quarterly	Only required if triggered.	n/a	

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RISK ASSESSMENT S2 and S3 Miniwall Extraction Plan Risk Assessment

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 			th affected landholders - send out ers of subsidence monitoring program	Mine Surveyor	31/03/19			
10			all Summerland Point foreshore nts where access is granted	Mine Surveyor	30/04/19			
11		cores to be und		Technical Services Manager	15/03/19			
12		neview illine acong. and contingency plans, adaptive		Technical Services Manager	15/03/19			
13				Technical Services Manager	If triggered	Only required if triggered.	n/a	
14		Bathymetric sur and end of S3 p	vey to be undertaken at the end of S2 anel.	Mine Surveyor	30/10/19 (Indicative)			
15				Technical Services Manager	15/03/19			
16		determine clays	floor cores along the north mains to stone thickness/properties to confirm h design assumptions.	Technical Services Manager	15/03/19			
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RISK ASSESSMENT S2 and S3 Miniwall Extraction Plan Risk Assessment

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17	Review Subsidence Management TARP after S2 panel, if greater than normal triggered. Revise predictions and management strategies as required	Technical Services Manager	01/09/19			
18	Apply further mine design and contingency plans/adaptive management measures in each management plan based on ongoing monitoring as mining progresses.	Technical Services Manager	If triggered	Only required if triggered.	n/a	

Wade Covey

Facilitator Name Signed for Wade 25/02/19

Dave Mclean

(Manager of Mining Engineering Name)

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S2 and S3 Miniwall Extraction Plan Risk Assessment

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MDG 1014 Review Checklist

RISK ASSESSMENT REVIEW CHECKLIST

Risk Assessment Title: S2 and S3 Miniwall Extraction Plan Risk Assessment Date: 20/12/19

Site: CVC

1. Report

[Circle or Highlight Yes or No for the following]

1.1	Is there a description of the operation or equipment being assessed?	Yes / No
1.2	Is there a summary of the strategic, corporate and risk management context?	Yes / No
1.3	Is there a list of the people involved in the risk identification step, together with their organizational roles and experience relevant to the risk assessment topic?	Yes / No
1.4	Is there an adequately detailed outline of the approach used to identify the risks?	Yes / No
1.5	Is there an outline of the method used for assessing the likelihood and consequences of the risks?	Yes / No
1.6	Is there, discussion of the basis for defining either the safety standard to be achieved, or the level of risk management expenditure?	Yes / No
1.7	Is there a list of the main actions to be taken to reduce risks and to manage risks?	Yes / No
1.8	Is there a timetable for implementing the main actions?	Yes / No
1.9	Does the report specify a requirement for a working audit requirement after completion of all stages?	Yes / No

2. Process

How	do you rate the following? [Circle or Highlight Poor to Very Good]	Poor/Very Good
2.1	The range of expertise of team which did the study.	1 2 3 4 5
2.2	The appropriateness of the degree of detail of the study.	1 2 3 4 5
2.3	The comprehensiveness of the systematic approach.	1 2 3 4 5
2.4	The identification of the key risk scenarios to be addressed.	1 2 3 4 5
2.5	The basis for deciding the required safety level or effort.	1 2 3 4 5
2.6	The method for assessing likelihood and consequences.	1 2 3 4 5
2.7	The thoroughness of consideration of planned risk reduction actions.	1 2 3 4 5
2.8	The thoroughness of consideration of existing or planned risk controls.	1 2 3 4 5
2.9	The objectivity and balance of the study (ie not unduly optimistic or pessimistic)	1 2 3 4 5

Signed:

Position: Environment and Community Coordinator

Review Date	Next Review Date	Revision No	Document Owner	Page						
25/02/2019	25/02/2022	1	Environment & Community Coordinator - Chain Valley Colliery	Page 36 of 36						
	DOCUMENT UNCONTROLLED WHEN PRINTED									

Date: 25/02/2019

CHAIN VALLEY COLLIERY- SUBSIDENCE MANAGEMENT TRIGGER ACTION RESPONSE PLAN (TARP)

		SUBSIDENCE MANA	<u>GEMENT NORTHERN MII</u>	NING DOMAIN S2 and S3	
	DETAILED PERFORMANCE INDICATORS	MONITORING REQUIREMENTS	CONTAINMENT/REMEDIATION MEASURES	ADAPTIVE MANAGEMENT MEASURES	CONTINGENCY PLANS
SUBSIDENCE	exceeds "12T + 10m" by at least 10m (refer to EP Table 10)	Miniwall supervisors to record extraction height shiftly			
PARAMETERS (Input Variable Validation)	Trigger Level 1 Constrained Zone thickness exceeds "12T + 10m" by <10m (refer to EP Table 10)	Mine Surveyor to confirm weekly that the average extraction height is ≤ 3.5m			Review mine plan and extraction height capabilities. Adjust extraction areas accordingly.
	Trigger Level 2 Constrained Zone thickness is <12T (refer to EP Table 10)		Cease extraction and review	Reduce extraction height where feasible	Conduct risk assessment Review mine plan, including extraction height, geological mapping and panel geometry to confirm that sub-critical behaviour still app
	Normal Subsidence ≤ 300mm	As per SM Program			
SUBSIDENCE	Trigger Level 1 Subsidence > 300mm to ≤ 500mm	6 monthly surveys until subsidence stabilises, then as per SM Program		Update subsidence predictions based on monitoring data Identify controlling mechanisms	Review ability to limit further increases based on understood mechanisms
PARAMETERS (Bathymetric Survey)	Trigger Level 2		Review if increase likely to create impact at foreshore/seagrass	Review potential change in impact on natural and built features & update management plans if reqd Implement further controls as applicable from review	
	Subsidence >500m to ≤780mm	6 monthly until subsidence stabilises then as per SM Program	or exceed final subsidence prediction Notify DP&E and DRE	Update subsidence predictions based on monitoring data	Review mine plan including panel width, pillar widths, extraction height and panel length in consultation with DP&E and DRE
	Normal		Notify OEH, affected landholders or infrastructure owner	Update impact assessment on natural and built features	Review and update Extraction Plan
	<20mm recorded movement	Monitoring as per SM Program			
	Trigger Level 1 <20mm recorded movement with slow (3-5mm/month) creep	Validate increase with additional monthy survey/s then as per SM program		Update subsidence predictions based on monitoring data Identify controlling mechanisms	
SUBSIDENCE PARAMETERS (Foreshore Survey over minimum of 2 adjacent				Review potential change in impact on natural and built features & update management plans if reqd	
pegs)	Trigger Level 2 >20mm recorded movement (assoicated with mining)	Implement Ecological Monitoring program for HWMSB exceedance	Cease extraction in panel in question until review conducted in consultation with DP&E and DRE	Investigate cause of exceedance (ie validate impact due to FAS extraction or not).	Provide offsets for any ecological communities or threatened species in the HWMSB if impacts detected
		Increase frequency of subsidence parameter monitoring to until rates stabilises. Then as per SM program	Notify DP&E and DRE Notify OEH, affected landholders or infrastructure owner	Update subsidence predictions based on monitoring data Update impact assessment on natural and built features	Review mine plan including panel width, pillar widths, extraction height in consultation with DP&E and DRE
					Review and update Extraction Plan
	Normal No damage requiring remediation	Monitoring as per SM Program			
	Trigger Level 1	RSM routine moniotirng navigation markers	Review navigational marker freeboard and notify		
BUILT FEATURES	Subsidence parameters exceeded such that Fassifern workings indicated to have potential impact on foreshore	Monitoring as per BFMP (Built Feature M.Plan)	RMS if impacted Notify DP&E and DRE		Develop BFMP in conjunction with owner for built features surrounding potential impact area
BUILT PEATURES	Private bore capacity reduced		Notify potentially affected landholders or infrastructure owner. Provide temporary water if required		
	Trigger Level 2 Impact to built feature		Cease extraction in panel in question until review conducted in consultation with DP&E and DRE		
		Monitoring as per BFMP	Assist owner with information to aid in MSB claim in	Update impact assessment based on observed damage	Review mine plan including panel width, pillar widths in consultation with DP&E and DRE Review and update Extraction Plan
			accord with BFMP		

CHAIN VALLEY COLLIERY- SUBSIDENCE MANAGEMENT TRIGGER ACTION RESPONSE PLAN (TARP)

			SUBSIDENCE MANAGEMENT NORTHERN MINING DOMAIN S2 and S3										
		DETAILED PERFORMANCE INDICATORS	MONITORING REQUIREMENTS	CONTAINMENT/REMEDIATION MEASURES	ADAPTIVE MANAGEMENT MEASURES	CONTINGENCY PLANS							
		Normal No impact	Monitoring as per SM Program and Public Safety MP										
			Increase visual inspection to forthnightly about N4 until satisfied no change in public risk										
		Trigger Level 1											
		Subsidence parameters exceeded such that Fassifern workings indicated to have potential impact on foreshore	public safety risk quantified as low		Review potential of flooding and drainage impacts about foreshore or stability concerns at steep slopes/ retaining walls. Undertake risk assessmentas to such								
			Inspect foreshore in vicinity of steep slopes and retaining walls for signs of movement ASAP. Implement TARP as required.										
	PUBLIC SAFETY (Foreshore area and	Trigger Level 2		Cease extraction in panel in question until review									
	steep slopes)			conducted in consultation with DP&E and DRE									
		Area around foreshore becomes unstable / shows signs of	Visual inspections frequency to be commensurate with level	Immediately implement temporary safety controls (barricades and signage available from mine site). Arrange for assistance and stay at site if immediate risk to public exists	Implement longer term safety controls	Foreshore stabilisation of unsafe areas in consultation with Council and DRE							
		mining inducted impact	of risk (ie increase until controls put in place)	assistance and stay at site if infinediate risk to public exists	imperient onger term salety controls								
		Flooding or drainage impacts considered likely as result of Fassifern extraction	Inspect foreshore in vicinity of other steep slopes and retaining	Inform ECC as to result of inspection		Flooding and drainage rectification works in consultation with infrastructure owner							
Triggers			walls for signs of movement ASAP. Implement TARP as required.	Geotechnical Engineer to inspect area ASAP.									
				Notify Council and RMS Notify OEH, DP&E and DRE									
	BENTHIC COMMUNITIES	Normal ANOVA/ANOSIM >5%	Monitoring as per Benthic MP										
=		Trigger Level 1	Liaise with monitoring consultant & undertake internal										
		ANOVA/ANOSIM level is approaching 5%	review to determine if impacts are related to mining										
			Arrange a peer review of the monitoring results and statistical										
		Trigger Level 2	analysis			Consult with relevant authorities to identify if offsets are required and							
		ANOVA/ANOSIM <5%	Undertake follow up monitoring at affected sites to obtain confirmation of impacts. Incident Report to be completed and distributed to relevant	Notify DPI-Fisheries, Council and DP&E	Consult with relevant authorities about monitoring and management controls	how these are to be implemented.							
		Normal	agencies										
		Negligible impact	Monitoring as per Seagrass MP										
		Trigger Level 1 Approaching 20% decline in condition	Liaise with monitoring consultant & undertake internal		Review if variation is within broader background variation range for the site.								
	SEAGRASS	Approaching 20mm of additional mine induced subsidence	review to determine if impacts are related to mining		range for the site.								
		within mapped seagrass Trigger Level 2											
		>20% decline in conditions from year baseline survey	Incident Report to be completed and distributed to relevant agencies	Notify DPI-Fisheries, Council and DP&E	Consult with relevant authorities about monitoring and management controls	Consult with relevant authorities to identify if offsets are required and how these are to be implemented.							
		≥150mm of additional mine induced subsidence at survey location											
	WATER INFLOW	Ongoing monitoring of water inflows and site water management thro	ugh operational Water Management and Monitoring TARP process	3									
		Coordinate and undertake all environmental monitoring as outlined in											
		Implement TARP actions in consultation with regulatory agencies as/ Notify the relevant Government agencies and other affected parties of											
es	ECC	Coordinate Subsidence Review as a aprt of Annual Environmental R Arrange for subsidence prediction and impact updates as required	eporting										
Ë		Update Extraction Plan as required											
idi		Audit public safety controls (barricades and signage) regularly											
Su		Co-ordinate subsidence monitoring											
Responsibilitie	Mine Surveyor	Review subsidence monitoring results against TARP triggers Inform relevant stakeholders as to subsidence monitoring trends											
		Ensure adequate financial and personnel resources are made availa	ble for implementation of this plan										
	Mine Manager	Review and approve required mine plan changes											



LAKECOAL PTY LTD CHAIN VALLEY COLLIERY GROUNDWATER MANAGEMENT PLAN

Lake Macquarie, NSW

CVC3-R2B 27 FEBRUARY 2019

GeoTerra Pty Ltd ABN 82 117 674 941

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Date	Rev.	Comments
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1. INTRODUCTION

This revised Groundwater Monitoring Program (GwMP) has been prepared in compliance with Schedule 3 (Condition 18D) of the LakeCoal Pty Ltd Chain Valley Colliery Extension Project Approval SSD 5465, as well as the addition of Miniwalls S2 and S3.

This report is to be read in conjunction with the Water Management Plan prepared for the Colliery (LakeCoal, 2019).

The plan includes:

- a groundwater water quality and quantity monitoring program,
- trigger levels for mining impacts on groundwater systems,
- procedures to be followed in the event that monitoring of groundwater indicates an exceedance of trigger levels,
- measures to mitigate, remediate and/or compensate for identified impacts,
- a protocol for the notification of trigger level exceedances, and;
- a contingency plan where, in the event of adverse effects on groundwater quality and/or quantity due to mining impacts, the Colliery will provide an equivalent supply until the affected supply is restored, or as agreed with the landowner and the NSW Office of Water (DIW).

Groundwater related operations at Chain Valley Colliery include the;

- historic Great Northern and Wallarah seams bord and pillar workings;
- · current Fassifern Seam development as well as miniwall workings; and
- water storage and management facilities owned and operated by the Colliery.

Operation of the GwMP needs a high level of management input to operate the Colliery within the relevant requirements and various water licences, particularly to ensure compliance with the water discharges authorised by Environment Protection Licence 1770.

An essential part of the plan is monitoring of all groundwater inflows and extraction into and out of the underground with reliable flow meters, as well as monitoring of groundwater levels and water quality in private bores.

This information is necessary for periodical reviews of the groundwater management system and to support any updates/changes to licences.

The proposed mitigation measures minimise and manage the impacts of any potential adverse effects on local aquifers within the GwMP area.

The proposed mitigation measures minimise, where possible, the impacts of the proposed mining on the various groundwater sources, aquifers or groundwater dependent ecosystems that may be present in the Project Area.



1.1 Objectives

The objective of the GwMP is to operate the Colliery so that the subsurface mining operations will be conducted in a manner which minimises the potential impacts on groundwater flow and quality, aquifer integrity, groundwater dependent ecosystems and other off-site groundwater related impacts.

In order to achieve this goal, the GwMP will be used to establish procedures to:-

- measure, control, mitigate and repair potential impacts that could, or do, occur to the groundwater system overlying Chain Valley Colliery, and;
- identify, measure, minimise or where possible, avoid potential significant adverse impacts that can result from mining and subsidence on the groundwater systems within the Project Area.

In addition, the GwMP will be used to

- monitor groundwater system changes in relation to the leaseholder's mining activities;
- assess the pre and post-mining condition of groundwater systems in the lease area;
- ensure all relevant groundwater criteria are met;
- minimise and manage any impacts on the availability of groundwater to potentially impacted residents, landholders or other groundwater users;
- minimise adverse changes on groundwater dependent ecosystems, where present
- provide a forum to record and discuss mining impacts, and;
- provide an annual report on the monitoring, observations and actions conducted within the preceding 12 months to the Department of Industry – Water (DIW).

These objectives will be met by:

- monitoring groundwater seepage and groundwater quality in the workings during mining within the mine lease area;
- installation of water monitoring appliance(s) to measure pumped water volumes to and from the mine workings. These appliances will be maintained in good working order. If required the mine will supply a test certificate to certify the current accuracy of the appliance(s) furnished by the manufacturer or by some duly qualified person or organisation. The mine water pumping records will be maintained and supplied to DIW upon request;
- providing a plan of action in the event that the impacts of mining are greater than anticipated and initiate action to mitigate or remedy potential significant impacts that may occur;
- ensuring that any tailwater drainage will not be allowed to discharge onto adjoining roads, crown land or other lands, or into any unauthorised stream, or any aquifer, by surface or subsurface drains or pipes or any other means without appropriate approval;
- ensuring that any groundwater extracted from the works will not be discharged into any watercourse or source of groundwater except in compliance with the *Protection* of the *Environment Operations Act (1997)*;
- any works used for the purpose of conveying, distributing or storing groundwater from the works will not be constructed or installed so as to obstruct the free passage of floodwaters flowing in, to or from a river or lake;
- all groundwater extracted from the works will be used or applied only on such land, and for such purposes, as approved by DIW, and;
- providing a forum to report, discuss and record impacts to the groundwater system that involves the Chain Valley Colliery, stakeholders, DIW as required.



1.2 Scope

The GwMP is to be used to protect, monitor and manage the condition of the groundwater system within the Chain Valley Colliery lease area that may potentially be impacted due to coal mining and mine subsidence within the lease area.

The GwMP also applies to persons employed or engaged by the Colliery when carrying out activities described by this plan.

This GwMP is to be read in conjunction with the current version of the Water Management Plan (EMP-D-16368) which outlines the monitoring and management of specific factors relating to surface water and groundwater issues due to the predicted subsidence.

All other water management components not directly related to the GwMP are contained as part of the Water Management Plan (EMP-D-16368).

The GwMP covers mining until completion of Domains 1 and 2, although the plan may be used beyond that benchmark with appropriate modification.

1.3 Definitions

For the purpose of this document, the GwMP area is defined as the groundwater systems within the Chain Valley Colliery Lease area. The main features in the GwMP area shown in **Figure 1** include the;

- current Chain Valley Colliery workings in the Fassifern Seam;
- the proposed extraction within Domains 1 and 2, and;
- the proposed extraction of Miniwalls S2 and S3

1.4 Limitations

This GwMP is based on current monitoring data and the proposed and approved operational aspects relating to Chain Valley Colliery. The relevant groundwater features have been identified from:

- existing studies;
- data supplied by Colliery representatives, and from;
- associated consultant's reports in the lake Macquarie area.

The impacts of mining on the groundwater system have been assessed in previous studies (see references). However, it is recognised that prediction and assessment of changes to, and effects from, operation of the colliery on the groundwater system can be relied upon only to a certain extent.

The environmental assessment groundwater study (GeoTerra, 2013) determined there is a low potential for the mine's impacts on the groundwater system to exceed the predictions and assessments. However, the possibility of impacts above predictions has been considered in this plan.

The GwMP will not necessarily prevent impacts from the proposed mining, but does identify appropriate procedures to manage the impacts within tolerable limits and identifies procedures that can be followed should evidence of increased impacts and unacceptable risk emerge.

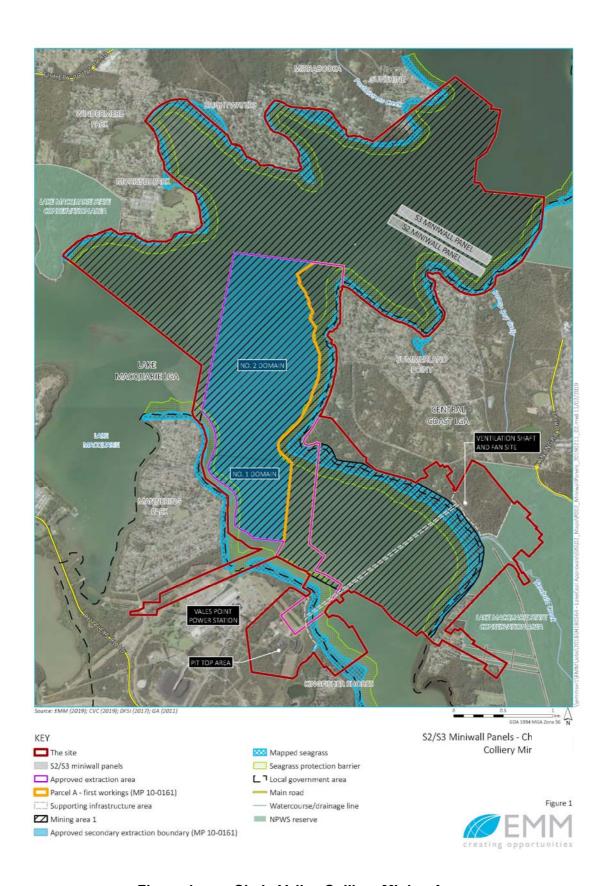


Figure 1 Chain Valley Colliery Mining Area



2. LEGISLATION

The following sub-sections outline New South Wales statutory requirements that apply to the proposed mining operation with respect to groundwater.

2.1 Water Management Act 2000

The key legislation for the management of water in the Project Area is *Water Management Act* 2000, which regulates water use for rivers and aquifers where water sharing plans have commenced.

The Project area is located in the *South Lake Macquarie Water Source* section of the Water Sharing Plan - Hunter unregulated water sources.

The object of the *Water Management Act 2000* is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The Act provides arrangements for controlling land-based activities that affect the quality and quantity of the State's water resources. It provides for four types of approval:

- Water use approvals authorise the use of water at a specified location for a particular purpose, for up to ten years;
- Water management work approvals;
- Controlled activity approvals; and
- Aquifer interference activity approvals authorise the holder to conduct activities that
 affect the aquifer. This approval is for activities that intersect groundwater, other than
 water supply bores and may be issued for up to ten years.

For controlled activities and aquifer interference activities, the Act requires that the activities avoid or minimise impacts on the water resource and land degradation, and where possible the land must be rehabilitated.

Under the *Water Management Act 2000*, the NSW Office of Water has prepared a range of statutory water management plans covering aspects such as water sharing, water use, drainage management and floodplain management. In NSW, 36 water sharing plans have commenced, covering 80 percent of water currently extracted. The plans cover most of the regulated river systems (those controlled by major dams for rural water supplies), a number of unregulated river systems and the major inland alluvial aquifers.

2.2 State Groundwater Policy

The NSW State Groundwater Policy (Framework Document) was adopted in 1997 and aims to manage the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three component parts:

- The NSW Groundwater Quality Protection Policy, adopted in December 1998;
- The NSW State Groundwater Dependent Ecosystems Policy, adopted in 2002; and
- The NSW Groundwater Quantity Management Policy.

2.2.1 Groundwater Quality Protection

The NSW Groundwater Quality Protection Policy (Department of Land and Water Conservation, 1998), states that the objectives of the policy will be achieved by applying the management principles listed below.

- All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.
- Town water supplies should be afforded special protection against contamination.
- Groundwater pollution should be prevented so that future remediation is not required.
- For new developments, the scale and scope of work required to demonstrate adequate



groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.

- A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwater that is incompatible with soil, vegetation and receiving waters.
- Groundwater dependent ecosystems will be afforded protection.
- Groundwater quality protection should be integrated with the management of groundwater quality.
- The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.
- Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.

2.2.2 Groundwater Dependent Ecosystems

The NSW State Groundwater Dependent Ecosystems Policy (Department of Land and Water Conservation, 2002) is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines Groundwater Dependent Ecosystems (GDEs), as "communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater".

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles follows:

- GDEs can have important values. Threats should be identified and action taken to protect them:
- Groundwater extractions should be managed within the sustainable yield of aguifers;
- Priority should be given to ensure that sufficient groundwater is available at all time to identified GDEs:
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs; and
- Planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater systems.

2.2.3 Groundwater Quantity Protection

The objectives of managing groundwater quantity in New South Wales are to:

- achieve the efficient, equitable and sustainable use of the State's groundwater;
- prevent, halt and reverse degradation of the State's groundwater and/or its dependent ecosystems;
- provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and to;
- involve the community in the management of groundwater resources.

3. CURRENT AND PROPOSED OPERATIONS

Chain Valley Colliery is an underground coal mine operated by LakeCoal Pty Ltd (LakeCoal).

The Colliery is located in the Newcastle Coalfields at the southern end of Lake Macquarie in NSW, and is approximately 60 kilometres south of Newcastle, within the Swansea-North Entrance Mine Subsidence District.

The Management Plan Area incorporates the relatively flat pit top area, existing ventilation shaft and fan site on Summerland Point, as well as foreshore areas and Lake Macquarie.

The terrestrial land within the GwMP Area is gently undulating and drains to Lake Macquarie.

Chain Valley commenced operation in the 1960's extracting coal from the Wallarah seam, the Great Northern seam and the Fassifern seam, and currently conducts mining within leases ML 1051, CCL 721 and ML 1632.

The current Fassifern Seam minimals are located underneath Lake Macquarie, within and to the north of Chain Valley Bay.

The mine has completed extraction of Miniwalls 1 to 12 (MW1 to MW12) and has an approved Extraction Plan for Miniwalls N1 and S1 in the Fassifern Seam. At the time of writing, the Chain Valley Colliery had recently completed MWS1 and most of MWN1.

No current or proposed secondary extraction underlies any terrestrial based surface water catchments, with all secondary extraction proposed to be underneath the saline, tidal region of Lake Macquarie.

The Colliery currently has Development Consent (SSD-5465 – as modified) for:

- extraction of up to a maximum of 2.1 million tonnes per annum until 31 December 2027 through continued mining via first workings and miniwall methods within the Fassifern Seam:
- continued coal transport for the surface facilities site:
- continued use of the existing surface facilities, and;
- continuation of passive underground activities within the old workings of the Wallarah seam, Great Northern seam and the Fassifern seam.

The proposed mining areas lie approximately 200m below the sediments of Lake Macquarie, within a boundary set to exclude secondary extraction within the High Water Mark Subsidence Barrier or the Seagrass Protection Barrier.

Bord and pillar mining was commenced in the Fassifern seam in 2006 and secondary extraction in the form of miniwall mining method in the Fassifern seam commenced in 2011.

The S2 and S3 miniwall panels will be 97m wide (rib to rib) with a 40m wide inter-panel pillar, with the panel widths being significantly less than those previously proposed for Chain Valley and adjacent mines – for example, at Wyee Colliery Longwalls 17 to 21 were up to 150m wide, and were extracted between 150m and 180m below surface.

The Development Consent (SSD-5465 – as modified) was approved on 23/12/2013 which permitted the above activities.

Historically, Chain Valley Colliery has mined within the Wallarah and Great Northern seams to the east with via bord and pillar methods, while to the south west and west Wyee State Mine (now named Mannering Colliery) has mined the Great Northern Seam and Fassifern using bord and pillar and longwall extraction.



Mining within the Wallarah and Great Northern Seams will not be undertaken as part of the Project.

The maximum water depth within the proposed mining areas is approximately 9m and the maximum depth to rock head is 20m. Directly above MWS2 and MWS3 the lake varies from 3 – 8m deep.

Sediment on the bottom of the lake varies from 9 – 23m deep over MWS2 and MWS3.

Overburden above the Fassifern Seam over Miniwalls S2 and S3, including the lake sediments, ranges from 164 – 172m.

3.1 Adjacent Workings

Chain Valley Mine is entirely surrounded by the existing Mannering, Myuna and Wallarah Collieries as well as by the historic Newvale and Moonee Collieries.

Mannering Colliery (formerly the Wyee State Mine), has conducted longwall mining in the Great Northern and Fassifern seams since the 1960s. Extraction continued until 2002, when mining became uneconomic. The mine was temporarily shut down until 2004 when it was reopened by Centennial Coal. Since 2004, mining progressed in the Fassifern Seam using bord and pillar methods.

The Myuna Colliery commenced operation in 1981 and is currently mining the Fassifern seam via bord and pillar techniques.

Wallarah Colliery operated from 1979 until 2002, when it was placed under care and maintenance.

Munmorah, Mandalong and Cooranbong Collieries are also nearby, but are not immediately adjacent to the Chain Valley Colliery holding boundary.

3.2 Predicted Subsidence

The maximum subsidence after completion of mining will be located under Lake Macquarie, with the 20mm subsidence line to be contained within the lake high water mark (Ditton Geotechnical Services, 2013) and (MSEC, 2018).

The maximum predicted subsidence, tilts and strains over the proposed workings (assuming a 200m depth of cover) are summarised in **Table 1**.

TABLE 1 Maximum Predicted Subsidence

Parameter	Miniwall Workings	Miniwalls S2 and S3			
Vertical subsidence	620mm	<290mm			
Tilt	17mm/m	<6mm/m			
Strain (Compressive and Tensile)	6.0mm/m	3 / 1mm/m			

To date, the maximum subsidence has been observed as summarised in Table 2.



TABLE 2 Maximum Observed Subsidence

Location	Maximum Subsidence (mm)
MW1 - MW3 and MW6 - MW12	750
MW7 – MW12 (western end)	1150
MW4 – MW5A (eastern end)	220 (after MW4) 350 (after MW5A)
MW5 and MW5A (western end)	460

It is predicted there will be no measureable subsidence at the lake foreshore (Ditton Geotechnical Services, 2013) and (MSEC, 2018).

3.3 Rainfall and Evaporation

Analysis of climatic data from the Bureau of Meteorology (BoM) weather station at Peats Ridge indicates the following rainfall data;

•	Maximum	2186 mm/annum
•	90th percentile	1685 mm/annum
•	75th percentile	1418 mm/annum
•	Median	1226 mm/annum
•	20th percentile	902 mm/annum
•	Minimum	567 mm/annum

The annual evaporation patterns at Peats Ridge BoM Station indicate the following;

•	Maximum	1420 mm/annum
•	90th %ile	1247 mm/annum
•	75th %ile	1210 mm/annum
•	Median	1170 mm/annum
•	20th %ile	1090 mm/annum
•	Minimum	410 mm/annum



4. LOCAL GROUNDWATER SYSTEM

For management purposes, groundwater within the GwMP area has been divided into the following classes;

(Mine water) groundwater and town water that is pumped into or out of the underground workings (Groundwater) water contained within strata overlying the mine workings

(Seeps and springs) groundwater that discharges to surface water catchments within the Project Area.

Groundwater flows from the "terrestrial" recharge areas, outside of Lake Macquarie, as well as from the saline waters of Lake Macquarie into the overburden under a regional hydraulic gradient, with dominantly horizontal confined flow along discrete discontinuities and fractures within bedding planes, and / or above fine grained, relatively impermeable strata within the overburden sequence.

The overburden generally contains low yielding aquifers with low hydraulic conductivities.

A schematic of the stratigraphic sequence is shown in **Figure 2**.

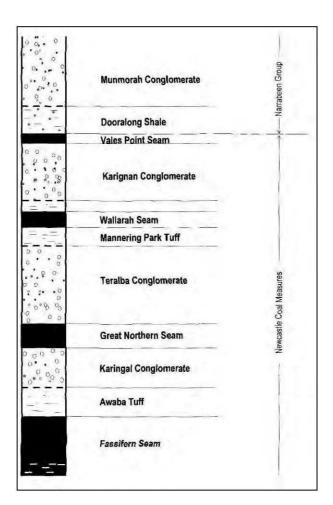


Figure 2 Local Area Stratigraphy



4.1 Alluvial Aquifers

Quaternary to recent alluvial terrestrial sediments comprising sand, gravel, clay and silt are associated with creeks and drainage channels in the local area, to the east, west and south the shores of Lake Macquarie.

Alluvium in the vicinity of the Project area is likely to be present associated with the drainage lines which discharge to Lake Macquarie.

No data is available for the thickness or lithology of alluvium within the Project area. However it is anticipated, if present, to be thin, with limited aerial extent, and no significant water storage or transmitting capacity.

Alluvial sediments within the "terrestrial" areas, outside of the Project Area, are generally too shallow and limited in extent to be used for groundwater supply.

4.2 Lake Macquarie Sediments

Sediments in the vicinity of MWS2 and MWS3 within Lake Macquarie consist of unconsolidated sands, clays, silts and gravels from 9 - 23m thick.

4.3 Shallow Bedrock

The shallow bedrock comprises weathered bedrock which potentially contains discontinuous perched aquifers developed at the interface between the soil and bedrock and along zones of locally increased permeabilities caused by weathering of bedrock and faulting.

The depth and permeability of any aquifers is likely to be dependent on the depth of weathering and the extent and frequency of any permeable fracture systems.

Recharge to the shallow bedrock aquifer is primarily through rainfall infiltration, with some infiltration into to the underlying basement through fractures, joints and faults.

4.4 Deep Bedrock

The Newcastle Coal Measures are overlain by the Munmorah Conglomerate and the Dooralong Shale of the Triassic Narrabeen Group which comprise the majority of the overburden.

The Munmorah Conglomerate extends to a depth of approximately 120m in the vicinity of the Project area and comprises mostly quartz-lithic sandstone interbedded with pebble conglomerate.

The Dooralong Shale is up 20m thick and comprises cross-bedded sandstone intercalated with siltstone and claystone (Forster and Enever, 1992).

Fractured bedrock aquifers would be present within the Narrabeen Group and the Newcastle Coal Measures with discrete water yielding horizons associated with zones of increased permeability i.e. faults and the coal seams.

The overburden and interburden is a low yielding sequence of essentially dry conglomerates and shales.

Joints and fractures associated with fractured bedrock systems tend to be laterally and vertically discontinuous, resulting in poor hydraulic connection and low groundwater yields.

Forster and Enever (1992) state that "neither the Narrabeen Group nor the Newcastle Coal Measures contain any significant quantities of groundwater and their permeabilities are known to be generally low (<10-7 m/s).



Any permeable zones which do occur are usually due to jointing, faulting and shearing on bedding planes.

Because of the extremely low permeability of the rock substance, groundwater flow through the overburden strata is almost exclusively by interconnecting defects such as joints and bedding.

For this reason, coal seams with their interconnecting cleat and joint patterns are often found to be 'aquifers' relative to the surrounding strata. Despite this, most underground coal mines on the Central Coast are quite dry, and rarely have any major groundwater problems."

Groundwater in the deep bedrock aquifer is of poor quality with salinity levels ranging from 3000 to 16,000 µS/cm.

Recharge to the deep bedrock aquifer is generally from infiltration of rainfall from overlying aquifers and the flow direction is expected to reflect the local topography.

4.5 Coal Seams

The coal deposits historically or currently mined in the area include the Wallarah, Great Northern and Fassifern seams of the Newcastle Coal Measures which are generally interbedded with tuffaceous claystone.

The coal seams generally have a low primary or inter-granular porosity and permeability, with bedding planes, joints, fractures and cleating imparting an enhanced secondary permeability.

The 4.5 - 5.5m thick Fassifern seam underlies the Wallarah and Great Northern seams within the Project area, and lies between 185m and 220m below surface, with a proposed mining height of up to 3.5m.

4.6 Structure and Intrusions

The overburden dips at approximately two degrees to the south-west.

Superimposed on the regional dip is the Macquarie Syncline, with an axis that runs through the Chain Valley Colliery holding, along with associated faulting and igneous intrusions.

Mapped and inferred geological structures in the Project Area include a number of faults and dykes, with two normal faults with throws of less than 10m located either side of MWS2 and MWS3 as shown in **Figure 3**.

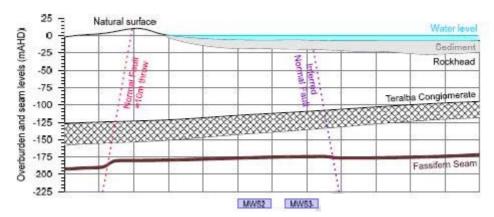


Figure 3 Faulting in the Vicinity of MWS2 and MWS3 (MSEC, 2018)

The Fassifern Seam workings have intersected numerous structures, however, no significant inflows have been observed to the workings (Strata2, 2018).



4.7 Private Bores Within or Adjacent to the Proposed Mining Area

Fifteen DIW registered bores are located within or near the GwMP area as shown in **Figure 4** and **Table 3**.

From the available data, the majority of bores are completed in shallow (<18.3mbgl) sandy alluvium with one coal exploration bore converted for use as a domestic water supply (GW31646)

All remaining private bores in the GwMP are potentially used for domestic garden or limited irrigation water supply.

Where the data is available from the DIW records, groundwater has been obtained from the shallow sandy alluvial / colluvial aquifers with low to moderate yields ranging from 0.13L/sec to 1.50L/sec.

Table 3 Registered Local Private Bores

				Depth	SWL	Aguifer	YIELD		Bore Currency
GW	E	N	Drilled	(m)	(m)	(mbgl)	(L/s)	Purpose	,
11915	363007	6329604	-	5.4	ı	-	-	Poultry	no response
24575	365969	6332788	1965	15.2	ı	-	-	Domestic	no response
31646	366742	6329317	1960	277.5	3.0	3.0 – 10.6	0.13	Dom. / Coal Explore	not present
34560	364130	6330883	1970	18.3	5.5	5.5	-	Domestic	not present
34600	367678	6332873	1971	61.0	5.7	18.2	0.06	Waste disposal	-
80489	366441	6329674	2003	-	-	-	-	Domestic	no internal access
80830	363757	6330850	2004	-	-	-	-	Test bore	capped / covered
201149	367104	6329608	2006	4.0	1.0	1.0 – 4.0	1.50	Irrigation spear	no response
201150	366840	6329640	2006	4.0	1.0	1.0 - 4.0	1.50	Irrigation spear	no response
201977	363730	6331388	2008	7.1	6.0	6.0 - 7.0	-	Monitoring	-
202028	363872	6334034	2007	5.5	1.6	-	-	Test bore	not present
202098	363829	6334141	2007	4.0	0.8	-	-	Test bore	not present
202246	363834	6334174	2007	3.5	1.2	0.6 - 3.5	-	Test bore	not present
202247	363899	6333964	2007	5.0	3.6	2.0 - 5.1	-	Test bore	not present
202248	363918	6333881	2007	5.0	-	2.0 - 5.0	-	Test bore	not present

Note: - no data available

4.8 Regional Groundwater Use

Registered bores in the vicinity of the GwMP area are generally installed into the Munmorah Conglomerate to a maximum depth of 61m, with the majority of bores installed to less than 30m.

Groundwater yields are generally less than 1 L/s, with one bore reporting a yield of 5 L/s.

The authorised uses of the bores include:

- stock watering;
- poultry
- industrial;
- domestic, and;
- waste disposal.

While it is recognised that not all existing bores are likely to be registered, the database gives an indication of groundwater usage in the area.

Overall, it is concluded that the importance and reliance on groundwater by local landowners and residents is limited.



Figure 4 Local Groundwater Bores



5. GROUNDWATER IMPACTS FROM PREVIOUS MINING

The Chain Valley Mine is surrounded by other collieries which have been extracting coal from as early as the 1940s using both longwall and bord and pillar methods.

Historical and current mining operations have resulted in extensive dewatering and depressurisation within and overlying the extracted coal seams.

Water is pumped out of the mines which results in a lowering of the potentiometric surface within the overlying aquifers.

Due to the extent of mining in the region, the subsidence effects would have partly depressurised the overburden.

5.1 Wyee State Mine

An extensive study by (Forster and Enever, 1992) at the adjacent Wyee State Mine (now called Mannering Colliery) assessed the impact of 150m wide longwall mining on the hydrogeological properties of the overburden.

The study assessed that longwall mining of the Great Northern Seam resulted in measurable changes in the hydrogeological properties over a large proportion of the overburden as a result of the redistribution of stresses. The changes reported for the overburden were:

- **Upper Strata** (more than 115 m above the Great Northern Seam) the hydrogeological properties of the strata after mining were generally similar to those measured prior to mining. Some strata reported a temporary drop in piezometric pressure which recovered soon after the completion of mining in that area.
- Intermediate Strata (65 to 115 m above the Great Northern Seam) experienced significant permanent piezometric pressure increases after mining. The cause of the increase in pressure was uncertain, however it was concluded that "since the intermediate strata have not lost piezometric pressure, it is certain that significant vertical drainage has not occurred from these strata and they have formed an effective barrier against vertical hydraulic connection between the surface and the mine."
- Lower Strata (less than 65 m above the Great Northern Seam) showed significant increased permeability and permanent decreases in piezometric pressure which indicated that significant cracking has occurred and allowed partial drainage into the workings.

Although measured changes in the lower strata indicate hydraulic connection was generated and groundwater seepage to the workings had occurred, the changes in the intermediate and upper strata was not significant, and were due to minor strata movements and the formation of fractures that were vertically discontinuous.

It was assessed that the intermediate and upper strata would form a barrier to vertical drainage and that aquifers from 65 - 115m above the workings should not be hydraulically vertically connected to the workings, and should not be drained as a result of subsidence.

Aquifers greater than 115m above the mine workings should not be impacted at all.

It should be noted that the subsidence studied over the Wyee mine related to 150m wide longwalls, whilst the maximum width of the proposed Chain Valley miniwalls is 97m, with 30.6m wide pillars. As a result, the predicted subsidence and the height of fracturing over the proposed workings will be significantly less than was observed over the Wyee longwalls.



5.2 Private Bores

No adverse changes to bore yields, pumping flow duration or groundwater quality have been observed or reported in private bores within the GwMP area.

5.3 Potable Mine Water Supply

The mine has a potable water supply connection from the Wyong Council town-water system.

Historically, a range of 132 - 162ML/year of potable water is supplied to the mine, of which approximately 15% is used for pit top operations and 85% is used for dust suppression in the underground.

As required by Schedule 3, Condition 18(b) of SSD-5465, practical measures to minimise potable water consumption and maximise recycled water use have been implemented and continue to be investigated by LakeCoal, as discussed in the associated WMP. However, the use of non-potable water in all operational activities is not possible due to its quality, work health and safety and equipment requirements.

5.4 Licensed Mine Water Discharges

The discharge of mine water from the sedimentation and pollution control ponds is licensed under the *Protection of the Environment Operations Act* 1997 by the Environment Protection Authority (EPA).

Under the Environmental Protection Licence (EPL) No. 1770 there is a single licensed discharge point for Chain Valley Mine (LDP1), which has a maximum discharge volume of 12,161 kL/day.

The Colliery obtained a 4,443 ML/year groundwater licence (20BL173107) on the 12th March 2013 under the *Water Act*, 1912 to enable water to be pumped from the underground workings to the sedimentation and pollution control ponds at the pit top.

5.5 Mine Water Pumping and Mine Groundwater Inflow

Historic data indicates that 1,914 - 2,536.4 ML/year of mine water has been extracted via two pumps in the Great Northern Seam workings sump, with a reduction in extraction volumes being evident over the last 3 years as shown in **Figure 5**.

The net groundwater seepage into the workings is estimated from the difference between the annual potable water intake and the annual water volume extracted from the underground workings.

The latest annual groundwater make from the mine is estimated at 1,817ML/yr, or 4.98ML/day.

Temporary increases in groundwater inflows to the mine have been reported in the vicinity of faults and associated fractures. The increases in inflow are usually short lived as the structures associated with fractured bedrock systems tend to be laterally and vertically discontinuous, resulting in poor hydraulic connection and have low groundwater yields (GeoTerra, 2013).

In general, the Fassifern Seam has to date been the driest seam, whilst mining of the overlying Wallarah Seam has been conducted without major adverse impacts to the overlying aquifers or inflow of water from Lake Macquarie (GeoTerra, 2013).

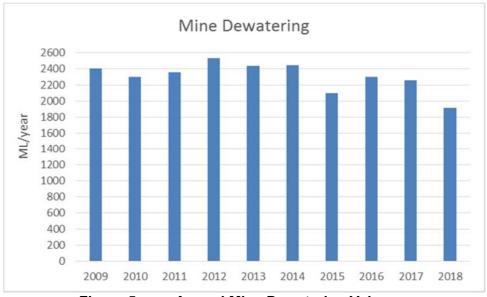


Figure 5 Annual Mine Dewatering Volumes

5.6 Mine Groundwater Quality

Groundwater monitored within the current and historic underground mining areas in the Chain Valley mine indicates the inflow water is brackish to relatively saline in subsided areas over the Great Northern Seam workings (11,800 - 28,200 mg/L) with a circum-neutral to mildly alkaline pH (7.30 - 7.76).

Groundwater seepage from a dyke at the northern end of the current Fassifern seam workings, over the unsubsided main headings, had a brackish salinity of 2,390mg/L and an alkaline pH of 8.63 as shown in **Tables 4** and **5**.

The data indicates that groundwater within the underground is significantly above the ANZECC 2000 criteria (default trigger values for physical & chemical stressors in SE Aust. lowland rivers and 95% protection of freshwater species) for;

- pH (Fassifern dyke);
- electrolytical conductivity (all samples);
- total nitrogen (all samples);
- total phosphorous (Fassifern dyke), as well as,
- filterable copper (GNS sump , Fassifern dyke), and
- filterable zinc (all samples except GNS2)

The exceedance in the mine water seepage depends on the guideline applied for the end use of the water.

The groundwater seepage is not generally suitable for potable, livestock or irrigation use, but is suitable for discharge under the EPA licence to Lake Macquarie.

Table 4 Water Chemistry - Major Ions

	pН	EC (uS/cm)	TDS	Na	Ca	к	Mg	CI	F	HCO3	SO4	Total P	Total N	DOC
ANZECC 2000	6.5 -8.0	2,200	-	-			-	-	-	1	-	0.05	0.5	-
Karignan Ck	6.93	185	100	29	2.2	2.3	3.5	54	0.10	10	6	0.15	0.6	17
Chain Valley Bay	7.64	47,300	36,100	10500	470	470	1100	19400	1.3	125	2200	0.06	0.4	<1
GNS SUMP	7.48	35,600	23,200	7640	590	125	690	13600	0.25	360	1200	0.04	2.3	2
GNS1 (roof)	7.30	40,400	28,200	7980	730	80	840	15600	0.47	435	1320	<0.01	3.4	<1
GNS2 (pond)	7.76	19,500	11,800	3950	140	38	230	6730	0.57	385	250	0.02	0.6	3
Fassifern dyke	8.63	3,500	2,390	925	1.9	9.1	2.1	310	5.6	2040	7	0.65	4.1	3

NOTE: all values in mg/L

samples collected 22/6/2012

Table 5 Water Chemistry - Metals

	Fe(T)	Fe	Mn(T)	Mn	Cu	Pb	Zn	Ni	Al	As	Li	Ва	Sr
ANZECC 2000	_	_	1.9	1.9	0.0014	0.0034	0.008	0.011	0.055	0.013 / 0.024	_	_	_
Karignan Ck	1.3	0.82	0.03	0.03	0.003	<0.001	0.014	<0.01	0.05	<0.01	<0.001	0.026	0.10
Chain Valley Bay	0.10	0.02	0.02	0.01	0.003	<0.001	0.013	<0.01	0.03	<0.01	0.38	0.041	4.8
GNS SUMP	0.18	0.07	0.06	0.04	0.004	<0.001	0.018	<0.01	0.04	<0.01	0.98	0.084	31
GNS1 (roof)	0.12	0.07	0.27	0.16	<0.001	<0.001	0.010	<0.01	0.03	<0.01	1.3	0.080	44
GNS2 (pond)	0.05	<0.01	<0.01	<0.01	<0.001	<0.001	0.003	<0.01	0.01	<0.01	0.59	0.17	11
Fassifern dyke	2.4	0.08	0.06	0.02	0.004	<0.001	0.019	<0.01	0.04	<0.01	0.28	0.37	1.0

NOTE: all values in mg/L

metals reported as acidified and 45um filtered samples except where Total (T) values are shown samples collected 22/6/2012



6. POTENTIAL GROUNDWATER IMPACTS

It is anticipated that subsidence over the 164 - 172m deep proposed S2 and S3 miniwall workings may affect the overlying groundwater system through;

- surface cracking to approximately 20m below surface;
- goaf fracturing to less than 96m above the seam (Strata2, 2018), with partial loss of groundwater if fracturing extends into an overlying aquifer, which can cause minor groundwater inflow from the goaf to the workings;
- an exponential decrease in overburden permeability with height above the workings;
- connectivity between the mine workings and overlying aquifers within the fractured goaf, which can result in depressurisation of the aquifers;
- dewatering and depressurisation of the Great Northern and Fassifern seams as mining progresses;
- increased aquifer permeability, and potentially
- reduced groundwater quality in the overlying aquifers.

6.1 Hydraulic Connection to Lake Macquarie

The (Forster and Enever, 1992) study at Wyee, with 150m wide longwalls, indicated there was no hydraulic connection at heights over 115m above the extracted workings.

It should be noted that the proposed miniwalls have a maximum width of 97m, which means the height of fracturing would be less than that observed over the 150m wide Wyee longwalls.

As a result, hydraulic connection between the mine and Lake Macquarie over the proposed secondary extraction workings (Miniwalls S2 and S3) is not likely as the minimum depth of cover is at least 172m (including lake bed sediments) or from 142 – 165 of basement (excluding the sediments in Lake Macquarie).

6.2 Aquifer / Aquitard Interconnection

Mining induced cracking and vertical subsidence of strata over the extraction area may potentially extend up to 20m below surface, with bedding dilation below from below the surface zone down to the upper goaf.

In the upper horizons, subsidence can alter the dominance of the pre-mining horizontal flow along or above aquitards to generate a combination of vertical and horizontal flow regimes as aquitards are breached and water drains to lower elevations in the strata.

Vertical flow continues down the strata until the drainage is restricted by intact aquitards, at which the depth the flow then resumes its horizontal dominance.

Below the surface cracked zone, an increase in horizontal flow component can occur due to dilation and bending of strata, even though the layers are not actually breached by vertical cracking. The increased horizontal permeability extends across the subsided area, gradually diminishing as the subsidence and dilation decreases out to the edge of the subsidence zone.

No adverse interconnection of aquifers and aquitards is anticipated within 20m of the lake bed as there are no recorded aquifers in this interval.

However, there may be an increased rate of recharge into the upper overburden from the lake waters due to the increased secondary porosity and permeability of the subsided, fractured overburden.



6.3 Regional Groundwater Depressurisation

Extensive mining of the Fassifern, Wallarah and Great Northern seams at Chain Valley and surrounding collieries for more than 60 years has significantly depressurised the overburden within the vicinity of the proposed workings.

Groundwater levels within the Fassifern seam has already been extensively impacted by mining in the area and therefore the proposed mining is likely to have little additional impact, if any.

The deeper basement lithologies have increased permeability in areas of partial or full extraction due to subsidence induced caving and fracturing over the workings which results in an increased groundwater storage capacity of the overburden through increased secondary porosity.

Groundwater flow rates within the deeper aquifers are likely to increase within the caved and fractured areas due to greater hydraulic connectivity between horizontal and vertical fractures.

A temporary lowering of the regional piezometric surface over the subsidence area of up to 1.0m due to horizontal dilation of strata may occur due to the increase in secondary porosity and permeability (GeoTerra, 2013). This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone.

Based on similar observations in NSW with similar mining layouts, surficial and mid depth strata groundwater levels may reduce by up to 15m, and may stay at that reduced level until maximum subsidence develops at a specific location. The duration of the reduction depends on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances to subsequent panels, and the length of time required to recharge the secondary voids.

The degree of groundwater level decline under the lake due to subsidence is predominantly determined by the proximity to a mined panel, however it can also be significantly affected by the rate of lake water infiltration and terrestrial rainfall recharge to an aquifer, as well as changes in the rate or duration of groundwater extraction in any adjacent groundwater bores.

On the basis that the pre-mining circumstances of lake water and rainfall recharge as well as any local bore pumping remain the same, it is anticipated that groundwater levels will recover over a few months as the secondary void space is recharged by lake water and rainfall infiltration.

There is generally no permanent post mining reduction in groundwater levels under the lake, as no new hydraulically connected outflow paths from within the overburden develop.

6.4 Private Bore Yields and Serviceability

Although 6 registered bore sites are located within the predicted 1.0m groundwater depressurisation area, no private bore yields or serviceability have historically been reported to be, or are predicted to be affected by subsidence or regional groundwater depressurisation associated with the proposed workings, which are entirely located under Lake Macquarie.

No beneficial users of the deep bedrock/coal measures aquifers have been identified in the vicinity of the GwMP Area.



6.5 Groundwater Dependent Ecosystems

Cumulative impacts from the proposed mining are not anticipated to adversely impact on groundwater dependant ecosystems in the 20mm subsidence area.

This is primarily because no groundwater dependent ecosystems have been identified in the proposed subsidence area within or under Lake Macquarie

6.6 Groundwater Quality

Previous observations in NSW Coalfields indicates that groundwater quality within the subsided overburden is not generally adversely affected, however there may be increased iron hydroxide precipitation and a lowering of pH if the groundwater is exposed to "fresh" surfaces in the strata with dissolution of unweathered iron sulfide (marcasite) or iron carbonate (siderite).

The degree of iron hydroxide and pH change due to subsidence is difficult to predict, and can range from no observable effect to a distinct discolouration of water pumped out of bores.

The discolouration does not pose a health hazard, however it can cause clogging of pumping equipment and piping in extreme cases.

It should be noted that many bores in the local area can already have significant iron hydroxide levels, and a pre-mining survey of the active bores is required to assess the baseline water quality prior to undermining.

Acidity (pH) changes of up to 1 order of magnitude can occur, however the change can be reduced if the bore has sufficient bicarbonate levels.

The potential for groundwater contamination also exists from spills of fuels, oils and chemicals from both the surface and underground mine workings. Spills may result in the contamination of soil, while the infiltration of rainfall or direct migration of contaminants to the water table has the potential to contaminate shallow aguifers.

The potential for impacts can be minimised through the appropriate storage of fuels and hazardous chemicals, the implementation of appropriate work procedures and regular inspections and maintenance of equipment and plant.

Leaks and spills should be handled in accordance with the Environmental Management Plan prepared for the project, and remediated as required on a case by case basis.

Infiltration of potentially contaminated water from the sedimentation dams also has the potential to impact groundwater quality. As the dams receive all site runoff, amenities water and mine water, as well as workshop and wash down water after treatment by an oil separator, there is potential for the water within the dams to be contaminated by dissolved petroleum hydrocarbons and heavy metals. It is understood the dams are not lined with a low permeability layer, and as such, seepage of potentially contaminated water within the dams may be infiltrating alluvial or shallow aquifers.



6.7 Groundwater Seepage to or From Terrestrial Streams

No known springs or streams are present in the GwMP area that would be affected by subsidence and associated regional groundwater depressurisation with the existing and proposed workings.

Overall, the terrestrial streams within the GwMP area will be subjected to no or very low tensile and compressive strains and are not anticipated to be adversely affected by subsidence related stream bed cracking.

No loss of overall stream flow or regional change in stream water quality within the local streams is anticipated to occur.

6.8 Groundwater Inflow to Mine Workings

Loss of lake water or any significant loss of connate groundwater within the overburden to the underlying workings has not been observed in mines in the local area at similar depths of cover to the proposed workings.

Vertical hydraulic connection to the workings is anticipated to be restricted by the Dooralong Shale and the Mannering Park Tuff aquitards, which are not anticipated to be breached by subsidence over the proposed Fassifern seam workings and are both below the surficial and above the goaf, vertically connected, dilation zones.

The horizontal permeability above and between the aquitards may be enhanced after subsidence, however there is no additional vertical connectivity through or below them to the underlying workings.

Based on available records, the 2018 annual groundwater seepage into the workings was 1,817ML/yr, or 4.98ML/day.

No obvious relationship between expansion of the mine and increased groundwater inflow to the workings is evident in the current data, with a reduction in mine water pumping evident over the last three years.

Based on a groundwater modelling assessment (GeoTerra, 2013) the inflow may increase up to 10.5ML/day as the Colliery expands.

7. GROUNDWATER MONITORING PLAN

The groundwater monitoring program at locations shown in **Figure 3** is designed to provide a database that enables:

- comparison of anticipated vs observed impacts on the groundwater system through miniwall as well as bord and pillar extraction of the Fassifern seam at Chain Valley Colliery and any associated subsidence effects, and;
- procedures to assess, manage or rehabilitate any adverse effects that exceed specified trigger levels.

As the proposed workings, and the anticipated associated subsidence impacts, are wholly located underneath or within Lake Macquarie, the monitoring plan specifically deals with the following issues.

7.1 Mine Groundwater Inflow

The active underground mining area should be monitored by the underground supervisors to assess whether observable groundwater inflow is occurring to the active panels and to note if any changes are noted.

Water flow monitoring appliances have been installed in the mine to measure pumped water volumes to and from the mine workings. These appliances will be maintained in good working order, and if required, the mine will supply a test certificate to certify the current accuracy of the appliances furnished by the manufacturer or by some duly qualified person or organisation.

Daily total mine water pumping records will be maintained, plotted and interpreted annually and will be supplied to DIW annually within the AEMR.

7.2 Private Bore Water Levels

Where property access is granted and access inside a bore is possible, water levels within the private bores could be measured at least once before and once after mining is conducted in the GwMP Area to assess if any adverse effects due to subsidence have occurred as shown in **Table 6**.

Where monitoring of groundwater levels is not possible due to installed pump head-works, the mine will assess any reports from landowners in regard to adverse effects on bore water availability that may occur during or after extraction of the proposed workings.

Each property owner may be interviewed before and after the proposed mining to assess the bore's status, pumping rate, its general duration of pumping as well as the type and set up of the pump. The bore yield should also be measured, and water levels measured where access inside the bore is possible.

Where private bores are being occasionally or frequently pumped, and could thereby temporarily distort the static regional groundwater levels, the depth to groundwater, where accessible, should be monitored during pump resting periods to assess the regional piezometric surface across the area.



Table 6 Private Bore Water Level Monitoring

GW	Monitoring Frequency	Monitoring Method	Units
11915	Upon access / post mining	Dip meter	mbgl
24575	Upon access / post mining	Dip meter	mbgl
34600	Upon access / post mining	Dip meter	mbgl
201149	Upon access / post mining	Dip meter	mbgl
201150	Upon access / post mining	Dip meter	mbgl
201977	Upon access / post mining	Dip meter	mbgl

Note: mbgl = metres below ground level

7.3 Groundwater Quality

7.3.1 Inactive Private Bores

Where property access is granted and access inside a bore is possible, a pre-mining water sample collection and analysis will be conducted within one month of access being granted and available, and will be repeated at the end of mining in the Project Area to enable assessment of any subsidence related changes in groundwater quality.

Each bore will be purged prior to sampling until pH and salinity measurements stabilise, which usually involves removal of at least three bore volumes of water.

Samples will be collected, appropriately preserved, kept on ice and transported under chain of custody documentation to arrive at the laboratory within appropriate holding times.

In addition, each piezometer or inactive bore will be monitored in the field for bi-monthly salinity $(\mu S/cm)$ and pH measurements.

7.3.2 Active Private Bores

Where property access is granted and access to the groundwater bore is possible, an initial water sample collection and analysis will be conducted within one month of access being granted and available, and will be repeated at the end of mining in the Project Area to enable assessment of any subsidence related changes in groundwater quality.

To date, access to one current bore has been granted (GW80489), however no sample could be obtained as the installed pump was not working.

The use, and any treatment, of the bore water should be ascertained and observations made on the quantum of iron hydroxide precipitating from the pumped water before and after mining.

Each bore will be purged prior to sampling until pH and salinity measurements stabilise, which usually involves removal of at least three bore volumes of water.

Samples will be collected from bores that are current and accessible as shown in **Table 7**, and will be appropriately preserved, kept on ice and transported under chain of custody documentation to arrive at the laboratory within appropriate holding times.



Table 7 Private Bore Water Quality Monitoring

GW Monitoring Frequency		Monitoring Method	Units	
11915	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)	
24575	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)	
34600	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)	
201149	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)	
201150	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)	
201977	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)	

During extraction within the GwMP area, the frequency of monitoring and the parameters to be monitored may be varied in consultation with DIW once the baseline groundwater quality and its response to mining (if any) is established.

The frequency of post mining monitoring will be reassessed after mining is complete in the GwMP Area as it may be possible, depending on results, to lengthen the intervals.

Table 8 presents the physical groundwater quality parameters to be measured.

 Table 8
 Groundwater Quality Monitoring Parameters

SUITE	ANALYTES
Initial monitoring / After	Field EC, Eh, pH, temp
mining is completed	TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P
	Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Li, Ba, Cs, Rb, Sr (filtered)

7.4 Groundwater Contamination

In accordance with the sites' Environmental Protection Licence, surface water discharged from the dams is monitored monthly for a range of pollutants as specified in the site EPL and associated Water Management Plan.

The range of analysis for surface water also includes oil and grease, which allows the assessment of impact, if any, that these dams may be having on underlying aquifers.



8. GROUNDWATER ASSESSMENT CRITERIA AND TRIGGERS

Management of impacts within predictions follow standard assessment review and response protocols.

Contingent measures are included in this plan to ensure the timely and adequate management of the proposed extraction and subsidence impacts outside of anticipated levels.

Where and if required, specialist hydrogeological / hydrological investigations and reports may include:

- the study scope and objectives
- consideration of any relevant aspect from this plan
- analysis of trends
- assessment of any impacts against prediction
- assessment of the cause of a change or impact
- options for management and mitigation
- assessment for the need for contingency measures
- any recommended changes to this plan, and;
- appropriate consultation with DIW, DRE and EPA

Site specific mitigation / remediation action plans may include:

- · a description of the impact to be managed
- results of the specialist investigations
- aims and objections for the plan
- specific actions required to mitigate/manage
- timeframes for implementation
- roles and responsibilities
- identification of and gaining appropriate approvals from landholders and government agencies, and;
- a consultation and communication plan.

Trigger values for further assessment of potential subsidence effects on groundwater systems within the plan area are discussed in the following sections.

The triggers have been developed to reflect the current variability in relevant parameters and to enable the identification of any changes that may be due to either subsidence effects, landowner impacts and/or natural causes.

If trigger values are exceeded, the cause and effect will be investigated and a management plan developed if it is directly related to mining.

The Manager Environment shall be responsible for the implementation of agreed actions and shall communicate such actions to the relevant landowners or authorities.

8.1 Mine Water Extraction and Discharge

Chain Valley Colliery holds a DIW license (20BL173107) to extract up to 4,443 ML/year from the workings, and currently holds EPL 1770 which permits volumetric discharge of up to 12,161 kL/day via its licensed discharge point into Lake Macquarie.

Mine water extraction will be measured daily and daily discharge volumes will be reported publically on a monthly basis via LakeCoal's website.

As part of the AEMR the average monthly groundwater extraction rates will be determined by assessing the difference between the potable water pumped into the workings and the total water pumped out of the workings. This assumes no hydraulic conductivity with Lake Macquarie,



surface potable water leaks, water theft or measurement error.

A trigger for the groundwater extraction will be where the monthly average extracted underground mine water exceeds **10.5ML/day** (75th percentile groundwater inflow – refer Table 3), and this average continues for at least 2 months.

8.2 Private Bore Groundwater Levels

It should be noted that landowners pumping their own bores, as well as the interference effect from other landholders pumped bores can significantly affect temporary standing water levels in a bore, without any influence from mining or subsidence.

On this basis, if the combined monitoring of the outlined private bores indicates a sustained drawdown of **greater than 2m over a 2 month period** in a private bore, or, if a landowner reports a lack of groundwater availability in a bore that cannot be accessed internally, then the cause of the exceedance will be investigated to assess whether the >2m drawdown or lack of supply is due to;

- lack of rainfall recharge, using comparison to the cumulative sum of daily rainfall,
- operation of landowner bores either within or outside an affected bores property,
- · subsidence, or
- any or all of the above.

The 2m drawdown trigger level has been derived through extrapolation of similar mining subsidence related effects in similar mining layouts and geomorphological areas in NSW and to be consistent with the minimal impact considerations of the NSW Aquifer Interference Policy.

8.3 Private Bore Groundwater Quality

If a landowner reports an increase in iron hydroxide precipitation or water salinity, as an initial default, the ANZECC 2000 irrigation and livestock guidelines shown in **Table 9** will be used as trigger levels to assess bore water quality.

As no bores are used for drinking water in the GwMP, drinking water quality criteria and triggers are not specified.

Table 9 Groundwater Chemistry Criteria (mg/L)

	рН	TDS	Hardness as CaCO3	Cu	Pb	Zn	Ni	Fe	Mn	As	Cd
Irrigation	6 - 8.5	-	>60-350	5	5	5	2	10	10	2.0	0.05
Livestock	-	<4000/5000	-	1/0.4	0.1	20	1	-	-	0.5	0.01

NOTE: all metals values are for filtered metals

irrigation criteria for short term trigger values (< 20 years)

Livestock criteria for beef / sheep

9. POTENTIAL GROUNDWATER AMELIORATIVE ACTIONS

9.1 Private Bore Yield

Although it is not anticipated due to the separation distance from the bores to the proposed subsidence area, should the accessibility, available drawdown or yield of a bore be impacted due to subsidence, the Colliery is required to provide an alternative water supply until the bore recovers.

If the level does not sufficiently recover and the effect is due to subsidence rather than regional climatic or anthropogenic factors, repairs or maintenance to a bore can be undertaken after maximum subsidence has developed. At this time the pump intake can be lowered, the bore extended to a greater depth or a new bore can be established.

With these mitigation measures in place it is unlikely that water supply to properties will be significantly impacted by the proposed mining.

In the event of a monitored or reported adverse impacts on the yield or saturated thickness of a private registered bore, the cause will be investigated.

If a groundwater level drop of over 2m for a period of over 2 months is recorded, and the reduction in bore yield is a consequence of subsidence, the mine will enter into negotiations with the affected landowners and the Mine Subsidence Board with the intent of formulating an agreement which provides for one, or a combination of;

- re-establishment of saturated thickness in the affected bore(s) through bore deepening;
- establishment of additional bores to provide a yield at least equivalent to the affected bore prior to mining;
- provision of access to alternative sources of water; and/or
- compensation to reflect increased water extraction costs, e.g. due to lowering pumps or installation of additional or alternative pumping equipment.

9.2 Private Bore Groundwater Quality

In the event of an adverse change in groundwater quality to a private bore, particularly in regard to salinity and / or iron levels, the mine will implement an investigation to determine if the cause is due to subsidence.

Although it is not anticipated due to the separation distance from the bores to the proposed subsidence area, if subsidence cracking has caused a notable increase in iron hydroxide precipitates or the landowner reports an adverse change in salinity, and that change that exceeds the trigger levels, the mine will enter into negotiations with the affected landowner with the intent of formulating an agreement which provides for one, or a combination of;

- re-establishment of the water supply from a new bore to provide water equivalent to the pre mining status of the bore (on the basis that the landholder has allowed for premining status of the bore to be established);
- provide access to an alternative source of water, or;
- compensate the bore owner to reflect the economic costs incurred due to the subsidence effects on the water quality.



10. CONTINGENCIES

In the event that the proposed monitoring indicates that a trigger has been reached or is being approached, LakeCoal will commission a hydrogeologist or hydrologist to review the data, with the outcomes of that review, including any recommendations, being subject to consultation with DIW.

A trigger of pH or EC would initially lead to an increase in the analytes monitored and/or frequency of sampling to confirm the magnitude and extent of the change in groundwater chemistry and verify the change is a consequence of mining.

Should the standing water level trigger be achieved in any bore, the mine staff shall notify the affected landowner(s) and, if it is the hydrogeologist's opinion that the reduction is a consequence of mining, mitigation measures identified in previous sections will be initiated.

An independent authority may also be used where a dispute arises as to the cause of the change, given that groundwater supply and quality can be affected by non-mining related factors such as bore siltation, aquifer depletion by adjoining mining operations, agricultural users, bacterial infection, fertilizer contamination etc.

11. AUDIT AND REVIEW

This document shall be reviewed, and if necessary revised, within 3 months of the following;

- the submission of an Annual Environmental Management Report;
- the submission of an incident report;
- the submission of an independent environmental audit; and
- following any modification to the project approval.

Other factors that may require a review of the GwMP are;

- observation of greater impacts on surface features due to mine subsidence than was previously expected;
- observation of fewer impacts or no impacts on surface features due to mine subsidence than was previously expected, and/or;
- observation of significant variation between observed and predicted subsidence.

Internal and external audits of this document will be carried out as described below. If possible internal and external audits shall be objective and be conducted by a person or organisation independent of the document being audited.

Audits shall be carried out by personnel who have the necessary qualifications and experience to make an objective assessment of the issues. The extent of the audit, although pre-determined may be extended if a potentially serious deviation from this document is detected.

Any audit non-conformances and/or improvement opportunities will have corrective and preventative actions implemented to avoid recurrence, these actions will be loaded into the site Incident Database to ensure the actions are assigned to the relevant people and completed.

11.1 Internal Audits

Internal audits of this document and all other Environmental Management System documents are to be undertaken every three years. Improvements from the audit are to be incorporated in the site action database to ensure the actions are assigned to the relevant people and completed.



11.2 External Audits

External audits will be conducted utilising external specialists and will consider the document and related documents. External auditors shall be determined based on skills and experience and upon what is to be accomplished. External audits will be periodically at a frequency determined by the site General Manager, or in response to significant environmental incidents for which a systems failure has been determined as a contributor to the incident.

An Independent Environmental Audit will be undertaken every three years (or as otherwise required by the Department of Planning and Infrastructure) by an audit team whose appointment has been endorsed by the Director-General of the Department of Planning and Infrastructure.

Any actions arising from external audits will be loaded into the site actions database to ensure the actions are assigned to the relevant people and completed.

12. RECORDS

Generally, the site Environmental co-ordinator will maintain all Environmental Management System records, which are not of a confidential nature. Records that are maintained include:

- Monitoring data and equipment calibration;
- Environmental inspections and auditing results;
- Environmental incident reports;
- Complaint register; and
- Licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of 4 years.



13. RESPONSIBILITIES AND ACCOUNTABILITIES

13.1 General Manager

• Ensure that the requisite personnel and equipment are provided to enable this plan to be implemented effectively;

13.2 Environmental Coordinator

- Authorise the Plan and any amendments thereto;
- Ensure this plan is reviewed should any changes to the mine plan or if levels of subsidence are greater than predicted. Notify the relevant authorities of any triggers being exceeded;
- Reporting in the Annual Environmental Management Report
- Ensure that inspections are undertaken in accordance with the schedule;
- Ensure that persons conducting the inspection are appropriately trained, understand their obligations and the specific requirements of this plan;
- Review and assess monitoring results and inspection checklists;
- Promptly notify the General Manager of any identified environmental issue

13.3 Hydrogeologist / Hydrologist

- Assist in compiling and/or reviewing the monitoring to the standard and frequency as outlined in this plan;
- Promptly notify the Environment and Community Coordinator of any identified environmental issue

14. TRAINING

All personnel who conduct inspections will be trained in the requirements of the plan.

Training will be conducted on maintaining and downloading monitoring equipment, operation of the field testing equipment and sampling procedure for laboratory analysis identification of the various subsidence impacts detailed in this plan.



15. REPORTING

15.1 Annual Environmental Management Report

An Annual Environmental Management Report (AEMR) will be submitted to DIW each year. As part of the AEMR the groundwater section will include;

- groundwater related activities, and the level of compliance with the GwMP;
- all groundwater monitoring volumes and rates taken by the works;
- the volume groundwater extracted from the works that was discharged via the Licensed Discharge Point;
- all groundwater extraction data;
- the extent of groundwater depressurisation and any groundwater salinity impacts compared with predictions in the Environment Assessment;
- interpretation of the data, discussion of trends and their implications;
- an overall comparison of groundwater performance with predictions for the life of the mine provided in the Environmental Assessment, and;
- an outline of proposed adaptive or remediation actions if required.

Notification of the groundwater monitoring results and interpretations will be reported within the required annual period to outline the natural trends and any impacts from mining on the groundwater system.

GeoTerra

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- Strata 2, 2018 Geotechnical Aspects of S2 and S3 panel Design

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the site, GeoTerra reserve the right to review the report in the context of the additional information.

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	ENV 00021 - Benthic Communities Management
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CHAIN VALLEY COLLIERY

Benthic Communities Management Plan ENVIRONMENTAL MANAGEMENT PLAN

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Date:	17/06/2019		

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1 Introduction

Chain Valley Colliery is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station, producing thermal coal for the domestic and export markets.

A formal Environmental Management System (EMS) has been developed as a systematic and structured approach to managing environmental issues at the operation. This has been developed in general accordance with the requirements of the international standard ISO 14001.

This Benthic Communities Management Plan (BCMP) is an element of the Chain Valley Colliery Environmental Management System.

This Benthic Communities Management Plan has also been completed to satisfy the requirement of Condition 7(h), Schedule 4 of Development Consent SSD-5465 (Modification 2), which states:

"The Applicant shall prepare an Extraction Plan for all second workings on site, to the satisfaction of the Secretary. Each Extraction Plan must:

(h) include a Benthic Communities Management Plan, which has been prepared in consultation with OEH, LMCC, and DPI Fisheries, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on benthic communities, and which includes:

- surveys of the lake bed to enable contours to be produced and changes in depth following subsidence to be accurately measured;
- benthic species surveys within the area subject to second workings, as well as control sites
 outside the area subject to second workings (at similar depths) to establish baseline data on
 species number and composition within the communities;
- a program of ongoing seasonal monitoring of benthic species in both control and impact sites;
- development of a model to predict likely impact of increased depth and associated subsidence impacts and effects, including but not limited to light reduction and sediment disturbance, on benthic species number and benthic communities composition, incorporating the monitoring and survey data collected; and
- updating the model every 2 years using the most recent monitoring and survey data;

The relevant requirements from Table 8 within Condition 2, Schedule 4 of SSD-5465 (Modification 2), including the relevant notes, are recreated in **Table 1**.

Table 1: Subsidence Impact Performance Measures

Biodiversity	
Benthic Communities	Minor environmental consequences, including minor changes to species composition and/or distribution

Notes:

- The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken
 using generally accepted methods that are appropriate to the environment and circumstances in which the feature or
 characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute
 over the appropriateness of proposed methods, the Secretary will be the final arbiter.
- The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.

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2 Purpose

The purpose of this Benthic Communities Management Plan is to:

- outline details of the benthic communities monitoring data collected;
- outline existing and predicted subsidence levels;
- outline the methodology to be used to identify depth changes at monitoring locations;
- · identify benthic community monitoring locations;
- identify reporting requirements;
- · detail benthic community management measures;
- identify the requirements for incident or exceedances reporting and reviews of the document; and
- identify persons responsible for implementation of requirements.



3 Background

3.1 Baseline Data on Benthic Communities

Both species diversity and abundance are recorded as part of the 6 monthly seasonal (autumn and spring) benthic communities monitoring, which commenced in 2012.

The mud basin off Summerland Point, in Chain Valley Bay and Bardens Bay, was found to be inhabited by 21 species of organisms greater than 1mm in size. Polychaete worms and bivalve molluscs were the most frequently encountered animals.

Bottom sediment in the study area was composed of a small fraction of black sand and shell fragments of various sizes. Most of the sediment was fine black or grey mud.

The sampling results of the benthos undertaken at six monthly intervals between February 2012 and September 2017 revealed the following:

- The similar suite of organisms dominated each of the 19 sample stations. These were polychaete worms and bivalves.
- Stations were distinguished by the relative abundance of the dominant species.
- Water depth was not the key parameter in determining the species composition at a station.
- Physical variables such as salinity (conductivity), dissolved oxygen concentration and turbidity of the bottom water, measured only on the day the benthos was sampled, had little influence on the species composition of the benthos over the period sampled.

The results collated to date appear to support the notion that increasing the water depth by the predicted levels of subsidence has, to date, had no discernible effect on the composition and abundance of organisms making up the benthos of the mud basin.

3.2 Bathymetric Surveys

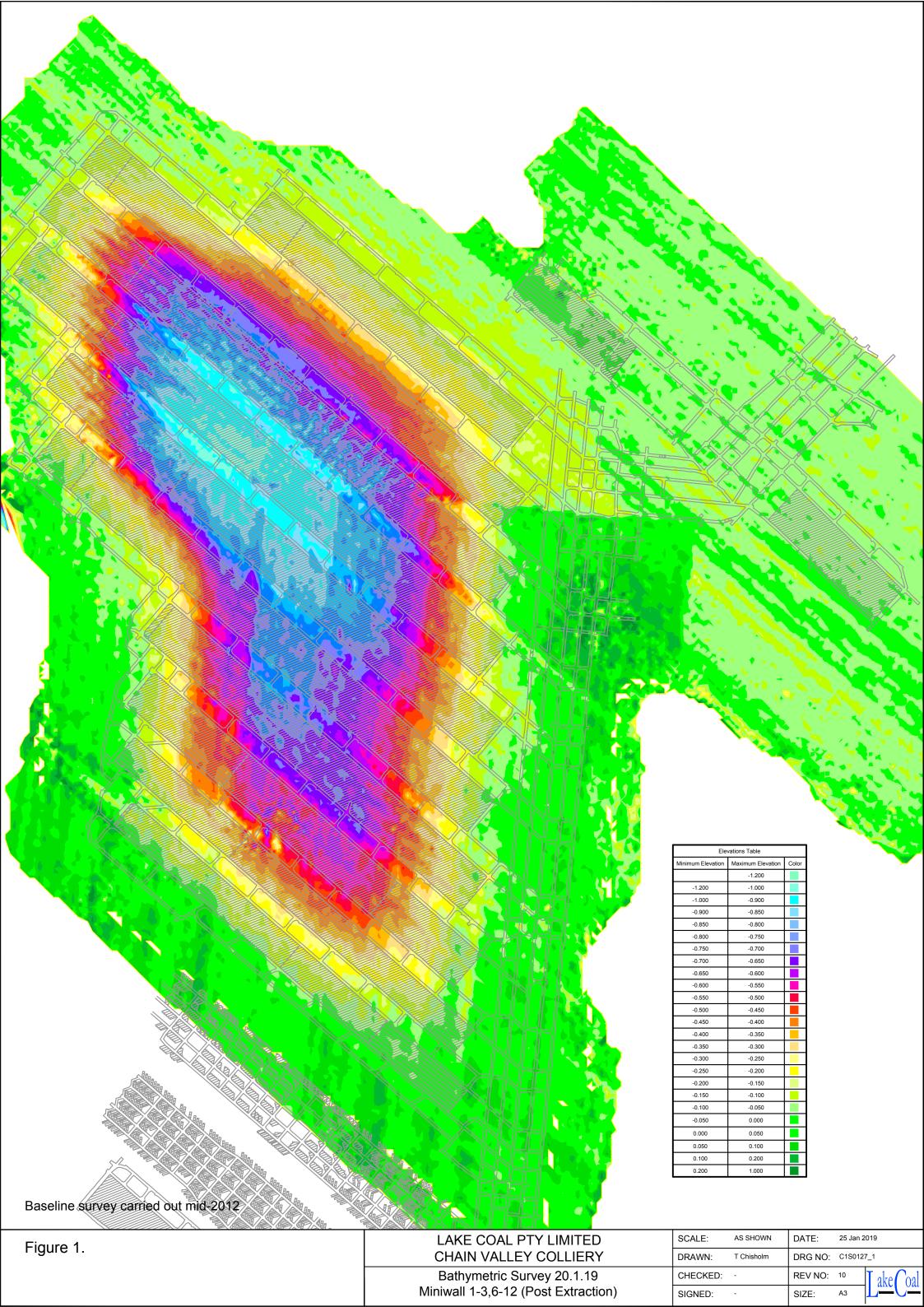
Bathymetric data from the NSW Office of Environment and Heritage (OEH) was obtained in draft format during 2012. Delta Coal was granted a license to use this OEH data for the purposes of monitoring changes in the bed of Lake Macquarie, and acknowledges the OEH's data which has enabled the subsidence comparison to be undertaken based on this 2010 data and data subsequently obtained in 2012 by Delta Coal. OEH notes that the data was obtained via use of differential GPS and a 200 kHz echosounder, which is noted to provide a general data accuracy of 0.1m.

Delta Coal commissioned Astute Surveying in March 2012 to undertake a bathymetric survey over the areas of current and proposed workings. The primary purpose of this survey was to obtain accurate baseline data for future subsidence assessments and to enable comparison with the draft OEH data from 2010. Importantly, the 2012 survey provided accurate details of the Lake depth within the proposed mining areas, which would enable future surveys to use as baseline data to monitor the future subsidence levels as a result of mining activities. Prior to 2018 bathymetric surveys have been conducted annually.

Following an exceedance of the subsidence predictions over Chain Valley Colliery's MW7-12 mining area in 2017 Delta Coal has committed to undertaking future bathymetric surveys at 6 monthly intervals to further understand the behavior of subsidence over the active mining areas. The latest January 2019 bathymetric survey results for Chain Valley Colliery are shown on **Figure 1**.

The surveys have shown that subsidence from the miniwall mining can be monitored with a useful level of accuracy and the surveys will be continued bi-annually to cover future mining areas and areas where mining has been completed.

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3.3 Subsidence Predictions and Management

Subsidence modelling has predicted up to approximately 1.23 metres of subsidence to the Lake floor associated with the planned miniwall mining where there is overlying workings, and 780mm where only single seam extraction is undertaken.

As outlined in **Section 3.2** Delta Coal recorded a subsidence exceedance over its Miniwall 7-12 area during the 2017 bathymetric survey where 1100mm of subsidence occurred. As a result of the exceedance Delta Coal has re-designed its future mining its future mining areas to ensure that subsidence values are within the approved predictions.

3.4 Consultation

The Benthic Communities Management Plan is required to be prepared in consultation with the OEH, LMCC and DPI Fisheries.

The original Benthic Communities Management Plan was developed in consultation with the OEH, DPI Fisheries and LMCC. These agencies were contacted on the 28 March 2012, and at this time a face-to-face meeting was offered to discuss the development of the methodologies and management plan, however all stakeholders requested information be provided for comment due to resource constraints. As a result each stakeholder was provided a summary of the survey methods for comment on the 11 April 2012. A response was received from LMCC on the 23 May 2012 regarding mitigation measures and these comments were addressed in the BCMP. No comments were received from OEH or DPI Fisheries.

Copies of the draft Benthic Communities Management Plan (Revision 1) were distributed to the OEH, LMCC and DPI Fisheries on the 13th March 2014 with comments requested back by the 1st April 2014, as of the 7th April 2014 only one response from the OEH had been received, dated the 21st March 2014. The OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided.

The previous version of the Benthic Communities Management Plan was sent to OEH, DPI Fisheries and LMCC on 4 November 2016 for review and comment. All three agencies provided comments on the revised Plan. LMCC and DPI Fisheries confirmed that the document was acceptable in its revised form while OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided on the content of the Plan.

A further review to the management plan was conducted in 2019 in consultation with DPE-resource assessments, OEH, LMCC and DPI Fisheries. Feedback from Department of Planning-resource assessments requested; the inclusion of the most recent bathymetric survey in January 2019 and an update of the latest mine plan in the monitoring. DPI Fisheries gave confirmation that this plan was adequate on the 05/06/2019. OEH remitted advice on the 05/06/2019 that they were not able to provide comment on plans. LMCC were requested on several occasions for comment on this Management Plan without comment received. A considerable amount of detailed consultation between the former Lake Coal and LMCC occurred in May 2018 for the earlier version of the BCMP.

4 Benthic Communities Monitoring Program

Based on contour mapping of Lake Macquarie and Delta Coal hydrographic surveys, it was identified that the mining operations are largely proposed to occur beneath areas of the Lake at water depths between 4-6m which represent the general Lake depths where subsidence is proposed and under which mining activities have been, will be or are proposed to occur. Accordingly, the monitoring program was designed to sample benthic invertebrate communities from these depths and to provide ongoing monitoring of the potential effects of subsidence. The methodology and monitoring details are presented in the following sections.

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4.1 Sampling Locations

In order to analyse the community assemblages and determine potential impacts of subsidence over time, sampling was, and will continue to be undertaken across two depth intervals from numerous site locations within three site types. The site types consist of;

- Impacted (site prefix "IM"): Sites which are currently, or were historically impacted upon by subsidence;
- Reference (site prefix "R"): Sites which are not currently impacted by subsidence but fall within the proposed future mining footprint. Following undermining, Reference sites are designated as Impacted sites; and
- Control (site prefix "C"): Sites which will not be impacted upon by subsidence.

The sampling locations are identified in Table 2 and Figure 2.

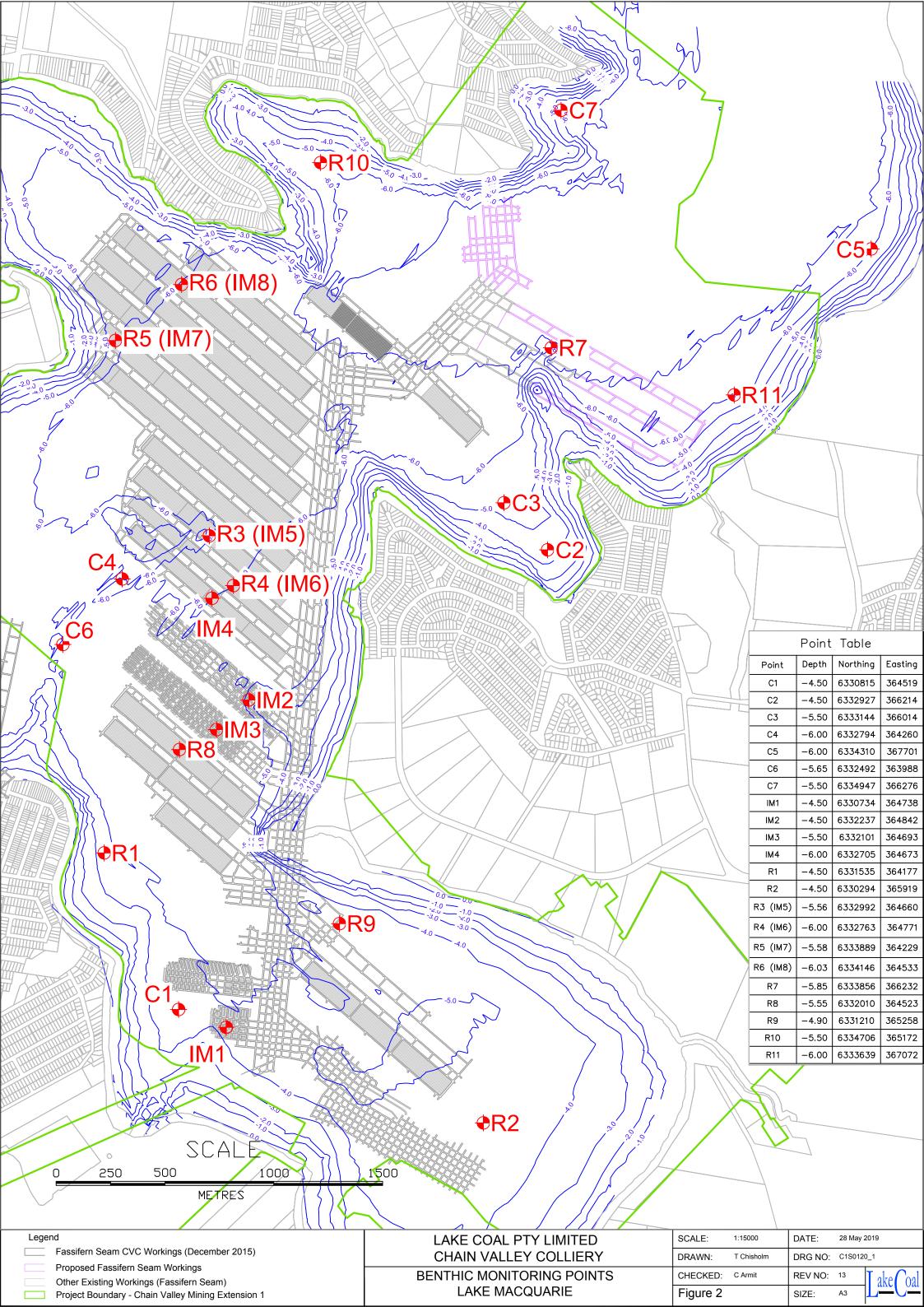
Table 2: Benthic Community Sampling Locations

Site Name	Sample Depth (m)	Easting	Northing
C1	-4.5	364519	6330815
C2	-4.5	366214	6332927
C3	-5.5	366014	6333144
C4	-6	364260	6332794
C5	-6.0	367701	6334310
C6	-5.5	363988	6332492
C7	-5.5	366276	6334947
R1	-4.5	364177	6331535
R7	-6.0	366232	6333856
R9	-4.5	365258	6331210
R10	-5.5	365172	6334706
R11	-6.0	367072	6333639
IM1	-4.5	364738	6330734
IM2	-4.5	364842	6332237
IM3	-5.5	364693	6332101
IM4	-6	364673	6332705
IM5 (previously R3)	-6	364771	6332763
IM6 (previously R4)	-5.5	364660	6332992
IM7 (previously R5)	-5.5	364229	6333889
IM8 (previously R6)	-6.0	364533	6334146
IM9 (Previously R8)	-5.5	364523	6332010
IM10 (Previously R2)	-4.5	365919	6330294

4.2 Sampling Methods

Each of the sites will be surveyed for biotic (benthic invertebrates) and environmental (water quality, benthic sediment) variables. The surveys will be undertaken during spring and autumn.

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4.2.1 Water Quality

General physico-chemical water quality variables will be measured at the sites during sampling. The water quality parameters will be measured at 0.5m below the surface and 0.5m above the Lake bed. The variables measured will include temperature ($^{\circ}$ C), pH, turbidity (NTU), conductivity (μ S/cm), dissolved oxygen (mg/L and % saturation) and oxygen reduction potential (ORP) or photosynthetically active radiation (PAR).

4.2.2 Benthic Sediment

Sediment samples will be collected to a depth of 20cm at each of the sites using 250mL jars. The jars will be labelled and transported to the laboratory for analysis via settlement method.

4.2.3 Benthic Invertebrates

At each site, five replicate samples of benthic sediment will be collected by a diver using 200x200x100mm sieve boxes with 1mm mesh.

The samples will be sieved to remove sediment particles less than 1mm in diameter. The residual material will then be transferred to a labelled 250mL plastic jar and preserved with formaldehyde. Large fragments of shell will be removed from the sample at this time to ensure that the sample volume did not exceed 250mL and the samples are retained for later inspection at the laboratory.

4.3 Laboratory Analysis

4.3.1 Benthic Sediment

The 250mL sample of the entire sediment from each site will be transferred into a 500mL clear glass measuring cylinder and the volume made up to 500mL with seawater. The cylinder is then to be stoppered and shaken vigorously to suspend the sediment in the seawater. The sample will then be allowed to settle and the volumes of each fraction (shell and coarse sand, fine sand, mud and fine silt) calculated and recorded. Results are then determined relative to the initial volume of sediment collected in the 250mL jar.

4.3.2 Benthic Invertebrate Identification

The contents of each jar is run through a 1mm mesh sieve and washed free of formalin and any remaining mud.

The washed material is then placed into two enamel dishes and portions of each sample placed in a 100mm diameter petri dish for examination under a stereoscopic binocular microscope to detect and recover small organisms. Organisms and parts of organisms are removed, counted, identified and the results entered into a spreadsheet. The benthic invertebrates are identified to genera and species where possible. This process is repeated until the debris of the entire sample had been examined. The results for each site are then entered into an excel spreadsheet for summary and analysis. All shell remaining in the sample is kept for later examination.

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4.4 Data Analysis

The biotic and environmental data will be analysed using a variety of univariate and multivariate analysis (**Table 3**). The statistical methods used to analyse the data were determined based on earlier monitoring data to provide the most statistically robust assessment of comparison between impacted and reference and control sites and environmental data. It must be noted that control and reference sites are the same until undermined.

Table 3: Data Analysis

Variable Type	Analysis	Description
Environmental: Water quality	ANZECC/ARMCANZ Guidelines (ANZECC Guidelines)	Trigger values for slightly – moderately disturbed ecosystems: Estuaries.
Biotic and Environmental	Univariate	Descriptive graphical statistics. Analysis of Variance and Similarity (2 way nested)
Biotic and Environmental	Multivariate	A square-root transformation was performed on the data and Bray-Curtis Similarity matrices created. Cluster analysis was then performed for each site and dendrogram plots produced.
	Multidimensional Scaling Ordination	The analysis represents the sites as points in space so the relative distances between samples show similarities in community structure. Samples that are placed closer together are more similar than samples further apart.
	BIOENV	The analysis matches environmental variables against biotic data which have been measured at the same sites. This analysis enables analysis of the extent to which the physiochemical data is related to the observed biological patterns. Correlations were performed for each site between the biotic and environmental factors using the BIOENV function in PRIMER5.

4.5 Monitoring Frequency

The baseline sampling program methods outlined in **Section 4** will form the basis for a seasonal monitoring program that will be undertaken during spring and autumn each year to survey biotic (benthic invertebrates) and environmental variables (water quality and sediment). The program has been designed to enable analysis and reporting of the data to monitor the impacts of subsidence and effects, including but not limited to light reduction and sediment disturbance, on benthic species number and benthic communities composition and distribution.

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In addition to the above, annual lake bed bathymetric surveys will be undertaken prior to each autumn survey. The annual bathymetric surveys will enable any change to the lake floor to be identified and addressed during the data analysis process.

4.6 Program Refinement

The survey methods will be reviewed every two years of seasonal sampling to refine the sampling program if required. Prior to each seasonal sampling event the sites will be reviewed against the mine plans to ensure that any reference sites that have become impacted upon by mining are reclassified as impact sites, and replacement reference sites are identified and sampled. This will result in additional reference sites being added to the program during the monitoring period.

5 Modelling to Monitor Potential Impacts

5.1 Model Background

Maximum subsidence for the proposed future mining activities is predicted to be 1230mm, or 780mm where no overlying workings exist. The analysis undertaken on the baseline data provides an initial assessment of biotic and environmental variables associated with the study area and forms the basis of the formation of the predictive modelling (JSA 2012). The results will be reported in biannual monitoring reports and the Annual Review.

The aim of the predictive modelling is to compare the condition of the baseline benthic community assemblages prior to mining to the benthic community assemblages after mining has occurred, to ensure that only minor environmental consequences occur due to mining activities. The effects of subsidence are required to result in only minor changes to species composition and/or distribution. As the environmental variables which affect benthic communities are complex, in order to determine whether community dynamics at reference sites are related to subsidence, seasonal biotic survey data will be analysed against environmental data and between impacted types. The analysis and modelling will be undertaken to determine whether:

- Overall community dynamics are related to seasonal and environmental variables and/or subsidence impacts;
- Abundance and diversity changes to community composition at reference sites that have been undermined are related to seasonal and environmental variables or subsidence impacts; and
- Changes identified in reference sites that have been undermined are considered minor.

5.2 Analysis

In order for the model to identify whether the environmental consequences of subsidence are considered minor (and therefore whether mitigation measures will be required) a series of statistical analysis will be undertaken and reported seasonally and annually. Based on the expected timing of subsidence impacts, the analysis will model scenarios to determine:



ENV 00021 - Benthic Communities Management Plan

- Changes in undermined reference sites with the baseline conditions at the same sites; and
- Similarity of impacted sites to control and reference sites at similar depths.

The modelling will be based on Multi-dimensional Scaling (MDS) Ordination, two way ANOVAs (analysis of variation) and ANOSIM (analysis of similarity) techniques to identify any links in community structure between sites at the same depth profiles. The modelling will be based on the existing benthic community structure, actual subsidence levels (determined from annual bathymetric surveys), predicted levels of increased subsidence and collection of seasonal data.

Figure 2 identifies the reference sites applicable to the project. The communities at the reference sites will be compared against control and reference sites at a similar depth profile. The determination of the level of impact of subsidence, once other environmental variables have been discounted by the model will be based on ANOVA/ANOSIM techniques.

Essentially, if ANOVA/ANOSIM results indicate that undermined reference site communities are changing at a rate of ANOVA/ANOSIM test of significance <5 % then the impacts will be considered to be moderate or major mitigation measures to manage impacts will be required. The use of 5% (the p significance level of 0.05) is a standard statistical method of determining level of significance, another is p= 0.01. Because the data set used in the initial analysis represents a single sampling event the use of the conservative 5% significance rule has been applied to determine minor impacts(other methods such as ranking and scaling were applied to the data but did not provide adequate measurable results). The 5% significance will be applied to seasonal data and revisited with regard to suitability based on data outcomes.

The options for mitigation measures to manage subsidence on the lake floor are largely limited to changes to mine design. If impacts are determined to be moderate or major, mine planning will be required to modify mine plans.

The benthic community results of surveys and annual monitoring undertaken have identified that while communities at some sites were defined by dominant species, the abundance and diversity of the communities did not identify clear links to location or impact type. Rather the analysis identified that natural environmental fluctuations in water quality, benthic substrate composition and natural depth intervals were influencing the communities (JSA 2013).

The results of sampling between February 2012 and September 2017 appear to support the notion that increasing the water depth by the predicted subsidence will have no discernible effect on the composition and abundance of organisms making up the benthos of the mud basin (Laxton & Laxton, 2017). This is supported by the statistical modelling of results which is undertaken every 3 years.

In January 2018 Delta Coal engaged JSA environmental to undertake the 3 yearly statistical modelling of the sites Benthos data set. Detailed ANOSIM analysis of the benthic community data between un-impacted and impacted sites between 2012 – 2017 identified a significance p value of 24.1%. This value indicates that there had been no significant differences between the un-impacted and impacted sites over the last 5 years.

If the assessment of results from future analysis indicate that impacts are outside the defined trigger level Delta Coal will investigate the cause of incident and implement corrective actions where required as outlined in Section 6.



6 Incident & Compliance Management

6.1 Introduction

The benthic community monitoring results will be reviewed on a biannual basis as survey reports are received to confirm compliance with the conditions specified in the *Subsidence Impact Performance Measures* found in **Table 1**.

The Annual Review will also include a summary of monitoring results during the past year, discussion with reference to the impact assessment criteria, and any relevant details related to comparisons between actual results and predictions in the Environmental Impact Statement. The Annual Review will be forwarded to the relevant authorities including Department of Planning and Environment, and Environment Protection Authority. The Annual Review will also be forwarded to members of the Community Consultative Committee and local Councils (Central Coast and Lake Macquarie). It will also be placed on the company's website along with a summary of environmental monitoring results.

6.2 Incident or Non Compliance Reporting

If monitoring reveals that, as a result of mining activities, greater than minor impacts have occurred, then Delta Coal will conduct an investigation into the cause of the non-compliance. The investigation will consider any activities or other factors that may have generated the non-compliance. The report will be provided to OEH, LMCC and Department of Planning and Environment.

The report will:

- a) describe the date, time and nature of the exceedance / incident;
- b) identify the cause (or likely cause) of the exceedance / incident;
- c) describe what action has been taken to date; and
- d) describe the proposed measures to address the exceedance / incident.

Delta Coal would implement the recommendations of the investigation in order to address any future non-compliance issues.

Additional details of the incident reporting process are provided in the Environmental Management Strategy.

7 Stakeholder Management and Response

7.1 Complaint Protocol

Delta Coal has a 24-hour telephone hotline (1800 687 557) for members of the public to lodge complaints, concerns, or to raise issues associated with the operation. This service aims to promptly and effectively address community concerns and environmental matters.

The full details of the complaints line are covered in the Environmental Management Strategy, but in summary, all complaints are recorded and responded to, if for some reason no action is taken then the reason why is recorded. The information recorded in the complaint register includes;

- date and time the complaint was lodged:
- personal details provided by the complainant;

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- nature of the complaint;
- action taken or if no action was taken, the reason why; and
- follow up contact with the complainant.

7.2 Dispute Resolution

If any disputes are not adequately addressed by the complaints handling process then they will be handled by the site Environment and Community Coordinator, if the response of Delta Coal is not considered to satisfactorily address the concern of the complainant, a meeting will be convened with the Mine Manager together with the Environment and Community Coordinator.

The complainant will be advised of the outcomes from the meeting and the actions to be implemented as a result.

After implementation of the proposed actions, the complainant will be contacted and advice sought as to the satisfaction or otherwise with the measures taken.

If no agreed outcome is determined or the complainant is still not satisfied by the action taken, then an Independent Review may be requested by the complainant. If determined to be warranted by the Secretary, an Independent Review will be undertaken in accordance with the requirements of the project approval to achieve an outcome to the satisfaction of the Secretary.

8 Roles and Responsibilities

Roles, responsibilities specific to completing the requirements of Benthic Communities Management Plan are identified in **Table 4**.

Table 4: Roles and Responsibilities

Role	Responsibilities
Mine Manager	Ensure that adequate financial and personnel resources are made available for the implementation of the Benthic Communities Management Plan.
Environment and Community Coordinator	 Co-ordinate benthic community monitoring. Review benthic community monitoring results on a seasonal and annual basis. Develop management actions in consultation with regulatory agencies as/if required from the monitoring results. Compile the Annual Review (including a summary of the benthic community monitoring). Respond to any potential or actual non-compliance and report these as required to regulatory bodies and other stakeholders. Undertake reviews of this document as per Section 9. Undertake or coordinate the required audits of this document, in accordance with Section 9.2. Notify DPI Fisheries, Department of Industry – Resources and Energy and Department of Planning and Environment if there are any exceedances in impact thresholds outlined in Section 1. Ensure complaint handling and response is undertaken, including determination of sources and potential remedial action to avoid recurrence.

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8.1 Training, Awareness and Competence

Training is an essential component of the implementation phase of this Benthic Communities Management Plan. Any person or position that has a role or responsibility under this document will be provided with a copy of the document and be advised verbally regarding their requirements by the Environment and Community Coordinator.

As the document owner, the Environment and Community Coordinator is the contact point for any person that does not understand this document or their specific requirements, and will provide guidance and training to any person that requires additional training regarding this management plan.

9 Audit and Review

9.1 Overview

This document shall be reviewed, and if necessary revised, within 3 months of the following:

- The submission of an Annual Review:
- The submission of an incident report under **Section 6.2**:
- The submission of an independent environmental audit; and
- Following any modification to the development consent.

As outlined in **Section 6.1**, the annual review will include a review of the seasonal monitoring program and mine plans to ensure that any reference sites that have been impacted by mining reclassified as impacted impact sites, and replacement reference sites identified and sampled. Survey methods will be reviewed every two years to refine the sampling program if required. Improvements identified during reviews or audits will be incorporated into the Benthic Communities Management Plan.

9.2 External Audits

An Independent Environmental Audit of the Chain Valley Colliery development consent will be undertaken every three years (or as otherwise required by Department of Planning and Environment) by an audit team whose appointment has been endorsed by the Secretary. This audit will review the relevant management plans that apply to the operation.

Any actions arising from external audits will be loaded into the site action management database to ensure the actions are assigned to the relevant people and completed.



10 Records

Generally the Environment and Community Coordinator will maintain all Environmental Management System records, which are not of a confidential nature. Records that are maintained include:

- monitoring data and equipment calibration;
- · environmental inspections and auditing results;
- environmental incident reports;
- · complaint register; and
- licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of 4 years.

11 Document Control

This document and all others associated with the Environmental Management System shall be maintained in a document control system which is in compliance with AS/NZS 4804; section 4.3.3.4 (Document Control) and in compliance with the site Document Control Standard which is available to all personnel.

Any proposed change to this document shall be via the document control administrator who is the only person able to access the controlled documents.

12 References & Associated Documents

AS/NZS ISO 14001:2004	Environmental management systems – Requirements with guidance for use
AS/NZS ISO 14004:2004	Environmental management systems – General guidelines on principles, systems and support techniques
ANZECC (2000)	Australian and New Zealand Guidelines for Fresh and Marine Water Quality.
SSD-5465	Development Consent SSD-5465 (Modification 2), 16 December 2015
JSA Environmental 2013	Chain Valley Colliery Mining Extension 1 Project Marine Ecology Assessment Delta Coal
JSA Environmental 2015	Chain Valley Colliery Modification 2 Marine Ecology Assessment Delta Coal
Laxton & Laxton, 2013	Lake Macquarie Benthos Survey Results of Sampling No. 4. September 2013.
Laxton and Laxton 2015	Benthic Communities Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW
Laxton and Laxton 2016	Lake Macquarie Benthos Survey Results No.10 September 2016. J.H. & E.S. Laxton - Environmental Consultants P/L. Report for Lake Coal Pty Ltd Chain Valley Colliery.

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13 Definitions

CVC

Delta Coal - Chain Valley Colliery

DTIRIS - Resources and Energy

Department of Trade, Investment, Regional Infrastructure and Services – Resources and Energy

DPI Fisheries

Department of Primary Industries - Fisheries NSW

EMS

Environmental Management System

LMCC

Lake Macquarie City Council

OEH

Office of Environment and Heritage

Secretary

Secretary of the Department of Planning and Environment, or nominee

SSD-5465

Development Consent SSD-5465 (for the Chain Valley Colliery Mining Extension 1 Project)

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Doc No: ENV 00020 - Seagrass Management Plan

CHAIN VALLEY COLLIERY

Seagrass Management Plan ENVIRONMENTAL MANAGEMENT PLAN

Author	Wade Covey / Chris Armit		
	Environment and Community Coordinator		
Authorised by:	Dave McLean		
	Mine Manager		
Date:	17/06/2019		

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1 Introduction

Chain Valley Colliery is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station, producing thermal coal for the domestic and export markets.

A formal Environmental Management System (EMS) has been developed as a systematic and structured approach to managing environmental issues at the operation. This has been developed in general accordance with the requirements of the international standard ISO 14001.

This Seagrass Management Plan is an element of the Chain Valley Colliery Environmental Management System.

This Seagrass Management Plan has also been completed to satisfy the requirements of Development Consent SSD–5465 (Modification 2), Schedule 4 Condition 7(i) and Schedule 4 Table 8, which states:

- "7. The Applicant shall prepare an Extraction Plan for all second workings on site, to the satisfaction of the Secretary. Each Extraction Plan must:
 - (i) include a Seagrass Management Plan, which has been prepared in consultation with OEH, LMCC, and DPI Fisheries, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on seagrass beds, and which includes:
 - a program of ongoing monitoring of seagrasses in both control and impact sites; and
 - a program to predict and manage subsidence impacts and environmental consequences to seagrass beds to ensure the performance measures in Table 8 are met."

In addition to the above, Condition 2 within Schedule 4 of SSD-5465 (Modification 2) also requires that:

"The Applicant shall ensure that the development does not cause any exceedance of the performance measures in Table 8 to the satisfaction of the Secretary."

The relevant seagrass requirements from Table 8 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 1**.

Table 1: Subsidence Impact Performance Measures - Natural and Heritage Features

Biodiversity				
Seagrass beds	Negligible environmental consequences including:			

Notes:

- •The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are
 appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans.
 In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.
- The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.

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2 Purpose

The purpose of this Seagrass Management Plan is to:

- outline details of the seagrass monitoring data collected;
- outline subsidence prediction methodology;
- outline the methodology to be used to identify depth changes at monitoring locations;
- identify seagrass monitoring locations;
- identify reporting requirements;
- · detail seagrass management measures;
- identify the requirements for incident or exceedances reporting and reviews of the document; and
- identify persons responsible for implementation of requirements.

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3 Background

3.1 Operations

Chain Valley Colliery is an underground coal mine with current coal mining methods including development of roadways in the coal seam known as first workings and secondary extraction. These first workings develop panels to support the installation of a miniwall, a modern secondary coal extraction method.

Lake Macquarie is the largest saline lake in New South Wales. It lies on the central coast between Sydney and Newcastle within the local government areas of Central Coast and Lake Macquarie Council's. Lake Macquarie has a catchment of 700 square kilometres and a water surface area of 125 square kilometres (Bell & Edwards, 1980). The lake has a permanent entrance to coastal waters at Swansea and has an average depth of around 6 meters (Laxton, 2005).

The catchment of Lake Macquarie is largely rural with large areas of bush land and grazing land. The shoreline of Lake Macquarie is heavily urbanised, especially the eastern, western and northern shorelines. The region has a relatively long history of coal mining and power generation, with mining occurring since the late 1800s and the first power station at Lake Macquarie commencing operations in 1958.

The Chain Valley Colliery is situated on the southern shores of Lake Macquarie near Mannering Park, NSW. The mine has been operating since 1962. Mining is currently undertaken using miniwall methods with first workings to support the development in advance of each miniwall panel. All secondary extraction is currently occurring in the Fassifern seam, in line with Development Consent SSD–5465 (Modification 2). The general layout of the Chain Valley Extension Project in respect to Lake Macquarie is shown on **Figure 1**.

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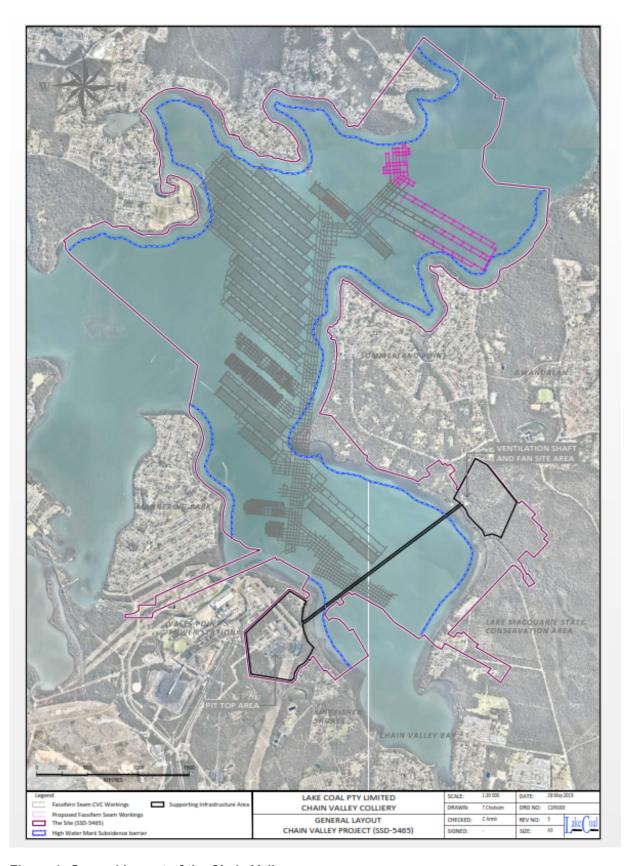


Figure 1: General Layout of the Chain Valley

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3.2 Seagrass Communities

Lake Macquarie contains approximately 10% of the total area of seagrass beds in NSW (DPI 2007). Four species of seagrass occur in Lake Macquarie: eel grass (*Zostera capricorni*); paddle weed (*Halophila ovalis*); *Ruppia sp.*; and strapweed (*Posidonia Australia*) which is listed as an endangered species under the Fisheries Management Act, 1994.

Seagrass distribution within estuaries is naturally influenced by light penetration, depth, salinity, nutrient status, bed stability, wave energy, estuary type, and the evolutionary stage of the estuary. Light is a major limiting factor for the growth of seagrasses and the effects of shading either by artificial structures or increased turbidity associated with sediment re-suspension are common light reducing factors in estuaries (BioAnalysis 2008).

Seagrass communities in Lake Macquarie appear to have declined since 1953, though there was a general increase in the cover of seagrass in Lake Macquarie between 2000 and 2004 due to a change in light penetration following a period of lower freshwater inputs (King and Barclay 1986; Wellington 2000; Gray and Wellington 2004).

Annual surveys of seagrass communities in Summerland Point, Chain Valley and Crangan Bay (i.e. within and adjacent to the current mining areas) have been undertaken on behalf of Delta Coal since 2008 by J.H. & E.S. Laxton - Environmental Consultants Pty Ltd. Additional survey locations in Bardens Bay were added in 2014. Two species of seagrass are present in these areas, namely, eel grass and paddle weed. The 2017 survey report Seagrass Survey of Chain Valley Bay, Summerland Point, Bardens Bay and Crangan Bay, Lake Macquarie, NSW (Results for 2008 to 2017) (JH & ES Laxton - Environmental Consultants, June 2017) reported seagrass cover along the transects ranged from 90.44 to 100% of the substratum in 2017. Since 2011 seagrass cover has generally increased progressively. This annual increases in seagrass cover is most likely attributable to the cessation of commercial fishing in Lake Macquarie which were known to impact on the seagrass beds through land based netting practices.

In 2018 there were no changes in sea bed height across transects greater than 0.10m (0.15m trigger level) compared with the datum from previous years.

Several studies have been conducted on the seagrass beds in Chain Valley Bay and Summerland Point that are relevant to this Seagrass Management Plan.

In July and August 2007, Delta Coal engaged JH & ES Laxton – Environmental Consultants to identify the environmental factors that included seagrasses, benthic fauna and bathymetry. The study area was the area east of Mannering Park. It was found that the seagrass beds were composed of *Zostera capricorni* (Eel grass) only.



It was concluded that seagrasses in Chain Valley Bay commenced along the lake edge and appeared to have a depth limit of less than 2m, and that any mining beneath the beds could lead to subsidence which would cause a decline of seagrasses along the outer edge of the seagrass beds. It was also concluded that the distribution and density of seagrass beds in Chain Valley Bay could change due to events unrelated to underground coal mining.

In July 2008, the seagrass survey was conducted to the west of Summerland Point (see **Figure 1**), from Frying Pan Point to Sandy Beach Reserve, Summerland Point, Lake Macquarie. The 2008 seagrass survey provided the baseline data for seagrass distribution, density and condition to which annual surveys are compared. It was determined that seagrass densities in Chain Valley Bay and Crangan Bay ranged from 17.74 to 99.32% of the substratum in the -0.19 to -2.34 A.H.D zone around the shore. Two forms of the seagrass *Zostera capricorni* were present; short leaved and long leaved forms. In Lake Macquarie, the distinction between these two forms of *Zostera capricorni* appeared to be arbitrary. In 2010 a second species of seagrass, *Halophila ovalis* (paddle weed), was discovered for the first time at transect E6 in Chain Valley Bay on 12th June 2010.

Subsequent annual seagrass surveys discovered large and unexplained changes in seagrass cover which were unrelated to underground coal mining, as no mining had impacted seagrass beds since commencement of monitoring. The precise reasons for these longer term changes in seagrass distribution are not always obvious but may be related to changes in water transparency, salinity, nutrient concentrations and the proliferation of epiphytic algae. Migration of sediment may also change the distribution of seagrasses over time. It is also thought that the cessation of commercial fishing in Lake Macquarie has positively contributed to the regrowth of seagrass beds around the Lake.

Seagrass is a vital component of Lake Macquarie's marine ecosystem. It captures the sun's energy and converts it into organic matter that may be utilised by the whole food chain. Destruction of seagrass beds could lead to a reduction in available organic matter for marine flora and faunal species. Seagrass also improves water quality as it decreases sediment within the water column and takes in many nutrients and heavy metals entering the waterway. Hence a reduction in seagrass population may also result in decreased water quality.

3.3 Seagrass Mapping

The seagrass bed assessment completed for Chain Valley Colliery by JH & ES Laxton – Environmental Consultants P/L found that two forms of the seagrass *Zostera capricorni* were present adjacent to the proposed mining operations. These were short leaved and long leaved forms of *Zostera capricorni*. It observed the seagrass beds commenced along the lake edge and terminated when water depths approached 2m.

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Further mapping undertaken as part of the Chain Valley Mining Extension 1 Project in 2011/2012, enabled the maximum depths and locations of seagrass to be considered in the mine design for the Mining Extension 1 Project. This resulted in the generation of a broader seagrass protection barrier, extending to the proposed mining areas, which was then used to refine the mine design and ensure subsidence impacts to seagrass communities could be avoided. This study found that the communities were dominated by *Zostera capricorni* and that in general, the areas were characterised by patchy individuals of *Zostera*. The seagrass beds were found to exist to a maximum depth of 1.9m.

Further visual assessments and remapping of seagrass beds within the areas of Sugar Bay, Frying Pan Bay and Point Wolstoncroft was undertaken by Delta Coal, JH & ES Laxton – Environmental Consultants P/L and Daly Smith Surveyors in February 2018. The mapping was commissioned by Delta Coal as part of the development of it's next extraction plan for its Northern Mining Area (NMA).

Details from these studies have been combined to produce the mapping of seagrass over the entirety of the historic, current and future mining areas, and enabled the seagrass protection barrier to be further defined. The current seagrass mapping is shown on **Figure 2**.

3.4 Subsidence Predictions and Management

Subsidence modelling has predicted up to approximately 1.23 metres of subsidence to the Lake floor associated with the planned miniwall mining where there is overlying workings, and 780mm where only single seam extraction is undertaken.

Delta Coal recorded a subsidence exceedance over its Miniwall 7-12 area during the 2017 annual bathymetric survey where 1100mm of subsidence was identified. As a result of the exceedance Delta Coal has re-designed its future mining areas to ensure that subsidence values are within the approved predictions in accordance with SSD 5465.

The seagrass communities within the entirety of the proposed mining areas have been mapped and the majority of the seagrass beds appear to extend to depths around 2-2.5m. As a result, if mining takes place beneath the seagrass beds, and subsidence takes place, it could be expected that the lower areas of the seagrass beds will potentially retreat with increased depth as a result of reduced light available for photosynthesis.

In light of Condition 7 (i) Schedule 4 and to ensure the performance measures in **Table 1** are met an essential component of this Seagrass Management Plan is the Seagrass Protection Barrier to ensure that any impacts associated with its mining operations are negligible. This barrier is further described in **Section 4.1**.

3.5 Consultation

The original version of this Seagrass Management Plan was provided to OEH, LMCC and DPI Fisheries for comment. Both LMCC and DPI Fisheries reviewed the Seagrass Management Plan, with comments from DPI Fisheries provided on the 28th June 2013. At that time DPI Fisheries had no objection to the plan being implemented as written. Comments from Lake Macquarie City Council were received on the 19th July 2013, which were addressed and incorporated into the document, this final version was then sent back to Council who confirmed on the 19th August 2013 that the changes had addressed their comments. The changes made previously to address Council's comments remain in the current version.

Revision 2 of the draft Seagrass Management Plan was provided to OEH, DPI Fisheries and LMCC on the 12th March 2014, with comments on the draft plan requested back by the 1st April 2014. The only response received was from OEH, dated the 21st March 2014. The OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided.

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Revision 3 of the Seagrass Management Plan was sent to OEH, DPI Fisheries and LMCC on 4 November 2016 for review and comment. All three agencies provided comments on the revised Plan. LMCC and DPI Fisheries confirmed that the document was acceptable in its revised form while OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided on the content of the Plan.

Revision 4 of the Seagrass Management Plan was provided to OEH, DPI Fisheries and LMCC on 26 February 2018 with the Extraction Plan application for Chain Valley Colliery's Northern Mining Area (NMA).

Revision 5 of the Seagrass Management Plan was sent to OEH, DPI Fisheries and LMCC in May 2019. On the 5 June 2019 DPI Fisheries responded that the Seagrass Management Plan was adequate. On 5 June 2019 OEH noted that they do not approve or endorse these documents and accordingly no comments were provided on the content of the Plan. No comments have been provided by LMCC.



4 Seagrass Management

No secondary extraction is being undertaken, nor is it planned to be undertaken beneath seagrass beds.

In addition, to achieve negligible impact on seagrass beds due to subsidence effects, a seagrass protection barrier has been established. This barrier is based on the seagrass mapping and the application of an "angle of draw" of 26.5° from the seagrass area to the coal seam being mined, as depicted in **Figure 2** and **Figure 3**.

Only first workings are to be undertaken within the seagrass protection barrier. In these areas subsidence will be limited to less than 20mm which is considered to be negligible.

The purpose of this plan is to monitor and report on any changes in seagrass communities over time. The monitoring program also includes physical surveys to detect if there is any vertical movement that could attributable to mine subsidence and if identified, determine if subsidence has caused anything other than a negligible impact. To achieve this, the following will be undertaken:

- an annual survey of the study area with 50 seagrass transects using differential GPS survey
 methods. These differential GPS survey methods will establish the precise location and height of the
 lake bed at inner and outer ends of each transect and compare these values against those of
 previous years and the baseline survey;
- a survey to determine the maximum seaward extent of the seagrass beds and the maximum depth at which they occurred;
- photographic survey of seagrass distribution, density and condition along each transect to be recorded using a video camera enclosed within a waterproof housing and mounted on a floating platform;
- conduct annual seagrass surveys while mining operations have the potential to impact seagrass communities. Reports of annual surveys will be sent to the Department of Primary Industries – Fisheries and Lake Macquarie City Council.
- a summary of the annual seagrass survey will be included in the Annual Review;
- responding to any potential or actual non-compliances and reporting as required to regulatory bodies and other stakeholders; and
- all complaints will be recorded in the complaints register with actions taken also noted.

The personnel responsible for the above management measures are detailed in **Section 8** (Roles and Responsibilities).

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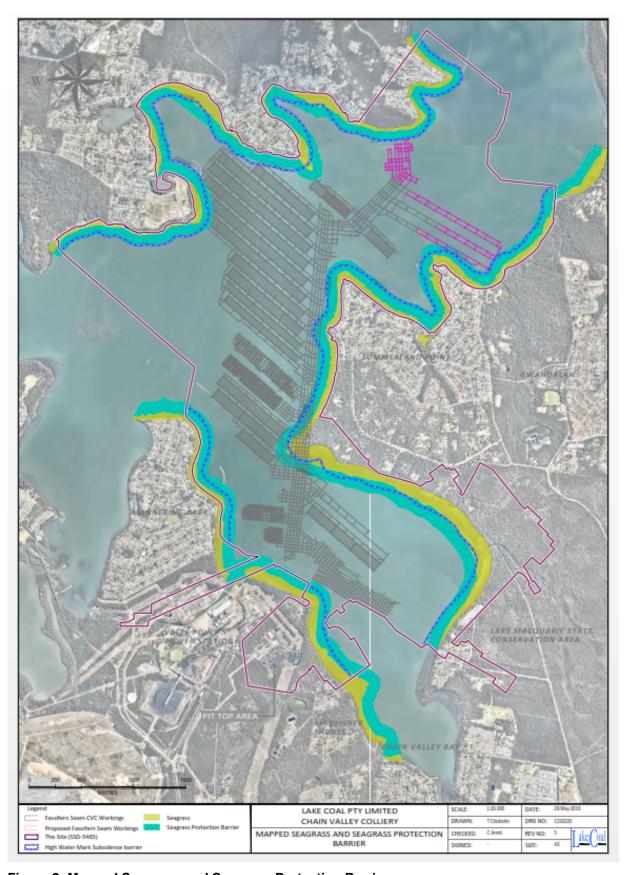


Figure 2: Mapped Seagrass and Seagrass Protection Barrier

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4.1 Seagrass Protection/Limits

As part of the protection of the lake foreshore, the Colliery holding mining leases require a protection barrier around the foreshore. This is known as the High Water Mark (HWM) Subsidence Barrier and is shown on **Figure 1**. The barrier is approximately 130 metres wide, but varies based on the depth of cover, and no secondary extraction occurs within this zone. Although similar in some locations, the HWM Subsidence Barrier and the Seagrass Protection Barrier are separate barriers, with the mine layout limited (among other factors) by either barrier at any specific location. The application of the HWM Subsidence Barrier and Seagrass Protection Barrier is depicted on **Figure 3**.

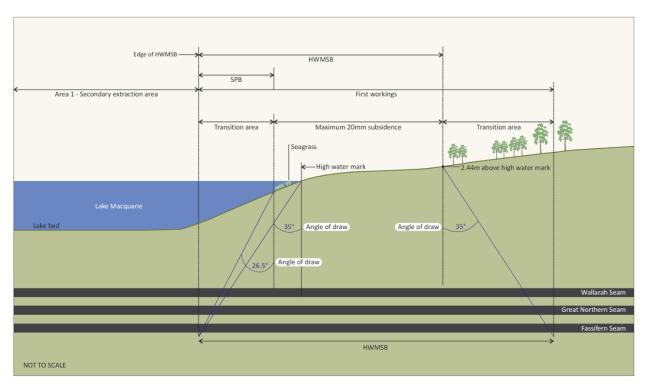


Figure 3: Protection Barrier Schematic

Despite the above barriers which are in place to protect the seagrass and foreshore areas, monitoring thresholds have been established based on observable change to seagrass beds or bed height, the following triggers have been set:

- 1. 20% decline in condition from the base year survey (i.e. earliest survey prior to mining occurring nearby).
- 2. Mining induced subsidence of 150mm or greater being recorded at one of the monitoring sites.

The Delta Coal Environment and Community Coordinator will notify DPI Fisheries, Lake Macquarie City Council and the Department of Planning and Environment if either of the above impact thresholds are exceeded, if deemed necessary by any of the parties, a meeting will be convened to discuss the results and determine any required future action.

It is noted that in prior years the 20% decline in baseline condition has been seen at a number of seagrass monitoring sites in the absence of any subsidence, as such, reaching a threshold may not in itself warrant the convening of a meeting or the requirement for further actions.

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4.2 Seagrass Impact Mitigation

If, through the monitoring program (refer **Section 5**), subsidence is found to occur in areas known to contain seagrass beds (as identified in **Figure 2**) and loss of seagrass habitat has been determined to have occurred as a direct result of this subsidence, then Delta Coal would commit to undertaking remediation strategies to replace an equal area of any loss of seagrass habitat that has occurred.

While Delta Coal's approach to manage seagrass is aimed at protection, if an investigation were to identify that an exceedance / incident has occurred that was a direct result of the mining activities and associated subsidence, then Delta Coal would develop a remediation plan, which would be submitted to DPI Fisheries, identifying the proposed remediation strategy. The strategy would identify proposed remediation measures which could include:

- Transplanting existing communities with additional fast growing locally occurring seagrass plants;
- Regrading: topographical restoration; and/or
- Fertilising: to stimulate lateral ingrowth of seagrass communities.

The exact method of remediation would be determined based on the existing integrity of the seagrass beds, existing species and specific impacts that have occurred, that is, the remediation strategy would be "site specific" to ensure the most appropriate remediation methodology is implemented in consultation with DPI Fisheries.

Should remediation on-site not be viable, mitigation could be undertaken at other sites within Lake Macquarie in consultation with DPI Fisheries and LMCC, that is, work would be completed to offset the impact arising as a result of mining activities.

5 Seagrass Monitoring

5.1 General Requirements

The detailed methods used to conduct the surveys to determine subsidence of the lake bed and the photographic surveys of seagrass distribution, density and conditions are described below. The same or similar methods should be used in future seagrass surveys to ensure consistency of results.

Seagrass photography

A video camera, fitted with a wide conversion lens and enclosed in an underwater housing is used to capture the video footage.

The camera in the underwater housing is mounted vertically in the centre of a 1m long surfboard. This rig is towed alongside a workboat. Experimentation revealed that the best photographic results are obtained when the boat and photographic rig were poled very slowly along the transect line on windless days. Good quality photographs were obtained both in boat shadow and full sunlight although half shadow sequences could still be evaluated satisfactorily.

The water depth along most of the transect lines ranges from around 0.5 to 2m (depending on the lake level). At the end of the transect line the water depth could be around 2m. Transect lines are photographed from the outer end to the inner end. The beginning of each transect is marked by photographing a plate with the transect number printed in large type.

At the end of the each day's photography, the hard drive of the video camera is downloaded, the film is paused at around 1m intervals along the transect line. Each still frame is examined and the following information is recorded on a data sheet:

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- 1. The file name and number of the video segment being examined.
- 2. The transect number and date the video was taken.
- 3. The percentage areas occupied by the following organisms in each still or quadrat was determined:
 - (a) % area occupied by long leaved seagrass (Zostera capricorni)
 - (b) % area occupied by short leaved seagrass (Zostera capricorni)
 - (c) % area occupied by the small seagrass (Halophila ovalis)
 - (d) degree of fouling of the seagrass leaves by algae 1=no fouling, 2=light fouling, 3=heavy fouling.
 - (e) % area occupied by the large brown alga (Sargassum sp., Hormosira banksii or Cystoseira trinodis)
 - (f) % area occupied by filamentous and thallous algae (green or brown algae)
 - (g) Number of the large bivalve Pinna bicolor
 - (h) % area of uncolonised (by macroscopic epibenthos) ground (bare ground).

At the end of the analysis of the photographs, the results are entered into a work sheet and mean values for each category of organism are calculated.

Surveying Methods

Surveyors have established base stations with their differential GPS equipment along the shore of Chain Valley Bay. A carbon fibre staff fitted with a 110mm diameter aluminium base plate (to prevent penetration into the sediment) is used to take the readings. Survey data (x, y & z coordinates) are recorded on a separate hand piece. Communication between the GPS receiver, the base stations and the hand piece is by coded radio signals.

The boat is maneuvered into position at the inshore end of each transect. The staff is placed on the lakebed and held vertically until the observation is made and recorded. The boat is then moved outwards from the shore where intermediate points along the transect were established and recorded. When the outer end of the transect is reached, the staff is placed alongside the concrete marker and the position and height of the lake bed was recorded.

The memory of the hand held gps is downloaded and the following plots made:

- A map of the position of transects in Chain Valley Bay, Summerland Point and Bardens Bay.
- A table of the coordinates of inner and outer ends of each transect and the coordinates of the base stations are made.
- The elevations of the seabed at the inner and outer ends of each transect, relative to AHD, are established and tabulated.

The results from the seagrass monitoring, including determination of compliance with seagrass impact thresholds, is undertaken and reported back to Delta Coal in a formal report to be provided annually following the completion of each annual seagrass survey.

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5.2 Monitoring Locations

Monitoring locations have been chosen based on the proposed mining activities that will be covered by the Seagrass Management Plan, over time, as this management plan is updated to reflect future mining locations, it is anticipated that additional monitoring transects will be incorporated and others removed from the monitoring regime as time progresses. More specifically, the monitoring locations proposed to be monitored are those that are adjacent to past, current and proposed mining activities that are within the review period of this management plan.

The monitoring locations are substantially derived from the original experimental and control transects selected by JH & ES Laxton – Environmental Consultants Pty Ltd and JSA Environmental Pty Ltd who completed the Marine Ecology assessment that supported the Environmental Assessment for the Mining Extension 1 Project. An additional 15 transects were added to the seagrass monitoring program as part of the latest revision to this plan to obtain baseline information within the areas of Frying Pan Bay, Sugar Bay and the Northern side of Point Wolstoncroft. Two additional Control Points (C5 and C6) were also added to the monitoring program in 2018.

The current monitoring locations are;

 Transects E1 to E16 	Transects primarily in Chain Valley Bay and adjacent Summerland Point
 Transects T1 to T8 	Transects adjacent Summerland Point
 Transects C1 to C6 	Control stations in Crangan Bay and Frying Pan Bay
 Transects A1 to A6 	Transects primarily in Bardens Bay
 Transect L1 	Transect above potential future first workings in Chain Valley Bay

Transects S1 to S6
 Transect adjacent Sugar Bay
 Transects F1 to F7
 Transects adjacent Frying Pan Bay and along Point Wolstoncroft.

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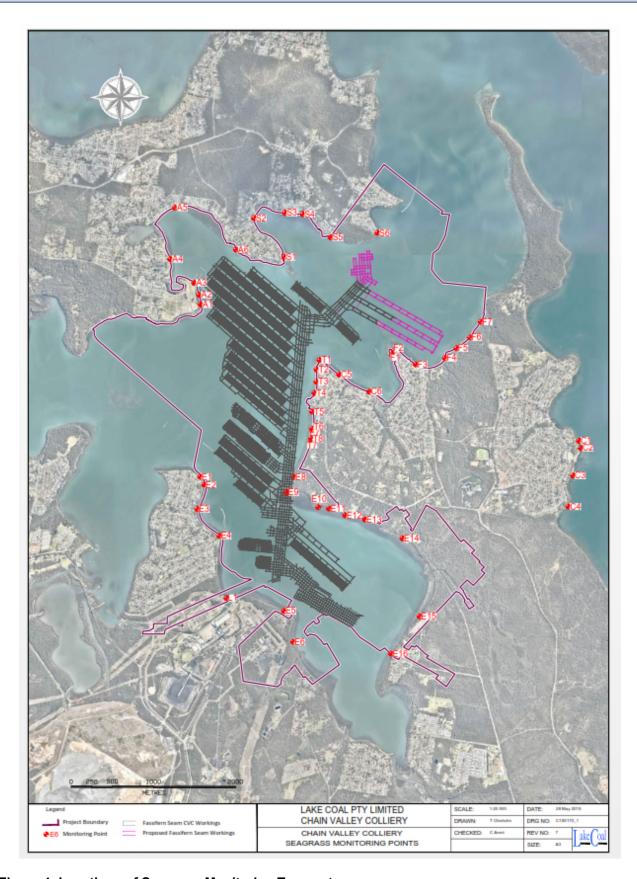


Figure 4: Locations of Seagrass Monitoring Transects

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Table 2 shows the GPS locations of the inner ends of the seagrass monitoring transects. Where available, reduced levels of the lakebed measured historically are presented. For sites that have not yet been surveyed by differential GPS, baseline depth levels will be obtained prior to any secondary extraction undertaken in the vicinity of the site. Transects in Crangan Bay were for control purposes only, i.e. no mining or subsidence impact potential, and accordingly no differential GPS depths/locations are required. Relocation of the control stations is done with hand held GPS.

Table 2: Seagrass Monitoring Transect Coordinates

Site	Easting	Northing	Reduced Level (m) - inner transect	Reduced Level (m) - outer transect
E1	363986	6331797	-0.68	-1.00
E2	364035	6331701	-0.64	-1.78
E3	363953	6331405	-0.32	-2.34
E4	364220	6331078	-0.46	-1.69
E5	365006	6330164	-0.46	-1.68
E6	365118	6329788	-0.48	-1.21
E7	365351	6332350	-0.24	-1.68
E8	365128	6331796	-0.27	-0.99
E9	365040	6331608	-0.19	-1.07
E10	365423	6331427	-0.41	-1.74
E11	365554	6331410	-0.40	-1.09
E12	365750	6331329	-0.59	-1.50
E13	365991	6331278	-0.59	-1.44
E14	366447	6331047	-0.52	-1.34
E15	366657	6330098	-0.39	-1.22
E16	366310	6329644	-0.55	-1.08
T1	365440	6333217	-0.40	-1.15
T2	365403	6333101	-0.70	-1.31
T3	365400	6332952	-0.29	-1.01
T4	365377	6332817	-0.46	-1.12
T5	365350	6332590	-0.42	-1.38
T6	365348	6332380	-0.47	-1.61
T7	365321	6332207	-0.17	-1.64
T8	365337	6332262	-0.20	-1.14
C1	368596	6332235	N/A	N/A
C2	368619	6332147	N/A	N/A
C3	368524	6331811	N/A	N/A
C4	368467	6331435	N/A	N/A
C5	365676	6333038	N/A	N/A
C6	366045	6332831	N/A	N/A
A1	363991	6333894	-0.51	-1.19
A2	363974	6334009	-0.39	-0.81
A3	363912	6334156	-0.33	-1.44
A4	363621	6334445	-0.16	-0.72
A5	363678	6335072	-0.30	-0.96
A6	364423	6334560	-0.14	-0.68
L1	364306	6330322	-1.12	-1.63
S1	365009	6334470	-0.64	-1.78
S2	364642	6334943	-0.28	-1.59
S3	365017	6335008	-0.11	-1.87

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Site	Easting	Northing	Reduced Level (m) - inner transect	Reduced Level (m) - outer transect
S4	365235	6334992	-0.11	-1.73
S5	365575	6334709	-0.69	-1.39
S6	366144	6334765	-0.1	-0.92
F1	366321	6333281	-0.25	-1.31
F2	366342	6333330	-0.24	-1.98
F3	366611	6333163	-0.11	-1.88
F4	366968	6333242	-0.11	-2.45
F5	367106	6333361	-0.33	-2.46
F6	367271	6333493	-0.3	-2.81
F7	367402	6333682	-0.48	-1.4

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6 Incident & Compliance Management

6.1 Introduction

The seagrass monitoring results will be reviewed on an annual basis as survey reports are received to confirm compliance with the conditions specified in the *Subsidence Impact Performance Measures - Natural and Heritage Features* found in **Table 1** and the criteria outlined in **Section 4.1**.

The Annual Review will also include a summary of monitoring results during the past year, discussion with reference to the impact assessment criteria, and any relevant details related to comparisons between actual results and predictions in the Environmental Impact Statement. The Annual Review will be forwarded to the relevant authorities including Department of Planning and Environment, and Environment Protection Authority. The Annual Review will also be forwarded to members of the Community Consultative Committee and local Councils (Central Coast and Lake Macquarie). It will also be placed on the company's website along with a summary of environmental monitoring results.

6.2 Incident or Non Compliance Reporting

If seagrass monitoring reveals that, as a result of mining activities, the criterion outlined in **Section 4.1** have been exceeded, then Delta Coal will conduct an investigation into the cause of the non-compliance. The investigation will consider any mining activities or other factors that may have generated the non-compliance. The report will be provided to DPI Fisheries and the Department of Planning and Environment.

The report will:

- a) describe the date, time and nature of the exceedance / incident;
- b) identify the cause (or likely cause) of the exceedance / incident;
- c) describe what action has been taken to date; and
- d) describe the proposed measures to address the exceedance / incident.

Delta Coal would implement the recommendations of the investigation in order to address any future non-compliance issues.

Additional details of the incident reporting process are provided in the Environmental Management Strategy.

7 Stakeholder Management and Response

7.1 Complaint Protocol

Delta Coal has a 24-hour telephone hotline (1800 687 557) for members of the public to lodge complaints, concerns, or to raise issues associated with the operation. This service aims to promptly and effectively address community concerns and environmental matters.

The full details of the complaints line are covered in the Environmental Management Strategy, but in summary, all complaints are recorded and responded to, if for some reason no action is taken then the reason why is recorded. The information recorded in the complaint register includes;

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- date and time the complaint was lodged;
- personal details provided by the complainant;
- nature of the complaint;
- action taken or if no action was taken, the reason why; and
- follow up contact with the complainant.

7.2 Dispute Resolution

If any disputes are not adequately addressed by the complaints handling process then they will be handled by the site Environment and Community Coordinator, if the response of Delta Coal is not considered to satisfactorily address the concern of the complainant, a meeting will be convened with the Mine Manager together with the Environment and Community Coordinator.

The complainant will be advised of the outcomes from the meeting and the actions to be implemented as a result.

After implementation of the proposed actions, the complainant will be contacted and advice sought as to the satisfaction or otherwise with the measures taken.

If no agreed outcome is determined or the complainant is still not satisfied by the action taken, then an Independent Review may be requested by the complainant. If determined to be warranted by the Secretary, an Independent Review will be undertaken in accordance with the requirements of the development consent to achieve an outcome to the satisfaction of the Secretary.



8 Roles and Responsibilities

Roles and responsibilities specific to completing the requirements of the Seagrass Management Plan are identified in **Table 3**.

Table 3: Seagrass Management Roles and Responsibilities

Role	Responsibilities
Mine Manager	Ensure that adequate financial and personnel resources are made available for the implementation of the Seagrass Management Plan.
Environment and Community Coordinator	 Co-ordinate seagrass monitoring, through the use of differential GPS surveying and photographic monitoring of seagrass beds. Develop management actions in consultation with regulatory agencies as/if required from the monitoring results. Review seagrass monitoring results on an annual basis. Send Annual Seagrass Monitoring reports to DPI Fisheries and Compile the Annual Review (including a summary of the annual seagrass survey). Respond to any potential or actual non-compliance and report these as required to regulatory bodies and other stakeholders. Undertake reviews of this document as per Section 9 Undertake or coordinate the required audits of this document, in accordance with Section 9. Notify the DPI Fisheries, Department of Industry – Resources and Energy and Department of Planning and Environment if there are any exceedances in impact thresholds outlined in Section 4.1 Ensure complaint handling and response is undertaken, including determination of sources and potential remedial action to avoid recurrence.

8.1 Training, Awareness and Competence

Training is an essential component of the implementation phase of this Seagrass Management Plan. Any person or position that has a role or responsibility under this document will be provided with a copy of the document and be advised verbally regarding their requirements by the Environment and Community Coordinator.

As the document owner, the Environment and Community Coordinator is the contact point for any person that does not understand this document or their specific requirements, and will provide guidance and training to any person that requires additional training regarding this management plan.

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9 Audit and Review

9.1 Overview

This document shall be reviewed, and if necessary revised, within 3 months of the following:

- The submission of an Annual Review;
- The submission of an incident report under **Section 6.2**;
- The submission of an independent environmental audit; and
- · Following any modification to the development consent

9.2 External Audits

An Independent Environmental Audit will be undertaken every three years (or as otherwise required by Department of Planning and Environment) by an audit team whose appointment has been endorsed by the Secretary.

Any actions arising from external audits will be loaded into the site Incident Database to ensure the actions are assigned to the relevant people and completed.

10 Records

Generally the Environment and Community Coordinator will maintain all Environmental Management System records, which are not of a confidential nature. Records that are maintained include:

- · monitoring data and equipment calibration;
- environmental inspections and auditing results;
- environmental incident reports;
- · complaint register; and
- Licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of 4 years.

11 Document Control

This document and all others associated with the Environmental Management System shall be maintained in a document control system which is in compliance with AS/NZS 4804; section 4.3.3.4 (Document Control) and in compliance with the site Document Control Standard which is available to all personnel.

Any proposed change to this document shall be via the document control administrator who is the only person able to access the controlled documents.

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12 References & Associated Documents

AS/NZS ISO 14001:2004 Environmental management systems - Requirements with guidance for use

AS/NZS ISO 14004:2004 Environmental management systems – General guidelines on principles, systems and

support techniques

EPL 1770 Environment Protection License 1770

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Extension 1 Project

POEO Act 1997 Protection of the Environment Operations Act, 1997

Bell, F.C. and Edwards, A.R. (1980) An Environmental Inventory of Estuaries and Coastal Lagoons in New South Wales. Total Environment Centre.

BioAnalysis (2008) assessment of seagrasses associated with proposal to expand the Lake Macquarie yacht club in Belmont Bay.

EMM (June 2015) Chain Valley Colliery Modification 2 Statement of Environmental Effects, prepared by EMGA Mitchell McLennan (EMM) dated 29 June 2015.

NSW DPI (2007) PrimeFacts 629 - Seagrasses.

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Laxton, E. and Laxton, J.H. (August 2007) Aquatic Biology of Chain Valley Bay Lake Macquarie, NSW. J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

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Laxton, J.H. and Laxton, E. (2011). Seagrass Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW (Results from 2008, 2010 and 2011) J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

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Laxton, J.H. and Laxton, E.S. (2017) Seagrass Survey of Chain Valley Bay, Summerland Point, Bardens Bay and Crangan Bay, Lake Macquarie, NSW (Results for 2008 to 2017). J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

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13 Definitions

CVC

Delta Coal - Chain Valley Colliery

DPI Fisheries

NSW Department of Primary Industries - Fisheries

EMS

Environmental Management System

нии

High Water Mark

LMCC

Lake Macquarie City Council

OEH

Office of Environment and Heritage

Secretary

Secretary of the Department of Planning and Environment, or nominee

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Safety Management Plan

Public Safety Management Plan S2/S3 Miniwall Panels

A the a m	Wade Covey / Chris Armit		
Author			
	LakeCoal – Chain Valley Colliery		
Authorised by:	Dave McLean		
	Operations Manager		
Date:	15/02/19		

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2 Introduction

Chain Valley Colliery is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station, producing thermal coal for the domestic and export markets.

An Extraction Plan has been developed in order to manage the process of mining layout design and mitigate any subsidence impacts on surface infrastructure and/or stakeholders. A part of the S2/S3 Extraction Plan is this Public Safety Management Plan, which has been developed from a risk assessment process.

The Public Safety Management Plan is an element of the Chain Valley Colliery Extraction Management Plan, and has been developed to satisfy the requirements of Development Consent SSD-5465, condition 7(j) and Table 9 in Schedule 4, which both state:

- 7. The Applicant shall prepare and implement an Extraction Plan for all second workings on site, to the satisfaction of the Director-General. Each Extraction Plan must:
- (j) include a Public Safety Management Plan, which has been prepared in consultation with DRE, to ensure public safety.

Condition 4 within Schedule 4 of SSD-5465 also requires that:

"The Applicant shall ensure that the development does not cause any exceedances of the performance measures in Table 9, to the satisfaction of the Director-General.

The relevant Public Safety requirements from Table 9 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in Table 1.

Table 1: Subsidence Impact Performance Measures – Built Features

Public Safety	
Public Safety	Negligible additional risk

Notes:

- The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the Built Features Management Plans or Public Safety Management Plan (see Condition 7 below).
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.
- The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.
- Requirement's regarding safety or serviceability do not preclude preventative actions or mitigation being taken prior to or during mining in order to achieve or maintain these outcomes.
- Requirement's under this condition may be met by measures undertaken in accordance with the Mine Subsidence Compensation Act 1961.

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3 Purpose and Scope

The purpose of this Public Safety Management Plan is to:

- Outline subsidence predictions associated with the mining of miniwall Panels S2 and S3;
- Identify potential public safety risks arising out of subsidence from extraction particular to the miniwall panels S2 and S3;
- Identify public safety monitoring requirements;
- Identify public safety reporting requirements;
- Ensure negligible additional public safety risk as a result of subsidence arising from Extraction associated with the mining of Panels S2 and S3.

4 Background

4.1 Operations

Chain Valley Colliery is an underground coal mine with current coal mining methods including development of roadways in the coal seam known as first workings and secondary extraction (miniwall). These first workings develop panels to support the installation of a miniwall, a modern secondary coal extraction method.

Lake Macquarie is the largest saline lake in New South Wales. It lies on the central coast between Sydney and Newcastle within the local government areas of Wyong and Lake Macquarie. Lake Macquarie has a catchment of 700 square kilometers and a water surface area of 125 square kilometers (Bell & Edwards, 1980). The lake has a permanent entrance to coastal waters at Swansea and has an average depth of around 6 meters (Laxton, 2005).

The catchment of Lake Macquarie is largely rural with large areas of bush land and grazing land. The shoreline of Lake Macquarie is heavily urbanised, especially the eastern, western and northern shorelines. The region has a relatively long history of coal mining and power generation, with mining occurring since the late 1800s and the first power station at Lake Macquarie commencing operations in 1958.

Chain Valley Colliery is situated on the southern shores of Lake Macquarie near Mannering Park, NSW. The mine has been operating since 1962. Mining is currently undertaken using miniwall methods with first workings to support the development in advance of each miniwall panel. All secondary extraction is currently occurring in the Fassifern seam, in line with Development Consent SSD–5465. The general layout of the Chain Valley Extension Project in respect to Lake Macquarie is shown on **Figure 1**.

4.2 Subsidence Predictions

Subsidence modelling has predicted up to approximately 290mm of subsidence to the Lake floor associated with the planned miniwall mining of Panels S2 and S3 within the sites Northern Mining Domain (**Figure 2**), with an approved maximum of 780mm. No additional subsidence is expected to occur within the seagrass or foreshore areas as a result of Fassifern extraction (**Figure 1**) due to the application of High Water and Seagrass Protection Barriers (extraction separation).

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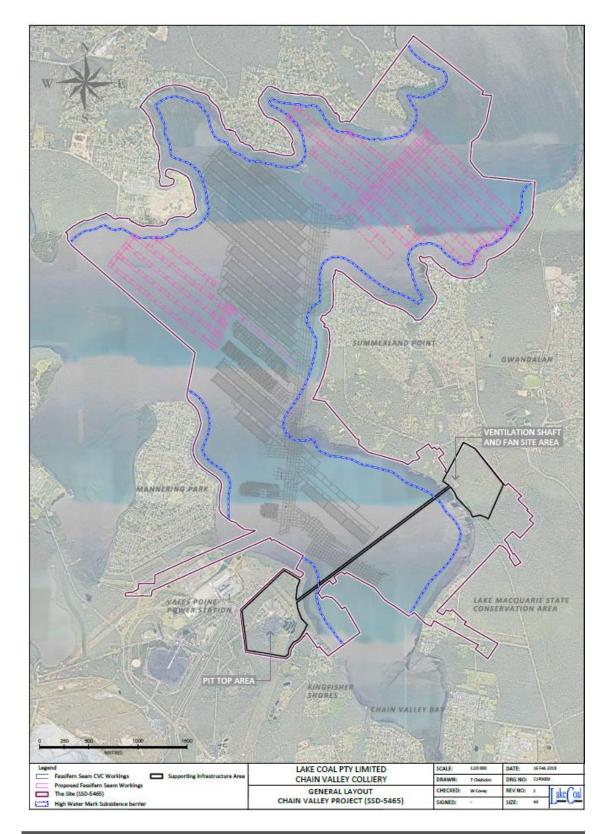


Figure 1: General Layout of the Chain Valley Northern Mining Domain

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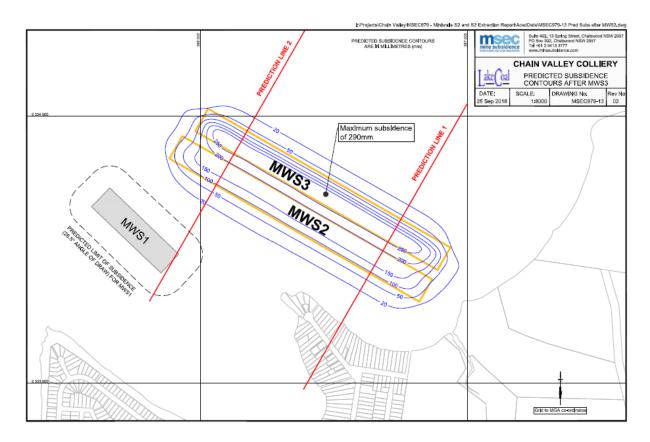


Figure 2: Predicted Subsidence Associated with Panels S2 and S3.

4.3 Public Safety Management - Scope

4.3.1 Identified Features

All mining activities within the Extraction Plan application area are to occur beneath Lake Macquarie and as such will have no direct impact on surface facilities and infrastructure due to vertical subsidence. Despite this, CVC will monitor the foreshore for change and if impacts were observed to be occurring, a review of public safety would be triggered via the Subsidence Management TARP. This focuses on potential changes to flooding and drainage as well as steep slopes.

The navigational marker located off Summerland Point is not predicted to see any significant impacts as a result of the mining of Panels S2 and S3. The marker located above the Tailgate S2 gate road on Pelican Rock (**Figure 3**) is expected to see less than 90mm of vertical subsidence. Roads and Maritime Services (RMS) have been consulted in relation to the markers and the level of subsidence impact, and have concluded that no direct management will be required and the marker will be able to be monitored as a part of their routine inspections. It is thus considered no additional public safety risk exists to these features.

The predicted low strains indicate a very low likelihood of impact to any sensitive features such as steep slopes/cliffs, retaining walls or jetties as a result of the extraction of Panels S2 and S3, with horizontal movement and strain less than accuracy of measurement techniques. As such routine visual inceptions during subsidence monitoring is proposed as sufficient to identify any changes outside those expected.

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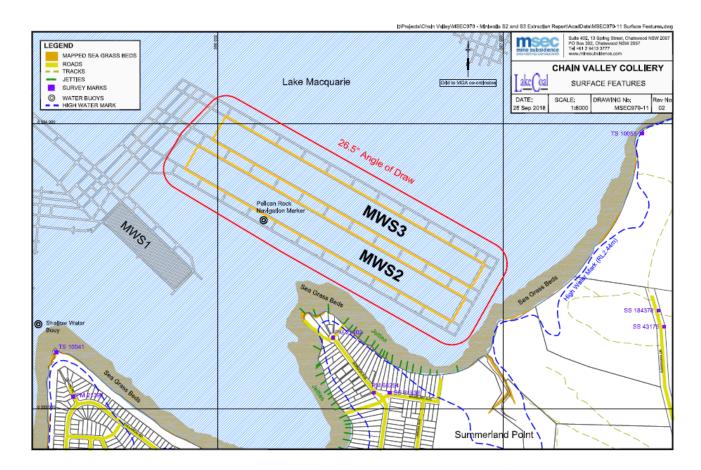


Figure 3: Chain Valley Colliery Surface Features

5 Public Safety Monitoring

5.1 Subsidence Monitoring Methods

5.1.1 Bathymetric Surveys

Bathymetric Surveys of the lake beds will occur across the area as described by the Subsidence Monitoring Program. These routine surveys will allow for identification of subsidence starting to develop outside predicted levels and thus trigger a review of any potentially new Public Safety concerns.

5.1.2 Foreshore Monitoring

Established and proposed (subject to access restrictions) survey monitoring points will be monitored around the southern and northern foreshore areas about the extraction plan area. These will consist of either star pickets, feno pegs or survey pins (**Figure 4**). The marks will be monitored as per the Subsidence Monitoring Program. These routine surveys prior, during and after extraction will allow for the identification and review of any subsidence starting to develop outside predicted levels and thus trigger a review of any potentially new Public Safety concerns.

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During the routine foreshore monitoring, observations and records for change will be noted as outlined in the Subsidence Monitoring Program. This will include observations for surface cracking, embankment movement, cracking, and validation of impacts to drainage or dwellings in areas of measured subsidence increase outside predicted.



Figure 4: Example subsidence monitoring point with safety cap.

6 Public Safety Management

6.1 Management Practices

Survey pegs installed for monitoring will be clearly identified and as appropriate have 'safety caps' placed on them as per **Figure 3.**

Given the expected negligible impact to public safety, any management practices will be triggered via the aforementioned monitoring strategies and the Subsidence Management TARP included in the Extraction Plan. Triggering of a potential requirement for a public safety response will be based on the following management strategy:

- Subsidence measured indicates potentially increased impact at the foreshore or to sensitive features;
- 2. Notify DP&E and DRE;
- 3. Investigate area of potential increase for any change in public safety risk;
- 4. Inform relevant parties that may be further impacted in relation to public safety (this may include, landholders, infrastructure owners, RMS, Lake Macquarie City Council, Central Coast Council and OEH)
- 5. Where required immediately implement public safety controls to control immediate risk (i.e. identification, barriers and signage, all of which are available at the mine site)
- 6. Develop long term safety control with relevant parties.

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6.2 Consultation

The Public Safety Management Plan is required to be prepared in consultation with DRE. DRE have been consulted as a part of the Extraction Plan Submission, and also as a part of the High Risk Activity Notification, which also deals with public safety.

RMS Project Officer (North Area) has been contacted during the development of the Extraction Plan and referred the matter to the RMS asset team, resulting in no further immediate actions being required in regard to the management of the navigation markers.

The LakeCoal Community Consultative Committee (CCC) was consulted on the proposed monitoring program during the most recent community meeting at the mine on 13 February 2019. The CCC will be routinely updated as to subsidence monitoring results and any change in impact or public safety concern.

7 Roles and Responsibilities

Roles, responsibilities specific to completing the requirements of this Subsidence Monitoring Program are identified in **Table 2**.

Table 2: Public Safety Management Roles and Responsibilities

Role	Responsibilities
Operations Manager	Ensure that adequate financial and personnel resources are made available for the implementation of the Subsidence Monitoring Program and Public Safety Management Plan
Mine Surveyor	 Co-ordinate subsidence monitoring, through the use of bathymetric surveys & conventional surveys along foreshore Review subsidence monitoring results against Subsidence Management TARP triggers Inform E&C Coordinator and Mine Manager of results and outcomes of monitoring reviews.
Environment and Community Coordinator	 Develop management actions in consultation with regulatory agencies as/if required from the monitoring results. Respond to any potential or actual non-compliance and report these as required to regulatory bodies and other stakeholders. Notify the relevant Government Agencies and other affected parties should exceedances in impact thresholds potentially be reached Regularly audit the public safety equipment made available at the mine site Ensure complaint handling and response is undertaken, including determination of sources and potential remedial action to avoid recurrence. Review, and if necessary revise this document: In the event of any exceedance in impact thresholds Following any modification to the development consent

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Doc Owner: Mine Surveyor

CHAIN VALLEY COLLIERY ENV 00029 Subsidence Monitoring Program MINIWALLS S2 – S3

	Tim Chisholm
Author	Registered Mine Surveyor
	LakeCoal – Chain Valley Colliery
Authorised by:	David Mclean
Authorised by.	Manager Mining Engineering
	LakeCoal – Chain Valley Colliery
Date:	25/01/2019

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2 Introduction

Chain Valley Colliery is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station, producing thermal coal for the domestic and export markets.

A formal Extraction Management Plan has been developed in order to manage the process of mining layout design and mitigate any subsidence impacts on surface infrastructure and/or stakeholders.

The Subsidence Monitoring Program is an element of the Chain Valley Colliery Extraction Management Plan, and has been developed to satisfy the requirements of Development Consent SSD-5465, condition 7(k) and Tables 8-9 in Schedule 4, which states:

- "7. The Applicant shall prepare and implement an Extraction Plan for all second workings on site, to the satisfaction of the Director-General. Each Extraction Plan must:
- (k) include a Subsidence Monitoring Program which has been prepared in consultation with DRE, which:
 - Provides data to assist with the management of the risks associated with subsidence;
 - Validates the subsidence predictions
 - Analyses the relationship between the predicted and resulting subsidence effects and predicted and resulting impacts under the plan and any ensuing environmental consequences; and
 - Informs the contingency plan and adaptive management process;

Condition 1, Schedule 4 of SSD5465 states:

"The Proponent shall ensure that vertical subsidence within the High Water Mark Subsidence Barrier and within Seagrass beds is limited to a maximum of 20 millimeters (mm)."

In addition to the above, Condition 2 within Schedule 4 of SSD-5465 also requires that:

"The Applicant shall ensure that the development does not cause any exceedance of the performance measures in Table 8 to the satisfaction of the Director-General."

The relevant subsidence monitoring requirements from Table 8 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 1**.

Table 1 - Subsidence Impact Performance Measures - Natural and Heritage Features

Biodiversity			
Threatened species or endangered populations	Negligible environm	ental consequences	
Seagrass beds	Negligible cNegligible cNegligible c	ental consequences including: hanges in size and distribution of hange in the function of seagrass hange to the composition or distr pecies within seagrass beds.	s beds; and
Benthic communities	Minor environmental consequences, including minor changes to species composition and/or distribution		

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Mine Workings	
First Workings under an approved Extraction Plan beneath any feature where performance measures in this table require negligible environmental consequences	To remain long term stable and non-subsiding
Second Workings	To be carried out only in accordance with and approved Extraction Plan.

Notes:

- The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.
- The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent

Condition 4 within Schedule 4 of SSD-5465 also requires that:

"The Applicant shall ensure that the development does not cause any exceedances of the performance measures in Table 9, to the satisfaction of the Director-General.

The relevant subsidence monitoring requirements from Table 9 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 2**

Table 2 - Subsidence Impact Performance Measures - Built Features

Built Features				
Trinity Point Marina Development Other built features	 Always safe Serviceability should be maintained wherever practicable. Loss of serviceability must be fully compensated Damage must be fully compensated 			
Public Safety				
Public Safety	Negligible additional risk			

Notes:

- The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.

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ENV 0	00029 -	Subsidence	Monitoring	Program -	 Miniwalls 	S2 :	and	S3
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- The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.
- Requirement's regarding safety or serviceability do not preclude preventative actions or mitigation being taken prior to or during mining in order to achieve or maintain these outcomes.
- Requirement's under this condition may be met by measures undertaken in accordance with the Mine Subsidence Compensation Act 1961.

3 Purpose

The purpose of this Subsidence Monitoring Program is to:

- define the subsidence monitoring scope;
- outline subsidence predictions;
- outline the methodology to be used to monitor subsidence impacts
- identify subsidence monitoring locations;
- identify reporting requirements;
- analyse the relationship between predicted and resulting subsidence effects;
- identify the requirements for incident or exceedances reporting.

4 Background

4.1 Operations

Chain Valley Colliery is an underground coal mine with current coal mining methods including development of roadways in the coal seam known as first workings and secondary extraction. These first workings develop panels to support the installation of a miniwall, a modern secondary coal extraction method.

Lake Macquarie is the largest saline lake in New South Wales. It lies on the central coast between Sydney and Newcastle within the local government areas of Wyong and Lake Macquarie. Lake Macquarie has a catchment of 700 square kilometers and a water surface area of 125 square kilometers (Bell & Edwards, 1980). The lake has a permanent entrance to coastal waters at Swansea and has an average depth of around 6 meters (Laxton, 2005).

The catchment of Lake Macquarie is largely rural with large areas of bush land and grazing land. The shoreline of Lake Macquarie is heavily urbanised, especially the eastern, western and northern shorelines. The region has a relatively long history of coal mining and power generation, with mining occurring since the late 1800s and the first power station at Lake Macquarie commencing operations in 1958.

The Chain Valley Colliery is situated on the southern shores of Lake Macquarie near Mannering Park, NSW. The mine has been operating since 1962. Mining is currently undertaken using miniwall methods with first workings to support the development in advance of each miniwall panel. All secondary extraction is currently occurring in the Fassifern seam, in line with Development Consent SSD–5465. The general layout of the Chain Valley Extension Project in respect to Lake Macquarie is shown in Error! Reference source not found.

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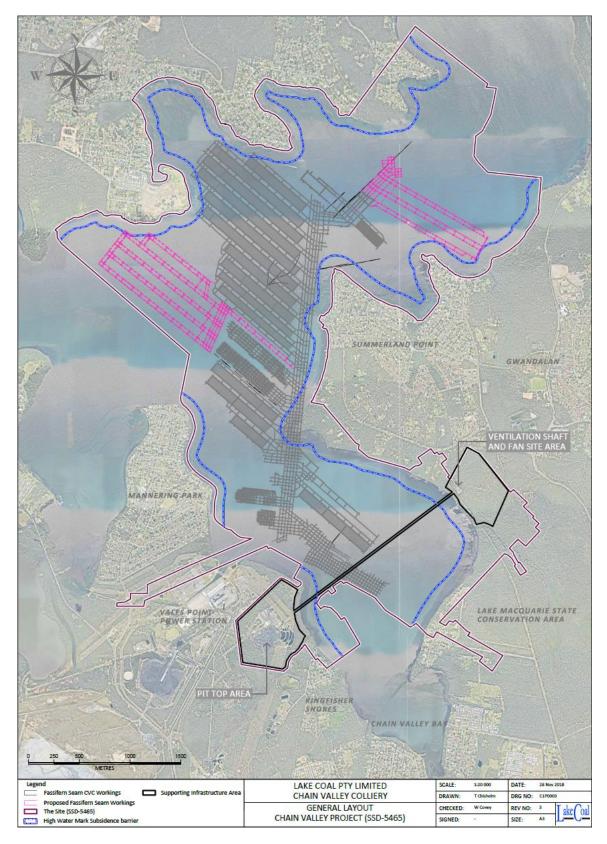


Figure 1 - General Layout of the Chain Valley Project

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4.2 Subsidence Predictions

Subsidence modelling has predicted up to approximately 290mm of subsidence to the Lake floor associated with the planned minimal mining in S2 and S3 (Figure 2), against an approved maximum of 780mm (SSD 5465). No additional subsidence is expected to occur within the seagrass or foreshore areas as a result of Fassifern extraction.

The subsidence parameters beneath the lake, after each panel are included in **Table 3 and 4** for reference of monitoring results against. Respective triggers points for additional monitoring and response are included in the Subsidence Management TARP.

Table 3 – Miniwall S2-S3 Subsidence Predictions (MSEC, September 2018 "MSEC979 Revision 2"

COURT ACTION	181.181.97		
Method	Predicted vertical subsidence (mm)	Notes	
Monitoring data for MW1 to MW12	200	Includes a component of	
Mills and Edwards (1997)	210	sag subsidence	
ACARP (2003)	150 mm (mean)	315 mm (upper 95 % confidence level)	
Elastic model (Das, 1986)	260	Pillar, roof and floor compression	

Table 4 - Miniwall S2-S3 Subsidence Predictions - Post Extraction (MSEC, September 2018 "MSEC979 Revision 2")

Due to miniwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km ⁻¹)	Maximum predicted incremental sagging curvature (km ⁻¹)
MWS2	130	2	0.03	0.07
MWS3	260	5	0.14	0.30

Miniwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km ⁻¹)	Maximum predicted total sagging curvature (km ⁻¹)
MWS2 and MWS3	290	6	0.10	0.30

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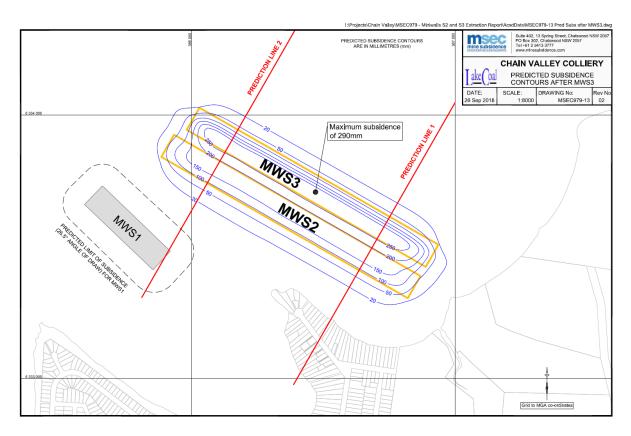


Figure 2 - Predicted Subsidence After S2 & S3

4.3 Subsidence Monitoring - Scope

4.3.1 Shoreline (High Water Mark)

The shoreline of Lake Macquarie is protected under Mining Lease Conditions requiring Ministerial Approval to carry out mining operations within the High Water Mark Subsidence Barrier (HWMSB). The HWMSB is defined in the seam by a line defined by an angle of draw of 35° drawn lakewards from the high water level of Lake Macquarie, and on the land side, a line drawn from the 2.44m contour at 35° towards the land (refer to Figure 3).

Condition 1, Schedule 4 of SSD5465 states:

"The Proponent shall ensure that vertical subsidence within the High Water Mark Subsidence Barrier and within Seagrass beds is limited to a maximum of 20 millimeters(mm)...."

A key objective of the mine design is to minimise vertical subsidence within the HWMSB and prevent additional subsidence above the high water mark. To ensure effectiveness of the mine design, monitoring of the shoreline is proposed via the installation and monitoring of fixed reference marks surveyed at regular intervals.

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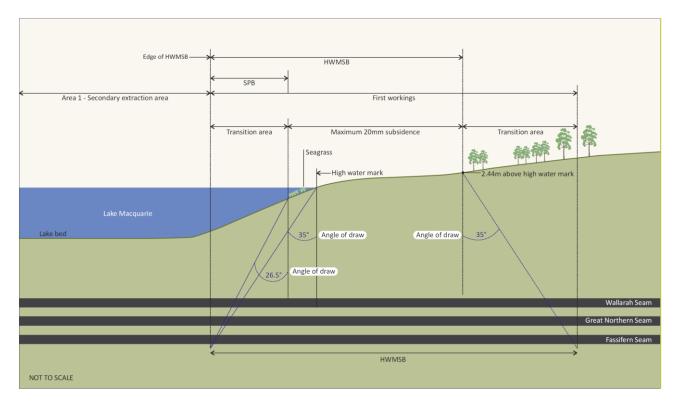


Figure 3 - High Water Mark Subsidence Barrier Typical Diagram

4.3.2 Seagrass

Condition 2, Schedule 4 of SSD-5465 specifies negligible environmental impacts on the species of seagrass found within the current area of mining operations as a condition of approval.

Seagrass distribution within estuaries is naturally influenced by light penetration, depth, salinity, nutrient status, bed stability, wave energy, estuary type, and the evolutionary stage of the estuary.

Regular surveys of the seagrass extents are undertaken in order to monitor impacts on the seagrass population. Lakecoal's Seagrass Management Plan ENV 00009 outlines the methodology used to determine changes to composition and quantity of seagrass populations in Lake Macquarie.

A 26.5° line taken from the lake side of the mapped seagrass location projected to the Fassifern Seam has been defined as a protection barrier, and no miniwall extraction is to take place within this barrier.

Subsidence Monitoring of the lakebed is also proposed via bathymetric survey over the current mining area in order to validate the subsidence prediction model.

4.3.3 Benthic Communities

The mud basin is inhabited by a diverse number of marine organisms. Condition 2, Schedule 4 of SSD-5465 specifies minor environmental consequences on the Benthic communities, including minor changes to species composition and/or distribution as a condition of approval.

Regular surveys of the lake bed are undertaken in order to monitor variations in the composition and density of benthos due to mining, environmental and/or other seasonal factors. Lakecoal's Benthic Communities

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Management Plan ENV 00006 outlines the methodology used to determine changes to species diversity and abundance.

Subsidence Monitoring of the lakebed is also proposed via bathymetric survey over the current mining area in order to validate the subsidence prediction model, and to determine approximate levels of subsidence on specific benthic sample locations.

5 Subsidence Monitoring

5.1 Subsidence Monitoring Methods

5.1.1 Bathymetric Surveys

Bathymetric data from the NSW Office of Environment and Heritage (OEH) was obtained in draft format during 2012. LakeCoal was granted a license to use this OEH data for the purposes of monitoring changes in the bed of Lake Macquarie, and acknowledges the OEH's data which has enabled the subsidence comparison to be undertaken based on this 2010 data and data subsequently obtained in 2012 by LakeCoal. OEH notes that the data was obtained via use of differential GPS and a 200 kHz echosounder, which is noted to provide general data accuracy of 0.1m.

LakeCoal commissioned Astute Surveying in 2012 to undertake a bathymetric survey annually over the areas of current and proposed workings. The primary purpose of this survey was to obtain accurate baseline data for future subsidence assessments and to enable comparison with the draft OEH data from 2010. Importantly, the ongoing surveys provided accurate details of the Lake depth within the proposed mining areas, which would enable future surveys to use as baseline data to monitor the future subsidence levels as a result of mining activities. Bathymetric surveys are currently to be conducted at least six monthly intervals subsequent to this baseline survey.

Comparative analysis of the surveys highlights some elevation changes which are unrelated to mining, generally however these appear to be minor movements, perhaps related to movement of sediment as a result of the wave climate in the Lake. The surveys have shown that subsidence from the miniwall mining can be monitored with a useful level of accuracy and the surveys will be continued to cover future mining areas and areas where mining has been completed.

5.1.2 Foreshore Monitoring

Subsidence monitoring around Summerland Point and into Frying Plan Bay has already been established due to previous mining operations to the immediate southwest of the extraction area. Each line will be extended past the area of effect prior extraction (**Figure 4**)

Monitoring points will be established along the foreshore at approximately 20-30m intervals and will be reestablished where missing. New monitoring locations will be subject to landholder access arrangements and permission.

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Figure 4 - Proposed Shoreline Subsidence Monitoring Locations, Summerland Point

The foreshore monitoring points will be monitored as follows:

- The points are to be established as per S2 to S3 Extraction Plan- Plan 7.
- X and Y locations will be measured using GPS equipment for plotting purposes (±0.050m)
- AHD RL (Z) component will be leveled using Automatic or Digital levelling equipment to an accuracy of 5mm/km.
- Surveys are to be conducted at intervals prescribed in Table 5, during mining operations and after completion of a panel.
- The results are uploaded to DRE's online subsidence web portal within 14 days of survey.

Additional as a part of the foreshore survey monitoring, observations will be made for visual impact or changes to public safety risk. A Subsidence Inspection Proforma will be completed with each survey. The proforma includes visual inspection of steep slopes, boulder or tree instability, ponding and other potential effects of mine subsidence.

Navigation markers will continue to be monitored by Roads and Maritime Services, who will inform LakeCoal of any abnormal changes potentially attributable to mine subsidence.

5.2 Subsidence Monitoring Frequency Requirements

Based on the monitoring program outlined above, the following monitoring frequencies are to be established to validate model outcomes, enable early detection of subsidence trending to increased impact levels over that predicted, allow early application of containment, adaptive and contingency measures to prevent impact outside approved and particularly increased impact to the foreshore.

All evaluations are to be made against the criteria outlined in the Subsidence Monitoring TARP.

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Table 5 - Subsidence Monitoring Frequencies

	Pre-Extraction	During Extraction	Post Extraction
Bathymetric surveys	Single baseline survey prior to extraction (June 2019)	End of panel for S2 End of panel survey for S3	Annual for 3 years unless TARP triggered
Foreshore Level Monitoring	Baseline survey prior to commencement of extraction	Monthly intervals	Annual for 3 years unless TARP triggered

5.3 Subsidence Monitoring Review

Chain Valley Colliery will undertake a review of available subsidence monitoring data against predictions and expected outcomes annually within its Annual Review as required by SSD-5465.

5.4 Consultation

The Subsidence Monitoring Plan is required to be prepared in consultation with DRE. DRE have been consulted during the submission of the Extraction Plan and also as a part of the High Risk Activity Notification.

Roads and Maritime Services Project Officer (North Area) has been contacted during the development of the Extraction Plan and referred the matter to the RMS asset team, resulting in no further immediate actions required in regard to management of the navigation markers.

The Community Consultative Committee (CCC) for the mine will be routinely updated on subsidence monitoring results and any change in impact or public safety concern.

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6 Roles and Responsibilities

Roles, responsibilities specific to completing the requirements of this Subsidence Monitoring Program are identified in **Table 6**.

Table 6: Subsidence Monitoring Program Roles and Responsibilities

Role	Responsibilities
Mine Manager	Ensure that adequate financial and personnel resources are made available for the implementation of the Subsidence Monitoring Program
Mine Surveyor	 Co-ordinate subsidence monitoring, through the use of bathymetric surveys, conventional surveys along foreshore and underground data collection. Review subsidence monitoring results against Subsidence Management TARP triggers Inform relevant stakeholders as to the subsidence monitoring results Review, and if necessary revise this document: In the event of any exceedance in impact thresholds Following any modification to the development consent
Environment and Community Coordinator	 Develop management actions in consultation with regulatory agencies as/if required from the monitoring results. Respond to any potential or actual non-compliance and report these as required to regulatory bodies and other stakeholders. Notify the relevant Government Agencies and other affected parties of any exceedances of the performance measures Coordinate the meeting of the Subsidence Review Committee Ensure complaint handling and response is undertaken, including determination of sources and potential remedial action to avoid recurrence.

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CHAIN VALLEY COLLIERY

Rehabilitation Management Plan ENVIRONMENTAL MANAGEMENT PLAN

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Date:	01/03/2019			

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Introduction

Chain Valley Colliery (the Colliery) is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station. The Colliery produces thermal coal for the domestic and export markets.

A formal Environmental Management System (EMS) has been developed as a systematic and structured approach to managing environmental issues at the operation. The EMS has been developed in general accordance with the requirements of the international standard ISO 14001.

This Rehabilitation Management Plan (RMP) is an element of the Colliery's EMS. The RMP is intended to be dynamic and changes will be made as warranted over time. The formal life of this RMP is three years and will be reviewed and amended, as required, as outlined in Section 14.

Mining operations in NSW are required, as a condition of an authorisation issued under the *Mining Act 1992*, to conduct mining operations in accordance with a Mining Operations Plan (MOP) that has been approved by the NSW Department of Trade and Investment, Regional Infrastructure and Services - Division of Resources & Energy (DRE). A MOP sets out in detail how mines will be rehabilitated over the course of the mining project. Each MOP has a maximum seven year period of application and has to be renewed as appropriate.

The existing guidelines for the preparation of MOPs state that premature or unplanned closure would typically require a new MOP to be developed. This new MOP should be prepared using the current MOP quidelines at the time, with additional information as required from the "Strategic Framework for Mine Closure", published by the Australian and New Zealand Minerals and Energy Council, and the Minerals Council of Australia.

The Colliery has Development Consent SSD-5465 (as modified) for mining operations to occur until 31 December 2027.

This RMP, as well as being an element of the Colliery's EMS, has also been completed to satisfy the requirements of Condition 27 within Schedule 3 of Development Consent SSD-5465 (as modified), which states:

"The Applicant shall prepare and implement a Rehabilitation Management Plan for the development, in consultation with OEH, NOW, WSC, LMCC, and the CCC, and to the satisfaction of the Executive Director Mineral Resources. This plan must:

- (a) be submitted to the Secretary and the DRE for approval within 12 months of the date of approval of this development consent;
- be prepared in accordance with any relevant DRE guideline and be consistent with the rehabilitation (b) objectives in the EIS and in Table 7;
- describe how the performance of the rehabilitation would be monitored and assessed against the (c) objectives in Table 7;
- (d) describe the process whereby additional measures would be identified and implemented to ensure the rehabilitation objectives are achieved;
- (e) provide for detailed mine closure planning, including measures to minimise socio-economic effects due to mine closure, to be conducted prior to the site being placed on care and maintenance; and
- (f) be integrated with the other management plans required under this consent.

The Rehabilitation Management Plan should address all land impacted by the development whether prior to, or Note: following, the date of this consent."

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In addition to the above requirements, Condition 26, within Schedule 3 also requires that "the Applicant shall carry out the rehabilitation of the site progressively, that is, as soon as reasonably practicable following disturbance".

2 Purpose

The purposes of this RMP are to:

- set out the rehabilitation objectives and proposals for the Colliery;
- meet the requirements of the Development Consent in respect of the RMP; and
- compliment the role of the Chain Valley Colliery MOP as an instrument to attain desired rehabilitation outcomes.

3 Background

This section provides an overview of the operations of the Colliery that are relevant to the future rehabilitation of the Colliery, with **Figure 3.1** showing the main surface features of the Colliery.

3.1 Site History

In August 1960, J&A Brown and Abermain Seaham Collieries Ltd commenced clearing the present site with drift and shaft sinking starting a few months later. Production of coal from the Wallarah seam, commenced with the first delivery to the adjacent Delta Electricity's Vales Point Power Station in April 1963.

LakeCoal was formed in 2001 to acquire BHP Billiton's 80% share in the Wallarah Coal Joint Venture (WCJV), the remaining 20% share was owned by Sojitz. In October 2006, Peabody Energy, a US listed company acquired LakeCoal Pty Limited.

In November 2009 LDO Coal Pty Limited purchased LakeCoal Pty Limited. LDO Coal is a consortium consisting of LD Operations, AMCI and private investors.

In March 2011 the 20% share in the WCJV which Sojitz held was acquired by LDO Coal shareholders through the entity Fassi Coal Pty Ltd.

The WCJV had operated the Wallarah, Moonee and Chain Valley underground coal mines and the Catherine Hill Bay Coal Preparation Plant, all located at the southern end of Lake Macquarie. At the time of LakeCoal's acquisition by LDO Coal, both the Wallarah and Moonee mines were closed.

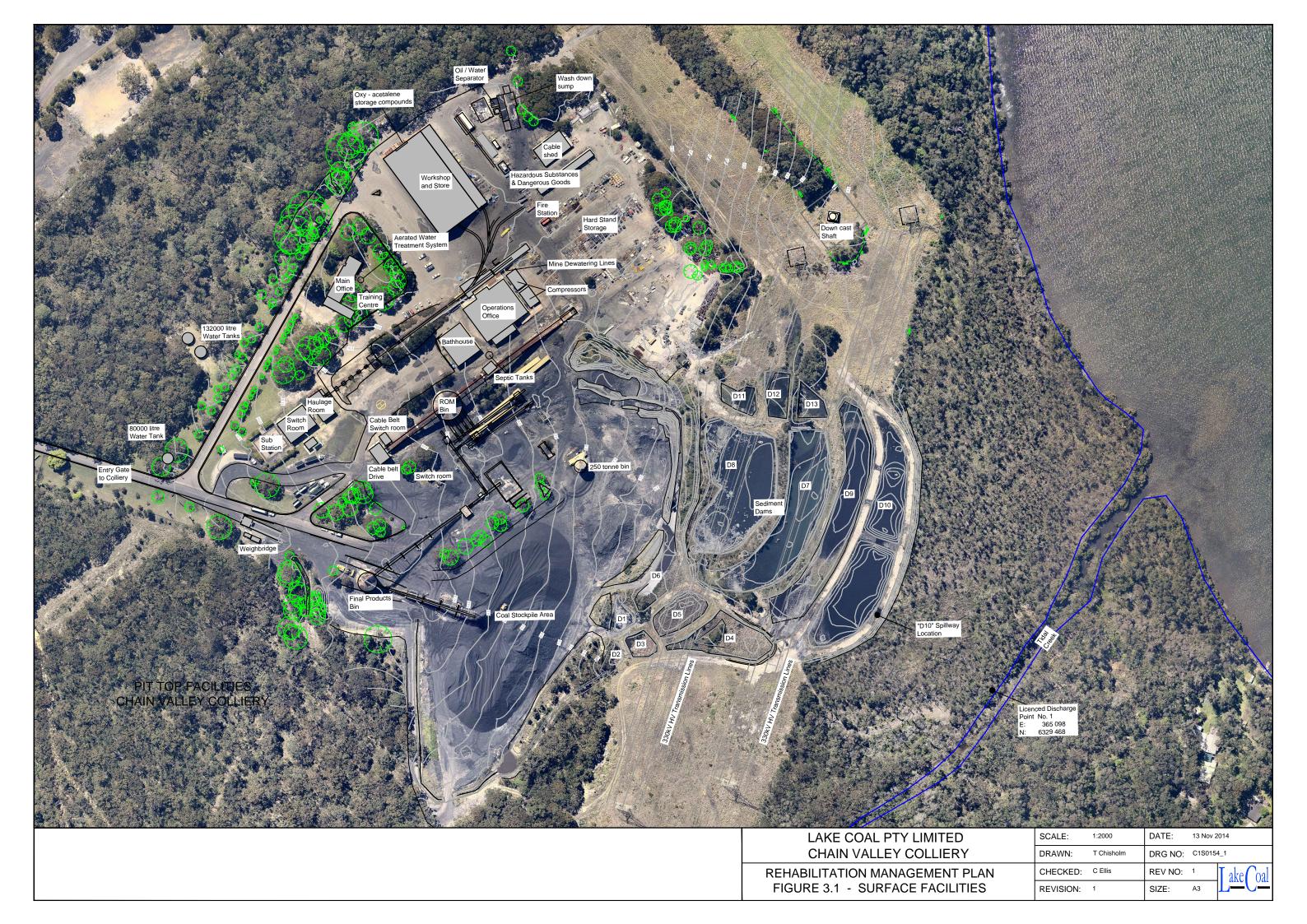
LakeCoal is currently undertaking the mine closure/rehabilitation process for the Moonee Colliery and the Catherine Hill Bay Coal Preparation Plant, subject to a separate Mining Operations Plan. The rehabilitation process for Wallarah Colliery has been completed and the lease in that area relinquished.

Chain Valley Colliery peaked with a workforce of approximately 380 men in the mid 1980's. As of mid 2014, Chain Valley Colliery has a workforce of approximately 150 full time employees/contractors.

The Wallarah, Great Northern and Fassifern seams have been mined at Chain Valley Colliery to produce a raw, crushed thermal coal with low sulphur, which is suitable for both export and domestic markets.

Mining in the Wallarah seam is complete in the Colliery holding area and mining was discontinued in the late 1990's. There is still some remaining resource within the Great Northern seam, however the focus of operations and current approval only permits mining within the Fassifern seam.

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3.2 Land Tenure and Use

Chain Valley Colliery comprises two individual surface areas, the main pit top area directly adjacent to the Vales Point Power Station and the ventilation shaft site on Summerland Point. The pit top area is comprised five (5) separate lots while the ventilation shaft site is a single lot, details of the lots and ownership is detailed in Table 3.1 and shown on Figure 3.2.

Table 3.1: Land ownership details

Site	Owner	Lot	Deposited Plan
Pit top area	Delta Electricity (utilised under access agreement)	А	379918
	ander access agreement,	В	379918
		С	349733
		А	187570
		1B	339441
Ventilation shaft site	LakeCoal Pty Ltd	1	226133

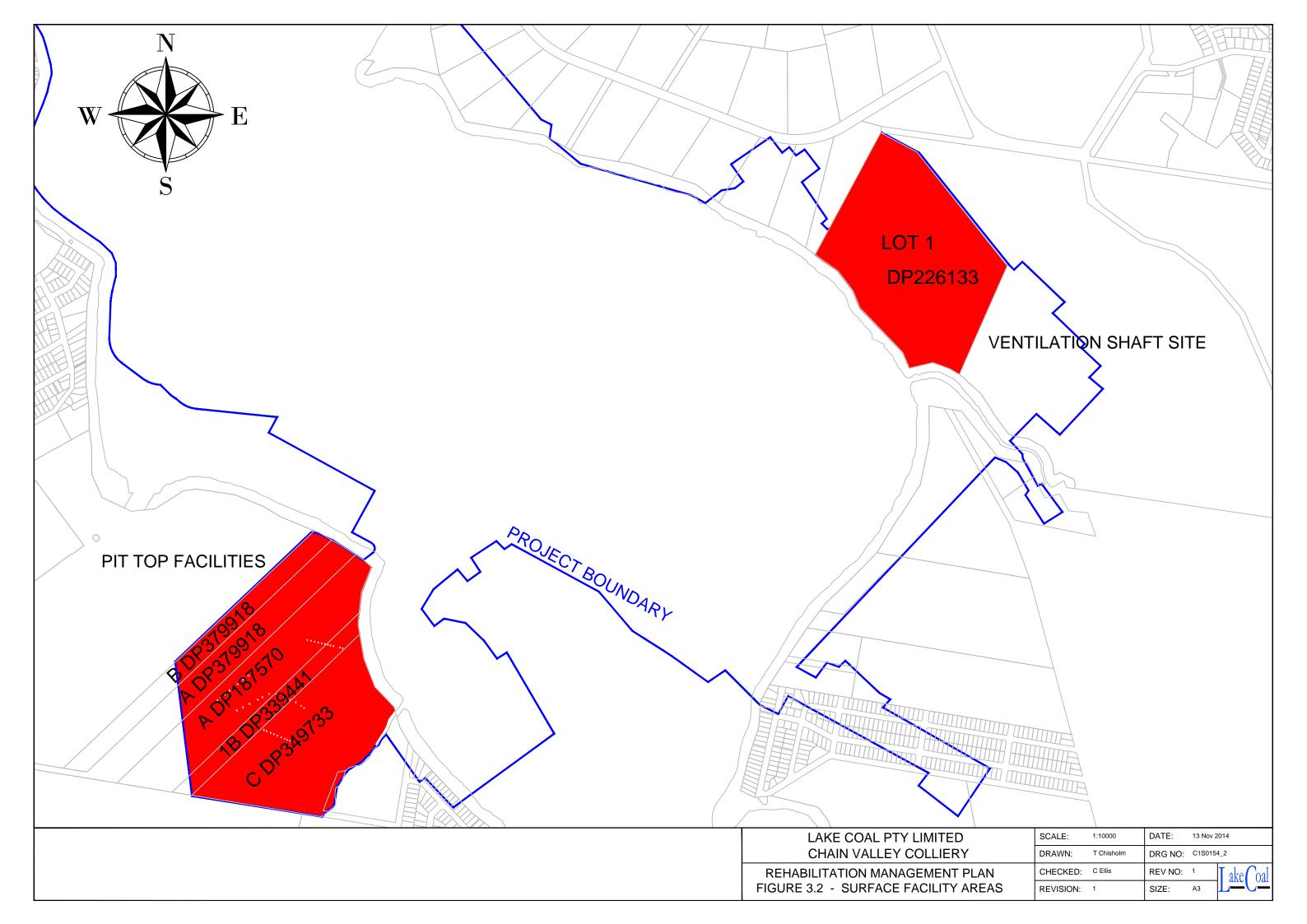
3.3 Mining methods

Coal mining at the Colliery has occurred since 1962 and consists of two phases: first workings where an initial cut of coal is extracted and negligible surface subsidence occurs; and secondary extraction where the majority of the coal resource is extracted and, therefore, is the more productive phase of mining. Secondary extraction is generally necessary for the commercial viability of a mine, whereas first workings are necessary to establish roadways for access and ventilation.

Up until 2011, operations consisted of bord and pillar methods for secondary extraction. Since 2011, secondary extraction at the Colliery has employed the minimal mining method. Historically coal has been extracted from three seams - the Wallarah, Great Northern and Fassifern seams. Current mining activities are limited to the Fassifern seam.

Historic workings are located under the southern extent of Lake Macquarie and areas of Summerland Point, Chain Valley Bay, Mannering Park and Kingfisher Shores. Areas of these historic Colliery workings are being used for passive operational activities such as ventilation; water drainage; movement of personnel, materials and coal; conveyors; and services.

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3.4 Coal processing

The Colliery produces a raw crushed thermal coal with relatively low sulphur, suitable for both export and domestic markets. Raw coal is transported to Mannering Colliery via underground conveyor where it is screened, crushed and sized on site and sent via surface conveyor to Vales Point Power Station.

3.5 Waste management

Waste management at Colliery consists of two main areas; solid waste management and liquid waste management.

A licenced waste contractor is engaged to remove and dispose of waste from the Colliery. Through the implementation of a total waste management system with the waste management contractor, continuous improvements are made on site to increase recycling and decrease waste to landfill.

Liquid waste product from washdown bays and the oil separator is removed from site via a licenced waste contractor under appropriate waste tracking. Stormwater runoff from the potentially hydrocarbon containing areas flow to the wash down sump which is subsequently treated by an oil water separator. Solids are removed in a grit trap and oil is removed from the water by packed bed oil water separator and stored in a waste oil tank prior to removal from site. Excess oil from the compressors (condensate) and surrounds is contained and piped to a separator tank which is inspected weekly and pumped out as required.

Coal fines, which are captured by sediment dams, sumps and other sediment control devices are recovered and re-incorporated to final product coal, further reducing potential waste streams.

3.6 Coal stockpiles

A ROM stockpile exists to the east of the pit top area (**Figure 3.1**) which is designed to balance market demands during times of lower production, extended maintenance or mine shutdown and shipping requirements. The stockpile has a maximum capacity of approximately 150,000 tonnes but more typically contains around 40,000 tonnes. There is no coal reject generated from production at Chain Valley Colliery.

3.7 Water management

A significant portion of the Colliery leases are under Lake Macquarie, with the predominately saline but otherwise uncontaminated groundwater seepage pumped to the surface prior to discharge via a licenced discharge point.

The underground mine water from the Wallarah, Great Northern and Fassifern Seams is dewatered or migrates naturally and is pumped to a central underground sump area in the Great Northern Seam. It is then pumped to the surface and mixed with bathhouse wastewater and stormwater runoff in the dams to the east of the pit top area. The dams act as settling and diffusing ponds and allow the water to migrate via the series of dams into a waterway which discharges into Lake Macquarie. Discharges are licenced under Environment Protection Licence 1770. Average mine water discharges to the surface settling ponds is approximately 50 megalitres a week.

3.8 Hydrocarbon Management

Oil and diesel fuel at Colliery is stored within a number of bunded areas. Drainage from the bunded areas is connected to the oil separator and sedimentation sumps. In the event of a major spill, the drainage system can be blocked off to contain any spill in the outdoor storage area. Spill kits, booms and absorbent are available on site if required. The diesel fuel storage tank of 14,900 litres is situated behind the main workshop.

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4 Consultation

A key component for the development of the RMP is consultation. As this version of the RMP is a revision of a prior version, which was also prepared in consultation with a number of stakeholders, this prior consultation and outcomes are detailed below (in **Table 4.1**). **Table 4.1** also provides a summary of the most recent items raised, and responses or changes as a result of the consultation for the current version of the document.

Table 4.1 Consultation Summary

Stakeholder	Comments	Response/Action
Community Consultative Committee	No comments were received	• N/A
Fisheries NSW	Raised concern over the potential for groundwater to build up post closure and breach surface seals, impacting Lake Macquarie	Addressed in Section 5.2.2
Wyong Shire Council (original comments)	Requested consideration of mine portals being used as habitat for microbats and site dams being used as fauna habitat.	Both of these comments were incorporated and addressed in Section 4.3.3
	Suggested the document be updated to include habitat augmentation such as nest boxes, hollow logs and frog ponds etc.	
Wyong Shire Council (comments on Revision 3)	Suggested including some details in the plan to enable rehabilitation efforts to commence in the shorter term prior to the detailed closure being developed. For example, providing a list of suitable plant species for the native revegetation to be re-established, which would allow these species to be propagated while the detailed closure plan is developed.	Suggestion has been incorporated into Section 7.6.
	Questioned to the alignment of rehabilitation completion criteria and performance measures in Table 7.2, for example considered that the criteria of a 'clear trend of increasing species diversity' may not equate to the objective of a 'self-sustaining ecosystem' as required by the rehabilitation objectives from the Development Consent.	Notwithstanding the detailed mine closure plan may expand on the performance measures, it is considered that increasing species diversity would be a significant indicator of a self-sustaining ecosystem, i.e. additional species are propagating within the rehabilitation area, which relies on the rehabilitation being able to support this propagation and diversity. Self-propagation in revegetated areas is also an existing completion criteria within ecosystem,/land use establishment. In addition, one of the performance measures proposed is monitoring and comparison to adjacent control

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Table 4.1 Consultation Summary

Stakeholder	Comments	Response/Action
		sites, which will enable comparison with these adjacent self-sustaining sites.
	Recommended that Section 10 (Risk Management) be updated to include hazards of bushfire, pests and disease/pathogens.	The Rehabilitation Management item that existed in Section 10 was further expanded to specifically mention these items.
Department of Planning & Environment	Provided comments on Section 10 (risk factors) and agency names and structures.	Both these sections (Section 10 and Section 12) were updated to incorporate / address comments provided.
Office of Environment and Heritage	No comments were received	• N/A
NSW Office of Water	No comments were received	• N/A
Lake Macquarie City Council	No comments were received	• N/A
Delta Electricity	Delta notes that closure is not planned and approval to continue operations exists until 31 December 2027.	Noted
	Delta advised they have no material additions to the plan other than some consideration should be given to the management of the current Licenced Discharge Point and what monitoring conditions will be required post closure and surrender of the EPL (if any)	Section 7.7.2 (Water Management) has been updated to provide additional information on proposed EPL surrender and water monitoring.

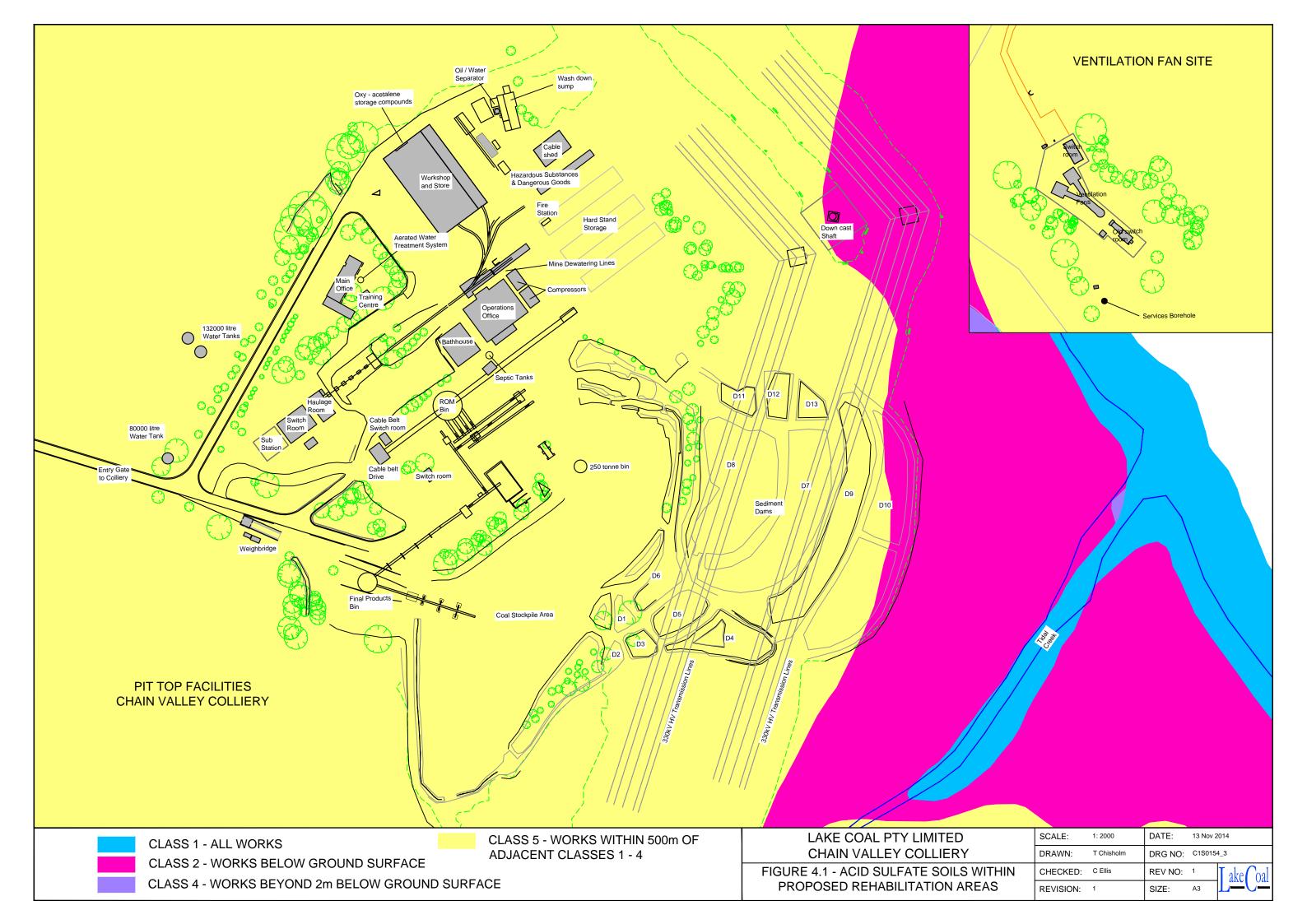
5 Environmental Characterisation

5.1 Physical Environment

The climate at the Colliery is borderline oceanic/humid subtropical with warm summers, mild winters and heavy precipitation in late autumn and early winter. A review of Bureau of Meteorology weather stations in the Lake Macquarie region found that the average annual rainfall in the vicinity of the Colliery is 1,200 mm with an average annual evaporation of 824 mm.

The pit top area and Summerland Point ventilation shaft site are located on lands comprising the Doyalson and Wyong soil landscapes. Doyalson soils are strongly acidic with low fertility and slight to high erodibility. Wyong soils are strongly acidic, poorly drained, impermeable, and saline with very low fertility. The *NSW Acid Sulfate Soil Risk Maps* for the Lake Macquarie area shows that acid sulfate soils are likely to occur at a depth of 1 to 2m along the foreshore of Lake Macquarie adjacent to the pit top area and the Summerland Point ventilation shaft. The acid sulfate soil risk warrants consideration during the development of the detailed mine closure plan and accordingly in provided as **Figure 4.1.**

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5.2 Hydrology

5.2.1 Surface water

The Colliery has a series of 13 sediment dams (**Figure 3.1**) into which receive inflow from surface catchment runoff, septic treated bathhouse wastewater, treated water from the oil water separator and, primarily, underground mine water. These ponds treat the wastewater and runoff through settlement of fines and suspended solids prior to discharge from the Colliery. The discharge is licenced under Environment Protection Licence 1770, which includes a volumetric limit of 12,161 kilolitres per day. The dams have been constructed with a mixture of earth, crushed road base and crushed recycled brick and stone, and are interconnected through a series of overflow pipes and spillways.

Potable water is supplied to the Colliery via a mains connection from the Wyong Shire Council water supply, while currently utilised for operational activities, the potable supply will be an important source of clean water when undertaking site rehabilitation works.

Details of the site surface water management are provided in the Water Management Plan.

5.2.2 Groundwater

The hydrogeological regime of the mining area and its surrounds comprises a Quaternary terrestrial and marine / estuarine alluvial / coalluvial groundwater system. There is also underlying Permian strata with low permeability and yielding sandstone, siltstone, conglomerate and tuff with low to moderately permeable coal seams which are the predominant water bearing strata.

The groundwater is naturally saline and migrates into the Colliery's underground workings in the Wallarah, Great Northern and Fassifern seams with the majority of inflows currently seen in the Great Northern and Wallarah seams. All water is transferred to a main sump within the Great Northern Seam, and then to the sediment dams on the surface via the main underground pumps. The groundwater cannot be used for operational purposes due to being highly saline and would not be suitable for use in mine rehabilitation for the same reason.

As the groundwater table is lower than any of the mine entries or shafts, there will be no risk of groundwater exiting through sealed drifts or shafts post mine closure.

Details of the groundwater systems in the vicinity of the Colliery are provided in the Water Management Plan.

5.3 Natural Environment

5.3.1 Geology

The stratigraphy in the local area comprises the Permian coal measures overlain by the Triassic Narrabeen subgroup and Quaternary lacustrine and terrestrial alluvial / colluvial deposits.

There are a number of faults and dykes which have been mapped or are inferred within the Colliery and its surrounds. The current Fassifern Seam workings have intersected some of these geological structures, which have impacted on approved mining activities; however, no significant inflows were observed when installing the main headings.

The Fassifern Seam is mined at a depth of approximately 200 m with the seam being approximately 30 m deeper than the Great Northern seam, which underlies the Wallarah seem by approximately 30 m also. The Fassifern seam is overlain by a tuffaceous claystone material which varies in thickness between 20-30 metres. The Fassifern seam measures up to 5 metres in thickness with roadway development carrying a coal roof and floor.

Figure 5.1 shows the typical stratigraphy at Chain Valley Colliery including the Wallarah, Great Northern and

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Fassifern seams.

5.3.2 Aquatic Ecology

The current mine workings are located in the southern part of Lake Macquarie, west of Summerland Point. Lake Macquarie is a large barrier estuarine lake characterised by an open water area of 115.1km². The Lake opens to the sea and strong tidal flows occur at the entrance channel, where the tidal range is 1.23m (Watterson *et al. 2011*). However, in areas removed from the Lake's entrance such as Chain Valley Bay which is 13km from the entrance, tidal range and influence is not as pronounced. Lake Macquarie is a wave-dominated estuary, with a high sediment trapping efficiency, naturally low turbidity and salt wedge/partially mixed circulation where there is likely to be sedimentation (Cardno Ecology Lab, 2011). The average depth of the Lake is 7m and exhibits a relatively flat floor characterised by fine soft silt/mud sediments. The approximate water depth in the vicinity of the mining areas ranges from 0.5m to 8.5m and depth of sediment varies in thickness up to approximately 10m (AECOM, 2011).

Seagrass communities within the Lake have been mapped adjacent to current workings and a seagrass protection barrier has been applied to the mine plan to ensure the seagrass beds are not subsided. Annual seagrass monitoring and reporting is also undertaken in accordance with the current Seagrass Management Plan.

Studies of benthic communities have also been undertaken both above the mining areas as well as at control sites and no correlation between mining activities and community abundance and/or diversity was found to exist, however, ongoing monitoring in accordance with the Benthic Communities Management Plan is planned and will ensure that potential impacts to benthic communities are monitored throughout mining activities.

Given the above, no rehabilitation at mine closure is expected in relation to the aquatic environment above the mining areas.

5.3.3 Terrestrial Ecology

Vegetation mapping undertaken during 2012 in areas surrounding the pit top identified the surrounding vegetation communities as coastal open woodland, swamp oak forest and swamp sclerophyl forest. Mapping was also undertaken at the ventilation shaft site and identified coastal open woodland, grassy open woodland and swamp sclerophyl forest as the vegetation communities surrounding the site. Additional details on the terrestrial ecology are contained within the Biodiversity Management Plan.

From the above both the swamp oak forest and swamp sclerophyl forest are listed as Endangered Ecological Communities under the Threatened Species Conservation Act, 1995.

The surrounding vegetation communities are also known to provide habitat for threatened fauna species such as the Squirrel Glider (*Petaurus norfolcensis*), Regent Honeyeater (*Anthochaera phrygia*), Swift Parrot (*Lathamus discolor*), Grey-headed Flying-fox (*Pteropus poliocephalus*) and microbats.

Accordingly, consideration of the valuable vegetation communities and habitat they provide will be an essential part of the detailed mine closure plan.

In additional to the natural habitat within the site, built structures are also known to provide potential habitat for a number of fauna species. Of relevance to the Colliery, it is known that endangered mircobat populations have inhabited mine portals elsewhere in NSW (Olsen Consulting Group, 2009), in addition the Colliery sediment dams have become used by a number of native fauna species. As a result of the potential impact to endangered mircobat populations and other fauna species as a result of undertaking mine closure activities these potential impacts will need to be considered as part of the mine closure plan, including undertaking a risk assessment in relation to the closure works.

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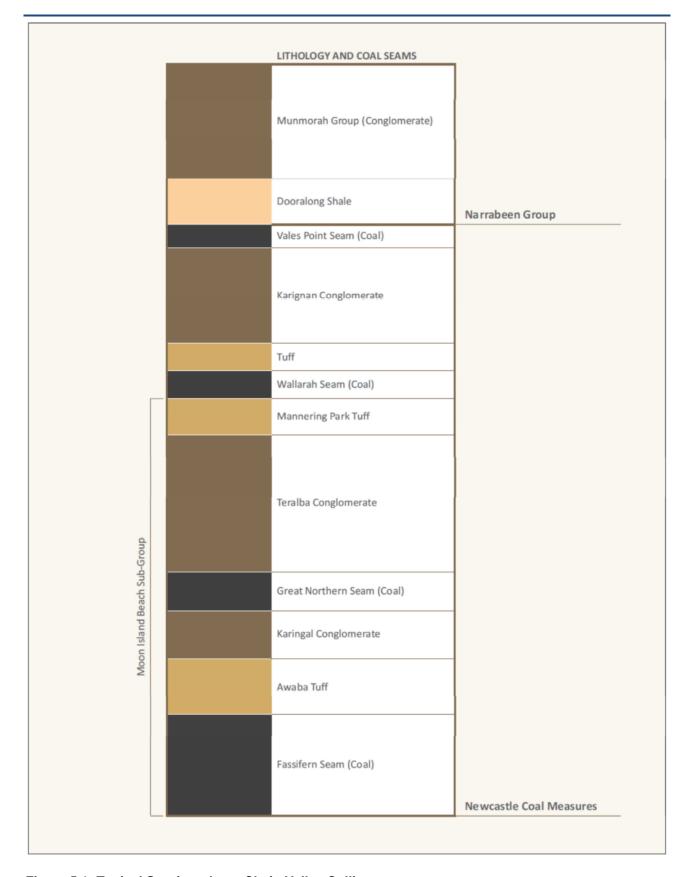


Figure 5.1: Typical Stratigraphy at Chain Valley Colliery

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6 Socio-economic and Cultural Environment

6.1 Workforce Profile

While not specifically related to mine rehabilitation, LakeCoal employees and contractors are major stakeholders when considering mine closure and subsequent rehabilitation. A workforce survey was undertaken in 2012 to identify the workforce demographics and other important features. The survey was undertaken over all shifts (day, afternoon and night) and rosters (mid-week and weekend), with the results of this survey summarised below.

While the below details are not exhaustive of the survey undertaken, they give a snapshot of the workforce profile which can be considered in the socio-economic aspects of mine closure planning to reduce potential impacts due to mine closure.

6.1.1 Demographics

- approximately 80% of the Colliery workforce are LakeCoal employees, while 20% are contractors to the company;
- approximately 60% of the Colliery workforce have been working at the Colliery for under 2 years, 15% between 5 to 7 years, 13% greater than 15 years and 12% between 3 to 5 years; and
- the largest working age group is 25 to 34 year olds (39%), followed by 45 to 54 year olds (25%) and 35 to 44 year olds (14%).

6.1.2 Residential location

- the majority of the Colliery workforce live in Lake Macquarie LGA (60%) followed by Wyong LGA (26%) and Newcastle LGA (8%). Approximately 27% of contractors come from outside these LGAs;
- a high proportion of the Colliery workforce have resided in their locality for more than 15 years (72.2%) indicating low levels of residential mobility; and
- approximately 85% of the Colliery workforce stated they already lived in the area when they commenced employment at the Colliery, indicating that the Colliery sources employment from the local labour pool.

6.1.3 Housing and household composition

- a high proportion of the Colliery workforce have either a mortgage or own their own homes (85%) with a smaller proportion living in rental accommodation (15%);
- approximately 55% of the Colliery workforce had partners in paid employment, while 27% of partners were not working (18% of workers had no partners);
- of those partners in employment, the highest proportion was full-time employment (32%) compared to part-time (23%), largely in areas of healthcare and office and administration support (11% each);
- the highest proportion of people living in a household is two people households (29%), followed by four people (27%) and three people (22%);
- the average family household size for the Colliery workforce is 3.11;

6.1.4 Household expenditure and service usage

- the majority of the Colliery workforce purchase their weekly household goods in Lake Macquarie LGA (55%), predominantly at Swansea and Belmont, followed by Wyong LGA (26%), primarily at Lake Haven;
- consistent with the above trend, the Colliery workforce use local medical facilities close to their place of residence (Lake Macquarie LGA - 56% and Wyong LGA -25%); and

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• of all households, 17% have a family member attending high school, 16% attending primary school and 13% attending childcare or preschool.

6.1.5 Charitable contributions

- over half the Colliery workforce (56%) makes voluntary donations, with 31% making donations to local schools, 17% to Salvation Army, 14% to the local surf club and 13% to local sporting clubs; and
- a small proportion of the Colliery workforce (16%) participates in local voluntary services, and of these 60% volunteer with the local surf club and 12% with schools and animal rescue groups.

6.2 Cultural Environment

LakeCoal has developed a Heritage Management Plan, which should be referenced for detailed background in relation to the cultural environment and stakeholders, the below sections build on this management plan in relation to rehabilitation and mine closure only.

6.2.1 Aboriginal heritage

Prior to European settlement, the Lake Macquarie area was inhabited by people of the Awabakal language group (also spelt Awabagal), a language name derived from the 'Awaba' place name for Lake Macquarie and the group of people belonging to that place (Awaba-gal). The Awabakal is bordered generally by the Darkinjung to the south west, Wonnarua to the north west and by the Worimi to the north beyond Newcastle.

Monitoring of the a single Aboriginal site, above the main headings, commenced in January 2013 in accordance with the Heritage Management Plan. Monitoring of this site and other sites as identified in the Heritage Management Plan will continue as required throughout the life of the mine.

As part of the site rehabilitation and closure final monitoring of these sites for any mine subsidence related affects will be considered, if not completed prior to this date.

6.2.2 Historic heritage

There are no identified sites of historic significance at the Colliery, however the Lake Macquarie Local Environmental Plan (LEP) 2004 identifies the "Wyee Coal Conveyor Railway Loop" as an item of local heritage significant. While the Wyee rail loop is over 5km away from the Colliery, the address of the "Wyee Coal Conveyor Railway Loop is identified in the Lake Macquarie LEP as "North of Wyee to Vales Point Power Station" which indicates that the conveyor linking the Wyee rail loop and power station form part of the local heritage item. Considering that the Colliery is directly adjacent to, and closely associated with, the Vales Point Power Station, this item of local heritage significance is considered to be proximate enough to the site to warrant consideration as part of RMP.

In addition to the above the Wyong Shire Council Heritage Review (Scobie Architects Pty Ltd, 2010) investigated the historical context of Wyong and identified areas of historic heritage significance. It identified the Vales Point Power Station, located directly adjacent to the Colliery as an item of local heritage significance and has recommended the power station be included in the Schedule of heritage items within the Wyong LEP (Scobie Architects Pty Ltd 2010).

Based on the above, there are no items of heritage significant within the Colliery surface areas or any that overlie mine workings. However the Vales Point Power Station, Wyee rail loop and conveyor from the Wyee rail loop to the power station have been identified as having local heritage significance.

In consideration of the above, and that Chain Valley Colliery has been providing coal to the power station since 1963, final mine closure and rehabilitation planning should include consultation with Delta Electricity (or future owners) of the Vales Point Power Station in relation to representing the historic linkage between the Colliery and the power station.

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7 Rehabilitation Management

7.1 Proposed rehabilitation during life of the current MOP

The current Chain Valley and Mannering Colliery MOP was approved in 26th September 2019, with a completion date of 30 November 2020. The current Development Consent will expire on 31 December 2027. Due to the continuing need for surface infrastructure for operational use, there is relatively little rehabilitation anticipated over the life of the current or proceeding MOP. Surface works are expected to be limited to replacement, upgrade or maintenance work for the existing surface improvements.

Final rehabilitation will not be achieved under the current MOP. However, the anticipated rehabilitation status at mine closure is generally rehabilitation to a semi-natural vegetation cover (while maintaining the existing 330kV power line easement) with a view to lease relinquishment. Rehabilitation to be implemented under a future MOP at mine closure is described in the current MOP.

7.2 Mine closure planning

A detailed mine closure plan will be prepared at least one year before the mine is closed. The plan will be comprehensive and not only consider such issues as the physical rehabilitation of the Colliery site and the decommissioning and removal of plant but also community engagement and socio-economic issues. It is not expected that such a plan would be required until approximately 2026, however this date would be dependant on future approvals and access to resources and reserves. This RMP will be revisited on a three yearly basis, and, as it will be reasonably up to date at the time the mine closure plan is being prepared, it will inform the plan and vice versa.

Should events occur that result in the Colliery being placed into temporary closure or care and mainternance, a risk assessment will be triggered with the resulting actions being included in a care and maintenance plan to be developed for the Colliery. The care and maintenance plan would be implemented until such a time that the Colliery resumes mining activities or a detailed mine closure plan is developed and approved.

7.3 Mine closure and final rehabilitation objectives

The current MOP describes LakeCoal's objectives for closure of the Colliery which are:

- prevent access to former underground workings;
- remove unwanted infrastructure from surface areas;
- ensure any remaining infrastructure is "fit for purpose" through identifying and managing associated risks:
- develop final landforms that are safe, permanent and suitable for subsequent land use as determined through consultation with stakeholders, including landowners (principally Delta Electricity), local communities and government departments;
- minimise maintenance requirements for remaining infrastructure and landforms; and
- progressively relinquish leases as rehabilitation is completed and accepted by the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS).

Generally, it is proposed to revegetate the surface facilities areas to a near-native ecosystem compatible with the surrounding vegetation communities (with exception of the area that lies within the 330kV power line easement, which will remain a grassland community). As the goal is to return the areas of disturbance to a native plant community (or communities) aligned with the surrounding bushland, no introduced species (e.g., *Melaleuca armillaris*, *Pinus radiata* and non-endemic eucalypts) would be used in the revegetation program. Rather, the focus of the works would be the use of plant material grown from locally sourced species. The Colliery is on land owned by Delta Electricity who will, therefore, be a key stakeholder in determining the final revegetation and landform of the area.

In addition to reinforcing the objectives of the MOP, the objectives of this RMP are prescribed in Table 7 of Condition 25, Schedule 3 of the Development Consent and are reproduced in **Table 7.1**.

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Table 7.1 Rehabilitation objectives

Feature	Objective
Mine site (as a whole)	Safe, stable and non-polluting.Final land use that is compatible with surrounding land uses.
Surface infrastructure	To be decommissioned and removed, unless the Executive Director Mineral Resources agrees otherwise.
Portals and ventilation shafts	 To be decommissioned and made safe and stable. Retain habitat for threatened species (eg bats), where practicable.
Other land affected by the development	Restore ecosystem function, including maintaining or establishing self-sustaining ecosystems comprised of; local native plant species (unless the Executive Director Mineral Resources agrees otherwise); and a landform consistent with the surrounding environment
Built features damaged by mining operations	Repair to pre-mining condition or equivalent unless: the owner agrees otherwise; or the damage is fully restores, repaired or compensated under the Mine Subsidence Compensation Act 1961.
Community	 Ensure public safety. Minimise the adverse socio-economic effects associated with mine closure.

Notes:

- These rehabilitation objectives apply to all subsidence impacts and environmental consequences caused by mining taking place after the granting of project approval MP 10_0161, and to all development surface infrastructure part of the development, whether constructed prior to or following the date of this consent.
- Rehabilitation of subsidence impacts and environmental consequences caused by mining which took place prior to the date of project approval (MP 10_0161) may be subject to the requirements of other approvals (eg under a mining lease or an Subsidence Management Plan approval).

7.4 Final rehabilitation planning criteria & performance measures

The main planning considerations for rehabilitation prior to mine closure are:

- consideration of the success and practicalities of previously implemented revegetation techniques;
- issues relating to soil contamination and the burial and/or removal from site of the building debris;
- the sealing of any unsealed boreholes and mine shafts in accordance with the guidelines and standards that pertain at the time;
- the rehabilitation of existing and historically used sediment and water control dams in relation to the decanting of existing water, removal of contaminated material, mixing of sediment and non contaminated material, filling and capping of the areas and establishment of a stable surface;
- management of existing weed populations, with particular emphasis on the reduction of Lantana (*Lantana camara*) and Bitou Bush (*Chrysanthemoides monilifera*);
- control of unauthorised access, particularly motor bikes and 4wd vehicles and rubbish dumping;
- mitigation of socio-economic impacts related to mine closure;
- ensuring public safety;
- management of the Colliery site rehabilitation while still facilitating access for bushfire fighting;
- suitable locations for the burial of "clean" material;
- removal of residual coal from stockpiles;
- availability of suitable capping material for disturbed areas such as dams and coal stockpiles;
- availability of seed, and brush material to assist with the revegetation of the Colliery site; and

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• reshaping, burial and removal of hardstand area material that includes bitumen, concrete and building rubble.

Table 7.2 below details the specific closure objectives, completion criteria and performance measures to be applied during the mine closure process.

 Table 7.2
 Rehabilitation Completion Criteria and Performance Measures

Phase	Objective	Completion criteria	Performance measures
Decommissioning.	No risk to public safety - All plant and equipment removed	All mining related plant and equipment removed from site (unless approved to remain, e.g. for heritage purposes)	Visual inspection and photos of site confirm plant and equipment has been removed. Photos included within Closure Report.
	No risk to public safety - All buildings and structures removed	Buildings and structures removed (unless approved to remain).	Visual inspection and photos of site confirm buildings have been removed. Photos included within Closure
	No risk to public safety - All underground infrastructure	Visible surface components of buried infrastructure removed (unless approved to remain).	Visual inspection and photos of site confirm infrastructure has been removed.
	(protruding above ground surface) removed.		Photos included within Closure Report.
	No risk to public safety - Access to former workings prevented	All surface entries to mine are sealed in accordance with MDG 6001 (Guidelines for the Permanent Filling and Capping of Surface Entries to Coal Seams). Note: currently MDG 6001	Engineer provides certification that bulkheads were constructed in accordance with the design. Copy of certification to be included within Closure Report As constructed drawings are
		guidelines suggest that the void from the inbye bulkhead (at a 15 depth of cover to solid rock strata) to the drift entrance of the mine should be completely filled, and a substantial bulkhead seal erected at the portal mouth, such as would not permit retention of habitat for threatened species.	provided to the Chief Inspector for inclusion with the abandonment file for the mine.
	No risk to public safety - All borehole connectivity to former workings sealed	All boreholes to the mine are sealed in accordance with EDG01 (Borehole Sealing Requirements on Land: Coal Exploration).	Closure report includes evidence that sealing has been completed to EDG01.
	Non-polluting - clean-up of potential/actual contamination.	Hydrocarbons less than assessment criteria. Heavy metals less than assessment criteria.	Environmental Site Assessment report completed and identifies any levels of contamination is below acceptable levels.
		No asbestos remains (unless bonded within buildings approved to remain)	Environmental Site Assessment appended to Closure Report.
Landform establishment	Slopes are stable.	Re-profiled areas are stable with slopes not exceeding 10°.	No evidence of slumping of slopes. Survey pick up of rehabilitated site confirms no slopes exceed 10°.

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 Table 7.2
 Rehabilitation Completion Criteria and Performance Measures

Phase	Objective	Completion criteria	Performance measures
			Final landform survey detail included within Closure Report.
	Growth medium replacement to permit vegetation establishment	Depth - ≥ 0.1 m.	Sampling / testing regime following placement and spreading of material to confirm depths. Revegetation becomes established
	Land use compatible with surrounds	Majority of established rehabilitation species are present in surrounding communities	Visual inspection and photos of rehabilitation confirm species established.
			Photos included within Closure Report.
Landform establishment	Mine water discharges	No discharge of underground mine water / water impacted by	Discharge water flow monitoring and reporting.
(surface water)	discontinued.	mining operations	Pipes that deliver water from underground to surface are disconnected
			Environment Protection Licence surrendered
	Appropriate management of surface water.	Diversion channels/drains to remain are stable and non-eroding.	Visual inspection and photos of dams/drains to confirm non-eroding.
		Remaining dams are stable and non-eroding	Photos included within Closure Report.
	Non-polluting	Not contributing excess sediment load to downstream watercourses.	Surface water monitoring and reporting for upstream and downstream locations in unnamed creek.
Ecosystem / land use	Establishment of vegetation	Clear trend of increasing species diversity.	Monitoring and comparison to adjacent control sites.
establishment.	communities.		Details of monitoring included within Closure Report.
		Number of weeds species and surface area cover ≤ adjacent	Monitoring and comparison to adjacent control sites
		control sites.	Details of monitoring included within Closure Report.
		Self-propagation in revegetated areas.	Visual inspection and photos of species self-propagation.
			Photos included within Closure Report.
	Vegetation cover to minimise	Clear trend of increasing density with no significant erosion.	Monitoring and comparison to adjacent control sites
	erosion.		Details of monitoring included within Closure Report.
		Clear trend of increasing foliage cover.	Monitoring and comparison to adjacent control sites
			Details of monitoring included within Closure Report.
Sustainable ecosystem / land use.	Landform generally blends in with	Absence of gullies >300mm wide or deep and gullies stable.	Monitoring and details of monitoring included within Closure Report.

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Table 7.2 Rehabilitation Completion Criteria and Performance Measures

Phase	Objective	Completion criteria	Performance measures
	surrounding landscape and is stable	Landscape function analysis (or other methodology) shows continued ecosystem function improvements	Monitoring and details of monitoring included within Closure Report.
	Weeds invasion adequately controlled by	Stable or reducing weed presence (i.e. weed presence not increasing)	Monitoring and comparison to adjacent control sites and/or prior monitoring.
	ecosystem		Details of monitoring included within Closure Report.

7.5 Interaction with other environmental management plans

As indicated in **Section 1**, this RMP is but one plan in a series of plans that sit under the Colliery's EMS. Like this plan, all of these plans have a three year review period at which time they will be revisited and updated. As the time approaches to prepare the mine closure plan, the latest version of the RMP is expected to inform the mine closure plan. Additionally, some of the other environmental management plans, specifically the Biodiversity Management Plan, Water Management Plan, Benthic Communities Management Plan, Seagrass Management Plan and Heritage Management Plan could be used to inform the RMP. For example the Biodiversity Management Plan might indicate what endemic species may be used in the rehabilitation seed mix / tube stock to meet the needs of surrounding fauna communities and what weeds may be targeted during closure works. The Water Management Plan might give direction on how watering needs for rehabilitation might be met post closure, such as the retention of the potable water supply until vegetation establishment is complete.

7.6 Progressive rehabilitation

Wherever possible LakeCoal would undertake rehabilitation on a progressive basis throughout the life of the mine. Opportunities for progressive rehabilitation are however considered limited due to the surface disturbance being restricted to areas required for operational activities. Notwithstanding, should opportunities arise which allow areas of the site to be rehabilitated, then the rehabilitation activities these would be planned, undertaken and reported in the Annual Review.

Preparation for rehabilitation may also be able to be undertaken once a decision for mine closure has been made, but prior to the completion of the detailed mine closure plan. This preparation would include undertaking longer lead time requirements that will come from the detailed mine closure plan, but are already known, such as native seed collection and propagation of species specifically to be used in the rehabilitation.

Seed would be collected only from native species in the vicinity of the site, in line with the closure objectives. A number of these species are detailed in the Biodiversity Management Plan, however a species list for seed collection is not provided here as it should not be limited to specific dominant species within the surrounding vegetation communities (although these likely form a significant component of the collection). Rather, the collection should be completed by suitably competent personnel experienced in native seed collection for use in rehabilitation, which will then inform the detailed mine closure plan to the extent that the species list can be commensurate with the availability of seed from endemic species in the vicinity of the site.

7.7 Final rehabilitation proposals

The following sub-sections provide a description of the elements of the final rehabilitation, as currently proposed.

7.7.1 Disturbed land

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Vegetation communities surrounding areas impacted by mining are discussed in Section 5.3.3. LakeCoal proposes to progressively revegetate all disturbed land not required for future use to a vegetation type consistent or compatible with the surrounding vegetation communities and future land use. As with any revegetation program, the success will rely on the effectiveness of the methods utilised, which are currently expected to include a combination of revegetation methods, such as:

- Growth medium development;
- · direct seeding;
- · the use of sterile cover crops;
- planting of tube stock; and
- hydro seeding for steeper slopes and batters (if required).

It is noted that due to the age of the mine and the lack of topsoil preservation in times past, there is a limited amount of topsoil stockpiled that will be available for use in the final rehabilitation activities. While this will be a significant consideration for the detailed mine closure plan, there are a substantial number of recycled organics that have been successfully utilised in mine rehabilitation (Kelly, 2006). Recycled organics used successfully in rehabilitation include fly ash, a source of which is available from the Vales Point Power Station, directly adjacent to the Colliery.

A maintenance component to address items such as erosion, weed control and plant mortalities will also be essential for effective rehabilitation.

As the goal for the revegetation program is to return disturbed land to a native plant community aligned to the surrounding bushland the use of introduced and non-endemic species will be avoided in the revegetation program. Focus will be placed on the use of plant material grown from locally sourced species or, if possible, seed collection and propagation from the surrounding vegetation for use in rehabilitation activities. A portion of the pit top area, primarily in the vicinity of the existing sediment dams, has existing high voltage (330kV) transmission lines and an associated easement for the lines. Rehabilitation of the site within the easement boundary is proposed to be a grassland community only, such as to be compatible with the current and future use of these high voltage transmission lines.

Consideration of bushfire risk and potential management measures for the LakeCoal owned houses, should they remain, will also need to be incorporated into the detailed mine closure plan.

7.7.2 Water management

The removal of large areas of sealed surfaces and buildings at mine closure could result in increased sediment load in the runoff during the early stages of the rehabilitation program. Conversely, the removal of the majority of the coal stockpiles and ensuing the removal of historically compacted surfaces will result in increased infiltration rates during the first few months of the rehabilitation program and reduce the amount of runoff reporting to the sediment dams. In addition as mining operations would have ceased, including the pumping of groundwater into the dams, a significant volume of the water managed within these dams would have been removed.

The current water management system and sediment dams will be retained during the rehabilitation program. Once the primary earthworks and initial revegetation are completed, including the removal of the hardstand areas, bitumen, concrete and the bulk of the coal stockpiles then a program of consolidation of the dams will be undertaken.

Where appropriate, the dams will be used as receptacles for excavated or crushed inert material. Once these are filled, the walls and batter will be used to cap the dams. These surfaces will then be stabilised using a cover crop consisting of a mixture of fast growing sterile species and native longer-lived seed.

Water quality will continue to be monitored at the licenced discharge point in accordance with the EPL, however at a point in closure, likely after the groundwater pumping ceases and the majority of water management structures are rehabilitated, the EPL would be surrendered. The timing of the EPL surrender is expected to be driven by the monitoring results showing that no environmental harm is occurring, rather than a specific point in rehabilitation progress. After this point no specific monitoring as required by the EPL would be undertaken, however as noted in Section 8, specific rehabilitation monitoring would be undertaken, which may include some water monitoring.

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Consideration will also need to be given in the detailed mine closure plan of the potential retention and/or construction of small dams or ponds which could either continue to provide habitat or allow fauna to relocate to these areas when the main sediment dams are rehabilitated upon closure, currently 3 dams are proposed to remain as part of the final rehabilitation design however this will be given further consideration during development of the detailed mine closure plan.

7.7.3 Rehabilitation trials and research

The proposed final rehabilitation program will be based on extensive experience of rehabilitation in coastal areas undertaken by Councils and mineral sand mining companies and research on mine rehabilitation in the hunter valley. Given this, and the limited amount of area disturbed, major rehabilitation trials or research programs are not expected to be necessary.

7.7.4 Community

The aims of the RMP with respect to communities are public safety and the minimisation of adverse socio-economic effects from mine closure. However, the mine is not expected to be closing for another thirteen years (dependent on a number of factors). The socio-economic environment of the local area, the region and indeed Australia will change in this period. Accordingly, it is not feasible to address socio-economic issues in detail in this RMP. Rather they will addressed in detail closer to the time of mine closure in the mine closure plan. It is expected though that the following principles would be considered.

- The establishment of the Colliery has brought significant infrastructure to the mine site, to the local community and to the broader region. Planning for mine closure could assist in mitigating the consequent reduction in access to useful infrastructure. With advanced and careful planning, it may be possible to develop capacity to maintain certain infrastructure facilities and services for future community or local government ownership or as part of arising business development opportunities.
- Planning for mine closure should be raised with the community as early as possible prior to the planning and design phase of the closure. The planning should consider how to minimise the adverse impacts of mine closure and to optimise the opportunities for community development.
- An early and effective community engagement strategy should be established and the community engaged.
- Planning for mine closure should ensure that the future public health and safety of the community is not compromised; the community's resilience to the adverse impacts of mine closure is strengthened; and the community can maximise opportunities for consequential land use and retain mining infrastructure of value to the community

7.7.5 Remaining features

During mine closure the following actions will be taken with respect to the buildings and structures associated with the mining, preparation and transport of the coal:

- preferentially any plant, structures, buildings or conveyors would be sold and/or relocated for reuse at another mining operation;
- the remaining the coal bins, surface conveyor plant, buildings and build structures will be demolished or removed. All demolition is to occur in accordance with AS 2601-2001: The Demolition of Structures (or its latest version);
- concrete pads and footings will either be covered with at least 300mm of growth medium or broken up and disposed of in an appropriate place;
- roadways not required for access to the mine site or other areas for purposes such as bushfire management will be rehabilitated; and
- below-grade structures such as concrete sumps will be filled and covered with growth medium.

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These proposals could be subject to change during the mine closure process depending on requests by the landowner for infrastructure to be left in accordance with alternative future land use options.

7.7.6 Other infrastructure and services

The Colliery has numerous services such as electricity, water and communications – both above and underground. All services not required will be disconnected. Above ground infrastructure will be removed while underground structures such as cables and pipes will be terminated at each end and remain buried. All areas where structures are removed will be decommissioned and rehabilitated to ensure public safety at mine closure and relinquishment.

7.8 Conceptual site land works

Figure 7.1 shows the conceptual land works planned for the Colliery at this stage. Generally the western two thirds of the Colliery and the ventilation shaft site will be cleared of all infrastructure items that are not required post mine closure and the land levelled. The eastern one third will be cut and filled generally to the original land levels, as deemed appropriate to match with the surrounding levels, during this process established native trees will be retained wherever possible.

Rehabilitation Monitoring

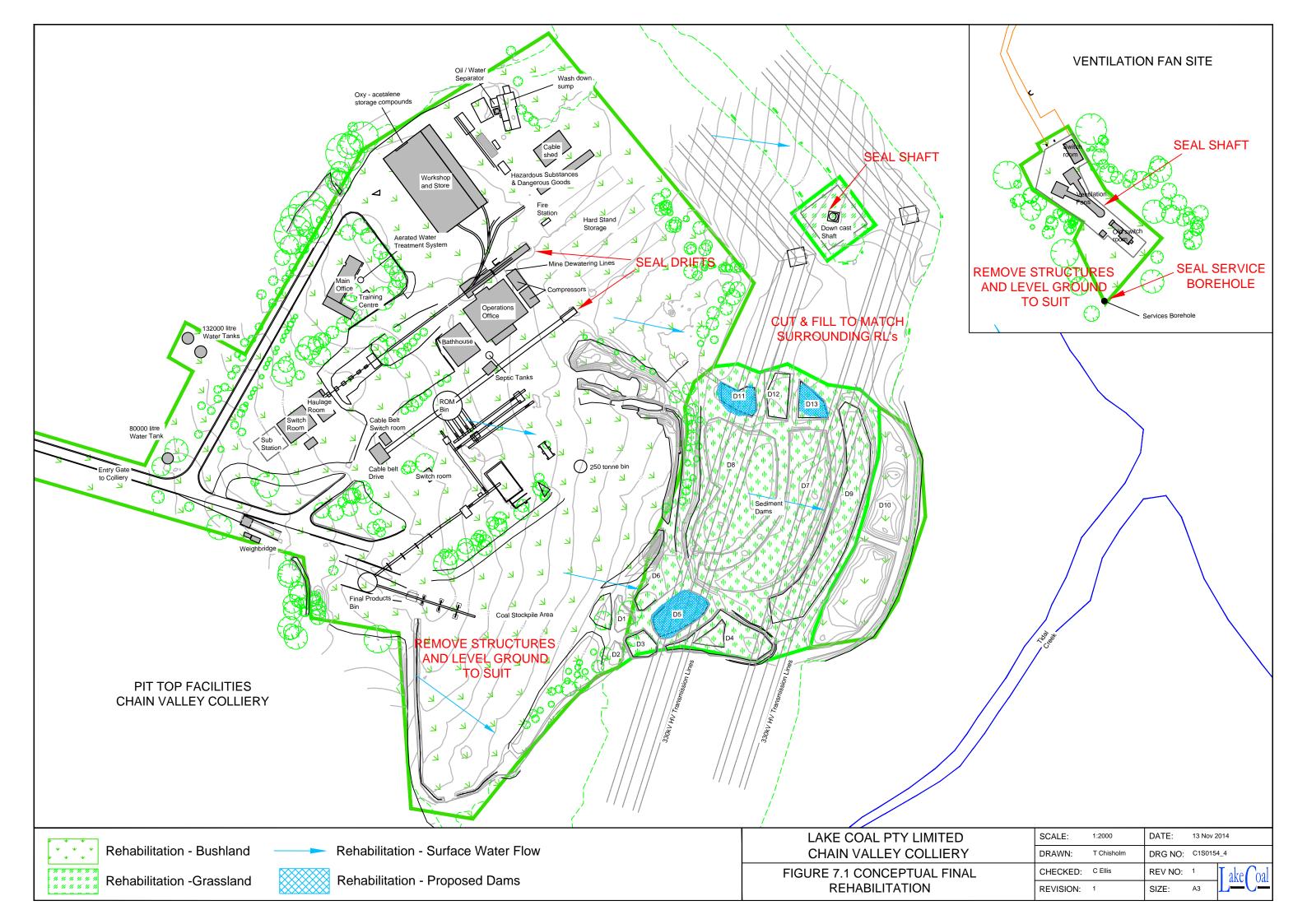
Detailed management and monitoring proposals for the final rehabilitation will be formulated closer to the time that the rehabilitation works will be required, currently estimated to be around 2027 (based on current Development Consent limits). The details will be included in both the MOP in force at the time and the mine closure plan which would be prepared at least one year prior to cessation of mining activities.

Detailed monitoring is likely to include monitoring of the following:

- decommissioning of infrastructure;
- landform;
- excessive erosion or sedimentation from areas with establishing vegetation cover;
- success of initial cover crop or grass cover establishment;
- success of tree and shrub plantings;
- extent of natural regeneration of native species;
- adequacy of drainage controls;
- general stability of rehabilitation areas;
- public safety of all rehabilitated areas; and
- socio-economic effects of closure.

Rehabilitation will be monitored to identify improvements that could be implemented to maximise the level of success for subsequent rehabilitation programs.

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9 Financial provisioning

The objective of financial provisioning is to ensure the cost of closure is adequately assessed and budgeted for by LakeCoal so that the community is not left with a liability.

The provision includes costs associated with the removal of infrastructure, sealing of all drifts, mine accesses and boreholes, rehabilitation and management of any contamination (if present) along with ongoing monitoring and statutory reporting obligations. Should any infrastructure be kept for specific purposes post mine closure provisions would be made to ensure these are safe and serviceable for the future owners.

These costs are determined on the basis of current costs and current legal requirements, over the life of the mine the costs will be reviewed and updated as required.

9.1 Planned Mine Closure

Chain Valley Colliery has no planned mine closure date. Current operations are expected to continue under the current development consent (SSD-5465) into the future. Approval for continuation of mining within the Fassifern seam exists until the 31st December 2027.

The main mechanism used to calculate (and recalculate) mine closure costs is DRE's Rehabilitation Cost Estimate spreadsheet.

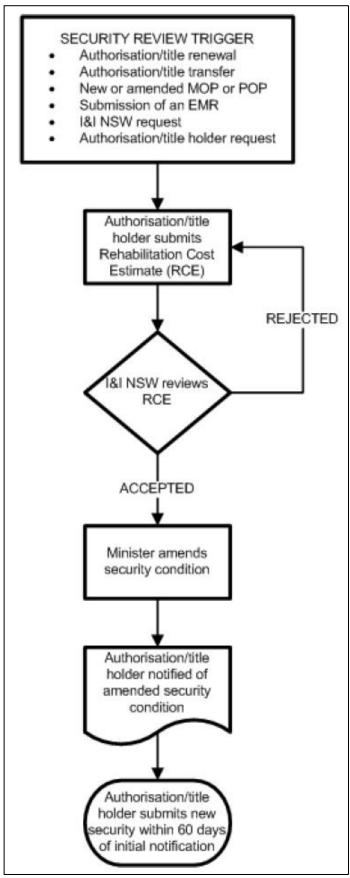
A rehabilitation cost estimate for the Colliery is required to be submitted by LakeCoal whenever a potential change in rehabilitation liabilities occurs. The rehabilitation cost estimate is used by DRE to assist in determining the amount of the security deposit. During this process DRE will review the calculation, if DRE rejects the calculation it needs to be recompleted until it is accepted. In line with DRE's Rehabilitation Cost Estimate Guidelines (ESG1), security reviews may also be triggered by title renewals, audits, environmental incidents or other changes to rehabilitation liabilities.

9.2 Unplanned Closure

In the event of unplanned closure and default by LakeCoal to undertake rehabilitation activities on the site a comprehensive process has been put in place by DRE to ensure that liabilities are not passed onto the community. This process is based on DRE Policy EDP11 – Rehabilitation Security Deposits, is underpinned by the *Mining Act (1992)* and ensures that, at all times, throughout the life of the mine a suitable security deposit is held by DRE.

In accordance with DRE a security deposit must cover the Government's full costs in undertaking rehabilitation in the event of default by the authorisation / title holder. This requirement is intended to minimise potential liabilities to the State in the event that the authorisation/title holder defaults on their rehabilitation obligations. The security review process is shown in **Figure 9.1**.

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Source: ESG1: Rehabilitation Cost Estimate Guidelines

Figure 9.1: Security review process

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9.3 Temporary Closure (care and maintenance)

The financial provisions for management during temporary closure in the event of the Colliery entering care and maintenance status will be provided by LakeCoal for the duration of the care and maintenance phase.

10 Risk Management

Closure risk management will be undertaken prior to the Colliery being placed on care and maintenance or closing permanently. The purpose of closure risk management is to reduce the likelihood and/or consequence of events related to the closure to levels deemed as low as reasonably practicable by the selected risk assessment team.

The closure risk assessment to be conducted for Chain Valley Colliery may include the following issues depending upon relevance at the time of closure (or temporary closure):

- Rehabilitation provisioning
- Environmental baseline data availability
- Legal obligations
- Stakeholder involvement
- Potential risk legacies
- Surface water and groundwater
- Acid sulfate soils
- Spontaneous combustion
- Rehabilitation management (including bushfire, pests and disease/pathogens)
- Employees and workforce
- Ongoing resource requirements
- Compensation cases
- Closure plan adequacy; and
- DTIRIS Division of Resources and Energy approval

10.1 Residual Risk Register

A formal risk assessment will be undertaken approximately one year prior to planned mine closure to best determine levels of residual risks posed upon potential end land users and relevant stakeholders. This risk assessment would take into account all relevant issues listed above in Section 10.

11 Incident and Compliance Management

When rehabilitation commences, implementation and success will be reviewed at minimum on an annual basis to confirm compliance with the relevant Development Consent and corrective action implemented where results or trends indicate risk of future non-compliance or environmental risk.

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The current MOP identifies and ranks risks for rehabilitation activities, accordingly these risks will be managed during the closure process in accordance with the risk assessment for closure activities to be completed prior to commencement of closure works.

If monitoring reveals that the Colliery rehabilitation actions have resulted in an environmental issue or that there has been non-compliance in relation to rehabilitation, then LakeCoal will conduct an investigation into the cause of the non-compliance.

12 Stakeholder Management and Response

Stakeholder management and response will not be an issue until the final rehabilitation begins, planned to be around 2027 (dependent on the approval of the proposed mining extension). Detailed stakeholder management and response will be planned closer to the mine closure date and will be incorporated in the mine closure plan.

12.1 Mine Closure and Rehabilitation Stakeholders

Relevant stakeholders at the time of preparing this plan are listed below, the below list should be reviewed and if necessary revised closer to mine closure, to ensure all relevant future stakeholders are identified and considered and where necessary consulted as part of the mine closure planning process. Relevant stakeholders include;

- Chain Valley Colliery
 - LakeCoal employees
 - Contractors
 - Suppliers
 - Community consultative committee
- Community
 - Neighbours
 - Local community members
 - Delta Electricity (Vales Point Power Station)
 - Local indigenous groups and land councils
 - Local progress associations and precinct committees
- Local Councils
 - o Lake Macquarie City Council
 - Central Coast Council
- Regulators
 - Department of Planning and Environment
 - Environment Protection Authority
 - Office of Environment and Heritage
 - Heritage Council of NSW
 - National Parks and Wildlife Service
 - Department of Trade and Investment, Regional Infrastructure and Services
 - Department of Primary Industries
 - Fisheries NSW
 - NSW Office of Water
 - Resources and Energy
 - Mine Subsidence Board
 - Transport for NSW
 - Roads and Maritime Services

12.2 Complaints Handling / Community Hotline

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LakeCoal has a 24-hour community hotline for members of the public to lodge complaints, concerns, or to raise issues associated with the operation. This service aims to promptly and effectively address community concerns and environmental matters.

The full details of the complaints line are covered in the Environmental Management Strategy, but in summary, all complaints are recorded and responded to, and, if for some reason no action is taken then the reason why is recorded. The information recorded in the complaint register includes;

- date and time the complaint was lodged;
- personal details provided by the complainant;
- nature of the complaint;
- action taken or if no action was taken, the reason why; and
- follow up contact with the complainant.

The same community hotline number also serves as a community information line, whereby members of the public can contact the Colliery to have specific questions answered by a representative of LakeCoal.

12.3 Dispute Resolution

If any disputes are not adequately addressed by the complaints handling process then they will be handled by the Colliery Environment and Community Coordinator. If the response of LakeCoal is not considered to satisfactorily address the concern of the complainant, a meeting will be convened with the General Manager together with the Environment and Community Coordinator.

The complainant will be advised of the outcomes from the meeting and the actions to be implemented as a result.

For mine closure and rehabilitation the requirements will be agreed in the detailed mine closure plan which will require approval from DRE. Disputes on the mine closure activities and site outcomes should be minimised through the consultation process to be undertaken as part of the mine closure plan development.

13 Roles and Responsibilities

Roles and responsibilities specific to completing the requirements of the RMP are identified in Table 12.1.

Table 12.1 Roles and responsibilities for rehabilitation management

Role	Responsibilities		
General Manager	 Ensure that adequate financial and personnel resources are made available for the implementation of the RMP. Including rehabilitation activities and security deposits. 		

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Role	Responsibilities
Environment and Community Coordinator	 Coordinate socio-economic mitigation measures prior to mine closure in accordance with the MOP.
	Compile the Annual Review.
	Follow up complaints or disputes.
	 Complete environmental monitoring data summaries and place on the company's website.
	 Respond to any potential or actual non-compliances and report these as required to regulatory bodies and other stakeholders.
	 Undertake reviews of this document as per Section 14.
	 Undertake or coordinate the required audits of this document, in accordance with Section 14.2 and 14.3.
	Complete notification process for any noncompliance or incident.
	 Coordinate the closure risk assessment process.
	Coordinate the development of a detailed mine closure plan.
	 Consult Delta Electricity (or future owners) of the Vales Point Power Station in relation to preserving or representing the historic linkage between the Colliery and the power station during the development of the mine closure plan.
	 Ensure acid sulfate soil risks are considered during the mine closure plan development.
	 Consider Endangered Ecological Communities and habitat they provide to protected fauna during the development of the mine closure plan.
	 Consideration of bushfire risk in the development of the mine closure plan.
	 Coordinate stakeholder engagement during the development of the mine closure plan.
	 Ensure established native trees are retained wherever possible during rehabilitation activities.
	 Ensure that ongoing rehabilitation in accordance with the MOP is being implemented.
	 Develop a care and maintenance plan for the Colliery should it be proposed to place the Colliery on care and maintenance.

14 Audit and Review

The RMP will be kept up to date through LakeCoal's standard audit and review process, however it is noted that significant planning for the detailed mine closure plan is not expected until around 2026. Current site audit and review arrangements are set out below.

14.1 Overview

This document will be reviewed, and if necessary revised, within three months of the following;

- The submission of an Annual Review;
- The submission of an incident report;
- The submission of an independent environmental audit; and

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Following any modification to the project approval.

Internal and external audits of this document will be carried out as described below. If possible, internal and external audits will be objective and be conducted by a person or organisation independent of the document being audited.

Audits will be carried out by personnel who have the necessary qualifications and experience to make an objective assessment of the issues. The extent of the audit, although pre-determined, may be extended if a potentially serious deviation from this document is detected.

Any audit non-conformances and/or improvement opportunities will have corrective and preventative actions implemented to avoid recurrence, these actions will be loaded into the Colliery Incident Database to ensure the actions are assigned to the relevant people and completed.

14.2 Internal audits

Internal audits of this document and all other EMS documents will be undertaken every three years. Improvements from the audit will be incorporated in the Colliery Incident Database to ensure the actions are assigned to the relevant people and completed.

14.3 External audits

External audits will be conducted utilising external specialists and will consider the document and related documents. External auditors shall be determined based on skills and experience and upon what is to be accomplished. External audits will be periodically at a frequency determined by the Colliery General Manager, or in response to significant environmental incidents for which a systems failure has been determined as a contributor to the incident.

An Independent Environmental Audit will be undertaken every three years (or as otherwise required by the DP&E) by an audit team whose appointment has been endorsed by the Secretary of DP&E.

Any actions arising from external audits will be loaded into the Colliery Incident Database to ensure the actions are assigned to the relevant people and completed.

15 Records and Document Control

Generally the Environment and Community Coordinator will maintain all EMS records that are not of a confidential nature. Current record keeping arrangements are set out below.

Records that are maintained include:

- monitoring data and equipment calibration;
- environmental inspections and auditing results;
- environmental incident reports;
- · complaint register; and
- licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of four years.

This document and all others associated with the EMS will be maintained in a document control system which is in compliance with AS/NZS 4804; section 4.3.3.4 (Document Control) and in compliance with the Colliery Document Control Standard (STD-0058) which is available to all personnel.

Any proposed change to this document will be via the document control administrator who is the only person able to access the controlled documents. A Document Change / Review Request Form (FRM-0010) in

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compliance with Change Management Health and Safety Standard (HSSTD-0009) is required to be completed to modify controlled documents.

16 References and Associated Documents

AS/NZS ISO 14001:2004 Environmental management systems – Requirements with guidance for use

Development Consent SSD-5465 (as modified)

Document Control Standard

Record Keeping Standard

Information and Communication Health and Safety Standard

Incident Reporting Health and Safety Standard

Environmental Management Strategy

Complaints Register

Water Management Plan

Heritage Management Plan

Biodiversity Management Plan

Seagrass Management Plan

Benthic Communities Management Plan

AECOM (2011). Environmental Assessment Chain Valley Colliery Domains 1 &2 Continuation Project, prepared for LakeCoal.

Cardno Ecology Lab (2011), Mannering Colliery Extension of Mining – Aquatic Ecology Assessment, prepared for Centennial Coal.

Commonwealth Department of Industry, Tourism and Resources Mine Closure and Completion Handbook 2006

Kelly, G.L., (2006) Recycled Organics in Mine Site Rehabilitation - A review of scientific literature, prepared for the Department of Environment and Conservation NSW, available online http://www.environment.nsw.gov.au/resources/warr/2006184_ORG_MineLitReview.pdf [accessed 17/1/2013]

LakeCoal (2018) Mine Operation Plan Chain Valley Colliery and Mannering Colliery 2018 - 2020

Olsen Consulting Group (2009), Review of Environmental Factors: Dendrobium Portals Sealing, available online http://www.resources.nsw.gov.au/__data/assets/pdf_file/0004/300676/20090917-ML-1596-REF-Dendrobium-Portals-Sealing-Gujarat-NRE-Minerals.Aug-09-.pdf [accessed 06/03/2103]

NSW Department of Trade and Investment, EDG01: Borehole Sealing Requirements on Land

NSW Department of Trade and Investment, 2013, ESG3 Mining Operations Plan (MOP) Guidelines, September 2013.

Minerals Council of Australia and Australian and New Zealand Minerals and Energy Council (ANZMEC) (2000) Strategic Framework for Mine Closure

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Watterson, E.K., Burston, J.M., Stevens, H. and Messiter, D.J., (2011) *The hydraulic and morphological response of a large coastal lake to rising sea levels.* Worley Parsons. pp 1-14.

Scobie Architects (2010) Wyong Shire-wide Heritage Review, prepared for Wyong Shire Council.

17 Definitions

CCC Community Consultative Committee

DP&E NSW Department of Planning and Environment

DRE NSW Department of Trade and Investment, Regional Infrastructure and Services, Division of

Resources & Energy

LEP Local Environmental Plan

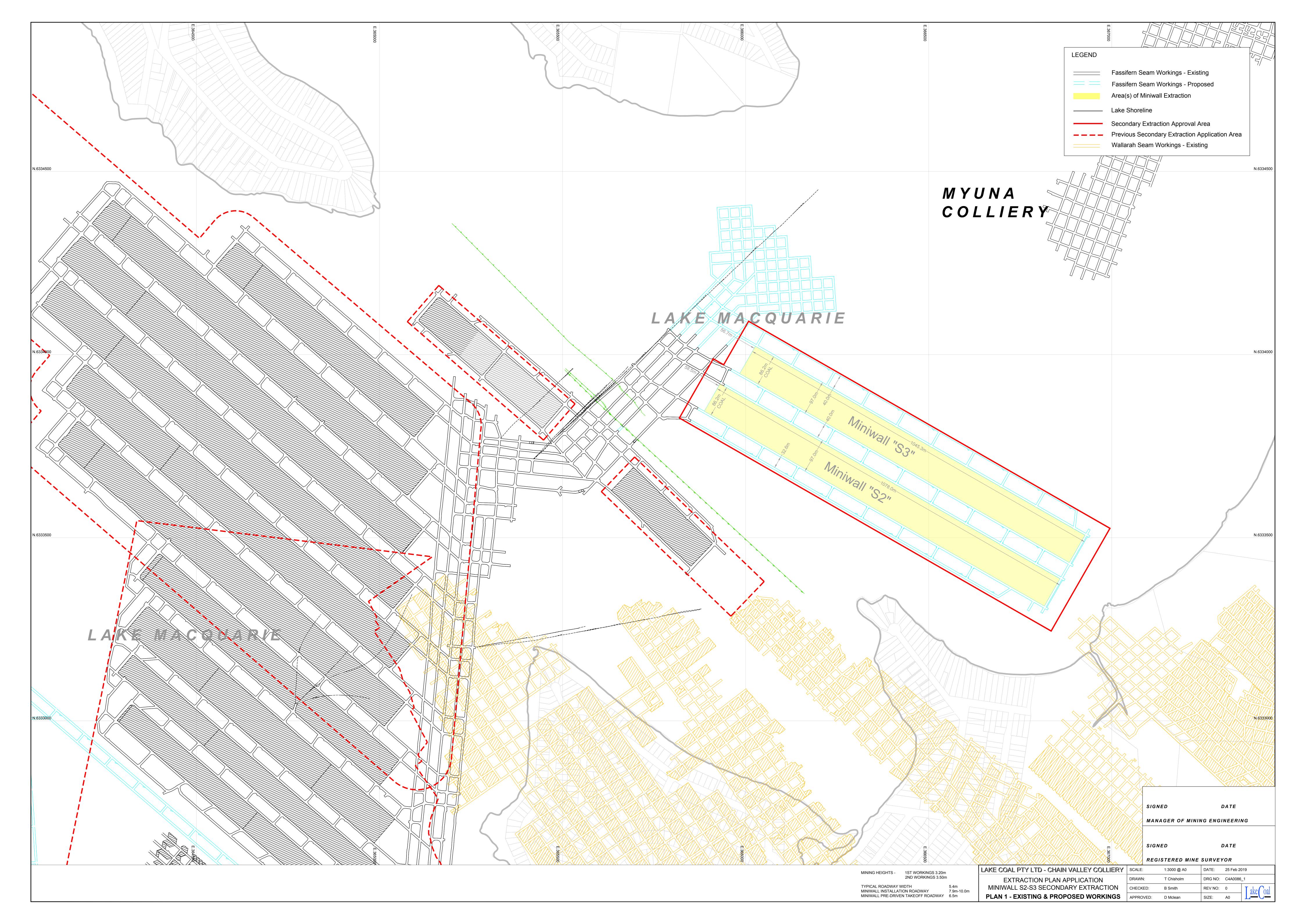
LGA Local Government Area

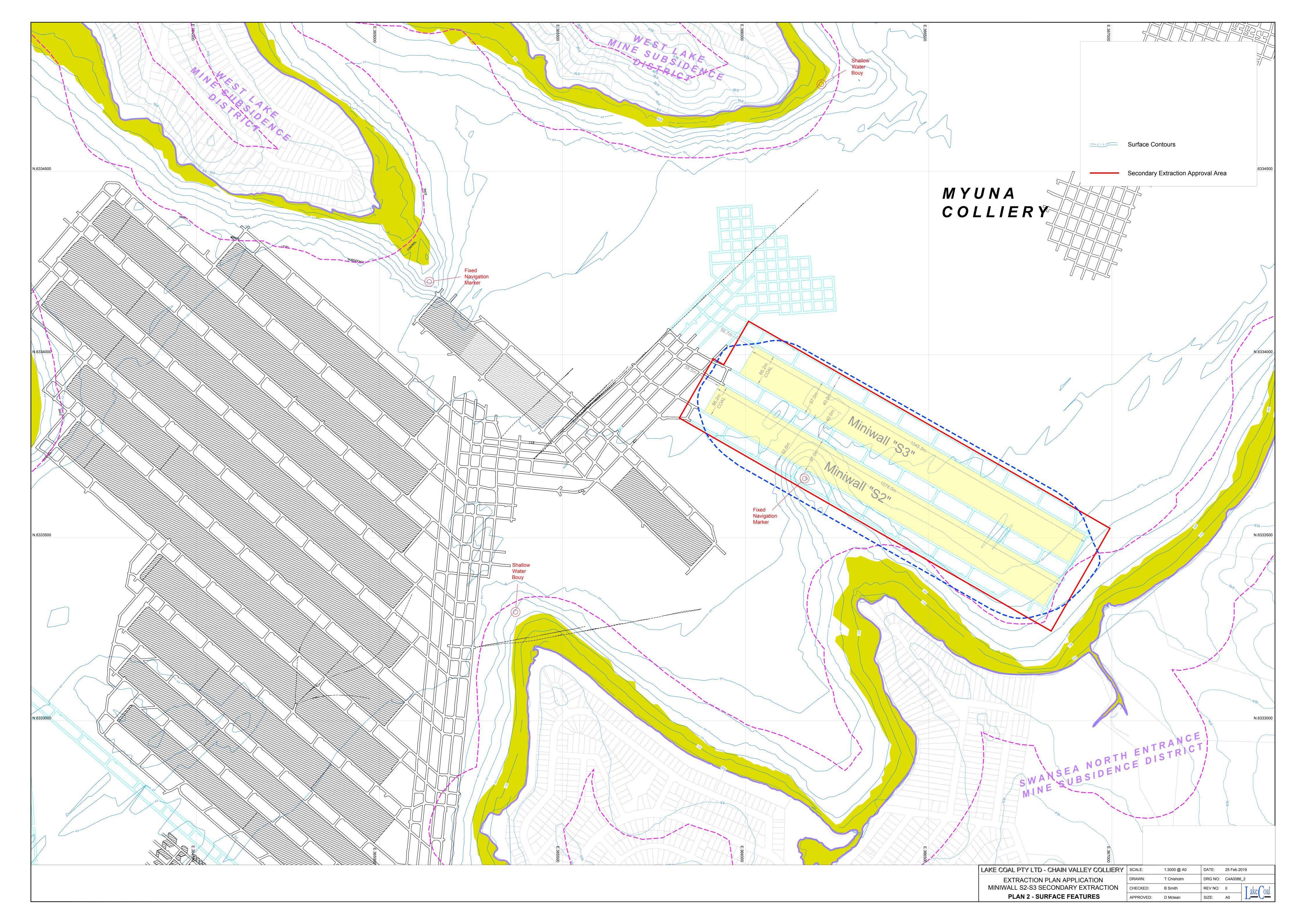
EMS Environmental Management System

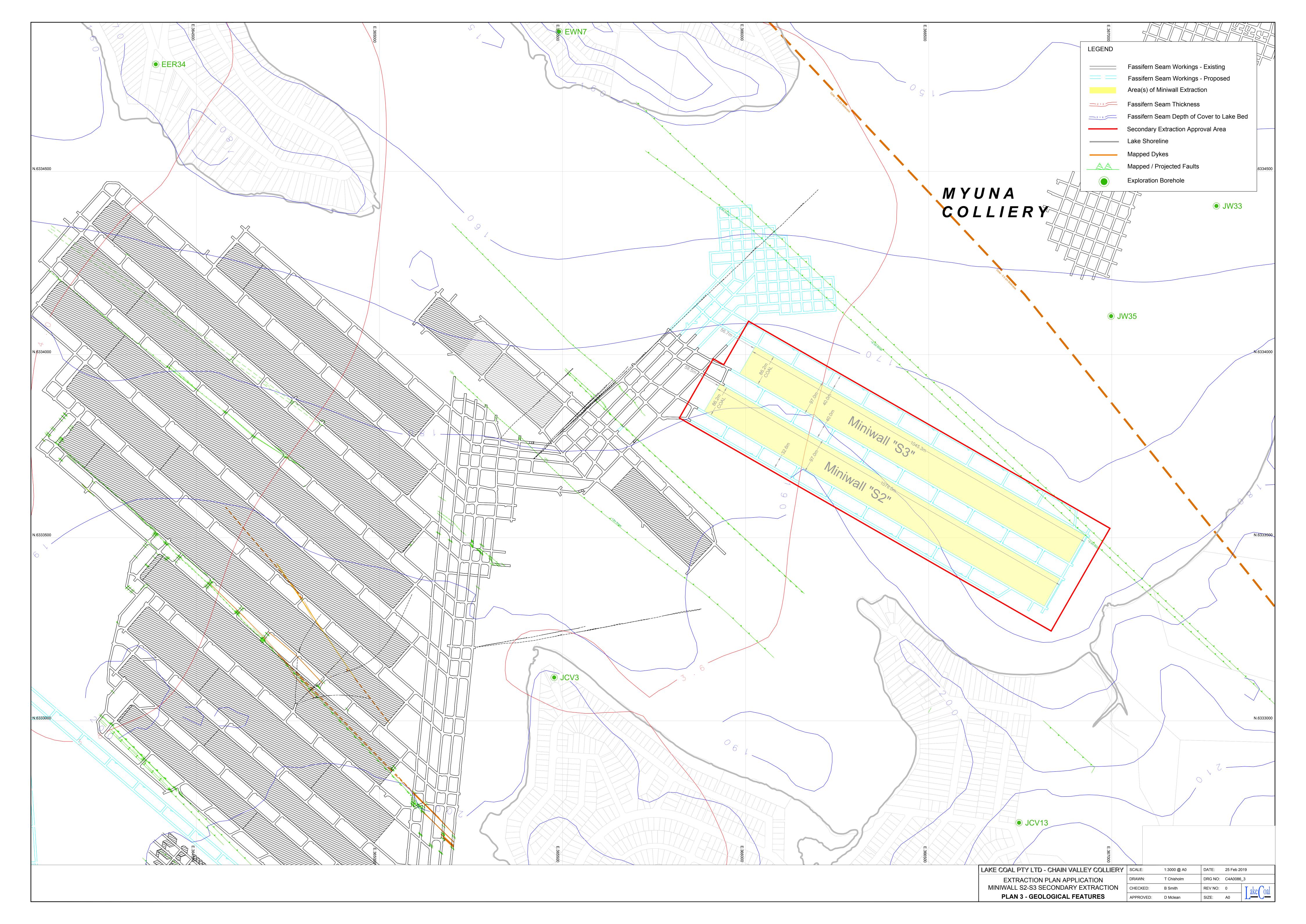
MOP Mining Operations Plan

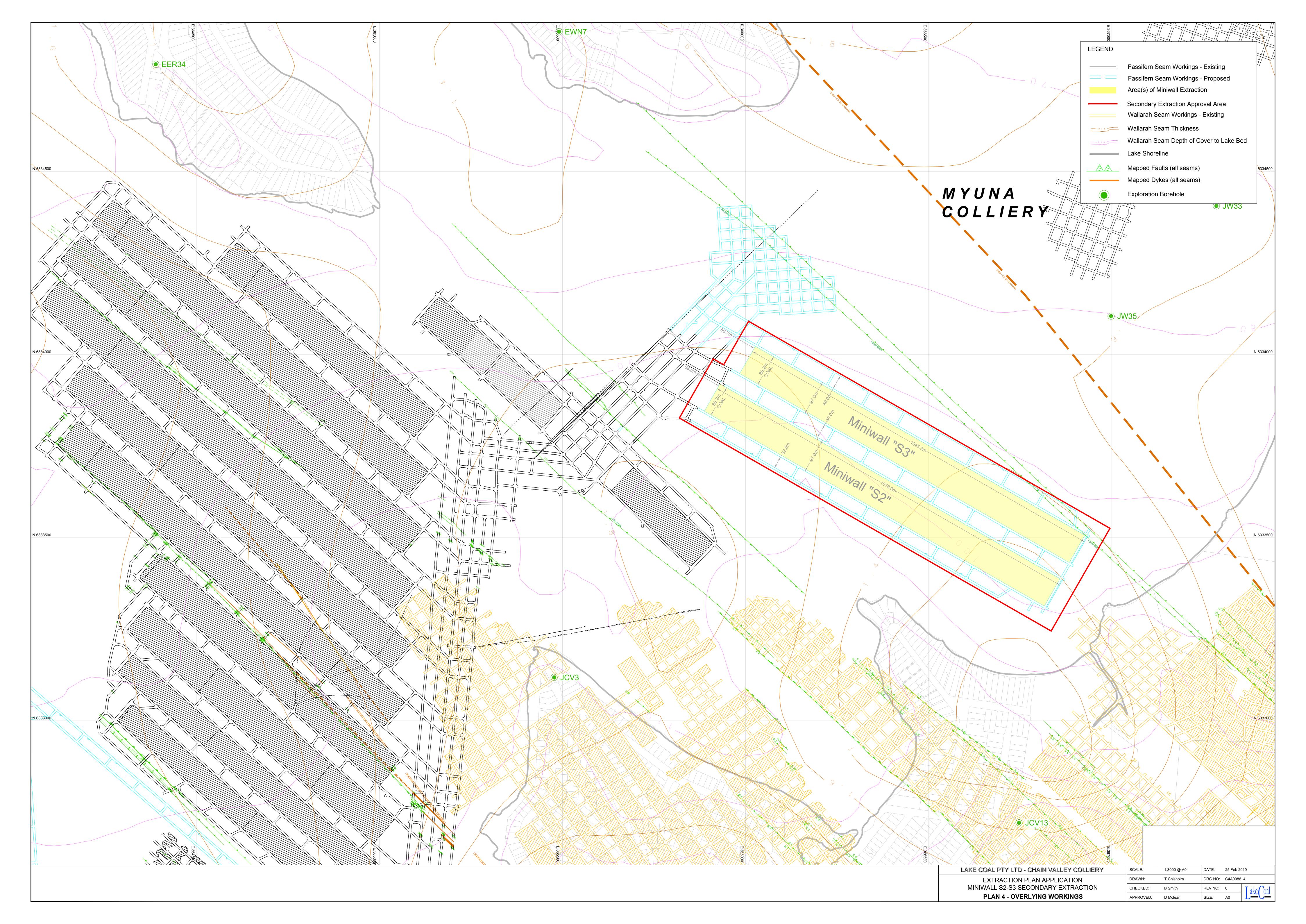
RMP Rehabilitation Management Plan

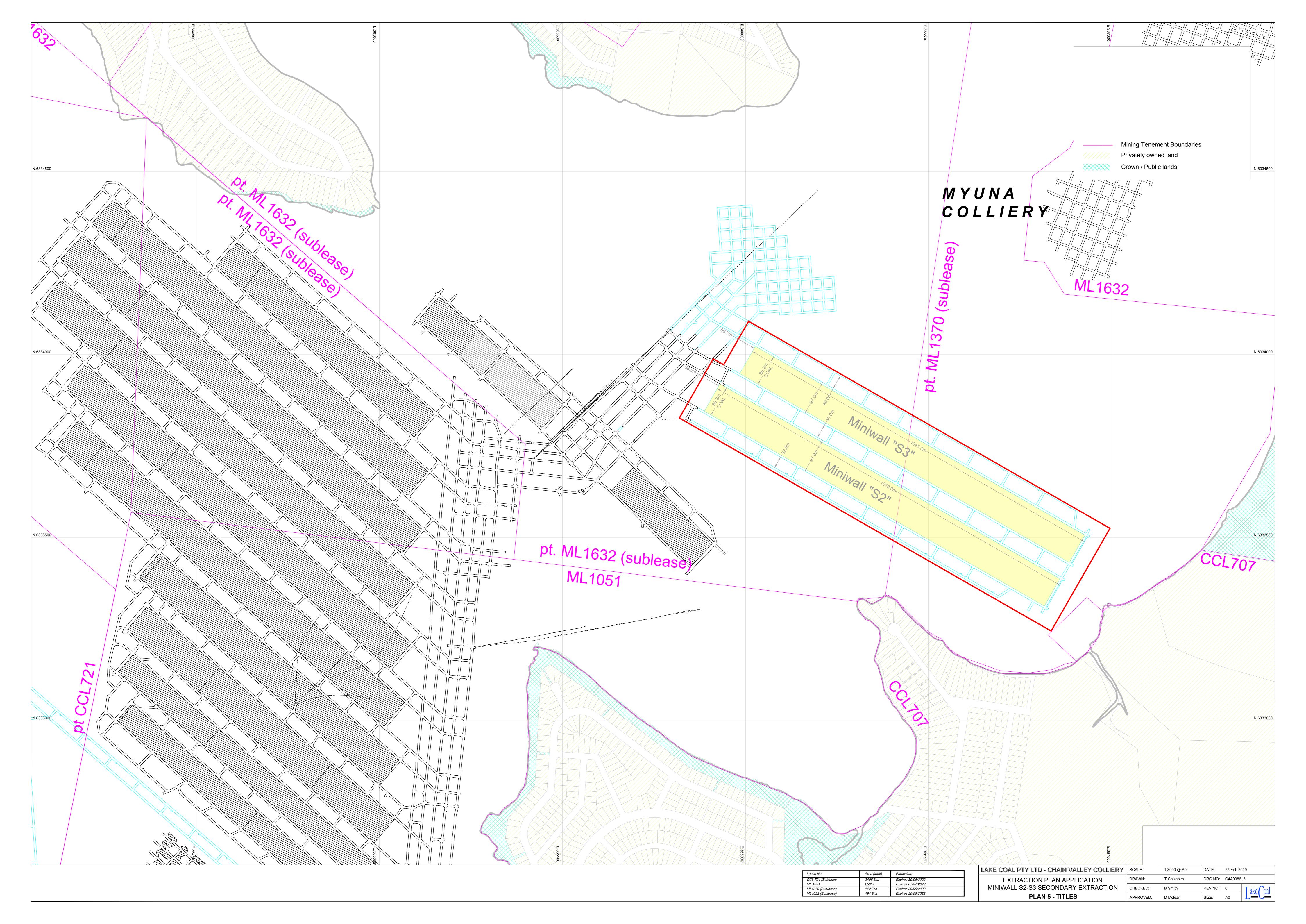
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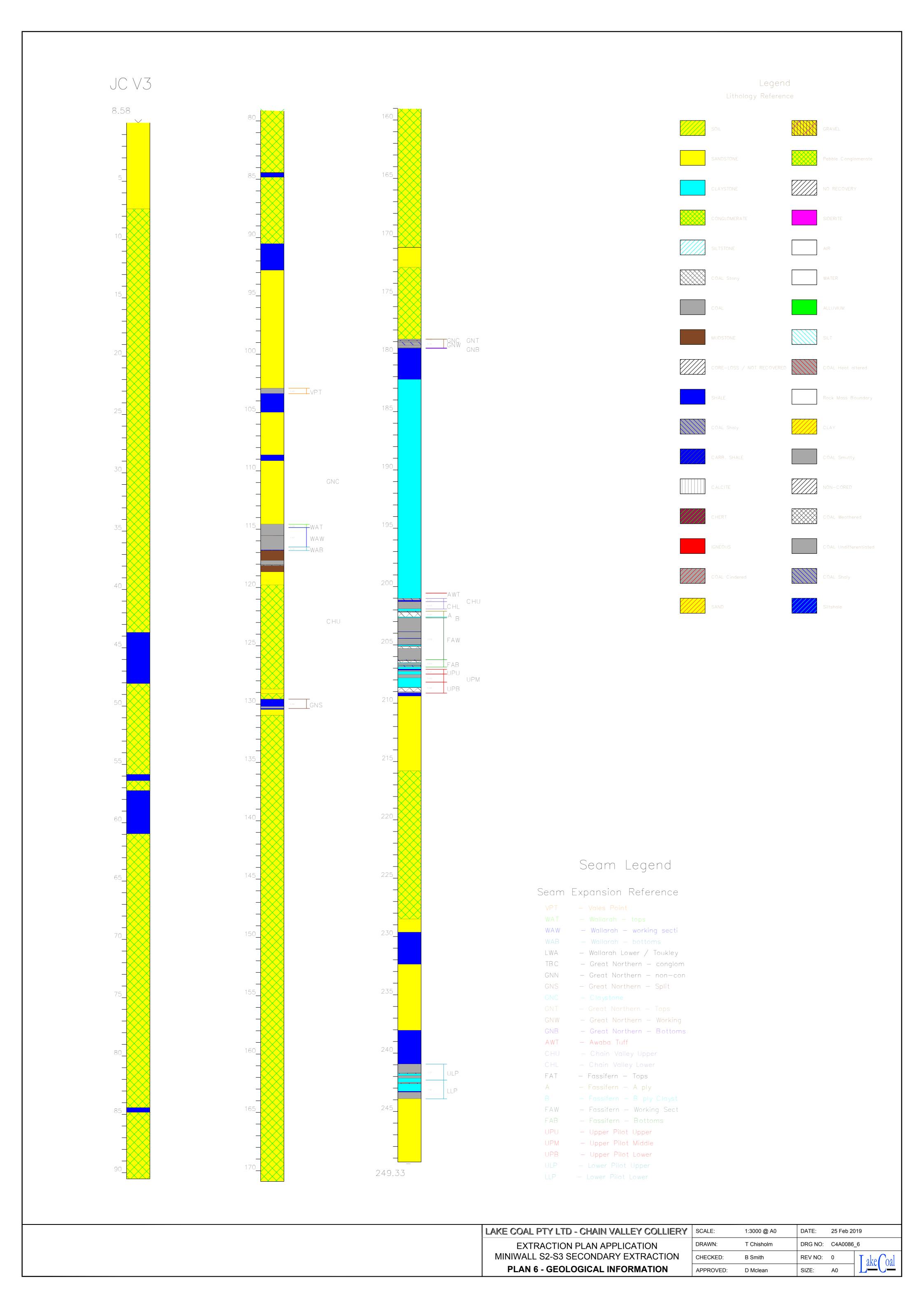


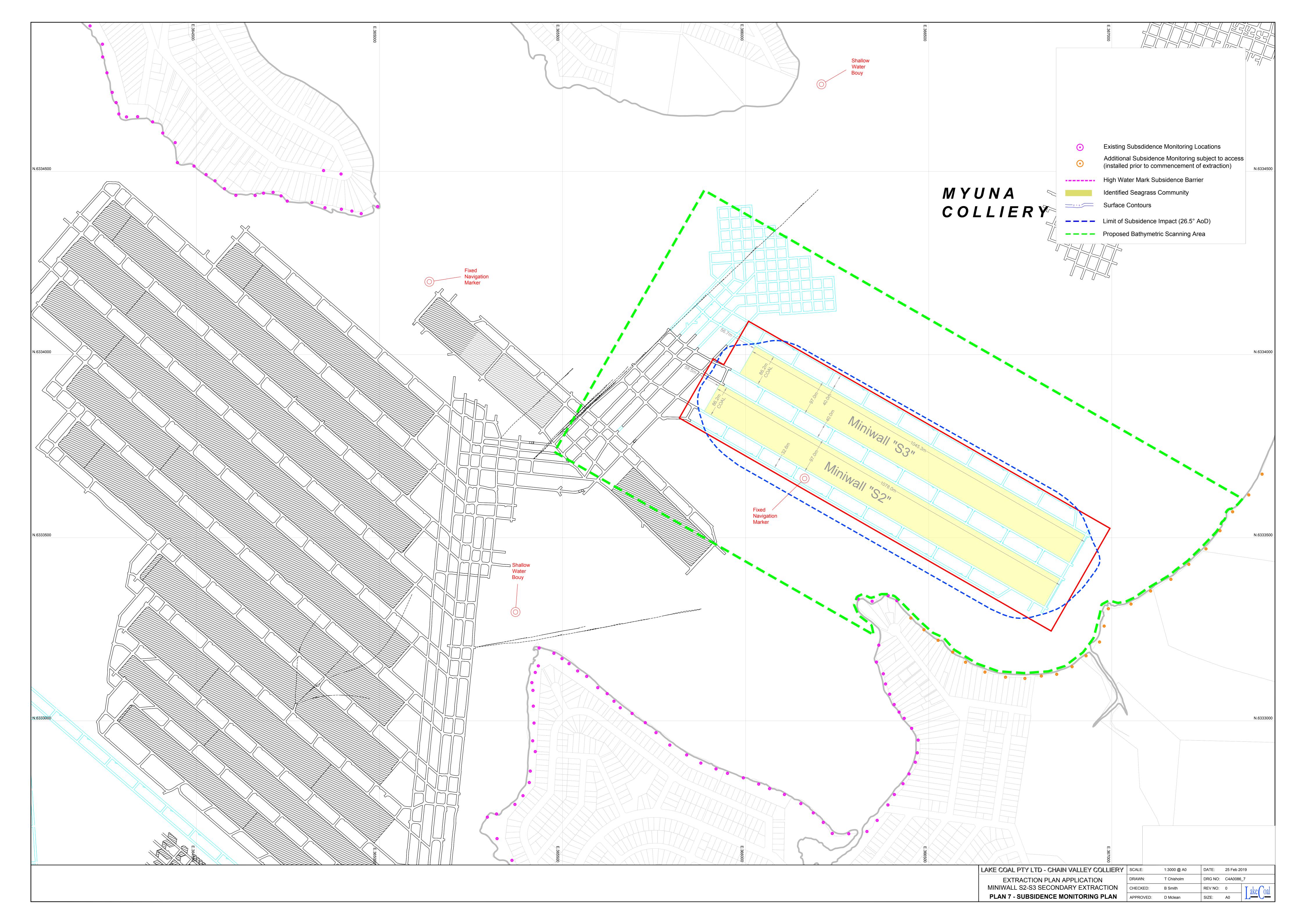


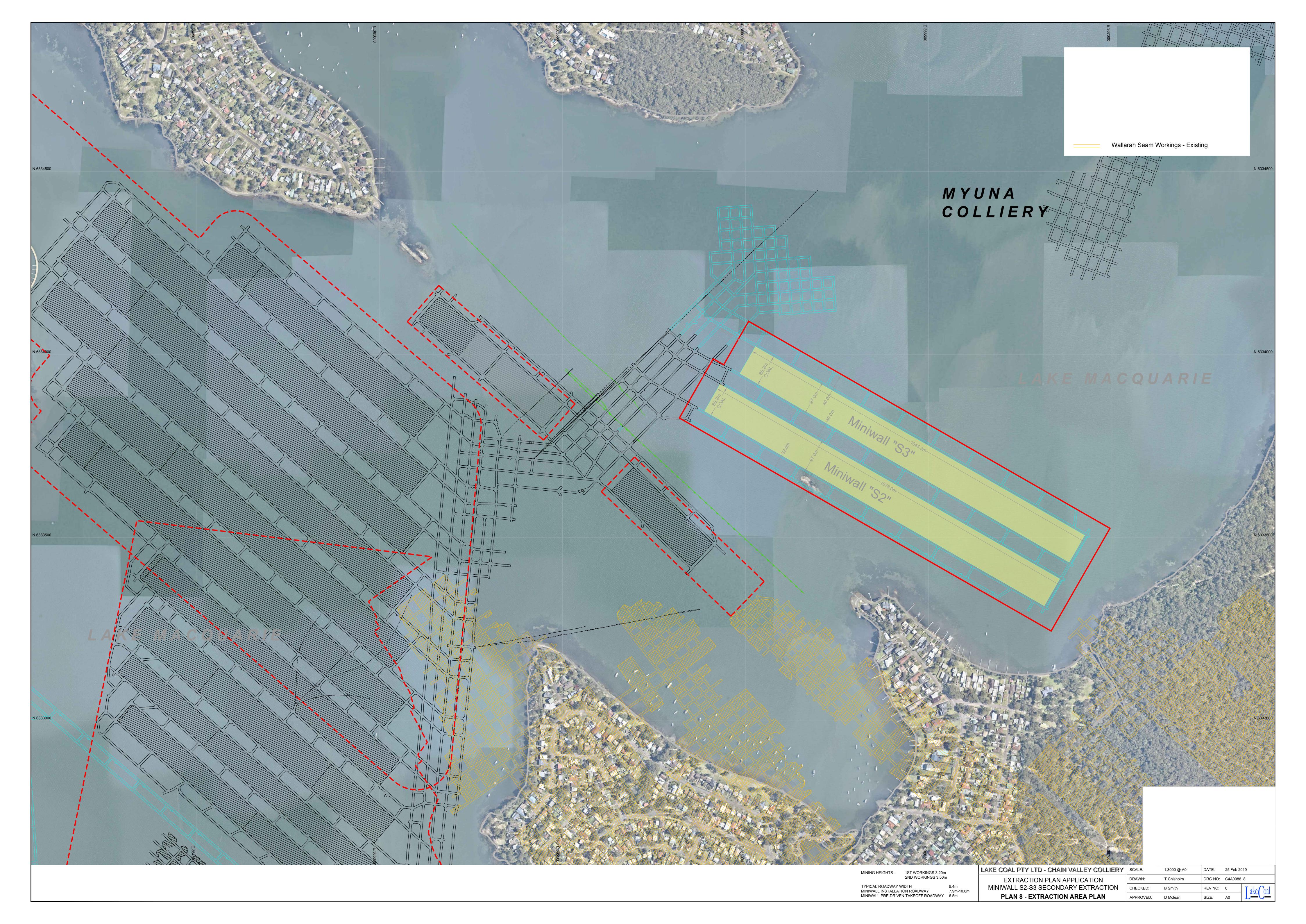














LAKE COAL:

Miniwalls S2 and S3

Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Miniwalls S2 and S3 in Support of the Extraction Plan

DOCUMENT REGIST	ER			
Revision	Description	Author	Checker	Date
01	Draft Issue	JB	ВМ	03 Sep 18
02	Draft Issue	JB	BM/DJK	26 Sep 18
А	Final Issue	JB	BM/DJK	7 Feb 19

Report produced to:

Support the Extraction Plan Application for the proposed Miniwalls S2 and S3 at to be issued to the Department of Planning and Environment.

Background reports available at www.minesubsidence.com¹:

Introduction to Longwall Mining and Subsidence (Revision A)
General Discussion of Mine Subsidence Ground Movements (Revision A)
Mine Subsidence Damage to Building Structures (Revision A)

¹ Direct link: http://www.minesubsidence.com/index_files/page0004.htm subsidence predictions and impact assessments for CVC MWS2 and MWS3 © MSEC FEBRUARY 2019 | REPORT NUMBER MSEC979 | REVISION A PAGE i

EXECUTIVE SUMMARY

Lake Coal Pty Ltd operates Chain Valley Colliery (CVC) which is located in the Newcastle Coalfield of New South Wales. The colliery is currently extracting miniwalls in the Fassifern Seam beneath the southern end of Lake Macquarie pursuant to their Development Consent (SSD 12 5465, as modified).

CVC proposes to extract Miniwalls S2 and S3 (MWS2 and MWS3) in the Fassifern Seam beneath Lake Macquarie. These two miniwalls are located north-east of the completed MWS1, at a minimum distance of 235 m. The two miniwalls each have a void width (including first workings) of 97 m and an inter-panel pillar width of 40 m. The depth of the Fassifern Seam below rockhead (i.e. excluding the lake bed sediment) varies between 142 m and 165 m and the working height is 3.5 m.

CVC has previously completed the extraction of Miniwalls 1 to 12 (MW1 to MW12) and Miniwall S1 (MWS1). The vertical subsidence measured above MW1 to MW6 and above the eastern ends of MW7 to MW12 were within predictions. However, increased vertical subsidence was observed above the western ends of MW7 to MW12. A detailed review was carried out by Ditton Geotechnical Services that found that the subsidence exceedance was caused by overloading the chain pillars due to the progressive widening of the overall mined-out area and gradual increase in the overall thickness of the claystone units in the seam floor. The vertical subsidence above MWS1 was not discernible outside the accuracy of the bathymetric survey.

Increased vertical subsidence is not anticipated for MWS2 and MWS3 due to the narrow overall mining void width (i.e. only two miniwalls in the series), shallower depth of cover (i.e. reduced load on the chain pillar) and wider chain pillar width (i.e. 40 m rather than 30 m to 33 m, with stability index greater than 2.7). The subsidence behaviour for MWS2 and MWS3 is therefore expected to be similar to that observed above MW1 to MW6 and above the eastern ends of MW7 to MW12.

The predicted subsidence parameters for MWS2 and MWS3 have been obtained using the Incremental Profile Method (IPM). The IPM has been calibrated for the local conditions using the locally available monitoring and geotechnical data at CVC and using other empirical and mechanistic methods. The maximum predicted subsidence parameters are: 290 mm vertical subsidence, 6 mm/m tilt (i.e. 6 %, or 1 in 167), 0.10 km⁻¹ hogging curvature (i.e. 10 km minimum radius) and 0.30 km⁻¹ sagging curvature (i.e. 3.3 km minimum radius).

The natural and built features located near MWS2 and MWS3 include the: lake bed sediment, sea grass beds and benthic communities on the lake bed, lake foreshore high-water mark (RL 2.44 mAHD), a navigation marker, jetties, moorings, residential buildings and other associated structures and services along the lake foreshore, and survey control marks.

The predicted changes in the levels of the lake bed directly above MWS2 and MWS3 are less than 0.3 m. These changes are small when compared with the overall depth of the lake which is typically greater than 5 m above the proposed mining area.

The Pelican Rock Navigation Marker is located on the rock outcrop that extends into Lake Macquarie from Summerland Point. The marker is outside but immediately adjacent to the tailgate of MWS2. The predicted vertical subsidence for the navigation marker is 90 mm. The predicted subsidence should be provided to Roads and Maritime Services so that management strategies can be developed for the marker, if required.

MWS2 and MWS3 are located outside the Sea Grass Protection Barrier, defined by a 26.5° angle of draw from the mapped extents of the sea grass beds. The predicted vertical subsidence at the mapped sea grass beds due to the proposed mining is less than 20 mm.

MWS2 and MWS3 are also located outside the High Water Mark Protection Barrier, defined by a 35° angle of draw from the high-water mark of RL2.44 mAHD. The predicted vertical subsidence at the high-water mark due to the proposed mining is also less than 20 mm. It is unlikely, therefore, that there would be measurable changes in the high-water mark due to the extraction of MWS2 and MWS3.

The predicted vertical subsidence at the mapped sea grass beds and, hence, at the lake foreshore is less than 20 mm. It is unlikely, therefore, that there would be adverse impacts on the surface features located above the sea grass beds (i.e. jetties and moorings) or along the lake foreshore, including houses, other associated structures, roads and services.

The state survey control marks located near to MWS2 and MWS3 could experience low-level horizontal movements. NSW Spatial Services should be notified so that the affected state survey marks can be managed and re-established after active subsidence, as required.

The assessments provided in this report indicate that the levels of impact due to mine subsidence on the natural and built features can be managed by the preparation and implementation of appropriate management strategies. The discussions provided in this report should be read in conjunction with the relevant management plans associated with this application.

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MSEC979-07	Depth of Fassifern Seam below rockhead contours	Α
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1.1. Background

Lake Coal Pty Ltd (LC) operates Chain Valley Colliery (CVC) which is located in the Newcastle Coalfield of New South Wales (NSW). The colliery is currently extracting miniwalls in the Fassifern Seam beneath the southern end of Lake Macquarie pursuant to their Development Consent (SSD 12_5465, as modified).

CVC has completed the extraction of Miniwalls 1 to 12 (MW1 to MW12). The colliery has an approved Extraction Plan for Miniwalls S1 and N1 (MWS1 and MWN1) in the Fassifern Seam. At the time of this report, CVC had completed MWS1 and was in the process of mining MWN1.

CVC proposes to extract Miniwalls S2 and S3 (MWS2 and MWS3) in the Fassifern Seam. These two miniwalls are located north-east of the completed MWS1, at a minimum distance of 235 m.

The locations of the existing and proposed miniwalls are shown in Drawings Nos. MSEC979-01 and MSEC979-02, in Appendix D. MWS2 and MWS3 have also been overlaid on an aerial photograph in Fig. 1.1. These two miniwalls are located north of the suburb of Summerland Point.



Courtesy of Nearmap

Fig. 1.1 Aerial photograph and MWS2 and MWS3

LC is currently preparing an Extraction Plan Application for MWS2 and MWS3. Mine Subsidence Engineering Consultants (MSEC) has been commissioned by LC to:

- prepare subsidence predictions for MWS2 and MWS3, including the cumulative movements due to the previously extracted and approved miniwalls;
- identify the natural and built features near the miniwalls;
- provide subsidence predictions for each of these surface features;
- prepare impact assessments for each of the natural and built features; and
- · recommend management strategies and monitoring.

This report has been prepared to support the Extraction Plan Application for MWS2 and MWS3 that will be submitted to the Department of Planning and Environment. The discussions provided in this report should be read in conjunction with the relevant management plans associated with this application.

Chapter 1 provides background information on the study, including the mining geometry, surface and seam levels and the overburden lithology.

Chapter 2 defines the Study Area and provides a summary of the natural and built features that have been identified within this area.

Chapter 3 provides an overview and the calibration of the methods that have been used to predict the mine subsidence movements due to the extraction of the miniwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the miniwalls. This chapter also provides the predicted fracture widths at rockhead and the predicted deformations deeper within the overburden.

Chapter 5 provides the descriptions, predictions and impact assessments for each of the natural and built features that could be affected by subsidence. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

1.2. Mining geometry

The locations of MWS2 and MWS3 are shown in Drawings Nos. MSEC979-01 and MSEC979-02. A summary of the dimensions of these miniwalls is provided in Table 1.1. The miniwalls will be extracted in the Fassifern Seam.

Miniwall Overall void length including installation heading (m) Overall void width including the first workings (m)

MWS2 1078 97
MWS3 1045 97 40

Table 1.1 Geometry of the miniwalls

The lengths of miniwall (i.e. secondary) extraction excluding the installation headings are 1070 m for MWS2 and 1037 m for MWS3. The miniwall face widths excluding the first workings are 86 m. The miniwalls will be extracted towards the main headings (i.e. retreat mining) from the south-east to the north-west.

The development headings are 5.4 m wide and 3.2 m high. The cut-throughs are at 100 m centres. The solid pillars between MWS2 and MWS3, therefore, are 95 m long by 40 m wide and 3.2 m high. The solid pillars on the tailgate side of MWS2 are 105 m long by 32.6 m wide and 3.2 m high and the solid pillars on the maingate of MWS3 are 105 m long by 40 m wide and 3.2 m high.

1.3. Surface, overburden and seam levels

The levels of the lake bed, rockhead, Teralba Conglomerate and Fassifern Seam based on the geological model were provided by Coal Resource Consulting (CRC, 2018). The natural surface level, thickness of the claystone floor of the Fassifern Seam and the graphical borehole logs were provided by CVC (2018). The approximate levels and thicknesses of the Munmorah, Karignan and Karingal Conglomerate members and the Awaba Tuff have been determined from the borehole logs.

Two cross-sections and one long-section have been taken through MWS2 and MWS3, as shown in Drawings Nos. MSEC979-03 to MSEC979-09. The levels of the natural surface, lake bed floor, rockhead, Teralba Conglomerate and Fassifern Seam along Cross-sections 1 and 2 and Long-section 1 are illustrated in Fig. 1.2 to Fig. 1.4, respectively. Cross-section 1 is located near the commencing (i.e. south-eastern) ends of the miniwalls and Cross-section 2 is located near the finishing (i.e. north-western) ends of the miniwalls. Long-section 1 has been taken through the centreline of MWS2.

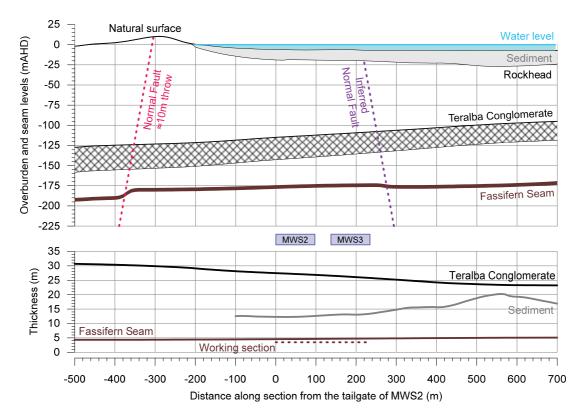


Fig. 1.2 Surface and seam levels along Cross-section 1 (near commencing ends)

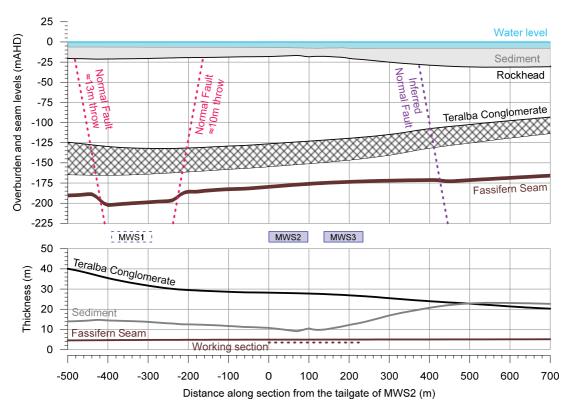


Fig. 1.3 Surface and seam levels along Cross-section 2 (near finishing ends)

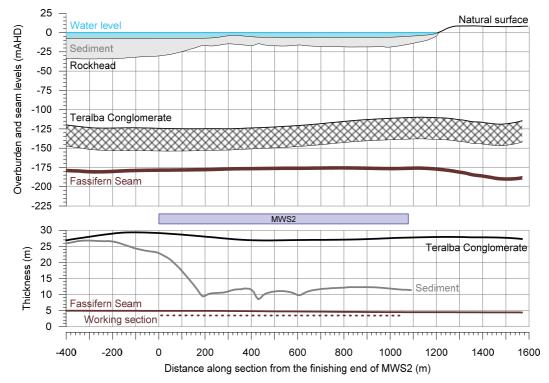


Fig. 1.4 Surface and seam levels along Long-section 1 (centreline of MWS2)

The natural surface and the lake bed contours are shown in Drawing No. MSEC979-03. MWS2 and MWS3 are located directly beneath Lake Macquarie. These two miniwalls are situated at a minimum distance of approximately 130 m from the lake foreshore based on the 0 m Australian Height Datum (mAHD) surface level contour.

The depth of the lake bed beneath the mean water level (i.e. 0 mAHD) varies between approximately 3 m and 8 m directly above MWS2 and MWS3. The thickness of the lake bed sediment is illustrated in Drawing No. MSEC979-08. The sediment thickness varies between approximately 9 m and 23 m directly above MWS2 and MWS3.

The rockhead level, Fassifern Seam floor level, Fassifern Seam thickness and depth of the Fassifern Seam below rockhead contours are shown in Drawings Nos. MSEC979-04 to MSEC979-07, respectively. It is noted that, in this report, the *depth of seam* contours refers to the distance between the top of the working section within the Fassifern Seam and rockhead, i.e. excluding the lake bed sediment. The working section (i.e. underside of C Ply) is located approximately 1.8 m below the roof of the Fassifern Seam.

The depth of the top of the working section in the Fassifern Seam below rockhead varies between 142 m at the finishing (i.e. north-western) end of MWS3 and 165 m above the tailgate of MWS2. The total depth of cover including the lake bed sediment varies between approximately 164 m and 172 m.

The Fassifern Seam dips from the north-east towards the south-west. The average seam dip across the width of the mining area is approximately 1 % to 2 %.

The thickness of the Fassifern Seam varies between 4.5 m and 5 m within the proposed mining area. The miniwalls will extract a height of 3.5 m within this seam. The top of the working section is at the underside of the C Ply which is approximately 1.8 m below the roof of the Fassifern Seam (refer to Fig. 1.5).

A summary of the mining geometry of MWS2 and MWS3 is provided in Table 1.2.

Table 1.2 Mining geometry of MWS2 and MWS3

Miniwall	Overall void length (m)	Void width (m)	Tailgate pillar width (m)	Depth below rockhead (m)	W/H ratio of miniwall void	W/H ratio of overall mining void	Working section height (m)
MWS2	1078	97	-	146 ~ 165	0.59 ~ 0.66	0.59 ~ 0.66	3.5
MWS3	1045	97	40	142 ~ 156	0.62 ~ 0.68	1.50 ~ 1.65	3.5

The width-to-depth ratios for each of the miniwall voids vary between 0.59 and 0.68. The void widths of MWS2 and MWS3 are therefore subcritical. The width-to-depth ratios of the overall mining width vary between 1.50 and 1.65 at the completion of MWS3.

1.4. Geological details

CVC is located in the Newcastle Coalfield in the northern part of the Sydney Basin. The stratigraphy comprises the upper sequences of the Permian Newcastle Coal Measures overlain by the Triassic Narrabeen Group. The bedrock is then overlain by sediment in the bed of Lake Macquarie. The stratigraphy of the area is illustrated in Table 1.3.

Table 1.3 Stratigraphy of the Lake Macquarie area of the Newcastle Coalfield

Period	Group	Subgroup	Lithology
Triassic	Narrabeen Group	Clifton	Munmorah Group (Conglomerate)
			Dooralong Shale
			Vales Points Coal
			Karignan Conglomerate
			Tuff
		Moon Island Beach	Wallarah Coal
			Mannering Park Tuff
			Teralba Conglomerate
Permian	Newcastle Coal Measures		Great Northern Coal
	_		Karingal Conglomerate
			Awaba Tuff
		Boolaroo Fassifern	
			Claystone and Pilot Coal
			Croudace Bay Conglomerate

The thickness of the Fassifern Seam varies between 4.5 m and 5 m within the extents of MWS2 and MWS3. The floor of the seam comprises interbedded coal and carbonaceous shale and moisture sensitive claystone (Strata², 2019). The bedding thicknesses vary between 50 mm and 300 mm with a total thickness of less than 2 m within the mining area. The claystone floor then overlies interbedded conglomerate, sandstone and shale units.

The Fassifern Seam is overlain by the Awaba Tuff which comprises a variable sequence of tuffaceous claystone, sandstone and siltstone, with the beds usually sandwiched between stronger shaley coal units (DgS, 2013). This unit has a thickness of approximately 20 m directly above MWS2 and MWS3. The Awaba Tuff tends to swell and degrade in the presence of moisture (Strata², 2019).

The overburden consists of interbedded conglomerate, sandstone, carbonaceous shale, coal and tuffaceous claystone and sandstone. There are several massive conglomerate units above the Fassifern Seam comprising (from bottommost to topmost) the Karingal, Teralba, Karignan and Munmorah (lower and upper) members.

The largest unit in the overburden is the Teralba Conglomerate. This unit is located between 25 m and 40 m above the Fassifern Seam. The overall thickness of the Teralba Conglomerate is illustrated in MSEC979-09 and it ranges between 26 m and 29 m directly above MWS2 and MWS3.

The approximate thicknesses of other conglomerate members, based on the drillholes near MWS2 and MWS3, are 6 m to 8 m for the Karingal Conglomerate, 20 m to 25 m for the Karignan Conglomerate and 20 m to 25 m for the Munmorah Conglomerate.

The rock is overlain with sediment on the bed of Lake Macquarie. The thickness of the lake bed sediment is shown in Drawing No. MSEC979-08 and it varies between 9 m and 23 m directly above MWS2 and MWS3.

The stratigraphy at CVC based on drillhole JCV3 is illustrated in Fig. 1.5. This drillhole is located on the headland to the south-west of MWS2 and MWS3, as shown in Drawing No. MSEC979-01.

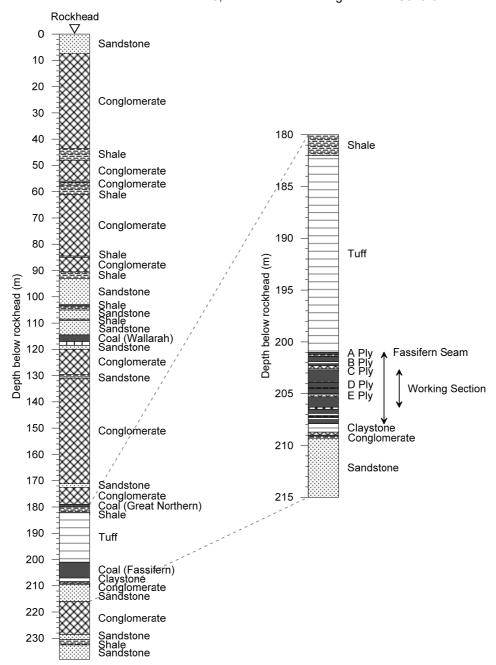


Fig. 1.5 Stratigraphy at CVC based on Drillhole JCV3

CVC is located to the west of the Macquarie Syncline. Regional structure comprises west-northwest to east-southeast orientated normal faults. The mapped and inferred geological structures near MWS2 and MWS3 are shown in MSEC979-10. The faults are also illustrated in the cross-sections in Fig. 1.2 and Fig. 1.3.

A fault zone is located on the south-western side of MWS2. The zone comprises normal faults with a strike of approximately 131°. The largest fault has a throw of 10 m and other faults in this zone have throws of less than 2 m. The faults dip towards the south-west with angles between 50° and 75° (DgS, 2018b).

The fault zone is located closest to MWS2 at its finishing end. The largest fault in this zone (i.e. 10 m throw) is located at a minimum distance of 175 m from this minimal at seam level. It is not anticipated that this fault zone would affect the subsidence that develops from MWS2 and MWS3 due to its distance from the mining area (i.e. more than one depth of cover from the minimalls).

A normal fault is located further to the south-west on the far-side of MWS1. This fault has a throw of approximately 13 m and dips towards the north-east. MWS1 is located within a horst bounded by the faults on the maingate and tailgate sides, as shown in Fig. 1.3.

An inferred normal fault is located on the north-eastern side of MWS3. This inferred normal fault has a west-northwest to east-southeast orientation and it has a throw of approximately 2 m. The inferred fault dips towards the north-east at an angle of approximately 60° (Strata², 2019).

The inferred normal fault is located adjacent to the maingate of MWS3 at its commencing end. The distance of the fault increases along the length of this miniwall. It is located approximately 220 m north-west of MWS3 at its finishing end. MWS2 and MWS3 are located within a graben bounded by the faults on the south-western and north-eastern sides, as shown in Fig. 1.3.

The effect of the inferred fault on the predicted subsidence for MWS2 and MWS3 was reviewed using a numerical model (refer to Section 3.5.6). The numerical analysis indicates that slightly increased vertical subsidence (i.e. less than 10 % of the maximum predicted value) could occur when mining immediately adjacent to a normal fault. Only low-level additional subsidence is anticipated due to the relatively high dip (i.e. 60°) and relatively small throw (i.e. approximately 2 m).

It is not expected, therefore, that the inferred normal fault would result in a significant increase in the vertical subsidence due to the extraction of MWS2 and MWS3. This is supported by the fact that there was no obvious relationship between vertical subsidence and the presence or absence of major geological structures for the existing MW1 to MW12 (Strata², 2019).

The surface expression (i.e. at rockhead) for the inferred fault is projected above MWS3 near its commencing end. It is possible that locally increased compressive strain could develop in this location due to the extraction of this miniwall. The numerical analysis did not show a significant change in the horizontal movements at rockhead. The lake bed sediment is more than 10 m thick at the commencing end of MWS3. It is unlikely that there would be measurable strain at the lake bed due to the thickness of the sediment.

The major principal stress direction is orientated north-northeast to north-east (DgS, 2018b). The in situ stress at rockhead is approximately 6.5 MPa and it increases by approximately 0.1 MPa per metre depth. The minor principal stress is near-zero at rockhead and it increases by approximately 0.06 MPa per metre depth (DgS, 2018b).

2.1. Definition of the Study Area

The *Study Area* is defined as the surface area that could be affected by the mining of MWS2 and MWS3. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- the 26.5° angle of draw line from the extents of MWS2 and MWS3; and
- the predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the minimals.

The depth of the Fassifern Seam below rockhead contours are shown in Drawing No. MSEC979-06. The depth of the seam below rockhead varies between 142 m and 165 m directly above MWS2 and MWS3. The 26.5° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 71 m and 83 m around the extents of the miniwall voids.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method (IPM). The description and calibration of the IPM are provided in Chapter 3. The predicted total subsidence contours, including the 20 mm subsidence contour, are shown in Drawing No. MSEC979-13. The predicted 20 mm subsidence contour is located entirely within the 26.5° angle of draw line.

The 26.5° angle of draw line for MWS2 and MWS3 is shown in Drawings Nos. MSEC979-01 and MSEC979-02. The features located outside the 26.5° angle of draw, that are predicted to experience far-field movements and could be sensitive to these movements, have been included in the assessments provided in this report. The features near MWS2 and MWS3 that are sensitive to far-field horizontal movements are the survey control marks.

2.2. Natural and built features within the Study Area

MWS2 and MWS3 are located directly beneath the southern part of Lake Macquarie. The miniwalls are north of the suburb of Summerland Point. Photographs of the lake foreshore near MWS2 and MWS3 are provided in Fig. 2.1.





Fig. 2.1 Lake foreshore at Summerland Point

A summary of the natural and built features located within or in the immediate vicinity of the Study Area is provided below:

- lake bed sediment:
- sea grass beds and benthic communities on the lake bed;
- lake foreshore high-water mark (RL 2.44 mAHD);
- · a navigation marker;
- · jetties and moorings;
- residential buildings and other structures along the lake foreshore; and
- · survey control marks.

The locations of these features are shown in Drawing No. MSEC979-11. The descriptions, predictions and impact assessments for the natural and built features are provided in Chapter 5.

3.1. Introduction

The following sections provide overviews of mine subsidence parameters and the methods that have been used to predict these movements. Further information is also provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from www.minesubsidence.com.

3.2. Overview of conventional subsidence parameters

The normal ground movements resulting from the extraction of underground panels are referred to as conventional or systematic subsidence movements. These movements are described by the following parameters:

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the panel goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.
- **Tilt** is the change in the slope of the ground as a result of differential subsidence and it is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.
- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of 1/kilometres (km⁻¹), but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in kilometres (km).
- Strain is the relative differential horizontal movements of the ground. Normal strain is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre* (*mm/m*). Tensile Strains occur where the distances between two points increase and Compressive Strains occur when the distances between two points decrease. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.
 - Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.
- Horizontal shear deformation across monitoring lines can be described by various parameters
 including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear
 index. It is not possible, however, to determine the horizontal shear strain across a monitoring line
 using 2D or 3D monitoring techniques. High deformations along monitoring lines (i.e. normal
 strains) are generally measured where high deformations have been measured across the
 monitoring line (i.e. shear deformations), and vice versa.

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters that result from the extraction of each panel. The **cumulative** subsidence, tilts, curvatures and strains are the accumulated parameters that result from the extraction of a series of panels. The **total** subsidence, tilts, curvatures and strains are the final parameters at the completion of a series of panels. The **travelling** tilts, curvatures and strains are the transient movements as the panel extraction face mines directly beneath a given point.

The measured horizontal movements at survey marks that are located beyond the panel goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as *far-field movements*.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures that are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between panels or near other previously extracted series of panels. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low-levels of tilt and strain.

3.3. Review of the monitoring data for MW1 to MW12

CVC has completed the extraction of MW1 to MW12 in the Fassifern Seam. The locations of these miniwalls are shown in Drawing No. MSEC979-01. The northern series comprises MW1 to MW3 and MW6 to MW12. The southern series comprises MW4, MW5 and MW5A.

A summary of the mining geometries of the existing miniwalls is provided in Table 3.1.

Table 3.1 Mining geometries of the existing MW1 to MW12

Miniwall	Overall void length (m)	Void width (m)	Tailgate pillar width (m)	Depth of seam below rockhead (m)	W/H ratio of miniwall void	W/H ratio of the overall mining void (eastern ends)	W/H ratio of the overall mining void (western ends)
MW1	920	71	-	185 ~ 190	0.37 ~ 0.39	0.37 ~ 0.39	-
MW2	930	74	30	185 ~ 190	0.39 ~ 0.40	0.92 ~ 0.95	-
MW3	900	97	30	185 ~ 190	0.52 ~ 0.53	1.60 ~ 1.63	-
MW6	880	97	33	185 ~ 190	0.51 ~ 0.53	2.28 ~ 2.35	-
MW7	1190	98	33	180 ~ 190	0.52 ~ 0.54	2.99 ~ 3.09	0.52 ~ 0.54
MW8	1185	97	33	180 ~ 190	0.52 ~ 0.54	3.68 ~ 3.84	1.21 ~ 1.27
MW9	1285	98	33	175 ~ 190	0.52 ~ 0.56	4.35 ~ 4.72	1.90 ~ 2.06
MW10	1245	97	33	170 ~ 190	0.52 ~ 0.57	5.06 ~ 5.55	2.59 ~ 2.84
MW11	1150	97	33	165 ~ 185	0.53 ~ 0.59	5.89 ~ 6.51	3.36 ~ 3.72
MW12	730	97	33	175 ~ 180	0.54 ~ 0.56	6.76 ~ 6.97	4.18 ~ 4.31
MW4	410	97	-	175 ~ 180	0.53 ~ 0.56	0.53 ~ 0.56	-
MW5	760	97	40	175 ~ 190	0.51 ~ 0.55	1.23 ~ 1.33	0.51 ~ 0.55
MW5A	805	98	30	180 ~ 190	0.51 ~ 0.55	1.89 ~ 2.04	1.17 ~ 1.26

The miniwalls were extracted from the Fassifern Seam. The seam has an overall thickness ranging between 5 m and 6 m. The working section was in the middle part of the seam (at the underside of C Ply). The mining height was 3.4 m for MW1 to MW7 and 3.5 m for MW8 to MW12 (Strata², 2019).

The subsidence of the lake bed has been measured annually since 2012 using bathymetric surveys. These surveys measure the depth to the lake bed and have an accuracy in the order ±100 mm. The base surveys of the lake floor were carried out between 2012 and 2016. The vertical subsidence has been determined by taking the difference between the base surveys and subsequent surveys carried out in August 2017 (MW4 to MW5A) and April 2018 (MW1 to MW3 and MW6 to MW12). The latest bathymetric survey was carried out in January 2019 and there was no appreciable change above MW1 to MW12 from the previous survey carried out in April 2018.

The measured vertical subsidence contours for MW1 to MW12 based on the bathymetric surveys are shown in Fig. 3.1. The contours outside of the mining areas have been cropped for clarity.

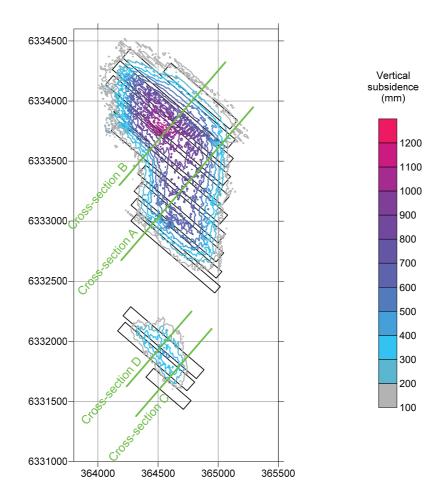


Fig. 3.1 Measured vertical subsidence contours for MW1 to MW12

The profiles of the measured vertical subsidence along Cross-sections A to D are shown in Fig. 3.2 to Fig. 3.5, respectively. The locations of these cross-sections are shown in Fig. 3.1.

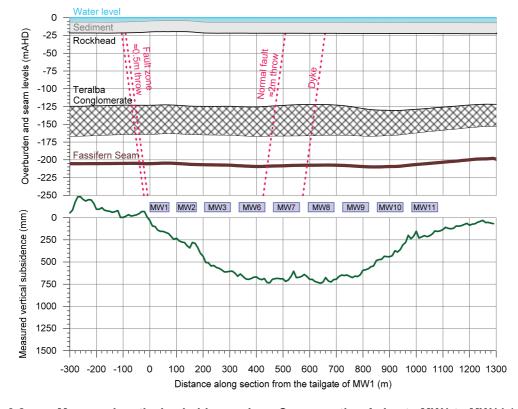


Fig. 3.2 Measured vertical subsidence along Cross-section A due to MW1 to MW11 (east)

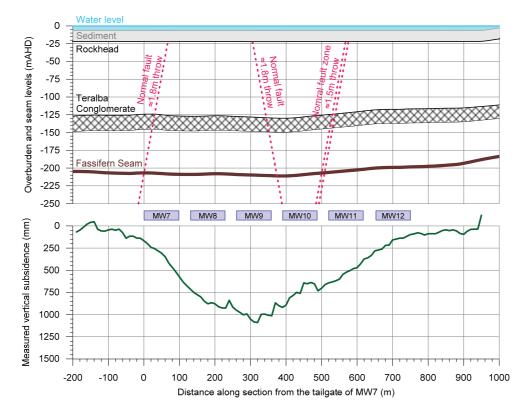


Fig. 3.3 Measured vertical subsidence along Cross-section B due to MW7 to MW12 (west)

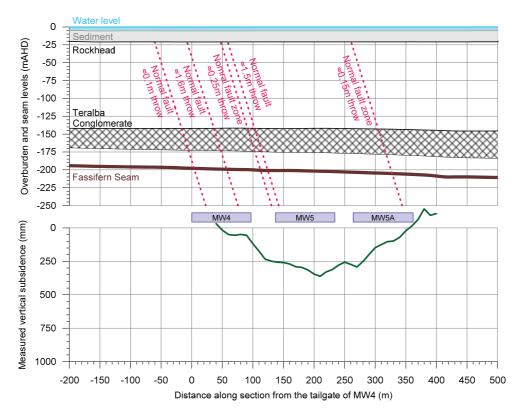


Fig. 3.4 Measured vertical subsidence along Cross-section C due to MW4 to MW5A (east)

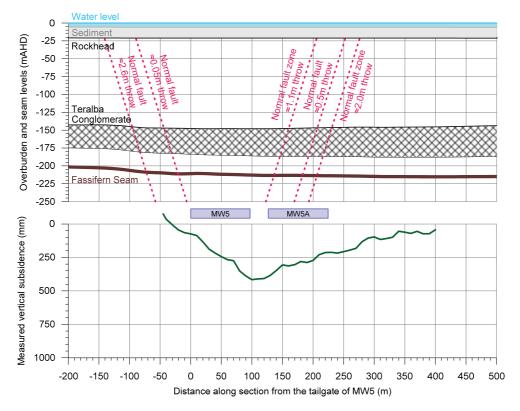


Fig. 3.5 Measured vertical subsidence along Cross-section D due to MW4 to MW5A (west)

A summary of the maximum measured vertical subsidence for MW1 to MW12 is provided in Table 3.2.

Table 3.2 Maximum measured vertical subsidence for MW1 to MW12

Miniwalls	Location	Maximum measured vertical subsidence (mm)
MW1 to MW3 and MW6 to MW12 (eastern ends)	Near Cross-section A (refer to Fig. 3.2)	750
MW7 to MW12 (western ends)	Near Cross-section B (refer to Fig. 3.3)	1150
MW4 to MW5A (eastern ends)	Near Cross-section C (refer to Fig. 3.4)	220 (after LW4) 350 (after LW5A)
MW5 and MW5A (western ends)	Near Cross-section D (refer to Fig. 3.5)	460

The maximum measured vertical subsidence for the existing MW1 to MW12 was 1150 mm and it occurred above the western part of MW9 (refer to Fig. 3.3). The maximum measured vertical subsidence above the eastern part of this existing series (i.e. MW1 to MW3 and MW6 to MW12) was 750 mm (refer to Fig. 3.2).

The maximum measured total vertical subsidence divided by the mining height versus the overall mining void width-to-depth ratio for MW1 to MW12 is illustrated in Fig. 3.6. The overall mining void width-to-depth ratios are based on the depth of rock (i.e. Fassifern Seam roof to rockhead). The results for Wyee LW17 to LW21 are also shown in this figure for comparison (Source: DgS, 2018b and Strata², 2019).

Wyee LW17 to LW23 had void widths ranging between 130 m and 150 m and chain pillar widths of 45 m. The longwalls were extracted in the Fassifern Seam with a working height of 3.2 m. The depths of cover vary between 170 m and 195 m. The width-to-depth ratios for the longwalls, therefore, vary between 0.75 and 0.81.

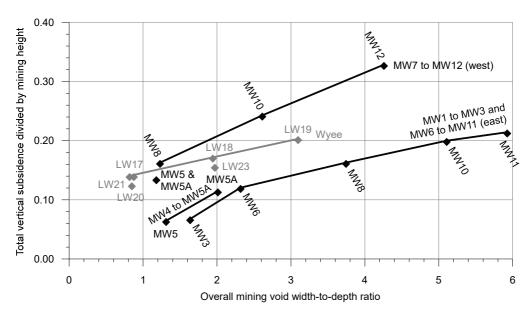


Fig. 3.6 Maximum measured total vertical subsidence divided by mining height versus overall mining void width-to-depth ratio

The subsidence predictions for MW1 to MW12 were provided by Ditton Geotechnical Services (DgS). The original predictions are outlined in Report. No. CHS-002/1 (DgS, 2013) which supported the Extraction Plan Application for MW7 to MW12.

The predictions were obtained using two empirical models (ACARP, 2003 and SDPS, 2007) and an analytical model (after Das, 1998). The maximum predicted vertical subsidence for MW7 to MW12 was 720 mm (DgS, 2013).

The vertical subsidence above the western ends of MW7 to MW12 exceeded the original predictions. An extensive review and assessment of the subsidence exceedance was carried out by DgS (2018a). It was concluded that the:

- "...subsidence exceedance over MW1-12 was caused by over-loading of the chain pillars. This was in turn primarily a result of:
 - (i) reducing overburden stiffness due to the progressive widening of the overall mined-out area, and
 - (ii) reducing pillar system strength due to a gradual increase in the overall thickness of the claystone units in the Fassifern Seam floor northwards towards MW12." (DgS, 2018a)

The review by DgS (2018a) found that the subsidence above the initial mined panels was limited by spanning conglomerate units in the overburden. The maximum measured subsidence for the first two panels in the series was less than 300 mm (i.e. less than 0.09 times the mining height). After the extraction of additional miniwalls, the conglomerate units in the overburden were less capable of spanning the overall mining void width when the width-to-depth was greater than the supercritical width (DgS, 2018a).

The reduced spanning capacities increased load on the chain pillars where the "average chain pillar stress is estimated at 15 to 20 MPa. This is of the same order as the bearing capacity of the claystone floor (15 to 21 MPa)." (DgS, 2018a). Hence, the "softened claystone at the pillar periphery would tend to deform laterally, reducing confinement and reducing the pillar core width. As pillar stiffness reduces, overburden deformation increases and more load sheds to the goaf." (DgS, 2018a).

At that point the "goaf strain-hardens under load produced by increasing overburden deflection. This provides support and assists the Munmorah Conglomerate to behave elastically and span until a late stage in the process" and that "subsidence then becomes simply a function of the resistance offered by the failed pillars and goaf" (DgS, 2018a). In the long-term it was "estimated that goaf consolidation could result in up to 300 mm of additional subsidence in the next two or more years, resulting in final subsidence of up to 1.45 m" (DgS, 2018a).

The increased vertical subsidence above the western ends of MW7 to MW12 appears to be the result of the wide overall mining void width (i.e. more than three miniwalls in the series) combined with narrower chain pillars (i.e. low stability index). This behaviour is not expected for MWS2 and MWS3 due to the narrow overall mining void width (i.e. only two miniwalls in the series), shallower depth of cover (i.e. reduced load on the chain pillar) and wider chain pillar width (i.e. higher stability index). The subsidence behaviour for MWS2 and MWS3 is therefore expected to be similar to that observed above MW1 to MW6 and above the eastern ends of MW7 to MW12.

3.4. Review of the monitoring data for MWS1

CVC has completed the extraction of MWS1 in the Fassifern Seam. A bathymetric survey was carried out in January 2019. The vertical subsidence above MWS1 was not discernible outside the accuracy of the bathymetric survey.

The subsidence along the foreshore of Frying Pan Bay was also measured using 2D survey marks fixed to structures including seawalls and jetties. The measured vertical subsidence along the lake foreshore is illustrated in Fig. 3.7. The latest survey was carried out on the 21 December 2018.

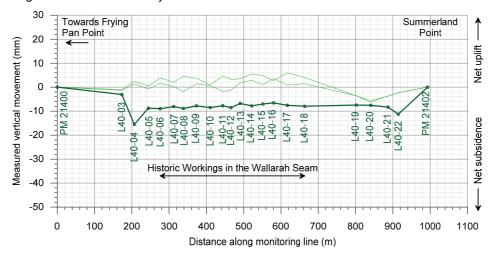


Fig. 3.7 Measured vertical subsidence along the foreshore of Frying Pan Bay

The vertical subsidence measured at the lake foreshore was typically less than 10 mm. Slightly higher values were measured at Marks L40-04 and L40-22; however, these marks could have been disturbed as they differ from the adjacent marks. The measurements were relatively uniform along the length of the monitoring line and, therefore, these could comprise a reasonable proportion of survey tolerance.

3.5. Subsidence model for MWS2 and MWS3

The void widths of MWS2 and MWS3 of 97 m are the same as the void widths for the existing MW3 to MW12, but are greater than the void widths of MW1 and MW2 of 72 m. The pillar width of 40 m is greater than the pillar widths for MW2, MW3, MW5A and MW6 to MW12 of 30 m to 33 m. The existing MW5 has a tailgate chain pillar width of 40 m and therefore it is the same width as the pillar between MWS2 and MWS3.

The overall mining void width for MWS2 and MWS3 of 234 m is less than the overall mining void widths of MW1 to MW3 plus MW6 to MW12 of 1215 m at their eastern ends and 750 m at their western ends. The overall mining void width of MWS2 and MWS3 is also less than that for the eastern ends of MW4 to MW5A of 360 m but it is similar to that for the western ends of MW5 and MW5A of 224 m.

The depth of the Fassifern Seam below rockhead for MWS2 and MWS3 varies between 142 m and 165 m. The depth of the seam below rockhead for the existing MW1 to MW12 varies between approximately 160 m and 190 m. The thickness of the Teralba Conglomerate above MWS2 and MWS3 of 26 m to 29 m is generally less than that above the existing miniwalls that varies between approximately 30 m to 40 m.

The vertical subsidence for MWS2 and MWS3 will therefore differ from that above the existing MW1 to MW12 due to the smaller overall mining void width, larger chain pillar width, shallower depth of cover and the thinner conglomerate units in the overburden.

The predictions for MWS2 and MWS3 have been obtained using the Incremental Profile Method (IPM). The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales. The IPM has been calibrated using the locally available monitoring and geotechnical data at CVC and using other empirical and mechanistic methods.

The database consists of detailed subsidence monitoring data from collieries in NSW including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Chain Valley, Clarence, Coal Cliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Gretley, Invincible, John Darling, Kemira, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each panel within a series of panels. It can be derived from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the IPM use the database of observed incremental subsidence profiles, the panel geometries, local surface and seam information and geology. The method tends to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the mining area.

Further details on the IPM are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*. The calibration of the IPM for the local conditions at CVC is discussed in the following sections.

3.5.1. Conceptual subsidence model

The miniwalls at CVC are located within the Fassifern Seam. The caving zone extends between approximately 5 and 10 times the mining height above the top of the working section. The top of the caving zone, therefore, is between 18 m and 35 m above C Ply in the Fassifern Seam.

The base of the Karingal Conglomerate is located approximately 15 m to 20 m above the Fassifern Seam within the mining area. The base of the Teralba Conglomerate is located approximately 25 m to 40 m above the seam. The caving zone, therefore, extends between the Karingal and Teralba Conglomerate members, depending on their spanning capacities.

The Subsidence Reduction Potentials (SRP) of the Karingal, Teralba, Karignan and Munmorah Conglomerate members have been determined using the method outlined in Australian Coal Association Research Program (ACARP) Project No. C10023 (ACARP, 2003). A summary of the SRP for these members (based on Figure 6.8 of ACARP, 2003) is provided in Table 3.3. The height above the seam and thickness of the Teralba Conglomerate have been determined from the geological model. The heights and thicknesses of the other members have been interpreted from the drillhole logs.

Member	Panel spanning width (m)	Average depth of seam below rockhead (m)	Height above the seam (m)	Thickness (m)	Height above seam divided by the depth below rockhead (y/H)	SRP
Munmorah	97	150	≈ 120	≈ 20 to 25	≈ 0.80	High
Karignan	97	150	≈ 80	≈ 20 to 25	≈ 0.53	High
Teralba	97	150	25 to 40	26 to 29	0.17 ~ 0.27	High
Karingal	97	150	15 to 20	6 to 8	0.10 ~ 0.13	Low

Table 3.3 Subsidence Reduction Potential for the conglomerate members

The Teralba, Karignan and Munmorah Conglomerate members are considered to have High SRP based on the 2003 ACARP method. The Karingal Conglomerate is considered to have Low SRP due to its smaller interburden with the Fassifern Seam and smaller thickness (i.e. less than 10 m). It has been assumed, therefore, that the Karingal Conglomerate cannot span the voids of the miniwalls.

The overburden between rockhead and the base of the Teralba Conglomerate spans the caving zones that develop above each of the miniwalls. The overburden is supported by the chain pillars and the strata beneath the Teralba Conglomerate within the angle of break of the chain pillars. On the perimeter of the mining area, the overburden is supported by the abutments.

The vertical subsidence develops from the combination of the:

- pillar component comprising compression of the chain pillar and the immediate floor and roof;
- abutment component comprising compression of the abutment adjacent to the mining area including the compression of the immediate floor and roof; and
- sagging component due to vertical deformation (i.e. "bending") of the overburden above the miniwall voids combined with horizontal shear through the overburden.

A cross-section showing the overburden above a generic series of miniwalls at CVC is illustrated in Fig. 3.8. The conceptual subsidence model comprising the pillar, abutment and sagging components of vertical subsidence is illustrated in Fig. 3.9.

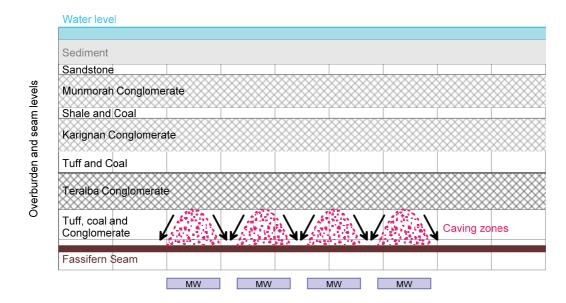


Fig. 3.8 Overburden above a generic series of miniwalls

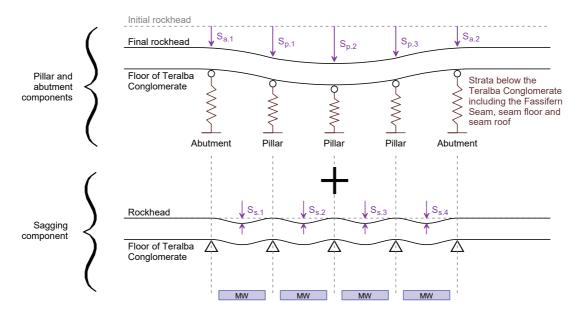


Fig. 3.9 Conceptual subsidence model

The total vertical subsidence for a series of miniwalls is equal to the combination of the pillar component (S_p) , abutment component (S_a) and the sagging component (S_s) . The ongoing extraction of miniwalls in the series increases the overall mining void. This reduces the spanning capacity of the overburden that in turn increases the load on the pillars which then may ultimately fail. The pillar component and sagging component of vertical subsidence increase, therefore, as additional miniwalls are mined within the series. This increased vertical subsidence was observed above the western ends of MW7 to MW12.

However, MWS2 and MWS3 have an overall mining void width of 234 m, which is less than the critical width that develops after the extraction of three or more miniwalls. The subsidence behaviour of MWS2 and MWS3 is expected to be similar to that for MW1 to MW6 and for the eastern ends of MW7 to MW12 where the pillars are believed to have remained intact.

There is a complex interaction between the pillar, abutment and sagging components of vertical subsidence. However, these components can be separated for MWS2 and MWS3 due to the: narrow miniwall void widths (i.e. subcritical width), the small overall mining void width (i.e. only two miniwalls in the series) and the wider pillar width (i.e. high stability index).

The overburden above MWS2 and MWS3 is supported by the chain pillar on one side and by an abutment on the other side. The total vertical subsidence (S_{max}), therefore, is the average of the pillar component (S_p) and the abutment component (S_a) plus the sagging component (S_s), as follows:

Equation 1
$$S_{max} = (S_p + S_a)/2 + S_s$$

The pillar, abutment and sagging components of vertical subsidence are described in the following sections.

3.5.2. Pillar component

There are various methods that can be used to predict the pillar component of vertical subsidence for subcritical panels. Four empirical methods have been used and these are described below.

Monitoring data for MW1 to MW12:

The predicted vertical subsidence due to MWS2 and MWS3 can be determined using the monitoring data from the existing minimals at CVC. The relationship between the maximum vertical subsidence divided by mining height versus the overall mining void width-to-depth ratio is illustrated in Fig. 3.6.

The pillar between MWS2 and MWS3 has a Stability Index greater than 2.7 (refer to the following section) and, therefore, it is expected to remain intact. The overall mining void width for MWS2 and MWS3 is 234 m (i.e. two times 97 m miniwalls plus 40 m pillar) which is less than the critical width that develops after the extraction of three or more miniwalls. It is expected, therefore, that the pillar will remain intact. The relationship between vertical subsidence and overall mining void width for MWS2 and MWS3 is expected to follow similar behaviours as for MW1 to MW6 and for the eastern ends of MW7 to MW12.

The panel width (97 m) and pillar width (40 m) and mining height (3.5 m) for MWS2 and MWS3 are similar to those for MW4 and MW5. The maximum measured vertical subsidence for these two existing miniwalls of 220 mm, therefore, provides a good indication of the subsidence for the proposed miniwalls.

The overall mining void width for MWS2 and MWS3 is 234 m (i.e. 97 m + 40 m + 97 m). The average depth of the Fassifern Seam below rockhead for these miniwalls is 150 m. The overall mining void width-to-depth ratio for MWS2 and MWS3 of 1.56 is similar to that for the existing MW1 to MW3 of 1.64 (i.e. 302 m overall mining void divided by 184 m rock cover). The measured vertical subsidence for MW1 to MW3 of 230 mm, therefore, also provides a good indication of the subsidence for the proposed miniwalls.

However, the overall depth of cover (including the lake bed sediment) of 170 m for MWS2 and MWS3 is less than that for MW4 and MW5 of 210 m and for MW1 to MW3 of 200 m. Also, the mining height for MWS2 and MWS3 of 3.5 m is slightly greater than that for MW1 to MW5A of 3.4 m.

The pillar load and, hence, the pillar component of vertical subsidence for MWS2 and MWS3 is reduced due to the shallower depth of cover but it is slightly increased due to the mining height. The maximum predicted vertical subsidence for MWS2 and MWS3 therefore is:

```
Equation 2 S_p = 220 \text{ mm x } (170/210) \text{ x } (3.5/3.4) = 185 \text{ mm} based on MW4 and MW5
```

Equation 3
$$S_p = 230 \text{ mm x } (170/200) \text{ x } (3.5/3.4) = 200 \text{ mm}$$
 based on MW1 to MW3

The maximum predicted value of 185 mm to 200 mm includes both the pillar component and the sagging component of vertical subsidence. The numerical analysis of the existing miniwalls (refer to Section 3.5.4) indicates that the sagging component for the existing miniwalls represents around 15 % of the overall vertical subsidence. It has been conservatively assumed, therefore, that the pillar component for MWS2 and MWS3 is 200 mm based on the monitoring data from the existing miniwalls.

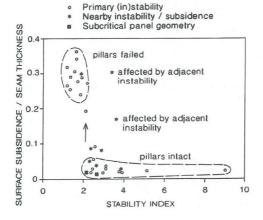
Mills and Edwards (1997):

The pillar component of vertical subsidence is dependent on whether the chain pillars remain intact or fail. The pillar Stability Index (SI) is the ratio of the pillar stress to pillar strength. The pillar strength can be predicted using the formula provided by Mills and Edwards (1997):

Equation 4
$$Q_p = 8(0.64 + 0.36 \text{ w/h})$$

```
where w = pillar width (m)
h = pillar height (m)
```

The relationship between surface subsidence and Stability Index is illustrated on the left side of Fig. 3.10 (Mills and Edwards, 1997). These data are based on mining in the Great Northern and Wallarah Seams in the Lake Macquarie area. Pillars with a Stability Index greater than approximately 2.7 can generally be considered to remain intact. Pillars with a Stability Index less than 2.0 have been typically observed to fail.



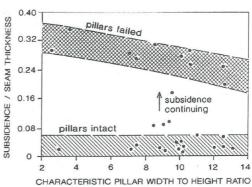


Fig. 3.10 Vertical subsidence versus Stability Index (left side) and versus pillar width-toheight ratio (right side) (Mills and Edwards, 1997)

The vertical subsidence versus the pillar width-to-height ratio is illustrated on the right side of Fig. 3.10 (Mills and Edwards, 1997). The vertical subsidence for intact pillars is less than 0.06 times the seam thickness (i.e. mining height). The vertical subsidence for failed pillars varies between 0.25 and 0.35 times the seam thickness (i.e. mining height), depending on the pillar width-to-height ratio.

The pillar between MWS2 and MWS3 has a width (w) of 40 m and a height (h) of 3.2 m. The pillar strength based on Mills and Edwards (1997) is as follows:

Equation 5
$$Q_p = 8(0.64 + 0.36 \times 40/3.2) = 41 \text{ MPa}$$

The pillar stress is determined from the weight of the overburden within its tributary area divided by the pillar area. The weights of the water, sediment and rock on the chain pillar between MWS2 and MWS3 are summarised in Table 3.4. The tributary width is equal to the miniwall width (97 m) plus the pillar width (40 m) down to the base of the Teralba Conglomerate. The tributary width beneath the Teralba Conglomerate is based on an angle of break of 20° on either side of the pillar. The tributary length is equal to the average pillar length (95 m) plus the cut-through width (5 m).

Table 3.4 Weight of the overburden on the chain pillar between MWS2 and MWS3

Unit	Unit weight (kg/m³)	Depth to base (m)	Thickness (m)	Tributary width (m)	Tributary length (m)	Weight (MN)
Water	1000	-7.4	7	137.0	100.0	1019
Sediment	1500	-17.4	10	137.0	100.0	2044
Rockhead to the base of the Teralba Conglomerate	2500	-150.4	133	137.0	100.0	45,544
Base of the Teralba Conglomerate to the roof of the Fassifern Seam	2500	-173.9	24	48.6	100.0	2863
					Total	51,470

The total stress in the pillar is equal to the weight on the pillar divided by its area:

Equation 6 $\sigma_p = 51,470 \text{ MN} / (95\text{m x } 40\text{m}) = 13.5 \text{ MPa}$

The pillar Stability Index (SI), therefore, is:

Equation 7 SI = 41 MPa / 13.5 MPa = 3.0

The SI is greater than 2.7 and, therefore, the pillar is considered to remain intact with minimal long-term creep. The vertical subsidence for an intact pillar (refer to the right side of Fig. 3.10) is 0.06h (i.e. 0.06 times the mining height of 3.5 m). The vertical subsidence based on Mills and Edwards (1997), therefore, is:

Equation 8 $S_p = 0.06 \times 3.5 \text{ m} = 0.21 \text{ mm}$ (i.e. 210 mm)

It is noted that the predicted vertical subsidence of 210 mm includes both the pillar component and sagging component of vertical subsidence.

ACARP (2003):

The original predictions for MW1 to MW12 (DgS, 2013) were determined using the method outlined in ACARP Project No. C10023 (ACARP, 2003). The exceedance above MW7 to MW12 has been considered to be the result of the supercritical mining width reducing the spanning capacity of the overburden which then in turn overloaded the chain pillars. This behaviour occurred after the overall mining void width was greater than the critical width that develops after the extraction of three or more miniwalls.

The overall mining void width for MWS2 and MWS3 is 234 m (i.e. two times 97 m miniwalls plus 40 m pillar) and it is less than the critical width. It is considered, therefore, that the 2003 ACARP should provide a reasonable indication of the vertical subsidence for the first two miniwalls in the current series (i.e. MWS2 and MWS3).

The relationship between the pillar component of vertical subsidence divided by mining height (S_p/T) versus the pillar stress (σ_p) is illustrated in Fig. 3.11 (Source: DgS, 2013 after ACARP, 2003).

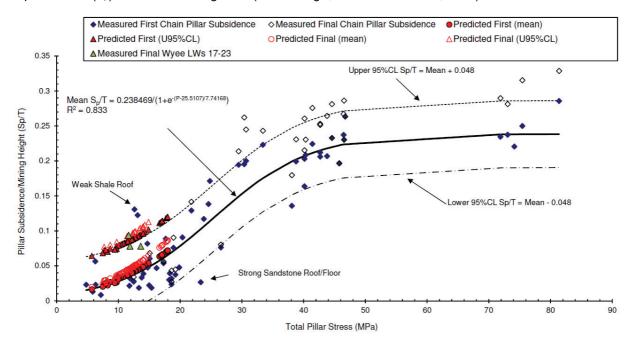


Fig. 3.11 Pillar component of vertical subsidence divided by mining height (S_p/T) versus total pillar stress (DgS, 2013 after ACARP, 2003)

The predicted mean pillar subsidence divided by mining height for a pillar stress is 13.5 MPa, therefore, is:

Equation 9
$$S_p/T = 0.238469/(1+e^{(-13.5-25.5107)/7.74168}) = 0.042$$

The predicted mean pillar subsidence based on a mining height of 3.5 m is:

Equation 10 $S_{p.mean} = 0.042 \times 3.5 \text{ m} = 0.150 \text{ m} \text{ (i.e. } 150 \text{ mm)}$

The upper 95 % confidence level based on a mining height of 3.5 m is:

Equation 11 $S_{p.95\%} = (0.042 + 0.048) \times 3.5 \text{ m} = 0.315 \text{ m} \text{ (i.e. } 315 \text{ mm)}$

The predicted pillar component of vertical subsidence obtained using the 2003 ACARP method therefore is 150 mm. The predicted upperbound vertical subsidence based on the 95 % confidence level is 315 mm.

Elastic model:

The chain pillar between MWS2 and MWS3 has an SI greater than 2.7 and a width-to-height (w/h) ratio greater than 5. It is expected that the pillar will remain intact with minimal long-term creep. The predicted pillar component of vertical subsidence therefore can be determined from the predicted elastic compression of the pillar, roof and floor. The methodology has been based on that outlined by Das (1986).

The pillar component of vertical subsidence is the sum of the compression of the pillar (P_p) , the roof strata (P_r) and floor strata (P_f) as follows:

Equation 12 $S_p = P_p + P_r + P_f$

The compression of the pillar is provided by:

Equation 13 $P_p = \sigma_{net} h/E_c$

where σ_{net} = change in vertical stress (MPa)

h = height of the pillar (m)

E_c = elastic modulus of coal (MPa)

The compression of the roof and floor is provided by:

Equation 14 $P_{r/f} = \sigma_{net} w(1-v^2)/E_{r/f}$

where w = width of the pillar (m)

 $E_{r/f}$ = elastic modulus of roof / floor strata (MPa)

v = Poisson's ratio

The roof and floor comprise interbedded strata of varying stiffnesses. The compression of multi-layered strata in the roof and floor is determined by summing the components from the strata within a distance of one pillar width (w) of the working section:

Equation 15 $P_{r/f} = \sigma_{net} \sum t_i (1-v_i^2)/E_i$

where t_i = thickness of the 'i^{th'} unit (m) located within a distance of

one pillar width (w) of the working section, i.e. Σ t_i = w

E_i = elastic modulus of the 'ith' unit (MPa)

v_i = Poisson's ratio of the 'ith' unit

The initial stress on the pillar (i.e. prior to secondary extraction) due to the weight of the water, sediment and rock in the overburden is 4.1 MPa. The final stress on the pillar (i.e. after secondary extraction) is 13.5 MPa, as shown in Equation 6. The change in stress (σ_{net}) due to secondary extraction, therefore, is 9.4 MPa.

A summary of the strata that are located within a distance of one pillar width (w, i.e. 40 m) of the working section and their thicknesses is provided in Table 3.5. The elastic modulus and Poisson's ratio for the coal seam, roof strata and floor strata (after DgS, 2013) are also provided in this table. These values represent the averages for each member and, therefore, are suitable for the elastic compression analysis.

Table 3.5 Properties of the roof, seam and floor (properties after DgS, 2013)

Location	Units	Thickness (m)	Elastic modulus (GPa)	Poisson's ratio
	Teralba Conglomerate	> 10	5.0	0.25
Roof	Sandstone	2	5.0	0.25
Roui	Karingal Conglomerate	8	5.0	0.25
	Awaba tuff and shale	20	1.5	0.25
Fassifern Seam	Working section	3.5*	1.5	0.25
rassilem Seam	Basal section	2	1.5	0.25
Floor	Claystone and shaley coal	2	1.5	0.35
FIUUI	Conglomerate, sandstone and shale	> 36	5.0	0.25

Note: * denotes that the full working thickness of 3.5 m has been adopted rather than the pillar height of 3.2 m.

The predicted component of vertical subsidence due to the pillar component (comprising compression of the pillar, roof and floor strata) is provided by:

Equation 16 $S_p = 20 + 155 + 85 = 260 \text{ mm}$

The predicted pillar component of vertical subsidence obtained using the elastic model therefore is 260 mm.

A summary of the predictions for the pillar component of vertical subsidence is provided in Table 3.6.

Table 3.6 Predictions for the pillar component of vertical subsidence for MWS2 and MWS3

Method	Predicted vertical subsidence (mm)	Notes
Monitoring data for MW1 to MW12	200	Includes a component of
Mills and Edwards (1997)	Mills and Edwards (1997) 210	
ACARP (2003)	150 mm (mean)	315 mm (upper 95 % confidence level)
Elastic model (Das, 1986)	260	Pillar, roof and floor compression

The predicted pillar component of vertical subsidence (S_p) has therefore been conservatively taken as 260 mm, being the maximum value derived from the four empirical methods.

3.5.3. Abutment component

The abutment on the tailgate side of MWS2 comprise 105 m by 32.6 m pillars separated by 5 m wide cut-throughs and the abutment on the maingate side of MWS3 comprise 105 m by 40 m pillars separated by 5 m wide cut-throughs. The minimum abutment pillar strength based on Mills and Edwards (1997) is as follows:

Equation 17 $Q_p = 8(0.64 + 0.36 \times 32.6/3.2) = 34 MPa$

The abutment pillars support the overburden on one side only (i.e. miniwall on one side and solid coal on the other side). It is predicted that the pillars support three-quarters of the abutment load and the adjacent solid coal supports the remaining one-quarter of the abutment load. The total stress in each of the abutment pillars is equal to the load on each pillar divided by its area:

Equation 18 $\sigma_p = 23,335 \text{ MN} / (105 \text{m x } 32.6 \text{m}) = 6.8 \text{ MPa}$

The pillar Stability Index (SI), therefore, is:

Equation 19 SI = 34 MPa / 6.8 MPa = 5.0

The Stability Index is greater than 2.7 and, therefore, the abutment pillars are considered to remain intact with minimal long-term creep. The predicted abutment component of vertical subsidence based on the elastic model (after Das, 1986) therefore is:

Equation 20 $S_a = 10 + 60 + 30 = 100 \text{ mm}$

The predicted abutment component of vertical subsidence (Sa) is 100 mm.

3.5.4. Sagging component

The strata between the base of the Teralba Conglomerate and rockhead span across the miniwall voids. The spanning capacities of these units are dependent on the many factors including the: miniwall void width, the overall mining void width, depth of cover, thickness and strength of the units, and the surcharge.

The sagging component of vertical subsidence has been determined using a numerical model based on Universal Distinct Element Code (UDEC). This method is a two-dimensional Discrete Element Method (DEM) comprising deformable elements that interact via compliant contacts (Itasca, 2015).

The numerical model has not been designed to analyse the complex interaction between the chain pillar, claystone floor and the immediate roof. The model has been designed to assess the sagging of the strata from rockhead down to the base of the Teralba Conglomerate (i.e. above the caving zone) across the miniwall voids. Whilst the chain pillars, seam floor and seam roof have been modelled, the deformations have only been assessed above the base of the Teralba Conglomerate.

The UDEC model has been derived from the *base model* that was originally developed for the Southern Coalfield (Barbato, 2017). The numerical model has been updated for the local stratigraphy at CVC and for the geometry of the miniwalls.

The void widths of MWS2 and MWS3 are 97 m and the chain pillar width is 40 m. The average depth of the Fassifern seam below rockhead within the mining area is 150 m. The edges of the numerical model have been taken as four times the average depth of the seam (i.e. 600 m) from the outsides of the miniwall edges. The overall width of the model therefore is 1434 m.

A summary of the stratigraphy adopted in the UDEC model is provided in Table 3.7. The overall depth of the numerical model is 258 m. The depths of the modelled element (i.e. blocks) have been taken as 5 m for the conglomerate and sandstone units, 3 m to 4 m for the shale and tuff units and 1 m for the coal and claystone units. The aspect ratio for the elements has been taken as 1.5 wide to 1.0 high.

Table 3.7 Stratigraphy adopted in the UDEC model

Unit	Thickness (m)	Depth below rockhead to base of unit (m)	Element size (H x V, m x m)
Sandstone	10	10	7.5 x 5
Conglomerate	20	30	7.5 x 5
Shale	20	50	6 x 4
Conglomerate	20	70	7.5 x 5
Sandstone	20	90	7.5 x 5
Conglomerate	30	120	7.5 x 5
Tuff	30	150	4.5 x 3
Coal (working section)	3*	153	1.5 x 1
Coal (basal section)	3	156	1.5 x 1
Claystone	2	158	1.5 x 1
Sub-floor	100	258	15 x 10

<u>Note</u>: * denotes that the working section has been modelled as 3 m thick. The results have been scaled by a factor of 1.17 to provide an equivalent mining height of 3.5 m.

The material properties for the UDEC model have been based on those outlined in the reports by DgS (2013 and 2018b). A summary of the properties for the conglomerate, sandstone/siltstone, shale, tuff and coal units is provided in Table 3.8. These values represent the latest and specific properties for each unit.

Table 3.8 Material properties adopted in the UDEC model (based on DgS, 2013 and 2018b)

Unit	Unit weight (kg/m³)	UCS (MPa)	Elastic modulus (GPa)	Poisson's ratio
Conglomerate	2500	40 to 60	5 to 15	0.25
Sandstone/Siltstone	2500	20 to 30	3 to 5	0.25
Shale	2500	12 to 15	1.5 to 2.25	0.25
Tuff	2500	1.65 to 2.15	1.5 to 3.0	0.25
Coal	1400	15 to 20	1.5 to 2.0	0.25

A parametric analysis has identified that the material strength properties (i.e. cohesion and friction angle) have little influence, if any, on the maximum modelled vertical subsidence (Barbato, 2017). The cohesion and friction angle for the block elements therefore have adopted the *base model* values. The parametric analysis also showed that the material stiffness properties (i.e. elastic modulus and Poisson's ratio) have a lesser influence on the sagging component of vertical subsidence when compared with that for the joint strength properties.

A Coulomb slip with residual strength model has been adopted for the horizontal and vertical discontinuities in the numerical model. The joint properties have been taken as the values calibrated in the *base model* for each of the member types. A parametric analysis identified that the joint stiffness properties (i.e. normal and shear) have little influence, if any, on the maximum modelled vertical subsidence (Barbato, 2017).

The numerical model was initially reviewed using the monitoring data for the existing MW1 to MW12. Four additional models were established comprising: five miniwalls with 97 m void widths and 33 m pillar widths; depths of the seam below rockhead ranging between 180 m and 200 m; and thicknesses of the Teralba Conglomerate ranging between 20 m and 40 m.

The modelled sagging component of vertical subsidence for these four numerical models ranged between 30 mm and 40 mm. It is not possible to compare these low-level movements with those measured above the existing MW1 to MW12 since they are less than the order of tolerance for the bathymetric surveys. The sagging component of vertical subsidence is not apparent in the monitoring data above MW1 to MW3 and MW6 and above the eastern ends of MW7 to MW12 (refer to Fig. 3.2) indicating that this component is considerably less than the pillar component.

The modelled profiles of incremental vertical subsidence obtained from the UDEC model for MWS2 and MWS3 are illustrated in Fig. 3.12. The incremental profiles represent the additional movements due to the extraction of each miniwall. The sagging component of vertical subsidence (S_s) is equal to the maximum modelled vertical subsidence minus the average vertical subsidence due to the pillar component (S_p) and abutment component (S_a).

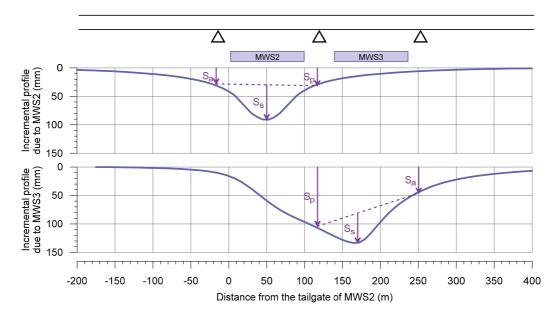


Fig. 3.12 Modelled profiles of vertical subsidence for MWS2 and MWS3

The predicted sagging component of vertical subsidence for MWS2 and MWS3 obtained from the numerical model is between 50 mm and 60 mm. This component is small when compared with the predicted pillar component of vertical subsidence of 260 mm. The lower-level sagging component of vertical subsidence indicates that the strata in the upper parts of the overburden arch over the extracted voids.

The sagging component of vertical subsidence for MWS2 and MWS3 has been taken as 60 mm.

3.5.5. Maximum predicted vertical subsidence

The IPM has been calibrated based on each of the predicted components of vertical subsidence. The model has adopted a pillar component of 260 mm, an abutment component of 100 mm and a sagging component of 60 mm. The IPM also includes an additional component due to long-term residual movements of approximately 10 % to 20 %.

The maximum predicted vertical subsidence due to the extraction of MWS2 and MWS3 obtained using the calibrated IPM therefore is 290 mm. The maximum predicted vertical subsidence, tilt, curvature and strain for the miniwalls are summarised in Chapter 4.

3.5.6. Effects of geological structures

An inferred normal fault is located on the north-eastern side of MWS3. The fault is adjacent to the maingate of MWS3 at its commencing end. The distance of the fault increases along the length of this miniwall. It is located approximately 220 m north-west of MWS3 at its finishing end. The throw of this fault is approximately 2 m and it dips towards the north-east at approximately 60° (Strata², 2019). It is also possible that other minor faults could be present within the mining area.

The effect of the inferred fault or other unidentified minor faults on the predicted subsidence for MWS2 and MWS3 was reviewed using the UDEC model. Several numerical models were analysed comprising a series of miniwalls with the depths of the seam below rockhead ranging between 150 m and 200 m and the thicknesses of the Teralba Conglomerate ranging between 20 m and 40 m. These ranges were selected to cover those for MWS2 and MWS3 as well as for the existing MW1 to MW12.

The modelled vertical subsidence for the base models were compared with those determined when normal faults (i.e. discontinuities) were introduced. These discontinuities were modelled with a 60° to 70° dip adjacent to the chain pillar midway through the series. The faults were modelled with dips towards and away from the direction of the mining sequence.

The numerical analyses found that there was slightly increased vertical subsidence of 10 mm to 20 mm due to the miniwall located immediately adjacent to the normal fault and within the hanging wall block (i.e. on the down-throw side). There was little to no increase in vertical subsidence for the miniwall located immediately adjacent to the normal fault and within the foot wall block (i.e. on the up-throw side). Similarly, there was no increase in vertical subsidence for the miniwalls located more than one panel width from the modelled faults.

It is not expected, therefore, that the inferred normal fault or other unidentified minor faults would result in a significant increase in the vertical subsidence due to the extraction of MWS2 and MWS3. This is supported by the fact that there was no obvious relationship between vertical subsidence and the presence or absence of major geological structures for the existing MW1 to MW12 (Strata², 2019).

The surface expression (i.e. at rockhead) of the inferred fault adjacent to the maingate of MWS3 could result in localised increased compressive strain. However, the numerical analyses did not show any significant change in the horizontal movements at rockhead. The lake bed sediment is more than 10 m thick at the commencing end of MWS3. It is unlikely, therefore, that there would be measurable strain at the lake bed due to the thickness of the sediment.

3.6. Historic workings in the Wallarah Seam

There are historic workings in the Wallarah Seam located to the south-west and to the south-east of MWS2 and MWS3. These historic workings are shown in Drawing No. MSEC979-01.

Historic partial extraction has been carried out in the panel located south-west of MWS2 and MWS3. The workings comprise 42 m wide goafs (i.e. extracted pillars) between 18 m by 18 m remnant pillars. These historic workings are located 300 m from MWS2 at their closest point, i.e. two times the depth of cover from the miniwalls. At this distance, it is very unlikely that the extraction of MWS2 and MWS3 would affect the load on or the stability of these historic workings.

Historic first workings only have been carried out to the south-east of MWS2 and MWS3 and beneath the foreshore. These historic workings are located outside the 26.5° and 35° angles of draw. It is unlikely that the extraction of MWS2 and MWS3 would affect the load on or the stability of these historic first workings.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of MWS2 and MWS3. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapter 5.

The predicted vertical subsidence, tilt, curvature and strain for MWS2 and MWS3 have been obtained using the IPM. The subsidence model has been calibrated using the locally available monitoring and geotechnical data at CVC and using other empirical and mechanistic methods, as described in Chapter 3.

4.2. Maximum predicted conventional vertical subsidence, tilt and curvature

A summary of the maximum predicted values of incremental conventional vertical subsidence, tilt and curvature due to the extraction of each of MWS2 and MWS3 is provided in Table 4.1. The incremental values are the additional movements due to each miniwall.

Table 4.1 Maximum predicted incremental conventional vertical subsidence, tilt and curvature due to the extraction of each of the miniwalls

Due to miniwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km ⁻¹)	Maximum predicted incremental sagging curvature (km ⁻¹)
MWS2	130	2	0.03	0.07
MWS3	260	5	0.14	0.30

The predicted total vertical subsidence contours after the extraction of MWS2 and MWS3 are shown in Drawings Nos. MSEC979-12 and MSEC979-13, respectively. The predicted limit of vertical subsidence (i.e. the 26.5° angle of draw line) for MWS1 is also shown in these drawings. The predicted limit of vertical subsidence for MWS1 is located outside the predicted 20 mm subsidence contour for MWS2 and MWS3. The additional vertical subsidence due to MWS1, within the predicted limit of vertical subsidence for MWS2 and MWS3, therefore, is considered to be negligible.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature after the extraction of MWS2 and MWS3 is provided in Table 4.2. The total parameters represent the accumulated movements within the 26.5° angle of draw for MWS2 and MWS3.

Table 4.2 Maximum predicted total conventional subsidence, tilt and curvature

Miniwa	ılls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km ⁻¹)	Maximum predicted total sagging curvature (km ⁻¹)
MWS2 and	MWS3	290	6	0.10	0.30

The maximum predicted total vertical subsidence of 290 mm represents 8 % of the proposed extraction height of 3.5 m. The greatest vertical subsidence occurs directly above MWS3.

The maximum predicted total tilt is 6 mm/m (i.e. 0.6 %, or 1 in 167) and it occurs adjacent to the maingate of MWS3. The maximum predicted total conventional curvatures are 0.10 km⁻¹ hogging and 0.30 km⁻¹ sagging, which represent minimum radii of curvatures of 10 km and 3.3 km, respectively.

The predicted conventional subsidence parameters vary across the mining area. To illustrate this variation, the predicted profiles of vertical subsidence, tilt and curvature have been determined along two prediction lines. The predicted profiles of total vertical subsidence, tilt and curvature along Prediction Lines 1 and 2 are shown in Figs. C.01 and C.02, respectively, in Appendix C. The locations of these prediction lines are shown in Drawings Nos. MSEC979-12 and MSEC979-13.

4.3. Predicted strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

The conventional (i.e. classical or systematic) strains can be determined based on the average relationship between curvature and strain. Similar relationships have been proposed by various authors. Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains.

The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Newcastle and Hunter Coalfields, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

The maximum predicted conventional strains at rockhead due to MWS2 and MWS3, based on applying a factor of 10 to the maximum predicted curvatures, are 1 mm/m tensile and 3 mm/m compressive. These strains represent typical values when the ground subsides regularly with no localised, elevated or irregular strains. The maximum strains can be greater than these typical values, especially in the locations of near-surface geological structures.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters that are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature.

There is limited ground monitoring data available for panels with widths and depths of cover similar to those for MWS2 and MWS3. Newstan LW6 and LW7 had void widths of 100 m and were extracted from the West Borehole Seam at a depth of cover of 200 m. The strains measured along the LW5XL-Line were less than 0.5 mm/m. The experience at Newstan may indicate that the actual strains at rockhead for MWS2 and MWS3 could be less than those predicted using the linear relationship with curvature.

The bedrock is overlain by 9 m and 23 m of sediment directly above MWS2 and MWS3. The sediment will smooth out the localised strains at rockhead. It is expected that the strains at the top of the sediment (i.e. lake bed) will be less than 0.5 mm/m.

The extraction of MWS2 and MWS3 could result in fracturing at rockhead. Also, localised compressive strains could develop at the surface expression of the inferred fault adjacent to the maingate of MWS3. It is unlikely that surface deformations at rockhead would be visible in the lake bed due to the considerable depth of the overlying sediment.

The maximum predicted conventional tensile strain due to MWS2 and MWS3 is 1 mm/m. The estimated fracture width, based on a typical joint spacing of 10 m, is in the order of 10 mm. However, it is more likely that a number of smaller fractures (i.e. widths of less than 10 mm) would develop rather than a single larger fracture.

The fractures at rockhead extend between 1 m to 3 m into the bedrock. The larger fractures would be infilled with the sediment on the lake bed. Further discussions on discontinuous and continuous fracturing and changes in the overburden permeability are provided in the report by Strata² (2019).

4.4. Predicted horizontal movements

The predicted conventional horizontal movements over the miniwalls are calculated by applying a factor to the predicted conventional tilt values. In the Newcastle and Hunter Coalfields a factor of 10 is generally adopted, being the same factor as that used to determine the conventional strains from the conventional curvatures, and this has been found to give a reasonable correlation with measured data. This factor will vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted conventional tilt for MWS2 and MWS3 is 6 mm/m. The maximum predicted conventional horizontal movement, therefore, is approximately 60 mm, i.e. 6 mm/m multiplied by a factor of 10. The horizontal movements are oriented towards the middle of the mining area.

The maximum modelled horizontal movement obtained from the numerical model (refer to Section 3.5.4) is 40 mm. This is a similar order to that obtained from the empirical relationship considering that it does not include the horizontal movement due to the pillar and abutment components.

The mining-induced horizontal movements can extend outside the 26.5° angle of draw line. These low-level horizontal movements tend to be bodily movements, towards the mining area, that are accompanied by very low-levels of strain, generally less than survey tolerance.

It is very unlikely that natural and built features near MWS2 and MWS3 would experience adverse impacts due to the far-field horizontal movements. However, features that could be sensitive to these low-level movements need to be considered. The features near MWS2 and MWS3 that are sensitive to far-field horizontal movements are the survey control marks.

4.5. Predicted deformations through the overburden

The deformations through the overburden have been determined from the UDEC model. The modelled profiles of vertical subsidence and horizontal movement through the overburden strata are illustrated in Fig. 4.1. The profiles have been taken through the centreline of MWS3, midway between the centreline and tailgate (referred to as the quarter point) and at the tailgate of this miniwall. The modelled profiles through MWS2 are similar to those presented below but with smaller magnitudes.

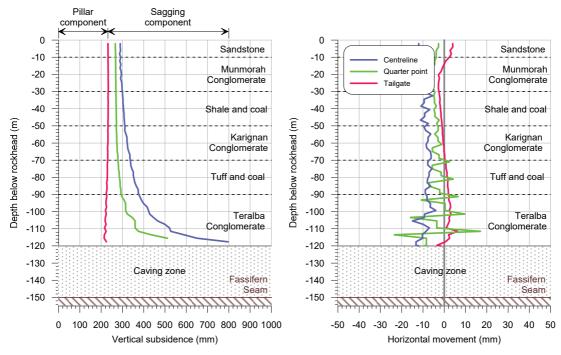


Fig. 4.1 Modelled profiles of vertical subsidence and horizontal movement through the overburden at the centreline, quarter point and tailgate of MWS3

The vertical subsidence at the minimal centreline varies from 290 mm (i.e. 8 % of the mining height) at rockhead to approximately 380 mm (i.e. 11 % of the mining height) near the top of the Teralba Conglomerate. The vertical subsidence increases more rapidly within the Teralba Conglomerate, with values exceeding 500 mm within the basal section. The vertical subsidence adjacent to the tailgate is approximately 260 mm (7 % of the mining height) from rockhead to the base of the Teralba Conglomerate.

The vertical strain (over a 20 m height) varies from 0.5 mm/m at rockhead to 1.5 mm/m at the base of the Karignan Conglomerate. The vertical strain within the Teralba Conglomerate varies from approximately 3.5 mm/m at the top to approximately 10 mm/m at the base of the unit. The vertical strain is greatest near the centreline of the miniwall and reduces towards the maingate and tailgate.

The horizontal shear on the bedding plane partings is small (i.e. less than 10 mm) between rockhead and the top of the Teralba Conglomerate. The horizontal shear within the Teralba Conglomerate varies from approximately 10 mm at the top to approximately 25 mm at the base of this unit. It is noted that the magnitudes of the horizontal shears are dependent on their spacings. Hence, fewer but larger horizontal shears, or more but smaller horizontal shears, could develop compared with those predicted, depending on their actual spacing.

Further discussions on discontinuous and continuous fracturing and changes in the overburden permeability are provided in the report by Strata² (2019).

5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE SURFACE FEATURES

The following sections provide the descriptions, predictions and impact assessments for the natural and built features located within the Study Area. The features located outside the Study Area, that are predicted to experience far-field movements and could be sensitive to these movements, have been included in these assessments, i.e. the survey control marks.

5.1. Lake bed

The existing and the predicted post-mining lake bed level contours are illustrated in Fig. 5.1. The existing contours have been derived from the base bathymetric surveys carried out between 2012 and 2016. These surveys measure the depth of the lake bed and have an accuracy in the order ±100 mm.

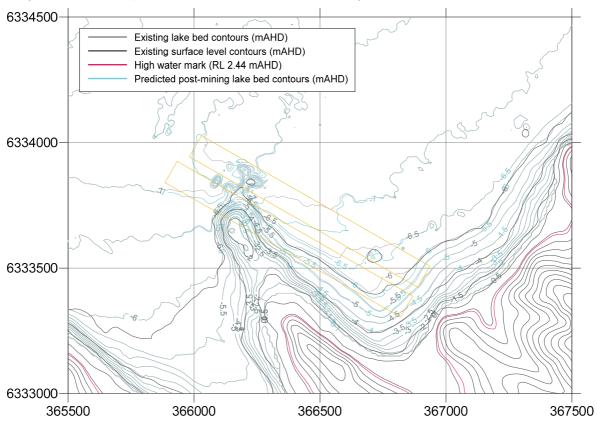


Fig. 5.1 Existing and predicted post-mining lake bed level contours

The predicted changes in the levels of the lake bed directly above the miniwalls are less than 0.3 m. These changes are small when compared with the overall depth of the lake which is typically greater than 5 m above the proposed mining area. It is considered unlikely, therefore, that there would be adverse impacts on the lake bed sediment due to these predicted low-level movements.

Further details on the benthic communities are provided in the Benthic Communities Management Plan which is included as part of the Extraction Plan.

5.2. Sea grass beds

The sea grass beds are located along the lake foreshore below the low-water mark. The mapped extents of the sea grass beds are shown in Drawing No. MSEC979-11. Photographs of these sea grass beds are also provided in Fig. 5.2.



Fig. 5.2 Sea grass beds along the lake foreshore

The Sea Grass Protection Barrier (SGPB) is defined by a 26.5° angle of draw from the mapped extents of the sea grass beds. It can be seen in Drawing No. MSEC979-02 and in Fig. 5.3 and Fig. 5.4 that MWS2 and MWS3 are located outside of the SGPB.

The predicted vertical subsidence at the mapped sea grass beds due to the proposed mining is less than 20 mm. Only low-level vertical subsidence is therefore expected at the sea grass beds due to the extraction of MWS2 and MWS3.

The monitoring and management strategies associated with the sea grass beds are undertaken in accordance with the Sea Grass Management Plan which is included as part of the Extraction Plan.

5.3. Lake foreshore

The lake foreshore is shown in Drawing No. MSEC979-11. The high-water mark, defined by the RL2.44 mAHD surface level contour, is also shown in that drawing.

The foreshore of Lake Macquarie at Summerland Point is located to the south and to the east of MWS2 and MWS3. Cross-section 1 and Long-section 1 have been taken near the commencing (i.e. south-eastern) ends of MWS2 and MWS3, where the miniwalls are closest to the lake foreshore. The locations of these sections are shown in Drawings Nos. MSEC979-03 to MSEC979-09. The natural surface, lake bed and seam level along Cross-section 1 and Long-section 1 near the commencing ends of the miniwalls are shown in Fig. 5.3 and Fig. 5.4, respectively.

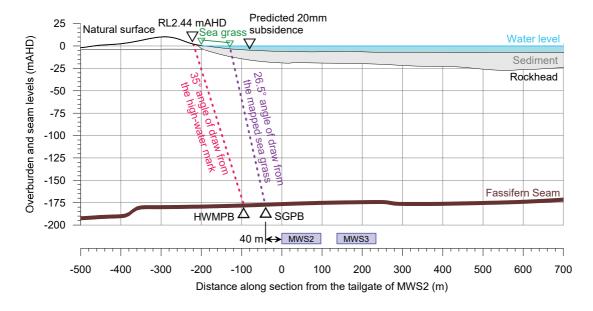


Fig. 5.3 Cross-section 1 near the commencing ends of MWS2 and MWS3

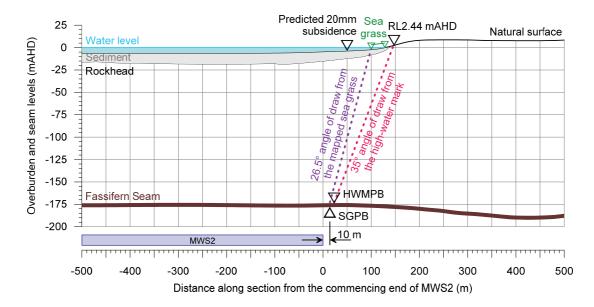


Fig. 5.4 Long-section 1 at the commencing end of MWS2

The High Water Mark Protection Barrier (HWMPB), defined by a 35° angle of draw from the high-water mark, is shown in Drawing No. MSEC979-02. It can be seen from that drawing and from Fig. 5.3 and Fig. 5.4 that MWS2 and MWS3 are located outside of the HWMPB. It can also be seen from the drawing and figures that MWS2 and MWS3 are also located outside the SGPB.

The predicted vertical subsidence at the high-water mark (i.e. RL2.44 mAHD) is less than 20 mm. It is unlikely, therefore, that there would be measurable changes in the high-water mark due to the extraction of MWS2 and MWS3.

5.4. Built features

The built features near MWS2 and MWS3 are shown in Drawing No. MSEC979-11.

The Pelican Rock Navigation Marker is located on the rock outcrop that extends into Lake Macquarie from Summerland Point. The marker is located outside but immediately adjacent to the tailgate of MWS2. A photograph of this navigation mark is provided in Fig. 5.5.



Fig. 5.5 Pelican Rock Navigation Marker

The predicted vertical subsidence for the navigation marker due to MWS2 and MWS3 is 90 mm. The predicted subsidence should be provided to Roads and Maritime Services (RMS) so that management strategies can be developed for the marker, if required.

Many of the built features located along the foreshore can be seen Fig. 5.6. These features include houses, other associated structures, jetties, moorings, roads and services.



Fig. 5.6 Built features along the foreshore at Summerland Point

The predicted vertical subsidence at the mapped sea grass beds and, hence, at the lake foreshore is less than 20 mm. It is unlikely, therefore, that there would be adverse impacts on the surface features located above the sea grass beds (i.e. jetties and moorings) or along the lake foreshore, including houses, other associated structures, roads and services.

The state survey control marks located near to MWS2 and MWS3 could experience low-level horizontal movements. NSW Spatial Services should be notified so that the affected state survey marks can be managed and re-established after active subsidence, as required.

APPENDIX A.	GLOSSARY OF TERMS AND DEFINITIONS

Glossary of terms and definitions

Some of the more common mining terms used in the report are defined below:

Angle of draw The angle of inclination from the vertical of the line connecting the goaf edge

of the workings and the limit of subsidence (which is usually taken as 20 mm

of subsidence).

Chain pillar A block of coal left unmined between the extraction panels.

Cover depth (H) The depth from the surface to the top of the seam. Cover depth is normally

provided as an average over the area of the panel.

Closure The reduction in the horizontal distance between the valley sides. The

> magnitude of closure, which is typically expressed in the units of millimetres (mm), is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible

strata mechanisms.

Critical area The area of extraction at which the maximum possible subsidence of one

point on the surface occurs.

Curvature The change in tilt between two adjacent sections of the tilt profile divided by

> the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of 1/kilometres (km-1), but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either

hogging (i.e. convex) or sagging (i.e. concave).

Extracted seam The thickness of coal that is extracted. The extracted seam thickness is

thickness normally given as an average over the area of the panel.

Effective extracted The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel. seam thickness (T)

Face length

The width of the coalface measured across the panel.

Far-field movements The measured horizontal movements at pegs that are located beyond the

panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area

and are accompanied by very low-levels of strain.

The void created by the extraction of the coal into which the immediate roof Goaf

layers collapse.

Goaf end factor A factor applied to reduce the predicted incremental subsidence at points

lying close to the commencing or finishing ribs of a panel.

Horizontal displacement The horizontal movement of a point on the surface of the ground as it settles

above an extracted panel.

Inflection point The point on the subsidence profile where the profile changes from a convex

curvature to a concave curvature. At this point the strain changes sign and

subsidence is approximately one half of S max.

Incremental subsidence The difference between the subsidence at a point before and after a panel is

mined. It is therefore the additional subsidence at a point resulting from the

excavation of a panel.

Panel The plan area of coal extraction.

Panel length (L) The longitudinal distance along a panel measured in the direction of (mining

from the commencing rib to the finishing rib.

Panel width (Wv) The transverse distance across a panel, usually equal to the face length plus

the widths of the roadways on each side.

Panel centre line An imaginary line drawn down the middle of the panel.

Pillar A block of coal left unmined.

Pillar width (Wpi) The shortest dimension of a pillar measured from the vertical edges of the

coal pillar, i.e. from rib to rib.

Shear deformations

The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear

Strain

The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation.

Tensile Strains are measured where the distance between two points or survey pegs increases and Compressive Strains where the distance between two points decreases. Whilst mining induced strains are measured along monitoring lines, ground shearing can occur both vertically, and horizontally across the directions of the monitoring lines.

Sub-critical area Subsidence

An area of panel smaller than the critical area.

The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured. but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.

Super-critical area

An area of panel greater than the critical area.

Tilt

The change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of millimetres per metre (mm/m). A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.

Uplift **Upsidence** An increase in the level of a point relative to its original position.

Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of millimetres (mm), is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

APPENDIX B. REFERENCES

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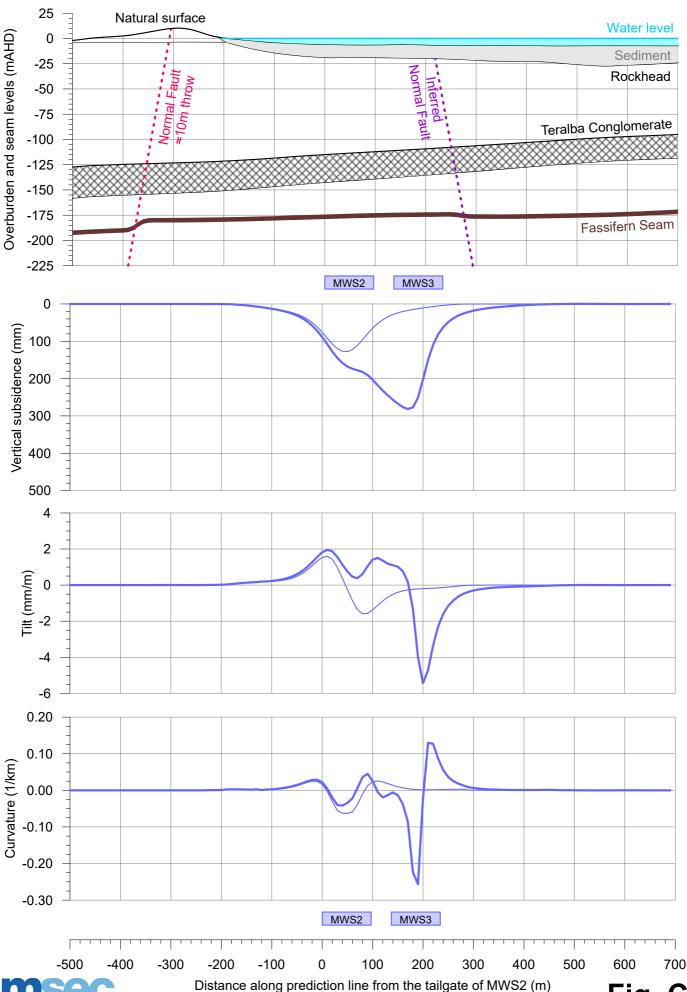
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APPENDIX C. FIGURES

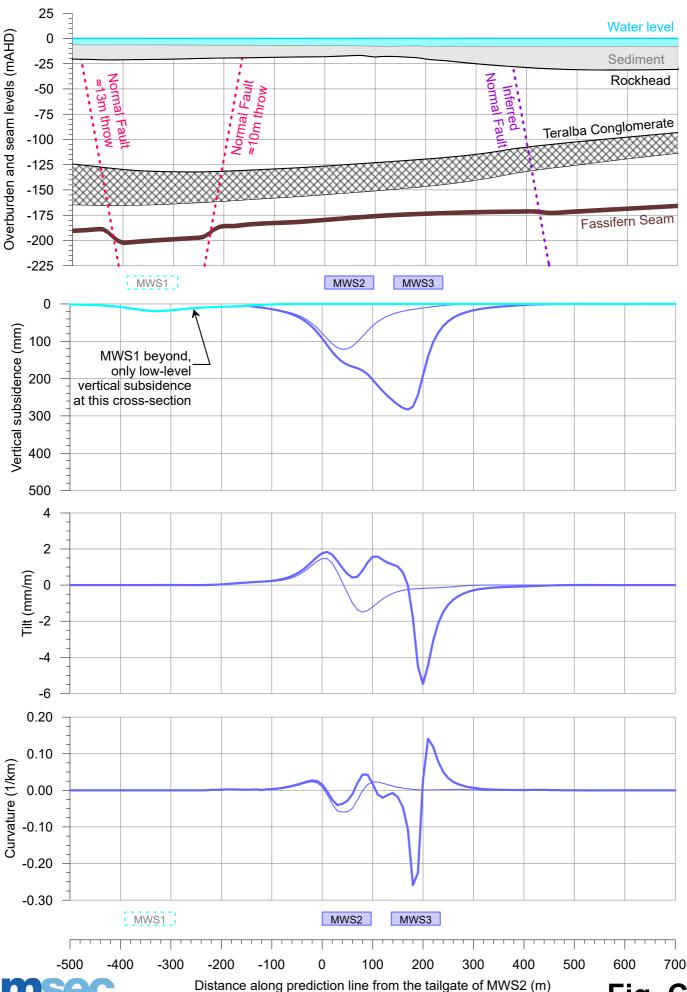
Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 due to the extraction of MWS2 and MWS3



msec

Fig. C.01

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 2 due to the extraction of MWS2 and MWS3



msec

Fig. C.02

APPENDIX D. DRAWINGS