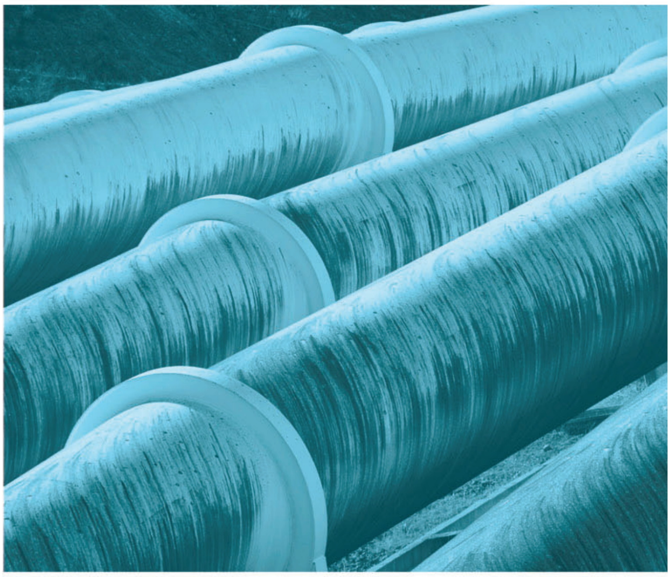
Statement of Environmental Effects

Mannering Colliery - Modification 5

Prepared for Great Southern Energy Pty Ltd (trading as Delta Coal)

May 2019



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Mannering Colliery - Modification 5

Report Number

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Client

Great Southern Energy Pty Ltd (trading as Delta Coal) (trading as Delta Coal)

Date

29 May 2019

Version

Final

Prepared by

Rachael Thelwell
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29 May 2019

Approved by

Nicole Armit
Associate Director
29 May 2019

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

Executive Summary

ES1 Proposed modification

Mannering Colliery (MC) is an underground coal mine located at the southern end of Lake Macquarie, approximately 60 kilometres (km) south of Newcastle. MC is approved under major project approval (MP06_0311) and is owned and operated by Great Southern Energy Pty Limited (trading as Delta Coal).

Underground mining commenced at MC in 1960 and extracted coal from the Great Northern and Fassifern Seams using both the bord and pillar and longwall mining methods. Coal extracted from MC is transported via a dedicated overland conveyor to Delta Electricity's Vales Point Power Station (VPPS) for domestic energy generation.

An underground linkage between MC and the adjacent Chain Valley Colliery (CVC) was approved and subsequently constructed in 2017 within the Fassifern Seam. CVC operates under State significant development consent (SSD-5465) and is also operated by Delta Coal. SSD-5465 permits the extraction of up to 2.1 Million tonnes per annum (Mtpa) of run-of-mine (ROM) coal from CVC's underground operations. At MC, MP06_0311 permits up to 1.1 Mtpa of ROM coal to be extracted and a total of up to 1.3 Mt sourced from MC or CVC to be handled annually at MC.

Delta Coal is seeking to modify the existing major project approval (MP06_0311) (Modification 5, referred to herein as the proposed modification) under Section 4.55 (2) of the NSW *Environmental Planning and Assessment Act 1979* primarily to enable:

- an increase in the rate of ROM coal handling at, and transport via overland conveyor from, MC up to the approved extraction limit at CVC;
- an extension of the project approval period from 30 June 2022 to 31 December 2027 (consistent with Schedule 2 Condition 5 of SSD-5465); and
- an alternative approach to mine design.

The proposed modification is an outcome of a review of Delta Coal's business requirements which:

- require the supply of coal in excess of the currently approved handling volume of 1.3 Mtpa to VPPS; and
- identified that capital and operating costs associated with the supply of coal from CVC to VPPS via MC will be lower than if supplied directly from CVC, as the existing infrastructure at MC has the proven ability to feed coal to VPPS at a higher and more efficient rate than CVC due to more advanced coal clearance infrastructure.

The increased volume of coal will be sourced either wholly from CVC which, as noted above, currently has an approved maximum extraction limit of 2.1 Mtpa of ROM coal, or from a combination of CVC and MC.

No changes to surface infrastructure at MC are proposed, with the existing infrastructure having adequate capacity to accommodate the additional coal throughput, and no additional plant or equipment are required. The increased coal throughput would all be dispatched via the existing overland conveyor to VPPS as currently approved. There will be no increase in approved employee numbers under the proposed modification.

ES2 Environmental considerations

Potential environmental and social impacts from the proposed modification were assessed as generally being indiscernible from those of the existing approved operations.

Environmental management at MC will continue under the proposed modification in accordance with the existing environmental management processes identified in the various approvals, licences and management plans.

ES2.1 Air quality

With respect to air quality, modelling of the MC operations was last completed in 2007 for the air quality assessment that accompanied the application for MP 06_0311. Although there will be no significant changes to surface infrastructure (the existing infrastructure has adequate capacity to accommodate the additional coal throughput) and no additional plant or equipment, the proposed modification provided the opportunity to complete a contemporary assessment of dust emissions and impacts of the MC operations.

ERM undertook the contemporary assessment of the approved project and determined the incremental change from the proposed modification compared to the approved project.

Two scenarios were assessed, based on the rate of coal handling and transportation at MC, namely ROM coal handling and transport of 1.3 Mtpa and 2.1 Mtpa, respectively. Dispersion modelling was conducted to predict the ground level concentrations at nearby sensitive receivers, applying conservative assumptions such as the simultaneous occurrence of all activities at the site at all times, when in reality it will rarely occur.

The modelling predicted a minimal change in the contribution of dust emissions from the proposed modification compared to the approved project and that the incremental PM_{10}, $PM_{2.5}$, total suspended particulates (TSP) and dust deposition are all below the impact assessment criteria at the closest assessment locations. The cumulative assessment, incorporating existing background dust levels, also indicates that the proposed modification is unlikely to result in any additional exceedances of relevant impact assessment criteria at the assessment locations.

ES2.2 Noise

NSW Department of Planning and Environment (DPE) requested that the previous operators of MC, LakeCoal, provide additional information regarding the effectiveness of noise mitigation works at the site, predicted noise emission levels and an analysis of further potential noise mitigation measures. Operational noise emissions are expected to be unchanged under the proposed modification and, therefore, no detailed noise assessment has been undertaken.

Potential noise emission levels from MC have been predicted and compared to the site's long-term noise goals outlined in MP 06_0311. Operational noise levels were assessed for the daytime, evening and night-time periods during worst case meteorological conditions.

Noise mitigation works implemented by the previous operators in 2018 have decreased site noise emission levels at all neighbouring noise-sensitive receivers. Further, current and proposed MC noise emissions are predicted to comply with the relevant long-term noise criteria outlined in MP 06_0311 at all assessment locations under worst case meteorological conditions. L_{Amax} noise level events at the site are also predicted to remain below the relevant sleep disturbance criteria.

ES2.3 Subsidence

Approved mining methods at MC are for bord and pillar first workings. Mine design parameters that have been stipulated in previous assessments for MC restrict mining methods to a particular bord and pillar configuration. The ability to use alternative configurations/layouts is sought as it would provide Delta Coal with increased flexibility in mining and the ability to maximise resource recovery. Any changes to mining layouts would be undertaken within existing approved levels of subsidence (ie <20 mm or 'zero' subsidence).

A detailed geotechnical assessment will be undertaken by a suitably qualified geotechnical engineer as part of the detailed mine plan design process.

ES3 Justification and conclusions

The proposed modification is a minor alteration to the approved development and is justified because:

- it will enable Delta Coal to meet Delta Electricity's requirement for the provision of coal in excess of the currently approved handling volume at MC of 1.3 Mtpa whilst reducing truck movements to VPPS by private roads (by reducing the volume of coal trucked directly from CVC to VPPS);
- it will enable the provision of additional coal to VPPS via an existing approved conveyor network and will enhance the security of coal supply to the local domestic power generator (Delta Electricity);
- capital and operating costs will be reduced across Delta Coal's operations as the existing infrastructure at MC has the proven ability to supply coal to VPPS at a higher rate;
- the increased flexibility in bord and pillar layout would result in maximised resource recovery from within the approved mining area;
- it will provide greater financial certainty for the mine, which in turn, will provide increased job security for Delta Coal's employees and associated ongoing social and economic benefits;
- the benefits can be achieved with minimal adverse environmental impact;
- it is aligned with the principles of ESD; and
- it meets all relevant government policies.

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1 Introduction

1.1 Background

Mannering Colliery (MC) is an underground coal mine located at the southern end of Lake Macquarie, approximately 60 kilometres (km) south of Newcastle (Figure 1.1). Underground mining commenced at MC in 1960 and has extracted coal from the Great Northern and Fassifern Seams using both the bord and pillar and longwall mining methods.

MC was granted project approval (MP06_0311) under Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) on 12 March 2008 and, as modified, permits the extraction of up to 1.1 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal until 30 June 2022. It also permits the handling of up to 1.3 Mtpa ROM coal with that coal transported via a dedicated overland conveyor to Delta Electricity's Vales Point Power Station (VPPS) for domestic energy generation.

Adjacent to and north-east of MC is Chain Valley Colliery (CVC), an underground coal mine also located at the southern end of Lake Macquarie. The CVC pit top is approximately 1.1 km north of MC's pit top area (see Figure 1.2). CVC operates under State significant development consent SSD-5465. An underground linkage between MC and CVC, enables the transfer of coal from CVC to MC. SSD-5465 permits the extraction of up to 2.1 Mtpa of ROM coal from CVC's underground operations.

Great Southern Energy Pty Limited (trading as Delta Coal) took over as owner and operator of MC and CVC in April 2019. Prior to the purchase by Great Southern Energy Pty Limited, LakeCoal Pty Ltd (LakeCoal) operated MC under an agreement with the owners of the mine; Centennial Mannering Pty Limited, a wholly owned subsidiary of Centennial Coal Company (Centennial).

1.2 Site and surrounds

MC's pit top area is within the Central Coast local government area (LGA) at the southern end of Lake Macquarie, approximately 3 km south of Mannering Park and west of Chain Valley Bay. The surface facilities (or pit top) are accessed from Ruttleys Road.

The closest residential areas to MC's pit top are the Macquarie Shores home village, Chain Valley Bay to the east, Kingfisher Shores to the north-east and Mannering Park beyond VPPS to the north. VPPS lies between MC's pit top and Mannering Park. Elsewhere, the areas to the north, south and west generally comprise industrial facilities and vegetation.

The land subject to the application comprises the land shown in Appendix 1 of MP06_0311 (as modified) with no changes as a result of the proposed modification. A site plan is provided as Figure 1.2.

Source: EMM (2019); DFSI (2017); GA (2011)

0 5 10 km

GDA 1994 MGA Zone 56

N

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KEY

- Mannering Colliery project approval boundary
- Rail line
- Main road
- Watercourse/drainage line
- Waterbody
- NPWS reserve
- State forest

Regional context

Mannering Colliery
Modification 5
Figure 1.1

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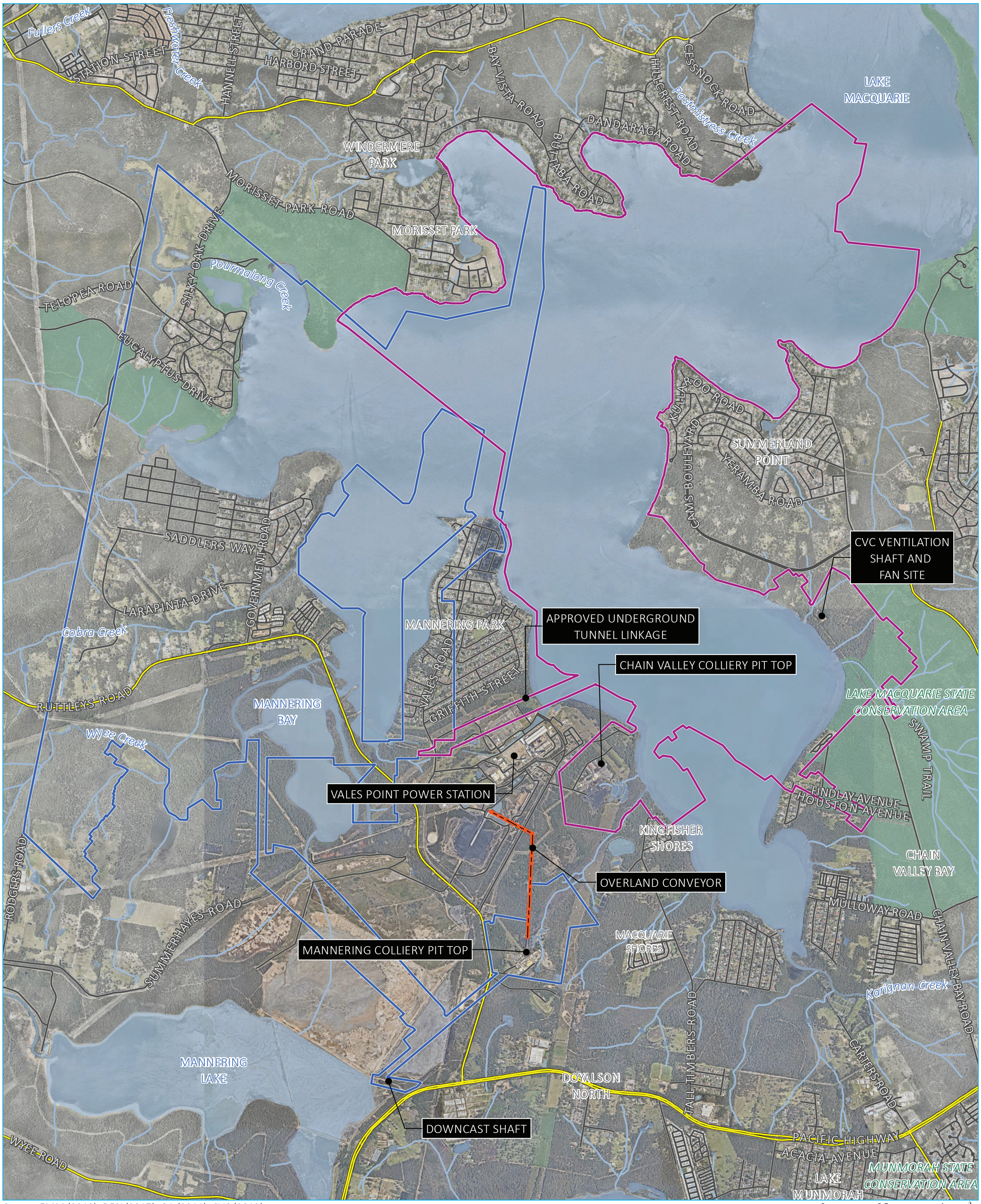

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Source: EMM (2019); DFSI (2017); GA (2011); CVC (2019)

0 0.5 1 km

GDA 1994 MGA Zone 56

N

KEY

- Chain Valley Colliery development consent boundary
- Mannering Colliery project approval boundary
- Alignment of overland conveyor to VPPS
- Main road
- Local road
- Watercourse/drainage line
- Waterbody
- NPWS reserve

Site plan

Mannering Colliery
Modification 5
Figure 1.2

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1.3 Proposed modification and justification

Delta Coal is seeking to modify MP06_0311 (Modification 5, referred to herein as the proposed modification) under Section 4.55(2) of the EP&A Act, primarily to enable:

- to permit an increase in the rate of ROM coal handling at, and transport via overland conveyor from, MC up to the approved extraction limit at CVC;
- an extension of the project approval period from 30 June 2022 to 31 December 2027 (consistent with Schedule 2 Condition 5 of SSD-5465); and
- greater flexibility in the bord and pillar working layout.

An underground linkage within the Fassifern Seam between CVC and MC enables coal extracted at CVC to be transferred and handled at MC. A separate modification of CVC's development consent (SSD-5465) is being sought to allow the transport of product coal from CVC to MC via the approved underground linkage at a rate up to the annual extraction level approved under SSD-5465.

As noted in Section 1.1, Delta Coal recently became both the owner and operator of MC and CVC. The common ownership enables the two operations to be managed as a combined operation with associated operational efficiencies. A review of Delta Coal's long term business requirements identified the need to increase the coal handling volume at MC as capital and operating costs associated with the supply of coal from CVC to VPPS via MC will be lower than if supplied directly from CVC as the existing infrastructure at MC has the proven ability to feed coal to VPPS at a higher and more efficient rate than CVC due to more advanced coal clearance infrastructure. Reduced capital and operating costs will result in greater financial certainty for both MC and CVC which, in turn, will provide increased job security for Delta Coal's workforce and associated ongoing social and economic benefits.

The proposed modification will also enable a reduction of haulage vehicle movements to and from VPPS due to the increased volume of coal being transferred via an existing conveyor network. This will result in a reduction in potential impacts relating to traffic, air quality and noise. The alternative, ie the supply of the additional coal requirement at VPPS directly from CVC, would necessitate an increase in truck movements, which could increase impacts associated with air quality, noise and public safety.

The proposed extension of the project approval period at MC aligns with CVC's development consent (SSD-5465), thereby enabling Delta Coal to operate both collieries in a co-ordinated manner. Environmental impacts beyond the current project approval period to 2027 would remain as approved.

Approved mining methods at MC are for bord and pillar first workings. Mine design parameters that have been stipulated in previous assessments for MC restrict mining methods to a particular bord and pillar configuration. The ability to use alternative configurations is sought as it would provide Delta Coal with increased flexibility in mining areas of remnant coal in the Fassifern Seam and the ability to maximise resource recovery. This modification, therefore, seeks increased flexibility in the bord and panel layout design. No change is sought to the currently approved levels of subsidence (ie <20 mm or 'zero' subsidence).

No changes to surface infrastructure are proposed, with the existing infrastructure having adequate capacity to accommodate the additional coal throughput, and no additional plant or equipment are required. The increased coal throughput would all be dispatched via the existing overland conveyor to VPPS as currently approved. There will also be no increase in approved employee numbers or operating hours under the proposed modification.

1.4 The applicant

The applicant is Great Southern Energy Pty Ltd and the relevant contact details are as follows:

Great Southern Energy Pty Ltd (trading as Delta Coal)
ACN: 621 409 201
ABN: 40 621 409 201
Level 7
287 Elizabeth Street
Sydney NSW 2000

Further information on MC and its operations can be found at deltacoal.com.au.

1.5 Report purpose

Delta Coal engaged EMM Consulting Pty Limited (EMM) to prepare this Statement of Environmental Effects (SEE), which is required to accompany an application to the NSW Department of Planning and Environment (DPE) to modify MP 06_0311. This SEE provides the background to and description of the proposed modification, an assessment of its potential impacts, management considerations and consultation undertaken.

2 Existing operations and proposed modification

2.1 Approved operations

2.1.1 Overview

Operations currently approved under MP 06_0311, include:

- extraction of up to 1.1 Mtpa of ROM coal from the Fassifern Seam until 30 June 2022;
- handling of up to 1.3 Mtpa of ROM coal from the site;
- first workings only using bord and pillar mining methods and the like;
- supply of coal to Delta Electricity's VPPS for domestic energy generation via a dedicated covered overland conveyor; and
- operation 24 hours, seven days a week.

MC was placed on care and maintenance on 27 November 2012 by then operators Centennial Coal. LakeCoal took over as operator of the mine in October 2013. Prior to being placed on care and maintenance, coal was extracted using bord and pillar mining (first workings) methods. The bord and pillar method involves the cutting of a regular grid of tunnels (headings and cut-throughs) within the coal seam whilst leaving behind pillars of coal bounded by the headings and cut-throughs to support the overlying strata.

Mining recommenced at MC between May 2016 and November 2017 to complete the construction of the underground linkage between MC and CVC which enables coal to transfer to VPPS via CVC then MC and its overland conveyors. The underground linkage was completed in August 2017.

Primary surface infrastructure at MC's pit top includes:

- offices, workshops, a bathhouse, stores, a lamp room, diesel and oil storage areas, firefighting equipment and water tanks;
- access roads and car parking facilities;
- product coal stockpile and reclaim facilities;
- a coal crushing facility (CCF) including a rotary breaker;
- conveyors for ROM and product coal transportation;
- a main haulage drift for personnel and materials movement;
- a conveyor drift for coal clearance and secondary access and egress;
- mine ventilation shaft and fans;
- reject stockpile and laydown areas;

- electrical substations; and
- water management infrastructure.

The existing approved operations allow for coal to be transported and handled from the underground workings at MC and/or CVC via a drift conveyor to the on-site CCF for screening and crushing at a total rate of up to 1.3 Mtpa. In periods when VPPS is unable to accept coal deliveries due to scheduled maintenance or conveyor breakdowns, the coal is temporarily stockpiled within the product coal stockpile area. Once VPPS is again able to accept coal, the stockpiled material is reclaimed, loaded onto the conveyor and dispatched to VPPS.

No coal is transported from MC via road.

2.1.2 Environmental management

Environmental management at MC is undertaken in accordance with:

- project approval MP06_0311, as modified;
- MC's Environmental Management Strategy and associated documents;
- various environmental management plans;
- MC's Environment Protection Licence (EPL) 191; and
- MC's mining operations plan (MOP) (*Chain Valley Colliery and Mannering Colliery, Mining Operations Plan, Rehabilitation Management Plan, 2018 – 2020* (LakeCoal 2018)).

The existing environmental management processes and procedures are referred to where relevant in the environmental assessment and management chapter (Chapter 5).

2.2 Proposed modification

A summary of the current approved operations and a comparison with the corresponding components of the proposed modification is provided in Table 2.1. The individual components of the proposed modification are further described in the following subsections.

Table 2.1 Current MC approval and proposed modification

Aspect	Current approval	Proposed modification
ROM coal extraction	Extraction of up to 1.1 Mtpa of ROM coal from the Fassifern Seam.	No change.
Mining methods	Bord-and-pillar mining methods where coal recovery is limited to first workings only.	No change to mining methods. Further detail on proposed mine design is given in Section 2.2.3.
Project life	Approved until 30 June 2022.	Extension to 31 December 2027.
Project approval area	Approximately 1,420 ha.	No change.
Existing surface infrastructure	Utilisation of existing surface infrastructure, including but not limited to the CCF, coal stockpile and reclaim facilities, overland conveyor between MC's pit top area and VPPS, worker's amenities, workshops, offices, carparks, ventilation fans. Asset Protection Zones (APZs) for bushfire protection around some main infrastructure at MC's pit top.	No change.
Coal processing	No coal processing other than use of CCF to screen and crush ROM coal.	No change.
Water demand and supply	Licensed daily discharge of up to 4 megalitres (ML). Potable water for use in surface facilities and underground operations supplied by Central Coast Council via a direct-metered pipeline.	No change.
Product coal transport	Up to 1.3 Mtpa of ROM coal transported/ handled directly to VPPS via a purpose built dedicated overland conveyor which is operated, maintained and located on land owned by Delta Electricity.	Handling and transport of ROM coal up to the approved extraction limit at CVC (currently at 2.1 Mtpa). Coal will be transported directly to VPPS via the overland conveyor for domestic power generation.
Hours of operation	24 hours, 7 days a week.	No change.
Mine access	Road access from Ruttleys Road.	No change.
Rehabilitation	Decommissioning of surface facilities and final rehabilitation at completion of operations.	No change.
Employment	Employment of 170 full time personnel.	No change.

2.2.1 Increase in rate of product coal handling and transport

The proposed modification seeks approval for an increase in the volume of ROM coal handled and transported via overland conveyor from MC from 1.3 Mtpa up to the approved extraction limit at CVC under SSD-5464 (currently at 2.1 Mtpa). Any extraction of coal from MC would be within this overall throughput limit.

As a result of the proposed modification, and requisite approvals for CVC (see Section 2.4), there is expected to be a net reduction in the volume of coal being trucked from CVC to VPPS via internal access roads (as the primary transfer of coal to VPPS is expected to be via the overland conveyor from MC).

All existing infrastructure at MC has adequate capacity to accommodate the proposed increase in coal handling and transport.

2.2.2 Extension to project approval period

As noted in Section 1.1, Delta Coal recently became the owner and operator of CVC and operator of MC. The common ownership enables the two operations to be managed as a combined operation with associated operational efficiencies. The proposed extension of the project approval period at MC from 30 June 2022 to 31 December 2027 aligns with CVC's development consent (SSD-5465), thereby enabling Delta Coal to operate both collieries in a co-ordinated manner.

2.2.3 Alternative approach to mine design

Bord and pillar mining is a method of underground coal mining where bords/headings and cut-throughs are driven to form pillars. The roadways and pillars formed are geotechnically designed to be long-term stable and, therefore, are considered a type of 'first workings' mining.

It is noted that previous assessments for MC have specified the following mine design parameters for bord and pillar mining:

- panels with five to seven headings and associated cut-throughs, resulting in long-term stable pillars on 30 metre (m) centres (24.5 m coal), with width to height ratios in excess of 8:1;
- barrier pillars approximately 54 m wide; and
- roadways generally maintained at 5.5 m wide and 2.9 m high.

These design parameters restrict the use of different bord and pillar configurations. To provide Delta Coal with increased flexibility in mining and the ability to maximise resource recovery, an alternative approach to mine design at MC is proposed whereby mining methods would be restricted by currently approved levels of subsidence (ie <20 mm or 'zero' subsidence) which would not change under the proposed modification.

A detailed geotechnical assessment will be undertaken by a suitably qualified geotechnical engineer as part of the detailed mine plan design process which would confirm that the bord and pillar configuration is long-term stable and would have less than 20 mm subsidence occurring. Further detail on subsidence is provided in Section 5.4.

2.3 Alternatives

Alternatives to the proposed increase to the rate of product coal handling and transport at MC would be for the rate to remain as per the currently approved limit, or for the limit to be increased but not to the approved extraction limit at CVC. Neither of these options would result in the improvement of potential environmental impacts as per the proposed modification. Both of these options would mean that trucking of product coal from CVC to VPPS would still be required via internal access roads rather than via MC's overland conveyor, with which there are associated operational costs and environmental impacts.

Another alternative to sending coal to VPPS via the underground link road and MC's coal clearance system would be to reconstruct/refurbish required components of the former overland conveyor and transfer system between CVC and the VPPS coal stockpile, a section of which is located immediately adjacent to CVC's access road. This alternative was previously considered under Modification 2 to SSD-5465 and was discounted due to the significant capital investment required to upgrade the former overland conveyor transfer system. The same considerations apply for the proposed modification and it is considered that this would not be a suitable alternative. The proposed modification will maximise the use of MC's existing surface infrastructure whilst removing the environmental impacts associated with the trucking of product coal from CVC to VPPS via internal access roads.

The greater financial certainty for MC and CVC which, in turn, will provide increased job security for Delta Coal's workforce and associated ongoing social and economic benefits resulting from the above, would not be realised if the proposed modification did not proceed. Further, if there were no extension of the project approval period, the benefits associated with the proposed modification would only be achieved to 2022, thereby missing the opportunity to extend these benefits until at least 31 December 2027.

Alternatives to the alternative approach to mine design would be to retain mine design parameters that restrict mining methods to particular bord and pillar configurations. This places additional restrictions on Delta Coal's ability to efficiently mine the approved resource with no added benefit of reduced environmental impacts such as subsidence.

2.4 Chain Valley Colliery

CVC operates under development consent SSD-5465, as modified, which was originally granted on 23 December 2013. The consent permits underground miniwall mining in the Fassifern Seam at a maximum rate of 2.1 Mtpa of ROM coal.

A modification application (Mod 3) to CVC's development consent SSD-5465 will be submitted separately to this application. CVC Mod 3 will seek approval for:

- transport of product coal from CVC to MC via the approved underground linkage between the two operations at a rate up to the annual production level approved under SSD-5465, as modified, which is currently 2.1 Mtpa; and
- a change in the definition of 'first workings' in SSD-5465 to allow the broader use of bord and pillar mining methods within the approved consent boundary.

CVC's Mod 3, together with this proposed modification, will provide Delta Coal with the ability, if required, to transport coal extracted at CVC under SSD-5465 to VPPS via the underground linkage and MC's facilities and conveyor system.

3 Statutory approval framework

3.1 Introduction

This chapter describes the relevant Commonwealth and State legislation and regulatory framework under which the proposed modification will be assessed and determined.

3.2 Planning approval history

Major project approval MP 06_0311 was granted by the Minister for Planning in March 2008. Prior to this date, MC operated under Section 74 of the *Mining Act 1992* (Mining Act), which exempted underground mines which had been operating under a mining lease granted prior to the implementation of the EP&A Act from the provisions of both environmental planning instruments and the EP&A Act. Section 74 of the Mining Act was repealed in December 2005 and an amendment of the NSW *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation) meant that an approval under the EP&A Act was required for MC's continued operation.

MP 06_0311 has been modified on four previous occasions. An overview of MP06_0311 as originally granted and each of the subsequent modifications is provided in Table 3.1. Further information on the approved operations is provided in Section 2.1.

Table 3.1 Overview of MP06_0311 and its modifications

Approval No.	Issue date	Summary of approved activity
MP 06_0311	March 2008	Extraction of up to 1.1 Mtpa of ROM coal from the Fassifern Seam by first workings only, using bord-and-pillar mining methods. Primary equipment items including but not limited to continuous miners, roof bolters, shuttle cars and drift conveyor systems. Primary infrastructure including but not limited to pit-top facilities such as coal crushing facility and conveyors for ROM and product coal; 25,000 tonne coal stock pile area; access roads and car parking facilities; mine ventilation shafts; and water management infrastructure. All of the coal produced at Mannering to be supplied directly to VPPS via a dedicated overland conveyor. Project approval period until 31 March 2018.
MP 06_0311 MOD1	25/10/2012	Extension of underground mining operations within the Fassifern Seam. Employment of up to 170 people full time.
MP 06_0311 MOD2	27/11/2014	Development and use of up to four first working headings within the Fassifern Seam to connect MC and CVC. Installation and use of an underground conveyor belt system and ancillary services enabling ROM coal to be transferred between CVC and MC. Use of existing MC infrastructure to transport coal from CVC's underground workings to VPPS at a rate not greater than 1.1 Mtpa, i.e. the rate approved under MP06_0311 at that time.
MP 06_0311 MOD3	16/12/2015	Extension of the project approval by approximately four years until 30 June 2022. Minor vegetation clearing/disturbance adjacent to some main infrastructure at MC's pit top to enable the extension/establishment of Asset Protection Zones (APZs) for bushfire fire protection and management.

Table 3.1 Overview of MP06_0311 and its modifications

Approval No.	Issue date	Summary of approved activity
		Use of existing infrastructure to handle and transport up to 1.3 Mtpa of ROM coal directly to VPPS via the overland conveyor (an increase of up to 0.2 Mtpa).
MP 06_0311 MOD4	18/8/2016	Administrative modification to confirm the use of the rotary breaker as part of ongoing operations at the Colliery.

3.3 State approvals

3.3.1 NSW Environmental Planning and Assessment Act 1979

i Former Part 3A projects

MP06_0311 was granted under Part 3A of the EP&A Act. Part 3A was repealed by the *Environmental Planning and Assessment Amendment (Part 3A Repeal) Act 2011* (Part 3A Repeal Act). As part of the repeal, transitional provisions were introduced (Schedule 6A of the EP&A Act) enabling 'transitional Part 3A projects' to continue to be subject to Part 3A of the EP&A Act (as in force immediately before the repeal and as modified by the Part 3A Repeal Act). Transitional Part 3A projects include projects that were the subject of an existing approval under Part 3A such as MP06_0311.

The transitional provisions retained the legal mechanism for Part 3A consents to be modified under the former Section 75W of the EP&A Act. The Part 3A Repeal Act also reintroduced the approval pathway for State significant development (SSD) under Division 4.1 of Part 4 of the EP&A Act. The pathway for modification of SSD consents was reverted to under Section 96 of the EP&A Act.

The transitional provisions for Part 3A projects and Section 75W in Schedule 6A of the EP&A Act were repealed by the *Environmental Planning & Assessment Amendment Act 2017* (2017 Amendment Act) which came into effect on 1 March 2018. The 2017 Amendment Act also renumbered sections of the EP&A Act, with Section 96 now referred to as Section 4.55.

Prior to any future modification application for former Part 3A projects being assessed or determined, they are required to be declared SSD under Clause 6 of Schedule 2 to the *Environmental Planning and Assessment (Savings, Transitional and Other Provisions) Regulation 2017*. The order of transition for MP06_0311 was published in the Government Gazette No 134 on 7 December 2018.

ii Modification applications

Due to the repeal of the transitional provisions for Section 75W, modification to MP06_0311 is required under Section 4.55 of the EP&A Act.

MP06_0311 is considered to be able to be modified under Section 4.55(2) which states:

> (2) Other modifications
>
> A consent authority may, on application being made by the applicant or any other person entitled to act on a consent granted by the consent authority and subject to and in accordance with the regulations, modify the consent if:
>
> (a) it is satisfied that the development to which the consent as modified relates is substantially the same development as the development for which consent was originally granted and before that consent as originally granted was modified (if at all), and
>
> (b) it has consulted with the relevant Minister, public authority or approval body (within the meaning of Division 4.8) in respect of a condition imposed as a requirement of a concurrence to the consent or in accordance with the general terms of an approval proposed to be granted by the approval body and that Minister, authority or body has not, within 21 days after being consulted, objected to the modification of that consent, and
>
> (c) it has notified the application in accordance with:
>
> (i) the regulations, if the regulations so require, or
>
> (ii) a development control plan, if the consent authority is a council that has made a development control plan that requires the notification or advertising of applications for modification of a development consent, and
>
> (d) it has considered any submissions made concerning the proposed modification within the period prescribed by the regulations or provided by the development control plan, as the case may be.
>
> Subsections (1) and (1A) do not apply to such a modification.

Satisfaction of the requirements of section 4.55(2) is demonstrated in Section 7.2 of this SEE.

iii Matters for consideration

Section 4.55(3) requires a consent authority to take into consideration relevant matters referred to in Section 4.15(1) of the EP&A Act when determining an application for modification of a consent under Section 4.55. The Section 4.15(1) matters and where they are addressed in this SEE are detailed in Table 3.2.

Table 3.2 EP&A Act Section 4.15(1) matters for consideration

Matter	Where addressed
(a) the provisions of:	
(i) any environmental planning instrument, and	Section 3.3.3
(ii) any proposed instrument that is or has been the subject of public consultation under this Act and that has been notified to the consent authority (unless the Planning Secretary has notified the consent authority that the making of the proposed instrument has been deferred definitely or has not been approved), and	Section 3.3.3
(iii) any development control plan, and	Development control plans do not apply to SSD projects.

Table 3.2 EP&A Act Section 4.15(1) matters for consideration

Matter	Where addressed
(iv) any planning agreement that has been entered into under section 7.4, or any draft planning agreement that a developer has offered to enter into under section 7.4, and	Not applicable to the proposed modification.
(v) the regulations (to the extent that they prescribe matters for the purposes of this paragraph)	Sections 3.3.1.iv and 3.3.1.v
that apply to the land to which the development application relates,	
(b) the likely impacts of that development, including environmental impacts on both the natural and built environments, and social and economic impacts in the locality,	Chapter 5
(c) the suitability of the site for the development,	Section 7.4
(d) any submissions made in accordance with this Act or the regulations,	The local community and relevant government agencies will be invited to make submissions on the proposed modification following submission of this SEE to DPE. The Minister for Planning and Public Places (or delegate) will consider any submissions received during determination of the application.
(e) the public interest.	Section 7.5

iv Form of application

The required content of a Section 4.55(2) application is detailed under Clause 115(1) of the EP&A Regulation. The Clause 115(1) requirements and where they are addressed in this document are detailed in Table 3.3.

Table 3.3 EP&A Regulation Clause 115(1) requirements

Requirement	Where addressed
(a) the name and address of the applicant	Section 1.2
(b) a description of the development to be carried out under the consent (as previously modified)	Section 3.1
(c) the address, and formal particulars of title, of the land on which the development is to be carried out,	The address of MC is: Off Ruttleys Road Doyalson North NSW 2259 For title details see Appendix 1 to MP06_0311.
(d) a description of the proposed modification to the development consent	Section 2.2
(e) a statement that indicates either: (i) that the modification is merely intended to correct a minor error, misdescription or miscalculation, or; (ii) that the modification is intended to have some other effect, as specified in the statement,	Section 1.3
(f) a description of the expected impacts of the modification;	Chapter 5
(g) an undertaking to the effect that the development (as to be modified) will remain substantially the same as the development that was originally approved;	Section 7.2

Table 3.3 EP&A Regulation Clause 115(1) requirements

Requirement	Where addressed
(g1) in the case of an application that is accompanied by a biodiversity development assessment report, the reasonable steps taken to obtain the like-for-like biodiversity credits required to be retired under the report under the report to offset the residual impacts on biodiversity values if different biodiversity credits are proposed to be used as offsets in accordance with the variation rules under the *Biodiversity Conservation Act 2016,*	The proposed modification will not result in any change to biodiversity impacts. The application is not required to be accompanied by a biodiversity development assessment report.
(h) if the applicant is not the owner of the land, a statement signed by the owner of the land to the effect that the owner consents to the making of the application (except where the application for the consent the subject of the modification was made, or could have been made, without the consent of the owner),	The application for the consent the subject of the modification was made, or could have been made, without the consent of the owner), as per clause 49 of the EP&A Regulation (see Section 3.3.1.v).
(i) a statement as to whether the application is being made to the Court (under section 4.55) or to the consent authority (under section 4.56),	Section 1.5
and, if the consent authority so requires, must be in the form approved by that authority.	The form of this application is consistent with DPE's requirements.

v Landowners notification

Clause 49 of the EP&A Regulation details the requirements for landowner's consent.

Under Clause 49(2) of the EP&A Regulation, landowner's consent is not required for an application for public notification development if the application instead gives notice of the application:

(a) by written notice to the owner of the land before the application is made, or

(b) by advertisement published in a newspaper circulating in the area in which the development is to be carried out no later than 14 days after the application is made.

The development is for public notification development and notification of the modification will be made in accordance with Clause 49(2) of the EP&A Regulation.

Clause 49(5) defines public notification development to include:

(i) State significant development set out in clause 5 (Mining) or 6 (Petroleum (oil and gas)) of Schedule 1 to State Environmental Planning Policy (State and Regional Development) 2011 but it does not include development to the extent that it is carried out on land that is a state conservation area reserved under the National Parks and Wildlife Act 1974, or

MP06_0311 applies to the land identified in Appendix 1 of MP06_0311. It is noted that part of this land overlaps with the Lake Macquarie State Conservation Area (SCA) which would exclude this area from the landowner's consent exemption under Clause 49(2). Section 3.10 of the *Mannering Colliery Environmental Assessment* (Hansen Bailey 2007) states that the project application excludes the surface areas to a depth of 40 m where the Lake Macquarie SCA (at the time a State Recreation Area) is. This is because the State Recreation Area was restricted to a depth of 40 m below the surface. Further, Section 3.3 of *Mannering Colliery – Extension of Mine Project Section 75W Modification to Project Approval 06_0311* (Centennial Coal 2012) notes that the now SCA (gazetted in 2011) was removed from the proposed extension of mining areas at MC.

This portion of the SCA (to a depth of 40 m) remains excluded from this modification application.

3.3.2 Other state legislation

The NSW *Protection of the Environment Operations Act 1997* (POEO Act) is the only Act relevant to the proposed modification as described below. The proposed modification will not involve any change to the previously approved underground mining at MC and there will be no change to existing surface facilities or infrastructure, all of which have adequate capacity to accommodate the proposed increase in coal handling and dispatch. Therefore, the provisions of the Mining Act, the NSW *Work Health and Safety (Mines) Act 2013* and the NSW *Coal Mine Subsidence Compensation Act 1961 2017* are not relevant to the activities associated with the proposed modification.

The POEO Act is the principal NSW environmental protection legislation and is administered by the NSW Environment Protection Authority (EPA). Delta Coal has an existing environment protection licence (EPL) No. 191 issued under the POEO Act for MC (EPL 191), which authorises the handling of up to 2 Mtpa of coal. Accordingly, approval of the proposed modification will require a variation to EPL No. 191 to reflect the increase in the rate of ROM coal throughput at MC.

3.3.3 Environmental planning instruments

i State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007

Mining operations at MC are permissible by virtue of Clause 7 of State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 (the Mining SEPP) which states that development for the purposes of underground coal mining is permissible on any land. Clause 12AB of the Mining SEPP identifies non-discretionary development standards for mining. Subclause (1) states that if a proposed development for the purposes of mining satisfies a development standard set out in that clause, the consent authority cannot require more onerous standards for those matters but does not prevent the consent authority granting consent even though any such standard is not complied with. The proposed modification satisfies the non-discretionary development standards for mining as detailed in Table 3.4.

Table 3.4 Assessment of the proposed modification against Mining SEPP non-discretionary development standards for mining

Development standard	Comments on compliance
The development does not result in a cumulative amenity noise level greater than the acceptable noise levels, as determined in accordance with Table 2.2 of the Noise Policy for Industry, for residences that are private dwellings.	The proposed modification will not result in additional noise emissions that will result in a cumulative amenity noise level greater than the acceptable noise levels. See Section 5.3 for further information. Therefore, this development standard is satisfied.
The development does not result in a cumulative annual average level greater than 25 $\mu g/m^3$ of PM_{10} or 8 $\mu g/m^3$ of $PM_{2.5}$ for private dwellings.	The proposed modification will not result in additional dust emissions that would result in a cumulative annual average level greater than 25 micrograms per cubic metre ($\mu g/m^3$) of PM_{10} or 8 $\mu g/m^3$ of $PM_{2.5}$ for private dwellings. See Section 5.2 for further information. Therefore, this development standard is satisfied.
Air blast overpressure caused by the development does not exceed: (a) 120 dB (Lin Peak) at any time, and (b) 115 dB (Lin Peak) for more than 5% of the total number of blasts over any period of 12 months, measured at any private dwelling or sensitive receiver.	The proposed modification does not involve activities that could cause ground vibration in excess of the development standards.

Table 3.4 Assessment of the proposed modification against Mining SEPP non-discretionary development standards for mining

Development standard	Comments on compliance
Ground vibration caused by the development does not exceed: (a) 10 mm/sec (peak particle velocity) at any time, and (b) 5 mm/sec (peak particle velocity) for more than 5% of the total number of blasts over any period of 12 months, measured at any private dwelling or sensitive receiver.	As above.
Any interference with an aquifer caused by the development does not exceed the respective water table, water pressure and water quality requirements specified for item 1 in columns 2, 3 and 4 of Table 1 of the Aquifer Interference Policy for each relevant water source listed in column 1 of that Table.	The proposed modification will not involve changes to the approved underground mining area or method and, as a result, no changes to groundwater or aquifers will occur.

The remaining Part 3 matters for consideration are detailed in Table 3.5 where relevant to the proposed modification.

Table 3.5 Mining SEPP Part 3 matters for consideration

Matter	Proposed modification
12 Compatibility of proposed mine, petroleum production or extractive industry with other land uses	
Before determining an application for consent for development for the purposes of mining, petroleum production or extractive industry, the consent authority must: (a) consider: (i) the existing uses and approved uses of land in the vicinity of the development, and (ii) whether or not the development is likely to have a significant impact on the uses that, in the opinion of the consent authority having regard to land use trends, are likely to be the preferred uses of land in the vicinity of the development, and (iii) any ways in which the development may be incompatible with any of those existing, approved or likely preferred uses, and (b) evaluate and compare the respective public benefits of the development and the land uses referred to in paragraph (a)(i) and a(ii), and (c) evaluate any measures proposed by the applicant to avoid or minimise any incompatibility, as referred to in paragraph (a)(iii).	Existing and approved uses of land in the vicinity of the development are detailed in Section 1.2. The proposed modification would not have a significant impact on these uses given that it is in relation to an existing underground mine, and there would be no change to the approved mining area, pit top infrastructure, operating hours or traffic generation. The proposed modification is likely to have a positive benefit on surrounding land uses by reducing the number of trucks transporting coal to VPPS.
12A Consideration of voluntary land acquisition and mitigation policy	
(2) Before determining an application for consent for State significant development for the purposes of mining, petroleum production or extractive industry, the consent authority must	The proposed modification is unlikely to result in any additional exceedances of relevant impact assessment criteria for noise or particulate matter at the assessment locations.

Table 3.5 Mining SEPP Part 3 matters for consideration

Matter	Proposed modification
consider any applicable provisions of the voluntary land acquisition and mitigation policy and, in particular: (a) any applicable provisions of the policy for the mitigation or avoidance of noise or particulate matter impacts outside the land on which the development is to be carried out, and (b) any applicable provisions of the policy relating to the developer making an offer to acquire land affected by those impacts.	The proposed extension to the project approval will extend potential noise and particulate matter impacts associated with the ongoing operation of MC. Environmental management at MC will continue in accordance with the existing environmental management processes identified in the various approvals, licences and management plans.
13 Compatibility of proposed development with mining, petroleum production or extractive industry	The proposed modification relates to an existing underground mine. Further, it will enable greater efficiencies across both of Delta Coal's operations (CVC and MC) due to more advanced coal clearance infrastructure at MC.
14 Natural resource management and environmental management	
(1) Before granting consent for development for the purposes of mining, petroleum production or extractive industry, the consent authority must consider whether or not the consent should be issued subject to conditions aimed at ensuring that the development is undertaken in an environmentally responsible manner, including conditions to ensure the following:	
(a) that impacts on significant water resources, including surface and groundwater resources, are avoided, or are minimised to the greatest extent practicable,	The proposed modification would not have impacts on surface or groundwater resources additional to those already approved. Refer to Section 5.5 for further information.
(b) that impacts on threatened species and biodiversity, are avoided, or are minimised to the greatest extent practicable,	The proposed modification would not impact on threatened species or biodiversity.
(c) that greenhouse gas emissions are minimised to the greatest extent practicable.	The proposed modification would not result in an increase in greenhouse gas emissions. The proposed extension to the project approval will extend the period of time over which greenhouse gas emissions are generated by MC. Environmental management at MC will continue in accordance with the existing environmental management processes identified in the various approvals, licences and management plans.
15 Resource recovery	
(1) Before granting consent for development for the purposes of mining, petroleum production or extractive industry, the consent authority must consider the efficiency or otherwise of the development in terms of resource recovery.	The proposed modification is a minor alteration to an approved coal mine operation which represents an orderly and economic use of a resource approved for extraction for use in domestic power generation. As noted in Section 1.1, Delta Coal recently became both the owner and operator of CVC and operator of MC. The common ownership enables the two operations to be managed as a combined operation with associated operational efficiencies.
16 Transport	The proposed modification does not propose to increase the volume of materials transported on public roads.
17 Rehabilitation	The proposed modification would not result in additional surface disturbance that would require rehabilitation of land.

ii Wyong Local Environmental Plan 2013

MC's pit top is located on land zoned SP2 Infrastructure and E2 Environmental Conservation pursuant to the Wyong Local Environmental Plan (LEP) 2013. Mining is not listed as being permissible with or without consent in the SP2 zone and, therefore, mining operations at MC would be prohibited under LEP 2013. However, as mentioned above, underground mining on any land is permissible under the Mining SEPP. In the event of an inconsistency, Section 36 of the EP&A Act stipulates that there is a general presumption that a State Environmental Planning Policy prevails over an LEP. Therefore, the prohibition under Wyong LEP 2013 does not affect permissibility.

A Draft Central Coast LEP was released for public exhibition from 6 December 2018 to 28 February 2019. Under the draft instrument the land remains zoned as SP2 and E2.

No further provisions of the Wyong LEP 2013 or the Draft Central Coast LEP are relevant to the proposed modification.

3.4 Commonwealth approvals

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) aims to protect matters deemed to be of national environmental significance (NES), namely:

- world heritage properties;
- places listed on the National Heritage Register;
- Ramsar wetlands of international significance;
- threatened flora and fauna species and ecological communities;
- migratory species;
- Commonwealth marine areas;
- the Great Barrier Reef Marine Park;
- nuclear actions (including uranium mining); and
- actions of development for coal seam gas or large coal mining on water resources.

If an action (or proposal) will, or is likely to, have a significant impact on any matters of NES, it is deemed to be a Controlled Action and requires approval from the Commonwealth Environment Minister or the Minister's delegate. To determine whether a proposed action would or is likely to be a Controlled Action, an action may be referred to the Department of the Environment and Energy.

As substantiated in Chapter 5, there are no matters of NES that have the potential to be impacted by the proposed modification. Therefore, a referral to the Commonwealth Department of the Environment and Energy is not required.

4 Stakeholder engagement

4.1 Introduction

As stated in its Environment and Community Policy, Delta Coal is committed to communicating and engaging with the community and other stakeholders regarding its activities. Consistent with this commitment, community consultation for MC is ongoing and includes a community consultative committee (CCC), Delta Coal's website deltacoal.com.au and information line (1800 687 557).

As outlined in the subsequent sections, consultation has been, and will continue to be, supplemented by activities that relate specifically to the proposed modification. The nature and extent of these stakeholder consultation activities reflect the modest nature and scale of the proposed modification and its potential impacts.

4.2 Consultation with government

Table 4.1 presents a summary of consultation undertaken with government agencies regarding the proposed modification. The outcomes of this consultation are reflected in the proposed modification's scope and matters addressed in this SEE.

Table 4.1 Summary of government consultation

Agency	Date and method of consultation	Description of outcomes
DPE	Face-to-face meeting held on 31 August 2016.	Items discussed during the meeting included matters related to both CVC and MC and a project briefing for MC Modification 5.
	Phone calls.	Numerous phone calls to provide regular updates on the progression of the environmental assessment and modification.
	Face-to-face meeting held on 14 January and 13 March 2019.	An update was given on MC Modification 5.
Lake Macquarie City Council	CCC meetings.	Items discussed during the meetings included an update on the project.
	Briefing letter sent 15 April 2019.	No response received to date.
Central Coast Council	CCC meetings.	Items discussed during the meetings included an update on the project.
	Briefing letter sent 15 April 2019.	No response received to date.
Environment Protection Authority	Briefing letter sent on 9 November 2016.	No response received to date.
	Briefing letter sent on 15 April 2019.	Confirmation of receipt received 18 April 2019. No comments provided at this stage.
Resources Regulator	Briefing letter sent 15 April 2019 to both Subsidence and Compliance departments.	Email received in response from Subsidence department. Further discussion about the proposed modifications was had via phone call with Delta Coal on 16 April 2019. No specific comments provided on MC Modification 5; however, confirmed that further information would be provided as part of this SEE.
NPWS Hunter Central Coast Branch	Briefing letter sent 15 April 2019.	No response received to date.

Table 4.1 Summary of government consultation

Agency	Date and method of consultation	Description of outcomes
Subsidence Advisory NSW	Briefing Letter sent 14 May 2019	No response received to date.

4.3 Consultation with community and special interest groups

The proposed modification was raised with the CVC and MC combined CCCs on several occasions with the most recent occasions being the meetings held on 13 February 2019 and 15 May 2019. No formal objections were raised regarding the proposed modification by community representatives or Central Coast Council or Lake Macquarie City Council representatives during these meetings.

Due to the minor changes in operations proposed, extensive community consultation for the proposed modification was not considered necessary. A briefing information sheet on the proposed modification is available for view on MC's website. The broader community will be notified of the proposed modification through an advertisement placed in a local newspaper following lodgement and through the public exhibition process where community members will be invited to make comment by way of formal submissions.

Further consultation is proposed to be undertaken with the community during exhibition of the proposed modification. Delta Coal will also continue to consult with the community during operation of MC through its CCC.

5 Impact assessment

5.1 Introduction

This chapter assesses the potential environmental, social and economic impacts arising from the proposed modification. A preliminary environmental risk assessment was completed for the proposed modification (Appendix A). All risks were rated as low.

With respect to air quality, modelling of MC operations was last completed in 2007 for the air quality assessment that accompanied the application for MP06_0311. Although there will be no changes to surface infrastructure (the existing infrastructure has adequate capacity to accommodate the additional coal throughput) and no upgrade or additional plant or equipment, the proposed modification has provided the opportunity to complete a contemporary assessment of the MC operations.

The proposed modification would not require a change to existing infrastructure, currently approved hours of operation, transport methods or employee numbers. Therefore, an assessment of noise is not required. However, a report which details recent noise mitigation measures employed at MC has been included with the SEE per a request from DPE.

The proposed extension to the project approval will extend potential environmental impacts associated with the ongoing operation of MC. However, during this period, environmental management at MC will continue in accordance with the existing environmental management processes identified in the various approvals, licences and management plans.

Air quality, noise and subsidence matters are addressed in Section 5.2, Section 5.3 and Section 5.4, respectively. Other environmental matters are addressed in Section 5.5.

5.2 Air quality

5.2.1 Introduction

An air quality assessment (AQA) of the proposed modification was undertaken by ERM (Appendix B). It provides a contemporary assessment of dust emissions from MC's approved project and those from the proposed modified project, both alone and cumulatively with existing background emissions.

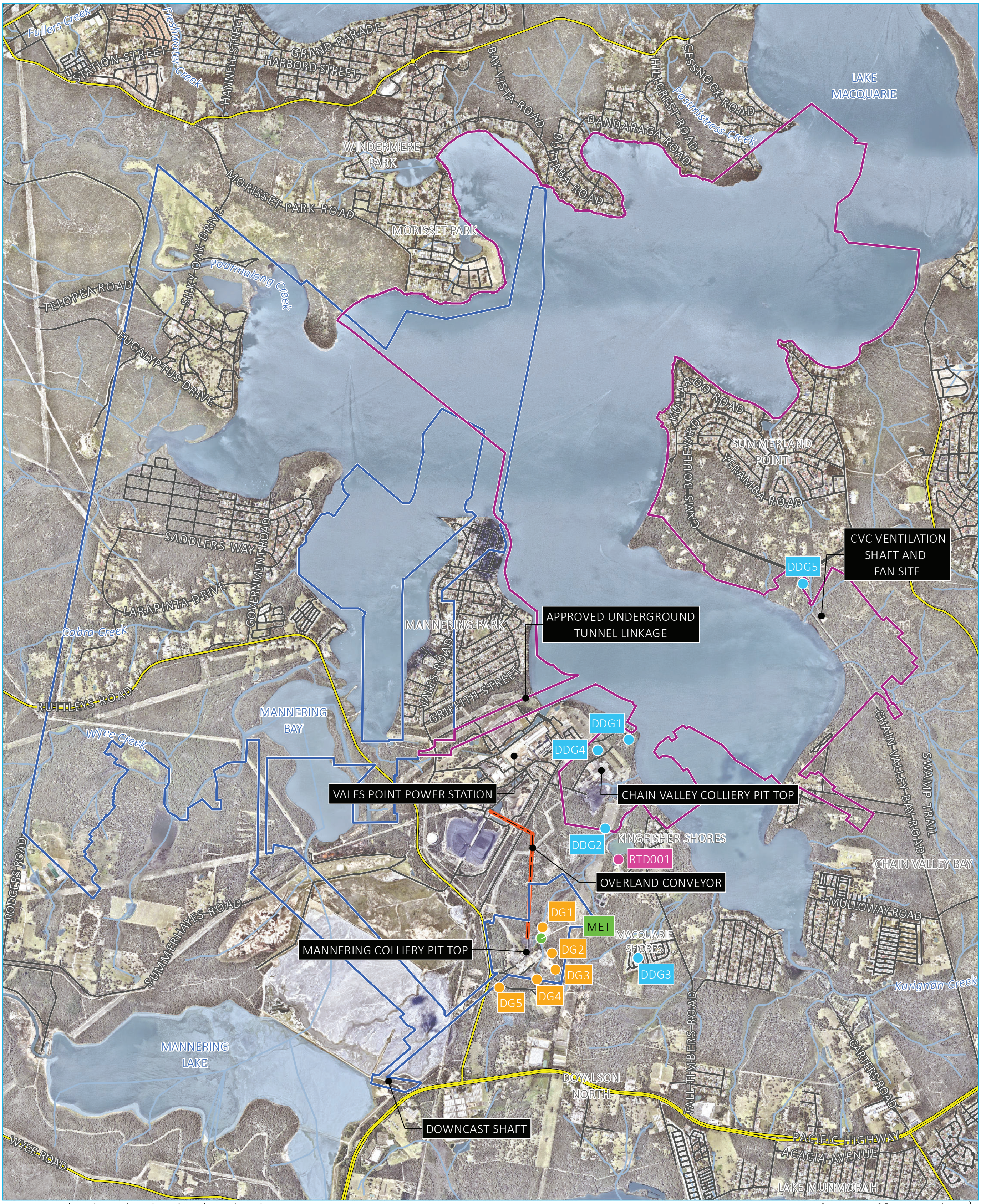
The assessment is presented in full in Appendix B and a summary is provided below.

5.2.2 Existing environment

Existing air quality in the local area is influenced by particulate matter emissions from mining activities, power generation, vehicle movements and other industrial activities.

There are various monitoring sites located at or nearby the MC and CVC surface facilities, as shown in Figure 5.1 and, given the close proximity of the collieries, both the CVC and MC monitoring sites are of relevance to the proposed modification. The network of air quality monitoring equipment includes dust deposition gauges and a PM_{10} monitor known as a Tapered Element Oscillating Microbalance (TEOM) in reference to the method of analysis utilised by the monitor.

The air quality monitors measure the existing dust deposition and particulate concentrations due to emissions from all sources that contribute to dust in the air. This data was used to characterise the existing or background conditions and was applied in the air quality modelling.



Source: EMM (2019); DFSI (2017); GA (2011); CVC (2019)

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KEY

Air quality assessment type

- TEOM
- Manning Colliery (dust gauge)
- Chain Valley Colliery (dust gauge)
- Meteorological station

- Chain Valley Colliery development consent boundary
- Mannering Colliery project approval boundary
- Alignment of overland conveyor to VPPS
- Main road
- Local road
- Watercourse/drainage line
- Waterbody

Air quality monitoring locations

Mannering Colliery
Modification 5
Figure 5.1

EMM
creating opportunities

The potential for particulate matter to disperse and result in impacts on nearby sensitive receivers is dependent on the quantity of particulate matter generated, its size, and the prevailing wind direction and speed.

A meteorological station is located at MC. Annual and seasonal windroses, which are provided in Appendix B, show that the predominant annual winds are from the south-west and these occur through autumn, winter and spring. During summer, the dominant winds are from the north-east.

Discrete assessment locations were selected for the AQA. These receivers represent assessment locations in close proximity to the MC surface facilities and are shown on Figure 5.4. The assessment locations are also consistent with those applied in the noise impact assessment (NIA) prepared by EMM for Modification 3 to MP 06_0311 (refer to Section 5.3).

5.2.3 Impact assessment

i Criteria

a NSW EPA Impact Assessment Criteria

The publication entitled *Approved Methods for Modelling and Assessment of Air Pollutants in NSW* (the Approved Methods) (EPA 2016) specifies air quality assessment criteria relevant for assessing impacts from air pollution.

Table 5.1 presents the air quality criteria for pollutants that are relevant to the AQA. These criteria are health-based (ie they are set at levels to protect against health effects). It is important to note that the criteria are applied to the cumulative impacts due to MC and other sources.

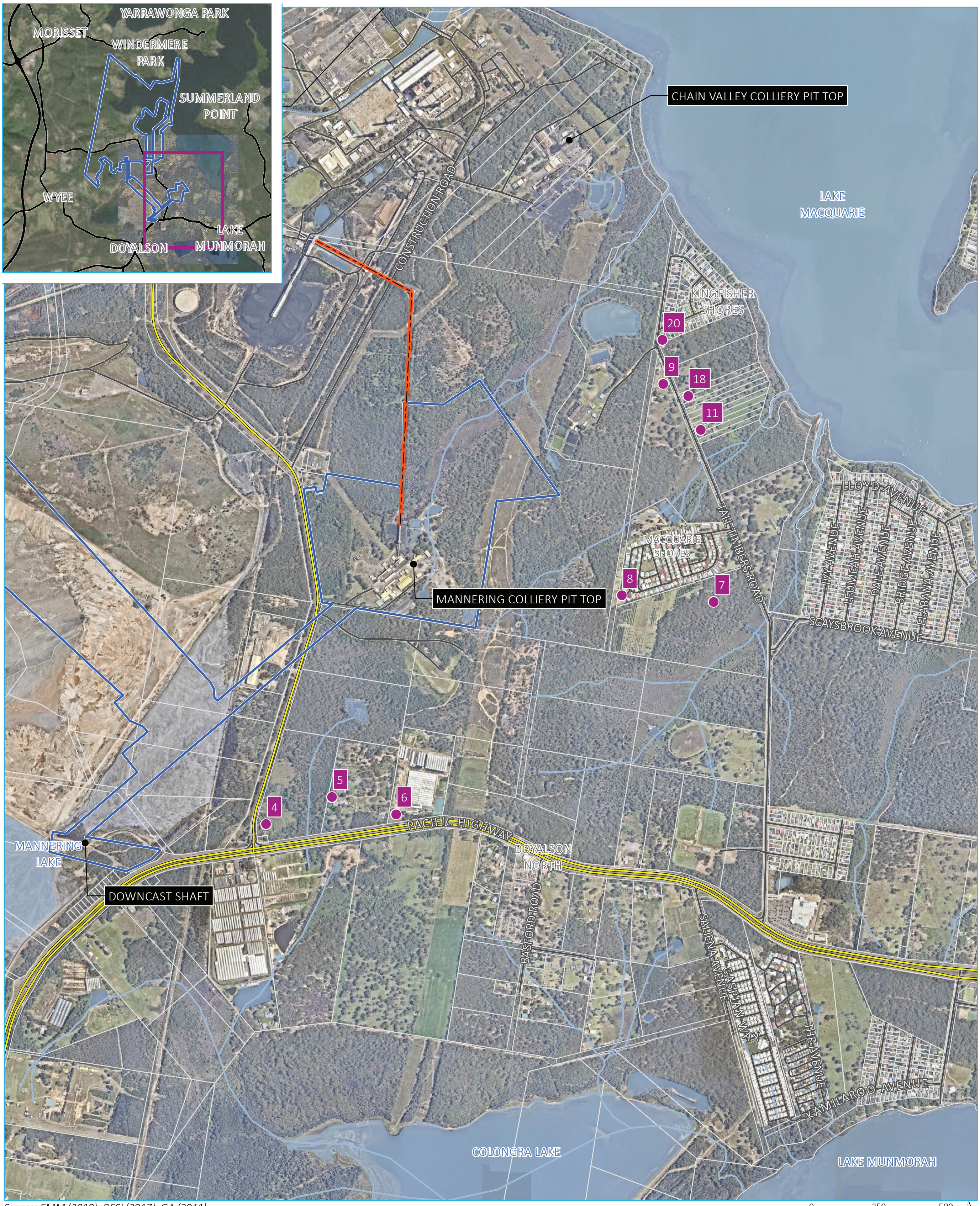
Table 5.1 NSW EPA impact assessment criteria for particulate matter concentrations

Pollutant	Standard	Averaging period
TSP	90 µg/m^3	Annual
PM_{10}	50 µg/m^3	24-Hour
	25 µg/m^3	Annual
$PM_{2.5}$	25 µg/m^3	24-Hour
	8 µg/m^3	Annual

Notes: µg/m^3 – micrograms per cubic metre

In addition to health impacts, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including vegetation. Larger particles do not tend to remain suspended in the atmosphere for long periods of time and will fall out relatively close to source. Dust deposition can soil materials and generally degrade aesthetic elements of the environment and are therefore assessed for nuisance or amenity impacts.

Table 5.2 shows the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective. These criteria for dust deposition levels are set to protect against nuisance impacts (EPA 2016).



Source: EMM (2019); DFSI (2017); GA (2011)

KEY

- Assessment location
- Mannering Colliery project approval boundary
- Alignment of overland conveyor to VPPS
- Main road
- Local road
- Watercourse/drainage line
- Cadastral boundary
- Waterbody

Air quality monitoring locations

Mannering Colliery
Modification 5
Figure 5.2

EMM
creating opportunities

Table 5.2 NSW EPA impact assessment criteria for dust (insoluble solids) fallout

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

Note: g/m^2/month grams per square metre per month

b Voluntary Land Acquisition and Mitigation Policy

In December 2014, DPE released a policy relating to mining, petroleum production and extractive industries, which included the identification of voluntary mitigation and land acquisition criteria for air quality and noise (NSW Government 2014). This is reflected in the Mining SEPP at Clause 12A.

The policy sets out voluntary mitigation and land acquisition rights where it is not possible to comply with the NSW EPA impact assessment criteria even with the implementation of all reasonable and feasible avoidance and/or mitigation measures.

A revised policy was issued by DPE in February 2018 and was formally adopted in September 2018 to align the criteria with the National Environment Protection Measures (NEPMs) and NSW EPA impact assessment criteria. The revised policy applies to modification applications that involve increases to the approved dust or noise impacts of a development.

The DPE voluntary mitigation and acquisition criteria for particulate matter are summarised in Table 5.3 and Table 5.4, respectively. The proposed modification has been assessed against these criteria, in addition to the NSW EPA impact assessment criteria discussed above.

Table 5.3 DPE particulate matter mitigation criteria

Pollutant	Criterion	Averaging Period	Application[a]
TSP	90 $\mu g/m^3$	Annual mean	Total impact[b]
PM_{10}	50 $\mu g/m^3$	24-hour average	Incremental impact[c]
	25 $\mu g/m^3$	Annual mean	Total impact[b]
$PM_{2.5}$	25 $\mu g/m^3$	24-hour average	Incremental impact[c]
	8 $\mu g/m^3$	Annual mean	Total impact[b]
Deposited dust	2 g/m^2/month	Annual mean	Incremental impact[c]
	4 g/m^2/month	Annual mean	Total impact[b]

Notes: (a) Voluntary mitigation rights may be applied where the proposal contributes to exceedances of the mitigation criteria at any residence on privately-owned land and, in some circumstances, a workplace on privately-owned land.
(b) Cumulative impact (ie increase in concentrations due to the development plus background concentrations due to all other sources).
(c) Incremental impact (ie due to the development alone), with zero allowable exceedances over the life of the development.

Table 5.4 DPE particulate matter acquisition criteria

Pollutant	Criterion	Averaging Period	Application[a]
TSP	90 µg/m^3	Annual mean	Total impact[b]
PM_{10}	50 µg/m^3	24-hour average	Incremental impact[c]
	25 µg/m^3		Total impact[b]
$PM_{2.5}$	25 µg/m^3		Incremental impact[c]
	8 µg/m^3	Annual mean	Total impact[b]
Deposited dust	2 g/m^2/month	Annual mean	Incremental impact[c]
	4 g/m^2/month	Annual mean	Total impact[b]

Notes: (a) Voluntary acquisition rights apply where the proposal contributes to exceedances of the acquisition criteria at any residence or workplace on privately-owned land, or, on more than 25% of any privately-owned land, and a dwelling could be built on that land under exiting planning controls.
(b) Cumulative impact (ie increase in concentrations due to the development plus background concentrations due to all other sources).
(c) Incremental impact (ie due to the development alone), with up to five allowable exceedances over the life of the development.

Total impact includes the impact of the proposed modification and all other sources, whilst incremental impact refers to the impact of the proposed modification considered in isolation.

ii Methodology

a Modelling system

The AQA followed a conventional approach commonly used for air quality assessment in Australia and outlined in the Approved Methods (EPA 2016).

The TAPM and CALMET/CALPUFF modelling system was chosen for the study.

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model developed by the CSIRO Division of Atmospheric Research. The model predicts airflows important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analysis.

CALMET is a meteorological pre-processor that includes a wind field generator factoring in aspects such as slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables to produce the 3-dimensional (3D) meteorological fields. The CALMET outputs were used by the CALPUFF dispersion model.

CALPUFF is a multi-layer, multi-species non-steady state puff dispersion model that can simulate the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal (Scire et al. 2000). Predicted concentrations are provided in the section iv below.

Continuous meteorological data for the year 2015 was used in the dispersion modelling. The meteorological data for 2013 to 2014 and 2016 to 2018 shows that the percentage of calms, annual average wind speed and percentage data recovery is similar to that of the modelling period and, therefore, confirms its appropriateness for the assessment. Further detail about the methodology and modelling systems used as part of the AQA is provided in Chapter 5 of Appendix B.

b Application of leading practice

The NSW EPA commissioned *the NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining* (herein referred to as the Best Practice Report) (Donnelly et al. 2011).

The Best Practice Report provides guidance on controls for reducing emissions for a range of dust-generating activities and is benchmarked on the international best practice.

Following the Best Practice Report, EPA inserted a condition into all EPLs under the heading Pollution Studies and Reduction Programs (PRPs) requiring each mining company to prepare a report on the practicability of implementing best practice measures to reduce particle emissions. The PRP requirements were included in the MC EPL 191 in December 2011, with the required report submitted to the NSW EPA in September 2012.

The best practice control measures relevant to activities at MC that are currently and will continue to be applied by Delta Coal at MC are summarised in Section 6.2 of Appendix B. These include items such as:

- primary crushing and sizing of coal underground;
- operation of enclosed crushers and conveyor transfers;
- dust suppression and water sprays;
- prioritising direct loading to conveyor over stockpiling; and
- use of a water on unsealed areas where required.

These measures were applied to the dispersion modelling for the AQA.

iii Predictions

The modelling predictions for the approved project and proposed modification are presented in the sections below.

Contour plots which provide a visual representation of the predicted impacts are provided in Chapter 8 of Appendix B.

a Annual average concentrations

Table 5.5 to Table 5.8 present the predicted annual average TSP, PM_{10} and $PM_{2.5}$ concentrations, and dust deposition levels at each of the sensitive receiver locations due to both the approved project and proposed modification-alone and cumulatively, ie including existing background concentrations.

A review of Table 5.5 to Table 5.8 shows there is a minimal predicted change in the contribution between the approved project and the project as modified and that there are no sensitive receivers predicted to experience annual average concentrations above the relevant impact assessment criterion for any particle size, either due to the approved project or proposed modification-alone or cumulatively (including background concentrations from the existing monitoring network – refer Section 5.2.2).

Table 5.5 Predicted annual average TSP concentrations due to the approved project and proposed modification-alone and cumulatively

	Project alone		Project plus background	
ID	**Approved**	**Proposed**	**Approved**	**Proposed**
Assessment criteria	-		90 $\mu g/m^3$	
4	0.7	1.1	37.5	37.9
5	0.7	1.1	37.5	37.9
6	0.5	0.8	37.3	37.6
7	0.4	0.6	37.1	37.3
8	0.7	1.2	37.5	37.9
9	1.0	1.5	37.7	38.2
11	0.6	0.9	37.4	37.7
18	0.8	1.2	37.5	37.9
20	0.9	1.3	37.6	38.1

Table 5.6 Predicted annual average PM_{10} concentrations due to the approved project and proposed modification-alone and cumulatively

	Project alone		Project plus background	
ID	**Approved**	**Proposed**	**Approved**	**Proposed**
Assessment criteria	-		25 $\mu g/m^3$	
4	0.5	0.8	15.2	15.5
5	0.5	0.7	15.2	15.4
6	0.4	0.5	15.1	15.2
7	0.3	0.4	15.0	15.1
8	0.5	0.7	15.2	15.4
9	0.6	0.9	15.3	15.6
11	0.4	0.6	15.1	15.3
18	0.5	0.7	15.1	15.4
20	0.5	0.8	15.2	15.5

Table 5.7 Predicted annual average $PM_{2.5}$ concentrations due to the approved project and proposed modification-alone and cumulatively

	Project alone		Project plus background	
ID	Approved	Proposed	Approved	Proposed
Assessment criteria	-		8 µg/m³	
4	0.4	0.6	7.4	7.6
5	0.4	0.6	7.4	7.6
6	0.3	0.4	7.3	7.4
7	0.2	0.3	7.2	7.3
8	0.4	0.6	7.4	7.6
9	0.5	0.7	7.5	7.7
11	0.3	0.5	7.3	7.5
18	0.4	0.6	7.4	7.6
20	0.4	0.6	7.4	7.6

Table 5.8 Predicted annual average dust deposition levels due to the approved project and proposed modification-alone and cumulatively

	Project alone		Project plus background	
ID	Approved	Proposed	Approved	Proposed
Assessment criteria	2 g/m²/month		4 g/m²/month	
4	0.04	0.06	1.04	1.06
5	0.04	0.06	1.04	1.06
6	0.03	0.04	1.03	1.04
7	0.02	0.04	1.02	1.04
8	0.04	0.07	1.04	1.07
9	0.06	0.09	1.06	1.09
11	0.04	0.06	1.04	1.06
18	0.05	0.07	1.05	1.07
20	0.06	0.08	1.06	1.08

b 24-hour average concentrations

Cumulative 24-hour average PM_{10} and $PM_{2.5}$ concentration predictions are presented in the following sections.

PM_{10}

The cumulative PM_{10} concentrations were calculated by adding the predicted 24-hour average concentration due to the approved project and proposed modification-alone at each sensitive receiver, to the corresponding concentration measured at the CVC TEOM on the same day for the meteorological year assessed (2015).It is considered that this approach is conservative as the proposed increased throughout at MC would have a corresponding reduction of throughput at CVC.

Table 5.9 presents the maximum predicted 24-hour average concentrations of PM_{10} at each of the sensitive receiver locations, due to the contribution from the approved project and proposed modification-alone, and cumulatively with existing background concentrations.

During the 2015 period there was one day (6 May 2015) where background levels were elevated near or above the PM_{10} cumulative assessment criterion of 50 $\mu g/m^3$ at each modelled receiver due to a regional dust storm. There are no additional exceedances of the cumulative assessment criterion of 50 $\mu g/m^3$ when considering either the approved project or the proposed modification.

The minor contribution of both the approved project and proposed modification is demonstrated in a time series plot showing the predicted 24-hour average PM_{10} contribution at the most impacted sensitive receiver due to the project-alone (ID 4) in combination with the adopted background (see Figure 5.3).

Table 5.9 Maximum predicted 24-hour average PM_{10} concentrations due to the approved project and proposed modification-alone and cumulatively

	Project alone		Project plus background	
ID	**Approved**	**Proposed**	**Approved**	**Proposed**
Assessment criteria	-		50 $\mu g/m^3$	
4	6.2	9.7	56.0	56.0
5	5.7	8.9	56.0	56.0
6	4.8	7.5	56.0	56.0
7	3.6	5.7	57.0	57.5
8	5.8	9.1	57.7	58.6
9	5.3	8.3	56.1	56.2
11	4.0	6.3	56.3	56.5
18	4.2	6.6	56.2	56.3
20	5.2	8.2	56.0	56.1

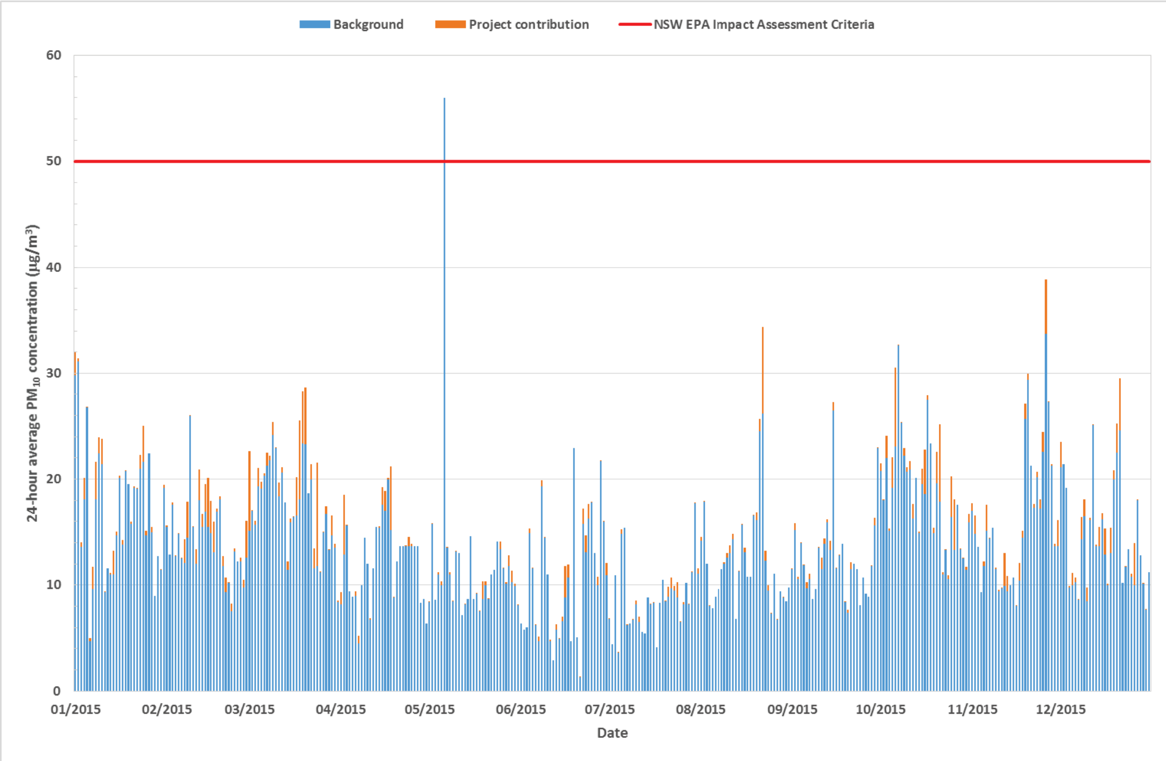
$PM_{2.5}$

The cumulative $PM_{2.5}$ concentrations were calculated by adding the predicted 24-hour average concentration due to the approved project and proposed modification to the estimated $PM_{2.5}$ concentration at the CVC TEOM on the same day for the meteorological year assessed (2015). The CVC $PM_{2.5}$ concentrations were estimated by applying the $PM_{2.5}$:PM_{10} ratio measured at the OEH Wallsend station to the measured CVC PM_{10} concentrations. The Wallsend station is approximately 36 km north-east of MC and average PM_{10} concentrations at Wallsend are slightly higher than measured at the CVC TEOM, which is not unexpected given the higher population and nature of activities in the vicinity of the Wallsend monitoring site. Therefore, predictions are conservative.

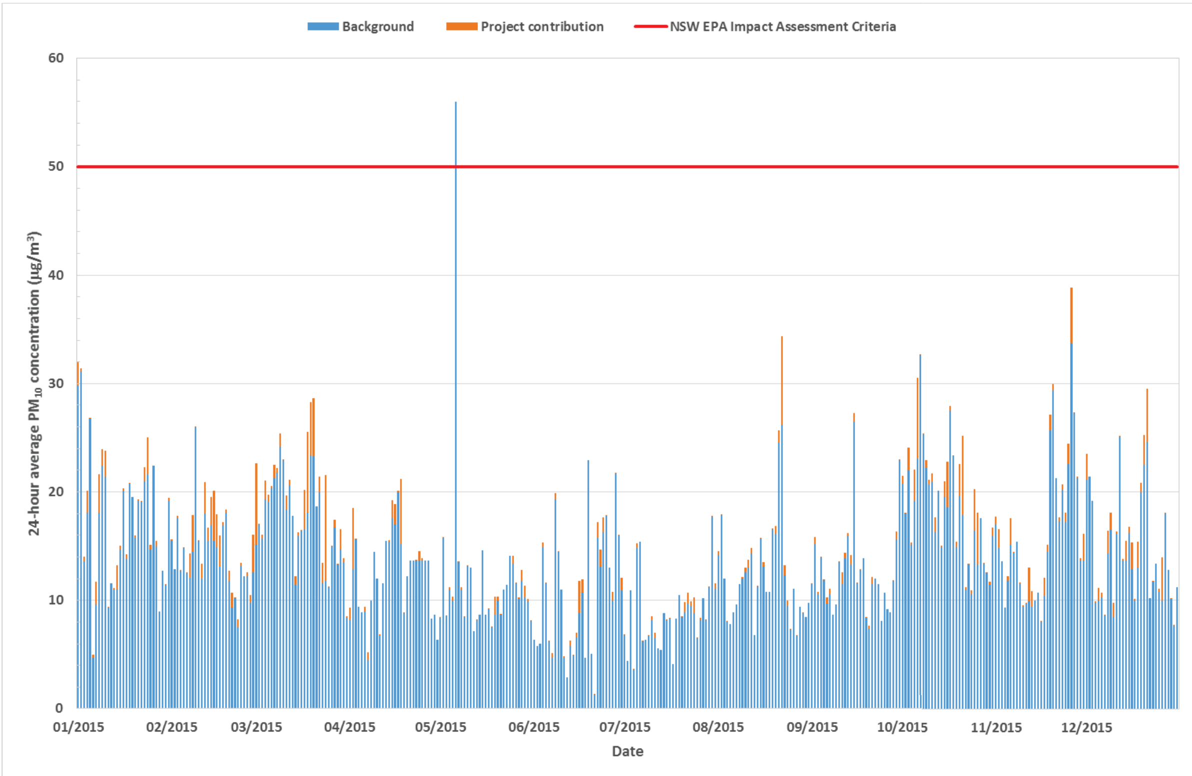
Table 5.10 presents the maximum predicted 24-hour average concentrations of $PM_{2.5}$ at each of the sensitive receiver locations due to the contribution from the approved project and proposed modification-alone, and cumulatively with existing background concentrations.

There are no predicted exceedances of the cumulative assessment criterion of 25 $\mu g/m^3$ when considering either the approved project or proposed modification-alone.

The minor contribution of both the approved project and proposed modification is demonstrated in a time series plot showing the predicted 24-hour average $PM_{2.5}$ contribution at the most impacted sensitive receiver due to the project-alone (ID 4) in combination with the adopted background (see Figure 5.4).

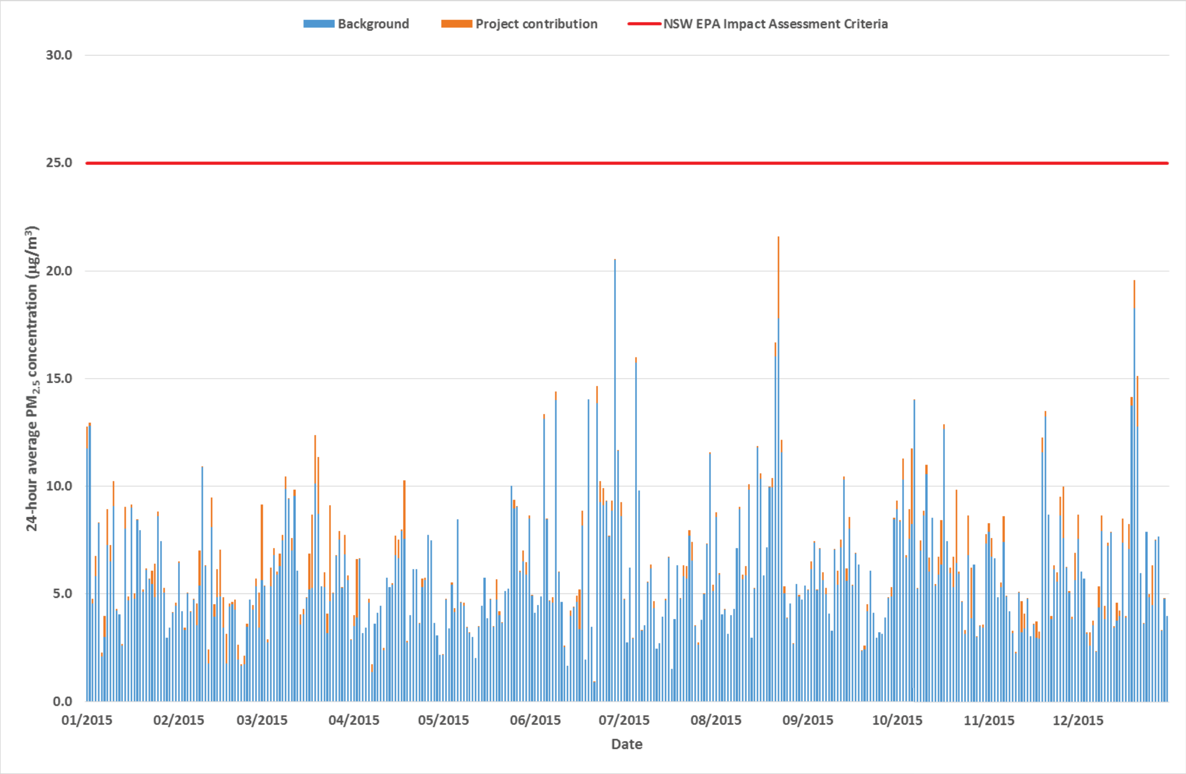


Approved project

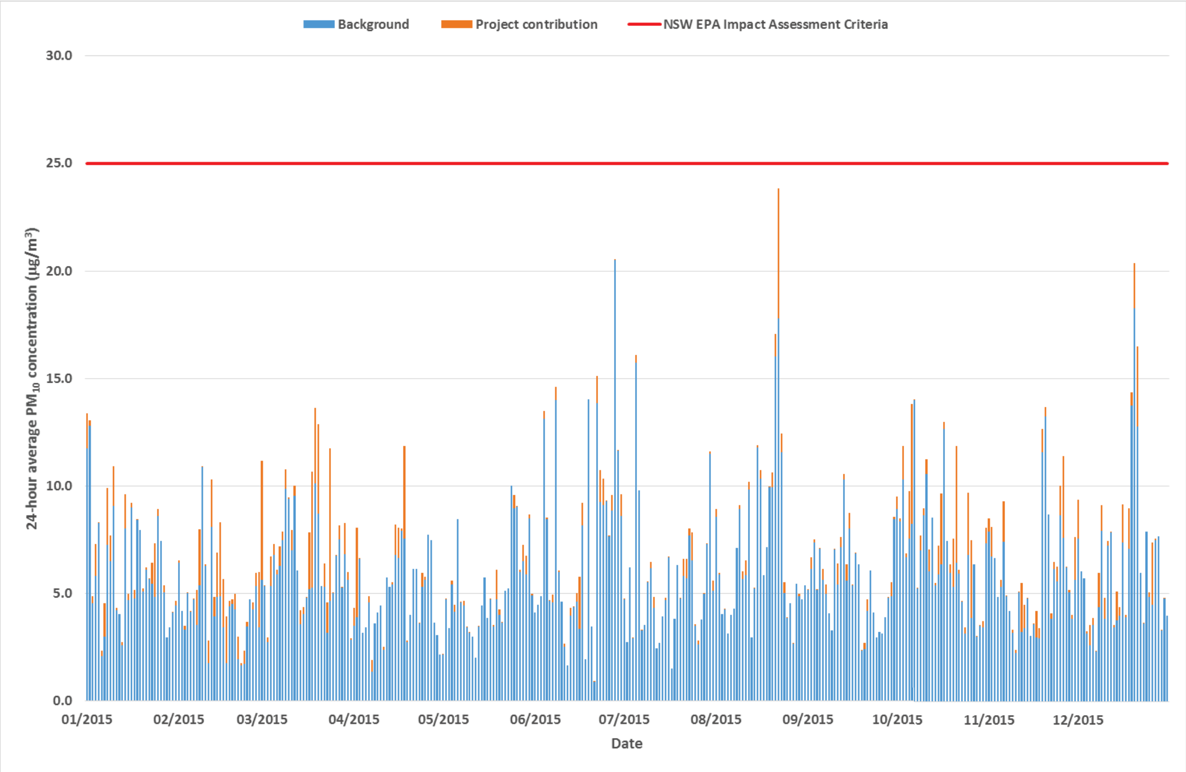


Proposed modification

Figure 5.3 Predicted 24-hour average PM_{10} concentrations at Receptor 4 – project-alone plus background at CVC TEOM (µg/m^3)



Approved project



Proposed modification

Figure 5.4 Predicted 24-hour average $PM_{2.5}$ concentrations at Receptor 4 – project-alone plus estimated background at CVC TEOM (µg/m³)

Table 5.10 Maximum predicted 24-hour average $PM_{2.5}$ concentrations due to the approved project and proposed modification-alone and cumulatively

	Project alone		Project plus background	
ID	**Approved**	**Proposed**	**Approved**	**Proposed**
Assessment criteria	-		25 µg/m^3	
4	4.5	7.1	21.6	23.8
5	4.3	6.7	21.7	23.9
6	3.6	5.7	20.5	20.5
7	2.7	4.3	20.6	20.6
8	4.3	6.8	20.6	20.7
9	4.0	6.3	21.2	21.6
11	3.0	4.8	20.8	21.0
18	3.2	5.0	21.0	21.3
20	3.9	6.2	21.2	21.6

5.2.4 Management and monitoring

i Management

Air quality at MC will continue to be managed in accordance with the existing air quality management regime prescribed in MC's air quality management plan. Management measures were developed in accordance with the Best Practice Report.

Based on the potential impacts predicted by the assessment, the existing management measures committed to and adopted at MC are considered feasible and reasonable. No additional management measures are considered warranted.

ii Monitoring

Air quality monitoring will continue to be undertaken in accordance with MC's air quality management plan applying the Approved Methods (EPA 2016).

The air quality data will continue to be reviewed on a monthly basis to verify compliance and a summary uploaded to MC's website as per current practice. In the unlikely event of any non-compliance, the relevant authorities will be advised as required under MP 06_0311 and/or EPL 191.

5.2.5 Conclusion

The contemporary AQA predicts a minimal change in the contribution of dust emissions from the proposed modification compared to the approved project.

Modelling predicts that the incremental PM_{10}, $PM_{2.5}$, TSP and dust deposition are all below the impact assessment criteria at the closest assessment locations.

A cumulative assessment, incorporating existing background dust levels, indicates that the proposed modification is unlikely to result in any additional exceedances of relevant impact assessment criteria at the assessment locations.

The conservative assessment concluded that it is unlikely that any of the relevant impact assessment criteria will be exceeded at any of the nearby receivers due to the proposed modification.

5.3 Noise

5.3.1 Proposed modification

As previously described, no significant changes to surface infrastructure are proposed under the modification, with the existing infrastructure having adequate capacity to accommodate the additional coal throughput with no additional plant or equipment required. The increased coal throughput would all be dispatched via the existing overland conveyor to VPPS, as currently approved. There would be no changes to approved employee numbers or operating hours.

Given there will be no significant change to any aspect of the surface operations or road traffic generation which have the potential to generate noise emissions at potentially sensitive receivers, increases in noise emissions are not predicted.

Notwithstanding this, DPE requested that assessment of the noise mitigation measures employed at MC to date be undertaken as part of Modification 5. A noise mitigation study which summarises these measures and provides an updated assessment has been prepared by EMM and is included as Appendix C. A summary of the noise mitigation study is provided in the following sections.

5.3.2 Previous assessments

A noise impact assessment (NIA) was prepared by EMM for Modification 3 to MP 06_0311 (refer to *Mannering Colliery – Modification 3 Noise Impact Assessment* dated 7 May 2015) and is relevant to the currently approved infrastructure. The NIA (EMM 2015) provided a contemporary assessment of noise emissions from MC. The NIA conservatively assumed that all plant and equipment would be operating simultaneously and also adopted a worst-case wind scenario which considered the highest potential noise levels at each assessment location.

The highly conservative NIA predicted exceedances of both the then current noise limits (as per Schedule 3, Table 1 of MP 06_0311), and Project Specific Noise Levels (PSNLs) at the representative receivers on the Pacific Highway and at Macquarie Shores Home Village. Noise emissions at representative receivers at Kingfisher Shores were predicted to remain below the current noise limits and the PSNLs.

DPE in its *Assessment Report – Mannering Colliery – Increased Coal Handling & Dispatch Modification (MP 06_0311 MOD3)* (DPE 2015) noted there had been no noise complaints either prior to or during care and maintenance period and there were no public submissions relating explicitly to noise in regard to the original assessment for MP 06_0311 and subsequent modifications, including Modification 3. It also noted, however, that MC should reduce future noise levels through the implementation of mitigation measures in order to meet contemporary noise criteria and maintain the amenity of residents in neighbouring areas, once coal production recommences.

Based on this feedback further analysis was completed by EMM (*Mannering Colliery – Modification 3 Noise Impact Assessment Addendum*, EMM 2015b) which demonstrated that MC would be able to reduce noise emissions through the implementation of noise mitigation measures once coal production recommenced. Consequently, MP 06_0311 was amended to incorporate 'alternative noise conditions' once underground coal extraction at MC recommenced. These are presented in Appendix 4B of MP06_0311 and include both 'interim' and 'long-term' noise criteria.

5.3.3 Mitigation measures employed to date

An acoustic specialist was employed at MC to undertake detailed investigations regarding noise mitigation options at the site. Initial monitoring identified the rotary breaker, coal preparation plant (CPP) and coal stockpile dozer as the primary sources of noise generation from the site.

Significant noise mitigation works have recently been undertaken at MC to reduce noise emissions from the site. The following controls have been implemented to date:

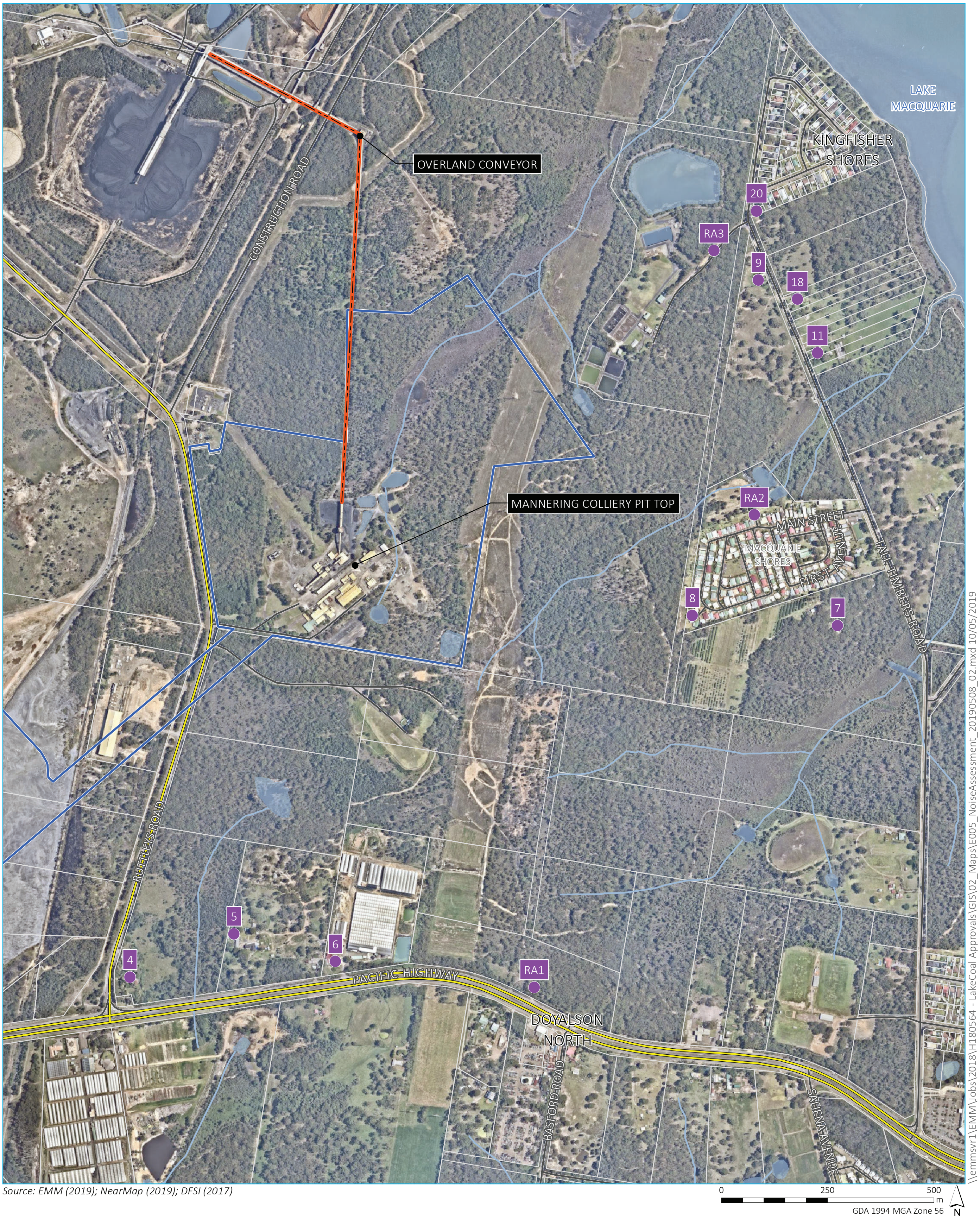
- replacement of the previous steel reject chute off the rotary breaker with a noise attenuated, poly-lined discharge catch hopper and chute;
- installation of slowing chains in the chute to reduce velocity of the reject product;
- re-machining of the rotary breaker trunnions to minimise vibration and intrusive noise from the structure;
- installation of custom designed acoustic walls around the rotary breaker structure;
- installation of inlet and outlet shrouds on the rotary breaker;
- rectified the conveyor belt screening around the drift belt transfer house;
- stabilisation of the screen deck foundations;
- replacement and redirection of the conveyor belt start up alarms with lower decibel units;
- full conveyor system roller audit and replacement of defective/noisy rollers; and
- replacement of the product coal dozer with a wheeled loader to reduce track slap impacts and overall noise from coal stockpiling activities.

It is noted that prior to and since implementation of the above controls, Delta Coal has received several complaints from a resident in the Macquarie Shores village in regard to noise emissions from MC. Some of these complaints have occurred at times when the primary sources of noise generation at MC (ie rotary breaker and the loader) were not in operation. Delta Coal is continuing to investigate the source of these complaints.

5.3.4 Operational noise assessment

An updated operational noise assessment was undertaken by modelling noise emissions from MC operations incorporating the recent noise mitigation works. Predicted noise emissions were compared to those presented in the previous NIA (EMM 2015a) and the long-term noise criteria provided in MP 06_0311. Representative assessment locations considered in the assessment of MC noise emissions are shown in Figure 5.5 and are those considered most likely to be affected by MC operations and are consistent with those nominated in the current approval (MP 06_0311). Adherence with noise criteria at these locations would indicate that noise criteria will be met at other surrounding noise-sensitive locations.

Predicted noise emission levels from MC at all assessment locations are provided in Table 5.11.



Source: EMM (2019); NearMap (2019); DFSI (2017)

KEY

- Assessment location
- Mannering Colliery project approval boundary
- Alignment of overland conveyor to VPPS
- Main road
- Local road
- Watercourse/drainage line
- Waterbody
- Cadastral boundary

Noise assessment locations

Mannering Colliery
Modification 5
Figure 5.5

EMM
creating opportunities

Table 5.11 Predicted operational noise levels - $L_{Aeq,15 minute}$

Assessment location	Period	Predicted dB		Difference (dB)	Long term noise criteria, dB(A)
		Mod 3 (pre-mitigation)	Mod 5 (post mitigation)		Table 2, Appendix 4B MP 06_0311
4	Day	39	35	-4	40
	Evening	39	36	-3	40
	Night	40	36	-4	40
5	Day	42	38	-4	41
	Evening	42	39	-3	41
	Night	43	39	-4	41
6	Day	41	36	-5	41
	Evening	41	37	-4	41
	Night	42	37	-5	41
7	Day	38	34	-4	39
	Evening	38	35	-3	39
	Night	39	35	-4	39
8	Day	45	41	-4	45
	Evening	45	42	-3	45
	Night	46	42	-4	43
9	Day	40	36	-4	41
	Evening	40	37	-3	41
	Night	41	37	-4	41
11	Day	38	35	-3	39
	Evening	38	36	-2	39
	Night	39	36	-3	39
18	Day	38	35	-3	39
	Evening	38	36	-2	39
	Night	39	36	-3	39
20	Day	39	35	-4	40
	Evening	39	36	-3	40
	Night	40	36	-4	40

Based on the results of noise modelling, noise mitigation works implemented at MC have resulted in decreased site noise emission levels by 2-5 dB at all assessment locations. Further, noise emissions from current and proposed site operations are predicted to comply with the relevant long-term noise criteria outlined in MP 06_0311 at all assessment locations under worst case meteorological conditions.

5.3.5 Sleep disturbance assessment

As per the previous NIA (EMM 2015a), the highest predicted L_{Amax} noise level (being the operation of the conveyor belt alarms) at any assessment location was L_{Amax} 47 dB at assessment location 8 under prevailing meteorological conditions and all results demonstrated that L_{Amax} noise levels were compliant with the relevant sleep disturbance criteria.

As noted above, the conveyor belt alarms have been replaced with lower decibel units and have been redirected away from sensitive receptors. Therefore, the L_{Amax} noise levels received at the nearest assessment locations are predicted to decrease due to the mitigation works. Hence, L_{Amax} noise level events at the site are predicted to remain below the relevant sleep disturbance criteria.

5.4 Subsidence

A geotechnical report considering design criteria for a bord and pillar mining method using a herringbone pattern, so as to achieve negligible surface subsidence effects, was prepared by Strata^2 (2019). This report is attached as Appendix D. The design process employed by Strata^2 was based on data obtained from other mines, most notably the herringbone operation at the adjacent Myuna Colliery, where similar systems have been employed successfully.

Strata^2 identify the most significant design constraints for a bord and pillar mining system at MC as follows:

1. The area of immediate interest is to the west of previous CVC Miniwalls 7 to 12 where the depth of cover ranges from approximately 140 m to 200 m and the potential working section varies between 3.4 m and 4 m, thinning to the west.

2. The system entails the development of large areas of permanent, first workings pillars. It follows that the pillars should be designed in a manner that is considered to preclude the potential for any form of sudden or rapid deterioration (primarily from an underground safety perspective). In this regard, pillar w/h ratios of >4 are considered likely to result in a "strain hardening" pillar deformation characteristic and, at worst, a gradual "squeezing" or "creep" mode of deterioration, in the event of any overloading.

3. Stable unsupported stubs are critical to the performance of the system and a typical stub width of 5.5 m is conservatively assumed.

4. The interval between stubs is partly a function of the required pillar size, but also dictated by the need to separate the adjacent alternating stubs for roof control purposes, thereby forming isolated three-way intersections.

Strata^2 (2019) referenced case studies undertaken of mining around Lake Macquarie in the Fassifern, Great Northern and Wallarah coal seams, encompassing 62 case studies. Based on the results of this review, Strata^2 recommend the following criteria for a bord and pillar style mining method at MC, in a herringbone layout similar to that adopted at Myuna, to ensure less than 20 mm subsidence occurs:

a) average final pillar stresses of <12 Mpa; and

b) factors of safety of ≥2.3.

As described in Section 2.2.3, MC is seeking approval to allow the use of different bord and pillar configurations throughout the approved mining area. A detailed geotechnical assessment will be undertaken by a suitably qualified geotechnical engineer as part of the detailed mine plan design process which would confirm the applicable pillar design criteria such that the bord and pillar configuration is long-term stable and would have less than 20 mm subsidence occurring.

5.5 Other aspects

An assessment of the other environmental, social and economic aspects as a consequence of the proposed modification is provided in Table 5.12. This assessment is commensurate with the negligible levels of projected impacts on each aspect arising from the proposed modification.

No additional specific management measures regarding these aspects are warranted as a result of the proposed modification. Management for these aspects will continue in accordance with existing project approval requirements, MC's EPL, and other approved plans as outlined in Section 2.1.2.

Table 5.12 Other environmental, social and economic aspects

Environmental aspect	Assessment
Ground water	The proposed modification would not result in a change to currently approved groundwater inflow volumes and, therefore, would not significantly impact on water resources (a MNES under the EPBC Act). Management of groundwater would continue as per the existing management system.
Surface water	The existing surface water management system has capacity to accommodate any additional pollutants that may be generated as a result of the increased throughput at MC's surface facilities without modification or upgrade.
Transport	The proposed modification will not generate additional employment at MC over and above that approved and will not, therefore, result in any changes to traffic or transport levels or impacts.
Greenhouse gases	There will be no mine life extension or increase in approved production rates under the proposed modification. Therefore, Scope 1 and 2 emissions will be unchanged as a result of the proposed modification. The proposed modification will not affect the level of Scope 3 emissions associated with the approved operations other than potential reductions in transport related emissions due to increased transport of CVC coal to VPPS via MC's conveyor system. Greenhouse gas emissions reporting will continue to be undertaken in accordance with the requirements of the *National Greenhouse and Energy Reporting Act 2007*.
Visibility	The proposed modification does not involve any new surface infrastructure. Therefore, the proposed modification will not result in any additional visual impacts. Visual amenity and lighting will continue to be managed in accordance with Schedule 3, Condition 19 of MP06_0311.

Table 5.12 Other environmental, social and economic aspects

Environmental aspect	Assessment
Social and economic	The reduction in capital and operating costs associated with utilisation of the MC coal clearance system for coal extracted at CVC, together with the contract with VPPS committing to an increase in the volume of coal supply, will result in greater financial certainty for both MC and CVC. This, in turn, will provide increased job security for the Delta Coal workforce and associated ongoing social and economic benefits. As described in Sections 5.2 and 5.3, there will be no significant change in noise or dust amenity impacts under the proposed modification. Further, the proposed modification would result in a reduction in noise and dust emissions from CVC associated with coal handling and transport to VPPS. The proposed modification would enable a reduction of haulage vehicle movements to and from the power station due to the increased volume of coal being delivered via an existing conveyor network. The potential reduction in haulage vehicle movements to and from the power station will result in a reduction of potential impacts from traffic, air quality and noise. The proposed modification will permit the ongoing employment and expenditure associated with MC through to 31 December 2027, resulting in positive socio-economic benefits.
Waste management	Small volumes of coarse material are likely to be increased from the rotary breaker. Non-production waste streams will continue to be managed in accordance with Schedule 3, Condition 23 of MP06_0311 and EPL 191. A total waste management system would continue to be implemented throughout the life of the project.
Hazards/risks	There would be no change to hazardous materials storage or the approved underground mining methods or extraction limits as a result of the proposed modification. Therefore, the level of hazards and risks will not be increased as a result of the proposed modification.
Ecology	There will be no additional surface disturbance as a result of the proposed modification and, therefore, no impact on native vegetation, fauna and fauna habitat including Commonwealth listed threatened species, communities or migratory birds.
Heritage	There will be no additional surface disturbance as a result of the proposed modification and, accordingly, no potential to adversely impact on any item or feature of Aboriginal heritage or historically significant heritage that may be present.
Rehabilitation	The mine closure and rehabilitation measures for MC are described in the combined existing CVC and MC MOP which is currently valid until 31 December 2020. Mine closure and rehabilitation will be in accordance with Conditions 13 and 15 of Schedule 3 in MP06_0311, with the surface facilities to be rehabilitated to the satisfaction of the Executive Director of Resources and Geoscience. As the proposed modification does not entail changes to the surface infrastructure, there will be no impact on mine rehabilitation. The MOP would, however, be updated to reflect the proposed modification.

6 Statement of commitments

Environmental management under the proposed modification will continue in accordance with the existing environmental management processes of the various approvals, licences and management plans documented in Section 2.1.2.

A detailed geotechnical assessment will be undertaken by a suitably qualified geotechnical engineer as part of the detailed mine plan design process.

The proposed modification will require a variation to EPL No. 191 to reflect the increase in the rate of ROM coal throughput.

7 Justification and conclusion

7.1 Introduction

This chapter considers the proposed modification against the relevant objects of the EP&A Act and provides a justification for its approval.

7.2 Substantially the same development

The proposed modification constitutes a minor change to an existing approved underground mine that would have negligible environmental impacts. The increase in throughput would have no additional amenity impacts and would result in a reduction of amenity impacts at the nearby CVC due to the reduction in the amount of coal handling and transport to VPPS. The increase in mine life can be undertaken without a need to increase the approved mining area and would mean that the existing socio-economic impacts from MC would continue for a further five-year period. There will be no change to the existing MC surface infrastructure, extraction rate, or operating hours under the proposed modification.

The proposed modification is, therefore, considered substantially the same as the approved development.

7.3 Objects of the Environmental Planning and Assessment Act 1979

The relevant objects of the EP&A Act are presented below, followed by a discussion on their application with regard to the proposed modification.

> (a) to promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,

The reduction in capital and operating costs associated with utilisation of the MC coal clearance system for coal extracted at CVC (or CVC and MC), together with the contract with VPPS committing to an increase in the volume of coal supply, will result in greater financial viability for CVC and MC. This, in turn, will provide increased job security for Delta Coal employees and associated ongoing social and economic benefits. In addition, the proposed modification would result in greater security of coal supply to VPPS which is important in meeting power supply demand in NSW. By obtaining coal from local sources, impacts related to coal deliveries to VPPS from more distant locations would also be decreased.

The minimal/negligible potential environmental impacts associated with the proposed modification will be managed in accordance with MC's existing environmental management processes.

> (b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,

The principles of Ecologically Sustainable Development (ESD) are outlined in Section 6 of the NSW *Protection of the Environment Administration Act 1991* and Schedule 2 of the Environmental Planning and Assessment Regulation 2000. The consistency of the modification with each of these principles is discussed below.

i) Precautionary principle:

The precautionary principle states that, if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

As described in Section 5.1, a preliminary environmental risk assessment was completed for the proposed modification with all risks rated as low (see Appendix B). Notwithstanding, a contemporary air quality assessment of the MC operations, including modelling, was completed for the proposed modification as modelling for the site operations was last completed in 2007. An updated operational noise assessment was also undertaken to assess recent noise mitigation measures employed at MC.

Where applicable, environmental safeguards have been developed to avoid or minimise any effect on the environment. On this basis, the proposed modification is consistent with the precautionary principle.

ii) Inter-generational equity:

The principle of inter-generational equity puts an onus on society to ensure that the health, diversity and productivity of the environment are maintained, or enhanced, for the benefit of current and future generations. The proposed modification does not affect the overall tonnage of approved coal production at MC or CVC. MC's approved impacts on the health, diversity or productivity of the environment will remain unchanged as a result of the proposed modification and, therefore, will not adversely impact the current or future generations.

iii) Conservation of biological diversity and maintenance of ecological integrity:

The approved impacts on biodiversity and ecological integrity will remain unchanged as a result of the proposed modification.

iv) Improved valuation and pricing of environmental resources:

Potential adverse environmental impacts from the proposed modification are limited. It is anticipated that enabling the handling of additional coal at MC surface facilities and its dispatch to VPPS by conveyor will provide for an improved amenity outcome when compared with the alternative of truck haulage of the additional volume required by the power station.

Continued operation of MC, in accordance with MP06_0311 as modified, will ensure that environmental resources are valued both during and post mining.

(c) to promote the orderly and economic use and development of land,

The proposed modification is a minor alteration to an approved coal mine operation which represents an orderly and economic use of a resource approved for extraction for use in domestic power generation. It would result in improved operational efficiencies associated with the combined operation of MC and CVC by Delta Coal and through the use of established infrastructure from local operations for the supply of coal to VPPS. The proposed modification will not impinge on land uses within and surrounding MC.

(d) to promote the delivery and maintenance of affordable housing,

The proposed modification relates to a coal mining operation and, therefore, this object is not relevant.

(e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,

The proposed modification would not involve any additional disturbance of native vegetation that would impact the conservation of threatened and other species or ecological communities. The proposed modification would utilise existing infrastructure and, therefore, no indirect impacts to ecological communities through light spill or noise and vibration are expected to occur additional to those currently approved.

(f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),

The proposed modification would not involve the disturbance of identified heritage items or any additional disturbance of previously undisturbed land that could contain unidentified cultural heritage.

(g) to promote good design and amenity of the built environment,

The proposed modification does not involve the construction of any new built elements. Approved built elements will remain unchanged under the proposed modification.

(h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,

The approved construction and maintenance requirements for existing buildings will remain unchanged under the proposed modification.

(i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State, and

The preparation of this SEE has involved engagement with relevant State and local government bodies as described in Chapter 4.

(j) to provide increased opportunity for community participation in environmental planning and assessment.

The community has been consulted during the preparation of the SEE through existing engagement tools and provision of briefing information and will continue to be involved and consulted through MC's CCC and other mechanisms. The community will also have the chance to comment on the application during the public exhibition process.

7.4 Suitability of the site

The site is an existing underground coal mine with established infrastructure and workforce. The proposed modification would not require variation to any operational aspects of the mine and, therefore, is considered to be suitable for the site.

7.5 Conclusion

Delta Coal seeks to modify MP 06_0311 to permit an increase in the rate of ROM coal handling at MC from 1.3 Mtpa up to the approved extraction limit at CVC (currently 2.1 Mtpa) to enable transfer of CVC coal to the surface via the approved underground linkage.

The proposed modification is a minor alteration to the approved development and is considered to be in the public interest as it:

- will enable the provision of coal in excess of the currently approved handling volume at MC of 1.3 Mtpa, whilst reducing truck movements to VPPS by private roads;
- will enable the provision of additional coal to VPPS via an existing approved conveyor network and will enhance the security of coal supply to the local domestic power generator (Delta Electricity);
- will lower capital and operating costs for Delta Coal's combined operations as the existing infrastructure at MC has the proven ability to supply coal to VPPS at a higher and more efficient rate than directly from CVC due to more advanced coal clearance infrastructure;
- will increase flexibility in bord and pillar layout which would result in maximised resource recovery from within the approved mining area;
- will provide greater financial certainty for the mine, which in turn, will provide increased job security for Delta Coal's employees and associated ongoing social and economic benefits;
- can achieve benefits with minimal adverse environmental impact;
- is aligned with the principles of ESD; and
- meets all relevant government policies.

References

Donnelly et al., 2011, *NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining.*

DPE 2014, *Voluntary Land Acquisition and Mitigation Policy.*

DPE 2015, *Assessment Report – Mannering Colliery, Increased Coal Handling & Dispatch Modification (MP06_0311 Mod 3)*.

EMM 2015a, *Mannering Colliery – Modification 3 Noise Impact Assessment*

EMM 2015b, *Mannering Colliery – Modification 3 Noise Impact Assessment Addendum*

EPA 2000, *Industrial Noise Policy (INP).*

EPA 2016, *Approved Methods for Modelling and Assessment of Air Pollutants in NSW.*

Scire et al., 2000*, User’s Guide for the CALPUFF Dispersion Model (Version 5).*

Appendix A

Preliminary environmental risk assessment

A.1 Methodology

An environmental risk assessment was undertaken for the proposed modification. It should be noted that the risk assessment and ranking applied relate only to the incremental change from the proposed modification compared to the approved development and does not reflect the overall environmental risks related to each aspect considered.

The risk assessment was undertaken using two variables, namely:

- the potential severity or consequences of the impact; and
- the likelihood of the impact occurring.

The variables were evaluated, assuming that appropriate mitigation measures would be in place.

The following definitions were applied:

- Severity or consequences of impact;
- Minor: Near-source confined and promptly reversible impact on-site with little or no off-site impact expected;
- Medium: Near source confined and short-term reversible impact on-site with little promptly reversible off-site impact;
- Serious: Near-source confined and medium-term recovery impact on-site with near-source and short-term reversible off-site impact;
- Major: Impact that is unconfined and requiring long-term recovery, leaving residual damage on-site with near-source confined and medium-term recovery of off-site impacts; and
- Catastrophic: Impact that is widespread and unconfined and requiring long-term recovery, leaving major residual damage on-site with off-site impact that is unconfined and requiring long-term recovery and leaving residual damage.

Likelihood of impact:

- Rare: Impact that is very unlikely to occur during the lifetime of the project;
- Unlikely: Impact that is unlikely to occur during the lifetime of the project;
- Possible: Impact that may occur during the lifetime of the project;
- Likely: Impact that may occur frequently during the lifetime of the project; and
- Almost Certain: Recurring event during the lifetime of the project.

Table A.1 shows the risk matrix used to identify environmental risks that were used to determine priorities for the SEE. In each case, a score of 1 to 5 is given for the consequence and likelihood of impact and the scores are added to determine environmental risk. There are four classes of environmental risk utilised in this assessment, as indicated below:

- **Low:** Risks that are below the risk acceptance threshold and do not require active management. Certain risks could require additional monitoring.

- **Moderate:** Risks that lie on the risk acceptance threshold and require active monitoring. The implementation of additional measures could be used to reduce the risk further.
- **High:** Risks that exceed the risk acceptance threshold and require proactive management. Includes risk for which proactive actions have been taken, but further risk reduction is impractical.
- **Critical:** Risks that significantly exceed the risk acceptance threshold and need urgent and immediate action.

Table A.1 Environmental assessment matrix

Likelihood of Impact	*Consequence* 1 Minor	2 Medium	3 Serious	4 Major	5 Catastrophic
5 Almost Certain	6 (Moderate)	7 (High)	8 (Critical)	9 (Critical)	10 (Critical)
4 Likely	5 (Moderate)	6 (High)	7 (High)	8 (Critical)	9 (Critical)
3 Possible	4 (Low)	5 (Moderate)	6 (High)	7 (Critical)	8 (Critical)
2 Unlikely	3 (Low)	4 (Low)	5 (Moderate)	6 (High)	7 (Critical)
1 Rare	2 (Low)	3 (Low)	4 (Moderate)	5 (High)	6 (High)

A.2 Results

The results of the environmental risk assessment are provided in Table A.2. All risks were rated low.

Table A.2 Environmental risk rating

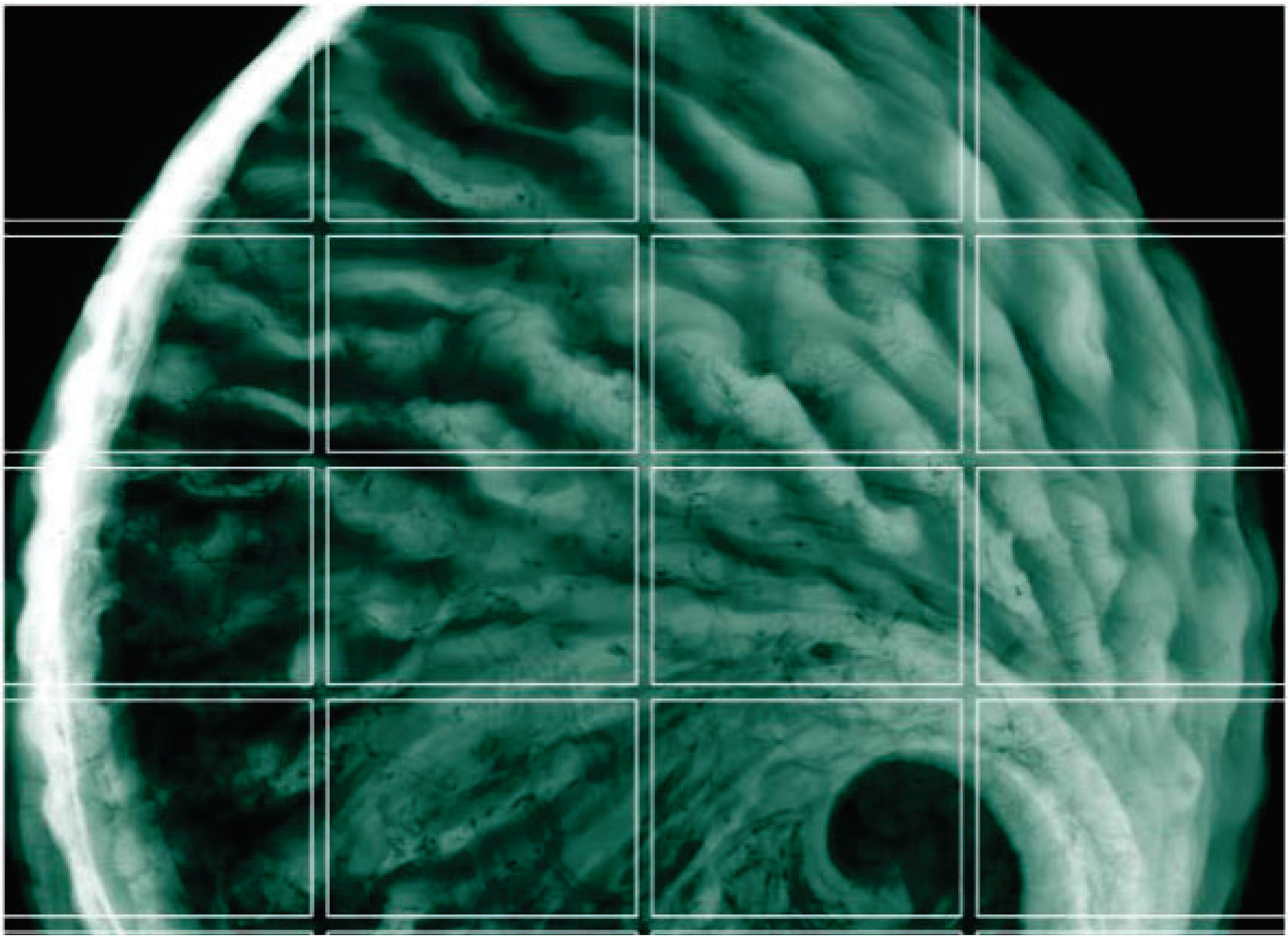
Environmental attribute	Likelihood	Consequence	Risk rating
Air quality and greenhouse gases			
Increase in dust emissions impacting sensitive receivers	2 (Unlikely)	2 (Medium)	4 (Low)
Increase greenhouse gas emissions	2 (Unlikely)	1 (Minor)	3 (Low)
Noise			
Increase in noise emissions impacting sensitive receivers	2 (Unlikely)	2 (Medium)	4 (Low)

Table A.2 Environmental risk rating

Environmental attribute	Likelihood	Consequence	Risk rating
Ecology			
Impacts on native vegetation and fauna habitat	1 (Rare)	1 (Minor)	2 (Low)
Heritage			
Impacts on Aboriginal heritage and historically significant heritage	1 (Rare)	1 (Minor)	2 (Low)
Surface water			
Changes required to surface water management system to manage pollutant load	2 (Unlikely)	2 (Medium)	4 (Low)
Socio-economic			
General amenity impacts on local community	1 (Rare)	1 (Minor)	2 (Low)
Waste management			
Additional waste generation	3 (Possible)	1 (Minor)	4 (Low)
Traffic and transport			
Increase in traffic on public roads	1 (Rare)	1 (Minor)	2 (Low)
Visual amenity			
Impacts on visual amenity at sensitive receivers	1 (Rare)	1 (Minor)	2 (Low)

Appendix B

Air quality assessment



Great Southern Energy Pty Ltd
(trading as Delta Coal)

Mannering Colliery Modification 5

Air Quality Assessment

21 May 2019

Project No.: 0503194

The business of sustainability

ERM

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21 May 2019

Mannering Colliery Modification 5

Air Quality Assessment

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1. INTRODUCTION

Mannering Colliery (MC) (the project) is an underground coal mine located at the southern end of Lake Macquarie approximately 60 kilometres (km) south of Newcastle. MC is approved under major project approval (MP06_0311) and is operated by Great Southern Energy Pty Ltd (trading as Delta Coal).

Underground mining commenced at MC in 1960, and since that time has extracted coal from the Great Northern and Fassifern Seams using both the bord and pillar and longwall mining methods. Coal extracted from MC is transported via a dedicated overland conveyor to Sunset Energy's Vales Point Power Station (VPPS) for domestic energy generation.

Construction of an underground linkage within the Fassifern Seam which allows for the movement of coal from the adjacent Chain Valley Colliery (CVC) has been completed. CVC operates under State significant development consent (SSD-5465) and is also operated by Delta Coal. SSD-5465 permits up to 1.3 Mtpa of run-of-mine (ROM) coal extracted at CVC to be handled within MC's surface facilities and conveyed to VPPS (hereafter referred to as the approved project).

Delta Coal is seeking to modify MP06_0311 under Section 4.55(2) of the NSW *Environmental Planning and Assessment Act 1979* to permit an increase in the rate of ROM coal handling at, and transport via overland conveyor from, MC up to the approved extraction limit at CVC (the proposed modification).

The increased volume of coal will be sourced from MC which has a maximum extraction limit of 1.1 million tonnes per annum (Mtpa); from CVC which has a maximum extraction limit of 2.1 Mtpa of ROM coal; or a combination of both.

It is noted that coal extracted from MC and CVC is crushed and screened.

No changes to surface infrastructure are proposed, with the existing infrastructure having adequate capacity to accommodate the additional coal throughput, and no upgrades or additional plant or equipment are required. The increased coal throughput would all be dispatched via the existing overland conveyor to VPPS as currently approved. There will be no changes to the employee numbers at MC as a result of the proposed modification.

It is noted that the dispersion modelling and report for the proposed modification were originally completed in August 2017 (prior to the ERM acquisition of Pacific Environment).

2. PROPOSAL DESCRIPTION

2.1 Scope of Assessment

The air quality assessment provides a contemporary assessment of the approved project and determines the incremental change from the proposed modification compared to the approved project.

2.2 Local Setting and Topography

The closest privately owned residential area to MC is Macquarie Shores Residential Development, approximately 950 m east of the MC Surface Facilities (see Figure 2-1). The surface areas occupied by MC lie within the Central Coast local government area (LGA), with the areas of underground activity straddling both the Central Coast and Lake Macquarie LGAs.

For the purposes of assessing impacts from the project, discrete assessment locations were selected as presented in Table 2-1 and Figure 2-2. These receptors represent assessment locations in close proximity to the MC surface facilities. Assessment locations are consistent with those applied in the most recent noise impact assessment prepared by EMM for Modification 3 to MP06_0311.

Figure 2-3 shows a pseudo three-dimensional (3D) representation of the local topography in the area of MC, CVC and surrounds. Vertical exaggeration is applied to emphasise terrain features.

Table 2-1: Sensitive receptor locations

ID	Location	Easting	Northing
Residential			
4	Ruttleys Road	363695	6327245
5	Pacific Highway	363940	6327347
6	Pacific Highway	364178	6327282
7	130 Tall Timbers Road	365360	6328072
8	150 Tall Timbers Road	365018	6328096
9	210 Tall Timbers Road	365173	6328884
11	187 Tall Timbers Road	365312	6328713
18	201 Tall Timbers Road	365265	6328839
20	221 Tall Timbers Road	365169	6329047

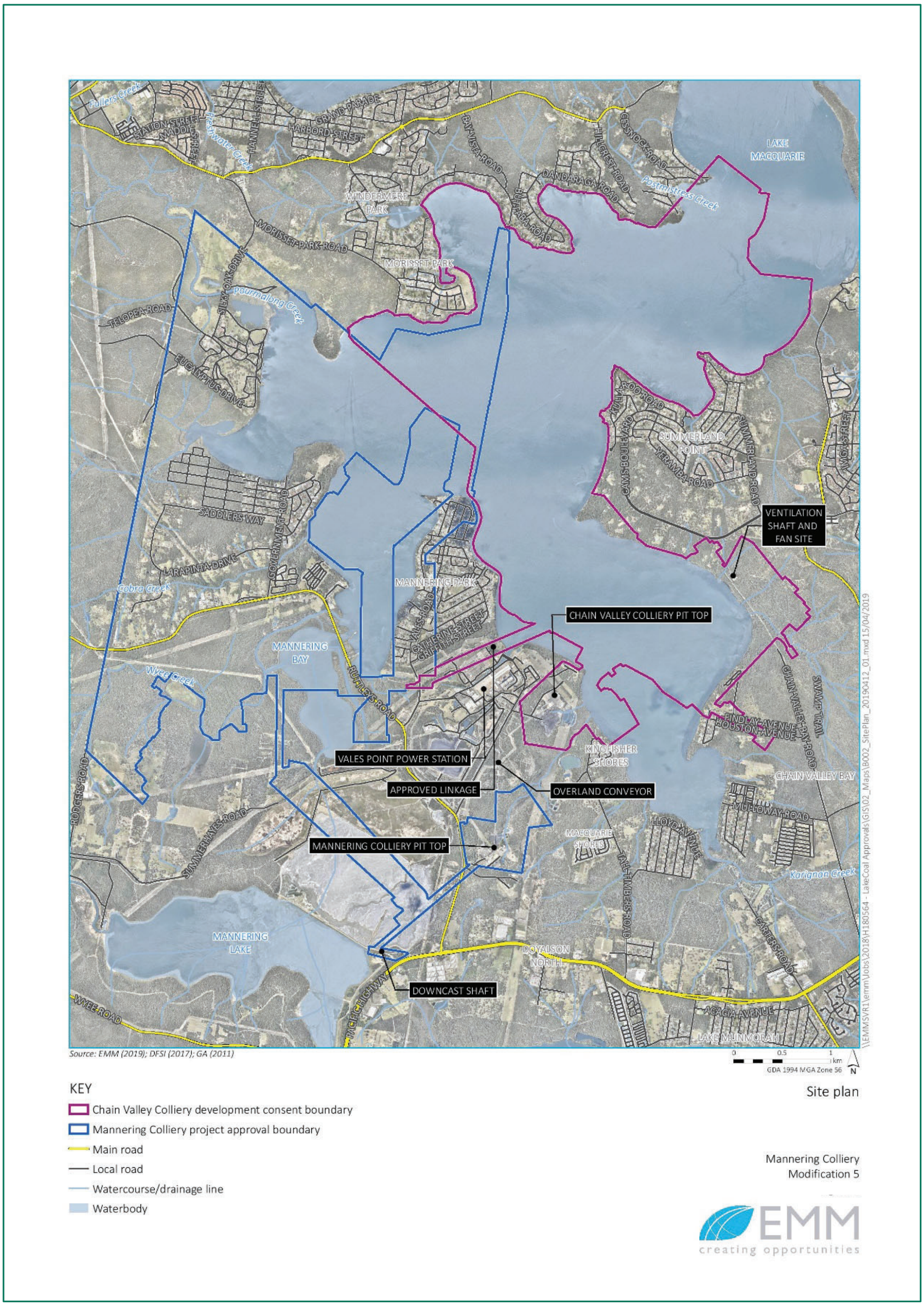


Figure 2-1: MC mine locality plan

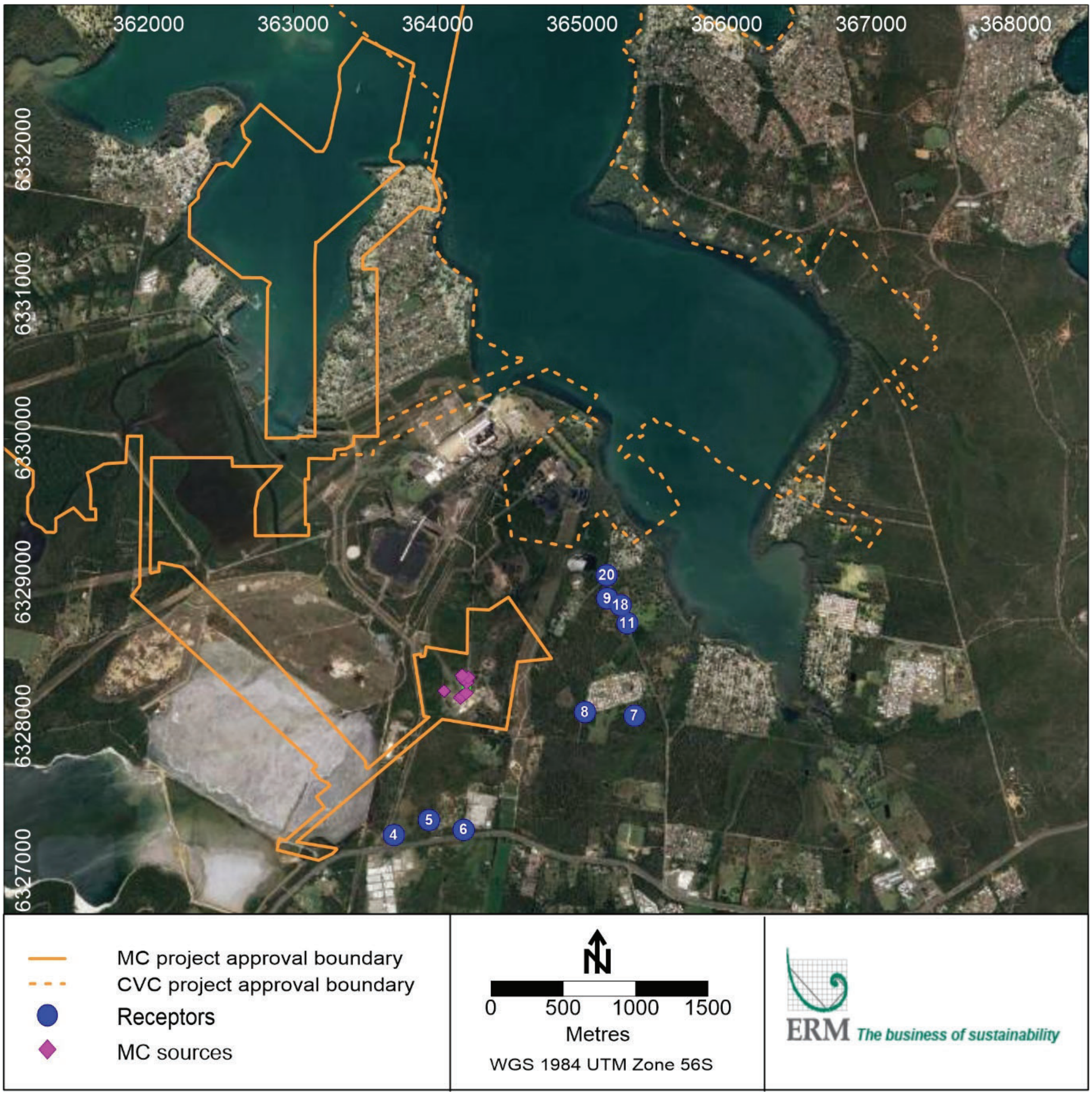


Figure 2-2: MC location and sensitive receptor locations

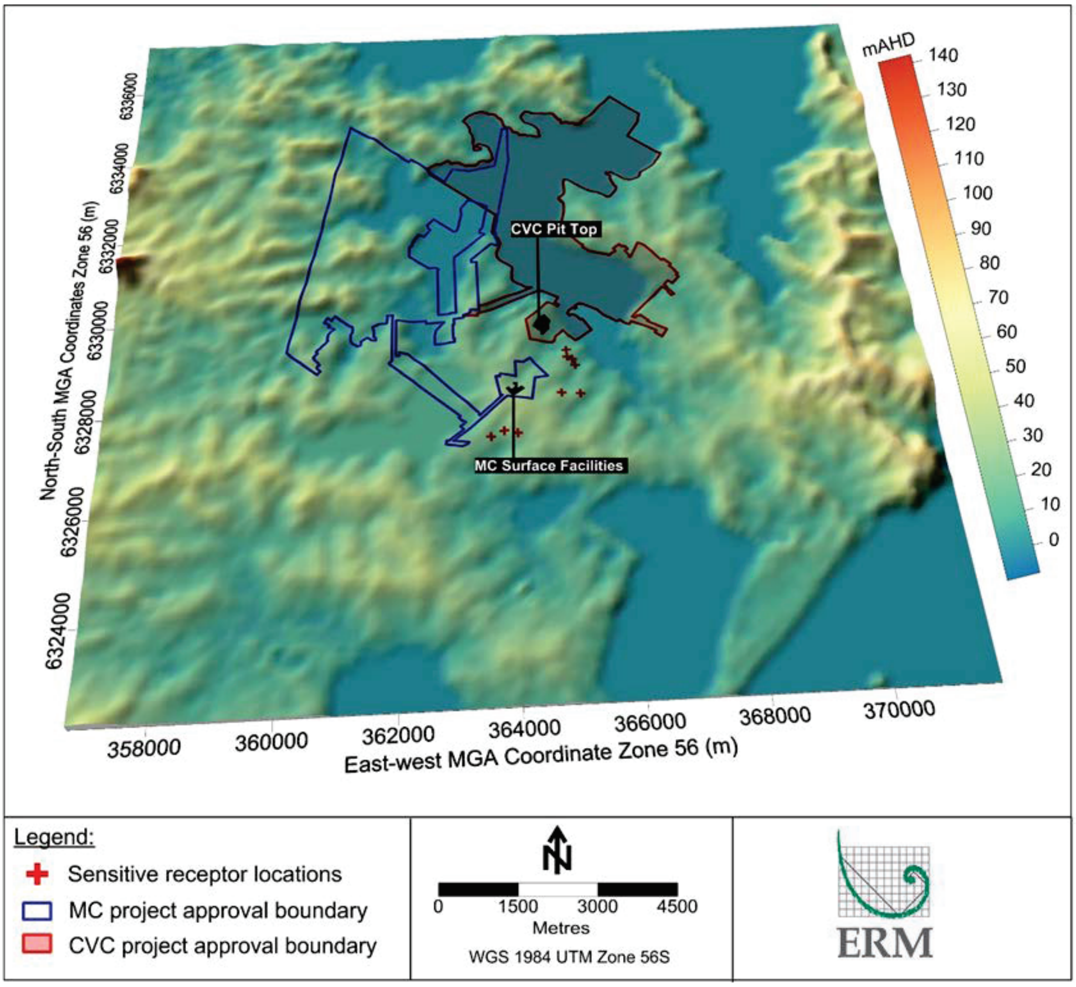


Figure 2-3: Pseudo 3-D representation of regional topography within modelling domain and sensitive receptor locations

3. AIR QUALITY CRITERIA

3.1 Emissions to Air

Activities with the potential to generate fugitive dust emissions requiring assessment are screening, conveying and stockpiling at the MC surface facilities area. Fugitive dust emissions can also be expected as a result of vehicle movements on unsealed surfaces, material handling on the site, wind erosion and from the ventilation shaft.

No changes to surface infrastructure are proposed, with the existing infrastructure having adequate capacity to accommodate the additional coal throughput, and no upgrades or additional plant or equipment are required.

The following sections provide information on the air quality criteria applied in this assessment.

3.2 NSW EPA Impact Assessment Criteria

The publication entitled "Approved Methods for Modelling and Assessment of Air Pollutants in NSW" (the Approved Methods) (NSW EPA, 2016) specifies air quality assessment criteria relevant for assessing impacts from air pollution.

These criteria are health-based (i.e. they are set at levels to protect against health effects) and for PM_{10} and $PM_{2.5}$ are consistent with Amended National Environment Protection Measure for Ambient Air Quality (Ambient Air-NEPM) (NEPC, 2016). In addition, the Approved Methods include other measures of air quality, namely dust deposition and Total Suspended Particulates (TSP) which are not stated in the Ambient Air-NEPM. The Approved Methods were updated at the end of 2016 to make the annual average PM_{10} criterion equivalent to the NEPM criterion, i.e. (25 µg/m³), prior to this the criterion was 30 µg/m³. The updated Approved Methods also introduced criteria for 24-hour average and annual average $PM_{2.5}$ of 8 µg/m³ and 25 µg/m³ respectively.

Table 3-1 presents the air quality criteria for pollutants that are relevant to this study. It is important to note that the criteria are applied to the cumulative impacts due to the project and other sources.

Table 3-1: NSW EPA Impact Assessment Criteria for Particulate Matter Concentrations

Pollutant	Standard	Averaging Period	Source
TSP	90 µg/m³	Annual	NSW EPA (2016)
PM_{10}	50 µg/m³ 25 µg/m³	24-Hour Annual	NSW EPA (2016)
$PM_{2.5}$	25 µg/m³ 8 µg/m³	24-Hour Annual	NSW EPA (2016)

Notes: µg/m³ – micrograms per cubic metre.

In addition to health impacts, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including vegetation. Larger particles do not tend to remain suspended in the atmosphere for long periods of time and will fall out relatively close to source. Dust deposition can soil materials and generally degrade aesthetic elements of the environment, and are therefore assessed for nuisance or amenity impacts.

Table 3-2 shows the maximum acceptable increase in dust deposition over the existing dust levels from an amenity perspective. These criteria for dust deposition levels are set to protect against nuisance impacts (NSW EPA, 2016).

Table 3-2: NSW EPA Impact Assessment Criteria for Dust (Insoluble Solids) Fallout

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

3.3 NSW Department of Planning and Environment Voluntary Land Acquisition and Mitigation Policy

In December 2014, NSW Department of Planning and Environment (DPE) released a policy relating to Mining, Petroleum Production and Extractive Industries and including the identification of voluntary mitigation and land acquisition criteria for air quality and noise (NSW Government, 2014). This is reflected in State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 (the Mining SEPP) at Clause 12A.

The policy sets out voluntary mitigation and land acquisition rights where it is not possible to comply with the NSW EPA impact assessment criteria even with the implementation of all reasonable and feasible avoidance and/or mitigation measures.

A revised VLAMP was issued by DPE in February 2018 and formally adopted in September 2018 (NSW Government, 2018), to align the criteria with the NEPM and NSW EPA impact assessment criteria.

The DPE voluntary mitigation and acquisition criteria are summarised in Table 3-3 and Table 3-4, respectively. The proposed modification has been assessed against these criteria, in addition to the NSW EPA impact assessment criteria discussed in Section 3.2.

Table 3-3: DPE Particulate Matter Mitigation Criteria

Pollutant	Criterion	Averaging Period	Application[a]
TSP	90 $\mu g/m^3$	Annual mean	Total impact[b]
PM_{10}	50 $\mu g/m^3$	24-hour average	Incremental impact[c]
	25 $\mu g/m^3$	Annual mean	Total impact[b]
$PM_{2.5}$	25 $\mu g/m^3$	24-hour average	Incremental impact[c]
	8 $\mu g/m^3$	Annual mean	Total impact[b]
Deposited dust	2 g/m^2/month	Annual mean	Incremental impact[c]
	4 g/m^2/month	Annual mean	Total impact[b]

Notes:

a) Voluntary mitigation rights may be applied where the Proposal contributes to exceedances of the mitigation criteria at any residence on privately-owned land and in some circumstances a workplace on privately-owned land.

b) Cumulative impact (i.e. increase in concentrations due to the development plus background concentrations due to all other sources).

c) Incremental impact (i.e. due to the development alone), with zero allowable exceedances over the life of the development.

Table 3-4: DPE Particulate Matter Acquisition Criteria

Pollutant	Criterion	Averaging Period	Application[a]
TSP	90 $\mu g/m^3$	Annual mean	Total impact[b]
PM_{10}	50 $\mu g/m^3$	24-hour average	Incremental impact[c]
	25 $\mu g/m^3$	Annual mean	Total impact[b]
$PM_{2.5}$	25 $\mu g/m^3$	24-hour average	Incremental impact[c]
	8 $\mu g/m^3$	Annual mean	Total impact[b]
Deposited dust	2 g/m^2/month	Annual mean	Incremental impact[c]
	4 g/m^2/month	Annual mean	Total impact[b]

Notes:

a) Voluntary acquisition rights apply where the Proposal contributes to exceedances of the acquisition criteria at any residence or workplace on privately-owned land, or, on more than 25% of any privately-owned land, and a dwelling could be built on that land under exiting planning controls

b) Cumulative impact (i.e. increase in concentrations due to the development plus background concentrations due to all other sources).

c) Incremental impact (i.e. due to the development alone), with up to five allowable exceedances over the life of the development.

Total impact includes the impact of the proposed modification and all other sources, whilst incremental impact refers to the impact of the proposed modification considered in isolation.

3.3.1 Protection of the Environment Operations (POEO) Act 1997

If the modification application is approved, Delta Coal's current MC Environmental Protection Licence (EPL No. 191) issued by the NSW EPA under the Protection of the Environment Operations Act 1997 (POEO Act) would be revised. With reference to air quality, the EPL outlines Delta Coal's requirements to minimise dust emissions and also specifies air quality monitoring requirements. The Protection of the Environment Operations (Clean Air) Regulations 2010 (POEO (Clean Air) Regulation) (POEO, 2010) sets out standards of concentration for emissions to air from scheduled activities. The maximum pollution levels allowed under the regulations for general activities are provided in Table 3-5.

Table 3-5: Maximum Allowable Emission Levels

Air Impurity	Activity or Plant	Standard of Concentration
Solid Particles	Any process emitting solid particles	50 mg/m^3

The NSW *POEO (Clean Air) Regulation* also prescribes requirements for domestic solid fuel heaters, control of burning, motor vehicle emissions and industrial emissions. Motor vehicle emissions would be addressed by regular maintenance of all vehicles associated with the ongoing operation of MC and no burning would be conducted on-site to minimise potential for smoke impacts on neighbouring receivers.

3.3.2 The Best Practice Report

The NSW EPA commissioned *the NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining* (Donnelly et al., 2011) (hereafter referred to as the Best Practice Report).

The Best Practice Report provides guidance on controls for reducing emissions and is benchmarked on the international best practice for the following activities:

- Trucks hauling on unpaved haul roads.

- Wind erosion of exposed materials and stockpiles.
- Bulldozing.
- Blasting.
- Drilling.
- Draglines.
- Loading and dumping overburden.
- Loading and dumping ROM coal.
- Monitoring, proactive and reactive management.

The potential best practice control measures relevant to activities at MC and currently applied by Delta Coal at MC are summarised in Section 6.

4. EXISTING ENVIRONMENT

This section describes the existing dust levels, local wind data and local climatic conditions in the area surrounding MC.

It is noted that at the time the air quality assessment was completed, data were only available to the end of 2016. Data for 2017 and 2018 have been included in the following sections and applied to the cumulative assessment where relevant.

4.1 Existing Air Quality

4.1.1 Introduction

Air quality standards and criteria refer to pollutant levels that include the cumulative contribution from existing sources and the project being assessed. To fully assess the potential impact of the proposed modification against all relevant air quality assessment criteria and standards (see Section 3) it is necessary to characterise the existing or background conditions.

There are various monitoring sites located at or nearby the MC and CVC surface facilities, as shown in Figure 4-1. Given the close proximity of the collieries, the CVC monitoring sites are of relevance to the proposed modification and are therefore referred to below. A meteorological station is located at MC - meteorological conditions are discussed in Section 4.2.

Dust deposition levels are monitored monthly at five different locations at each of MC and CVC. Since December 2013, CVC has also operated a Tapered Element Oscillating Microbalance (TEOM) station which measures PM_{10}. The TEOM is located at the Wyong Waste Water Treatment Plant on Tall Timbers Road Kingfisher Shores.

The air quality monitors measure the existing dust deposition and particulate concentrations due to emissions from all sources that contribute to dust in the air. These sources include current operations at CVC, activities at MC, activities at the neighbouring VPPS and other anthropogenic sources, as well as natural emission sources in the local and broader area.

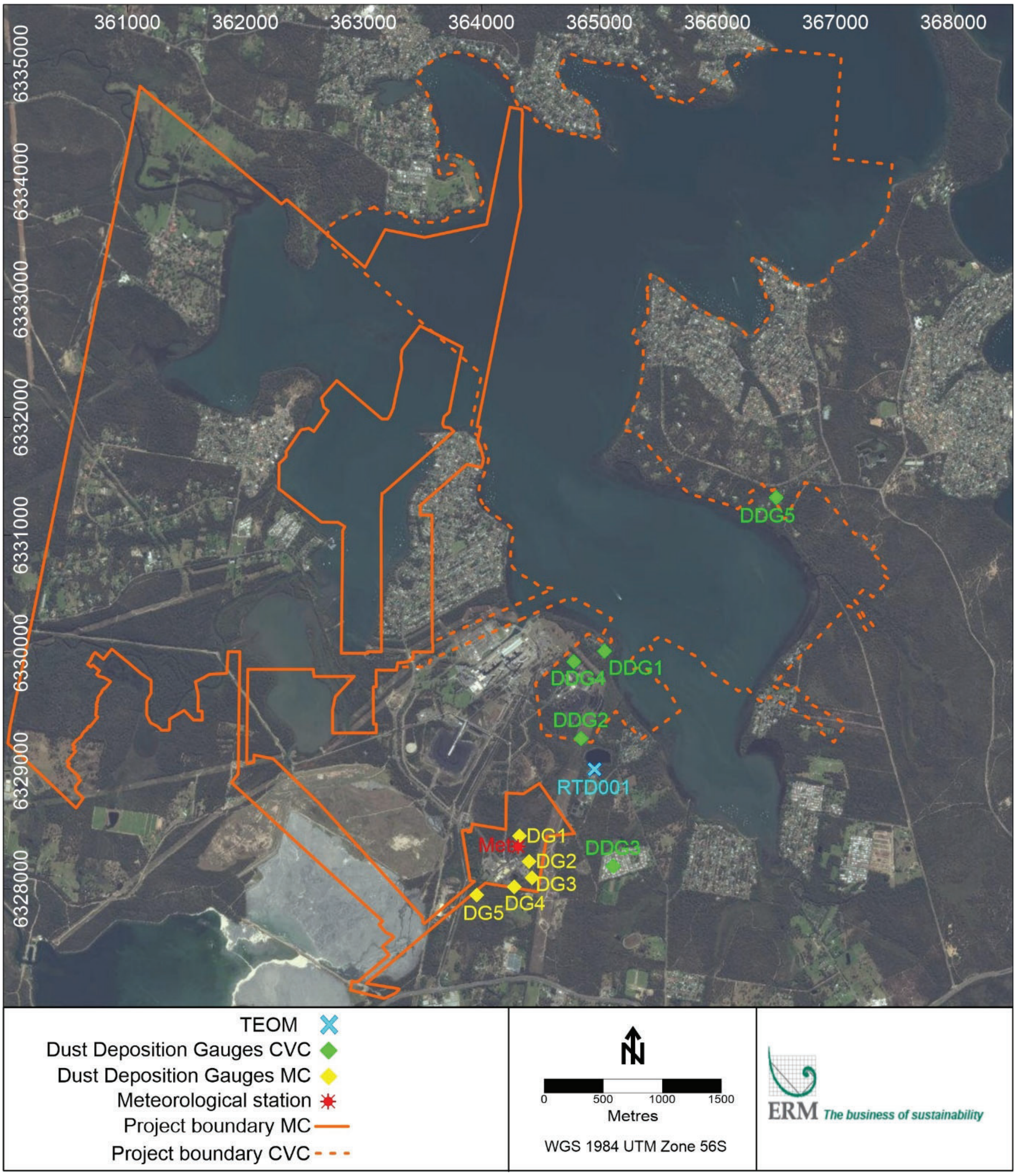


Figure 4-1: Air Quality Monitoring Network

4.1.2 Dust deposition

Table 4-1 summarises the insoluble solids deposition levels monitored at MC since 2006 and CVC since 2012. Samples affected by any potential contaminating influences such as bird droppings have been excluded from the averages of the reported dust deposition.

There have been not exceedances of the EPA dust deposition criteria of 4 g/m^2/month at the MC or CVC dust deposition gauges since their installation, with the annual average dust deposition at individual sites ranging from 0.3 g/m^2/month to 3.7 g/m^2/month. Across all sites, the annual average dust deposition is 1.0 g/m^2/month.

Table 4-1: Annual average (insoluble solid) deposition levels (g/m²/month)

Year	Mannering					Chain Valley				
	DG1	DG2	DG3	DG4	DG5	DDG1	DDG2	DDG3	DDG4	DDG5
2006	0.8	1.0	1.0	0.7	0.9	-	-	-	-	-
2007	0.9	0.7	1.2	1.1	0.9	-	-	-	-	-
2008	1.0	0.8	0.9	1.0	0.6	-	-	-	-	-
2009	1.9	1.3	1.4	1.4	1.2	-	-	-	-	-
2010	2.7	0.7	2.0	0.8	0.5	-	-	-	-	-
2011	0.8	0.6	0.7	0.6	0.8	-	-	-	-	-
2012	0.6	0.5	0.5	0.5	0.6	1.2	0.9	3.5	2.8	-
2013	1.1	0.7	0.8	0.7	0.7	0.8	1.0	2.1	2.0	1.0
2014	0.6	0.6	0.6	0.7	0.6	1.2	1.1	1.1	1.1	1.0
2015	0.5	0.6	0.5	0.8	0.6	0.7	0.8	1.5	1.7	1.2
2016	0.7	0.9	0.9	1.1	0.7	0.5	0.7	1.1	1.1	1.7
2017	0.7	0.6	0.9	1.0	0.3	0.8	1.0	1.1	1.0	2.2
2018	1.0	0.7	0.7	1.0	0.8	0.8	0.7	0.7	1.0	2.0
Average	1.1	0.8	1.0	0.9	0.8	0.9	0.9	1.6	1.5	1.0
Average all data	**1.0**									

4.1.3 PM_{10} and $PM_{2.5}$ concentrations

Delta Coal operate a TEOM to measure PM_{10} that is located at the Wyong Waste Water Treatment Facility in Kingfisher Shores. PM_{10} data have been collected here since 23 December 2013. Figure ***4-2*** presents a plot of the 24-hour average PM_{10} concentrations since that time to the end of 2018.

There is a clear seasonal variation with elevated measurements occurring in the warmer months when the area is drier and also when bushfires and dust storms can often occur. Since the installation of the TEOM there has been one exceedance of the 24-hour average PM_{10} criterion of 50 µg/m³ on the 6th May 2015, and four exceedances on the 19th March, 18th July, 22nd and 23rd November 2018. The 24-hour average PM_{10} concentration on these days was 56 µg/m³, 50.2 µg/m³, 57.8 µg/m³, 113 µg/m³ and 91.6 µg/m³ respectively. The New South Wales Air Quality Statement 2015 (NSW OEH, 2016) states that a dust storm occurred on 6th May. Another exceptional event due to long-range dust transport occurred on 18 July (NSW OEH, 2018). A dust storm originating from South Australia and drought affected regions in New South Wales was noted on 21 November (NSW OEH,2018)..
Annual average PM_{10} measurements between 2014 and 2018 are shown in Table 4-2. There are no recorded exceedances of the annual average PM_{10} assessment criterion of 25 µg/m³.

Table 4-2: Annual average PM_{10} at CVC

Year	PM_{10} (µg/m³)
2014	14.9
2015	13.7
2016	13.4
2017	15.1
2018	16.1
Average	**14.7**

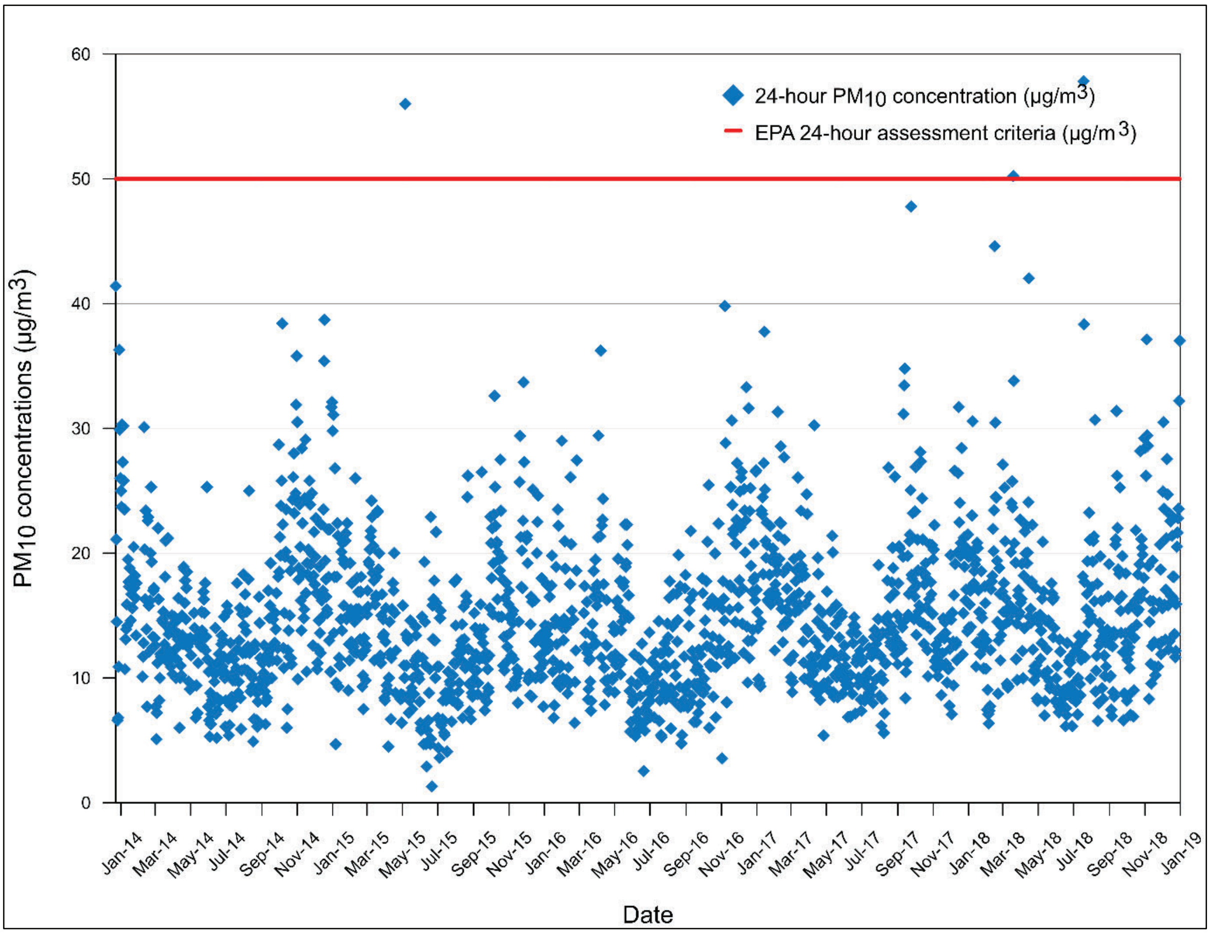


Figure 4-2: 24-hour average PM_{10} TEOM measurements at CVC

NSW Office of Environment and Heritage (OEH) has operated an ambient air and meteorological monitoring station at Newcastle City Council Swimming Pool, Wallsend since 1994. The monitoring station is approximately 36 km northeast of MC. Ambient air data collected at the station includes PM_{10}, using a real-time TEOM, and $PM_{2.5}$, using a fine particle nephelometer.

The annual average PM_{10} and $PM_{2.5}$ concentrations at the Wallsend OEH monitoring site for the period 2012 to 2018 are presented in Table 4-3. There are no exceedances of the annual average impact assessment criterion recorded for either PM_{10} or $PM_{2.5}$ during that time.

Table 4-3: Annual average PM_{10} and $PM_{2.5}$ OEH monitoring data from Wallsend (2012-2016)

Year	PM_{10}	$PM_{2.5}$
	($\mu g/m^3$)	
2012	14.9	5.1
2013	17.4	7.7
2014	16.9	6.7
2015	16.7	7.3
2016	16.6	8.0
2017	17.5	7.1
2018	19.3	7.3
Average	**17.0**	**7.0**

The average PM_{10} concentrations at Wallsend are slightly higher than measured at the CVC TEOM, which is not unexpected given the higher population and nature of activities in the vicinity of the Wallsend monitoring site. The average PM_{10} concentrations at Wallsend over the five years was 17.0 $\mu g/m^3$ and the average $PM_{2.5}$ concentration was 7.0 $\mu g/m^3$ resulting in an average $PM_{2.5}$ to PM_{10} ratio of 0.41. Applying this ratio to the average PM_{10} concentration measured at the CVC TEOM between 2014 and 2018 of 14.7 $\mu g/m^3$ gives an estimated existing annual average $PM_{2.5}$ concentration of 6.0 $\mu g/m^3$. However, in order to present a conservative assessment, it has been assumed the existing annual average $PM_{2.5}$ concentration in the vicinity of MC is the same as at Wallsend, i.e. 7.0 $\mu g/m^3$.

4.1.4 TSP concentrations

In the absence of TSP monitoring data, the annual average TSP concentrations can be estimated from the PM_{10} measurements by assuming that 40% of the TSP is PM_{10}. This relationship was obtained from data collected by co-located TSP and PM_{10} monitors operated for long periods of time in the Hunter Valley (NSW Minerals Council, 2000). Use of this relationship on the 2014 – 2018 PM_{10} annual average of 14.7 $\mu g/m^3$ gives an existing annual average TSP concentration of approximately 37 $\mu g/m^3$.

4.1.5 Existing air quality for assessment purposes

In summary, for the purposes of assessing potential air quality impacts arising from the proposed modification, the following existing air quality levels have been adopted:

- Annual average TSP concentration of 37 $\mu g/m^3$.
  - 2014 to 2018 average PM_{10} at CVC TEOM multiplied by 2.5 per Section 4.1.4 .
- Annual average PM_{10} concentration of 14.7 $\mu g/m^3$.
  - 2014 to 2018 average at CVC TEOM.
- Annual average $PM_{2.5}$ concentration of 7.0 $\mu g/m^3$.
  - 2012 to 2018 average of Wallsend OEH monitoring per Section 4.1.3.
- Annual average dust deposition of 1 g/m^2/month.
  - 2006 to 2018 average of data collected at MC and CVC.
- 24-hour average PM_{10} concentrations.
  - Daily varying based on CVC TEOM.
- 24-hour average $PM_{2.5}$ concentrations.
  - Daily varying based on Wallsend OEH $PM_{2.5}$:PM_{10} ratio to CVC PM_{10}.

4.2 Meteorological Data

Meteorological data including wind speed, wind direction, temperature, humidity and sigma-theta have been collected at the MC weather station since 2013. The station's location is shown on Figure 4-1.

Hourly average data collected over the period of July 2013 – December 2018 were used to create annual and seasonal wind roses which are presented in Figure 4-3 to Figure 4-5. The predominant annual winds are from the southwest and these occur through autumn, winter and spring. During summer the dominant winds are from the northeast.

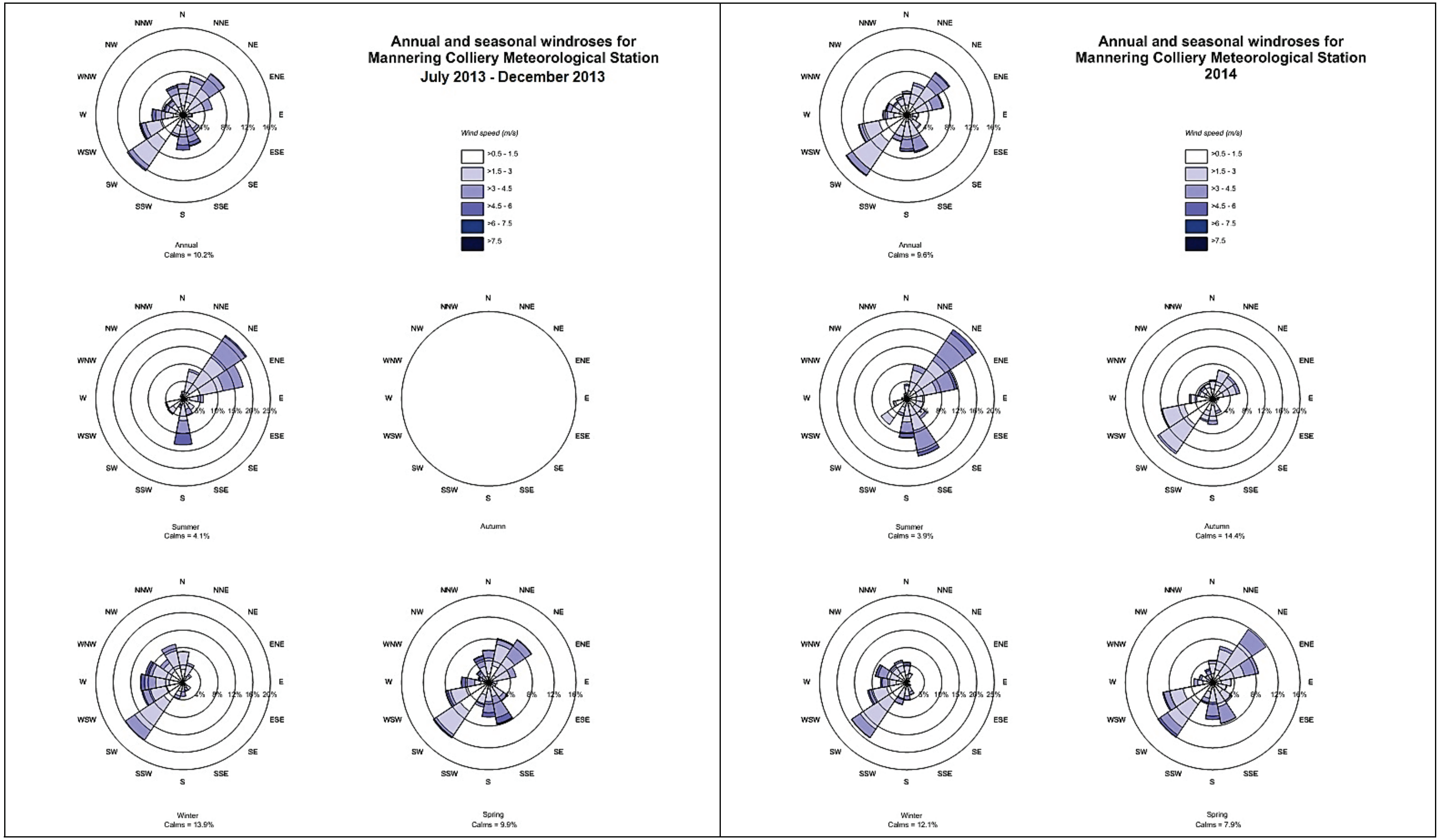
It is important to note that as required by the Approved Methods, dispersion modelling requires the use of a full year of continuous meteorological data. For a full 12–month period this equates to 8,760 hours (in a non-leap year). Therefore, any data from sites that are only collected at 9am and 3pm are not valid for use in an assessment of this nature. The period chosen for modelling is the complete year 2015.

Table 4-4 provides statistics for four calendar years of meteorological data (July 2013 to December 2018) which includes the modelling data period. The data for 2013 to 2014 and 2016 to 2018 shows that the percentage of calms, annual average wind speed and percentage data recovery is similar to that of the modelling period and, therefore, confirms its appropriateness for the assessment. The percentage of calms ranges from 9.1% to 10.4%, the average wind speed between 1.8 m/s and 1.9 m/s and the data recovery was 100% for all periods.

Table 4-4: Comparative Statistics for Meteorological Data

Period	% Calms	Average Wind Speed (m/s)	% Data Recovery
July - December 2013	10.2%	1.8	100%
January - December 2014	9.7%	1.9	100%
January - December 2015	9.1%	1.8	100%
January - December 2016	10.4%	1.9	100%
January - December 2017	10.4 %	1.9	100%
January - December 2018	10 %	1.9	100%

Wind roses for MC for the modelling period (January – December 2015) and the periods as listed in Table 4-4 are shown in Figure 4-3 to Figure 4-5.



NB: 2013 data only available July to December therefore no winter data

Figure 4-3: Annual and seasonal windroses for Mannering Colliery (July-December 2013 and January-December 2014)

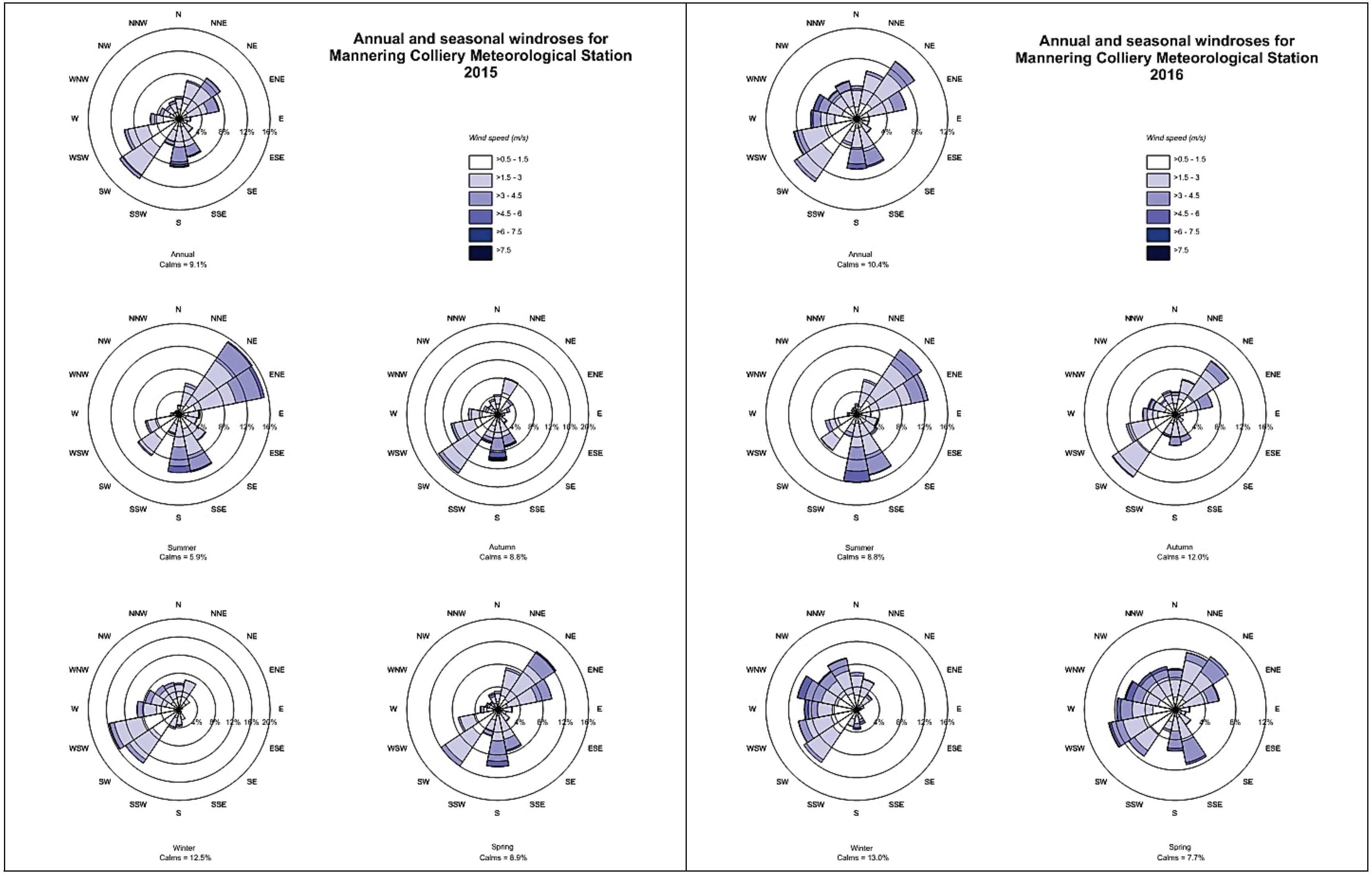


Figure 4-4: Annual and seasonal windroses for Mannering Colliery (January-December 2015 and January-December 2016)

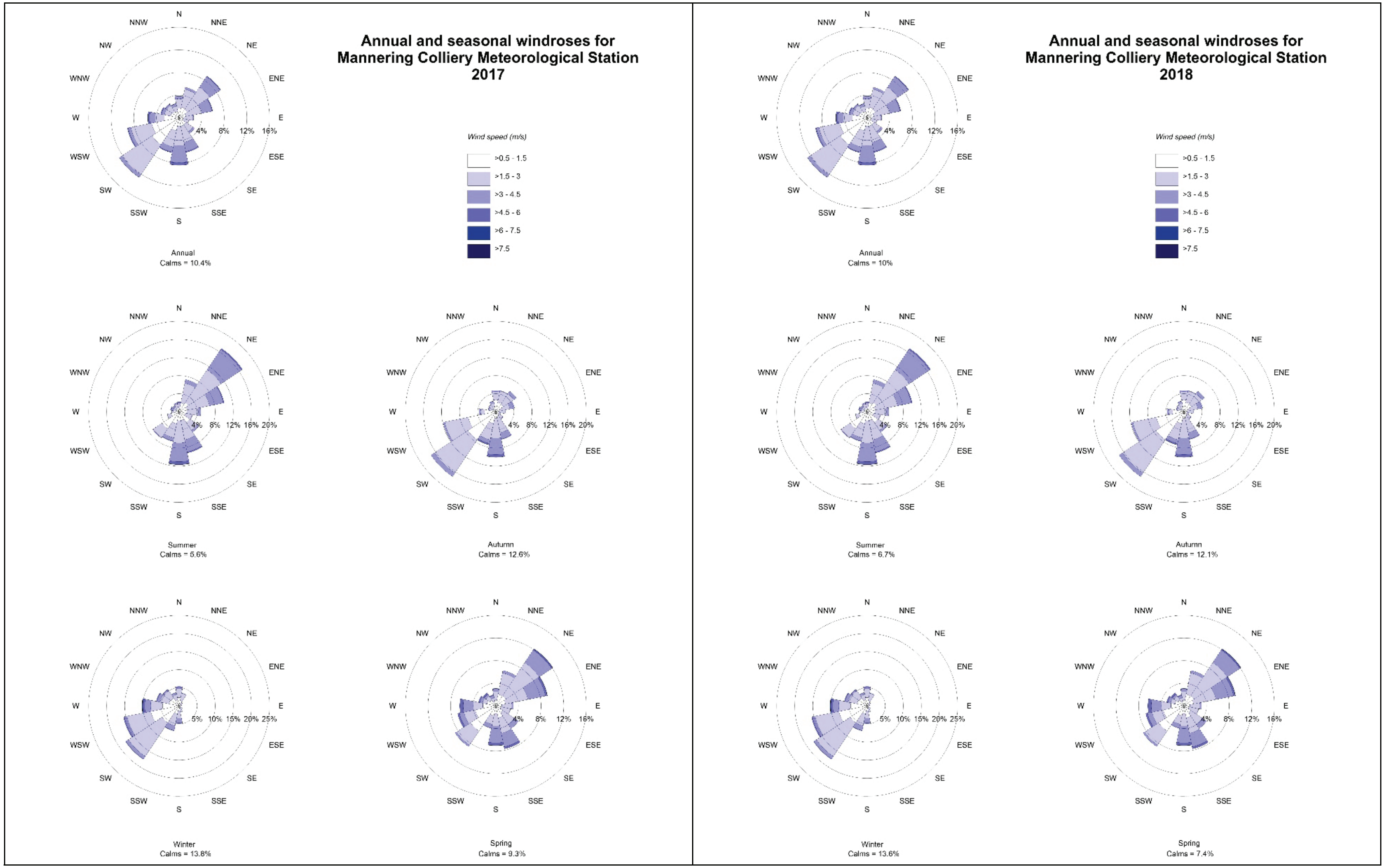


Figure 4-5: Annual and seasonal windroses for Mannering Colliery (January-December 2017 and January-December 2018)

4.3 Climate Data

The closest Bureau of Meteorology (BoM) station is located at Norah Head (Station Number 61366), approximately 15km to the south of the MC surface facilities. The station collects information on the long-term average values of climatic elements such as temperature, humidity, rainfall, the number of rain days per year etc.

Table 4-5 presents temperature, humidity and rainfall data collected at Norah Head over the period from 1964 to April 2019 (Bureau of Meteorology, 2019). Temperature and humidity data consist of monthly means of 9am and 3pm readings. Monthly averages of maximum and minimum temperatures are also presented. Rainfall data consist of mean and median monthly rainfall and the average number of rain days per month.

The annual mean maximum and minimum temperatures experienced at Norah Head are 22.3°C and 15.2°C. On average, January is the hottest month with an average maximum temperature of 26.2°C. July is the coldest month, with average minimum temperature of 9.8°C.

The annual mean relative humidity reading collected at 9am at Norah Head is 71%, and at 3pm the annual mean is 65%. The month with the highest humidity on average is February with a 9am average of 78%, and the lowest is August with a 3pm average of 56%.

Rainfall data collected at Norah Head shows that June is the wettest month, with a mean rainfall of 157 mm over 14 days. The mean annual rainfall is 1153.5 mm with a mean of 146.2 rain days.

Table 4-5: Climate Averages for the Norah Head AWS for 1964-15 June 2017

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
9am Mean Dry-bulb and Wet-bulb Temperatures (ºC) and Relative Humidity (%)													
Dry-bulb	22.3	22.4	21.1	19.3	16.2	13.7	12.8	14.5	17.2	19.3	20.0	21.6	18.4
Humidity	76.0	78.0	76.0	71.0	72.0	72.0	69.0	63.0	64.0	65.0	72.0	72.0	71.0
3pm Mean Dry-bulb and Wet-bulb Temperatures (ºC) and Relative Humidity (%)													
Dry-bulb	24.0	24.2	23.3	21.2	18.9	16.7	16.1	17.4	19.0	20.3	21.5	23.1	20.5
Humidity	70.0	72.0	69.0	65.0	64.0	63.0	59.0	56.0	60.0	64.0	68.0	68.0	65.0
Daily Maximum Temperature (ºC)													
Mean	26.2	26.1	25.2	23.0	20.3	18.0	17.5	18.9	21.1	22.7	23.8	25.0	22.3
Daily Minimum Temperature (º C)													
Mean	19.8	20.0	18.9	16.0	13.1	11.1	9.8	10.5	12.8	14.9	16.8	18.5	15.2
Rainfall (mm)													
Mean	82.7	107.7	115.2	129.1	132.8	156.6	82.0	67.3	61.3	63.9	93.9	67.9	1153.5
Rain days (Number)													
Mean	12.5	12.0	13.7	14.0	13.5	14.0	10.8	9.1	11.2	11.0	12.6	11.8	146.2

Station number 061366; Commenced: 1989, Latest record: 2017; Latitude (deg S): 33.28; Longitude (deg E): 151.58. Source: BoM (2019)

5. METHODOLOGY

5.1 Modelling System

The assessment follows a conventional approach commonly used for air quality assessment in Australia and outlined in the Approved Methods (NSW EPA, 2016).

The CALMET/CALPUFF modelling system was chosen for this study. CALMET is a meteorological pre-processor that includes a wind field generator containing objective analysis and parameterised treatments of slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro meteorological variables to produce the 3-dimensional (3D) meteorological fields that are utilised in the CALPUFF dispersion model. CALMET uses the meteorological inputs in combination with land use and geophysical information for the modelling domain to predict gridded meteorological fields for the region. CALPUFF is a multi-layer, multi-species non-steady state puff dispersion model that can simulate the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal (Scire et al., 2000). The model employs dispersion equations based on a Gaussian distribution of pollutants across the puff, and takes into account the complex arrangement of emissions from point, area, volume, and line sources.

In March 2011, NSW OEH published generic guidance and optional settings for the CALPUFF modelling system for inclusion in the Approved Methods (TRC, 2011). The model set up for this study was undertaken in consideration of these guidelines.

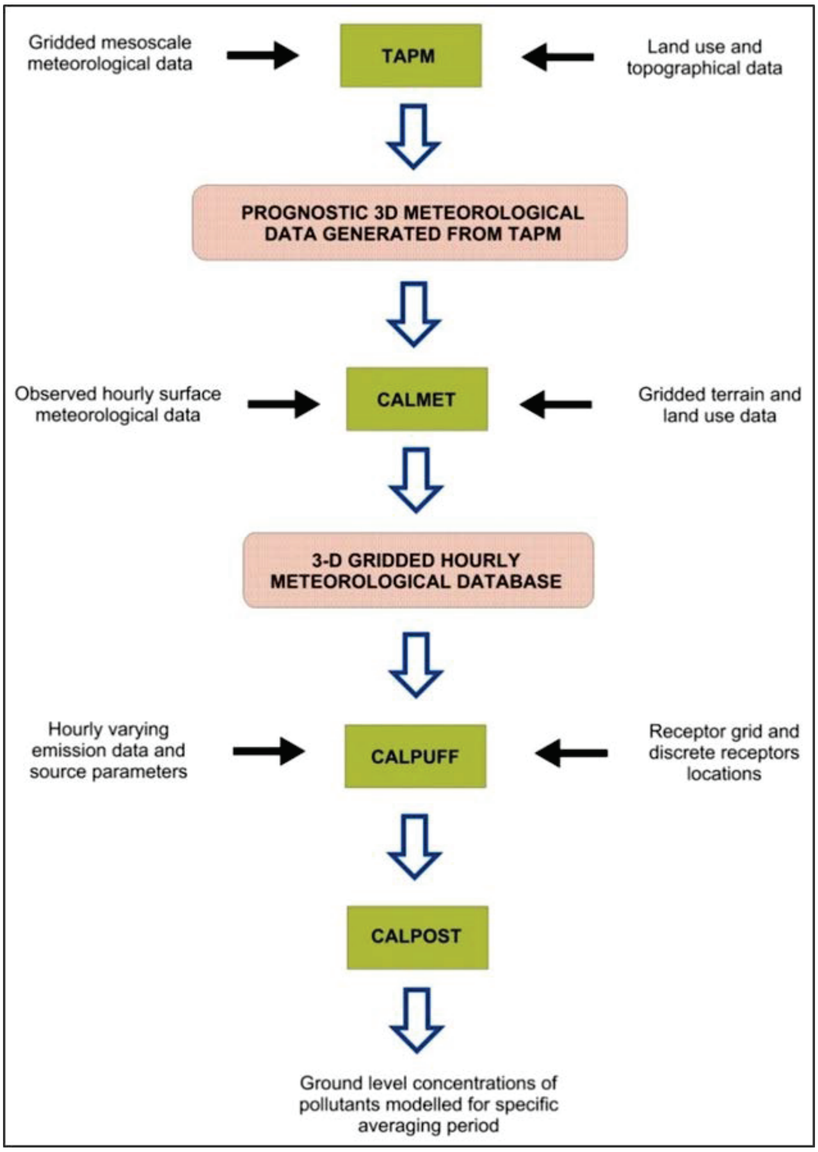


Figure 5-1: Modelling methodology used in this study

Output from TAPM, plus regional observational weather station data, were entered into CALMET. From this, a 1-year representative meteorological dataset suitable for use in the 3-dimensional plume dispersion model, CALPUFF, was compiled. Details on the model configuration and data inputs are provided in the following sections.

A summary of the TAPM, CALMET and CALPUFF model set up and inputs can be found below.

5.2 TAPM

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model developed by the CSIRO Division of Atmospheric Research. Detailed descriptions of the TAPM model and its performance can be found in Hurley (2008) and Hurley et al (2009).

TAPM utilises fundamental fluid dynamics and scalar transport equations to predict meteorology and (optionally) pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components. The model predicts airflows important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

For the assessment, TAPM was set up with five domains of 30km, 10km, 3km, 1km and 500m in resolution, composing of 35 grids along both the X and the Y axes, centred on -33˚ 10’ Latitude and 151˚ 33’ Longitude (364810E, 6329300N in UTM zone 56), to capture both the inner and outer modelling domains.

Default TAPM terrain values are based on a global 30-second resolution (approximately 1 km) dataset provided by the US Geological Survey, Earth Resources Observation Systems (EROS). Default land use and soils datasets for TAPM were used.

TAPM was used to generate gridded prognostic data (3D.dat) for the CALMET modelling domain.

5.3 CALMET

The choice of the CALMET/CALPUFF modelling system for this study was based on the fact that simple Gaussian dispersion models such as ISC assume that the meteorological conditions are uniform spatially over the entire modelling domain for any given hour. While this may be valid for some applications, in complex flow situations, such as areas with complex terrain, the meteorological conditions may be more accurately simulated using a wind field model such as CALMET.

CALMET is a meteorological pre-processor that includes a wind field generator containing objective analysis and parameterised treatments of slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables to produce the three-dimensional meteorological fields that are utilised in the CALPUFF dispersion model.

CALMET was run with a single domain covering a 15 km x 15 km area, with the origin (SW corner) at 356759E and 6322300N (UTM Zone 56S). This consisted of 150 x 150 grid points, with a 0.1 km resolution along both the X and Y axes.

Observed hourly surface wind speed, wind direction, temperature and relative humidity data from the onsite weather station (364096E and 6328060N), as well as 3D TAPM output were used as input for CALMET. It also used the cloud amount and cloud heights observations at the Williamtown station (approximately 54 km northeast of the MC surface facilities), the nearest BOM site with cloud data.

To model variable wind flows within the domain induced by terrain and to control the weights of TAPM wind vs. observed wind, the following parameters are specified in the CALMET setup file:

- TERRAD: 5 km (a parameter used to model).
- RMAX1, RMAX2, RMAX3: 4 km each.
- R1 and R2: 2.5 km each.

Land use for the domain was determined by aerial photography from Google Earth. Terrain for this area was derived from 90 m DEM (digital elevation model) data sourced from NASA.

5.4 Wind Speed and Direction

As discussed in Section 5.3, a CALMET data file was generated for the modelling domain. To compare the wind field produced by the model with observed data at the MC monitoring station, a meteorological dataset was extracted from the CALMET output. Windroses generated from the observed wind data at MC for 2015 and generated from CALMET output at the MC meteorological station are shown in Figure 5-2 . As would be expected they exhibit very similar patterns.

The annual percentage of calms for the CALMET data is 8.7%, which is approximately 0.4% lower than measured at the Mannering weather station.

In CALMET output, the wind flow is variable within the CALMET modelling domain, reflecting the influence of terrain and land/water bodies. An example of the output shown in Figure 5-3.

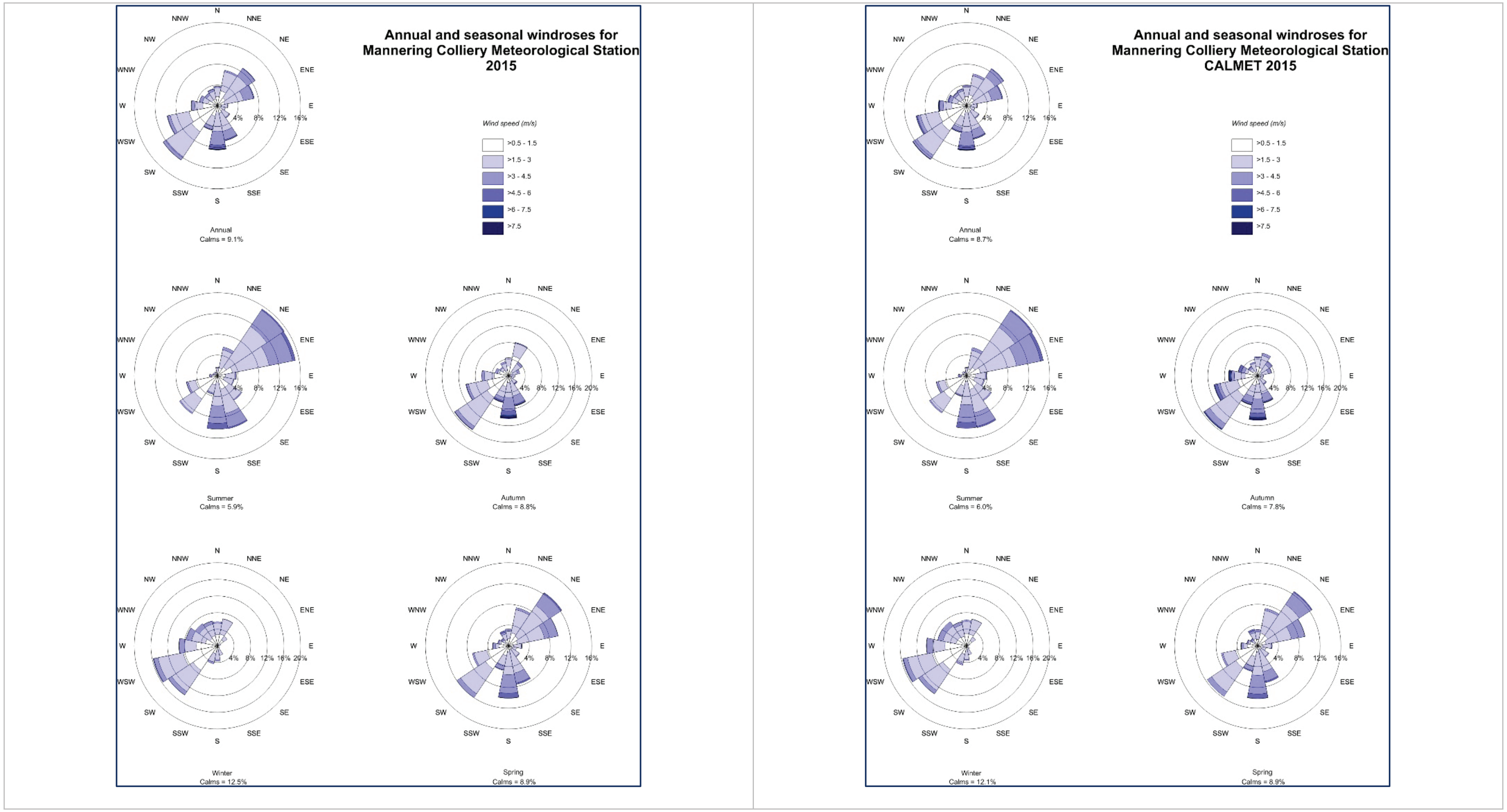


Figure 5-2: Annual and seasonal windroses - MC meteorological station compared with CALMET output at MC meteorological station (2015)

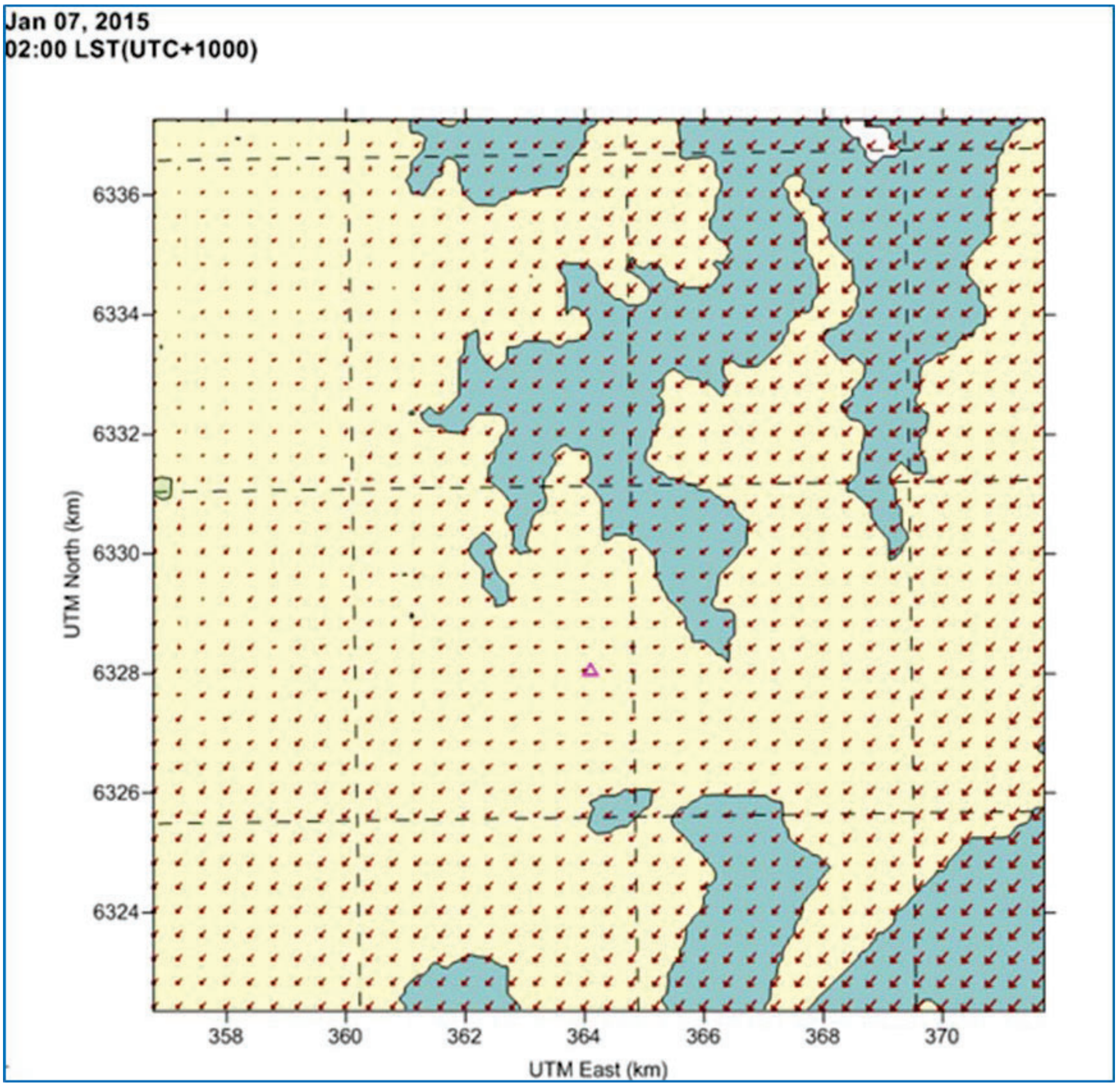


Figure 5-3: Example of variable horizontal wind pattern in CALMET output

5.5 CALPUFF

CALPUFF (Scire et al., 2000a) is a multi-layer, multi-species, non-steady state puff dispersion model that can simulate the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal. The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer-range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects. The model employs dispersion equations based on a Gaussian distribution of pollutants across the puff and takes into account the complex arrangement of emissions from point, area, volume, and line sources.

As with any air dispersion model, CALPUFF requires inputs in three major areas:

- Meteorology (described in Section 5.3).
- Emission rates and source details (described in Section 7).
- Terrain and geophysical data (terrain, land use), as well as specification of specific receptor locations (incorporated into CALMET and CALPUFF).

6. OVERVIEW OF BEST PRACTICE DUST CONTROL

6.1 Introduction

This section outlines existing and proposed controls for the management and control of dust emissions at the MC.

Best practice air quality mitigation measures have been based on the recommendations of the Best Practice Report (Donnelly et al., 2011), a study that was commissioned by the EPA. Following the Benchmarking study, EPA inserted a condition into all EPLs under the heading Pollution Studies and Reduction Programs (PRPs) requiring each mining company to prepare a report on the practicability of implementing best practice measures to reduce particle emissions. The PRP requirements were included in the Delta Coal's MC EPL (EPL 191) in December 2011, with the required report submitted to the EPA in September 2012.

6.2 Existing Dust Management and Control Procedures

Table 6-1 summarises the control measures applied to this assessment.

Table 6-1: Best practice controls

OEH best practice		Mining Activity	Best Practice Control Method		% control from application per Best Practice document	Applied at site (Y/N/Not applicable)	Comments For example: -Is there any site-specific information on effectiveness? -Are controls applied consistently (e.g. are some roads treated and not others)?
Section	Table						
9.2	66	Hauling on Unsealed Roads (Note: reductions achieved by use of larger vehicles, conveyors and lower grader speeds calculated from emission factors)	Vehicle restrictions	Speed reduction from 75 km/h to 50 km/h	40-75%	n/a	No haulage undertaken at MC - all coal dispatched via overland conveyor.
				Speed reduction from 65 km/h to 30 km/h	50-85%	n/a	
				Grader speed reduction from 16 km/h to 8 km/h	75%	n/a	
			Surface improvements	Pave the surface	>90%	n/a	
				Low silt aggregate	30%	n/a	
				Oil and double chip surface	80%	n/a	
			Surface treatments	Watering (standard procedure)	10-74%	n/a	
				Watering Level 1 (2 L/m^2/h)	50%	n/a	
				Watering Level 2 (>2 L/m^2/h)	75%	n/a	
				Watering grader routes	50%	n/a	
				Watering twice a day for industrial unpaved road	55%	n/a	
				Dust suppressants (please specify)	84%	n/a	
			Other	Use of larger vehicles	90t to 220t:40%	n/a	
					140 to 220t:20%	n/a	
					140t to 360t:45%	n/a	
				Conveyors in place of haul roads	>95%	Y	Conveyors are used to dispatch all product coal from site, overland conveyor from MC to VPPS. Not quantifiable in emission inventory.

OEH best practice Section	OEH best practice Table	Mining Activity	Best Practice Control Method		% control from application per Best Practice document	Applied at site (Y/N/Not applicable)	Comments For example: -Is there any site-specific information on effectiveness? -Are controls applied consistently (e.g. are some roads treated and not others)?
9.3	71	Wind Erosion on Exposed Areas & Overburden Emplacements	Avoidance	Minimise pre-strip	100% per m^2 of pre-strip avoided	n/a	No pre-strip activities undertaken - underground mine.
			Surface stabilisation	Watering	50%	Y	Water Cart used as required on unsealed roads and laydown areas.
				Chemical suppressants	70-84%	N	
				Paving and cleaning	>95%	Y	Significant proportion of surface facilities area is bitumen surfaced. Carpark sealed, major internal hardstands are concrete. Road sweeper used on entry road. Waste management contractor engaged also sweeps hardstand and workshop areas as required.
				Application of gravel to stabilise disturbed open areas	84%	N	
				Rehabilitation goals	99%	Y	All surface facilities areas are utilised. There are no cleared areas that are unused awaiting rehabilitation.
			Wind speed reduction	Fencing, bunding, shelterbelts or in-pit dump	30-80%	N	
				Vegetative ground cover	70%	N	
9.3	72	Wind Erosion and Maintenance - Coal Stockpiles	Avoidance	Bypassing stockpiles	75%	Y	Wherever possible coal is sent directly via the overland conveyor system to VPPS, and not placed on the product coal stockpile at all. There is no ROM coal stockpile at all. All other coal storage is within underground or above ground (enclosed) coal bins. For the purpose of the air quality assessment it has been assumed that 80% of the time coal will be sent directly via conveyor to VPPS and not sent to the stockpile.
			Surface stabilisation	Water sprays	50%	N	
				Chemical wetting agents	80-99%	N	
				Surface crusting agent	95%	N	
				Carry over wetting from load in	80%	Y	During coal extraction and transport underground there are numerous water sprays to reduce airborne dust, which result in moisture being present in the coal delivered to the surface and subsequently to the coal stockpile (if coal is stockpiled - see above control).

OEH best practice		Mining Activity	Best Practice Control Method		% control from application per Best Practice document	Applied at site (Y/N/Not applicable)	Comments For example: -Is there any site-specific information on effectiveness? -Are controls applied consistently (e.g. are some roads treated and not others)?
Section	Table						
			Enclosure	Silo with bag house	95-100%	N	
			Enclosure	Cover storage pile with a tarp during high winds	99%	N	
			Wind speed reduction	Vegetative windbreaks	30%	Y	There are windrows, vegetation and some concrete barriers around the outside of the stockpile at MC.
			Wind speed reduction	Reduced pile height	30%	Y	Maximum stockpile height is limited by the conveyor infrastructure overhead.
			Wind speed reduction	Wind screens/fences	75->80%	N	
			Wind speed reduction	Pile shaping/orientation	<60%	N	
			Wind speed reduction	Erect 3-sided enclosure around storage piles	75%	N	
9.4	76	Bulldozers on OB	Minimise travel speeds and distance		Not quantified	n/a	No overburden.
9.4	76	Bulldozers on OB	Travel routes and material kept moist		50%	n/a	
9.5	81	Blasting and drilling	Blasting	Delay shot to avoid unfavourable weather conditions	Not quantified	n/a	No surface blasting.
9.5	81	Blasting and drilling	Blasting	Minimise area blasted	Not quantified	n/a	
9.5	82	Blasting and drilling	Drilling	Fabric filters	99%	n/a	No drilling.
9.5	82	Blasting and drilling	Drilling	Cyclone	80-90%	n/a	
9.5	82	Blasting and drilling	Drilling	Water injection while drilling	3-96%	n/a	
9.6	85	Draglines (Note: Reduction due to reduced drop height and water have been inferred from the dragline emission factor)	Minimise drop height	Reduce from 30m to 5m	70%	n/a	No dragline.
9.6	85		Minimising drop height	Reduce from 10m to 5m	40%	n/a	
9.6	85		Modify activities in windy conditions		Unquantified	n/a	
9.6	85		Water sprays		50%	n/a	

OEH best practice Section	Table	Mining Activity	Best Practice Control Method		% control from application per Best Practice document	Applied at site (Y/N/Not applicable)	Comments For example: -Is there any site-specific information on effectiveness? -Are controls applied consistently (e.g. are some roads treated and not others)?
			Minimise side casting		Unquantified	n/a	
9.7	90	Loading and dumping overburden (Note: Reduction due to reduced drop height and water have been inferred from the dragline emission factor and rounded down to nearest 10%)	Excavator	Minimise drop height (3m to 1.5m)	30%	n/a	No loading/dumping overburden.
			Truck dumping	Minimise drop height (3m to 1.5m)	30%	n/a	
				Water application	50%	n/a	
				Modify activities in windy conditions	Unquantified	n/a	
9.8	95	Loading and dumping ROM coal	Avoidance	Bypass ROM stockpiles - dumping	50%	n/a	The only loading or dumping of ROM coal would occur via the MC stockpile. After it is dumped by tripper conveyor it would be reclaimed using either a loader or dozer into a coal valve which has been constructed on the coal pad.
				Bypass ROM stockpiles - forming stockpiles (e.g. dozer push)	100%	n/a	
			Truck or loader dumping coal	Minimise drop height (10m to 3m)	30%	n/a	
				Water sprays on ROM pad	50%	n/a	
			Truck or loader dumping to ROM bin	Water sprays on ROM bin or ROM pad	50%	n/a	
				Three sided and roofed enclosure of ROM bin	70%	n/a	
				Three sided and roofed enclosure of ROM bin + water sprays	85%	n/a	
				Enclosure with control device	90-98%	n/a	
9.9	96	Conveyors and transfers	Conveyors	Application of water at transfers	50%	Y	At some transfer points.
				Wind shielding - roof OR side wall	40%	N	Roof and Side walls for surface conveyors.

OEH best practice		Mining Activity	Best Practice Control Method		% control from application per Best Practice document	Applied at site (Y/N/Not applicable)	Comments For example: -Is there any site-specific information on effectiveness? -Are controls applied consistently (e.g. are some roads treated and not others)?
Section	Table						
				Wind shielding - roof AND side wall	70%	Y	Roof and Side walls for surface conveyors.
				Belt cleaning and spillage minimisation	Not quantified	Y	
			Transfers	Enclosure	70%	Y	Surface conveyor transfer points are all enclosed.
9.1	97	Stacking and reclaiming product coal	Avoidance	Bypass coal stockpiles (bypassing stacker)	75%	Y	Wherever possible coal is loaded directly onto overland conveyor without staking out to stockpile. No more than 20% of ROM Coal would be stored on the stockpile during any time.
			Loading coal stockpiles	Variable height stack	25%	N	The stacker at Mannering is very low compared to most contemporary sized stockpiles and stacker systems.
				Boom tip water sprays	50%	N	
				Telescopic chute with water sprays	75%	N	
			Unloading coal stockpiles	Bucket-wheel, portal or bridge reclaimer with water application	50%	N	
9.11	-	Train and truck load out and transportation	Limit load size to ensue coal is below sidewalls		Not quantified	n/a	No train/truck loading, all product delivered by overland conveyor.
			Maintain a consistent profile			n/a	
			Water sprays			n/a	
			Use bed liners to minimise seepage			n/a	
			Cover load with tarpaulin			n/a	
			Utilise truck wheel wash			n/a	

7. EMISSIONS TO AIR

7.1 Introduction

This section discusses the calculation of the emissions for the assessment. Emission calculations capture all MC operations including both the surface operations and underground operations where the emissions would be via the ventilation fans.

The incremental change from the proposed modification compared to the approved project is based on two scenarios:

- the existing approved limit of ROM coal handling and transport for MC of 1.3 Mtpa, and
- the proposed limit of ROM coal handling and transport for MC of 2.1 Mtpa.

7.2 Mining Operations

Total dust emissions were estimated by analysing the types of dust generating activities taking place at the surface facilities as part of the proposed modification. All significant dust generating activities have been identified and dust emission estimates are presented in Table 7-2. For the modelling, dust generating activities were represented by a series of volume sources situated according to the location of activities, i.e. with the exception of the ventilation shaft, which was modelled as two point sources as it has two outlets. The source locations are presented in Figure 7-1.

It conservatively assumed in both scenarios that 20% of ROM coal is stored and handled at the Mannering stockpile, prior to transfer to the VPPS conveyor. It is also assumed that 20% of the ROM is passed through the rotary breaker.

All activities and emissions were assumed to occur 24 hours per day, seven days per week TSP, PM_{10}, and $PM_{2.5}$ emission rates were calculated using emission factors derived from US EPA (1995). The estimated emissions take account of existing air pollution controls including enclosure of the crusher and conveyor transfer points (refer to Section 6).

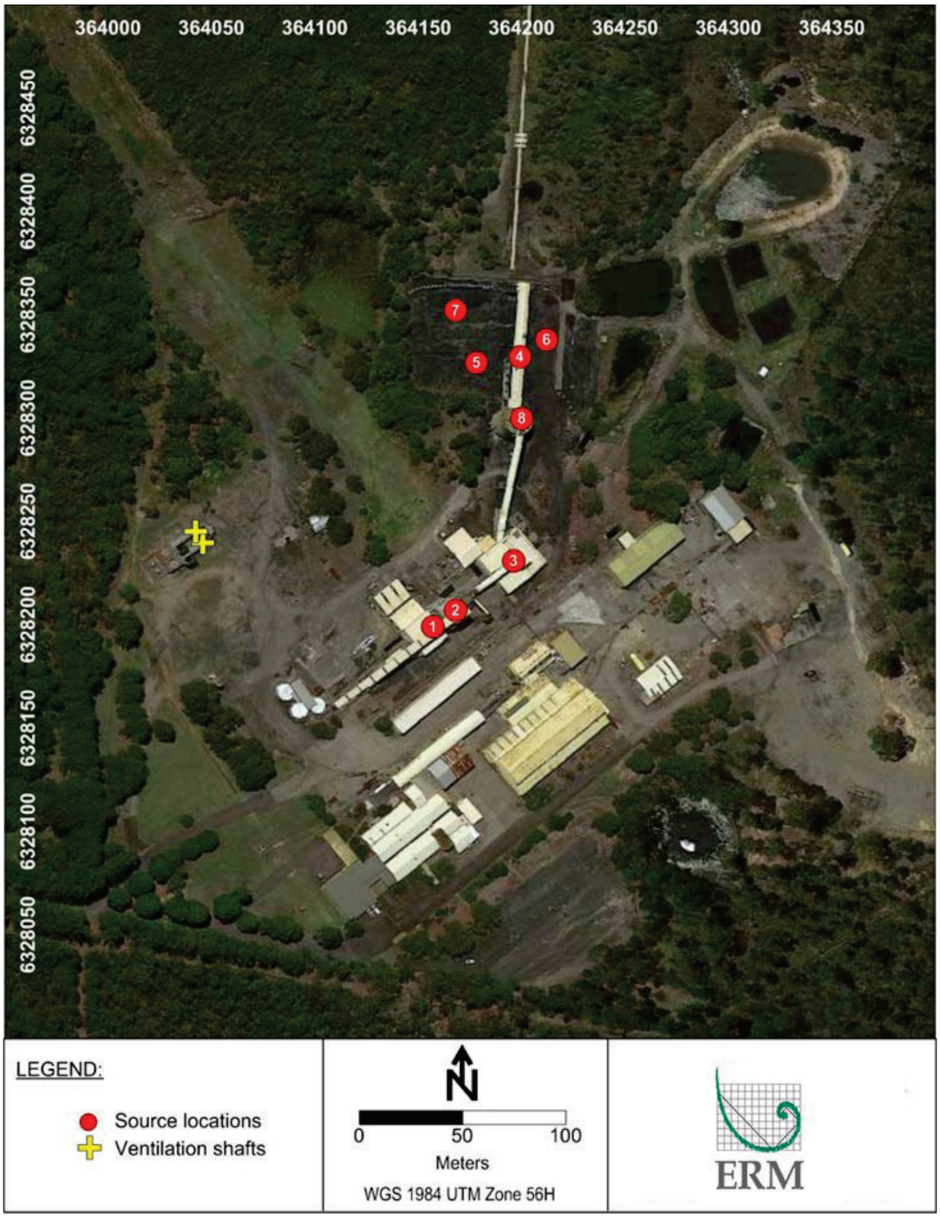


Figure 7-1: Location of modelled dust sources at MC

Table 7-1: Source locations

Mine Activity	Sources ID		
CL - Crusher (enclosed)	3		
CL - Unloading of coal to emergency stockpile (20%)	4		
CL - Pushing coal on the stockpile using FEL/Ex	5		
CL - Conveyor transfers (enclosed)	1	3	8
CL - Rotary Breaker (part-enclosed) 20% of ROM	2		
WE - Stockpiles	5	6	7

Table 7-2: Estimated TSP, PM_{10} and $PM_{2.5}$ emissions– approved project and proposed modification (kg/year)

ACTIVITY	Emission rates (kg/y)					
	TSP		PM_{10}		$PM_{2.5}$	
	Approved	Proposed	Approved	Proposed	Approved	Proposed
COAL						
CL - Crusher (enclosed)	1,053	1,701	468	756	468	756
CL - Loading of coal to emergency stockpile (20%)	43	69	20	33	3	5
CL - Pushing coal on the emergency stockpile using FEL/Ex	13,438	21,707	1,896	3,062	1,896	3,062
CL - Conveyor transfers (enclosed)	64	104	30	49	5	7
CL - Rotary Breaker (part-enclosed) 20% of ROM	702	1,134	312	504	312	504
WIND EROSION						
WE - Stockpiles	298	298	149	149	22	22
TOTAL	**15,598**	**25,013**	**2,875**	**4,553**	**2,706**	**4,357**

7.3 Ventilation Shaft

7.3.1 Particle emissions

The ventilation shaft has two outlets (see Figure 7-1) and was therefore modelled as two vertical discharge points. The adopted in-stack pollutant concentrations were used to derive emission rates for the ventilation shaft. The existing flowrate of 95 m^3/s per shaft, and a proposed flowrate of 150 m^3/s per shaft.

Table 7-3 presents a summary of the vent shaft parameters.

The precise concentration of particulate matter in the ventilation air is unknown and will depend on a number of factors, in particular the effectiveness of dust controls in the underground workings. As there are no stack emissions data from the MC vent shaft, TSP concentrations have been assumed to be 5 mg/m^3 as per the 2013 CVC air quality assessment (PAEHolmes, 2013). PM_{10} and $PM_{2.5}$ emissions will, in turn, be a portion of the total TSP and have been estimated based on a TSP:PM_{10} ratio of 0.5, and a TSP:$PM_{2.5}$ ratio of 0.33.

Table 7-3: Modelling parameters used for the ventilation shaft

Parameter	Units	Vent shaft 1		Vent shaft 2	
		Approved	Proposed	Approved	Proposed
X	m	364046		364042	
Y	m	6328240		6328245	
Stack Height	m	11.8			
Stack diameter*	m	4.5			
Area	m_2	15.9			
Flow	m^3/s	95	150	95	150
Exit velocity	m/s	6.0	9.4	6.0	9.4
Exit Temp	K	293	293	293	293
TSP	mg/m^3	5.00			
PM_{10}	mg/m^3	2.50			
$PM_{2.5}$	mg/m^3	1.67			
TSP	g/s	0.475	0.750	0.475	0.750
PM_{10}	g/s	0.238	0.375	0.238	0.375
$PM_{2.5}$	g/s	0.158	0.250	0.158	0.250

** The rectangular exit points are assigned an equivalent diameter calculated from 4 x 4m dimensions.*

7.4 Rejects management

Emissions from the management of rejects at MC have not been explicitly included in the emission estimates or dispersion modelling, predominately due to the infrequent occurrence of these activities and the inability to capture this accurately in the dispersion modelling. In addition, as outlined below, the total annual TSP emissions from rejects management (see Table 7-4) are approximately 1% of the total TSP emissions modelled from surface activities (per Table 7-2). Extensive experience has shown that even if these emissions were included in the dispersion modelling, the predicted concentrations would not change. A detailed emission inventory is presented in Appendix A.

Reject material is made up of over-sized plastic, coal, concrete, timber and stone which are unloaded from the rotary breaker's waste bunker. The bunker is emptied approximately once a week by a front-end-loader (FEL) which then travels across the site (see Figure 7-2) and unloads them at the stockpile.

It is estimated that a maximum of 1,000 tpa of material is transferred from the bunker to the stockpile. The material is then either:

- placed in a large bin as a mixed waste and taken to a licensed waste facility for disposal, or
- is sorted into coal, concrete and other materials (ie timber, steel and plastic) following which the coal is sent back to the ROM stockpile area and the concrete and other materials are sent to a licensed facility for recycling or disposal.

Table 7-4: Estimated TSP emissions from rejects management

Activity	TSP emissions/year (kg)
Reject Material - unloading from rotary breaker to bunker	0.11
Reject Material - FEL loading from bunker	0.11
Reject Material - FEL travel on sealed roads	18.15
Reject Material - FEL travel on unsealed roads	229.14
Reject Material - unloading from FEL to stockpile	0.11
Wind erosion - stockpile	13
Total TSP from rejects management	**260.3**
TSP % increase (exc. Vent stack emissions)	**1.0**

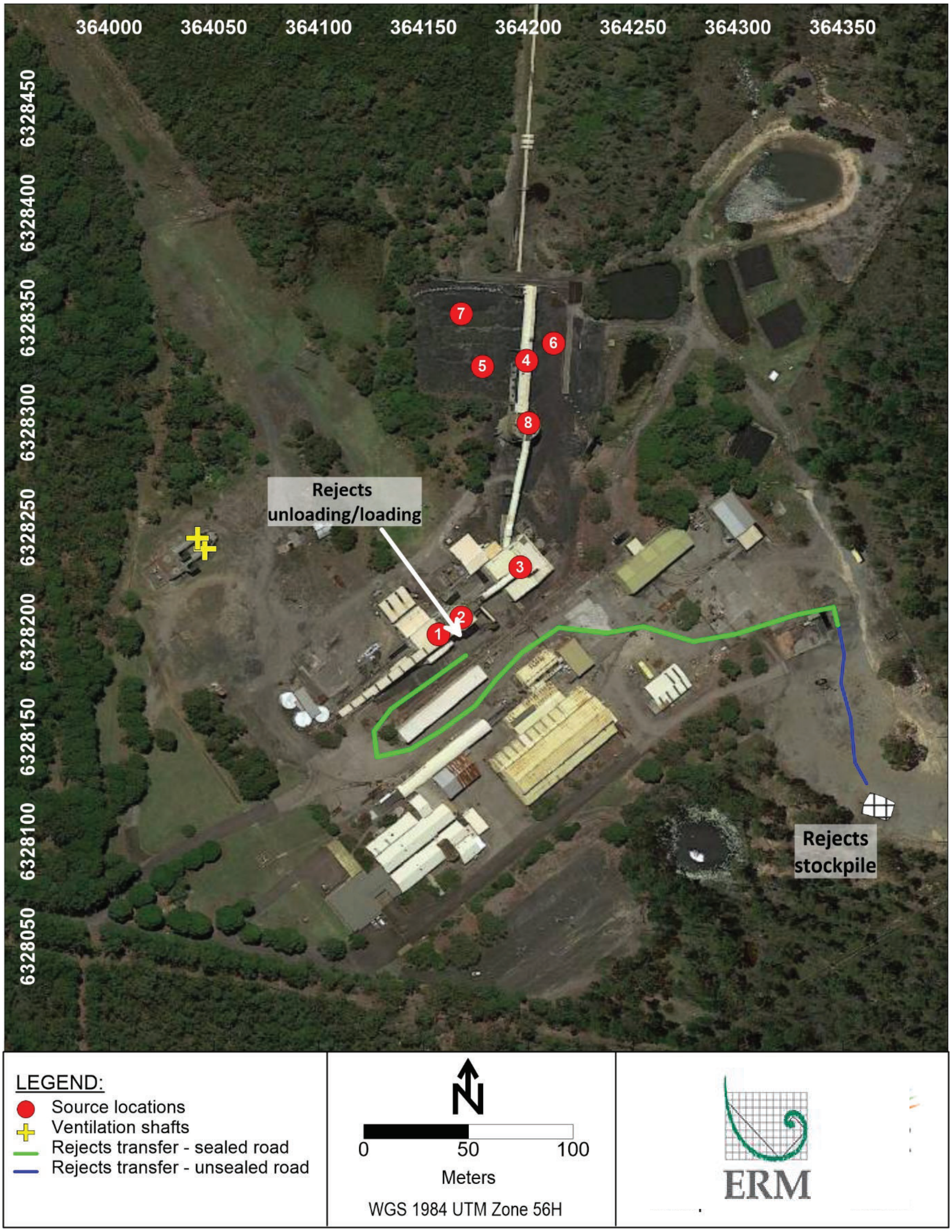


Figure 7-2: Rejects management at MC

8. ASSESSMENT OF IMPACTS

8.1 Introduction

The modelling predictions for the approved project and proposed modification are presented in the sections below. The contour plots are indicative of the concentrations that could potentially be reached under the conservative assumptions modelled. It is important to note that the isopleth figures are presented to provide a visual representation of the predicted impacts. To produce the isopleths, it is necessary to make interpolations between predicted concentrations at individual modelled receptors and, as a result, the isopleths will not always match exactly with predicted impacts at any specific location.

In the case of maximum 24-hour average concentrations, it is also important to note that individual contour plots do not represent one moment in time, but rather the maximum 24-hour average that could potentially occur at a sensitive receptor over the period of a year. Cumulative 24-hour average concentrations are presented in Section 8.3.

8.2 Annual average concentrations

Table 8-1 to Table 8-4 present the predicted annual average TSP, PM_{10} and $PM_{2.5}$ concentrations, and dust deposition levels, at each of the sensitive receptor locations due to both the approved and proposed modification-alone and cumulatively, including existing background concentrations. The assumed background concentrations have been outlined previously in Section 4.1.5.

Contour plots of the predicted annual average concentrations due to the approved project and proposed modification-alone and cumulatively with existing background concentrations are presented in Figure 8-1 to Figure 8-8.

There is a minimal predicted change in the contribution between the approved project and the project as modified.

The results show that there are no sensitive receptors predicted to experience annual average concentrations above the relevant impact assessment criterion for any particle size, either due to the approved project or proposed modification-alone and cumulatively, when including existing background concentrations.

Table 8-1: Predicted annual average TSP concentrations due to the approved project and proposed modification-alone and cumulatively

ID	MGA coordinate Zone 56		Annual Average - TSP (µg/m³)			
			Project Alone		Project plus Background	
	Easting (m)	Northing (m)	Approved	Proposed	Approved	Proposed
Assessment criteria			-		*90 µg/m³*	
4	363695	6327246	0.7	1.1	37.5	37.9
5	363940	6327348	0.7	1.1	37.5	37.9
6	364178	6327283	0.5	0.8	37.3	37.6
7	365360	6328072	0.4	0.6	37.1	37.3
8	365018	6328097	0.7	1.2	37.5	37.9
9	365173	6328884	1.0	1.5	37.7	38.2
11	365312	6328713	0.6	0.9	37.4	37.7
18	365265	6328839	0.8	1.2	37.5	37.9
20	365169	6329047	0.9	1.3	37.6	38.1

Table 8-2: Predicted annual average PM_{10} concentrations due to the approved project and proposed modification-alone and cumulatively

ID	MGA coordinates Zone 56		Annual Average - PM_{10} (µg/m³)			
			Project Alone		Project plus Background	
	Easting (m)	Northing (m)	Approved	Proposed	Approved	Proposed
Assessment criteria			-		*25 µg/m³*	
4	363695	6327246	0.49	0.76	15.2	15.5
5	363940	6327348	0.47	0.73	15.2	15.4
6	364178	6327283	0.35	0.54	15.1	15.2
7	365360	6328072	0.26	0.40	15.0	15.1
8	365018	6328097	0.48	0.73	15.2	15.4
9	365173	6328884	0.57	0.85	15.3	15.6
11	365312	6328713	0.37	0.56	15.1	15.3
18	365265	6328839	0.45	0.68	15.1	15.4
20	365169	6329047	0.51	0.77	15.2	15.5

Table 8-3: Predicted annual average $PM_{2.5}$ concentrations due to the approved project and proposed modification-alone and cumulatively

ID	MGA coordinates Zone 56		Annual Average - $PM_{2.5}$ ($\mu g/m^3$)			
			Project Alone		Project plus Background	
	Easting (m)	Northing (m)	Approved	Proposed	Approved	Proposed
Assessment criteria			-		*8 $\mu g/m^3$*	
4	363695	6327246	0.4	0.6	7.4	7.6
5	363940	6327348	0.4	0.6	7.4	7.6
6	364178	6327283	0.3	0.4	7.3	7.4
7	365360	6328072	0.2	0.3	7.2	7.3
8	365018	6328097	0.4	0.6	7.4	7.6
9	365173	6328884	0.5	0.7	7.5	7.7
11	365312	6328713	0.3	0.5	7.3	7.5
18	365265	6328839	0.4	0.6	7.4	7.6
20	365169	6329047	0.4	0.6	7.4	7.6

Table 8-4: Predicted annual average dust deposition levels due to the approved project and proposed modification-alone and cumulatively

ID	MGA coordinates Zone 56		Annual Average - Dust Deposition ($g/m^2/month$)			
			Project Alone		Project plus Background	
	Easting (m)	Northing (m)	Approved	Proposed	Approved	Proposed
Assessment criteria			*2 $g/m^2/month$*		*4 $g/m^2/month$*	
4	363695	6327246	0.04	0.06	1.04	1.06
5	363940	6327348	0.04	0.06	1.04	1.06
6	364178	6327283	0.03	0.04	1.03	1.04
7	365360	6328072	0.02	0.04	1.02	1.04
8	365018	6328097	0.04	0.07	1.04	1.07
9	365173	6328884	0.06	0.09	1.06	1.09
11	365312	6328713	0.04	0.06	1.04	1.06
18	365265	6328839	0.05	0.07	1.05	1.07
20	365169	6329047	0.06	0.08	1.06	1.08

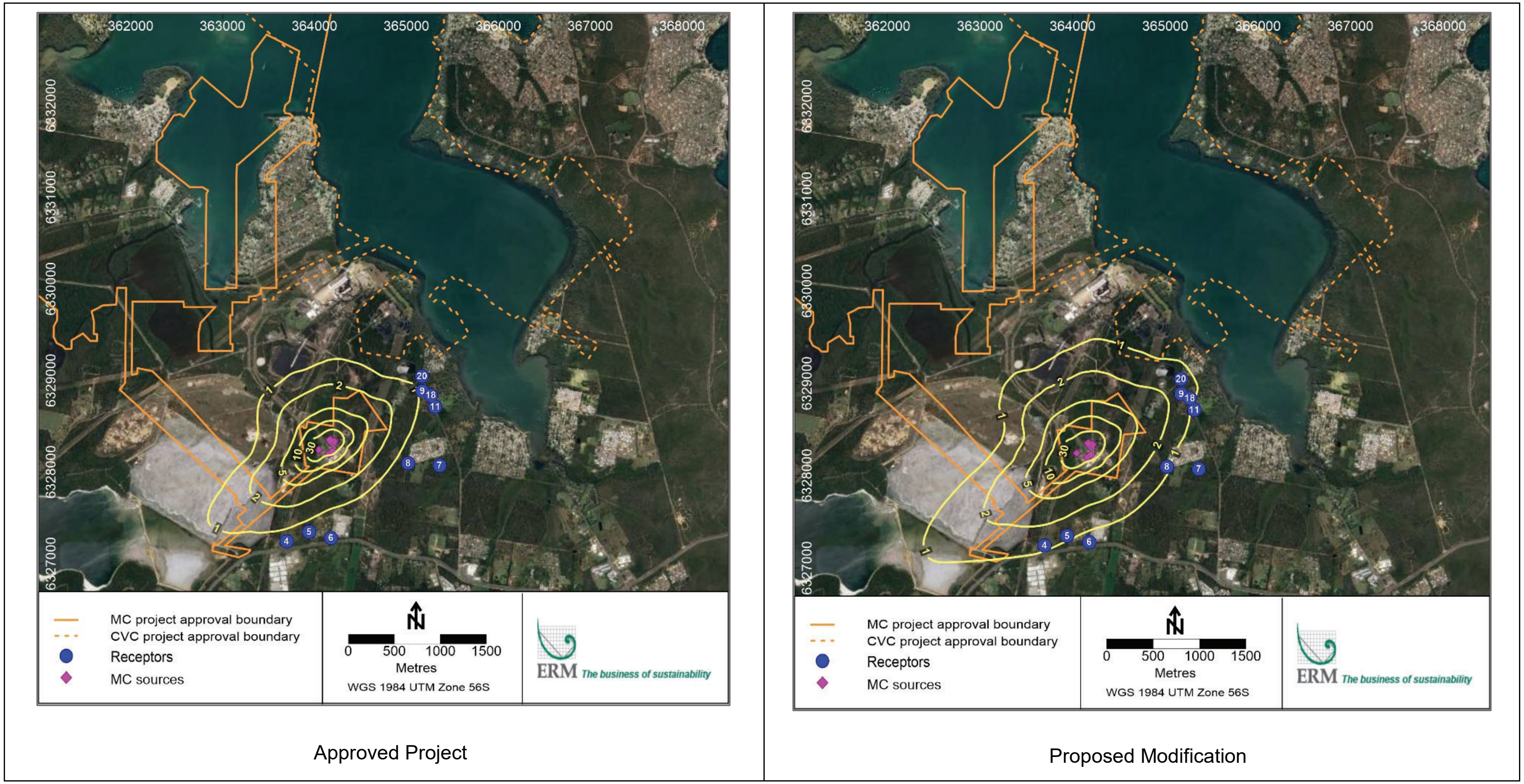
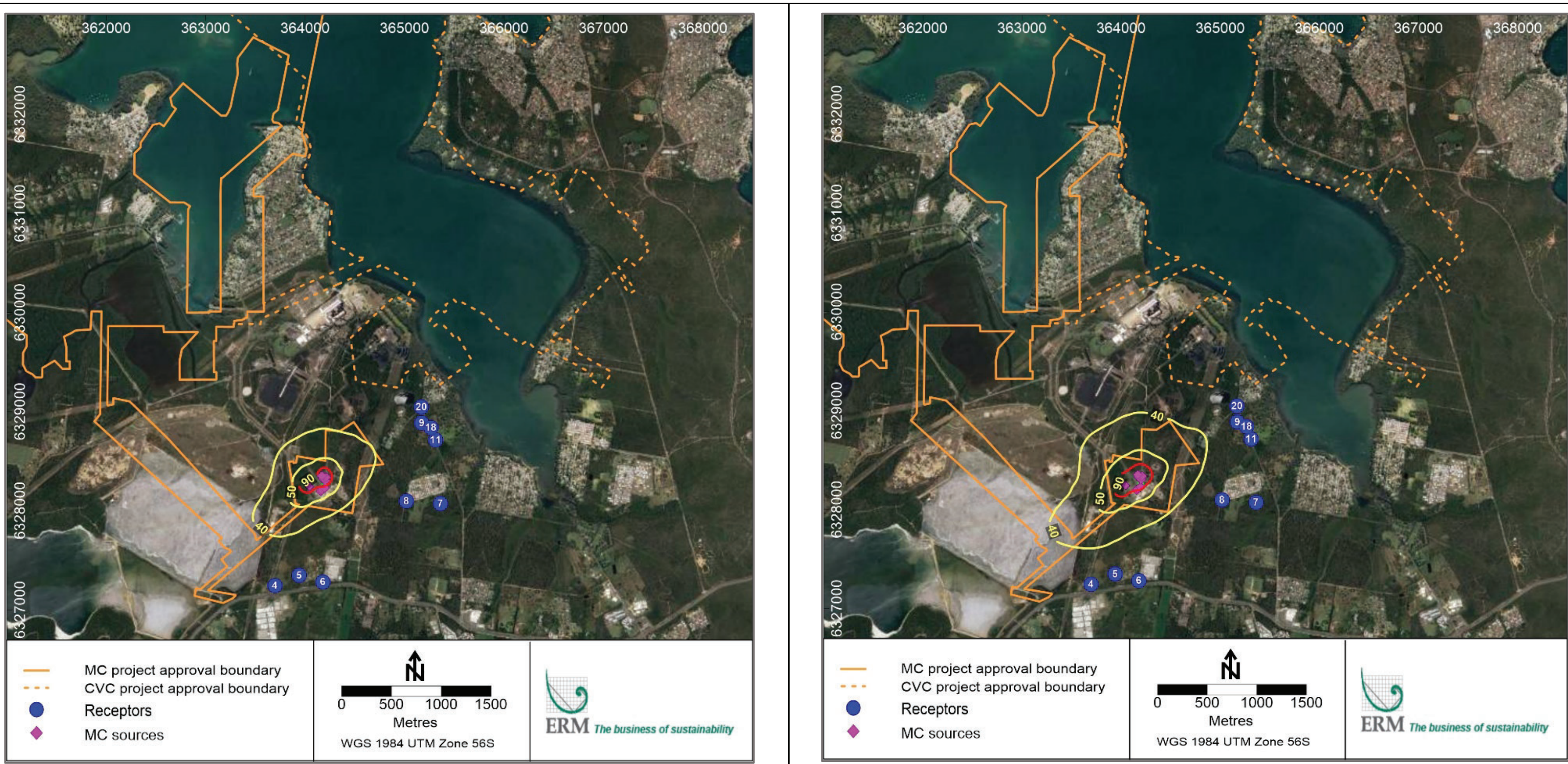


Figure 8-1: Predicted annual average TSP concentrations due to emissions from Project-alone (µg/m³)



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Proposed Modification

Figure 8-2: Predicted annual average TSP concentrations due to emissions from Project and existing background ($\mu g/m^3$)

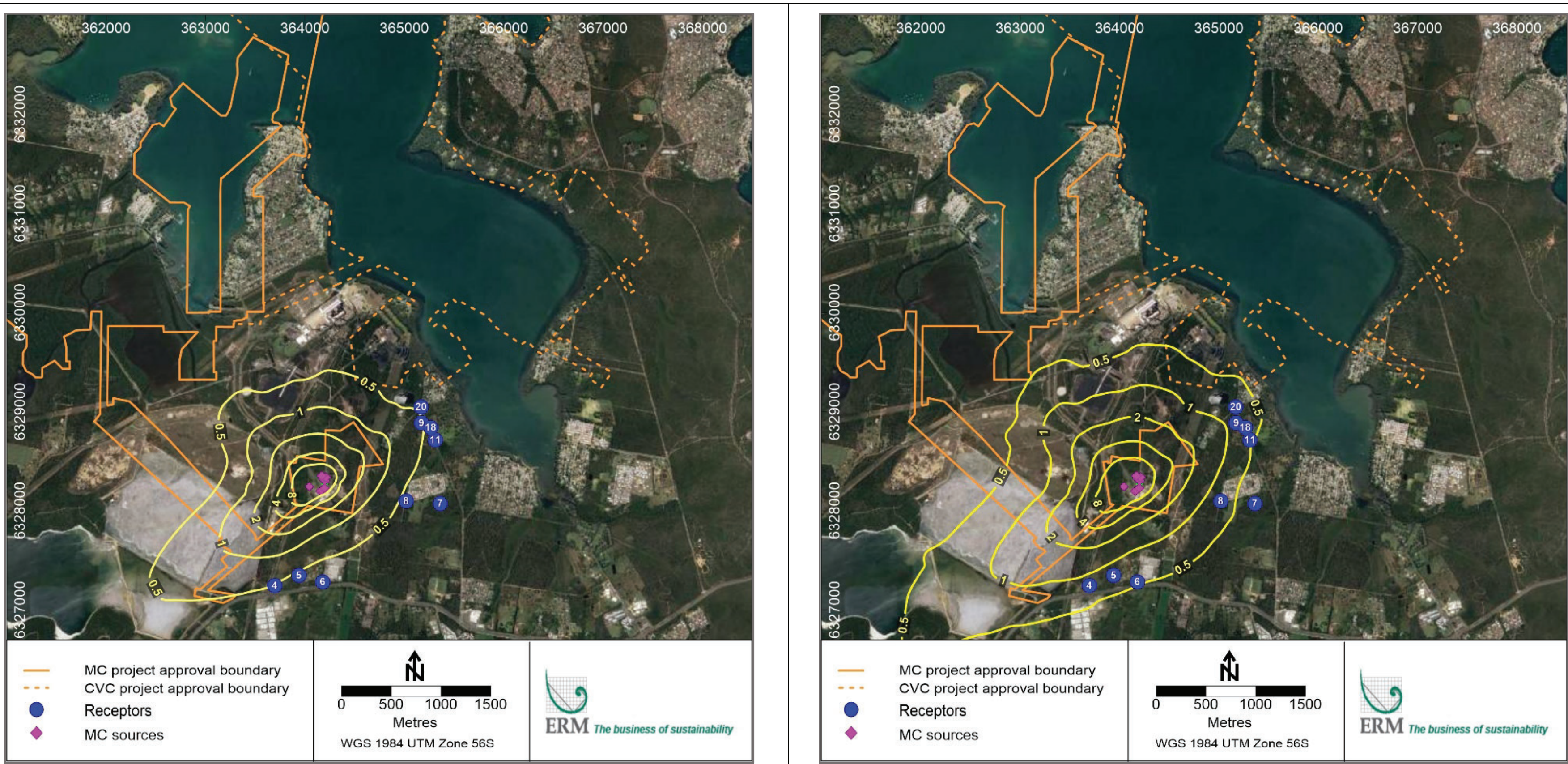

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Figure 8-3: Predicted annual average PM_{10} concentrations due to emissions from Project-alone (µg/m³)

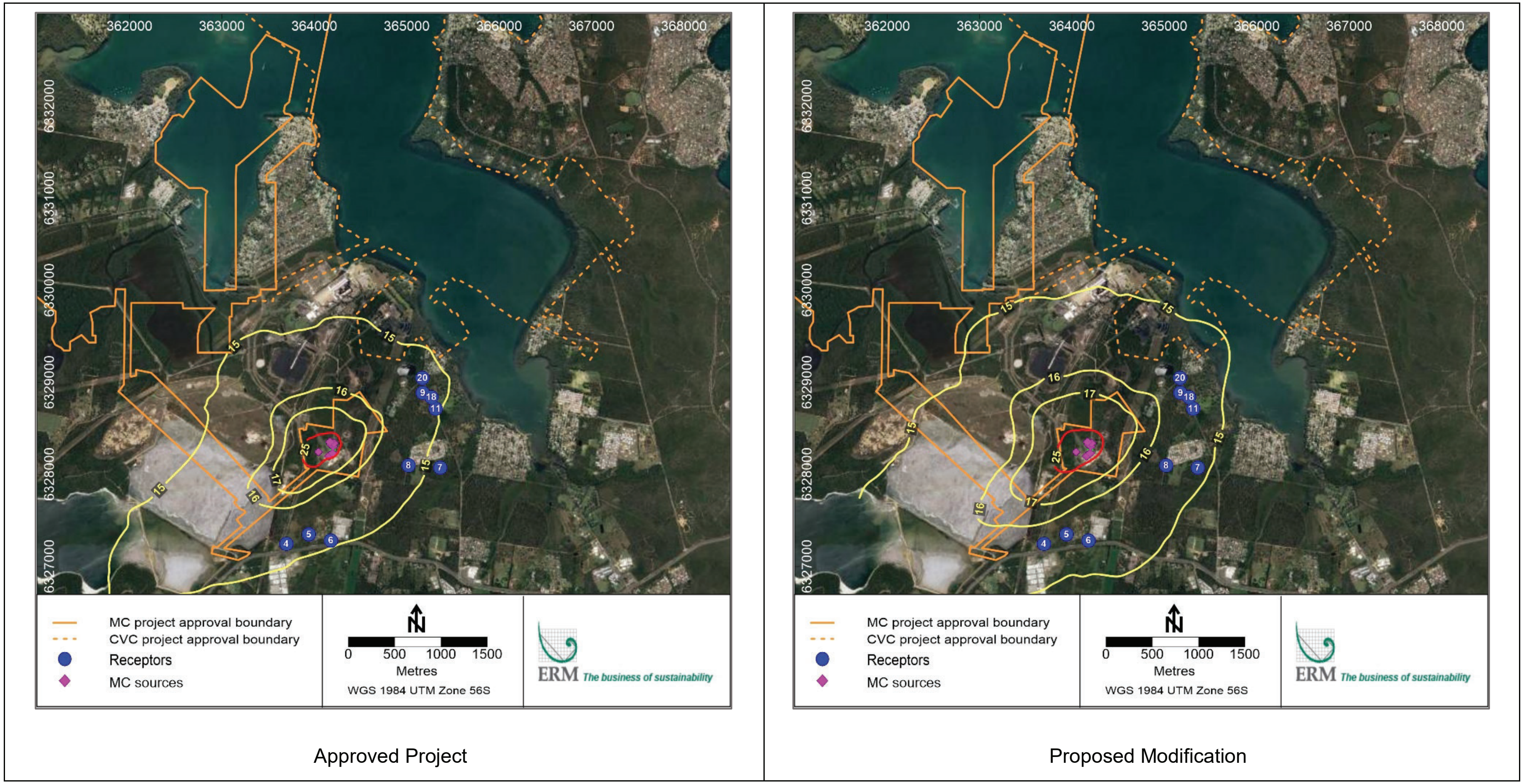
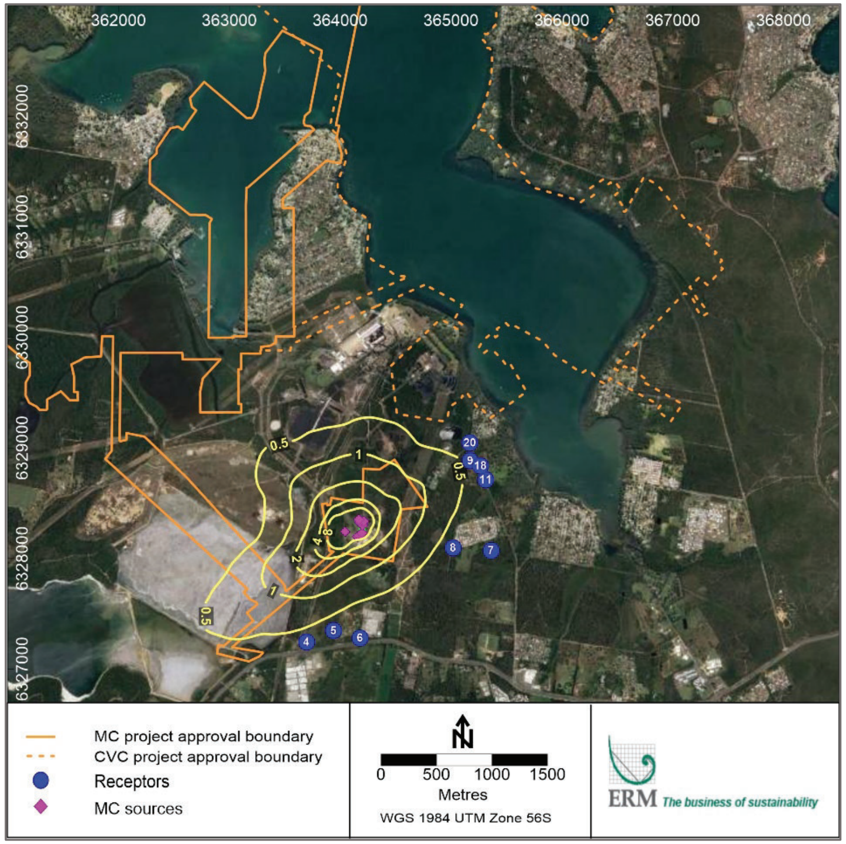


Figure 8-4: Predicted annual average PM_{10} concentrations due to emissions from Project and existing background (µg/m³)



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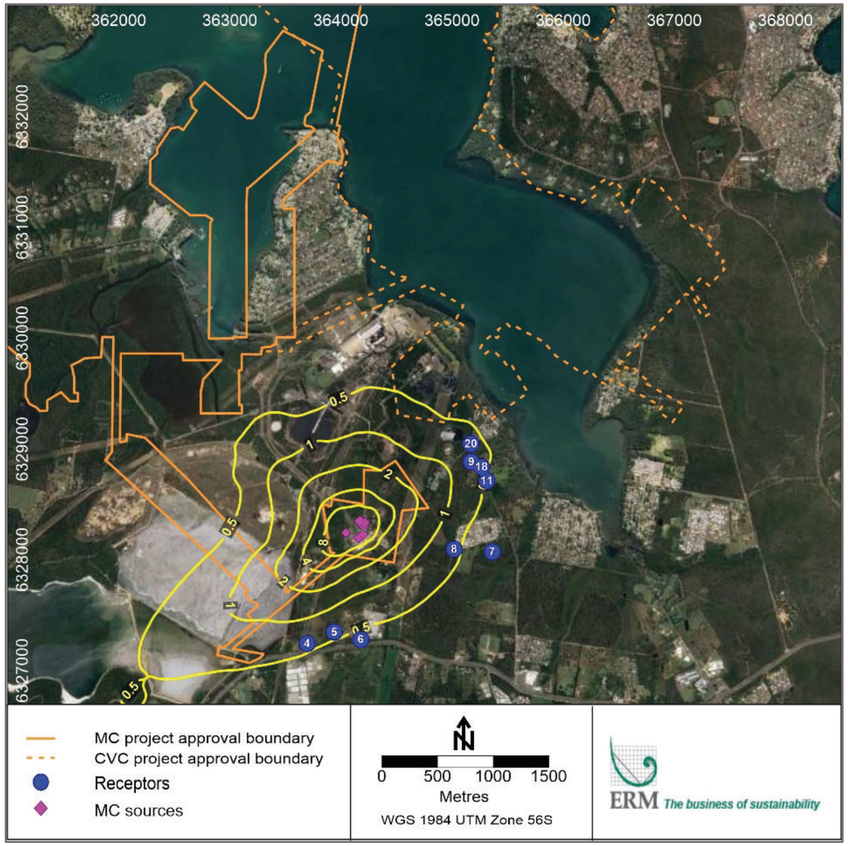

Proposed Modification

Figure 8-5: Predicted annual average $PM_{2.5}$ concentrations due to emissions from Project-alone (µg/m^3)

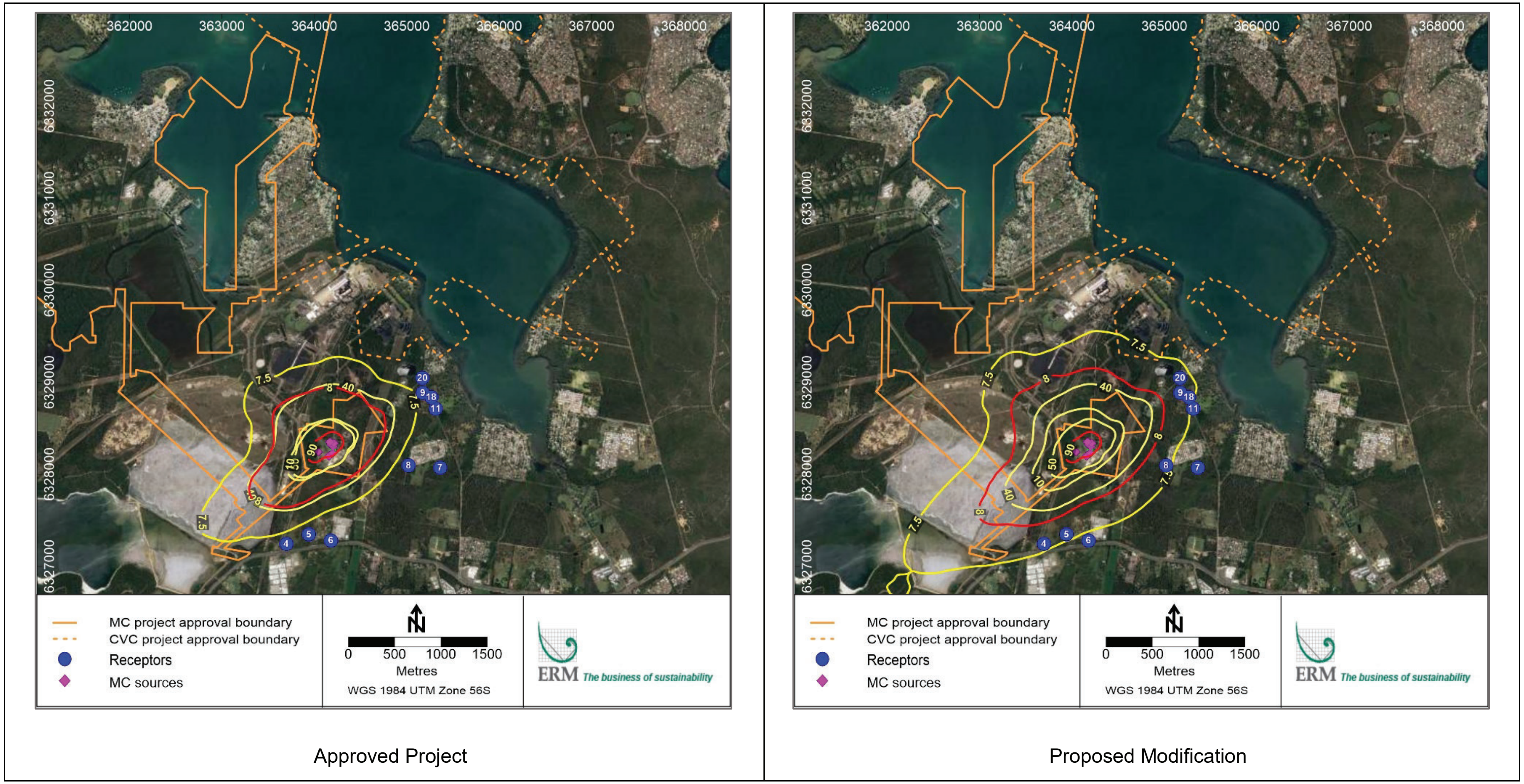

Figure 8-6: Predicted annual average $PM_{2.5}$ concentrations due to emissions from Project and existing background ($\mu g/m^3$)

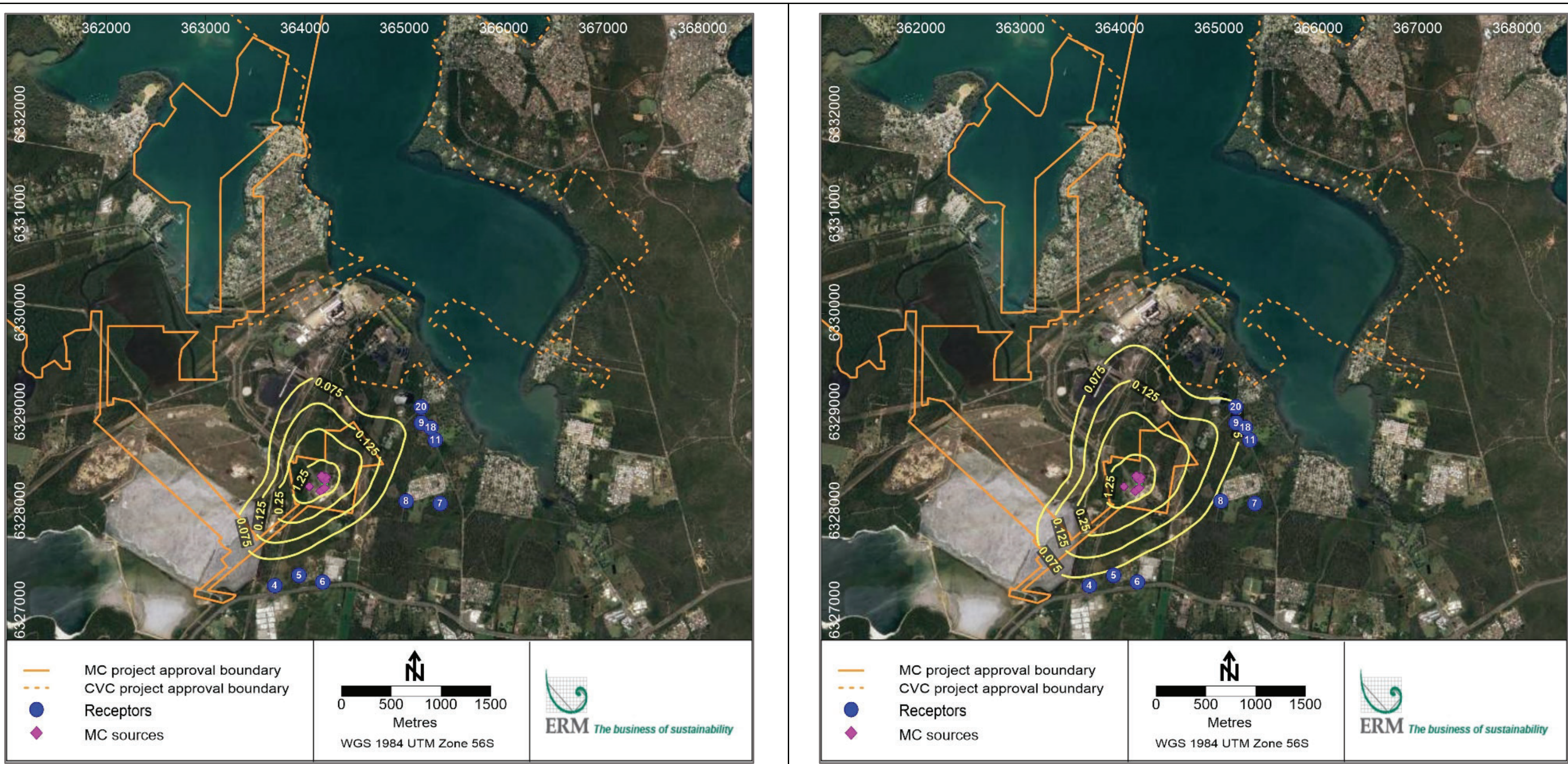

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Figure 8-7: Predicted annual average dust deposition levels due to emissions from Project-alone (g/m²/month)

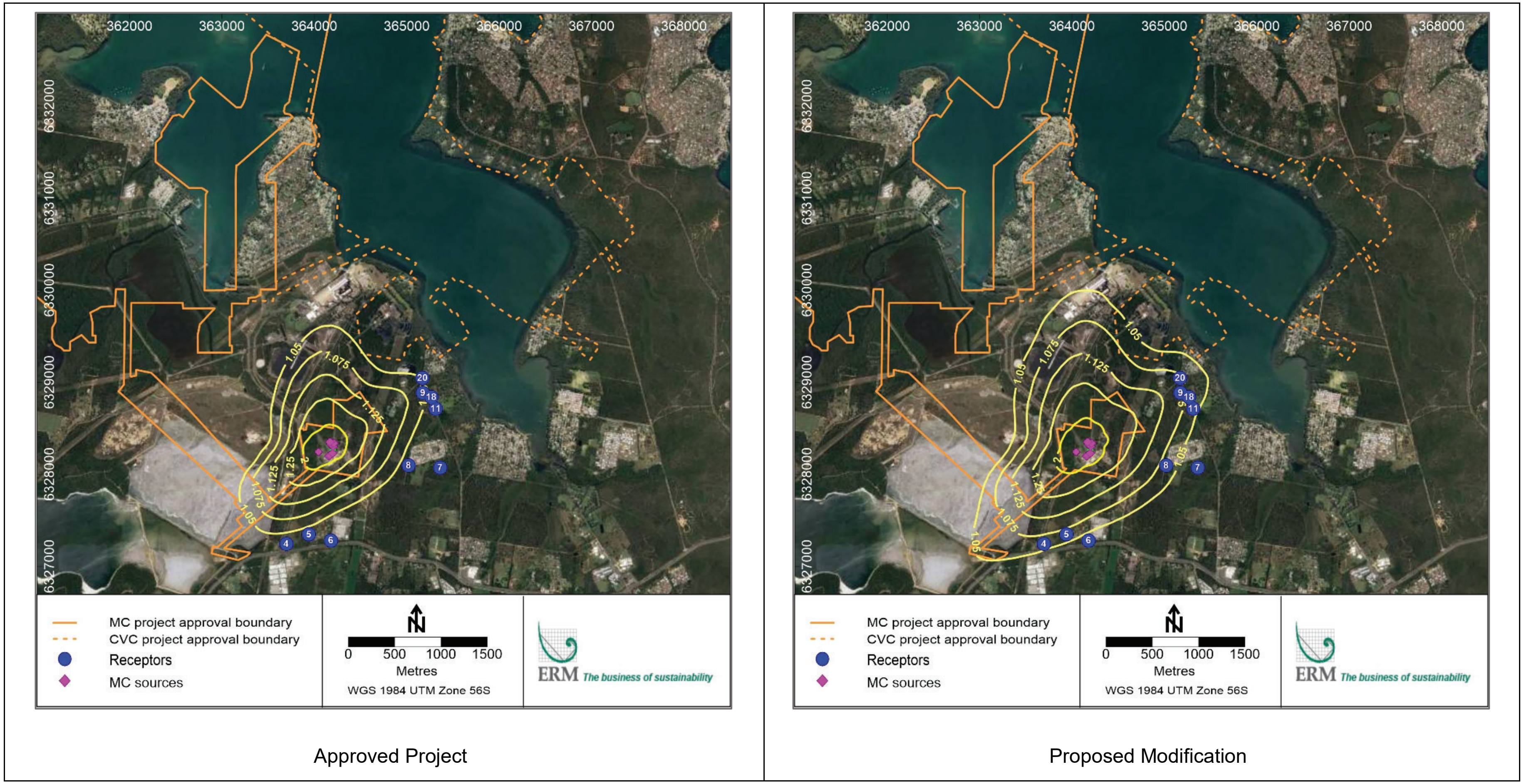


Figure 8-8: Predicted annual average dust deposition levels due to emissions from Project and existing background (g/m²/month)

8.3 24-hour average concentrations

8.3.1 Introduction

It is important to note that it is not possible to accurately predict cumulative 24-hour average concentrations many years into the future using dispersion modelling, principally due to the variability in ambient levels and spatial and temporal variation in any day-to-day anthropogenic activity. Experience shows that the worst-case 24-hour PM_{10} concentrations are strongly influenced by other sources in an area, such as bushfires and dust storms, which are essentially unpredictable.

8.3.2 PM_{10}

The cumulative PM_{10} concentrations were calculated by adding the predicted 24-hour average concentration due to the approved project and proposed modification-alone at each sensitive receptor, to the corresponding concentration measured at the CVC TEOM on the same day for the meteorological year assessed (2015).

Table 8-5 presents the maximum predicted 24-hour average concentrations of PM_{10} at each of the sensitive receptor locations, due to the contribution from the approved project and proposed modification-alone, and cumulatively with existing background concentrations.

Contour plots of the maximum predicted 24-hour average concentrations due to the approved project and proposed modification-alone are presented in Figure 8-9.

There are no additional exceedances of the cumulative assessment criterion of 50 µg/m^3 when considering either the approved project or proposed modification. The only predicted exceedance occurs on 6 May which, as detailed in Section 4.1.3, was due to a regional dust storm. All other predictions are well below the criterion.

The minor contribution of both the approved project and proposed modification is demonstrated in a time series plot showing the predicted 24-hour average PM_{10} contribution at the most impacted sensitive receptor due to the Project-alone (ID 4) in combination with the adopted background (see Figure 8-10).

Table 8-5: Maximum predicted 24-h average PM_{10} concentrations due to the approved project and proposed modification-alone and cumulatively

ID	MGA coordinates Zone 56		24 hour Average - PM_{10} (µg/m^3)			
			Project Alone		Project plus Background	
	Easting (m)	Northing (m)	Approved	Proposed	Approved	Proposed
Assessment criteria			-	-	*50 µg/m^3*	
4	363695	6327246	6.2	9.7	56.0	56.0
5	363940	6327348	5.7	8.9	56.0	56.0
6	364178	6327283	4.8	7.5	56.0	56.0
7	365360	6328072	3.6	5.7	57.0	57.5
8	365018	6328097	5.8	9.1	57.7	58.6
9	365173	6328884	5.3	8.3	56.1	56.2
11	365312	6328713	4.0	6.3	56.3	56.5
18	365265	6328839	4.2	6.6	56.2	56.3
20	365169	6329047	5.2	8.2	56.0	56.1

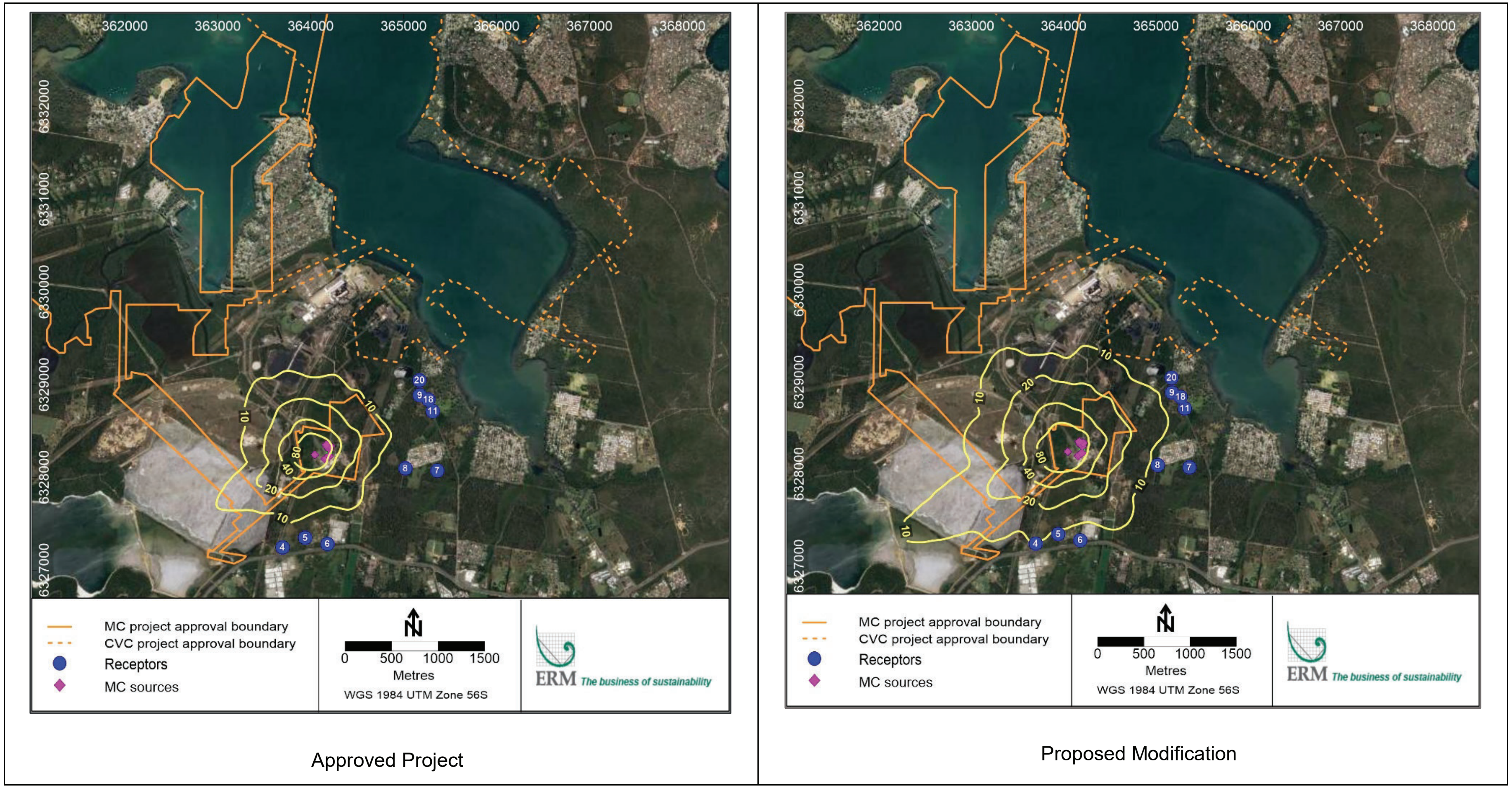
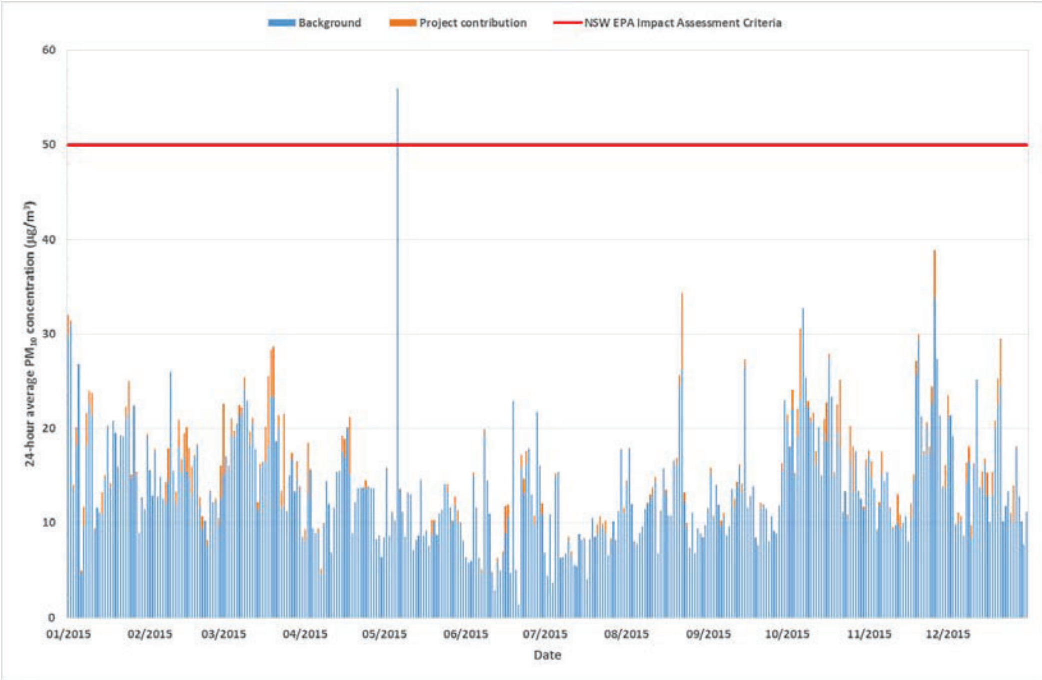
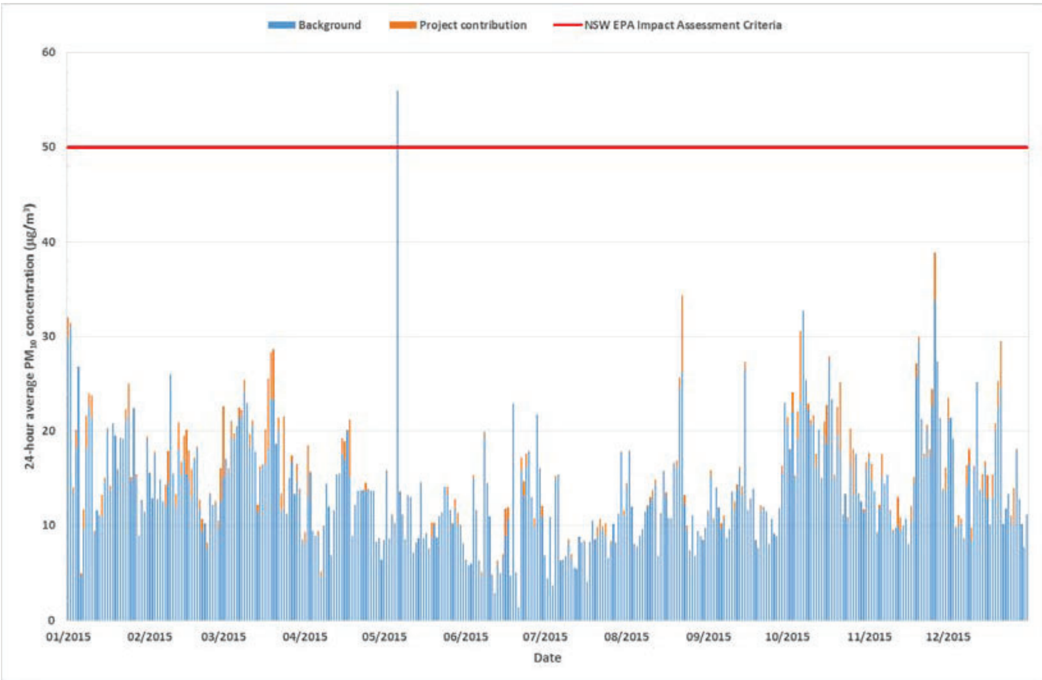


Figure 8-9: Maximum predicted 24-hour average PM_{10} concentrations due to emissions from Project-alone (µg/m^3)



Approved Project



Proposed Modification

Figure 8-10: Predicted 24-hour average PM_{10} concentrations at Receptor 4 Project-alone plus background at CVC TEOM (µg/m³)

8.3.3 $PM_{2.5}$

The cumulative $PM_{2.5}$ concentrations were calculated by adding the predicted 24-hour average concentration due to the approved project and proposed modification to the estimated $PM_{2.5}$ concentration at the CVC TEOM on the same day for the meteorological year assessed (2015). The CVC $PM_{2.5}$ concentrations were estimated by applying the $PM_{2.5}$:PM_{10} ratio measured at the OEH Wallsend station to the measured CVC PM_{10} concentrations.

Table 8-6 presents the maximum predicted 24-hour average concentrations of PM2.5 at each of the sensitive receptor locations due to the contribution from the approved project and proposed modification-alone, and cumulatively with existing background concentrations.

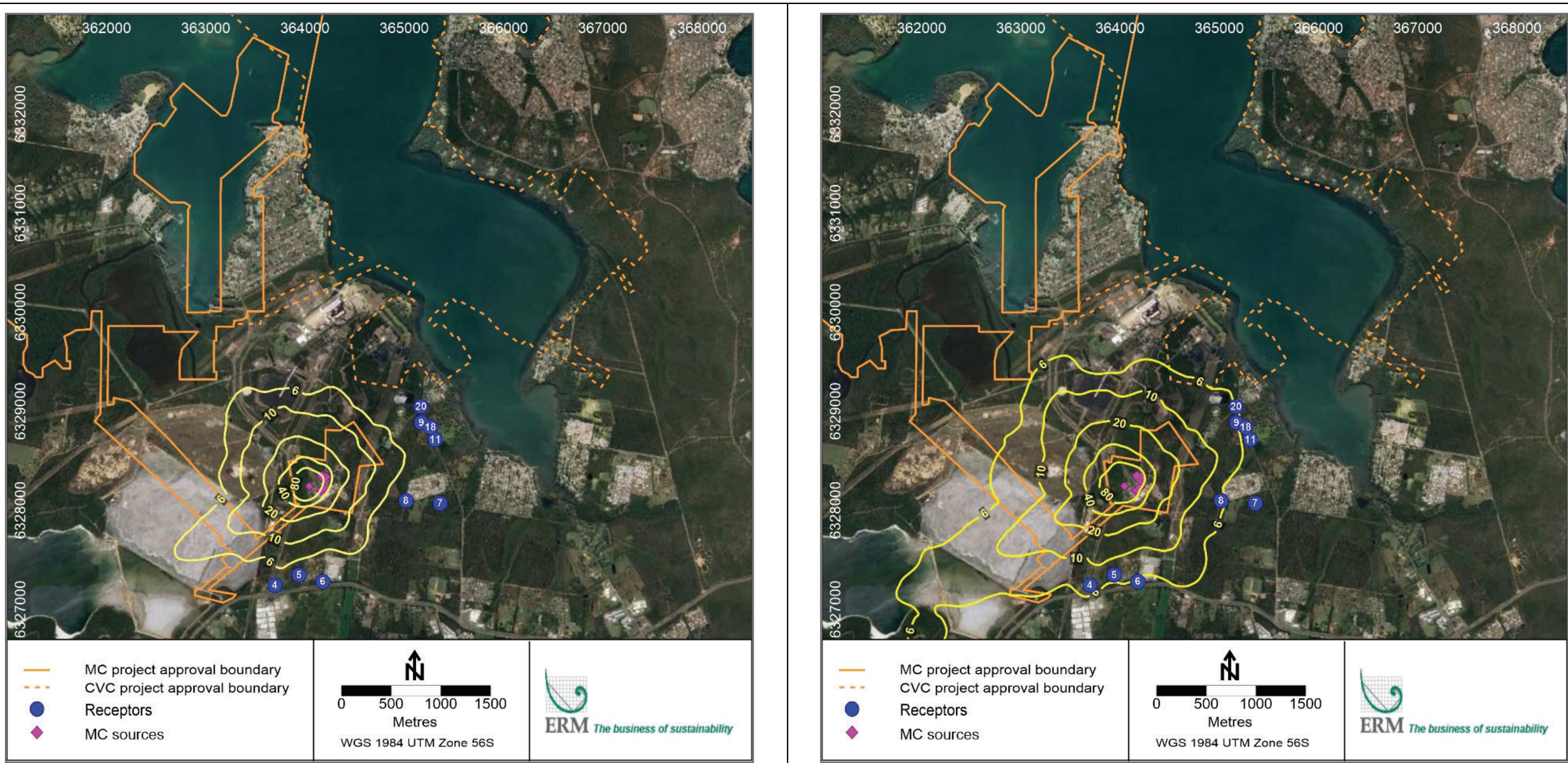
Contour plots of the maximum predicted 24-hour average concentrations due to the approved project and proposed modification-alone are presented in Figure 8-11.

There are no predicted exceedances of the cumulative assessment criterion of 25 µg/m3 when considering either the approved project and proposed modification-alone.

The minor contribution of both the approved project and proposed modification is demonstrated in a time series plot showing the predicted 24-hour average $PM_{2.5}$ contribution at the most impacted sensitive receptor due to the Project-alone (ID 4) in combination with the adopted background (see Figure 8-12)

Table 8-6: Maximum predicted 24-h average $PM_{2.5}$ concentrations due to the approved project and proposed modification-alone and cumulatively

ID	MGA coordinates Zone 56		24 hour Average - $PM_{2.5}$ (µg/m^3)			
			Project Alone		Project plus Background	
	Easting (m)	Northing (m)	Approved	Proposed	Approved	Proposed
Assessment criteria			-	-	*25 µg/m^3*	
4	363758	6330736	4.5	7.1	21.6	23.8
5	364001	6330868	4.3	6.7	21.7	23.9
6	363990	6330529	3.6	5.7	20.5	20.5
7	364145	6330566	2.7	4.3	20.6	20.6
8	365218	6329389	4.3	6.8	20.6	20.7
9	365213	6329348	4.0	6.3	21.2	21.6
11	365949	6328530	3.0	4.8	20.8	21.0
18	365145	6328317	3.2	5.0	21.0	21.3
20	366560	6328590	3.9	6.2	21.2	21.6



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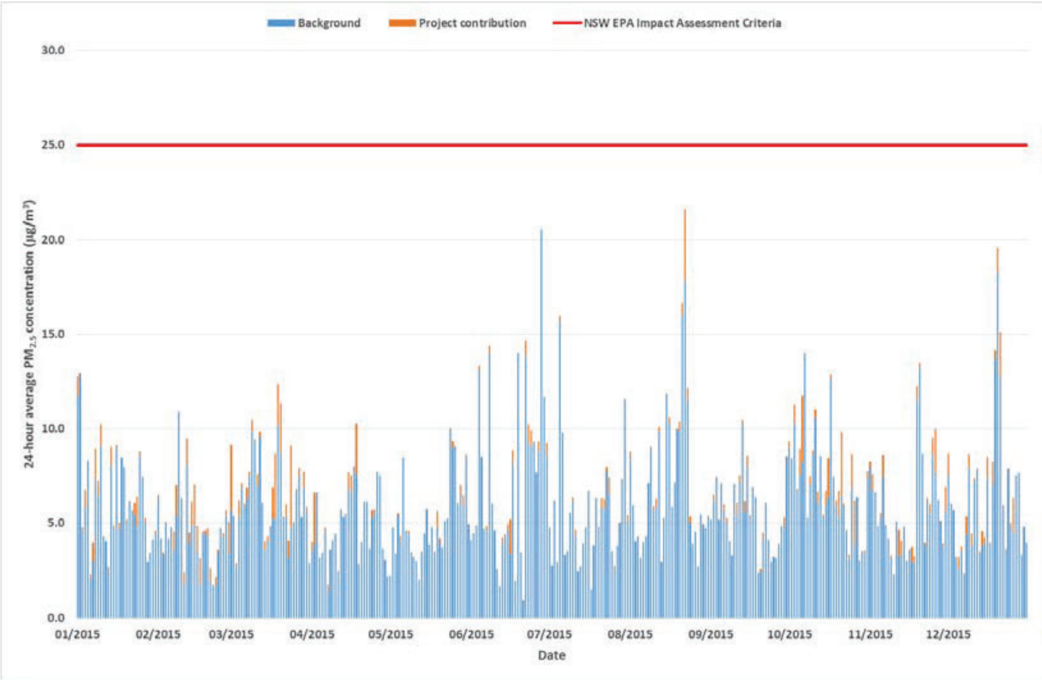
Proposed Modification

Figure 8-11: Maximum predicted 24-hour average $PM_{2.5}$ concentrations due to emissions from Project-alone ($\mu g/m^3$)



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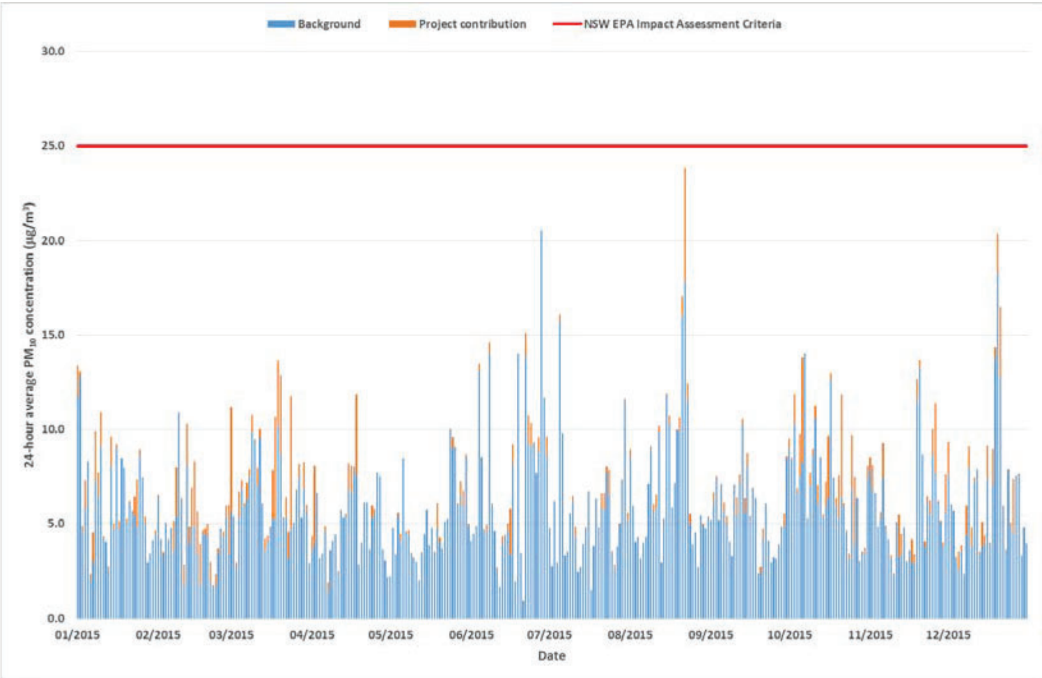

Proposed Modification

Figure 8-12: Predicted 24-hour average $PM_{2.5}$ concentrations at R4 – Project only plus estimated background at CVC TEOM (µg/m³)

9. MANAGEMENT AND MONITORING

The Mannering Colliery Air Quality Management Plan (AQMP) was developed in 2012 and subsequently approved by the Department of Planning (now DPE) (Centennial Coal, 2012). The AQMP provides guidance for the management and monitoring of dust and GHG emissions generated by MC.

9.1 Operational Dust Control

Sources of emissions during operation of MC are described in Section 7 of this report and the management measures are outlined in Section 6. The management measures were developed in accordance with NSW EPA best practice document and include:

- primary sizing of coal underground;
- operation of enclosed crushers and conveyor transfers; and
- prioritising direct loading to conveyor over stockpiling.
- Use of a water on unsealed areas where required.

Based on the potential impacts predicted by the assessment, the existing management measures committed to at MC are considered feasible and reasonable. No additional management measures are considered warranted.

9.2 Monitoring

Delta Coal operates a network of air quality monitoring locations, including ten dust deposition gauges and one real-time PM_{10} monitor in accordance with the *Approved Methods for the Sampling and Analysis of Air pollutants in NSW*. The air quality data will be summarised on a monthly basis to verify compliance and a summary uploaded to the MC website as per current practice. In the unlikely event of any non-compliance, the relevant authorities will be advised as required under the development consent and/or EPL.

10. CONCLUSIONS

ERM (formerly Pacific Environment) has completed a contemporary assessment of the approved project and has determined the incremental change from the proposed modification compared to the approved project.

Two scenarios were assessed, based on the proposed change to operations: ROM coal handling and transport of 1.3 Mtpa; and ROM coal handling and transport of 2.1 Mtpa.

Dispersion modelling was conducted to predict the ground level concentrations at nearby sensitive receptors applying conservative assumptions, such as the simultaneous occurrence of all activities at the site at all times when in reality it will rarely occur.

Modelling predicts a minimal change in the contribution of dust emissions from the proposed modification compared to the approved project.

Modelling predicts that the incremental PM_{10}, $PM_{2.5}$, TSP and dust deposition are all below the impact assessment criteria at the closest assessment locations.

A cumulative assessment, incorporating existing background dust levels, indicates that the proposed modification is unlikely to result in any additional exceedances of relevant impact assessment criteria at the assessment locations.

It is therefore considered the predicted concentrations represent a conservative assessment and it is unlikely that any of the relevant impact assessment criteria will be exceeded at any of the nearby receptors due to the proposed modification.

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APPENDIX A EMISSION ESTIMATIONS

TSP Emission inventories

Approved Project

ACTIVITY	TSP emission rate kg/y	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Control	Units	Source Types	Assumptions	Emission Factors Sources
COAL														
CL - Crusher (enclosed)	1,053	1,300,000	t/y	0.0027	kg/t					70	% control	2	Enclosed	AP42 11.19.2 Table 11.19.2-1
CL - Unloading of coal to emergency stockpile (20%)	43	260,000	t/y	0.00017	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %			2		AP42 13.2.4
CL - Pushing coal on the stockpile using FEL/Ex	13,438	260,000	t/y	0.05	kg/t			7.50	moisture content in %			2		AP42 11.9 Table 11.9-2
CL - Conveyor transfers (enclosed)	64	1,300,000	t/y	0.00017	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %	70	% control	2	Enclosed	AP42 13.2.4
CL - Rotary Breaker (part-enclosed) 20% of ROM	702	260,000	t/y	0.0027	kg/t							2	Enclosed	AP42 11.19.2 Table 11.19.2-1
WIND EROSION														
WE - Stockpiles	298	0.35	ha	850.0	kg/ha/y									AP42 11.9 Table 11.9-4
TOTAL	**15,598**													

Proposed Modification

ACTIVITY	TSP emission rate kg/y	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Control	Units	Source Types	Assumptions	Emission Factors Sources
COAL Mannering														
CL - Crusher (enclosed)	1,701	2,100,000	t/y	0.0027	kg/t					70	% control	2	Enclosed	AP42 11.19.2 Table 11.19.2-1
CL - Loading of coal to emergency stockpile (20%)	69	420,000	t/y	0.00017	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %			2		AP42 13.2.4
CL - Pushing coal on the emrgency stockpile using FEL/Ex	21,707	420,000	t/y	0.05	kg/t			7.50	moisture content in %			2		AP42 11.9 Table 11.9-2
CL - Conveyor transfers (enclosed)	104	2,100,000	t/y	0.00017	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %	70	% control	2	Enclosed	AP42 13.2.4
CL - Rotary Breaker (part-enclosed) 20% of ROM	1,134	420,000	t/y	0.0027	kg/t							2	Enclosed	AP42 11.19.2 Table 11.19.2-1
WIND EROSION Mannering														
WE - Stockpiles	298	0.35	ha	850.0	kg/ha/y							3		AP42 11.9 Table 11.9-4
TOTAL TSP kg/y	25,013													

Rejects management

ACTIVITY	TSP emissions/year in kg	Intensity	Units	Emission factor	units	Variable 1	Units	Variable 2	Units	Variable 3	Units	Variable 4	Units	Variable 5	Units
REJECT MATERIAL Mannering															
Reject Material - unloading from rotary breaker to bunker	0.11	1,000	t/y	0.00011	kg/t	0.89	average of (wind	10.00	moisture content in %						
Reject Material - FEL loading from bunker	0.11	1,000	t/y	0.00011	kg/t	0.89	average of (wind	10.00	moisture content in %						
Reject Material - FEL travel on sealed roads	18.15	1,000	t/y	0.03108	kg/t	6.00	t/load	18.15	Mean Vehicle Ma	1	km/return trip	0.2	kg/VKT	3	g/m2 silt loading
Reject Material - FEL travel on unsealed roads	229.14	1,000	t/y	0.22914	kg/t	6.00	t/load	18.15	Vehicle gross ma	0.3	km/return trip	4.6	kg/VKT	5.1	% silt content
Reject Material - unloading from FEL to stockpile	0.11	1,000	t/y	0.00011	kg/t	0.89	average of (wind	10.00	moisture content in %						
WE - Stockpiles	13	0.015	ha	850.0	kg/ha/y										
Total TSP from reject material	**260.29**														
TSP % increase (exc stacks)	**1.04**														
[illegible]	[illegible]														

PM_{10} Emission inventories

Approved Project

ACTIVITY	PM10 emission rate kg/y	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Control	Units	Source Types	Assumptions	Emission Factors Sources
COAL														
CL - Crusher (enclosed)	468	1,300,000	t/y	0.0012	kg/t					70	% control	2	Enclosed	AP42 11.19.2 Table 11.19.2-1
CL - Unloading of coal to emergency stockpile (20%)	20	260,000	t/y	0.00008	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %			2		AP42 13.2.4
CL - Pushing coal on the stockpile using FEL/Ex	1,896	260,000	t/y	0.01	kg/t			7.50	moisture content in %			2		AP42 11.9 Table 11.9-2
CL - Conveyor transfers (enclosed)	30	1,300,000	t/y	0.00008	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %	70	% control	2	Enclosed	AP42 13.2.4
CL - Rotary Breaker (part-enclosed) 20% of ROM	312	260,000	t/y	0.0012	kg/t							2	Enclosed	AP42 11.19.2 Table 11.19.2-1
WIND EROSION														
WE - Stockpiles	149	0.35	ha	425.0	kg/ha/y									AP42 11.9 Table 11.9-4
TOTAL	**2,875**													

Proposed Modification

ACTIVITY	PM10 emission rate kg/y	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Variable 3	Units	Control	Units	Source Types	Assumptions	Emission Factors Sources
COAL Mannering																
CL - Crusher (enclosed)	756	2,100,000	t/y	0.0012	kg/t							70	% control	2	Enclosed	AP42 11.19.2 Table 11.19.2-1
CL - Loading of coal to emergency stockpile (20%)	33	420,000	t/y	0.00008	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %					2		AP42 13.2.4
CL - Pushing coal on the emrgency stockpile using FEL/Ex	3,062	420,000	t/y	0.01	kg/t			7.50	moisture content in %					2		AP42 11.9 Table 11.9-2
CL - Conveyor transfers (enclosed)	49	2,100,000	t/y	0.00008	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %			70	% control	2	Enclosed	AP42 13.2.4
CL - Rotary Breaker (part-enclosed) 20% of ROM	504	420,000	t/y	0.0012	kg/t									2	Enclosed	AP42 11.19.2 Table 11.19.2-1
WIND EROSION Mannering																
WE - Stockpiles	149	0.35	ha	425.0	kg/ha/y									3		AP42 11.9 Table 11.9-4
TOTAL kg/y	**4,553**															

$PM_{2.5}$ Emission inventories

Approved Project

ACTIVITY	PM2.5 emission rate kg/y	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Control	Units	Source Types	Assumptions	Emission Factors Sources
COAL														
CL - Crusher (enclosed)	468	1,300,000	t/y	0.0012	kg/t					70	% control	2	Enclosed	AP42 11.19.2 Table 11.19.2-1
CL - Unloading of coal to emergency stockpile (20%)	3	260,000	t/y	0.00001	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %			2		AP42 13.2.4
CL - Pushing coal on the stockpile using FEL/Ex	1,896	260,000	t/y	0.01	kg/t			7.50	moisture content in %			2		AP42 11.9 Table 11.9-2
CL - Conveyor transfers (enclosed)	5	1,300,000	t/y	0.00001	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %	70	% control	2	Enclosed	AP42 13.2.4
CL - Rotary Breaker (part-enclosed) 20% of ROM	312	260,000	t/y	0.0012	kg/t							2	Enclosed	AP42 11.19.2 Table 11.19.2-1
WIND EROSION														
WE - Stockpiles	22	0.35	ha	63.8	kg/ha/y									AP42 11.9 Table 11.9-4
TOTAL	**2,706**													

Proposed Modification

ACTIVITY	PM2.5 emission rate kg/y	Intensity	Units	Emission Factor	Units	Variable 1	Units	Variable 2	Units	Variable 3	Units	Control	Units	Source Types	Assumptions	Emission Factors Sources
COAL Mannering																
CL - Crusher (enclosed)	756	2,100,000	t/y	0.0012	kg/t							70	% control	2	Enclosed	AP42 11.19.2 Table 11.19.2-1
CL - Loading of coal to emergency stockpile (20%)	5	420,000	t/y	0.00001	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %					2		AP42 13.2.4
CL - Pushing coal on the emrgency stockpile using FEL/Ex	3,062	420,000	t/y	0.01	kg/t			7.50	moisture content in %					2		AP42 11.9 Table 11.9-2
CL - Conveyor transfers (enclosed)	7	2,100,000	t/y	0.00001	kg/t	0.89	average of (wind speed/2.2)^1.3 in m/s	7.50	moisture content in %			70	% control	2	Enclosed	AP42 13.2.4
CL - Rotary Breaker (part-enclosed) 20% of ROM	504	420,000	t/y	0.0012	kg/t									2	Enclosed	AP42 11.19.2 Table 11.19.2-1
WIND EROSION Mannering																
WE - Stockpiles	22	0.35	ha	63.8	kg/ha/y									3		AP42 11.9 Table 11.9-4
TOTAL	**4,357**															

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Appendix C

Noise mitigation report

Mannering Colliery Modification 5

Noise Mitigation Study

Prepared for Great Southern Energy Pty Ltd (trading as Delta Coal)
April 2019

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Mannering Colliery - Modification 5

Noise mitigation study

Prepared for Great Southern Energy Pty Ltd (trading as Delta Coal)
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Mannering Colliery - Modification 5

Noise mitigation study

Report Number

H180564 RP#1

Client

Great Southern Energy Pty Ltd (trading as Delta Coal)

Date

12 April 2019

Version

v2-0 Final

Prepared by	**Approved by**
Lucas Adamson	**Katie Teyhan**
Acoustic consultant	Associate
12 April 2019	12 April 2019

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1 Introduction

Mannering Colliery (MC) is an underground coal mine located at the southern end of Lake Macquarie, approximately 60 kilometres (km) south of Newcastle. MC is approved under major project approval (MP 06_0311) and is operated by Great Southern Energy Pty Ltd (trading as Delta Coal).

Delta Coal is seeking to modify the existing major project approval (MP 06_0311) to permit an increase in the run of mine (ROM) coal handing at MC and its transport via overland conveyor to Vales Point Power Station (VPPS) from 1.3 million tonnes per annum (Mtpa) to a maximum of 2.1 Mtpa (the proposed modification).

The previous operators of MC, LakeCoal Pty Limited (LakeCoal), were requested by the NSW Department of Planning and Environment (DPE) to provide additional information with regard to the effectiveness of noise mitigation works at the site, predicted noise emission levels and an analysis of further potential noise mitigation measures, if required. EMM Consulting Pty Limited (EMM) were engaged by LakeCoal to prepare a report in response to this request suitable to accompany the application for the proposed modification.

Several technical terms are required for the discussion of noise and vibration. These are explained in Appendix A.

2 Project description

2.1 The proposed modification

Delta Coal is seeking approval to modify MP 06_0311 to permit an increase in the rate of ROM coal handling at, and transport via overland conveyor from, MC from 1.3 Mtpa up to the approved extraction limit at Chain Valley Colliery (CVC) (ie a maximum of 2.1 Mtpa under project approval SSD 5465).

No significant changes to surface infrastructure are proposed, with the existing infrastructure having adequate capacity to accommodate the additional coal throughput, and no additional plant or equipment are required. The increased coal throughput would all be dispatched via the existing overland conveyor to VPPS as currently approved. There will also be no increase in approved employee numbers under the proposed modification.

2.2 Approved operations

Operations currently approved under MP 06_0311, include:

- extraction of up to 1.1 Mtpa of ROM coal from the Fassifern Seam until 30 June 2022;
- transportation of up to 1.3 Mtpa of ROM coal from the site;
- first workings only using bord-and-pillar mining methods and the like;
- supply of coal to Delta Electricity's VPPS for domestic energy generation via a dedicated covered overland conveyor; and
- operation 24 hours, seven days a week.

MC was placed on care and maintenance on 27 November 2012 by Centennial Coal Company Limited. LakeCoal took over as operator of the mine in October 2013. Prior to be being placed on care and maintenance, coal was extracted using bord-and-pillar mining (first workings) methods.

Construction of an approved underground linkage between MC and the adjacent CVC was completed in August 2017 which enables coal to be transferred from CVC to VPPS via MC and its overland conveyors.

Primary surface infrastructure at MC's pit top includes:

- offices, workshops, a bathhouse, stores, a lamp room, diesel and oil storage areas, firefighting equipment and water tanks;
- access roads and car parking facilities;
- a nominal 25,000 tonne (t) product coal stockpile and reclaim facilities;
- a coal preparation plant (CPP)
- a coal crushing facility (CCF) including a rotary breaker, with a nominal capacity of 1,200 t per hour (tph);
- conveyors for ROM and product coal transportation;
- a main haulage drift for personnel and materials movement;

- a conveyor drift for coal clearance and secondary access and egress;
- mine ventilation shaft and fans; and
- water management infrastructure.

The existing approved operations allow for coal to be transported and handled from the underground workings at MC and/or CVC via a drift conveyor to the on-site CCF for screening and crushing at a total rate of up to 1.3 Mtpa. The coal is then conveyed to a 1,000 t product bin for subsequent transport to the VPPS via a purpose built overland covered conveyor which is operated, maintained and located on land owned by Delta Electricity. In periods when the VPPS is unable to accept coal deliveries due to scheduled maintenance or conveyor break-downs, the coal is temporarily stockpiled within the product coal stockpile area. Once VPPS is again able to accept coal, the stockpiled material is reclaimed, loaded onto the conveyor and dispatched to VPPS.

3 Background

A noise impact assessment (NIA) was prepared by EMM for Modification 3 to MP 06_0311 (refer to *Mannering Colliery – Modification 3 Noise Impact Assessment* dated 7 May 2015a) and is relevant to the currently approved infrastructure.

The NIA (EMM 2015a) provided a contemporary assessment of noise emissions from MC. The NIA conservatively assumed that all plant and equipment would be operating simultaneously and adopted a worst-case wind scenario which considered the highest potential noise levels at each assessment location.

The highly conservative NIA predicted exceedances of both the current noise limits and the Project Specific Noise Levels (PSNLs) at representative receivers on the Pacific Highway and at Macquarie Shores Home Village. Noise emissions at representative receivers at Kingfisher Shores were predicted to remain below the current noise limits and the PSNLs.

DPE in its *Assessment Report – Mannering Colliery – Increased Coal Handling & Dispatch Modification (MP 06_0311 MOD3)* (DPE 2015) noted there had been no noise complaints either prior to or during care and maintenance period and there were no public submissions relating explicitly to noise regarding the original assessment for MP 06_0311 and subsequent modifications, including Modification 3. DPE (2015) also stated that LakeCoal should reduce future noise levels through the implementation of mitigation measures in order to meet contemporary noise criteria and maintain the amenity of residents in neighbouring areas, once coal production recommences.

Based on this feedback, a preliminary analysis was completed by LakeCoal to demonstrate that it would likely be able to reduce noise emissions through the implementation of noise mitigation measures once coal production recommenced (refer to *Mannering Colliery – Modification 3 Noise Impact Assessment Addendum*, EMM 2015b).

DPE (2015) noted that, in accordance with the procedures in the *Industrial Noise Policy* (INP) (EPA 2000) for existing operations, the focus should be on ensuring LakeCoal is implementing all reasonable and feasible noise mitigation measures at MC.

LakeCoal committed to assessing noise emissions and implementing mitigation measures once MC recommenced coal production. However, it identified problems in accurately assessing predicted noise emissions and appropriate mitigation measures while the mine remained on care and maintenance. Accordingly, MP06_0311 was amended to incorporate 'interim noise criteria' which apply for a period of 18 months following recommencement of MC's underground mining operations, while LakeCoal investigated and implemented noise mitigation measures. It was anticipated that LakeCoal would undertake noise monitoring during coal production and handling for a period of six months and identify the reasonable and feasible mitigation measures required to achieve the long-term noise criteria. The assessment and implementation of mitigation measures would then occur within 12 months of the completion of noise monitoring. The relevant noise criteria are provided in MP06_0311 and reproduced in Section 4 of this report.

Once mitigation measures have been implemented, Delta Coal, as the current operators of MC, are required to undertake a noise compliance investigation to assess compliance with the more stringent long-term noise criteria in Appendix 4B, Table 2 of MP06_0311. DPE (2015) noted that it believes these measures would ensure that the noise impacts from recommencement of coal mining at MC would be significantly reduced below currently approved impacts.

4 Noise criteria

4.1 Project approval MP06_0311

Noise criteria for MC, once underground coal extraction has recommenced, are specified in Conditions 1 and 2, Appendix 4B of MP06_0311 and have been reproduced below:

1. From the recommencement of underground coal extraction at Mannering Colliery until 18 months thereafter, the Proponent must ensure that the noise generated by the project does not exceed the noise impact assessment criteria in Table 1 at any residence on privately-owned land.

Table 1: Noise limits dB(A)

Location	Day $L_{Aeq,15\ minute}$	Evening $L_{Aeq,15\ minute}$	Night $L_{Aeq,15\ minute}$	Night $L_{A1,1\ minute}$
4 – di Rocco	40	40	40	49
5 – Keighran	43	43	41	49
6 – Swan	42	42	41	49
7 – Druitt	39	39	39	47
8 – May	46	46	46	47
9 – Jeans	41	41	41	51
11 – Jeans	39	39	39	49
18 – Jeans	39	39	39	51
20 –Knight and all other Chain Valley Bay residences	40	40	40	51

Noise generated by the project is to be measured in accordance with the relevant requirements of the *NSW Industrial Noise Policy* (as may be updated from time-to-time). Appendix 4A sets out the meteorological conditions under which these criteria apply, and the requirements for evaluating compliance with these criteria. However, these criteria do not apply if the Proponent has an agreement with the owner/s of the relevant residence or land to generate higher noise levels, and the Proponent has advised the Department in writing of the terms of this agreement.

2. Following the expiry of the 18-month period referred to in condition 1 above, the Proponent must ensure that the noise generated by the project does not exceed the noise impact assessment criteria in Table 2 at any residence on privately-owned land.

Table 2: Noise limits dB(A)

Location	Day $L_{Aeq,15\ minute}$	Evening $L_{Aeq,15\ minute}$	Night $L_{Aeq,15\ minute}$	Night $L_{A1,1\ minute}$
4 – di Rocco	40	40	40	49
5 – Keighran	41	41	41	49
6 – Swan	41	41	41	49
7 – Druitt	39	39	39	47
8 – May	45	45	43	47
9 – Jeans	41	41	41	51
11 – Jeans	39	39	39	49
18 – Jeans	39	39	39	51
20 –Knight and all other Chain Valley Bay residences	40	40	40	51

Noise generated by the project is to be measured in accordance with the relevant requirements of the *NSW Industrial Noise Policy* (as may be updated from time-to-time). Appendix 4A sets out the meteorological conditions under which these criteria apply, and the requirements for evaluating compliance with these criteria.

However, these criteria do not apply if the Proponent has an agreement with the owner/s of the relevant residence or land to generate higher noise levels, and the Proponent has advised the Department in writing of the terms of this agreement.

5 Existing noise environment

5.1 Assessment locations

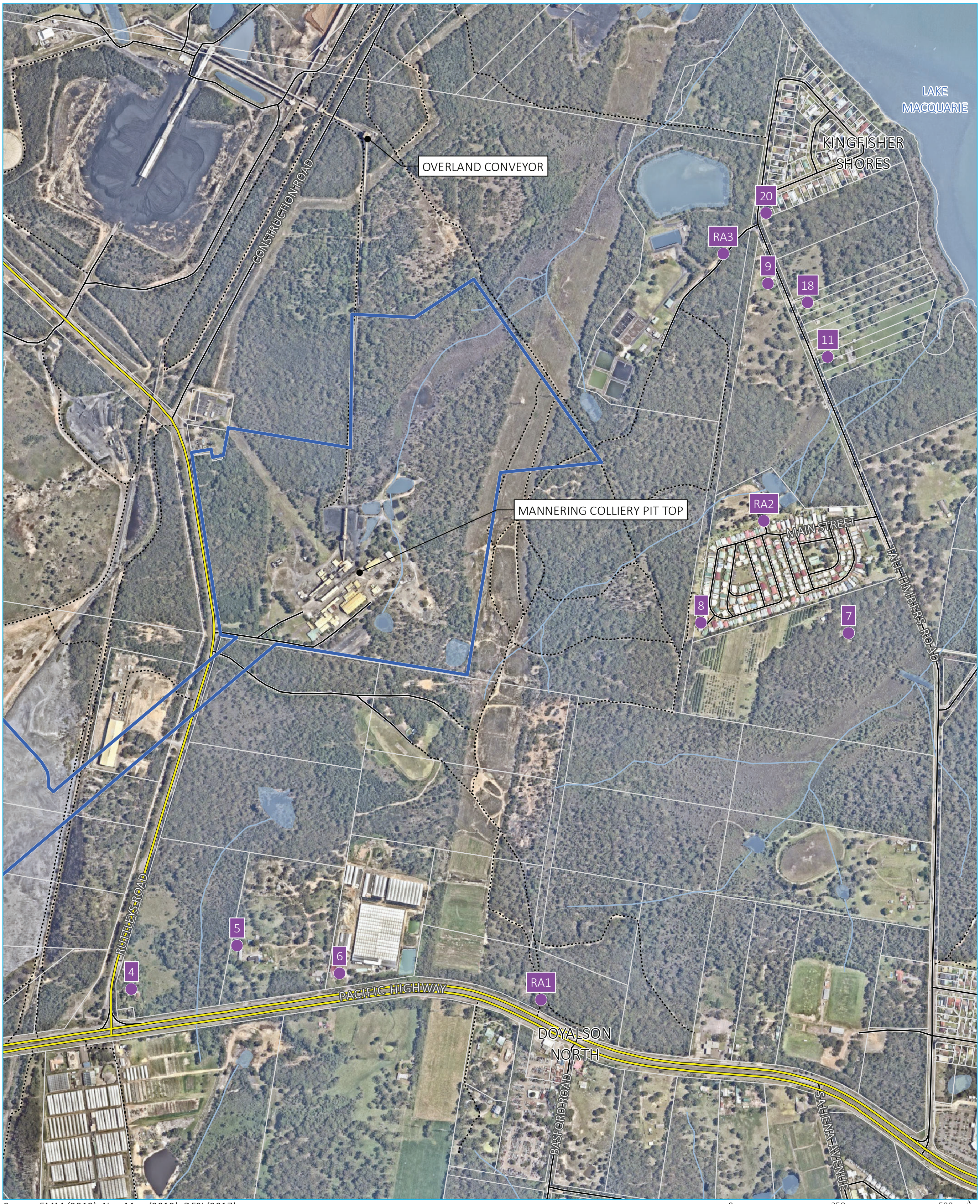
The nearest residential areas to MC are the Macquarie Shores mobile home village, Kingfisher Shores and Chain Valley Bay to the east, several isolated residences on the Pacific Highway to the south and Mannering Park beyond the VPPS to the north. The areas to the north, south and west generally comprise industrial facilities and vegetation.

Representative assessment locations considered in the assessment of MC noise emissions are shown in Table 5.1 and Figure 5.1.

Table 5.1 Assessment locations

Location	Description	Easting	Northing
4 – di Rocco	Residential	363695	6327245
5 – Keighran	Residential	363940	6327347
6 – Swan	Residential	364178	6327282
7 – Druitt	Residential	635360	6327761
8 – May	Residential	365018	6328096
9 – Jeans	Residential	365173	6328884
11 – Jeans	Residential	365312	6328713
18 – Jeans	Residential	365265	6328839
20 –Knight	Residential	365169	6329047

The assessment locations represent those most likely to be affected by MC operations and are consistent with those nominated in the current approval (MP 06_0311). Adherence with noise criteria at these locations would indicate that noise criteria will be met at other surrounding noise-sensitive locations.



Source: EMM (2019); NearMap (2019); DFSI (2017)

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KEY

- Assessment locations
- Mannering Colliery project approval boundary
- Main road
- Local road
- Vehicular track
- Watercourse/drainage line
- Waterbody
- Cadastral boundary

Assessment locations

Mannering Colliery
Noise mitigation and compliance report
Figure 5.1

creating opportunities

5.2 Existing MC noise emissions

Noise emissions from MC operations are currently managed in accordance with the approved Noise Monitoring Program (LakeCoal 2016) which has included monthly (up to December 2018) or quarterly (2019 onwards) noise monitoring and operator attended surveys at three monitoring locations (RA1, RA2 and RA3 shown on Figure 5.1).

An analysis of the MC noise monitoring results from July 2018 to March 2019 was conducted.

In summary, noise from MC operations was generally found to be inaudible at all noise monitoring locations (RA1, RA2 and RA3) during the daytime and evening periods. Operational noise from MC was also generally found to be inaudible during the night-time period at locations RA1 and RA3.

At location RA2, during the night time period, MC operational noise was found to be audible during three of the seven noise monitoring surveys, with site noise contributions of $L_{Aeq,15\ minute}$ 38 dB, $L_{Aeq,15\ minute}$ 40 dB and $L_{Aeq,15\ minute}$ 33 dB during the July, August and December noise monitoring surveys, respectively. During the August noise monitoring survey, the MC site contribution was measured to be $L_{Aeq,15\ minute}$ 40 dB at RA2, which is 1 dB above the noise limit for this location.

Typically, MC noise is identified as MC continuum and rotary breaker noise. Other noise sources noted to be of significance in the area include insects, birds, aircraft noise, road traffic noise and other industrial noise.

6 Noise mitigation

Delta Coal has engaged an acoustic specialist and undertaken detailed investigations regarding noise mitigation options at the site. Initial monitoring identified the rotary breaker, coal preparation plant (CPP) and coal stockpile dozer as the primary sources of noise generation from the site.

Significant noise mitigation works have recently been undertaken at MC to reduce noise emissions from the site. The following controls have been implemented to date:

- Replacement of the previous steel reject chute off the rotary breaker with a noise attenuated, poly-lined discharge catch hopper and chute.
- Installation of slowing chains in the chute to reduce velocity of the reject product.
- Re-machining of the rotary breaker trunnions to minimise vibration and intrusive noise from the structure.
- Installation of custom designed acoustic walls around the rotary breaker structure.
- Installation of inlet and outlet shrouds on the rotary breaker.
- Rectified the conveyor belt screening around the drift belt transfer house.
- Stabilisation of the screen deck foundations.
- Replacement and redirection of the conveyor belt start up alarms with lower decibel units.
- Full conveyor system roller audit and replacement of defective/noisy rollers.
- Replacement of the product coal dozer with a wheeled loader to reduce track slap impacts and overall noise from coal stockpiling activities.

Before and after photos of some of the implemented mitigation measures have been included below (Figures 6.1 to 6.4).

Figure 6.1 Transfer house and breaker before (left) and after mitigation (right)

Figure 6.2 Rotary breaker outlet before (left) and after mitigation (right)

Figure 6.3 Existing front-end loader (left) and new front-end loader (right)

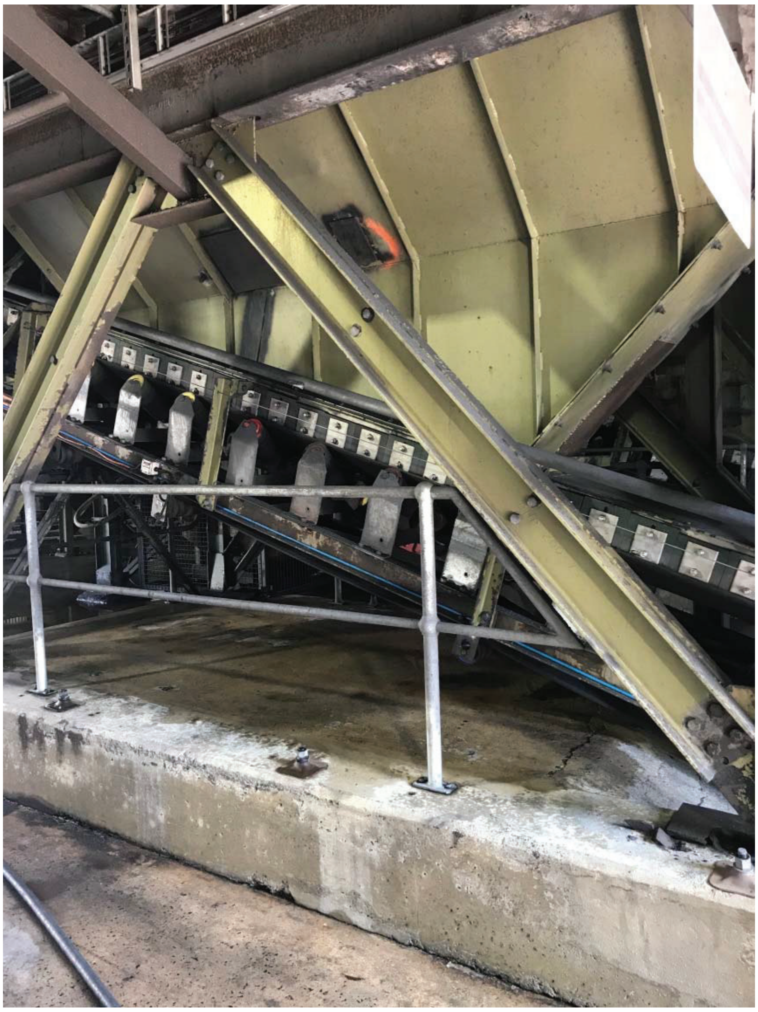


Figure 6.4 Structural changes to screen deck in the washery

7 Operational noise modelling and assessment

7.1 Overview

The proposed modification will only involve additional coal throughput via existing infrastructure and will not change any aspect of the surface operations or road traffic generation. Hence, the change in noise levels associated with the proposed modification compared to the existing, approved development is predicted to be negligible. Notwithstanding this, noise emissions from MC operations have been modelled incorporating the recent noise mitigation works. Predicted noise emissions from MC have been compared to those presented in the previous NIA (EMM 2015a) and the strictest noise criteria provided in MP 06_0311.

7.2 Noise modelling methodology

This section presents the methods and assumptions used to model noise emissions from MC operations.

Noise modelling was based on three-dimensional digitised ground contours of the surrounding land. Noise predictions were carried out using Brüel and Kjær Predictor noise prediction software. 'Predictor' calculates total noise levels at assessment locations from the concurrent operation of multiple noise sources. The model has considered factors such as:

- the lateral and vertical location of plant;
- source to assessment location distances;
- ground effects;
- atmospheric absorption;
- topography of the site and surrounding area; and
- applicable meteorological conditions.

Plant and equipment have been modelled at locations and heights representing activities during typical MC operations. Assumed locations of acoustically significant plant and equipment are shown in Appendix B.

7.3 Modelled meteorological conditions

Predicted noise levels from MC operations at the assessment locations have been calculated based on the meteorological parameters shown in Table 7.1. Worst case meteorological conditions, including a 3 m/s source to receiver wind, have been assumed as per the previous NIA (EMM 2015a).

Table 7.1 Weather conditions considered in noise modelling

Period	Meteorological condition	Air temperature	Relative humidity	Wind speed	Wind Direction	Stability category
Day	Calm	20°C	70%	0 m/s	N/A	D class
	Wind	20°C	70%	3 m/s	All[1]	D class
Evening	Calm	20°C	70%	0 m/s	N/A	D class
	Wind	20°C	70%	3 m/s	All[1]	D class
Night	Calm	10°C	90%	0 m/s	N/A	D class
	Wind	10°C	90%	3 m/s	All[1]	D class
	Temperature inversion	10°C	90%	0 m/s	N/A	F class
	Temp inv + Wind	10°C	90%	2 m/s	All[1]	F class

Notes: 1. Source to receiver wind direction.

7.4 Sound power levels

EMM conducted a site visit on 20 February 2019 to undertake noise measurements at the MC for the purpose of determining sound power levels of relevant equipment after mitigation had been applied. Sound power levels of equipment available on-site were determined from the results of near-field noise surveys. Noise surveys of all relevant equipment were undertaken whilst the equipment was undertaking normal operational cycles.

Where direct measurement was not possible, sound power data has been obtained from previous site surveys when the site was fully operational (eg *Noise Impact Assessment Report J0130-10-R1* prepared by Bridges Acoustics dated 21 March 2007) or an EMM database of similar equipment. Sound power data adopted for the noise model are provided in Table 7.2. The noise modelling conservatively assumed that all plant and equipment will be operating concurrently.

Table 7.2 Operational plant and equipment sound power levels

Plant and equipment	Sound power level (L_w) $L_{Aeq,15\ minute}$, dB	
	Mod 3 (pre-mitigation)	Mod 5 (post mitigation)
Compressors (x2)	106 per compressor[1]	106 per compressor[1]
Transfer house/Bradford breaker	113[2]	108[1]
Crushing facility	113[2]	108[1]
Vent fan (x2)	93 per fan[2]	90 per fan[1]
Excavator	106[3]	106[3]
Dozer (D9 or similar)	113[3]	n/a
Wheeled loader (Komatsu WA320)	n/a	103[1]
Storage bin	106[3]	106[3]
Conveyor – from underground to transfer house	92[1]	92[1]
Conveyor – transfer house to crushing facility	87[1]	87[1]
Conveyor – crushing facility to bin	100[1]	100[1]
Conveyor – belt tensioner	98[1]	98[1]
Conveyor – opening under bin	85[1]	85[1]
Conveyor – bin to stockpile area	99[1]	99[1]
Conveyor – overland conveyor	85/m[3]	85/m[3]

Notes: 1. Obtained from direct measurement by EMM.
2. Obtained from the previous Bridges 2007 report.
3. Obtained from EMM database of similar equipment

As can be seen from the results of on-site measurements, there has been a significant reduction in the overall sound power level of the three major contributors to off-site noise levels from MC; a 5 dB reduction for both the rotary breaker and CPP; and a 10 dB reduction as a result of the change from the dozer to a wheeled loader in the stockpile area.

7.5 Noise modelling results and discussion

7.5.1 Operational noise levels

Predicted noise emission levels from MC at all assessment locations are provided in Table 7.3. Noise levels have been predicted based on the meteorological conditions provided in Table 7.1.

Table 7.3 Predicted operational noise levels - $L_{Aeq,15\ minute}$

Assessment location	Period	Predicted dB		Difference (dB)	Noise criteria, dB(A)
		Mod 3 (pre-mitigation)	Mod 5 (post mitigation)		Table 2, Appendix 4B MP 06_0311
4	Day	39	35	-4	40
	Evening	39	36	-3	40
	Night	40	36	-4	40
5	Day	42	38	-4	41
	Evening	42	39	-3	41
	Night	43	39	-4	41
6	Day	41	36	-5	41
	Evening	41	37	-4	41
	Night	42	37	-5	41
7	Day	38	34	-4	39
	Evening	38	35	-3	39
	Night	39	35	-4	39
8	Day	45	41	-4	45
	Evening	45	42	-3	45
	Night	46	42	-4	43
9	Day	40	36	-4	41
	Evening	40	37	-3	41
	Night	41	37	-4	41
11	Day	38	35	-3	39
	Evening	38	36	-2	39
	Night	39	36	-3	39
18	Day	38	35	-3	39
	Evening	38	36	-2	39
	Night	39	36	-3	39
20	Day	39	35	-4	40
	Evening	39	36	-3	40
	Night	40	36	-4	40

Based on the results of noise modelling, noise mitigation works implemented by LakeCoal (as the previous operator of MC) have decreased site noise emission levels by 2-5 dB at all assessment locations. Further, noise emissions from current and proposed site operations are predicted to comply with the relevant long-term noise criteria outlined in MP 06_0311 at all assessment locations under worst case meteorological conditions.

7.5.2 Sleep disturbance assessment

As per the previous NIA (EMM 2015a), the highest predicted L_{Amax} noise level (being the operation of the conveyor belt alarms) at any assessment location was L_{Amax} 47 dB at assessment location 8 under prevailing meteorological conditions and all results demonstrated that L_{Amax} noise levels were compliant with the relevant sleep disturbance criteria.

As noted in Section 5, the conveyor belt alarms have been replaced with lower decibel units and have been redirected away from sensitive receptors. Therefore, the L_{Amax} noise levels received at the nearest assessment locations are predicted to decrease due to the mitigation works. Hence, L_{Amax} noise level events at the site are predicted to remain below the relevant sleep disturbance criteria.

8 Conclusion

EMM has prepared a noise mitigation study to accompany Delta Coal's application to modify MP 06_0311 to increase the rate of ROM coal handling at MC. Operational noise emissions are expected to be unchanged under the proposed modification and, therefore, no detailed noise assessment has been undertaken.

DPE requested that the previous operators of MC, LakeCoal, provide additional information regarding the effectiveness of noise mitigation works at the site, predicted noise emission levels and an analysis of further potential noise mitigation measures, if required.

Potential noise emission levels from MC have been predicted and compared to the sites long-term noise goals outlined in MP 06_0311. Operational noise levels were assessed for the daytime, evening and night-time periods during worst case meteorological conditions.

Noise mitigation works implemented by the previous operators in 2018 have decreased site noise emission levels at all neighbouring noise-sensitive receivers. Further, current and proposed MC noise emissions are predicted to comply with the relevant long-term noise criteria outlined in MP 06_0311 at all assessment locations under worst case meteorological conditions. L_{Amax} noise level events at the site are also predicted to remain below the relevant sleep disturbance criteria.

Appendix A

Glossary of acoustic terms

A number of technical terms are required for the discussion of noise. These are explained in Table A.1.

Table A.1 Glossary of acoustic terms

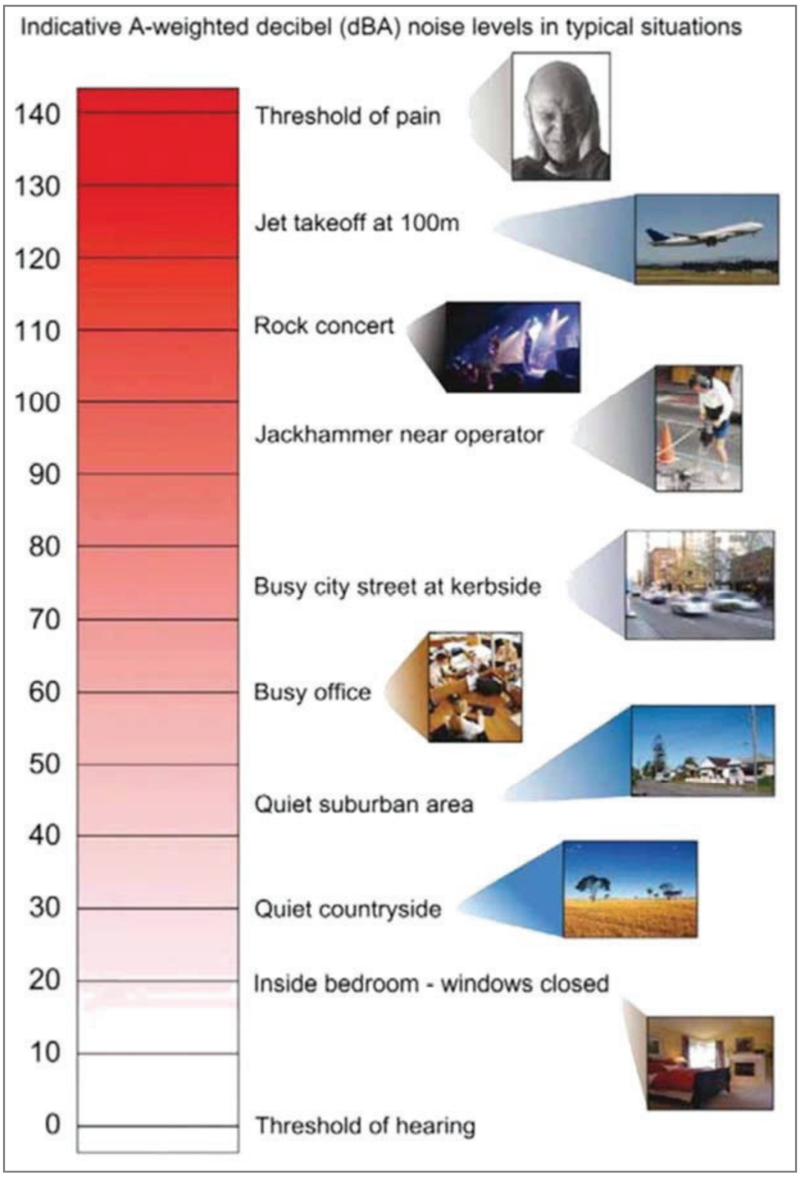
Term	Description
dB	Noise is measured in units called decibels (dB).
A-weighting	There are several scales for describing noise, the most common being the 'A-weighted' scale. This attempts to closely approximate the frequency response of the human ear.
L_{A1}	The A-weighted noise level exceeded for 1% of a measurement period.
L_{A10}	The A-weighted noise level which is exceeded 10% of the time. It is approximately equivalent to the average of maximum noise levels.
L_{A90}	Commonly referred to as the background noise, this is the A-weighted level exceeded 90% of the time.
L_{Aeq}	The A-weighted energy average noise from a source and is the equivalent continuous sound pressure level over a given period. The $L_{Aeq,15\ minute}$ descriptor refers to an L_{Aeq} noise level measured over a 15-minute period.
L_{Amax}	The maximum root mean squared A-weighted sound pressure level received at the microphone during a measuring interval.
RBL	The Rating Background Level (RBL) is an overall single value background level representing each assessment period over the whole monitoring period.
Sound power level	This is a measure of the total power radiated by a source. The sound power of a source is a fundamental property of the source and is independent of the surrounding environment.

It is useful to have an appreciation of decibels (dB), the unit of noise measurement. Table A2 gives an indication as to what an average person perceives about changes in noise levels:

Table A.2 Perceived change in noise

Change in sound level (dB)	Perceived change in noise
1 to 2	typically indiscernible
3	just perceptible
5	noticeable difference
10	twice (or half) as loud
15	large change
20	four times (or quarter) as loud

Examples of common noise levels are provided in Figure A.1.



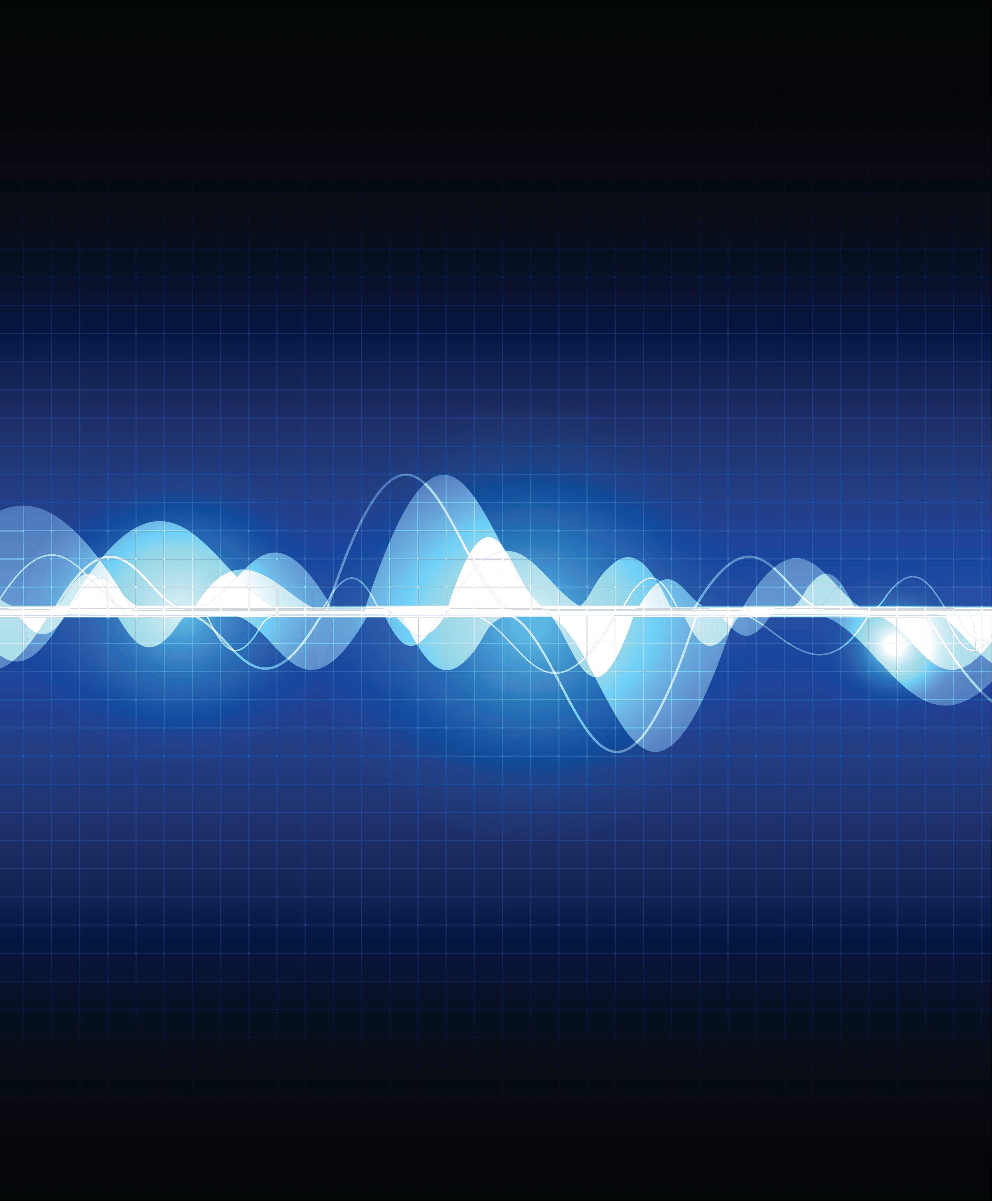
Source: Road Noise Policy (Department of Environment, Climate Change and Water 2011).

Figure A.1 Common noise levels

Appendix B

Modelled locations of plant and equipment

Industrial noise - ISO 9613.1/2, [2019-02-28 - Base model] , Predictor V11.00



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Appendix D

Geotechnical report

DELTA COAL
MANNERING COLLIERY

Proposed Herringbone Layout for Mannering Colliery - Design Criteria for Negligible Surface Effects

APRIL 2019

Report No: CHV-012-Rev0

ABN 19 622 292 460
First Floor, Building B, Edgeworth Town Square
720 Main Road
Edgeworth NSW 2285

REPORT TO : Dave McLean
General Manager
Delta Coal

REPORT ON : Proposed Herringbone Layout for Mannering Colliery
- Design Criteria for Negligible Surface Effects

REPORT NO : CHV-012-Rev0

REFERENCE : PO 601904

Rev	Date	Prepared	Status	Signature
A	09/04/2019	D. Hill	Draft	
0	15/04/2019	D. Hill	Final	

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Appendix A: Hill (2010) Paper
Appendix B: Extract from SCT Report No. CHA 4803

1.0 INTRODUCTION

This report addresses the design of a "herringbone" pillar layout for future Fassifern Seam workings at Mannering Colliery that is considered long-term stable and results in negligible subsidence effects (defined for this purpose as vertical subsidence of ≤ 20mm). The layout is shown schematically in **Figure 1**. The system initially involves the drivage of a mains panel up to five headings wide. Either side of this mains, individual panels are developed by driving a "sub-mains" three-headings wide. From the sub-mains, "run-out" roadways are driven, typically 80m long (mainly limited by wheeling distances). Finally, stubs or "free cuts" are driven from these run-out roadways to form the final pillars; depending on the ground conditions and serviceability requirements of these free cuts, they may or may not remain unsupported (for example, some are bolted to facilitate long-term return airway ventilation).

The most significant geotechnical design constraints for this system at Mannering Colliery are as follows:

i) The area of immediate interest is to the west of previous Chain Valley (CVC) Miniwalls 7 to 12 see **Figure 2**. The depth of cover ranges from approximately 140m to 200m and the potential working section varies between 3.4m and 4m, thinning to the west.

ii) The system entails the development of large areas of permanent, first workings pillars. It follows that the pillars should be designed in a manner that is considered to preclude the potential for any form of sudden or rapid deterioration (primarily from an underground safety perspective). In this regard, pillar w/h ratios of >4 are considered likely to result in a "strain hardening" pillar deformation characteristic and, at worst, a gradual "squeezing" or "creep" mode of deterioration, in the event of any overloading.

iii) Stable unsupported stubs are critical to the performance of the system. This issue was addressed in previous **Strata2 Report No. CHV-005** and a typical stub width of 5.5m is conservatively assumed herein.

iv) The interval between stubs is partly a function of the required pillar size, but also dictated by the need to separate the adjacent alternating stubs for roof control purposes, thereby forming isolated three-way intersections. Practically, allowing for break-offs, this dictates a stub (solid) interval of around 20m.

It should be apparent from the preceding points that design of a herringbone panel geometry requires some compromise and also a focus on maintaining flexibility wherever possible. In this regard, the design process summarised herein has sought to learn from the relevant experiences of other mines, most notably the herringbone operation at the adjacent Myuna Colliery, where the system has been employed successfully for a number of years.

2.0 GEOLOGICAL / GEOTECHNICAL ENVIRONMENT

The geological and geotechnical environment in the Fassifern Seam has been described in detail in **LDO Report CHV-016: Chain Valley Bay – Geotechnical Review (2017)**. Familiarity with that report is assumed herein.

From a pillar design perspective, a key issue is the presence of weak claystone layers within 2m of the working floor. The cumulative thickness of claystone bands with a UCS of ~5 MPa is around 1m over CVC MWs 7 to 12 (**DGS, 2018**). For the purpose of this and previous studies, "weak floor" has been defined simply as a total thickness of ≥ 1m of rock with a UCS of ≤ 5MPa, within 2m of the immediate floor. Although the Fassifern Seam floor strength is therefore regarded as only "marginally weak", a conservative approach is warranted, given that the interpretation of "weak claystone" thickness in this area is based very largely on the interpretation of widely spaced lithological logs, without geomechanical or geophysical data. **Figure 3** shows the Fassifern Seam section at exploration borehole EBU 11, immediately west of CVC MW9; the claystone and "tuffaceous shale" layers in the floor total ~1.0m in thickness. The pillar design methodology therefore recognises and addresses this aspect.

3.0 PILLAR DESIGN METHODOLOGY

3.1 Bieniawski Stability Factor Approach

The pillar design methodology adopted herein builds on the methodology summarised in **Hill (2010)** and the Stability Index "SI" approach put forward for Lake Macquarie Coalfield soft (predominantly claystone) floor environments by **SCT (1993)**. The SI methodology was most recently applied in the Chain Valley Bay area of CVC **(SCT, 2018)**. For convenience, **Hill (2010)** is attached as **Appendix A** and the relevant extract from **SCT (2018)** is attached as **Appendix B**.

The key finding of **Hill (2010)** is as follows:

> *"For Australian conditions, an ARMPS Stability Factor of ≥ 1.5, coupled to a w/h ratio of ≥ 5, would effectively obviate the potential for long-term failure (i.e. collapse due to the failure of any element, roof, floor or the pillar, in the overall structural system)."*

The ARMPS Stability Factor is calculated using **Bieniawski's (1967)** pillar strength equation, namely:

$$\sigma_{PS} = k(0.64+0.36w/h)$$

where:

σ_{PS} = pillar strength (MPa)
k = unit coal strength (MPa)
and w/h is the pillar width to height ratio.

In Australia, a k value of 6.2MPa is commonly applied **(Colwell, 1998)**.

SCT (1993) arbitrarily increased the k value to 8MPa, to distinguish their Stability Index (SI) from **Bieniawski's** Stability Factor (SF).

Therefore: SF = 6.2 x SI / 8

The critical Stability Factor of 1.5 suggested in **Hill (2010)** equates to a Stability Index of 1.9. SCT use the approach to define Stability Indices that equate to different subsidence outcomes (see **Table 1** of **Appendix B**). Long-term stability, subsidence and surface impacts are all important considerations in this environment. Even if the pillar system is regarded as long-term stable, the magnitude of subsidence may be unacceptable in a given circumstance (e.g. foreshore areas).

Therefore, the **Hill (2010)** pillar design conclusion has been calibrated against the Lake Macquarie "weak floor" data, focusing on the subsidence outcomes. The case studies encompass the Great Northern, Wallarah and Fassifern Seams, encompassing four decades of local experience. The total number of Lake Macquarie case histories is 62, including 15 of the original SCT case histories (the remaining 25 could not be verified and

/ or acceptably reproduced). In general, those cases involving complex geometries and significant uncertainty with regard to the caving environment were discarded.

Figure 4 illustrates the failed pillar database, plus the Lake Macquarie weak floor data. The following comments are made regarding **Figure 4**:

i) The Lake Macquarie weak floor cases have initially been divided into stable and failed on the basis of the subsidence outcomes. The 39 cases associated with ≤200mm of subsidence have been classed as stable (i.e. strata deformation largely due to elastic system compression), whereas the 23 cases that resulted in >200mm of subsidence have been classed as failed (i.e. higher deformation, more typical of an overloaded system).

ii) The Lake Macquarie failed cases have Stability Factors ranging from 0.91 to 2.23.

iii) The Lake Macquarie stable cases have Stability Factors ranging from 1.34 to 21.60.

iv) The overlap between the failed and the stable cases is largely a function of the natural variability in the geotechnical properties of the strata (i.e. some of the failures are associated with particularly weak rock, whilst some of the stable cases are associated with relatively stronger strata).

v) The case with the highest Stability Factor of 2.23 involved 220mm of subsidence (i.e. marginal in terms of the 200mm failed / stable criterion). The associated data point is from CVC MG4 (Fassifern Seam) and is highlighted on the graph.

vi) **Figure 4** suggests that a revised design criterion for long-term pillar stability in weak floor conditions could be defined by a higher Stability Factor of ≥ 2.3.

vii) The database is dominated by the Great Northern Seam (37 case histories), followed by 16 Fassifern Seam and 9 Wallarah Seam case studies. **Figure 5** presents the Lake Macquarie database on a seam-specific basis. Accepting the limited size of the sub-sets for the Fassifern and Wallarah Seam, there is no obvious evidence of a difference in behaviour of any of the three seams (i.e. one seam does not appear to be either stronger or weaker than the others).

viii) **Figure 6** reproduces **Figure 5**, with the exclusion of the CVC Fassifern Seam miniwall panels, which involved relatively large (30m to 40m wide) and highly stressed pillars (typical final average stresses of 14 to 18MPa). The “limiting” value for failure equates to a Stability Factor of 2.15.

Figure 7 presents all the Lake Macquarie data in histogram form. Subsidence is negligible (≤ 20mm) at a Stability Factor of ≥ 2.3.

Therefore, a Stability Factor of ≥ 2.3 is recommended for the herringbone pillar layout in situations requiring negligible (≤ 20mm) subsidence.

3.2 UNSW Pillar Methodology

Apart from Bieniawski’s Stability Factor, the other empirical coal pillar design formulae widely used in Australia are those developed at the UNSW (**Salamon *et al*, 1996**). When applying the “UNSW Formulae”, it is common in Australia to use the term “Factor of Safety” (FoS), to differentiate the approach and outcomes from those related to the use of Bieniawski’s coal pillar strength formula. However, Factor of Safety is analogous to Stability Factor (i.e. FoS = pillar strength / pillar stress).

The UNSW formulae are founded on extensively researched and broadly-based databases of mining experience. These formulae represent the culmination to-date of work commenced some 40 years ago in South Africa after the 1960 Coalbrook disaster (**Salamon and Munro, 1967**). A combined Australian and South African database has been applied to the derivation of formulae that are considered widely applicable.

The range of parameters within the UNSW combined failed and intact pillar database can be summarised as follows:

- Depth: 20m to 510m
- Mining Height: 1.0m to 9.2m
- Smallest Pillar Dimension: 2m to 32m
- Bord Width: 3.7m to 15.0m
- Percentage Extraction: 30% to 90%
- Width to Height (w/h) Ratio: 0.9 to 11.2
- Time to Failure: 0 to >80 years

The strength formula for Australian coal pillars with w/h ratios of >5 is as follows:

$$\text{Strength, } \sigma_s = 27.63^{0.51}(0.29*((w_m/5h)^{2.5} - 1) + 1)/(w^{0.22} \times h^{0.11})$$

where:

w_m = minimum pillar width (m)
h = roadway height (m)
Θ = a dimensionless ‘aspect ratio’ factor for rectangular pillars defined by **Salamon *et al,* 1996**.

For pillars with w/h ratios of ≤ 5, the strength formula is as follows:

$$\sigma_s = 8.6(w_m\Theta)^{0.51}/h^{0.84}$$

FoS can be related to the nominal probability of failure of a panel of pillars. A probability of stability of 99.9% is attained at a Factor of Safety of 1.63, see **Figure 8**, and further increases in FoS have little effect, as the probability of stability curve approaches 100% asymptotically. From a risk management perspective, increasing the FoS beyond 1.63 can only reduce the failure probability by <0.1%.

The consequences of collapse are a key consideration, as these determine the acceptable probability of failure, which in turn allows an appropriate FoS to be determined. For example, prudent risk management suggests that the probability of failure for long-term first workings panels beneath sensitive surface structures should be negligible. In Australia, long-life critical pillars (e.g. in main headings and for the protection of surface infrastructure) are often designed to an FoS of ≥ 2.11, which equates to a nominal failure probability of one panel in a million. This reduces the probability of failure to a level that would be considered acceptable in other key fields of public interest.

It should be understood that the nominal probability of failure is related to the life-time of the pillar database that underpins the design methodology; currently this averages approximately fifty years (i.e. of the order of 100 years of coal pillar history is available). The annualised probability of failure (a concept more commonly applied in engineering practice) is therefore about one-fiftieth of the nominal failure probability.

The South African and Australian databases from which the UNSW formulae were derived cover a broad range of roof and floor materials, including mudrocks, coal, siltstones and sandstones. Therefore, these materials and the variability in strength that may be associated with them are implicitly recognised and largely catered for in the FoS approach. Uncertainty associated with the natural variability in coal measures strata often prohibits design to low FoS values. Geological variability partly accounts for the scatter in the population of failed pillar cases and usually necessitates design to FoS values of >1.5, equivalent to low failure probabilities. Back analysis indicates that incidences of pillar instability traditionally associated with weak floor, for example, can very often be explained in terms of 'conventional' empirical design criteria.

Similarly, the database encompasses pillars in a significant number of seams in different geotechnical environments; consequently, the existence of pillar weaknesses is very largely reflected and implicit within the variability in the failed and intact pillar cases, such that these weaknesses are again very largely catered for by adopting appropriate FoS values.

Figure 9a/b reproduces the Lake Macquarie database outcomes from **Figures 5** and **6**, but according to the FoS values. The overall picture is very similar; there is no evidence of one seam performing better of worse than another and, if the highly stressed CVC chain pillars are excluded, the highest FoS of a "failed" case is 2.08.

The database is reproduced in histogram form in **Figure 10** and the following comments are made regarding the outcomes:

i) Almost all the failures (>200mm of subsidence) are associated with Factors of Safety of <2.11 (i.e. 22 out of 23 failed cases, or 96%).

ii) A rapid transition occurs at Factors of 2.11 to 2.7. The average subsidence magnitude is 93mm, with a maximum of 220mm. Such magnitudes of subsidence would generally be associated with minimal surface impacts.

iii) However, if the CVC chain pillars are excluded, subsidence is negligible (≤ 20mm) at FoS values of >2.3.

Therefore, the following criteria are recommended for the herringbone pillar layout in situations requiring negligible (≤ 20mm) subsidence:

- **average final pillar stresses of <12MPa,**
- **Factors of Safety of ≥ 2.3.**

3.3 Pillar Design Outcomes
3.3.1 Depth Sensitivity

The design outcomes for cover depths of 140m to 200m are summarised in **Table 1**.

Table 1: Herringbone Pillar Design for <20mm of Subsidence, at Depths of up to 200m

Roadway Width (m)	Depth (m)	Pillar							Stub		Bieniawski Stability Factor	Pillar FoS (Salamon)
		Height (m)	Width (m)	Length (m)	w/h Ratio	Stress	Strength		Interval (m)	Length (m)		
							Bieniawski	Salamon				
5.5	140	3.8	18.2	24.5	4.8	5.6	14.7	12.8	21.0	14.1	2.6	2.3
5.5	150	3.7	19.6	24.5	5.3	5.9	15.8	13.5	22.6	14.1	2.7	2.3
5.5	160	3.7	21.4	24.5	5.8	6.2	16.9	14.2	24.7	14.1	2.7	2.3
5.5	170	3.7	23.2	24.5	6.3	6.4	18.0	14.8	26.8	14.1	2.8	2.3
5.5	180	3.6	23.9	24.5	6.6	6.8	18.8	15.6	27.6	14.1	2.8	2.3
5.5	190	3.4	23.5	24.5	6.9	7.2	19.4	16.6	27.1	14.1	2.7	2.3
5.5	200	3.4	24.5	24.5	7.2	7.5	20.1	17.1	28.3	14.1	2.7	2.3
5.5	150	3.5	18.2	24.5	5.2	6.0	15.6	13.8	21.0	14.1	2.6	2.3
5.5	160	3.3	18.2	24.5	5.5	6.4	16.3	14.7	21.0	14.1	2.5	2.3
5.5	170	3.1	18.2	24.5	5.9	6.8	17.1	15.8	21.0	14.1	2.5	2.3
5.5	180	3.0	18.2	24.5	6.1	7.2	17.5	16.4	21.0	14.1	2.4	2.3
5.5	190	2.8	18.2	24.5	6.5	7.6	18.5	17.7	21.0	14.1	2.4	2.3
5.5	200	2.7	18.2	24.5	6.7	8.0	19.0	18.6	21.0	14.1	2.4	2.3
5.5	120	3.1	12.5	24.5	4.0	5.3	13.0	12.7	Mains - rectangular pillars		2.5	2.4
5.5	120	3.6	14.3	24.5	4.0	5.1	12.8	11.8	Mains - rectangular pillars		2.5	2.3
5.5	150	3.1	15.4	24.5	5.0	6.2	15.1	14.4	Mains - rectangular pillars		2.4	2.3
5.5	150	3.6	18.8	24.5	5.2	5.9	15.6	13.6	Mains - rectangular pillars		2.6	2.3
5.5	180	3.1	19.2	24.5	6.2	7.1	17.8	16.3	Mains - rectangular pillars		2.5	2.3
5.5	180	3.6	24.5	24.5	6.8	6.8	19.2	15.9	Mains - square pillars		2.8	2.4
5.5	200	3.1	21.5	24.5	6.9	7.7	19.5	17.5	Mains - rectangular pillars		2.5	2.3
5.5	200	3.4	24.5	24.5	7.2	7.5	20.1	17.1	Mains - square pillars		2.7	2.3

The following comments are made regarding these results:

i) A uniform roadway and stub width of 5.5m is assumed. In practice, it is likely that reduced stub widths of ≤ 5.2m would promote improved stub roof stability at depths of >170m.

ii) The table is structured in a manner that illustrates the effect on pillar width of attempting to maximise mining height, as well as the effect on mining height of attempting to maintain a constant stub interval of 21m.

iii) At depths of ≤ 160m, it would be possible to increase the current design drivage height of 3.2m.

iv) A maximum overall height of 3.8m is achievable at a depth of 140m.

v) A maximum (solid) pillar length of 24.5m is stipulated, consistent with the Myuna practice. This facilitates a consistent design stub length of 14m, again as per Myuna.

vi) The stub interval is the solid dimension between stubs, whereas pillar width is the minimum solid (plan) dimension (i.e. the perpendicular distance between adjacent stubs, allowing for the 60° stub angle).

vii) Pillar stresses are low (≤ 8MPa), consistent with the design criteria.

viii) Bieniawski Stability Factors range from 2.4 to 2.8, consistent with the design criteria.

ix) UNSW Factors of Safety range narrowly from 2.3 to 2.4, again consistent with the design criteria.

3.2.2 Comparison with Previous Design Approaches from Adjacent Mines

Seedsman (2011) previously assessed the performance of workings at Mannering Colliery designed to achieve a maximum of 20mm of subsidence. The standard Mannering layout of that time involved:

- first workings only on 30m centres,
- a nominal roadway width of 5.5m,
- a height of 2.9m and
- depths of around 180m to 190m.

Seedsman (2011) concluded that in a single seam only situation, such a layout would continue to result in around 8-15mm of surface subsidence in the long-term. This conclusion relates to pillars with Stability Factors of around 3.2 and Factors of Safety of around 3.0, which is higher than the minimum values adopted herein. However, the database indicates that the proposed criteria would maintain the design requirement of slightly greater (i.e. ≤ 20mm) of subsidence.

In designing the “Zone A” pillars for a maximum of 20mm of subsidence at Myuna Colliery to the north and west, **Seedsman (2010)** stipulated a minimum pillar Factor of Safety of 2.11, equivalent to a nominal probability of failure of one panel in a million, according to the power law formulae of **Salamon *et al* (1996)**. As noted in **Section 3.2.1**, the proposed Mannering FoS values range upwards from 2.3. The approach recommended herein is therefore more conservative than the Myuna approach.

It is concluded that the design criteria adopted herein are rational and consistent with ≤ 20mm of subsidence in the long-term.

3.2.3 “Dog-Kennel” Pillar Design

The smaller “dog-kennel” pillars at the start of each successive run-out should be designed according to **Table 2**, where the stub interval is the solid dimension defined in **Figure 11** for a worked example. This will ensure that the design criteria are met across the potential depth and mining height range. Note that the solid stub intervals result in minimum plan dimensions that are consistent with the regulatory “10m or one-tenth of the depth, whichever is the greater” rule.

Table 2: Solid Stub Interval Dimensions for “Dog Kennel” Pillars

Depth (m)	Mining Height (m)			
	2.8	**3.2**	**3.6**	**4.0**
100	6.4	6.8	8.1	9.4
120	8.4	8.9	10.5	12.4
140	10.4	11.1	13.4	15.9
160	12.4	13.9	16.9	20.4
180	14.4	16.5	20.3	28.2
200	16.4	19.1	26.2	39.9
220	18.4	21.4	35.9	N/A

3.2.4 Benched Pillar Option

An option under consideration is the potential to adopt a benched profile during bottom coaling, an approach that can assist with rib control during mining. The concept is shown schematically in **Figure 10** and the design outcomes are summarised in **Table 3**.

Table 3: Benched Pillar Design for <20mm of Subsidence

Roadway Width (m)	Depth (m)	Pillar							Stub		Bieniawski Stability Factor	Pillar FoS (Salamon)	Bottom Coal (m)
		Height (m)	Width (m)	Length (m)	w/h Ratio	Stress	Strength		Interval (m)	Length (m)			
							Bieniawski	Salamon					
5.3	140	4.05	19.4	24.7	4.8	5.4	14.7	12.5	22.4	14.3	2.7	2.3	1.4
5.3	160	4.05	23.8	24.7	5.9	5.9	17.1	13.6	27.5	14.3	2.9	2.3	1.4
5.3	180	3.70	24.4	24.7	6.6	6.7	18.7	15.3	28.2	14.3	2.8	2.3	1.0
5.4	200	3.40	24.6	24.6	7.2	7.4	20.1	17.2	28.4	14.2	2.7	2.3	0.7
5.3	140	3.90	18.2	24.7	4.7	5.5	14.4	12.5	21.0	14.3	2.6	2.3	1.2
5.4	150	3.60	18.2	24.6	5.1	5.9	15.3	13.4	21.0	14.2	2.6	2.3	0.9
5.4	160	3.30	18.2	24.6	5.5	6.3	16.3	14.7	21.0	14.2	2.6	2.3	0.6
5.5	180	3.00	18.2	24.5	6.1	7.2	17.5	16.4	21.0	14.1	2.4	2.3	0.2
5.5	200	2.80	19.0	24.5	6.8	7.9	19.1	18.3	21.9	14.1	2.4	2.3	0.0

The following comments are made regarding these results:

i) The design roadway width is the weighted average of the 5.5m and 4.9m wide sections.

ii) Similarly, the design height is the weighted average for the benched profile, assuming a constant 2.8m high first pass.

iii) At depths of up to 160m, the design height of 4.05m facilitates the extraction of up to 1.4m of bottoms, as per **Figure 12**.

iv) At greater depths, the progressively reducing design height entails a rapid reduction in the thickness of bottom coal minable.

v) At depths of >180m, final design heights of ≤ 3.4m may not warrant the benched profile.

vi) The table also illustrates the effect on average height and the available bottom coal height of attempting to maintain a constant stub solid interval of 21m. This approach is considered practicable at depths of up to 160m.

vii) Average pillar stresses are below 8MPa, consistent with the design criteria.

viii) Bieniawski Stability Factor ranges from 2.4 to 2.9, consistent with the design criteria.

ix) UNSW Factors of Safety are constant at 2.3, consistent with the design criteria.

3.2.5 Alternative Main Headings Options

A further option under consideration is to reduce the main headings roadway width and height, with the main aim of increasing the drivage rate and overall mine productivity. Obviously, such reductions would also tend to enhance roadway stability. **Table 4** illustrates the design results for a main headings roadway width of 4.8m, at two potential design heights, 2.8m and 3.1m. An attempt has been made to maintain the pillar length constant, at 30m centres.

Table 4: Main Headings Pillar Design for a Roadway Width of 4.8m

Roadway Width (m)	Depth (m)	Pillar							Bieniawski Stability Factor	Pillar FoS (Salamon)
		Height (m)	Width (m)	Length (m)	w/h Ratio	Stress	Strength			
							Bieniawski	Salamon		
4.8	140	2.8	11.7	25.2	4.2	5.9	13.3	13.5	2.3	2.3
4.8	170	2.8	14.6	25.2	5.2	6.7	15.6	15.4	2.3	2.3
4.8	200	2.8	17.6	25.2	6.3	7.6	18.0	17.5	2.4	2.3
4.8	140	3.1	13.1	25.2	4.2	5.7	13.4	13.1	2.4	2.3
4.8	170	3.1	16.7	25.2	5.4	6.5	16.0	15.0	2.5	2.3
4.8	200	3.1	20.3	25.2	6.5	7.4	18.6	17.0	2.5	2.3

The following comments are made regarding these results:

i) Pillar width reduces significantly with reducing depth.

ii) In places, the required pillar width falls below the “1/10 of depth rule” and it would probably be expedient to simply adopt the latter in those cases.

iii) Average pillar stresses are below 8MPa, consistent with the design criteria.

iv) Bieniawski Stability Factor ranges from 2.3 to 2.5, consistent with the design criteria.

v) UNSW Factors of Safety are constant at 2.3, consistent with the design criteria.

4.0 CONCLUDING REMARKS

This report has addressed pillar design requirements to achieve ≤ 20mm of subsidence across the depth range relevant to the area of interest at Mannering Colliery.

The proposed design criteria are considered conservative and there would be the potential for some optimisation, based on:

- additional subsidence monitoring data from areas of specific interest (e.g. foreshore areas) and
- a programme of floor coring, to better define the thickness and properties of the claystone within the first 3m of floor.

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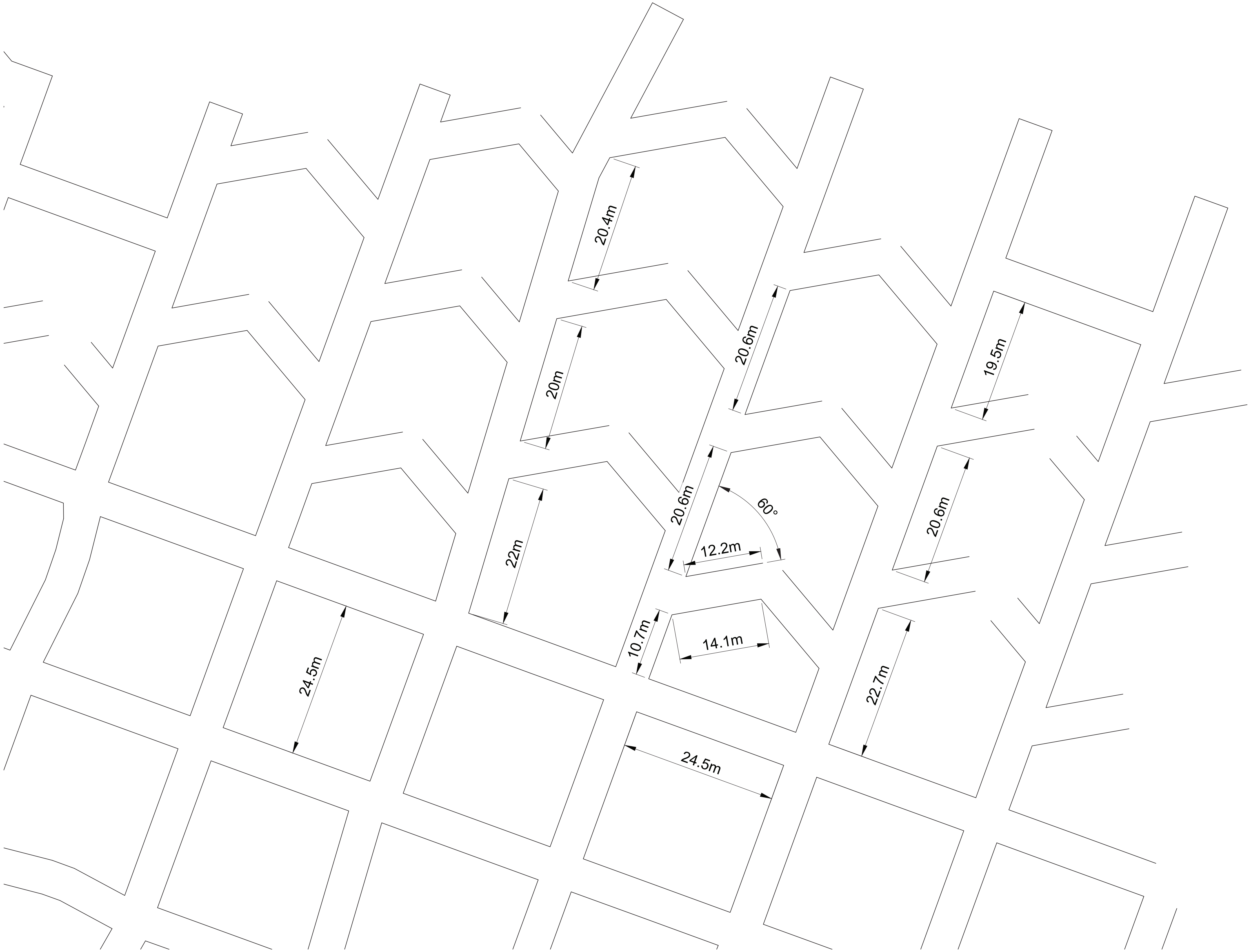
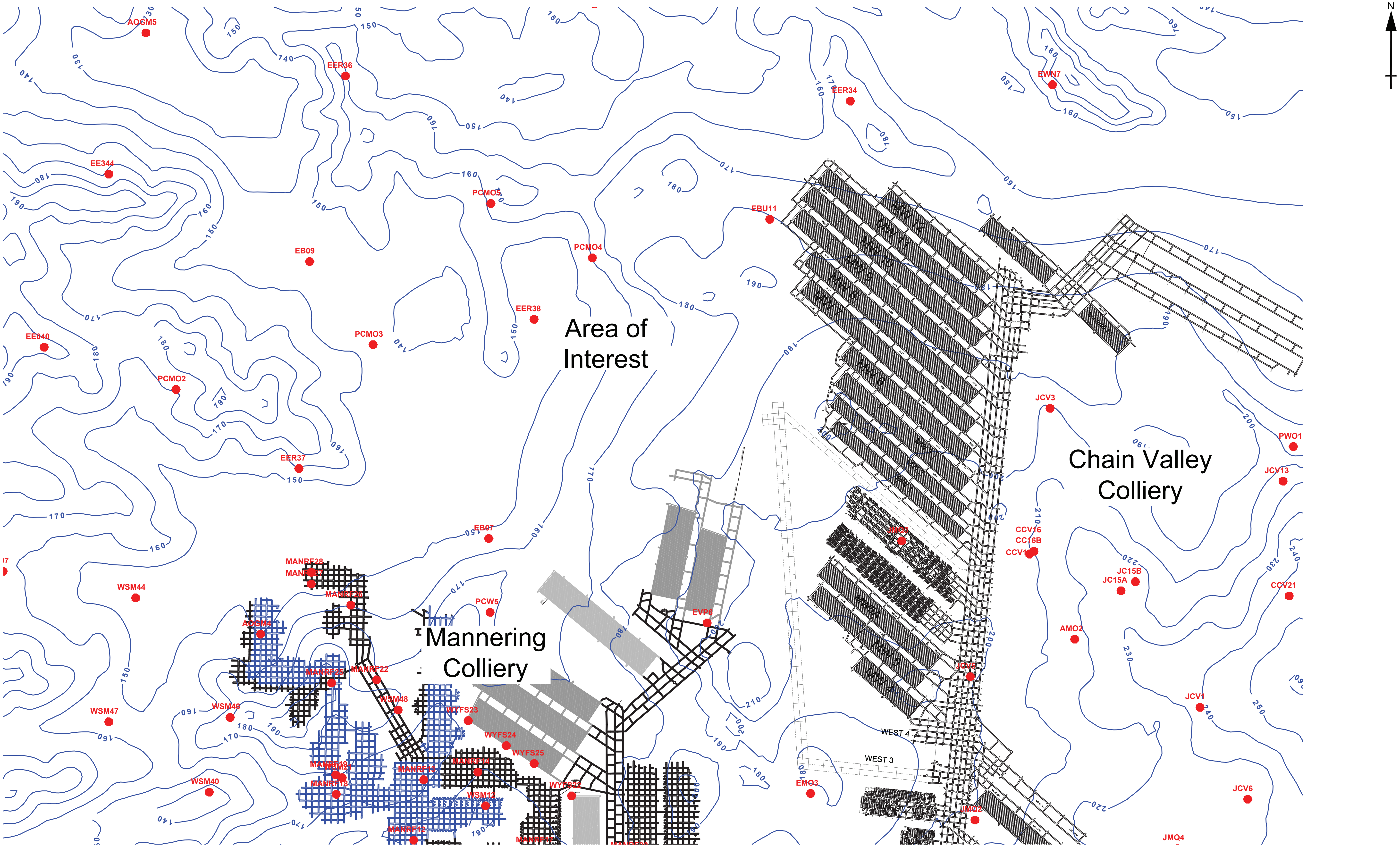


Engineer:	D. Hill	**Client:**	Chain Valley Colliery		
Drawn:	I. Saliamon	**Title:**	Schematic Showing Typical Herringbone Pillar Layout, as Applied at Myuna Colliery		
Date:	01.04.19				
STRATA²		**Ref:**	CHV-012	**Revision No:**	0
		Scale:	NTS	**Figure No:**	1



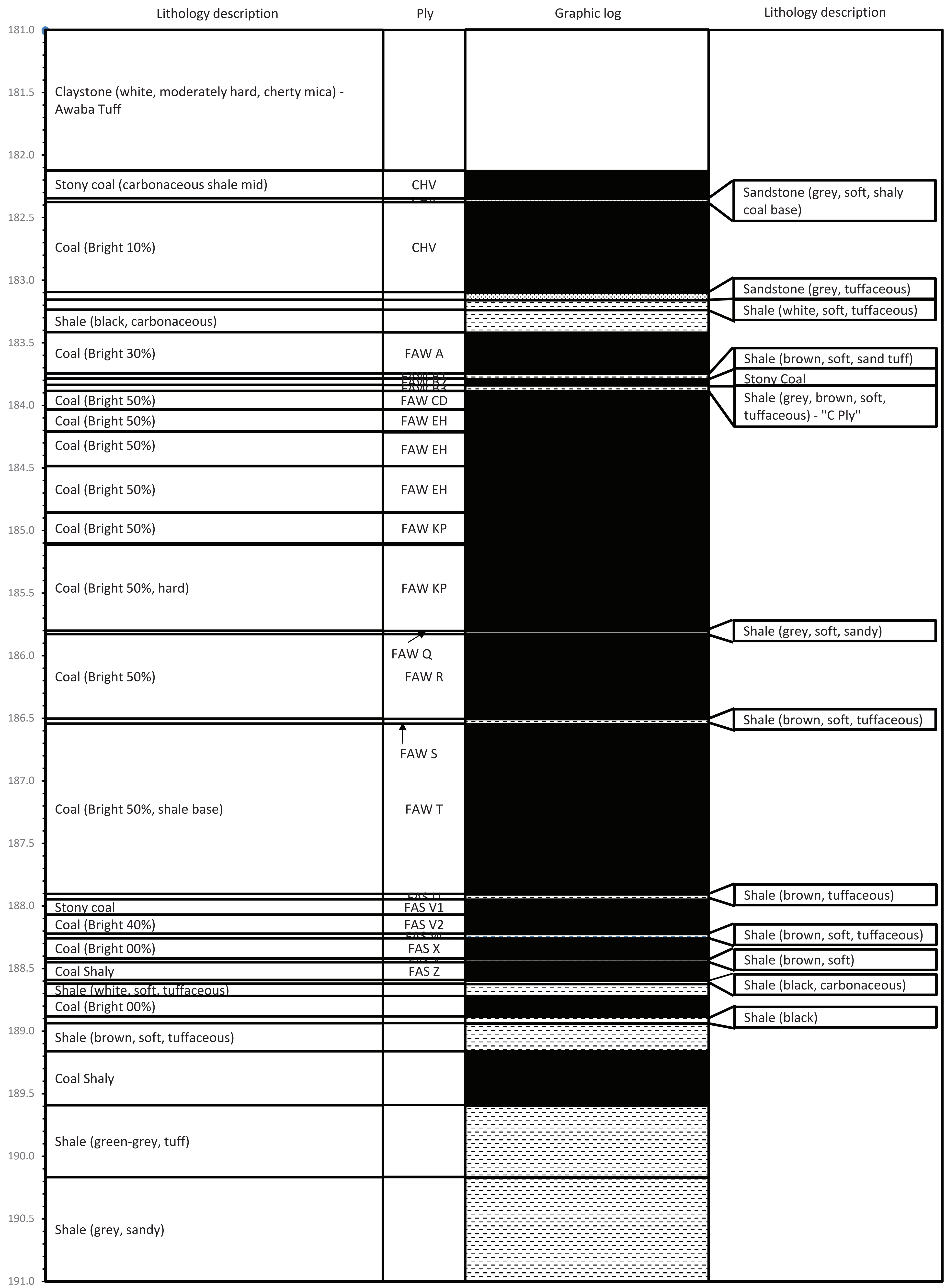
Key:

- Depth of Cover (m)
- EER38 - Borehole

Engineer:	D. Hill	**Client:**	Mannering Colliery
Drawn:	I. Saliamon	**Title:**	Mine Plan Showing Depth of Cover of Fassifern Seam and Borehole Locations
Date:	09.04.19		

STRATA²

Ref:	CHV-012	**Revision No:**	0
Scale:	NTS	**Figure No:**	2



Engineer:	D. Hill	**Client:**	Chain Valley Colliery		
Drawn:	R. de Laubadere	**Title:**	EBU11 Lithology Log - Fassifern Seam Horizon		
Date:	09.04.2019				
STRATA2		**Ref:**	CHV-012	**Revision No:**	0
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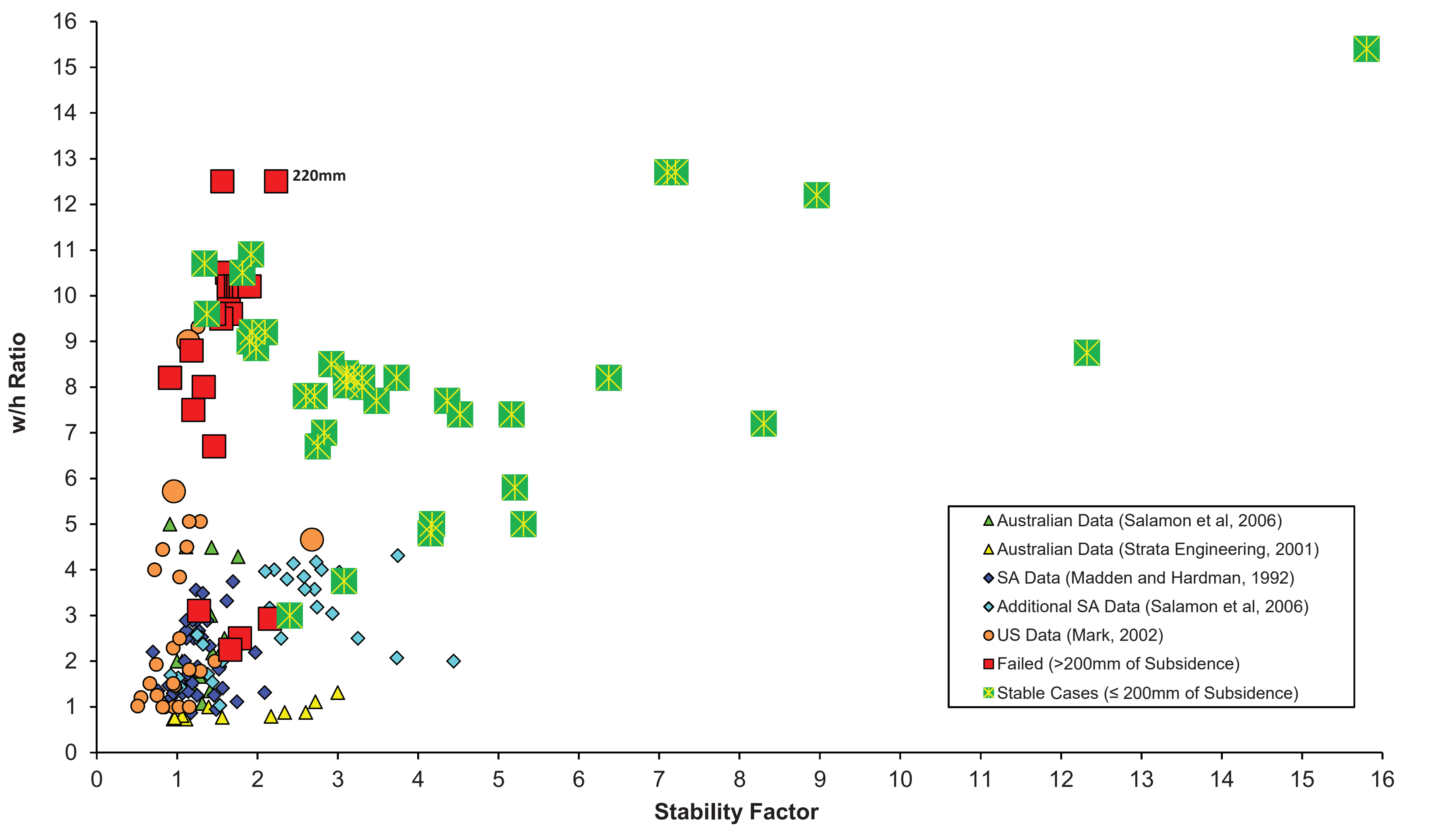
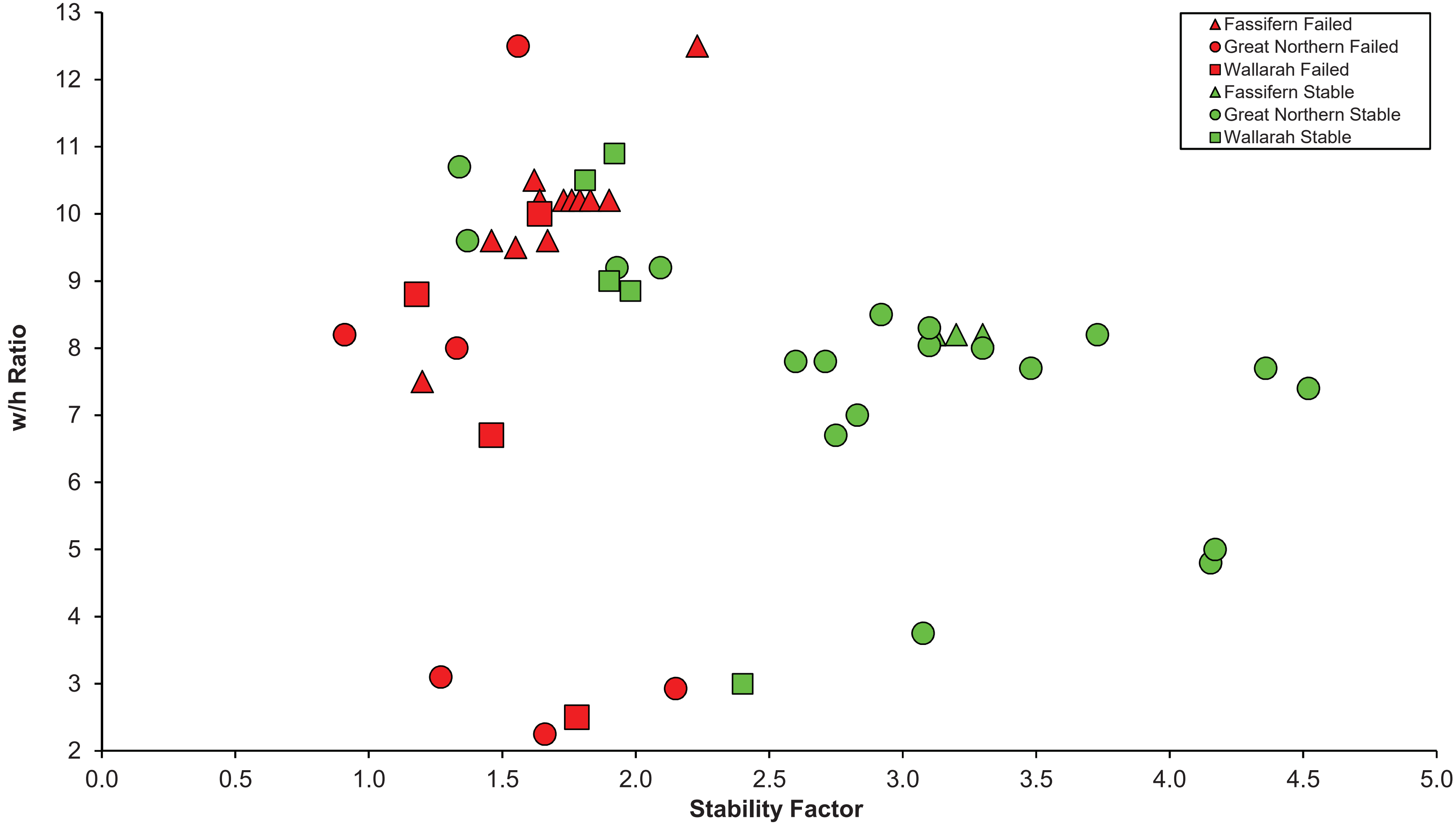
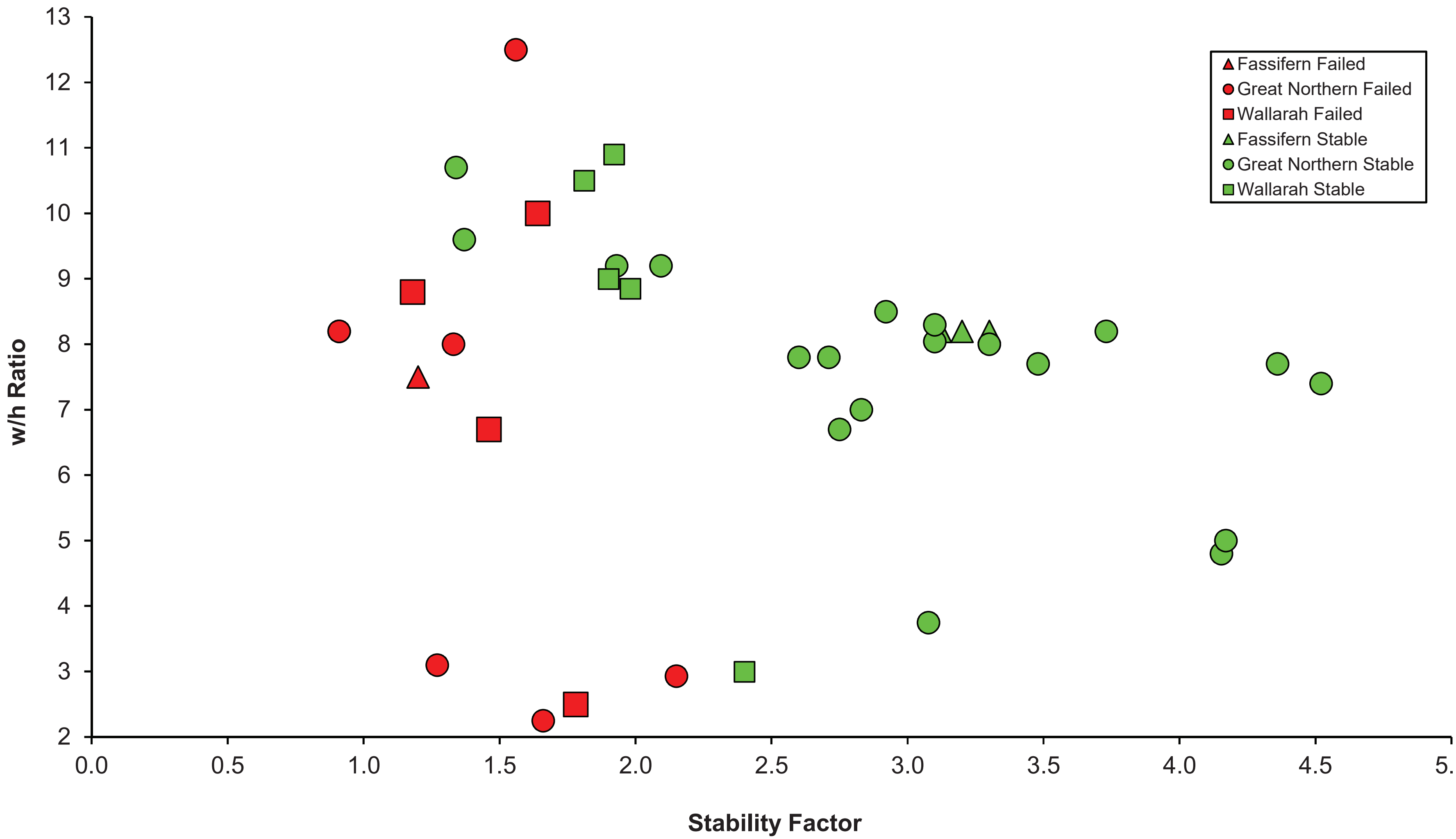


Engineer:	D. Hill	**Client:**	Chain Valley Colliery
Drawn:	D. Hill	**Title:**	Failed Coal Pillar Database - Bieniawki Stability Factor versus Pillar Width to Height Ratio; including Stable and Failed Weak Floor Cases from the Lake Macquarie Area
Date:	15.04.2019		
STRATA²		**Ref:**	CHV-012
		Revision No:	0
		Scale:	N/A
		Figure No:	4



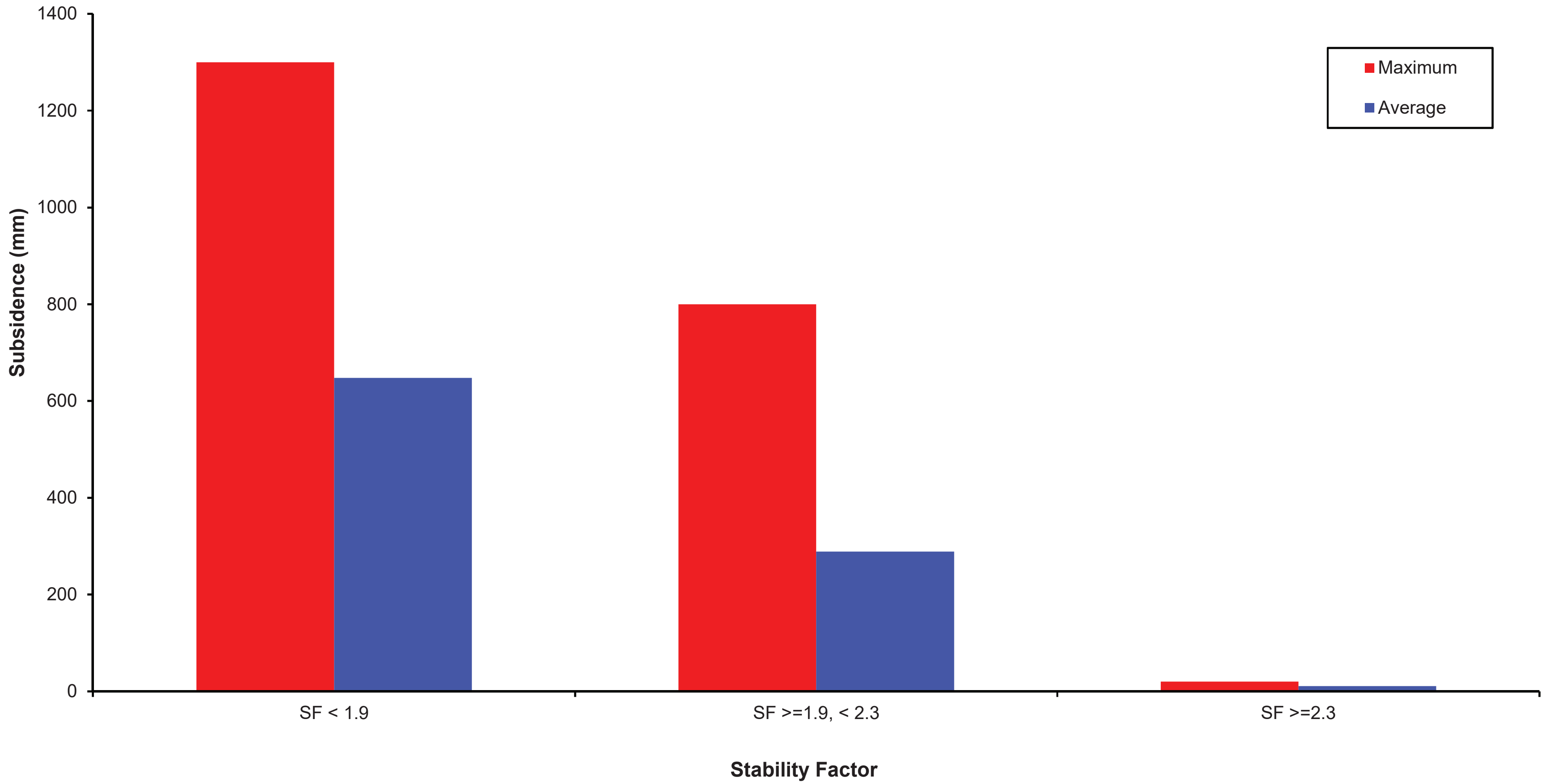
Note: Cases with Stability Factors >5 excluded (practically irrelevant)

Engineer:	D. Hill	**Client:**	Chain Valley Colliery
Drawn:	D. Hill	**Title:**	Stability Factor versus w/h Ratio: Stable and Failed Weak Floor Cases from the Lake Macquarie Area on a Seam-Specific Basis
Date:	15.04.2019		
STRATA²		**Ref:**	CHV-012
		Revision No:	0
		Scale:	N/A
		Figure No:	5



Note: Cases with Stability Factors >5 excluded (practically irrelevant)

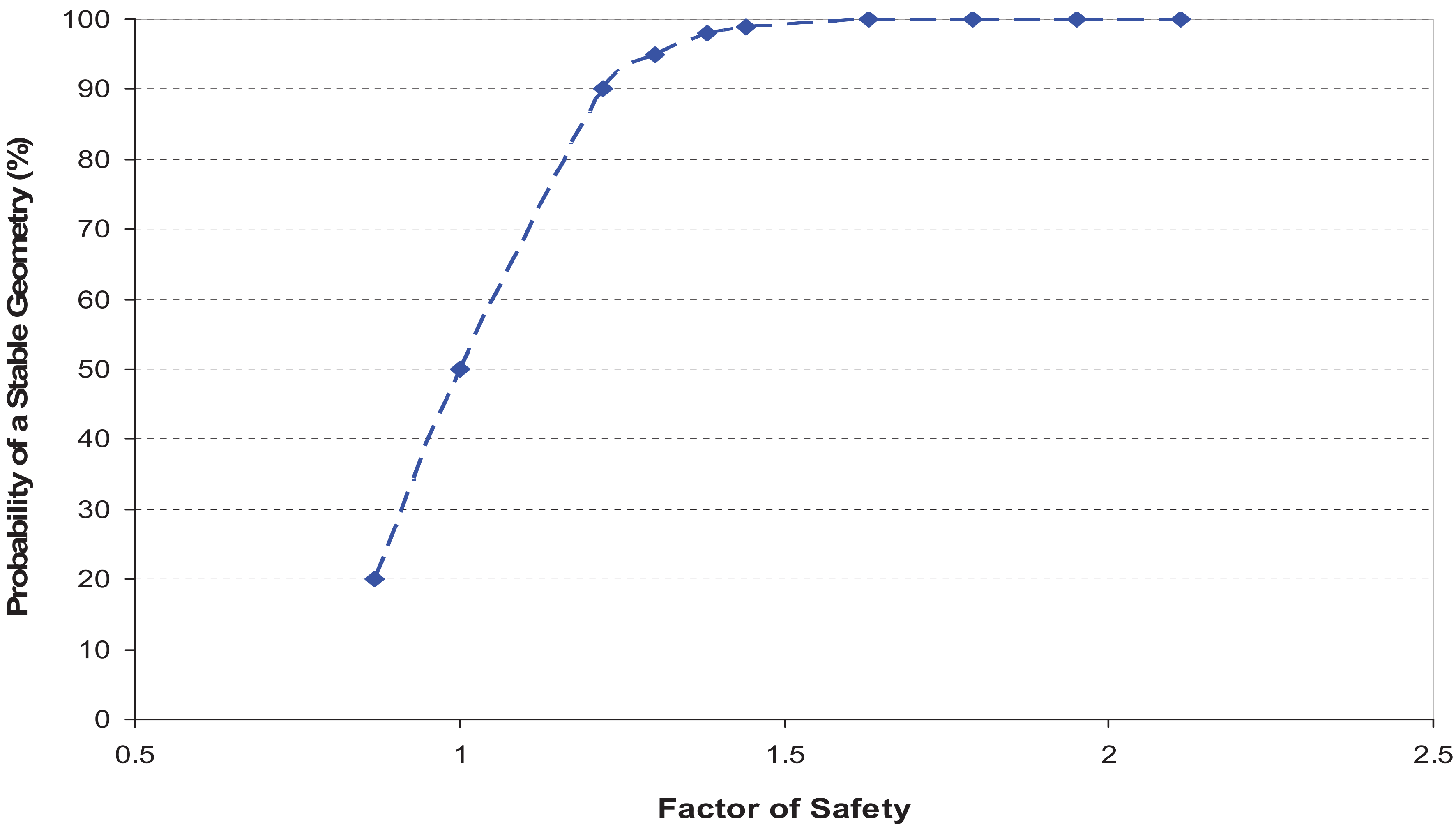
Engineer:	D. Hill	**Client:**	Chain Valley Colliery	
Drawn:	D. Hill	**Title:**	Stability Factor versus w/h Ratio: Stable and Failed Weak Floor Cases from the Lake Macquarie Area on a Seam-Specific Basis, excluding the CVC Miniwalls	
Date:	15.04.2019			
STRATA²		**Ref:**	CHV-012	**Revision No:** 0
		Scale:	N/A	**Figure No:** 6



Engineer:	D. Hill	**Client:**	Chain Valley Colliery
Drawn:	D. Hill	**Title:**	Lake Macquarie Case Histories - Subsidence versus Bieniawski Stability Factor
Date:	15.04.2019		

STRATA²

Ref:	CHV-012	**Revision No:**	0
Scale:	N/A	**Figure No:**	7



Engineer:	D. Hill	Client:	Chain Valley Colliery
Drawn:	D. Hill	Title:	Salamon Factor of Safety versus Probability of Stability
Date:	15.04.2019		
STRATA2		Ref:	CHV-012
		Revision No:	0
		Scale:	N/A
		Figure No:	8

Figure 9a: Lake Macquarie Failed and Stable Cases Database - Factor of Safety versus Pillar w/h Ratio

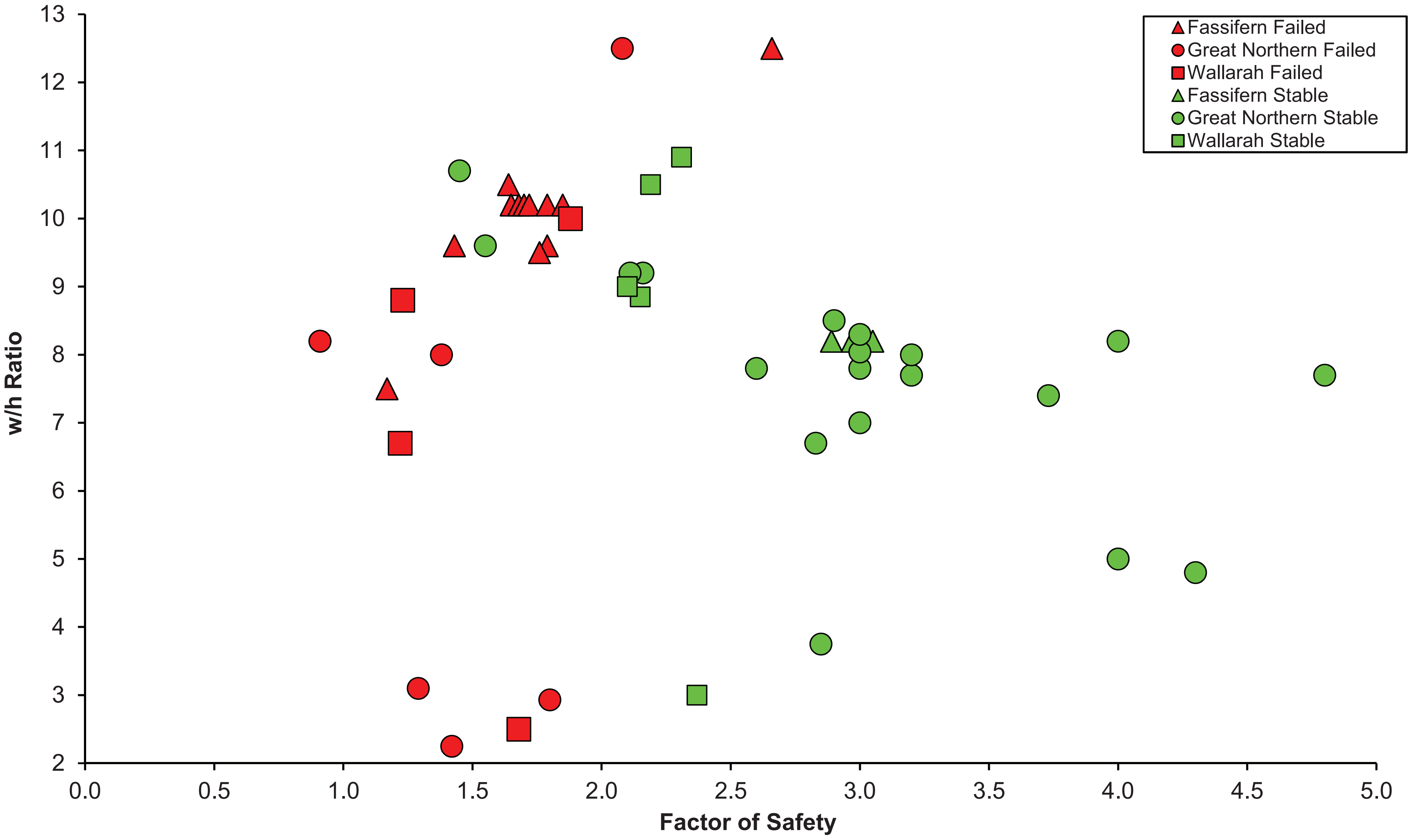
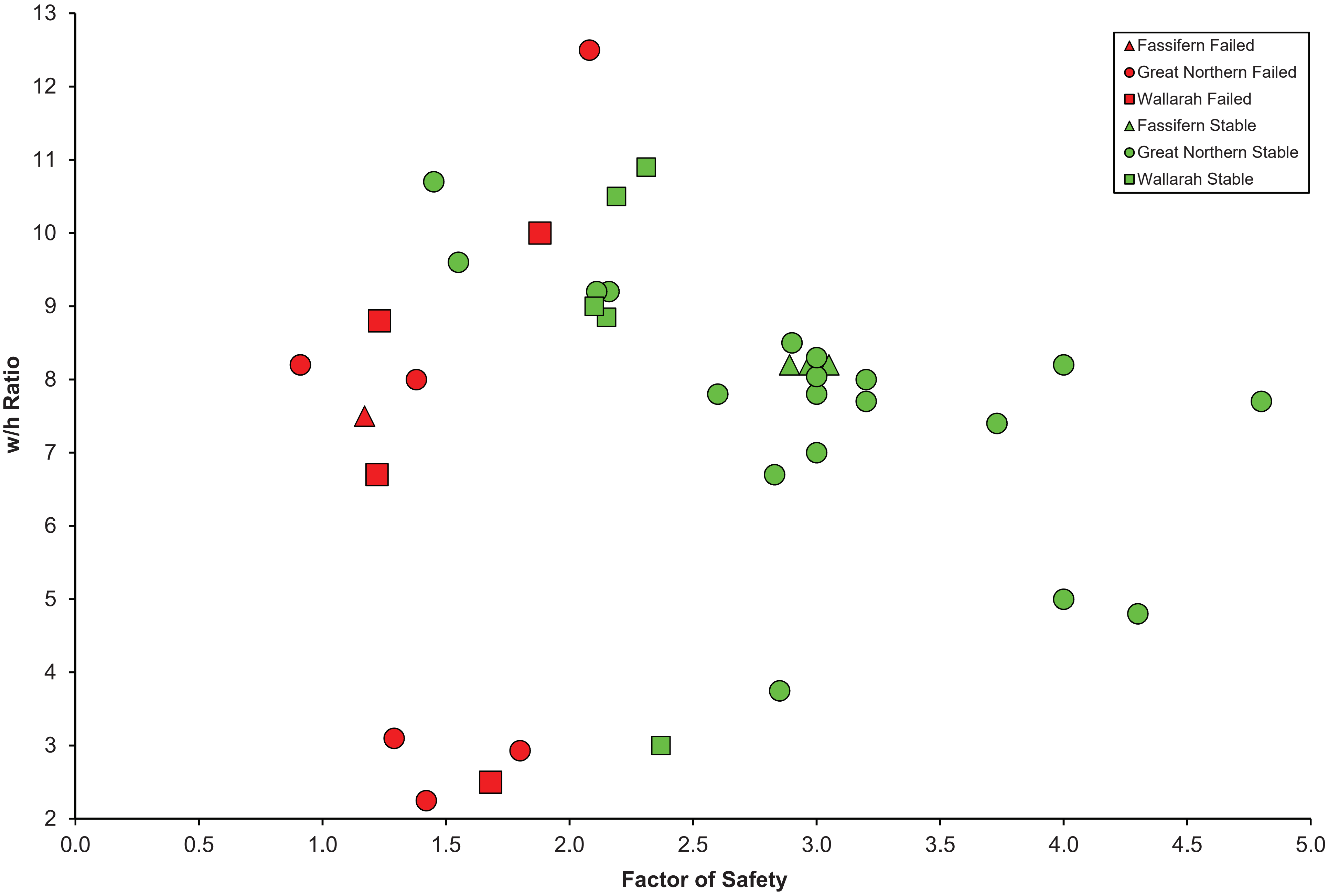
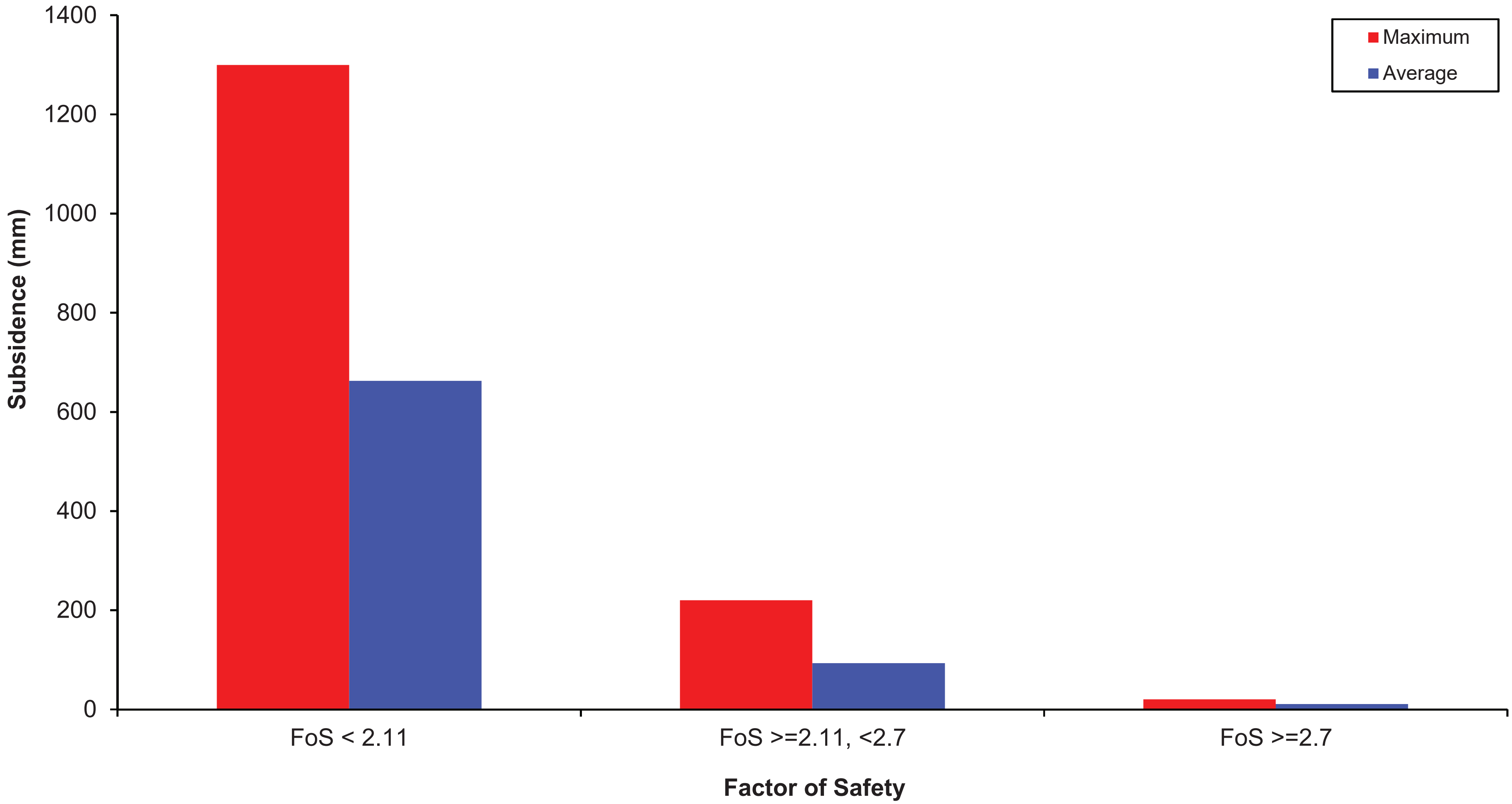


Figure 9b: Lake Macquarie Failed and Stable Cases Database - Factor of Safety versus Pillar w/h Ratio; CVC Miniwalls Excluded



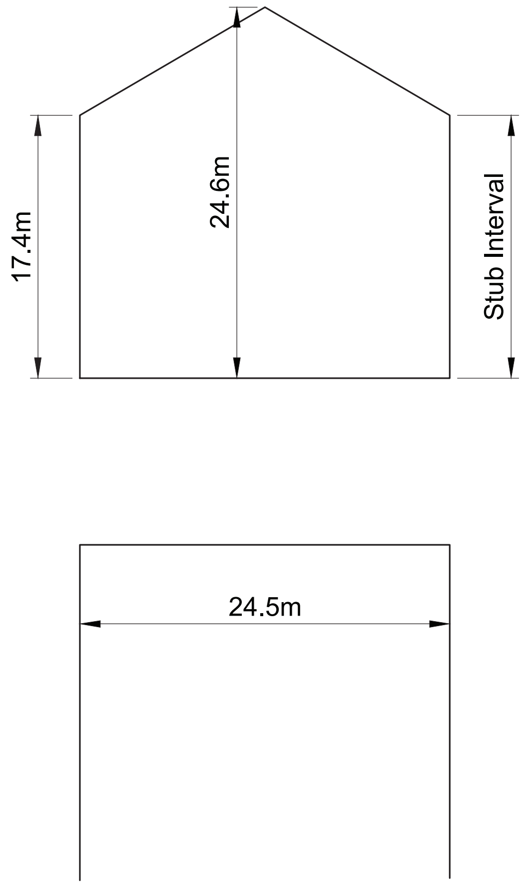
Engineer:	D. Hill	**Client:**	Chain Valley Colliery		
Drawn:	D. Hill	**Title:**	Lake Macquarie Database reproduced using Salamon Factor of Safety		
Date:	15.04.2019				
STRATA²		**Ref:**	CHV-012	**Revision No:**	0
		Scale:	N/A	**Figure No:**	9a/b



Engineer:	D. Hill	**Client:**	Chain Valley Colliery
Drawn:	D. Hill	**Title:**	Lake Macquarie Case Histories - Subsidence versus Salamon Factor of Safety
Date:	15.04.2019		

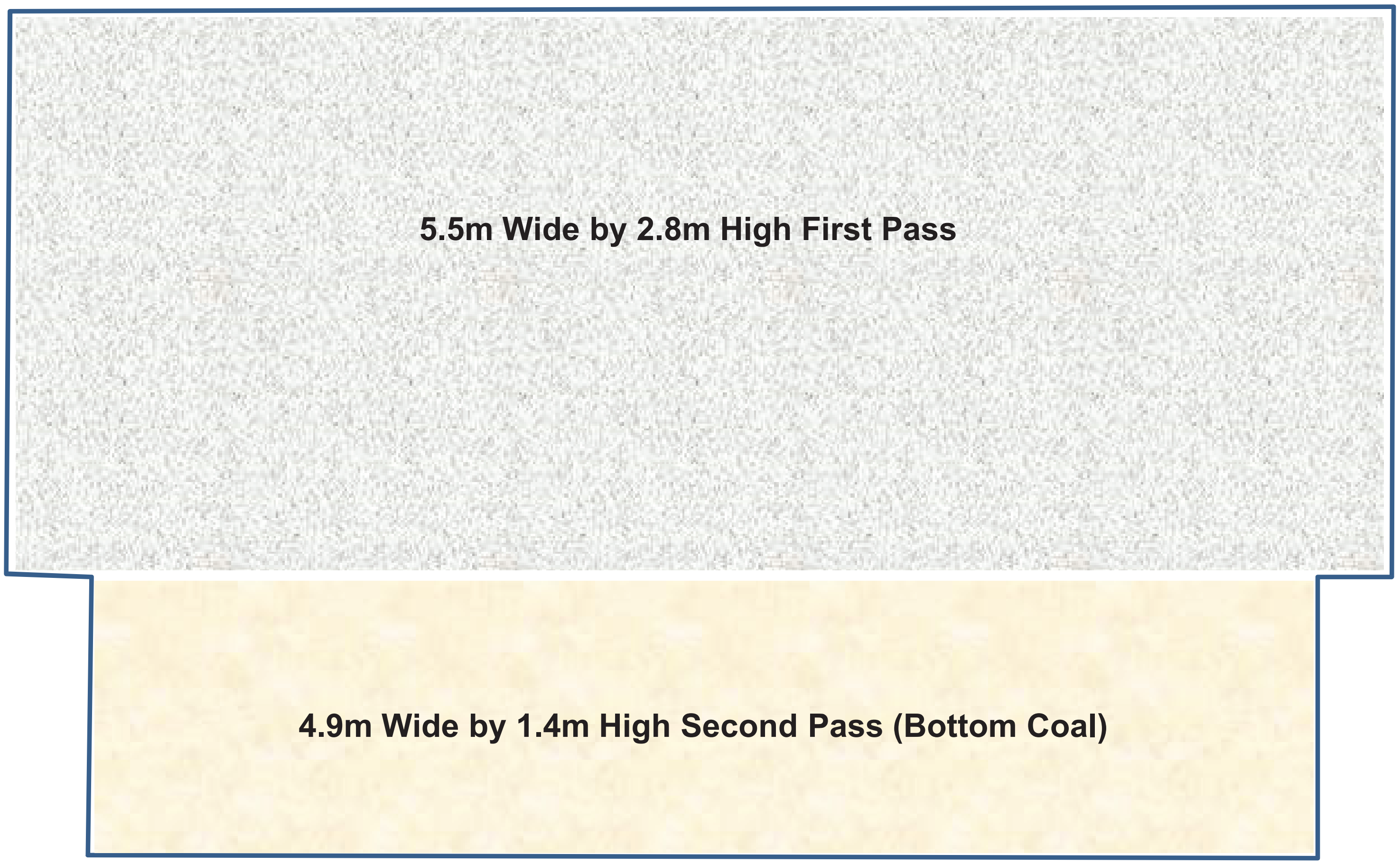
STRATA²

Ref:	CHV-012	**Revision No:**	0
Scale:	N/A	**Figure No:**	10



Average Pillar Width
= (17.4+24.6) / 2
= 21m

Engineer:	D. Hill	**Client:**	Mannering Colliery		
Drawn:	I. Saliamon	**Title:**	Example of Configuration of "Dog-Kennel" Pillar (Plan Dimensions)		
Date:	09.04.19				
STRATA²		**Ref:**	CHV-012	**Revision No:**	0
		Scale:	NTS	**Figure No:**	11



Average Roadway Width = 5.3m
Average Roadway Height = 4.05m

Engineer:	D. Hill	**Client:**	Chain Valley Colliery
Drawn:	D. Hill	**Title:**	Benched Roadway Profile
Date:	15.04.2019		

STRATA²

Ref:	CHV-012	**Revision No:**	0
Scale:	N/A	**Figure No:**	12

Appendix A: Hill (2010)

Long-Term Stability of Bord and Pillar Workings

David Hill, Principal, Strata Engineering (Australia) Pty Ltd

ABSTRACT

In Australia, large surface areas are permanently supported on coal pillars, both in extensive old workings and current drivages in active operations. The continued growth of civil infrastructure is resulting in more surface development above old mines and an increased need for underground development beneath existing, potentially sensitive, surface structures and features. The result is a greater likelihood of conflict between miners, developers and regulatory bodies.

However, over the last fifty years there has been significant improvement in the general level of understanding of bord (room) and pillar behaviour, both in Australia and overseas. This paper examines some of the design issues to be considered when undermining surface structures.

The Factor of Safety (FoS) methodology widely employed for the assessment of pillar stability is reviewed, including the key geometrical, geological and statistical concepts associated with the probability of coal pillar failure. Relevant Australian and international experiences are examined and significant parameters isolated. Common concerns are addressed in the context of practical experience, utilising a risk management approach. Tools for assessing the long-term stability of bord and pillar workings are put forward, along with criteria for arriving at rational design outcomes.

INTRODUCTION

Pillars serve two main roles: promoting the serviceability of underground roadways adjacent to areas of extraction (eg longwall chain pillars) and maintaining long-term regional stability (eg main heading pillars). These pillars are an operational constraint determining the amount of roadway development required. As such, the general need is to minimise pillar widths wherever possible, noting that overly-large coal pillars do not result in significant improvements in serviceability or enhanced regional stability. On the other hand, inadequately-sized pillars can cause major operational difficulties and large-scale rock mass instability, which may be manifested as discernible surface ground movement (i.e. subsidence), with impacts on other stakeholders.

Over 200 years of underground coal mining in Australia has resulted in large areas of ground supported on coal pillars, including very extensive old workings in generally inaccessible redundant mines and current drivages in active mining operations. Also, the continuing growth in the size and complexity of civil infrastructure is resulting in more surface development above old bord and pillar mines, as well as the increasing need for mine development beneath existing, frequently sensitive, surface structures or features. The result is greater potential for conflict between coal miners, developers and regulatory bodies, with the potential for sterilisation of underground resources and / or escalating surface development and infrastructure protection costs.

Coal pillar sizes in New South Wales (NSW) are regulated primarily by Clause 88 of the NSW Coal Mine Health and Safety Regulation (CMHSR) 2006, which contains a long-standing provision that the plan dimension of a coal pillar should be not less than one-tenth of the cover depth or 10 m, whichever is the greater. Given a representative maximum drivage height of around 3.5m and a prescribed maximum bord width of 5.5m in NSW, this is akin to specifying a Factor of Safety (FoS) of ≥ 1.6, assuming full tributary area loading and based on the Australian coal pillar strength formulae given in **Salamon *et al*, 1996**, as well as a minimum width to height (w/h) ratio of 2.9. Clause 32 of the CMHSR 2006 goes further in addressing the content of strata failure management plans, requiring a description of any coal pillars with a width to height ratio of 4:1 or less, together with any special provisions made for them.

EMPIRICAL PILLAR DESIGN METHODOLOGIES

Empirically-based coal pillar design techniques are in widespread use in Australia, South Africa and the US. The underpinning databases of experience have guided the derivation of the various strength formulae and the selection of appropriate Factors of Safety for specific circumstances. These databases also offer considerable insight with regard to the mechanics of pillar behaviour.

For example, it is widely appreciated that pillar strength increases with pillar width (w) and decreases with height (h), such that pillar w/h ratio is a commonly quoted key parameter, as reflected in the comments regarding the NSW regulatory framework. **Figure 1** presents a combined database of bord and pillar panel failures with respect to w/h ratio. The US data (**Mark, Personal Communication, 2002**) is a sub-set taken from the ARMPS database that relates to first workings only (i.e. ARMPS Loading Condition 1); failure data related to secondary extraction was deliberately excluded. The exclusion of failures associated with abutment loading from adjacent areas is intended to be consistent with the Australian and South African data, which are taken from **Salamon *et al*, 1996** and **Salamon *et al*, 2006** respectively. It is apparent from the figure that in all three countries there is a concentration of failures at w/h ratios of ≤ 2, noting that 2.0 is the median w/h value for the 124 failed cases and the median values for the individual countries vary only between 1.9 (USA), 2.0 (S. Africa) and 2.1 (Australia). Also, 95% of the failed cases involve w/h ratios of ≤ 5 and the maximum w/h ratio of a failed case is 9.32.

Considering the South African and US data in more detail, **Figures 2** and **3** illustrate the respective cumulative frequency distributions of the failed cases. Prominent in the South African data, **Figure 2**, is the slope change at a w/h ratio of 1.6; 38% of the 77 failures involve w/h ratios of 0.87 to 1.56. A similar pattern is seen in **Figure 3** for the US data, with a distinct change in slope at a w/h ratio of between 2 and 2.5 and 37% of the data falling within a w/h ratio range of 1.00 to 1.52.

These distributions for the failed cases should be seen in the context of the equivalent distributions for the recorded intact cases, which are presented in **Figures 4** and **5** for South Africa and the US respectively. The intact cases in the South African database cover a w/h ratio range of 1.00 to 15.45, with a median value of 3.67, see **Figure 4**. Although there is a concentration of South African data in a w/h ratio range of 2.6 to 5.2, there are significant numbers of intact cases at low w/h ratios; for example, there are 13 intact cases (i.e. 5% of the total) at w/h ratios of ≤ 1.75. The intact cases for the US mainly involve higher w/h ratios, with a concentration in the 4.5 to 8.4 range, see **Figure 5**; this partly reflects a lower average mining height of 2.2m, in comparison to both Australia and South Africa (i.e. around 3m). There are few US intact cases at w/h ratios of ≤ 3 (i.e. <4% of the total) and the minimum value for an intact case is 1.52 (noting again that 37% of the US failed cases involve w/h ratios of ≤ 1.52).

The associated ranges of pillar widths for the failed and intact cases are illustrated in **Figures 6** and **7** respectively, for all three databases.

With regard to the failed cases, **Figure 6**:

- 21.8% involve minimum pillar widths of ≤ 4m,
- the median value is 6.4m,
- 75% of the failed cases involve pillar widths of ≤ 10m, the NSW regulatory minimum and
- 95% of the failures involve pillar widths of ≤ 16.5m.

With regard to the intact cases, **Figure 7**:

- only 4.5% involve pillar widths of ≤ 6m,
- 75% involve minimum pillar widths of >9m,
- the median value is 12.0m and
- 95% of the intact cases involve pillar widths of ≤ 21.3m.

The median pillar widths of 6.4m for the failures and 12.0m for the intact cases reflect a concentration of data points at these geometries, which for the South African data in turn reflects a widespread industry shift from driving on 40’ (12.2m) to 60’ (18.3m) centres following the Coalbrook disaster.

The concentration of failed cases at small pillar widths is the most prominent feature of the data. **Salamon and Oravecz 1976** urged caution in the case of low pillar widths, pointing out that the potential discrepancy between ‘nominal’ and ‘as built’ pillar dimensions increases as the design dimensions get smaller. They concluded that:

“It is therefore recommended that special care should be taken if small pillars are used and, also, that no pillar width of less than 3 metres should be used. Moreover, the safety factor of pillars between 3.0 and 4.5m in width should be at least 1.7”.

It is often stated that caution should be adopted in applying the results of an empirical study outside of the range of the underpinning data. In this regard, the data ranges for the three countries are summarised in **Tables 1** to **3** below.

Table 1: Australian Data

Parameter	Failed	Intact
Depth (m)	58 – 336	22 – 510
Mining Height (m)	1.8 – 9.2	1.0 – 6.0
Minimum Pillar Width (m)	3.5 – 25.0	2.0 – 32.0
Bord Width (m)	5.5 – 15.0	5.0 – 15.0
Percentage Extraction (%)	42 – 84	30 – 89
w/h Ratio	1.1 – 8.2	1.7 – 11.2

Table 2: South African Data

Parameter	Failed	Intact
Depth (m)	19 – 205	13 – 254
Mining Height (m)	1.3 – 6.2	1.1 – 6.4
Minimum Pillar Width (m)	3.2 – 17.0	4.3 – 35.0
Bord Width (m)	4.8 – 8.5	4.9 – 10.0
Percentage Extraction (%)	44 – 91	23 – 89
w/h Ratio	0.9 – 4.3	1.0 – 15.4

Table 3: US Data

Parameter	Failed	Intact
Depth (m)	53 – 396	61 – 610
Mining Height (m)	0.8 – 5.3	0.8 – 4.0
Minimum Pillar Width (m)	1.5 – 16.5	1.5 – 33.5
Bord Width (m)	5.5 – 11.1	4.3 – 6.1
Percentage Extraction (%)	37 – 89	28 – 89
w/h Ratio	1.0 – 9.3	1.5 – 18.3

The three databases are complimentary in nature. For example, the US data includes five failed cases with w/h ratios of >5, whereas the combined Australian and South African database has just one. Also, the US data includes failed and intact cases with mining heights of <1m, which are not represented in the other data sets, as well as a significant proportion of rectangular and parallelepiped pillars. As previously noted, the South African database contains significant numbers of intact cases at w/h ratios of <1.75.

The US failed cases encompass several failure modes, as shown in **Figure 8** (noting again that the data relates to ARMPS Loading Condition 1). Sudden collapses were characterised by air blasts and are associated with w/h ratios of ≤ 2.5. Progressive (ie slow) pillar failures ("squeezes") occur across the full range of w/h ratios, but become the predominant mode of failure at w/h ratios of >3.5. There is a bump case at a w/h ratio of 5.7 (with an associated depth of 305m) and a single floor-related failure at a w/h ratio of 4.7 (involving a minimum pillar width of 7.1m). Finally, there is one case classed as borderline / marginal, at a w/h ratio of 9.0.

The South African database focuses specifically on cases of pillar collapse resulting in surface subsidence. The original study by **Salamon and Munro (1967)** and that of **Madden and Hardman (1992)** covered most of the South African coalfields and seams. The more recent investigation by **Salamon *et al* (2006)** focussed on deriving seam-specific strength formulae and included more data from seams in the Vaal Basin and Natal, with weaker coal and / or weaker surrounding strata. **Figure 9** illustrates the progressive development of the South African database in terms of the distribution of failed cases versus pillar w/h ratio. It can be seen that the 1992 update by **Madden and Hardman** had minimal impact on the distribution of the data, with the average w/h ratio increasing from just 1.9 to 2.0. However, the addition of data from seams with weaker coal and roof / floor contacts in the 2006 study by **Salamon *et al*** results in a small, but distinct shift in the distribution towards higher w/h ratios; the average increases again, from 2.0 to 2.2 and the maximum w/h ratio for a failed case increases from 3.7 to 4.3.

The Australian database is relatively small and understood to be limited to collapses of the pillar element, excluding failures associated with weak contacts or the bearing capacity of the roof and floor. Although the locations of the individual case histories remain unpublished, it is understood that the intact and failed cases cover a number of coalfields and seams, with a variety of associated adjacent strata. There is nothing in the distributions of the failed and intact cases that would appear to demonstrate an appreciable difference in pillar behaviour, or any other inconsistency, in comparison to the South African and US databases.

The preceding summary of Australian, South African and US experience confirms the role of increasing pillar width and w/h ratio in promoting enhanced pillar stability. Furthermore, back analysis of case histories from elsewhere has also shown that w/h ratio exerts a major influence on coal pillar strength. At low ratios (<3) overloaded pillars tend to fail in a brittle, uncontrolled fashion, whereas at higher ratios (>4) the coal pillars demonstrate a more plastic form of deformation: significant displacement may take place in the form of convergence of the roof and floor, as well as rib spall, but the pillar core remains confined and tends to retain some load carrying ability, such that a ‘squeeze’ occurs.

The w/h ratio effect was illustrated in the laboratory by **Das (1986)** in tests on Indian coals, see **Figure 10** and also by **Madden (1987)** in tests on sandstone discs during the development of the squat pillar formula (Madden used sandstone, as coal samples are more heterogeneous and difficult to prepare), see **Figure 11**. Back analysis of the results of *in situ* tests by **Van Heerden (1975)** suggests that the post-peak modulus of coal pillars becomes zero or positive at w/h ratios of >4.08 (**Madden and van der Merwe, 2002**), obviating the potential for violent failure. **Zipf (2005)** demonstrated the same change in pillar behaviour with increasing w/h ratio using finite difference modelling.

Referring to the South African and US failed cases shown in **Figures 2** and **3**, the disproportionate number of failures at w/h ratios of <2 reflects a lack of confinement to the core of the pillars. Apart from reducing confinement, the potential impact of discontinuities (i.e. localised structural defects, such as faults) also increases rapidly as w/h ratio decreases. Similarly, the influence of weak bands reduces as their aspect ratio (i.e. length / width) increases with increasing pillar width. Recognition of the vulnerability of small pillars led **Madden (1989a)** to suggest that at shallow depths (i.e. <40m), pillars be designed to a width of >5m and a w/h ratio of >2; in addition, the Factor of Safety was to be >1.6 (according to the **1967 Salamon and Munro** formula).

A great variety of coal pillar strength formulae have been derived either directly from the back analysis of case histories, or from approaches involving laboratory and / or *in situ* testing, generally coupled to reviews of practical experience. The formulae enable the estimation of strength according to the pillar dimensions and generally incorporate w/h ratio as a key element. In South Africa, for example, the original **Salamon and Munro (1967)** formula, as well as the subsequent extension for 'squat' (w/h ratio >5) pillars (**Madden, 1989b**) have proven effective in preventing catastrophic failures in active workings. In the mid-1980s, the author personally mined panels in the Witbank Coalfield involving pillar widths of typically 6m to 6.5m and final heights of around 6m; the workings were designed using the **Salamon and Munro** formula and remain intact to this day.

As more experience becomes available, better estimates of coal pillar strength become possible. Both **Madden (1989a)** and **van der Merwe (1999)** found that the **Salamon and Munro (1967)** formula over-predicted coal pillar strength at w/h ratios of <3 and derived alternative formulae for general South African use. As previously noted, seam -specific formulae have now been developed in South Africa. The definition of the constants within both the Australian and South African squat pillar formulae remains an unresolved issue, noting that conservative values were originally adopted in the face of limited information (i.e. at the time of derivation, the maximum w/h ratio for a South African failed case was 3.74). There is now over 20 years experience with the application of the original squat pillar strength formula, with no known significant incident.

In Australia, both the **Bieniawski (1967)** and the **Salamon *et al* (1996)** formulae are currently in widespread use. **Salamon *et al* (1996)** developed both Australian and joint Australian / South African formulae, concluding that the application of the joint Australian / South African formulae was preferred, due to the limited size of the Australian database in isolation. However, the use of these combined formulae is not ideal, as the underpinning database is composed largely of failed cases with w/h ratios of <5, whereas the Australian norm involves squat pillars (i.e. w/h ratios of >5).

With specific regard to the **Salamon *et al* (1996)** formulae, given:

- the reservations that have been expressed with respect to the use of these formulae at low w/h ratios,
- the limited data at a w/h ratio of >5 and
- their limitation to pillars with "good" roof and floor contacts,

it is considered that these formulae should only be used in conjunction with additional controls. The Australian industry would benefit significantly from an expanded local database and would have much to gain from the derivation of updated formulae that incorporate and build on US experiences with pillars at w/h ratios of >5.

Recognising the limitations of the Australian strength formulae, one initial approach was to "quarantine" the failed cases (**Strata Engineering, 2000**). **Figure 12** illustrates the Factor of Safety versus w/h ratio relationship for the Australian (**UNSW, 1995**) and South African (**Madden and Hardman, 1992**) failed cases. The Australian intact cases are also shown for interest.

The following comments are made with regard to **Figure 12**:

i) There are no failed cases in the combined South African / Australian database with a w/h ratio of greater than 8 (according to **UNSW 1995**, although this was later corrected to 8.16 by **Salamon *et al* 1996**) even at a very low Factor of Safety, and there is only one failed case at a w/h ratio of greater than 5.

ii) The highest Factor of Safety assigned to a pillar collapse is 2.1 and this was associated with a w/h ratio of only 2.2.

iii) A limit envelope was defined for the database of failed cases, illustrated by the curve and given by the following equation:

$$\text{w/h ratio} = 19.328e^{-1.047*(\text{Factor of Safety})}$$

iv) If it is reasonable to assume that the pillars are, or will at some point in the future, be subjected to full tributary loading, then it is considered prudent to design the pillars to be outside (above) the failed case envelope, even though there are many examples of stable pillars that fall within it.

This approach has been used successfully for over ten years and was subsequently refined to the design nomogram shown in **Figure 13 (Hill and Buddery**, **2004)** which adds a third database derived from the back analysis of failed Australian highwall mining cases (**Strata Engineering, 2001**). The highwall mining cases cover the lower end of the range of w/h ratios, from 0.7 to 1.3. Although there are failed highwall mining pillars with Factors of Safety of 2.2 to 2.4, the pillars involved have w/h ratios of only 1.1 to 1.3.

The current limit envelope for the database of failed cases is defined by the following equation:

$$\text{w/h ratio} = 22.419e^{-1.148*(\text{Factor of Safety})}$$

Beyond this envelope, there is no precedent for failure within these databases. Note that the inclusion of the highwall mining pillar data does not materially change the shape of this limit envelope.

In the case of important long-life pillars (e.g. main headings), it is considered prudent to allow an additional margin beyond this envelope. A margin of 20% is the suggested minimum, which is defined by the second, outer curve in **Figure 13** and the following equation:

$$\text{w/h ratio} = 26.903e^{-0.957*(\text{Factor of Safety})}$$

In the case of pillars required for the permanent protection of critical surface features or structures, a broader review of coal pillar behaviour suggested, even in extreme circumstances involving unusually weak floor, coal and / or roof, that the potential for failure could be effectively excluded by designing to a Factor of Safety of ≥ 2.11, coupled to a w/h ratio of ≥ 5. Note that in this context, "failure" means panel collapse due to the failure of any element (i.e. roof, floor or the pillar) in the overall structural system.

Also shown in **Figure 13** are the practical design restrictions that flow from the NSW regulatory framework (i.e. Clauses 32 and 88 of the CMHSR (2006), as discussed previously). It can be seen that the regulatory approach is logical and, to an extent, mimics the Strata Engineering methodology, effectively placing design restrictions on both pillar Factor of Safety and w/h ratio.

The question then arises as to the possibility of incorporating and learning from the US experience, with particular regard to the behaviour of pillars with high w/h ratios. Of the various available approaches, only the Mark-Bieniawski formula (**Mark and Chase, 1997**) is considered appropriate for use across the full range of the data. The Australian and South African data have therefore been reprocessed and the combined database is presented in **Figure 14**, in terms of ARMPS Stability Factor (SF) versus w/h ratio.

The following comments are made with regard to **Figure 14**:

i) Excluding the single US floor failure, 70% of the failed cases have Stability Factors of <1.5.

ii) Again excluding the one floor failure, 90% of the failed cases involved w/h ratios of ≤ 4. This is consistent with the previously outlined studies of the positive impact of increasing w/h ratio on pillar strength and deformation.

iii) All of the failed cases with Stability Factors of >1.5 have w/h ratios of <4.5, apart from the floor failure, which had a w/h ratio of 4.66.

This broader, updated database is regarded as consistent with the previously described design methodology, as illustrated in **Figure 13**. In particular, for the purpose of long-term surface protection, there is no precedent for pillar failure at a Stability Factor of ≥ 1.5, coupled to a w/h ratio of ≥ 5.

The single US floor failure case raises the wider issue of the potential for surface impacts due to bearing capacity failure of the roof and / or floor, as opposed to failure of the pillar element. When pillar failure occurs, the physical manifestations very often include roof damage and floor heave, as pillar deformation and spall result in increases in both excavation span and bearing stress. The degree to which one aspect of this overall deformation (i.e. rib spall, roof falls or floor heave) is more prevalent than the other elements is a function of the geometry and the competency of the roof, seam and floor. Environments in which one aspect is evident in virtual isolation are very rare. The division, therefore, between pillar collapse and bearing capacity failure of the roof and / or floor is not as well defined as is often simplistically portrayed.

The previously discussed databases of pillar behaviour cover a broad range of roof and floor materials, including mudrocks, coal, siltstones and sandstones. Therefore, these materials and the variability in pillar strength that may be associated with them are implicitly recognised and should be very largely catered for within a Stability Factor approach. The uncertainty associated with the natural variability in Coal Measures strata often prohibits design to low Stability Factors (e.g. designing to a SF of 1.01 is not usually acceptable, even though strength nominally exceeds stress). Geological variability partly accounts for the scatter in the population of failed pillar cases and generally results in design Stability Factors of ≥ 1.5, equivalent to very low probabilities of failure.

Within the Australian and South African coal industries, there remain no known panel collapses (i.e. involving the structural failure of the roof, pillar or floor elements) that cannot be explained in terms of the combined Factor of Safety and w/h ratio criteria illustrated previously in **Figure 13**. This includes, for example, collapses in the Great Northern Seam (Lake Macquarie area, Australia), which historically have often been attributed to bearing failure of the Awaba Tuff floor. This often has a high smectite content, with an associated tendency to swell and degrade in the presence of moisture. It should be noted that those practical design parameters with a positive impact on pillar stability also invariably enhance bearing capacity (the obvious example being increasing pillar width), such that pillar and bearing capacity Factors of Safety tend to align closely. Even in known very weak floor environments, incidences of coal pillar collapse are concentrated at low w/h ratios (**Marino and Bauer, 1989**).

Nonetheless, there are geotechnical environments that warrant specific consideration of the behaviour of extremely weak floor materials. The prime example is the weak underclay of the Illinois Basin, where bearing capacity failure has been experienced at very high pillar Stability Factors, coupled to w/h ratios of up to 6.3 (**Gadde, 2009**). Similarly, there are very shallow workings that require specific consideration of overburden properties and the potential for sinkhole development.

The issue of potential long-term deterioration of workings leading to eventual failure is an important consideration, particularly if surface features warrant protection. In the Australian and South African databases, apart from one uncertain Australian case (i.e. at between 80 and 170 years) the maximum recorded time interval from mining to subsequent pillar failure is 52 years and the average time to failure is seven years. US experience appears generally consistent with this, even in weak floor conditions.

Expressed in the context of ARMPS SF and w/h ratio values, it can be shown that the failure probability reduces with time. **Figure 15** indicates that after an elapsed period of 14 years, there is only one Australian or S. African case of collapse at a Stability Factor of >1.6. The exception case involved a w/h ratio of 2. Referring to **Figure 16**, it is seen that after a period of 14 years, there are no cases of collapse at pillar w/h ratios of >2.5. After 40 years, there are no failed cases at w/h ratios of >2.

The industry databases illustrate that the majority of failures occur within a short time of mining, due either to inappropriate design or some form of local anomaly. As time progresses, the actual likelihood of failure decreases and those collapses that do occur involve designs that would be considered increasingly marginal. There is no evidence to suggest that pillar failure becomes inevitable or even more likely over time. On the contrary, the historical data suggests that pillar deterioration (e.g. associated with spall and weathering) tends to a limit over time.

CONCLUDING REMARKS

None of the empirically derived formulae in common use are considered to provide accurate estimates of coal pillar strength in Australian conditions. In particular, these formulae tend to overestimate pillar strength at w/h ratios of <4.

The Australian industry would benefit greatly from improved, updated pillar strength formulae based on expanded local databases, incorporating also US experiences with regard to pillar behaviour at w/h ratios of >5. This is of particular interest, given that NIOSH has recently been updating the ARMPS database.

In the interim, coal pillar designs that take cognisance of both w/h ratio and Stability Factor (or FoS) are considered most appropriate for ensuring the stability of workings. In this regard, both the NSW regulatory approach and the methodology developed by Strata Engineering over the last ten years are considered to remain rational.

For Australian conditions, an ARMPS Stability Factor of ≥ 1.5, coupled to a w/h ratio of ≥ 5, would effectively obviate the potential for long-term failure (i.e. collapse due to the failure of any element, roof, floor or the pillar, in the overall structural system).

Finally, it is re-iterated that the comments herein refer solely to the "first workings" or ARMPS "Loading Condition 1" situation. Obviously, the impacts of any secondary extraction are more complex and would require further consideration.

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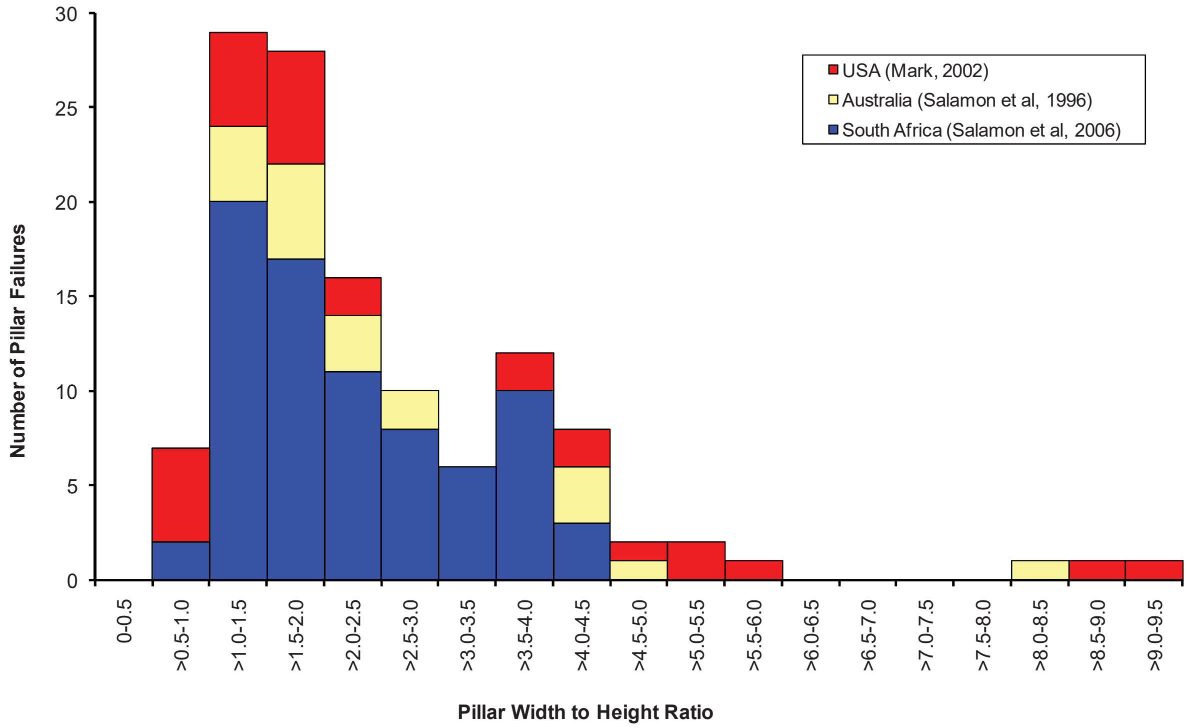
Figure 1



30
25
20
15
10
5
0
Number of Pillar Failures
USA (Mark, 2002)
Australia (Salamon et al, 1996)
South Africa (Salamon et al, 2006)
0-0.5
>0.5-1.0
>1.0-1.5
>1.5-2.0
>2.0-2.5
>2.5-3.0
>3.0-3.5
>3.5-4.0
>4.0-4.5
>4.5-5.0
>5.0-5.5
>5.5-6.0
>6.0-6.5
>6.5-7.0
>7.0-7.5
>7.5-8.0
>8.0-8.5
>8.5-9.0
>9.0-9.5
Pillar Width to Height Ratio

Figure 2

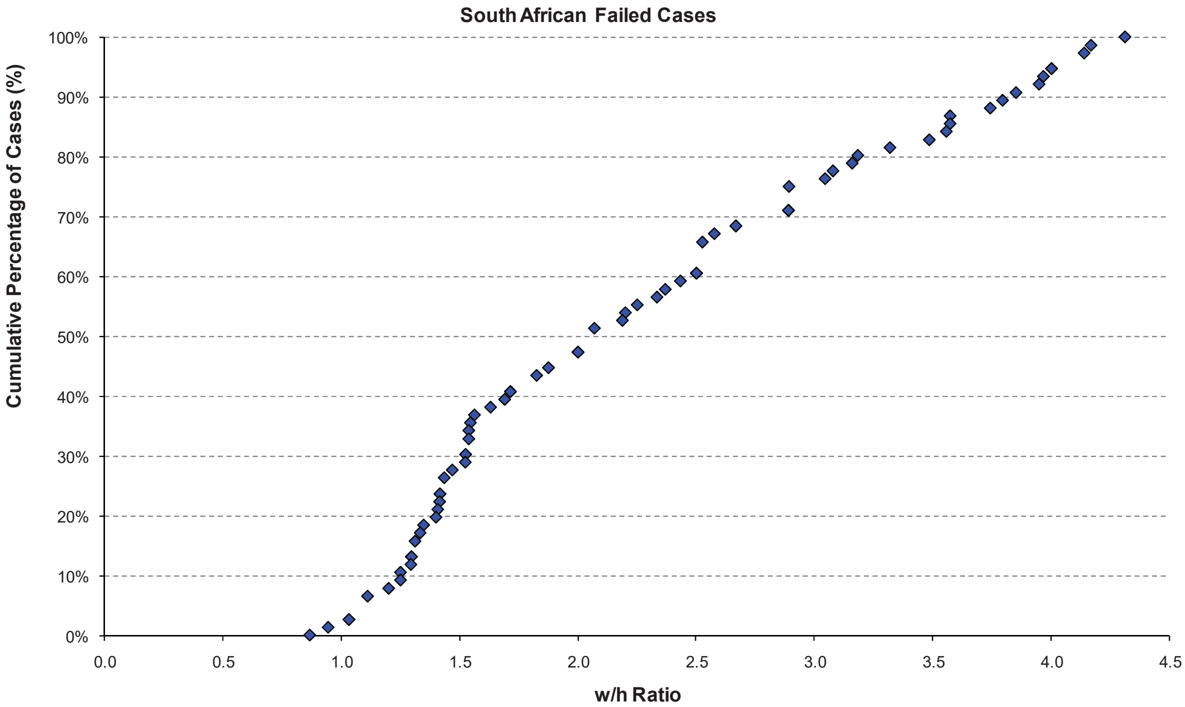
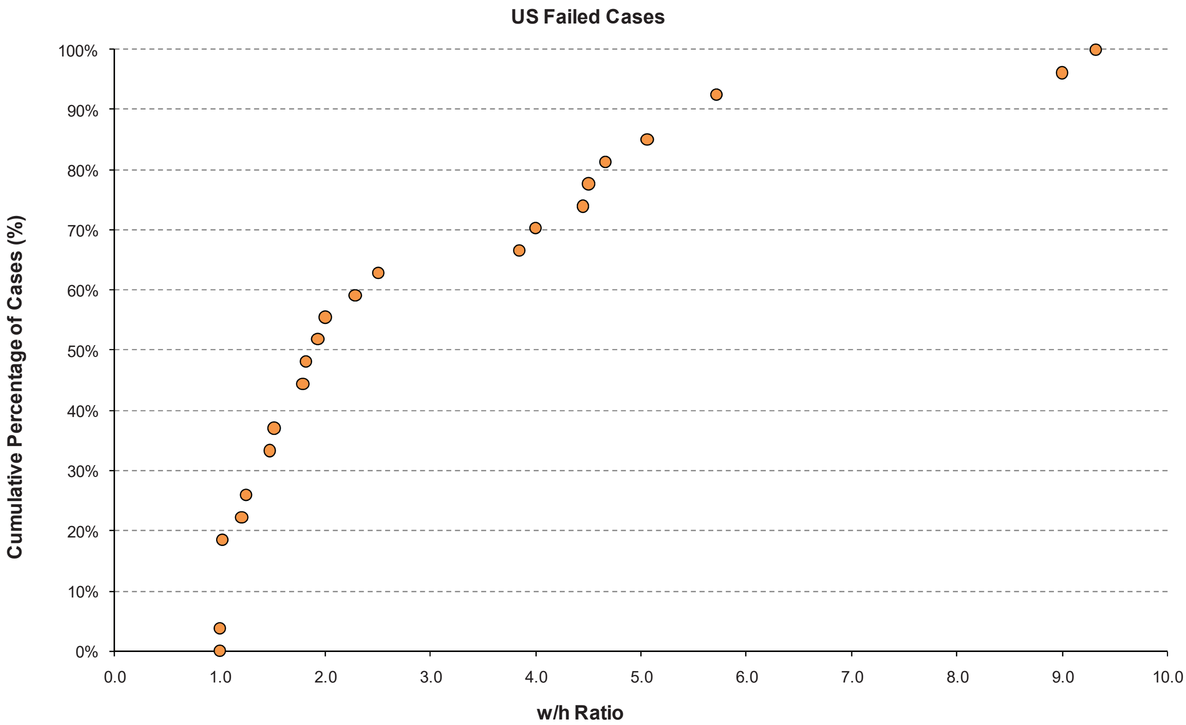
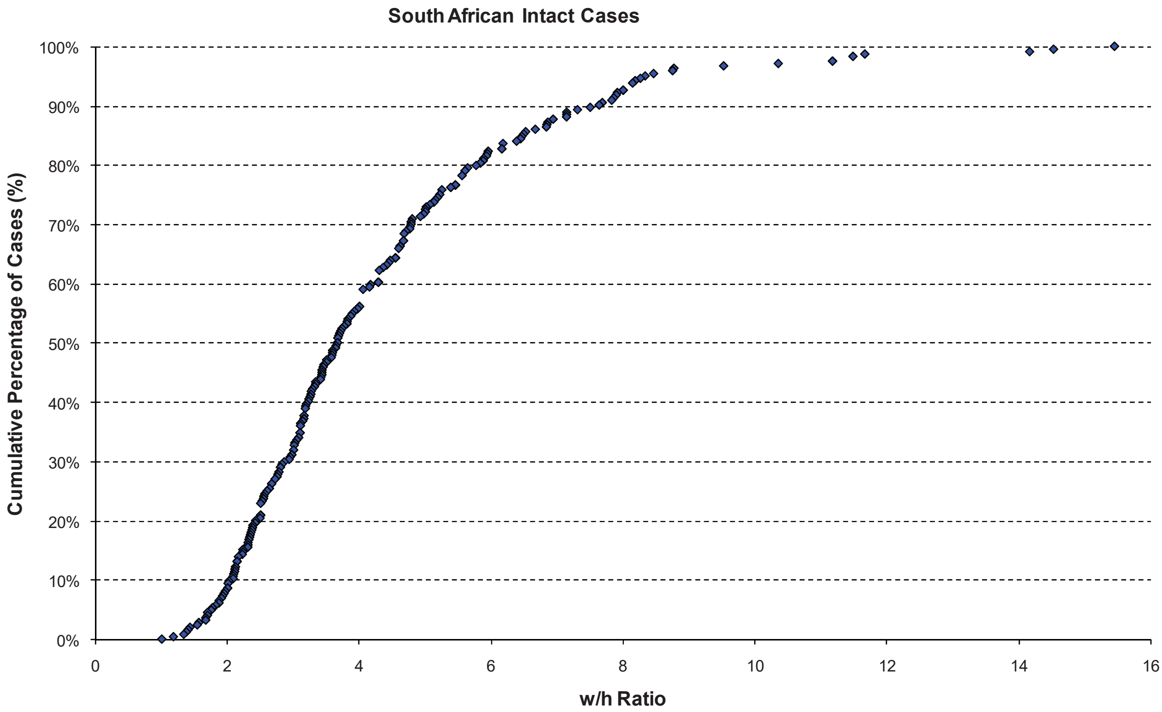

South African Failed Cases
Cumulative Percentage of Cases (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
w/h Ratio

Figure 3



US Failed Cases
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative Percentage of Cases (%)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
w/h Ratio

Figure 4



South African Intact Cases
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative Percentage of Cases (%)
0
2
4
6
8
10
12
14
16
w/h Ratio

Figure 5

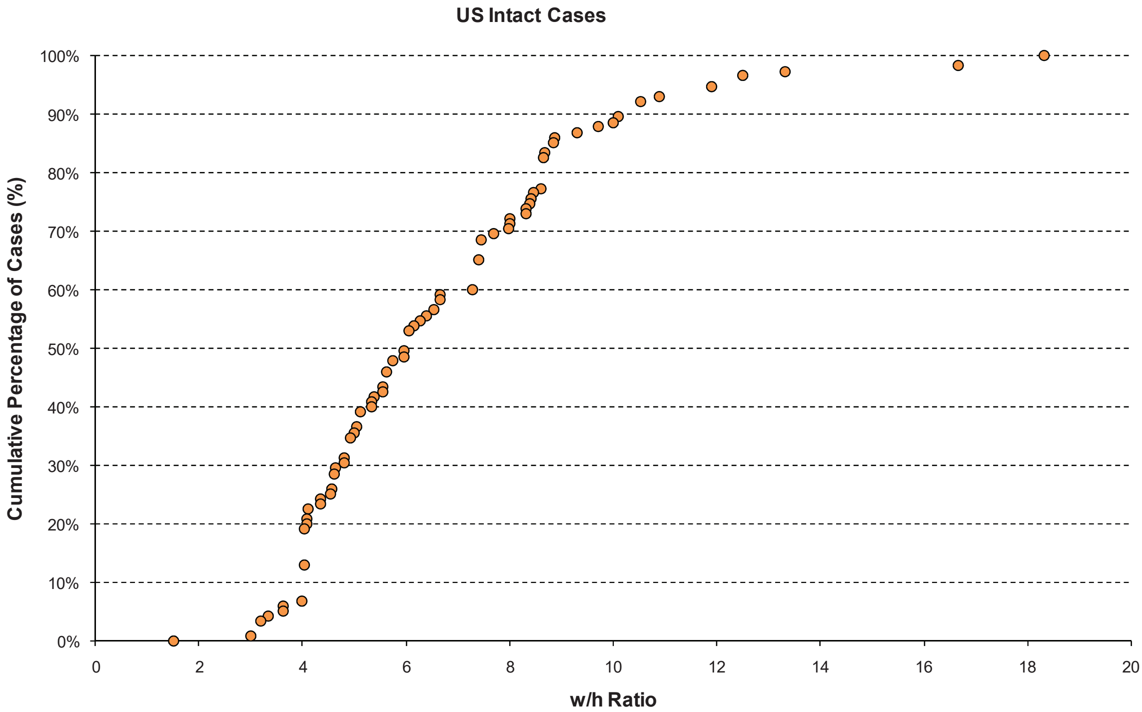
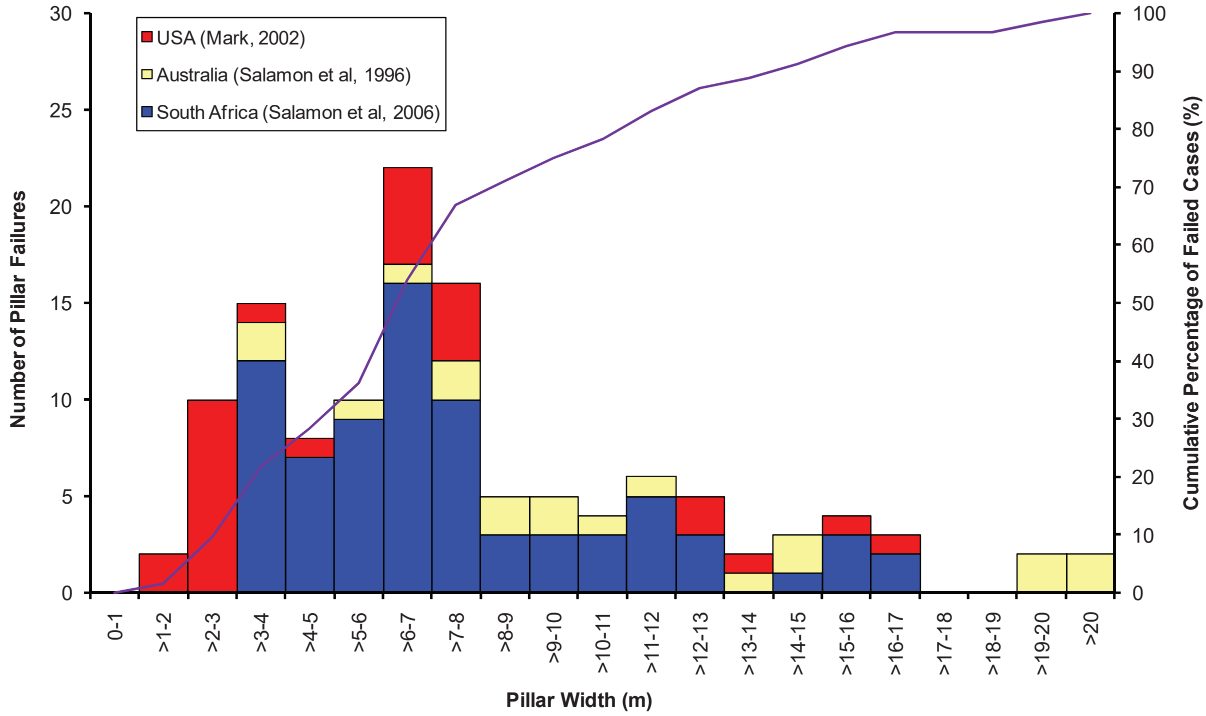
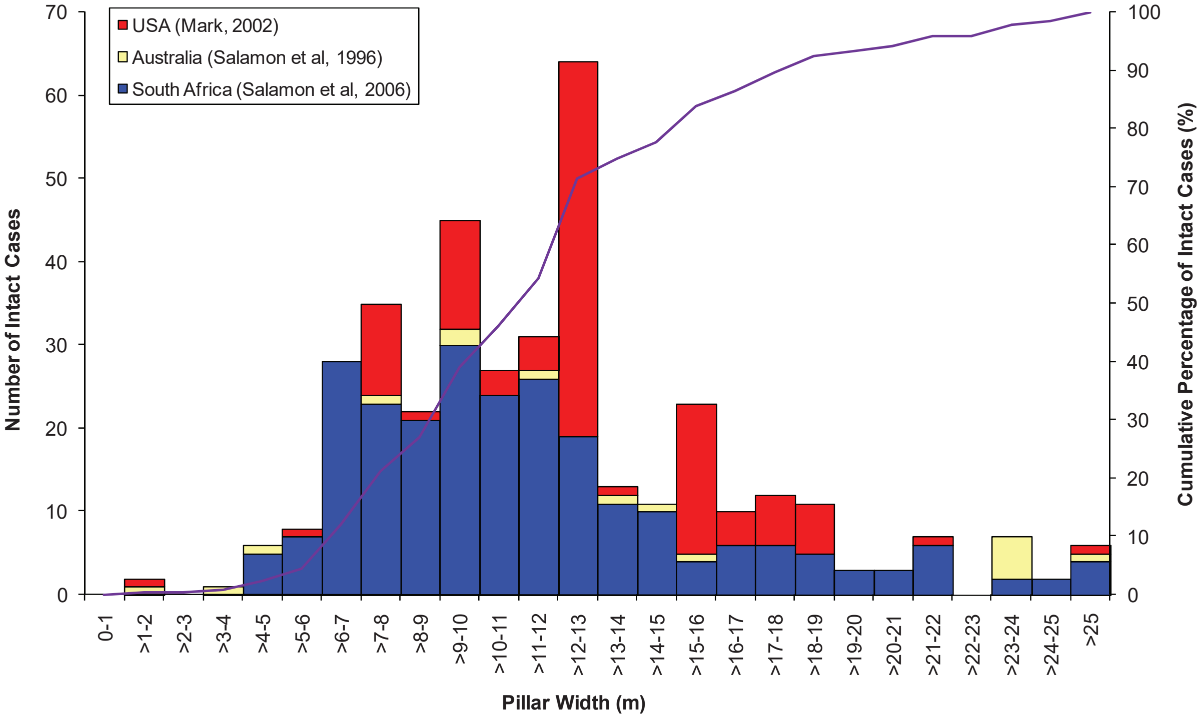

US Intact Cases
Cumulative Percentage of Cases (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
2
4
6
8
10
12
14
16
18
20
w/h Ratio

Figure 6



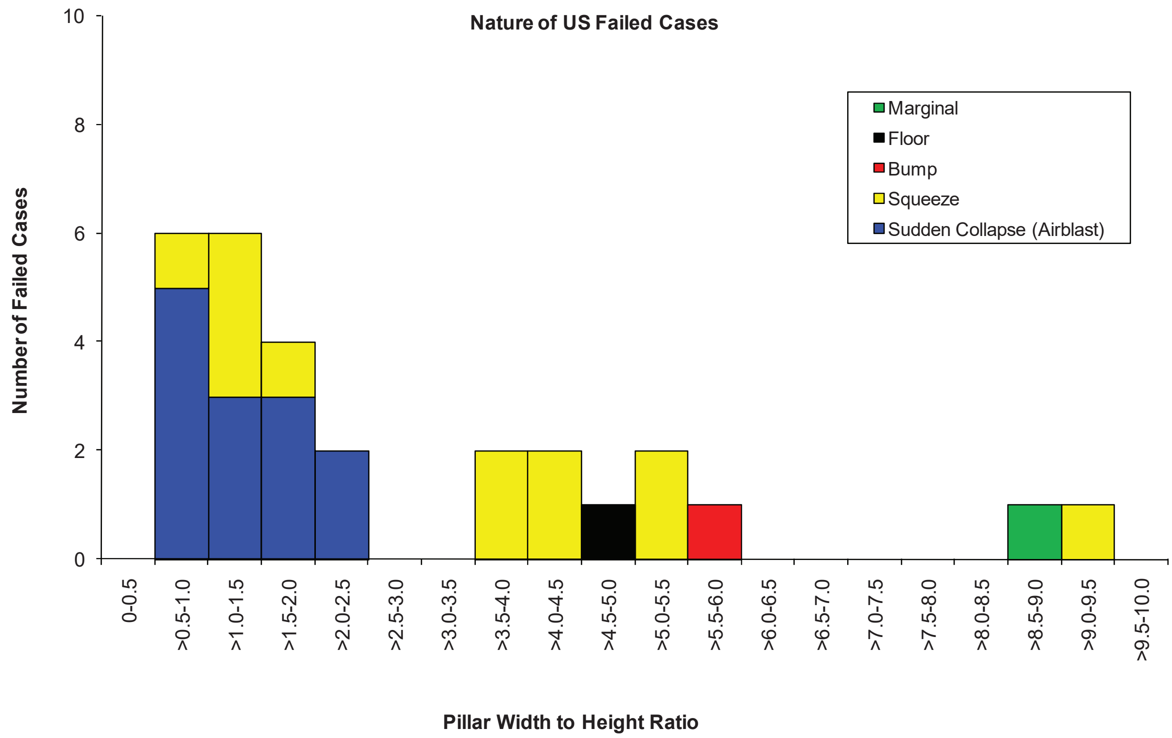
USA (Mark, 2002)
Australia (Salamon et al, 1996)
South Africa (Salamon et al, 2006)
Number of Pillar Failures
Cumulative Percentage of Failed Cases (%)
Pillar Width (m)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0-1
>1-2
>2-3
>3-4
>4-5
>5-6
>6-7
>7-8
>8-9
>9-10
>10-11
>11-12
>12-13
>13-14
>14-15
>15-16
>16-17
>17-18
>18-19
>19-20
>20

Figure 7



USA (Mark, 2002)
Australia (Salamon et al, 1996)
South Africa (Salamon et al, 2006)
Number of Intact Cases
Cumulative Percentage of Intact Cases (%)
Pillar Width (m)
0
10
20
30
40
50
60
70
80
90
100
0-1
>1-2
>2-3
>3-4
>4-5
>5-6
>6-7
>7-8
>8-9
>9-10
>10-11
>11-12
>12-13
>13-14
>14-15
>15-16
>16-17
>17-18
>18-19
>19-20
>20-21
>21-22
>22-23
>23-24
>24-25
>25

Figure 8



Nature of US Failed Cases
Marginal
Floor
Bump
Squeeze
Sudden Collapse (Airblast)
Number of Failed Cases
10
8
6
4
2
0
0-0.5
>0.5-1.0
>1.0-1.5
>1.5-2.0
>2.0-2.5
>2.5-3.0
>3.0-3.5
>3.5-4.0
>4.0-4.5
>4.5-5.0
>5.0-5.5
>5.5-6.0
>6.0-6.5
>6.5-7.0
>7.0-7.5
>7.5-8.0
>8.0-8.5
>8.5-9.0
>9.0-9.5
>9.5-10.0
Pillar Width to Height Ratio

Figure 9

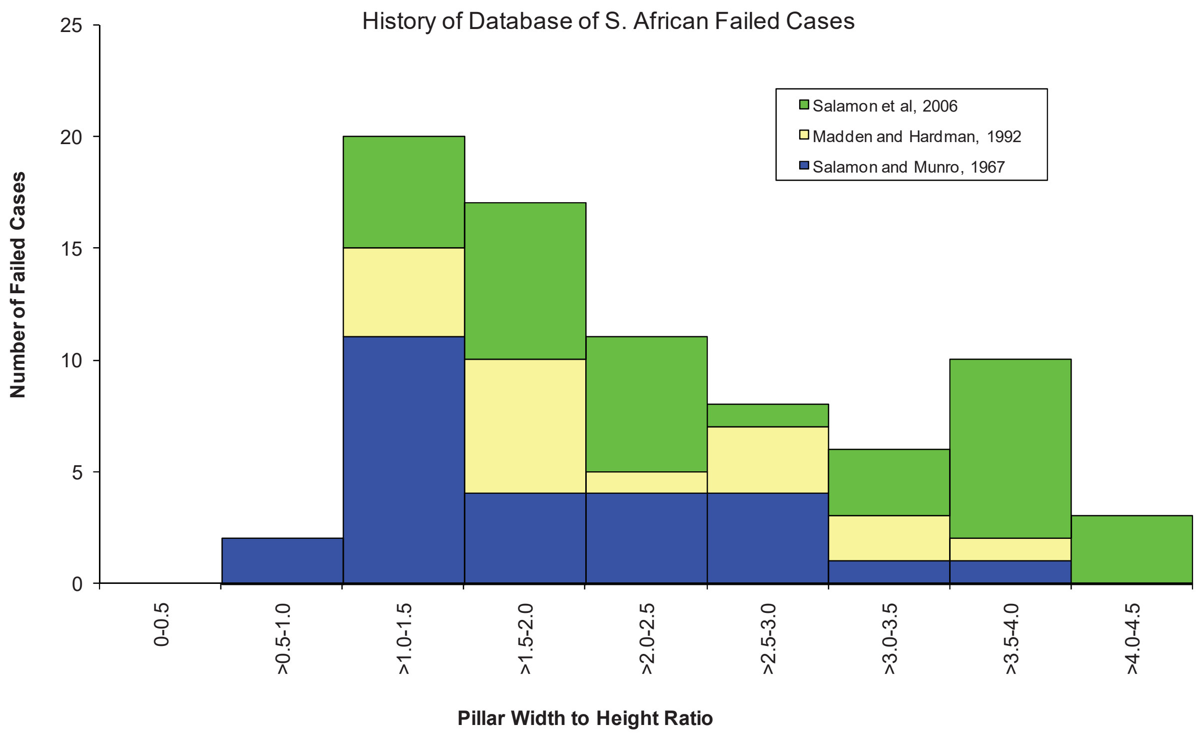
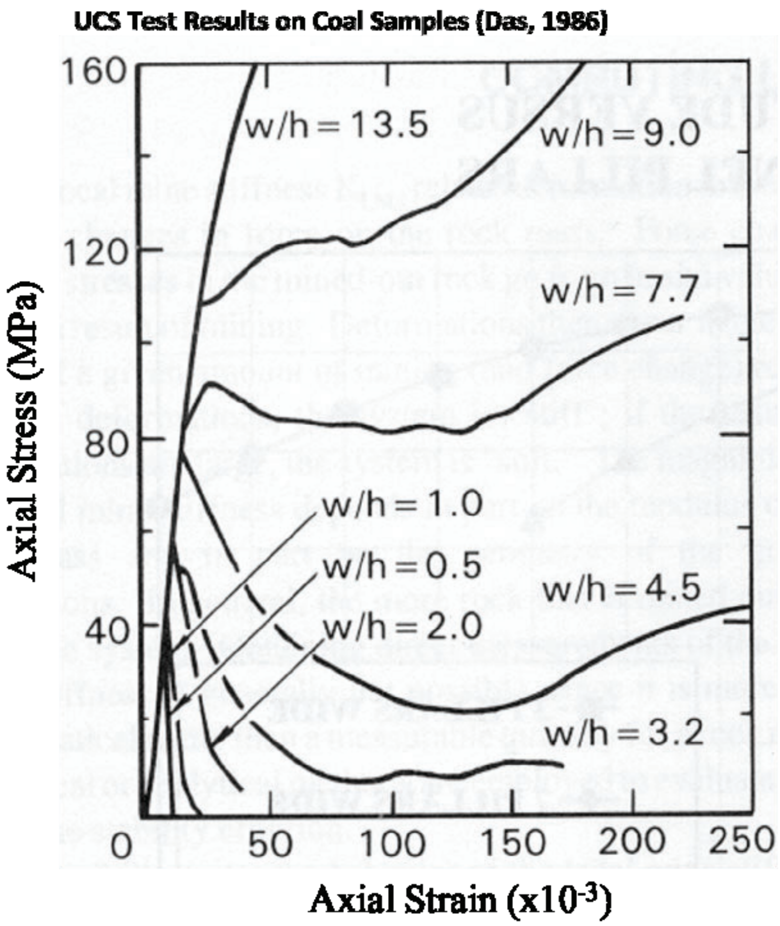
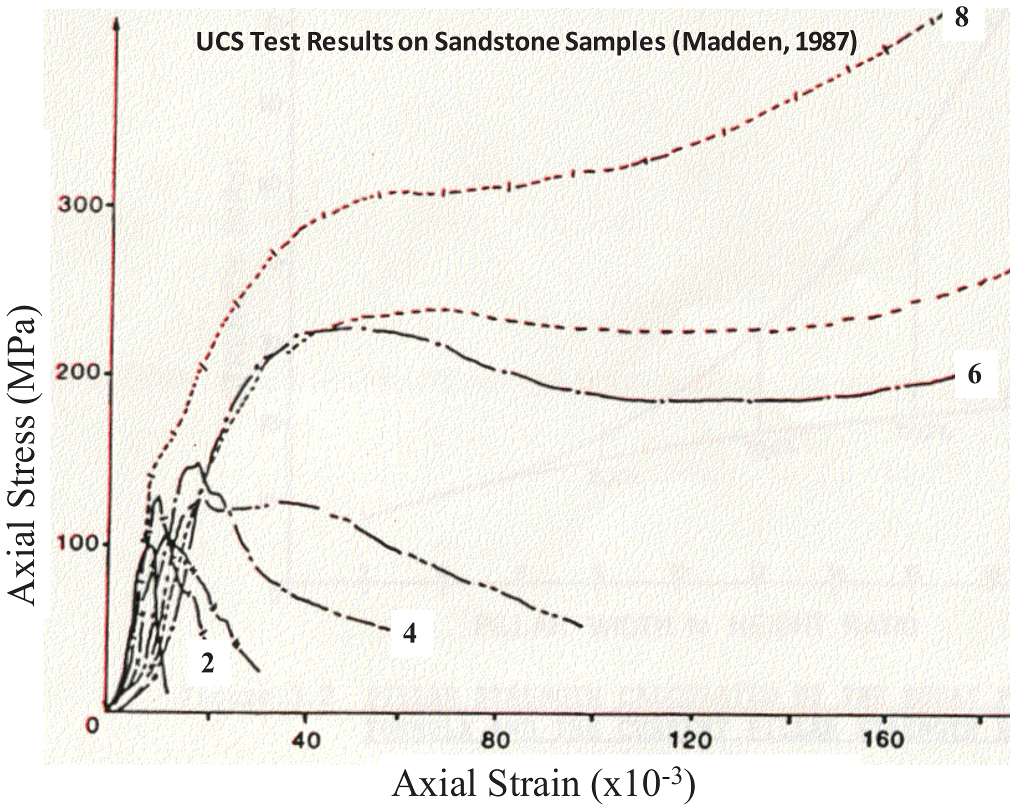

History of Database of S. African Failed Cases
Salamon et al, 2006
Madden and Hardman, 1992
Salamon and Munro, 1967
Number of Failed Cases
0
5
10
15
20
25
0-0.5
>0.5-1.0
>1.0-1.5
>1.5-2.0
>2.0-2.5
>2.5-3.0
>3.0-3.5
>3.5-4.0
>4.0-4.5
Pillar Width to Height Ratio

Figure 10



UCS Test Results on Coal Samples (Das, 1986)
160
120
80
40
0
50
100
150
200
250
w/h = 13.5
w/h = 9.0
w/h = 7.7
w/h = 1.0
w/h = 0.5
w/h = 2.0
w/h = 4.5
w/h = 3.2
Axial Stress (MPa)
Axial Strain (x10-3)

Figure 11



UCS Test Results on Sandstone Samples (Madden, 1987)
Axial Stress (MPa)
300
200
100
0
40
80
120
160
Axial Strain (x10-3)
8
6
4
2

Figure 12

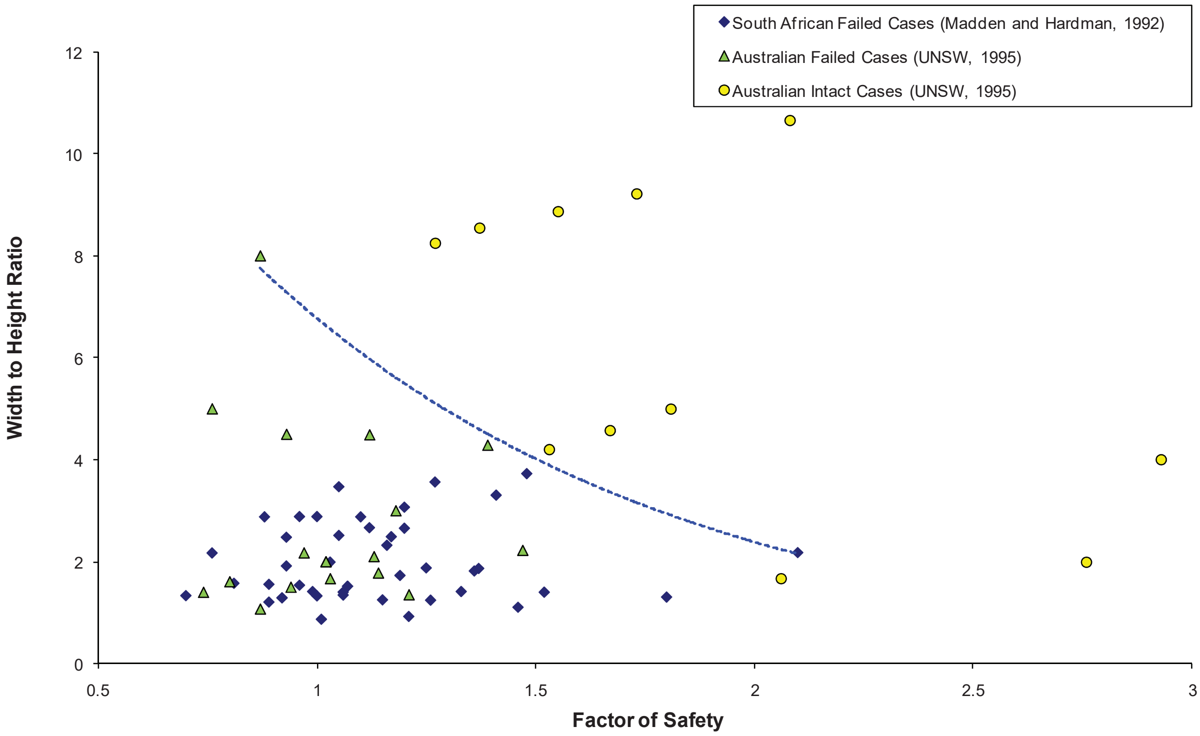
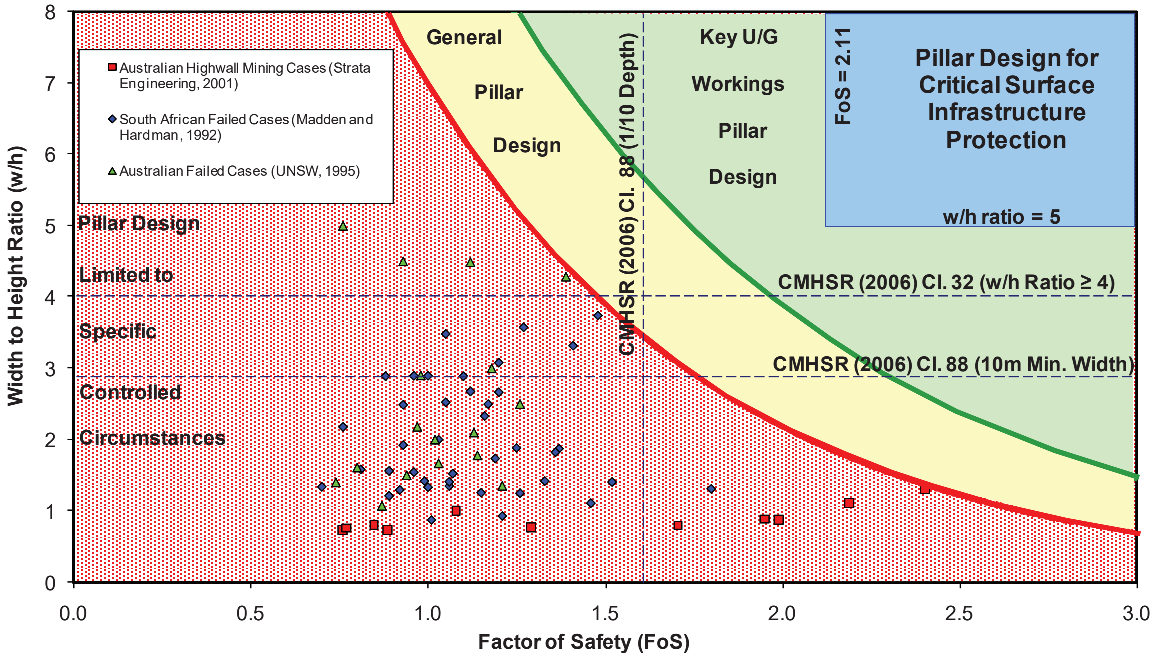
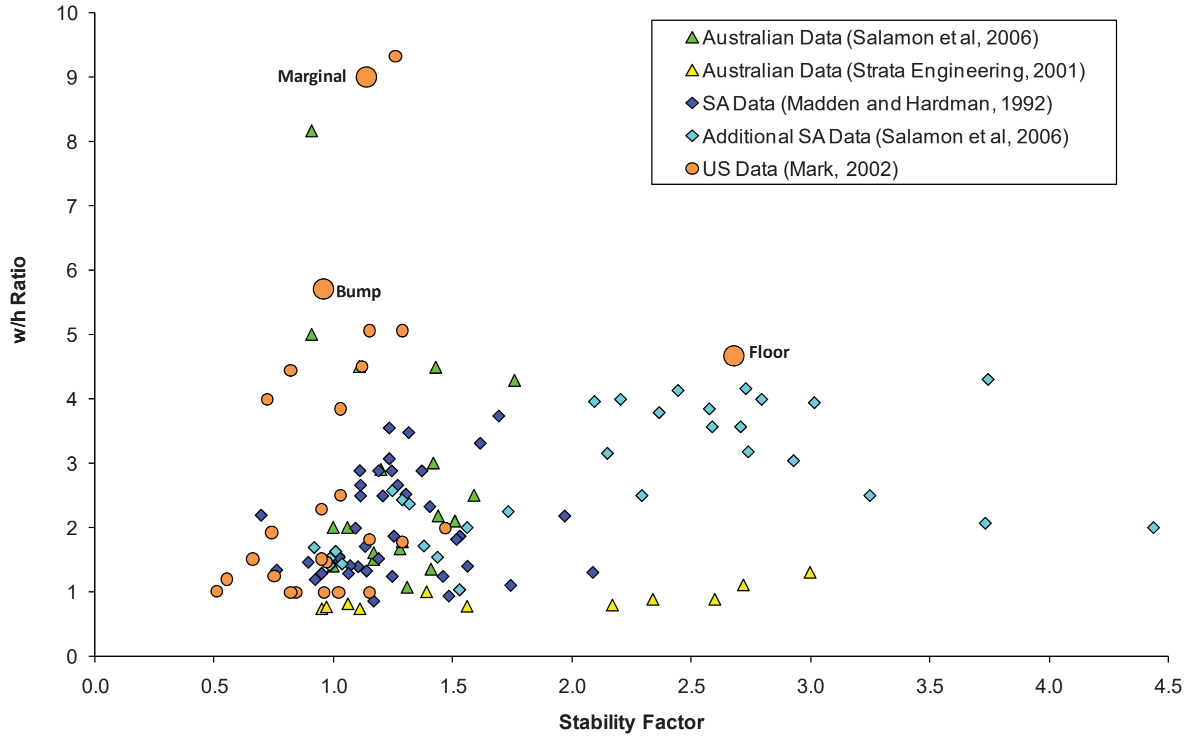

South African Failed Cases (Madden and Hardman, 1992)
Australian Failed Cases (UNSW, 1995)
Australian Intact Cases (UNSW, 1995)
Width to Height Ratio
Factor of Safety
0
2
4
6
8
10
12
0.5
1
1.5
2
2.5
3

Figure 13



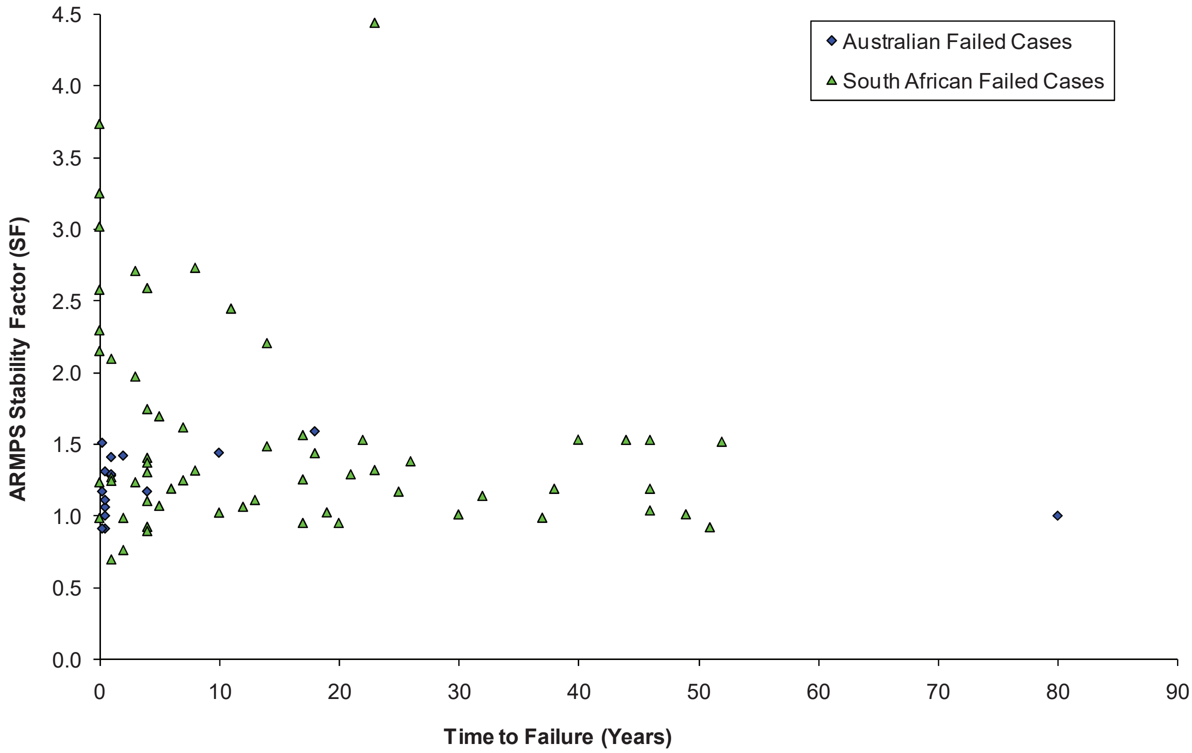
Australian Highwall Mining Cases (Strata Engineering, 2001)
South African Failed Cases (Madden and Hardman, 1992)
Australian Failed Cases (UNSW, 1995)
Pillar Design
Limited to
Specific
Controlled
Circumstances
General
Pillar
Design
CMHSR (2006) Cl. 88 (1/10 Depth)
Key U/G
Workings
Pillar
Design
FoS = 2.11
Pillar Design for Critical Surface Infrastructure Protection
w/h ratio = 5
CMHSR (2006) Cl. 32 (w/h Ratio ≥ 4)
CMHSR (2006) Cl. 88 (10m Min. Width)
Width to Height Ratio (w/h)
Factor of Safety (FoS)
0
1
2
3
4
5
6
7
8
0.0
0.5
1.0
1.5
2.0
2.5
3.0

Figure 14



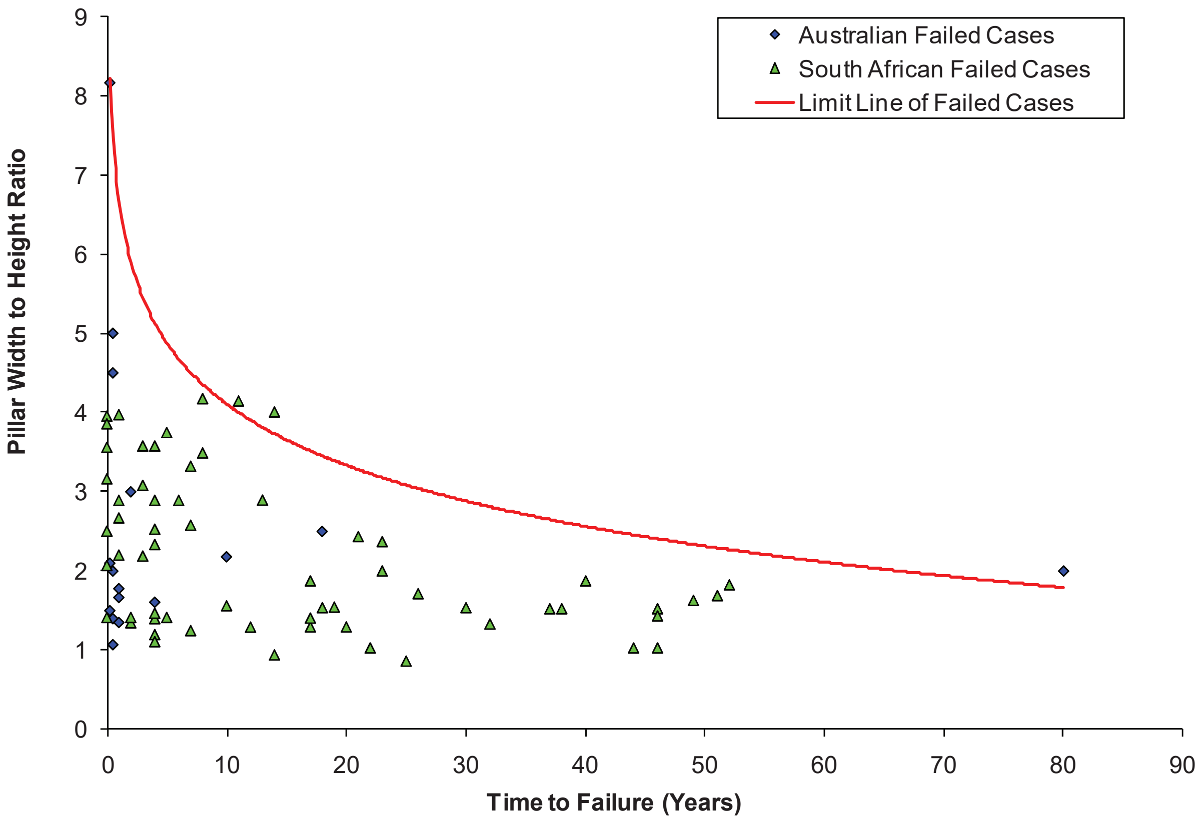
Australian Data (Salamon et al, 2006)
Australian Data (Strata Engineering, 2001)
SA Data (Madden and Hardman, 1992)
Additional SA Data (Salamon et al, 2006)
US Data (Mark, 2002)
Marginal
Bump
Floor
w/h Ratio
Stability Factor
0
1
2
3
4
5
6
7
8
9
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5

Figure 15



Australian Failed Cases
South African Failed Cases
ARMPS Stability Factor (SF)
Time to Failure (Years)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90

Figure 16


Australian Failed Cases
South African Failed Cases
Limit Line of Failed Cases
Pillar Width to Height Ratio
Time to Failure (Years)
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
90

Appendix B: Extract from SCT (2018)

The Stability Index approach is based on the widely used pillar design approach of comparing load against an estimate of pillar strength. The load is calculated as the weight of overburden strata tributary to the pillar. Pillar strength is estimated using a formula that varies linearly with pillar width to height ratio.

The difference with the Stability Index approach is that the pillar strength formula was based on an arbitrarily chosen variant of Bieniawski's pillar design formula so as not to be confused with Factor of Safety and to step away from debates that were occurring at the time as to which pillar design formula was the best. The ratio of nominal strength versus loading was compared to experience of surface subsidence above the various panels reviewed. In all but three of the panels reviewed, the panels were of supercritical width. In supercritical width panels, surface subsidence clearly reflects pillar stability.

The variant of the Bieniawski pillar formula used in the Stability Index approach is:

$$Q_P = 8\ (0.64+0.36\ W/H)$$

where Q_P is the nominal pillar strength, W is the pillar width and H is the mining height. No allowance is made for pillar shape but it is common practice for individual pillars in partial panels to be square or very nearly so.

Tributary area loading is calculated on a plan area basis. The overburden density is assumed to be 2,500kg/m^3. In most cases, the tributary area load is calculated on the basis that the overburden strata is able to fully bridge across the extracted panels. This approach is valid where there is significant conglomerate strata in the immediate roof and the void widths are less than about 70m. An allowance for caving can be made when caving is expected to occur.

Abutment loading adjacent to a fully extracted goaf or area of failing pillars is calculated using the approach described in **Mills (2001)**. Total abutment load is estimated based on the weight of a triangle of overburden strata extending from the goaf edge to a point indicated by subsidence monitoring experience as the furthest distance at the surface that can be supported on the abutment. In practice, this distance is typically observed to be in the range 0.6-0.7 times depth. This total abutment weight is then distributed over the abutment pillars based on SCT's experience of monitoring experience of the stress distributions about goaf edges at multiple sites.

Given the generally regular layout of partial extraction panels used in the Southern Lake Macquarie area, a representative Stability Index can be calculated for each row of pillars. Alternatively, the nominal load bearing capacity of each individual pillar can be calculated and compared for the full row or for more irregular geometries. For a regular row of pillars, there is no difference and both approaches were used to develop the database presented in **SCT (1993)**.

The Stability Index is calculated using representative pillar geometries for each row. Pillar instability is observed to initiate in areas of low Stability Index and to propagate outward from there. Occasional larger pillars or small remnant stooks are typically ignored in the calculation of Stability Index because at the scale of the panel they do not contribute significantly to estimating the stability of the pillar system where a domino type failure process can develop. Although larger individual pillars can contribute more load bearing while all other pillars remain stable, their effectiveness at preventing failure of the overall system is limited should the more regular groups of pillars become overloaded.

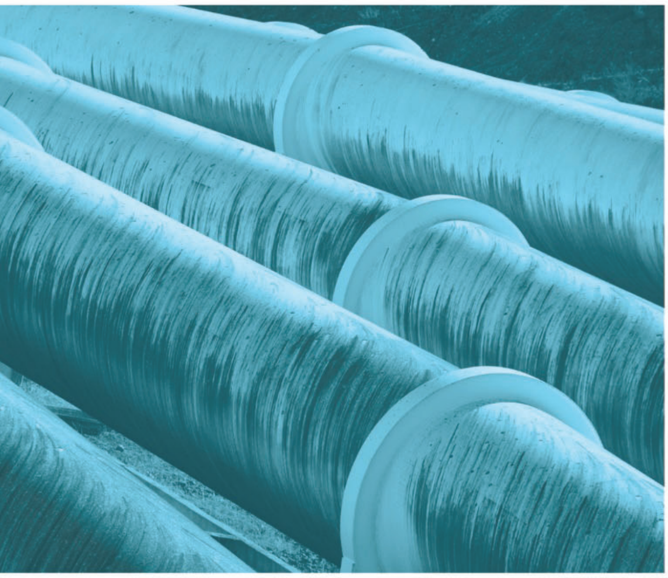
Experience of using the Stability Index approach to compare observed subsidence behaviour with pillar stability is summarised in **Table 1** and **Figure 3** reproduced from **Figure 6** in **SCT (1993)**.

Table 1: Summary of Stability Index as an Indicator of Subsidence Behaviour in the Southern Lake Macquarie area.

Stability Index Range	Subsidence Experience
< 2.0	Subsidence event occurs soon after mining with maximum subsidence in the range 0.25 to 0.36 times mining height
2.0-2.5	Subsidence event occurs after some time. Perceptible surface movements are typically evident at an increasing Rate prior to a rapid acceleration and onset of a subsidence event.
2.5-4.0	Ongoing movements are evident at very slow rates but stability is maintained at least for some decades. Panel stability is not sufficient to control or halt the progress of subsidence associated with nearby instability or goaf creation (e.g. Sites 20 & 21).
>4.0	Low level subsidence in the order of 0.02 times seam thickness is evident but long term stability is maintained and adjacent subsidence events are able to be controlled.

It should be recognised that the Stability Index approach is only a guide to allow past experience to guide future expectations of pillar behaviour. It is not a design methodology as such and should not be regarded so. The claystone materials that exist within the floor strata below pillar systems in the Southern Lake Macquarie area is known to deteriorate with time. Any long-term assessment of stability needs to recognise this deterioration.



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