Mount Thorley Warkworth

2019 Annual Review

Name of Operations	Mount Thorley Warkworth
Name of Operator	Coal & Allied (NSW) Pty Ltd (wholly owned subsidiary of Yancoal Australia Ltd)
Development consent /project approval	SSD-6464 & SSD-6465
Name of holder of development consent/project approval	Warkworth Mining Ltd Mt Thorley Operations Pty Ltd
Mining Lease #	Contained within Section 3.1 of this report
Name of holder of mining lease	Warkworth Mining Ltd Mount Thorley Operations Pty Ltd
Water Licence #	Contained within Section 3.1 of this report
Name of holder of water licence	Contained within Section 3.1 of this report
MOP/RMP start date	14/12/2018
MOP/RMP end date	30/11/2021
Annual Review Start Date	01/01/2019
Annual Review End Date	31/12/2019

I, Gary Mulhearn, certify that this audit report is a true and accurate record of the compliance status of Mount Thorley Warkworth for the period 1 January 2019 to 31 December 2019 and that I am authorised to make this statement on behalf of Coal & Allied (NSW) Pty Ltd.

Note.

a) The Annual Review is an 'environmental audit' for the purposes of section 122B(2) of the Environmental Planning and Assessment Act 1979. Section 122E provides that a person must not include false or misleading information (or provide information for inclusion in) an audit report produced to the Minister in connection with an environmental audit if the person knows the information is false or misleading in a material respect. The maximum penalty is, in the case of a corporation, $1 million and for an individual, $250, 000.

b) The Crimes Act 1900 contains other offences relating to the false and misleading information: section 192G (Intention to defraud by false or misleading statement- maximum penalty 5 years imprisonment); sections 307A, 307B and 307C (False or misleading applications/information/documents – maximum penalty 2 years imprisonment or $22,000, or both).

Name of Authorised Reporting Officer	Mr Gary Mulhearn
Title of Authorised Reporting Officer	Environment and Community Manager
Signature of Authorised Reporting Officer	
Date	5/6/2020

Executive Summary

Mount Thorley Warkworth (MTW) is an integrated operation of two open cut coal mines, Warkworth Mining Limited (WML) and Mount Thorley Operations (MTO). This Annual Review reports on the environmental performance of MTW for the period 1 January 2019 to 31 December 2019.

This report has been prepared in accordance with conditions of the development consents and Mining Leases (ML) held by MTW which require a report of the operation's environmental performance to be provided on an annual basis. The structure of the 2019 Annual Review aligns with the NSW Department of Planning, Industry and Environment (DPIE) *Post-approval requirements for State significant mining developments – Annual Review Guideline* (October 2015).

MTW produced 17.6 million tonnes of run-of-mine (ROM) coal during 2019, and 12.0 million tonnes of saleable coal, against an approved ROM coal production rate of 28 million tonnes per annum (mtpa).

Noise

There were no non-compliances recorded against MTW's consented noise limits. There was an increase (from 38 to 94) in the number of supplementary attended noise measurements which exceeded the internal trigger levels for corrective action compared to 2018. A total of up to 1,203 hours of mine stoppages were recorded due to proactive and reactive measures to minimise noise.

Blasting

During the reporting period 250 blast events were initiated at MTW. There was one non-compliance against ground vibration criteria, and one non-compliance against airblast overpressure criteria.

On 4 April 2019, one blast exceeded the 120dB(L) threshold for airblast overpressure (AOP) at the Warkworth blast monitor. The exceedance was reported to DPIE and to the NSW Environment Protection Authority (EPA) on 5 April 2019. A written report was provided to the DPIE and EPA for this blast which concluded that "The reason that the AOP level that resulted at the Warkworth monitoring station was greater than predicted was due to the fact that the actual meteorological data, and hence the actual effects of meteorology, were different from that predicted." WML received a penalty notice for the AOP exceedance incident, which was received in September 2019. The penalty notice was issued by DPIE for a non-compliance of the blasting limits of the Warkworth Development Consent (SSD 6464). Further details on this incident and the actions taken by MTW are provided in **Section 10.**

At the end of the 12 month 2019 calendar year, there were a total of 16 blast events initiated at MTO, of which a single blast vibration result at the Wollemi Peak Road monitor was recorded in the range of 5-10mm/s (actual result 5.67mm/s). Due to the small number of blasts at MTO, this has resulted in 6.3% of blasts at the Wollemi Peak Road monitoring location being in the range of 5-10mm/s, which is greater than the requirements of development consent SSD-6465 which permits up to 5% of blasts to record in the range of 5-10mm/s. The non-compliance was reported to DPIE and to the EPA (via the MTO Annual Return). Further details on this incident and the actions taken by MTW are provided in **Section 10.**

Air Quality

During 2019, MTW complied with all short term and annual average air quality criteria. A total of 6,762 hours of mine stoppage was recorded following implementation of proactive and reactive measures to minimise dust.

Heritage

Although no Aboriginal or historic heritage assessments or salvage programs were conducted at MTW in 2019, heritage matters continued to be managed in accordance with the MTW Aboriginal Cultural Heritage Management Plan (ACHMP) and Historic Heritage Management Plan (HHMP).

Annual ACHMP and an HHMP compliance inspections were conducted during the 2019 reporting period by a consultant archaeologist assisted by internal mine site personnel, representatives of the Aboriginal community and representatives from the sites community heritage advisory group (CHAG).

There were no incidents or any unauthorised disturbance to any heritage sites at MTW during the reporting period.

One new cultural heritage site (artefact scatter) was identified and recorded during the reporting period in accordance with the provisions outlined in the ACHMP.

Surface Water

2019 was a drier than average year with a total of 303.8 mm rainfall recorded at MTW's Charlton Ridge Meteorological station. The average annual rainfall at Charlton Ridge is 630mm, as calculated from 2007 to 2019 annual totals.

There were no new water management structures constructed during the reporting period at MTW.

There was one externally reportable water related incident during the reporting period which occurred on 30 March 2019. The incident involved the overtopping of two boundary dams at Warkworth (Dam 46N and Dam 53N) as a result of a greater than design rainfall event (52 mm). WML received two penalty notices for the water discharge incident, which were received in August 2019. One penalty notice was issued by the EPA for a breach of EPL 1376 and a second penalty notice was issued by DPIE for a breach of the Warkworth Development Consent (SSD 6464). An official caution was also received from the EPA in September 2019. Further details on this incident and the actions taken by MTW are provided in **Section 10.**

Groundwater

Groundwater monitoring activities were undertaken in 2019 in accordance with the MTW Water Management Plan and groundwater monitoring programme. The monitoring results are used to establish and monitor trends in physical and geochemical parameters of surrounding groundwater potentially influenced by mining.

Groundwater monitoring data is reviewed on a quarterly basis. There were no non-compliances related to groundwater in 2019.

Visual Amenity

The Putty Road visual bund was extended to the west, to the junction of the Sealed Geo Road (former Wallaby Scrub Road), during 2019. Vegetation screening has also been implemented to the west of the former Wallaby Scrub Road to improve visual amenity for passing motorists. A section of deceased trees along the South Pit of Warkworth adjacent to the Putty Road were also removed in 2019 to improve visual amenity, with infill planting to occur in 2020 in this area.

Rehabilitation and Land Management

A total of 82.7 ha rehabilitation was completed during 2019 against a MOP target of 82.1 ha. Total disturbance undertaken was 99.7 ha, higher than the 2019 MOP projection of 79.2 ha. The additional reported disturbance was due to re-classification of topsoil stockpiles from rehabilitation to disturbed land. This re-classification of rehabilitation resulted from an independent review of rehabilitation progress at MTW that was commissioned in response to section 240 notices issued by the Resources Regulator on 5 July 2019. Tailings Dam 2 closure activities continued with capping completed on a portion of the southern area of the tailings beach. This allowed for 2.2 ha of rehabilitation to be completed on the Tailings Dam 2 footprint.

The net rehabilitation progress (i.e. rehabilitation minus rehabilitation disturbance) for the current MOP period (2015 to 2019) is 347.8ha, which is 35.6ha lower than the MOP target of 383.4ha. The net rehabilitation result has also been affected by the reporting of rehabilitation disturbance to account for the re-classification of topsoil stockpiles from rehabilitation to disturbed land. Cumulative new disturbance over the MOP period is 377.9ha which is lower than the MOP forecast of 388.5ha for the same period.

Biodiversity and Offset Management

Restoration of the Warkworth Sands Woodland vegetation community continued in the Northern Biodiversity Area, with over 3,000 seedlings planted. Restoration activities for the Central Hunter Grey Box – Ironbark Woodland River Oak Forest and Warkworth Sands Woodland continued in the Southern Biodiversity Area, with over 20,000 seedlings planted. Planting at the Goulburn River Biodiversity area to increase the suitability of habitat for the Regent Honeyeater commenced with 17,000 tube stock planted into the existing cleared areas of Yellow Box – Grey Box – Red Gum Grassy Woodland and riparian woodland areas. Weed control, vertebrate pest management activities, seed collection, and fence repairs were conducted during 2019 in the Local and Regional Biodiversity Areas in accordance with the Offset Management Plans.

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1 STATEMENT OF COMPLIANCE

A Statement of Compliance against the relevant approvals is provided in **Table 1.1**. **Table 1.2** provides a brief summary of the non-compliances and a reference to where these are addressed within this Annual Review.

TABLE 1.1 STATEMENT OF COMPLIANCE

Approval	Were all conditions complied with?
DA SSD-6465 (MTO)	No
DA SSD-6464 (WML)	No

TABLE 1.2 NON COMPLIANCES

Relevant approval	Condition number	Condition description (summary)	Compliance status	Section in this Annual Review it is addressed.
SSD-6464 (WML)	Schedule 3 Condition 27	Water Management Plan	Non-compliant	6.7.3
SSD-6464 (WML)	Schedule 3 Condition 8	Blasting Criteria	Non-compliant	6.3.2
SSD-6465 (MTO)	Schedule 3 Condition 6	Blasting Criteria	Non-compliant	6.3.2

TABLE 1.3 COMPLIANCE STATUS KEY FOR TABLE 1.2

Risk level	Colour Code	Description
High	Non-compliant	Non-compliance with potential for significant environmental consequences, regardless of the likelihood of occurrence
Medium	Non-compliant	Non-compliance with : Potential for serious environmental consequences, but is unlikely to occur; or Potential for moderate environmental consequences, but is unlikely to occur
Low	Non-compliant	Non-compliance with : Potential for moderate environmental consequences, but is unlikely to occur; or Potential for low environmental consequences, but is unlikely to occur
Administrative non-compliance	Non-compliant	Only to be applied where the non-compliance does not result in any risk of environmental harm (e.g. submitting a report to government later than required under approval conditions)

Source: NSW Government Post-approval requirements for State significant mining developments – Annual Review Guideline (October 2015).

2 INTRODUCTION

Mount Thorley Warkworth Coal Mine (MTW), is an integrated operation consisting of Warkworth Mining Limited (WML) and Mount Thorley Operations (MTO) (**Figure 1**) situated 14 km southwest of Singleton, in the Upper Hunter Valley region of NSW. MTW is managed and operated by Coal & Allied (NSW) Pty Ltd, a wholly owned subsidiary of Yancoal Australia Limited (YAL). A summary of MTW tenements is shown in **Figure 2.**

2.1 Scope

This Annual Environmental Review (AER) covers the twelve-month reporting period from **1 January 2019 to 31 December 2019.**

This report summarises the environmental performance of MTW in accordance with conditions of the development consents and Mining Leases (ML) held by site. The structure of the 2019 Annual Review aligns with the *DPIE Post-approval requirements for State significant mining developments – Annual Review Guideline* (October 2015).

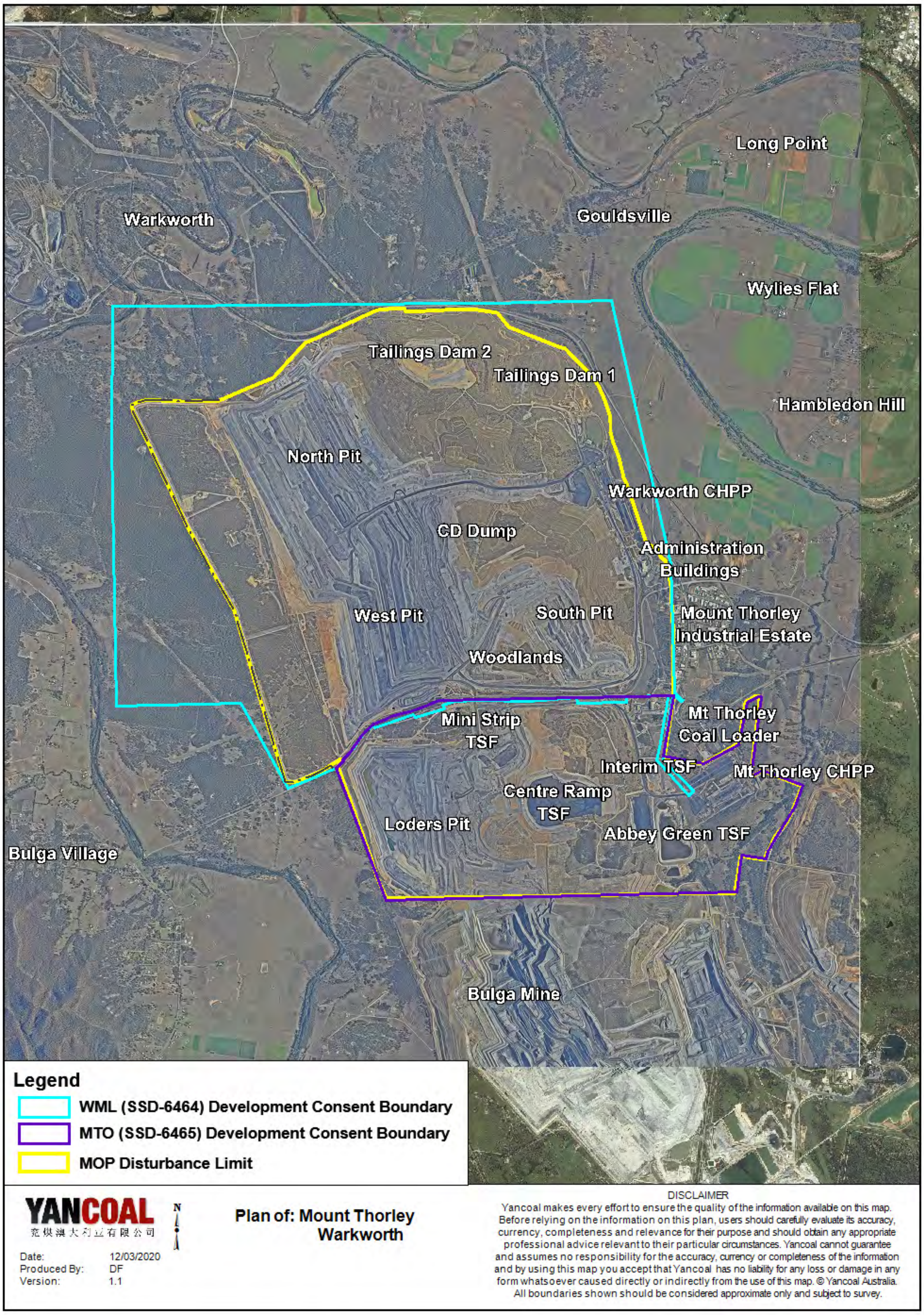


Figure 1: MTW Site Layout and Locality Plan

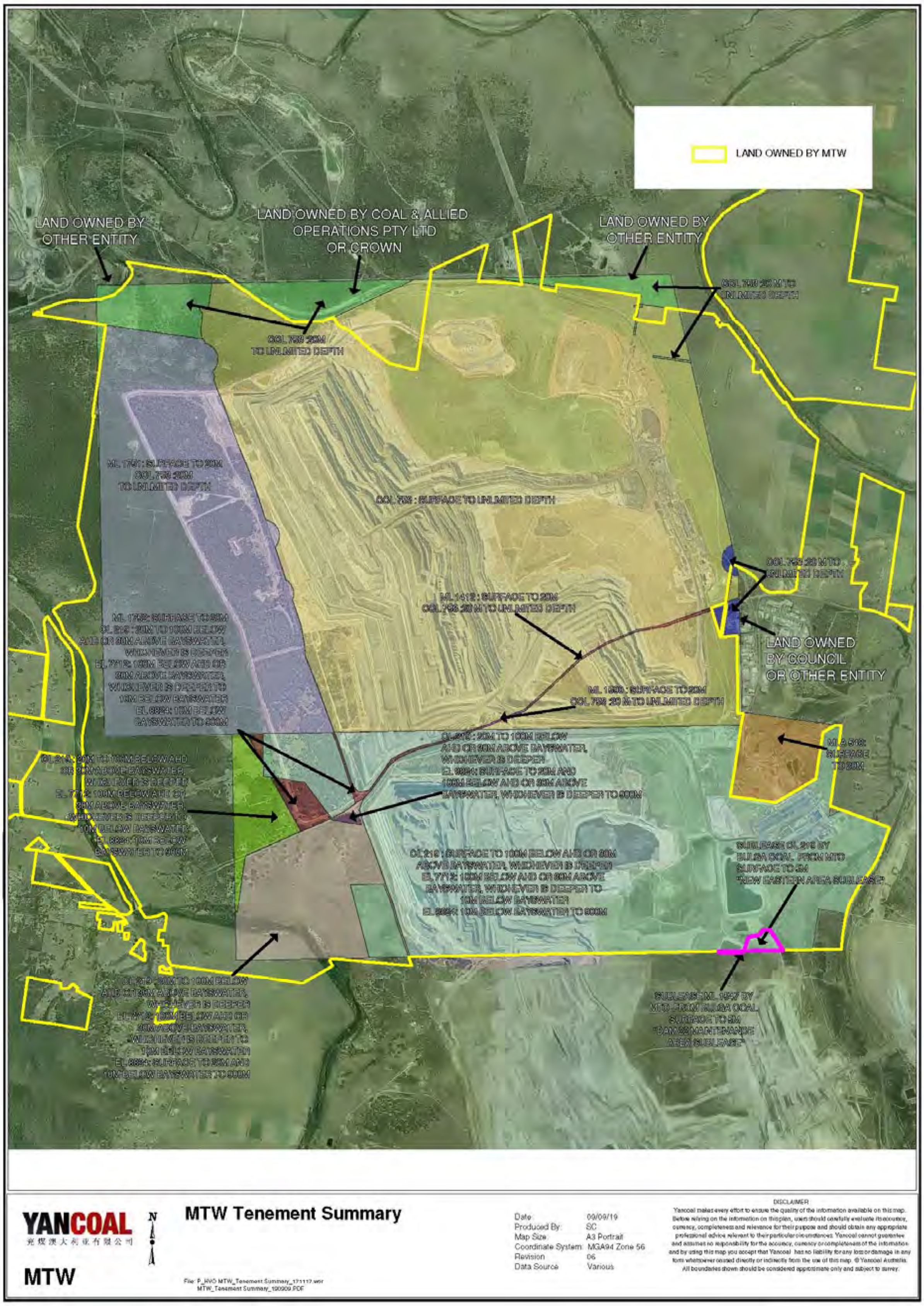


FIGURE 2: MTW TENEMENT SUMMARY

2.2 Mine Contacts

Table 2.1 outlines the contact details for site personnel responsible at Mount Thorley Warkworth.

TABLE 2.1 SITE PERSONNEL

Position	Name	Contact Number
General Manager – MTW	Jason McCallum	(02) 6570 1501
Environment & Community Manager - MTW	Gary Mulhearn	(02) 6570 1734

3 APPROVALS

3.1 Approvals, Leases and Licences

3.1.1 Current Approvals

The status of MTO and WML development consents, licenses and relevant approvals at 31 December 2019 are summarised in **Table 3.1** to **Table 3.6**.

TABLE 3.1 OPERATIONS APPROVALS- WARKWORTH

Approval Number	Description	Authority	Date of Approval / Variations
SSD-6464	Warkworth Continuation Project development consent	DPIE	26/11/2015
EPBC 2009/5081	Approval under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) to extend the existing Warkworth Coal Mine over an additional 705 hectares of land at Warkworth NSW including associated modifications to existing mine infrastructure	Commonwealth Department of the Environment and Energy	9/8/2012 – 31/3/2033 (varied on 14/10/2018)
EPBC 2002/629	Approval under the EPBC Act to construct and operate an open cut coal mine extension at the Warkworth Coal Mine	Commonwealth Department of the Environment and Energy	18/2/2004 – 25/02/2039 (varied on 6/4/2004, 24/5/2004, 19/11/2004, 13/7/2012, 14/10/2018)

TABLE 3.2 OPERATIONS APPROVALS - MOUNT THORLEY

Approval Number	Description	Authority	Date of Approval / Variations
SSD-6465	Mount Thorley Continuation Project development consent	DPIE	26/11/2015

TABLE 3.3 LICENCES AND PERMITS

Licence No	Description	Authority	Date of Approval / Variations
Warkworth			
EPL 1376	Environment Protection Licence	EPA	28/02/2020
5061122	Radiation Licence	EPA	01/07/2013
XSTR100160	Licence to Store – Explosives Act	WorkCover NSW	18/08/2019
Mount Thorley			
EPL 24	Environment Protection Licence	EPA	24/11/2016
EPL 1976	Environment Protection Licence	EPA	26/04/2019
5061110	Radiation Licence	EPA	01/07/2013

Note: Environment Protection Licences remain in force until the licence is surrendered by the licence holder or until it is suspended or revoked by the EPA or the Minister. A licence may only be surrendered with the written approval of the EPA.

TABLE 3.4 MINING TENEMENTS

Mining tenement	Type	Purpose	Status	Grant Date	Expiry Date
Warkworth					
CCL 753	Consolidated Coal Lease	Prospecting and Mining Coal	Granted	23/05/1990	17/02/2023
ML 1412	Mining Lease	Prospecting and Mining Coal	Renewal Pending	11/01/1997	10/01/2018
ML 1590	Mining Lease	Prospecting and Mining Coal	Granted	27/02/2007	26/02/2028
ML 1751	Mining Lease	Prospecting, Mining Coal and Purposes	Granted	17/03/2017	17/03/2038

Mining tenement	Type	Purpose	Status	Grant Date	Expiry Date
Mount Thorley					
CL 219	Coal Lease	Prospecting and Mining Coal	Granted	23/09/1981	23/09/2023
(Part) ML 1547	Sub-Lease	Mining Purposes	Registered	The part sublease area known as the "Dam 22 Long Term Mining Sublease" was registered on 10th January 2018 for a term until 3 April 2025.	03/04/2025
ML 1752	Mining Lease	Prospecting, Mining Coal and Purposes	Granted	17/03/2017	17/03/2038
EL 7712	Exploration Licence	Prospecting Coal	Granted (renewal pending)	23/2/2011	23/02/2020
EL 8824	Exploration Licence	Prospecting Coal	Granted	15/02/2019	15/02/2025
Mount Thorley Coal Loading Limited					
MLA 548	Mining Lease Application	Mining Purposes	Application Pending	Mining Lease Application Lodged 13/11/2017	N/A

TABLE 3.5 WATER LICENCES

Licence Number	Type	Purpose	Legislation	Description	Renewal Date
20BL168821	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: MTAGP1, MTAGP2, ABGOH07, ABGOH43, ABGOH44, ABGOH45	Perpetuity
20BL171729	Bore	Monitoring Bore	Part 5 Water Act 1912	G3	Perpetuity
20BL171841	Bore	Monitoring Bore	Part 5 Water Act 1912	OH1126	Perpetuity
20BL171842	Bore	Monitoring Bore	Part 5 Water Act 1912	OH944	Perpetuity
20BL171843	Bore	Monitoring Bore	Part 5 Water Act 1912	OH1137	Perpetuity

Licence Number	Type	Purpose	Legislation	Description	Renewal Date
20BL171844	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: OH1123 (E), OH1123 (W)	Perpetuity
20BL171845	Bore	Monitoring Bore	Part 5 Water Act 1912	OH1124	Perpetuity
20BL171846	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: OH786, OH942	Perpetuity
20BL171847	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: OH1127, OH787	Perpetuity
20BL171848	Bore	Monitoring Bore	Part 5 Water Act 1912	OH1125	Perpetuity
20BL171849	Bore	Monitoring Bore	Part 5 Water Act 1912	OH1122	Perpetuity
20BL171850	Bore	Monitoring Bore	Part 5 Water Act 1912	OH1138	Perpetuity
20BL171891	Bore	Monitoring Bore	Part 5 Water Act 1912	Bores: OH1121, OH788, OH943	Perpetuity
20BL171892	Bore	Monitoring Bore	Part 5 Water Act 1914	Bores: WOH2153 (PZ2), WOH2154 (PZ1), WOH2155 (PZ4), WOH2156 (PZ3)	Perpetuity
20BL171893	Bore	Monitoring Bore	Part 5 Water Act 1918	Bores: WOH2141 (PZ6), Ground Water Alluvial Modelling	Perpetuity
20BL171894	Bore	Monitoring Bore	Part 5 Water Act 1913	WOH2139 (PZ5)	Perpetuity
20BL172272	Bore	Monitoring Bore	Part 5 Water Act 1912	PZ9S, PZ9D	Perpetuity
20BL172273	Bore	Monitoring Bore	Part 5 Water Act 1912	PZ8S, PZ8D	Perpetuity
20BL172439	Bore	Monitoring Bore	Part 5 Water Act 1912	Windermere	Perpetuity
20BL172518	Bore	Monitoring Bore	Part 5 Water Act 1912	Windermere: MBW01, MBW02, MBW03, MBW04	Perpetuity
20BL173276	Bore	Monitoring Bore	Part 5 Water Act 1912	Windermere	Perpetuity
20BL173065	Bore	Monitoring Bore	Part 5 Water Act 1912	SR012	Perpetuity
20FW213276 (formerly 20CW802601)	Flood Work Approval	Block Dam	Water Management Act 2000	Charlton Rd Levee	23 August 2020
20WA209905 (Formerly 20SL051292)	Stream Diversion	Bywash Dams	Water Management Act 2000	Doctors Creek Bywash	31 July 2022
20CA209904 WAL - 19022	Stream Diversion	Bywash Dams	Water Management Act 2000	Sandy Hollow Creek	25 February 2023

TABLE 3.6 WATER ACCESS LICENCES

Licence Number	Description	Water Source	Water Sharing Plan	Water Source – Management Zone	Licence Allocation (ML)*
WAL963	Warkworth Mining Limited Hunter River Pump (General Security)	Hunter River	Hunter Regulated River WSP	Zone 2b (Hunter River From Wollombi Brook Junction To Oakhampton Rail Bridge)	243
WAL10543	Mount Thorley Joint Venture (MTJV) water supply scheme, held by Singleton Shire Council	Hunter River	Hunter Regulated River WSP	Zone 2b (Hunter River From Wollombi Brook Junction To Oakhampton Rail Bridge)	1,907 (MTW share is 1,009)
WAL43056	Warkworth Mining Limited (High Security)	Hunter River	Hunter Regulated River WSP	Zone 2b (Hunter River From Wollombi Brook Junction To Oakhampton Rail Bridge)	2,000
WAL10544	(Hunter Regulated River – Domestic and Stock)	Hunter River	Hunter Regulated River WSP	Zone 2b (Hunter River From Wollombi Brook Junction To Oakhampton Rail Bridge)	5
WAL18233	Old Farm	Hunter River Alluvium	Hunter Unregulated and Alluvial Water Sources WSP	Hunter Regulated River Alluvial Water Source – Downstream Glennies Creek Management Zone	5
WAL18558	Hawkes	Wollombi Brook	Hunter Unregulated and Alluvial Water Sources WSP	Lower Wollombi Brook Water Source	50
WAL19022	Sandy Hollow Creek	Unregulated River	Hunter Unregulated and Alluvial Water Sources WSP	Singleton Water Source	60
WAL40464 (previously 20BL170011)	Mt Thorley Pit Excavation	Permian Coal Seams	North Coast Fractured and Porous Rock Groundwater Sources WSP	Sydney Basin – North Coast Groundwater Source	180

Licence Number	Description	Water Source	Water Sharing Plan	Water Source – Management Zone	Licence Allocation (ML)*
WAL40465 (previously 20BL170012)	Warkworth Pit Excavation	Permian Coal Seams	North Coast Fractured and Porous Rock Groundwater Sources WSP	Sydney Basin – North Coast Groundwater Source	750

** Licence allocations are for 1 July to 30 June reporting year. Actual usage can exceed licence allocation in the table above if carryover provisions are available and have been applied during the water year.*

3.1.2 Management Plans, Programmes and Strategies

Table 3.7 details the management plans and strategies which are required under the Warkworth (SSD-6464) and Mount Thorley (SSD-6465) Development Consent instruments.

A Mining Operations Plan (MOP) was developed to replace the previous MOP and cover the existing MTW operations, as well as the approved operations outlined in the Environmental Impact Statements for the Warkworth Continuation 2014 and Mt Thorley Operations 2014. The MOP outlines the proposed operational and applicable environmental management activities planned for MTW. Details regarding the submission and approval dates for the current MOP are shown in **Table 3.8**.

TABLE 3.7 STATUS OF MANAGEMENT PLANS REQUIRED UNDER WARKWORTH CONTINUATION (SSD-6464) AND MOUNT THORLEY OPERATIONS (SSD-6465) DEVELOPMENT CONSENTS

Plan / Program / Strategy	Status (approval date)
Air Quality Management Plan	28/08/2019
Noise Management Plan	28/08/2019
Blast Management Plan	28/08/2019
Water Management Plan	20/09/2018
WML Biodiversity Management Plan	20/09/2018
Rehabilitation Management Plan (addressed in MOP)	11/06/2019 (MOP Amendment B)
Environmental Management Strategy	28/08/2019
MTW Historic Heritage Management Plan	11/10/2017
MTW Aboriginal Heritage Management Plan	28/08/2019
Wollombi Brook Aboriginal Cultural Heritage Conservation Area Conservation Management Plan	11/10/2017
Loder Creek Aboriginal Cultural Heritage Conservation Area Plan of Management	19/03/2019
Management Plan for Goulburn River Biodiversity Area	30/04/2018 (DP&E)
Management Plan for Bowditch Biodiversity Area	30/04/2018 (DP&E)
Management Plan for Southern Biodiversity Area	30/04/2018 (DP&E)
Management Plan for Northern Biodiversity Area	26/06/2017 (DP&E)

Plan / Program / Strategy	Status (approval date)
Management Plan for North Rothbury Biodiversity Area	30/04/2018 (DP&E)
Warkworth Sands Woodland Integrated Management Plan	Pending (Submitted to OEH 15/02/2017)
Warkworth Sands Woodland Performance Criteria	Pending (Submitted to OEH 15/02/2017)

TABLE 3.8 MOP APPROVAL STATUS FOR MOUNT THORLEY WARKWORTH

Mining Operations Plan	Date Submitted	Date Approved
Mount Thorley Warkworth MOP Amendment A 2018 - 2021	11/10/2018	14/12/2018
Mount Thorley Warkworth MOP Amendment B 2018 - 2021	23/5/2019	11/6/2019

4 OPERATIONS DURING THE REPORTING PERIOD

4.1 Summary of Mining Activities

Areas to be mined are geologically modelled, a mine plan is formed and the relevant mining locations are surveyed prior to mining. **Figure 3** illustrates the mining process. MTW have no active underground workings.

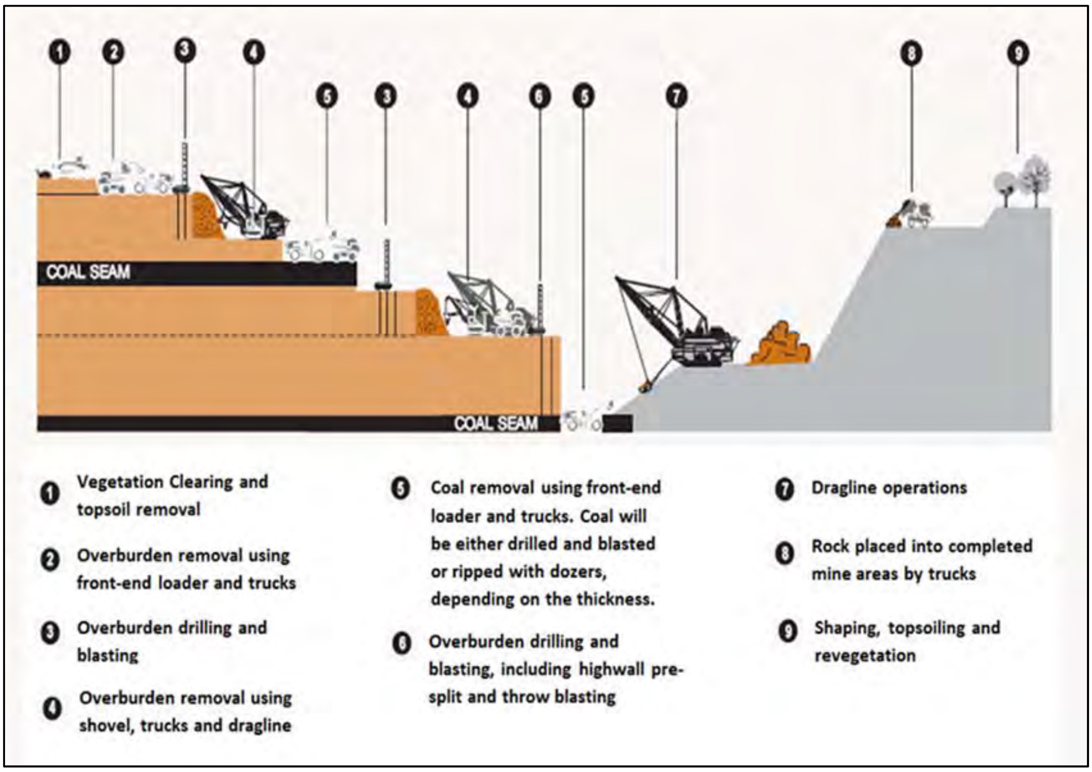


FIGURE 3: MINING PROCESS

Within Warkworth, mining activities will continue to advance in a westerly direction in both North and West Pits. South Pit has reached its final limit with regards to excavation. This area is currently being utilised for dumping activity. Within Mount Thorley, two small areas in the northern and southwestern extents of the mining lease will reach their final limits during 2020 with remaining reserves to be mined to depth during 2020. Exploration drilling was conducted within the relevant mining leases ahead of mining and within the pit to gain further information on the resource. All mining related activity is in line with the current MOP.

The planned 2020 production and waste schedule for MTW is summarised below:

- 18.1 Mt ROM coal;
- 12.3 Mt Product coal;
- 127 Mbcm overburden (including rehandle); and
- 5.5 Mt Tailings and reject

The forecasted ROM coal production represents approximately 65% of the approved maximum ROM coal production for MTW. Coal will continue to be transported via conveyer to the Mount Thorley Coal Loader and railed to the port.

4.2 Mineral Processing

All processing and rejects/tailings disposal activities undertaken in 2019 were consistent with the approved MOP and no changes were made to the processing and rejects/tailings disposal methods.

Currently active tailing emplacements include the Centre Ramp Tailings Storage Facility and Abbey Green South Tailings Storage Facility. Tailings Dam 2 was previously used to receive ash from Redbank Power Station but ceased in July 2014 following the cessation of operations at Redbank Power Station. During 2019 capping works on Tailings Dam 2 continued.

4.3 Production Statistics

Approved extraction of up to 28 million tonnes of ROM coal from MTW is permitted in a calendar year, comprising up to 18 million tonnes of ROM coal from the Warkworth Mine and 10 million tonnes from the Mount Thorley Mine. MTW Production Statistics for the previous, current and future reporting period are summarised in **Table 4.1.**

TABLE 4.1 SUMMARY OF PRODUCTION AT MTW IN 2019

Material	Approved Limits	Reporting Period 2018	Reporting Period 2019	Forecast for 2020
Prime Overburden Waste (kbcm)	N/A	98,568	96,765	107,119
MTO ROM Coal (Mtpa)	10 (SSD-6465)	3.02	0.71	0.57
WML ROM Coal (Mtpa)	18 (SSD-6464)	14.59	16.90	17.57
ROM Coal (Mtpa)	28 (Combined)	17.61	17.61	18.14
Coarse Reject (kt)	N/A	4,306	4,236	4,437
Fine Reject – Tailings (kt)	N/A	1,070	1,196	1,109
Product (kt)	N/A	12,121	12,000	12,317

All product coal was transported by rail. MTW transported 11,910 kt of product coal via rail during the 2019 reporting period.

4.4 Summary of Changes (Developments and Equipment Upgrades)

In 2019 a Liebherr R9800 excavator was purchased ultimately as a replacement for Shovel 342 (P&H 4100A) which is nearing the end of its life.

5 ACTION(S) REQUIRED FROM PREVIOUS ENVIRONMENTAL MANAGEMENT REVIEW

An annual environmental inspection was undertaken by the Resources Regulator on 17 June 2019. **Table 5.1** below summarises the actions required following this inspection. The actions were required to be completed by 30 September 2019.

TABLE 5.1 ACTION(S) FROM/FOLLOWING THE PREVIOUS ANNUAL REVIEW

Action Required	Requested by	Section of Annual Review
Engage a suitably qualified independent person(s) to prepare and submit a report (Report) to the satisfaction of the Regulator which: 1. assesses the adequacy of progressive rehabilitation strategies carried out within Authorisations CL 219 and CCL 753 (Mining Act 1973), ML 1412, ML 1590, ML 1751, Ml 1752 (Part) and ML 1547 (Mining Act 1992) and performance against the implementation of those progressive rehabilitation strategies to date. The assessment must assess performance at each phase of rehabilitation as specified in the approved Mining Operation Plan (MOP). 2. provides a plan(s) displaying the status of progressive rehabilitation within the Authorisations. This must include: 1. The rehabilitation domains as described in the MOP and provide a general background for each, including area, rehabilitation commencement year, target revegetation type (i.e. whether pasture or woodland); 2. The current rehabilitation phase for each domain; 3. The current expected year of completion of each rehabilitation phase for each domain until relinquishment of the Authorisations. 3. outlines any proposed measures or actions to improve progressive rehabilitation performance within the Authorisations. 4. provides a timeline and outline of the implementation of works for the proposed measures/actions.	Resources Regulator, NSW Department of Planning, Industry and Environment	7.12

6 ENVIRONMENTAL MANAGEMENT AND PERFORMANCE

6.1 Meteorological Data

Meteorological data is collected to assist in day to day operational decisions, planning, and environmental management and to meet development consent requirements. MTW operates a real time meteorological (weather) station located on Charlton Ridge. The meteorological station measures wind speed, wind direction, temperature, humidity, solar radiation, rainfall, and sigma theta. Instruments are installed, calibrated, and maintained according to the relevant Australian Standard AS 3580.14 (2011). Meteorological data is available to site personnel and provides mining operations with trend assessment details to inform operational decisions aimed at minimising impacts. Daily Meteorological data summaries are presented in the Monthly Environmental Monitoring reports, available via the MTW website: http://insite.yancoal.com.au.

6.2 Noise

6.2.1 Noise Management

MTW manages noise to ensure compliance with permissible noise limits at nearby private residences. A combination of both proactive and reactive control mechanisms is employed on a continuous basis to ensure effective management of noise emissions is maintained. Noise management strategies and processes employed at MTW are detailed in the MTW Noise Management Plan available for viewing via the MTW website: http://insite.yancoal.com.au.

MTW's 2019 noise performance metrics are shown below:

- Community noise complaints received – reduced by ~35% from 2018
- Number of Community Response Officer (CRO) (supplementary) noise measurements which exceed the internal trigger level for action – increased to 94 from 38 in 2018; and
- Number of equipment downtime hours logged in response to noise management triggers – increased by ~ 11% from 2018.

A range of noise management projects and processes were undertaken during 2019. These are described herein.

6.2.1.1 Real Time Noise Management

MTW's Real-Time noise management framework provides an effective tool for managing instances of elevated noise, ensuring compliance is maintained, and responding to community concerns.

MTW utilise CROs to provide an interface between the mine and community. They are effective in implementing the management framework, validating real-time alerts through supplementary

handheld noise measurements and audible observations, driving operational change as required, and responding to community complaints. A summary of supplementary handheld noise measurements conducted by the CROs in 2019 is presented in **Table 6.1**.

MTW's "InSite" website allows members of the general public to access noise, meteorological, air quality data as well as any operational changes made during shift via MTW's interactive website. Viewer access: http://insite.yancoal.com.au

TABLE 6.1 SUMMARY OF SUPPLEMENTARY ATTENDED NOISE MONITORING CONDUCTED BY COMMUNITY RESPONSE OFFICERS 2019

Monitoring Location	Number of Assessments	Number of measurements >WML trigger^	Number of measurements > MTO trigger^	Average WML noise level ($L_{Aeq\ 5min}$ dB(A))*	Average MTO noise level ($L_{Aeq\ 5min}$ dB(A))*
Wollemi Peak Road (Bulga RFS)	1072	41	13	33.4	32.9
Bulga Village	651	3	-	32.4	31.1
Inlet Road	671	27	1	33.4	32.4
Inlet Road West	407	-	-	30.1	27.7
Long Point	1133	5	-	31.1	30.6
South Bulga	0	-	-	-	-
Wambo Road	305	4	-	33.5	31.7
Total	4239	80	14	-	-

^Triggers are internally set thresholds for operational response and are specified in the MTW Noise Management Plan. The number of measurements greater than the trigger cannot be used an assessment or interpretation of compliance. A compliance assessment is provided in Sections 6.2.2 and 6.2.2.1.

**Average noise levels do not take account of measurements taken where the noise source of interest was recorded as inaudible.*

In response to the events listed in **Table 6.1** which exceeded the trigger, up to 1203 hours of equipment downtime were recorded to manage noise during 2019. This is an increase (approximately 11%) to the number of downtime hours recorded in 2018 coinciding with an increase in the number of supplementary noise measurements completed which exceed the trigger for management action.

6.2.2 Noise Performance

A total of 98 compliance measurements were undertaken by an independent acoustic specialist in accordance with the MTW Noise Monitoring Programme during the reporting period. Each measurement involves an assessment of mine noise against the various L_{Aeq}, 15 minute and L_{A1}, 1min noise criteria. Noise monitoring results are presented in the Monthly Environmental Monitoring Reports, available via the MTW website http://insite.yancoal.com.au.

In accordance with Fact Sheet C of the Noise Policy for Industry (NPfI), MTW has assessed measured noise levels collected during the attended compliance programme for low frequency content, and applied the modifying factor correction where applicable.

The application of the modifying factor resulted in one (1) exceedance of the WML L_{Aeq} Impact Assessment Criteria (refer to **Table 6.2)** during the reporting period on 17 January 2019 at 21:41 at Inlet Road**.** A subsequent measurement was taken at 22:40, on the same night. The re-measure confirmed compliance was achieved with the L_{Aeq},15minute criteria. Follow up monitoring was conducted on the night of 24 January 2019, which complied with the L_{Aeq},15minute criteria and no further action was required. As both the re-measure and follow up monitoring were compliant, the initial exceedance does not constitute a non-compliance, as per MTW's approved Noise Management Plan. DPIE were notified in writing of the exceedance on 18 January 2019, and the result of follow up monitoring on 25 January 2019.

TABLE 6.2 ATTENDED NOISE MEASUREMENTS EXCEEDING CONSENT CONDITIONS FOLLOWING APPLICATION OF NPFI LOW FREQUENCY MODIFYING FACTOR

Location	Date/Time	Relevant Criteria	Criterion (dB)*	L_{Aeq}(dB)	Revised L_{Aeq} (dB)	Exceeds by (dB)
Inlet Road	17/01/2019 21:41	WML L_{Aeq} impact assessment criteria	37	37	39	2

6.2.2.1 Comparison against Last Years' Results

A comparison of non-compliances and exceedances between years is used as a measure of the effectiveness of noise management measures employed on site.

Details of this comparison are provided in **Table 6.3** which demonstrates a continuation of the effective management delivered in 2019.

TABLE 6.3 COMPARISON OF 2019 NOISE MONITORING RESULTS AGAINST PREVIOUS YEARS'

Year	Number of assessments	Number of exceedances)	Number of non-compliances
2019	588	1	0
2018	594	1	0
2017	576	0	0
2016	576	0	0
2015	665	0	0
2014	700	0	0
2013	456	11	7
2012	562	13	3
2011	572	11	4
2010	561	3	3
2009	569	10	4

Given the large dataset available, a comparison between the results collected through the supplementary noise monitoring regime from year to year is also considered valuable. The data shows increases in the number of assessments made, coinciding with an increase in the number of measurements exceeding the WML and MTO noise management triggers (shown in **Table 6.4** below) and a general increase in the average WML noise levels. This also coincided with up to an 11% increase in equipment stoppages due to noise delays.

TABLE 6.4 COMPARISON OF CRO (SUPPLEMENTARY) NOISE MEASUREMENT PERFORMANCE

Monitoring Location	Number of Assessments		Number of Measurements >WML Trigger^		Number of Measurements > MTO Trigger^		Average WML Noise Level ($L_{Aeq\ 5min}$ dB(A))*		Average MTO Noise Level ($L_{Aeq\ 5min}$ dB(A))*	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Wollemi Peak Road (Bulga RFS)	1075	1072	13	41	3	13	32.6	33.4	32.1	32.9
Bulga Village	609	651	1	3	-	-	31.8	32.4	30.9	31.1
Inlet Road	499	671	13	27	-	1	33.3	33.4	31.9	32.4
Inlet Road West	290	407	1	-	-	-	29.7	30.1	28.5	27.7
Long Point	1000	1133	1	5	-	-	30.1	31.1	30.9	30.6
South Bulga	0	0	-	-	-	-	-	-	-	-
Wambo Road	112	305	6	4	-	-	35.2	33.5	32.3	31.7
Total	3594	4239	35	80	3	14	-	-	-	-

^Triggers are internally set thresholds for operational response and are specified in the MTW Noise Management Plan. The number of measurements greater than the trigger cannot be used an assessment or interpretation of compliance. Compliance assessment is provided in 6.2.3 and 6.2.4.

**Average noise levels do not take account of measurements taken where the noise source of interest was recorded as inaudible.*

6.2.2.2 Comparison against EA Predictions

Table 6.5 provides a comparison of 2019 attended monitoring data and the predicted noise levels modelled in the 2014 Warkworth Continuation EIS. Comparison has been made against the modelled worst-case noise levels for Year 3 of the development (nominally 2017). The comparison data has been sourced from the modelled noise levels at the nearest residential receivers to the current monitoring locations. Reported 2019 data is the calculated quarterly average of WML contribution to measured LAeq (15 minute) results obtained through compliance assessment (irrespective of applicability of noise criteria due to meteorological conditions).

Where a monitoring event has been assessed as being "inaudible" or "not measurable", a conservative value of 25dB has been used to calculate the LAeq average for the quarter. The comparison shows that measured noise is lower than that predicted.

TABLE 6.5 PREDICTED NIGHT TIME WML (EIS 2014) LAEQ (15 MINUTE) NOISE LEVELS AND AVERAGED 2019 MONITORING RESULTS

Monitoring Location	Year 3 Modelled Noise	Quarter 1 2019 average	Quarter 2 2019 average	Quarter 3 2019 average	Quarter 4 2019 average
	$L_{Aeq\ (15\ minute)}$ (dB)	$L_{Aeq\ (15\ minute)}$ (dB)	$L_{Aeq\ (15\ minute)}$ (dB)	$L_{Aeq\ (15\ minute)}$ (dB)	$L_{Aeq\ (15\ minute)}$ (dB)
Wollemi Peak Road*/Bulga RFS	≤38	25.0	26.3	28.0	25.0
Bulga Village	≤38	28	26.7	28.7	25.0
Gouldsville Road	≤35	28.3	26.7	28.0	28.3
Inlet Road	≤37	31.5	27.3	29.0	27.7
Inlet Road West*	≤35	25.0	25.0	26.7	27.0
Long Point*	≤35	26.0	25.0	25.0	25.0
South Bulga	≤38	25.0	25.0	25.0	25.0
Wambo Road	≤38	28.3	27.0	27.7	25.0

**Denotes – No nearby receiver location modelled*

6.3 Blasting

6.3.1 Blast Management

During the reporting period, the MTW blast monitoring network operated in accordance with AS2187.2-2006 to measure ground vibration and air blast overpressure of each event at a high sampling frequency. Monitors function as regulatory compliance instruments in accordance with the MTW Blast Monitoring Programme (appended to Blast Management Plan) and are located on (or in locations representative of) privately owned land. During 2019 monitors were located at:

- Abbey Green (Abbey Green Station, Putty Road, Glenridding);
- Bulga Village (Wambo Road, Bulga);
- Putty Road, Mount Thorley (known as MTIE)
- Wambo Road (Wambo Road, Bulga);
- Warkworth Village (former Warkworth Public School, Warkworth); and
- Wollemi Peak Road (intersection of Putty & Wollemi Peak Roads, Bulga).

These locations are shown on **Figure 4** below.

FIGURE 4: BLAST MONITORING LOCATIONS

6.3.2 Blast Performance

During the reporting period 250 blast events were initiated at MTW. One (**1**) blast event on **4 April 2019** recorded an air blast overpressure result of **121.2 dB(L),** exceeding the 120 dB(L) threshold for air blast overpressure at the Warkworth monitoring location.

A preliminary notification of the suspected airblast overpressure exceedance was reported to the DPIE and to the EPA on 5 April 2019. A written report was subsequently provided to DPIE and to the EPA for this blast which concluded that "The reason that the AOP level that resulted at the Warkworth monitoring station was greater than predicted was due to the fact that the actual meteorological data, and hence the actual effects of meteorology, were different from that predicted." WML received a penalty notice for the AOP exceedance incident, which was received in September 2019. The penalty notice was issued by DPIE for a non-compliance of the blasting limits of the Warkworth Development Consent (SSD 6464). Further details on this incident and the actions taken by MTW are provided in **Section 10.**

On 7 August 2019 a blast was detonated in the North Pit of the Warkworth Mine. The resulting blast dust travelled to the east over land associated with Warkworth Coal Mine, Putty Road, and the Mount Thorley Industrial Estate before dissipating over farmland east of the licenced premises. Further details on this incident and the actions taken by MTW are provided in **Section 10.**

During the reporting period 16 blast events were initiated at MTO. Of the 16 blasts, a single blast vibration result at the Wollemi Peak Road monitor on 10 December 2019 was recorded in the range of 5-10mm/s (actual result 5.67mm/s). Due to the small number of blasts at MTO, this has resulted in 6.3% of blasts at the Wollemi Peak Road monitoring location being in the range of 5-10mm/s, which is greater than the requirements of development consent SSD-6465 which permits up to 5% of blasts to record in the range of 5-10mm/s in a 12 month period.

The non-compliance was reported to DPIE and to the EPA (via the MTO Annual Return). An investigation undertaken into the 10 December 2019 vibration result identified that ground conditions related to drought conditions and a presplit shot fired shortly after the main production shot, may have both contributed to a higher than predicted result. Further details on this incident and the actions taken by MTW are provided in **Section 10.**

Road closures occurred for all blasts within 500 metres of a public road. Public roads were also closed on occasions to mitigate potential impact upon road users from dust or when blast fume management zones encompassed public roads.

In accordance with Schedule 3, Conditions 9 and 10 of SSD-6464, Warkworth Mining Limited carried out blasting on site between 7am and 5pm Monday to Saturday inclusive. No blasts occurred on Sundays or on public holidays. Warkworth Mining Limited carried out not more than 3 blasts per day and not more than 12 blasts per week (averaged over a calendar year).

In accordance with Schedule 3, Conditions 7 and 8 of SSD-6465, Mt Thorley Operations Limited carried out blasting on site between 7am and 5pm Monday to Saturday inclusive. No blasts occurred on Sundays or on public holidays. Mt Thorley Operations carried out not more than 2 blasts per day and not more than 6 blasts per week (averaged over a calendar year).

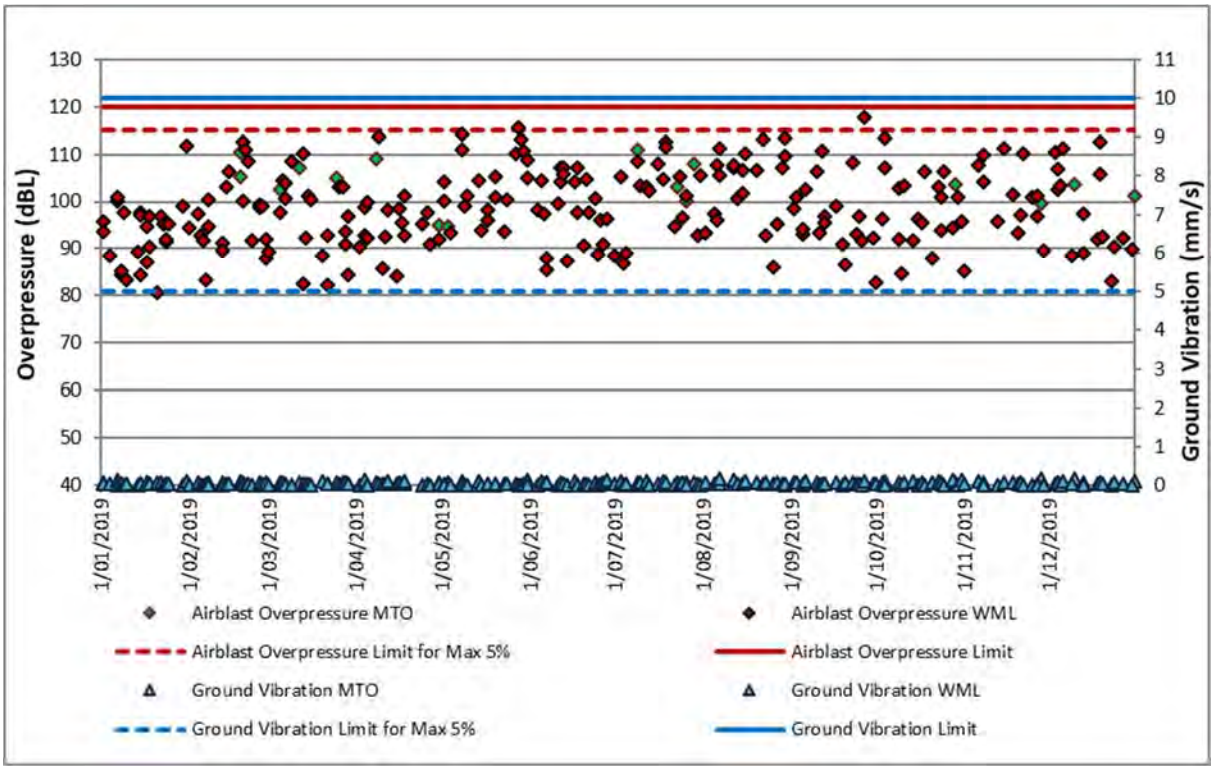


FIGURE 5: ABBEY GREEN BLAST RESULTS

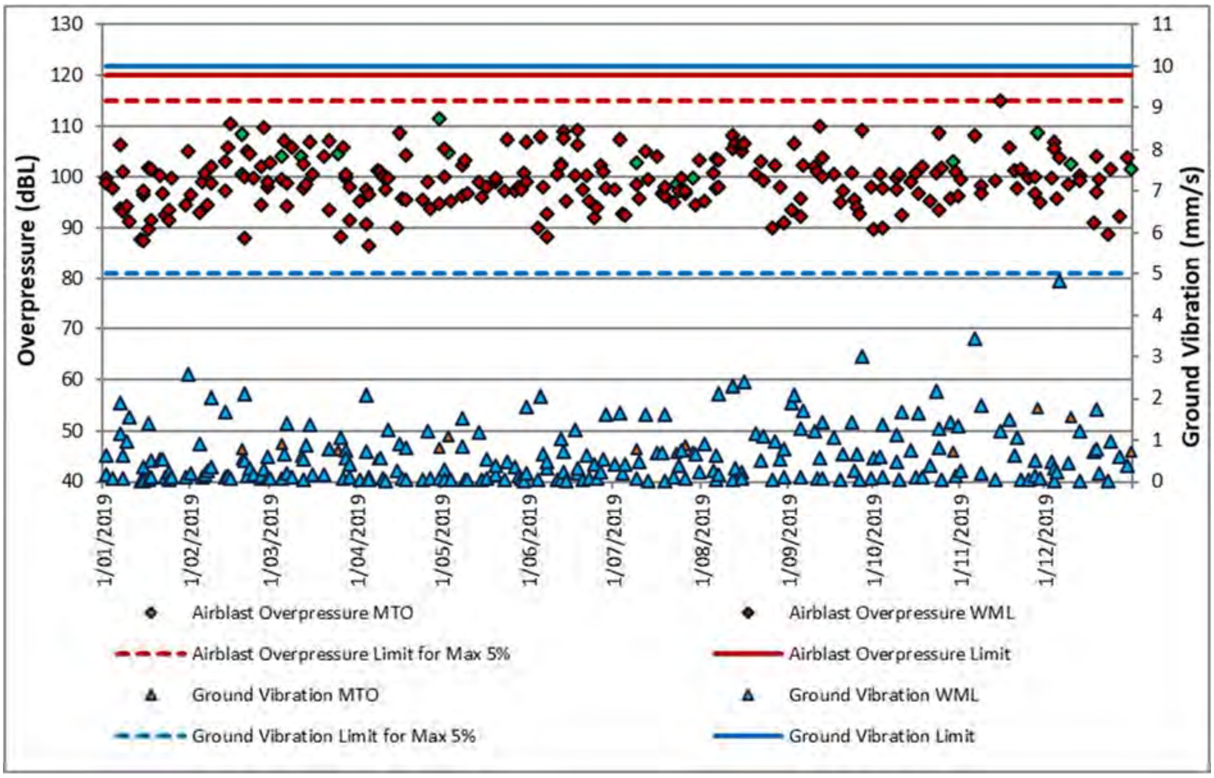


FIGURE 6: BULGA VILLAGE BLAST RESULTS

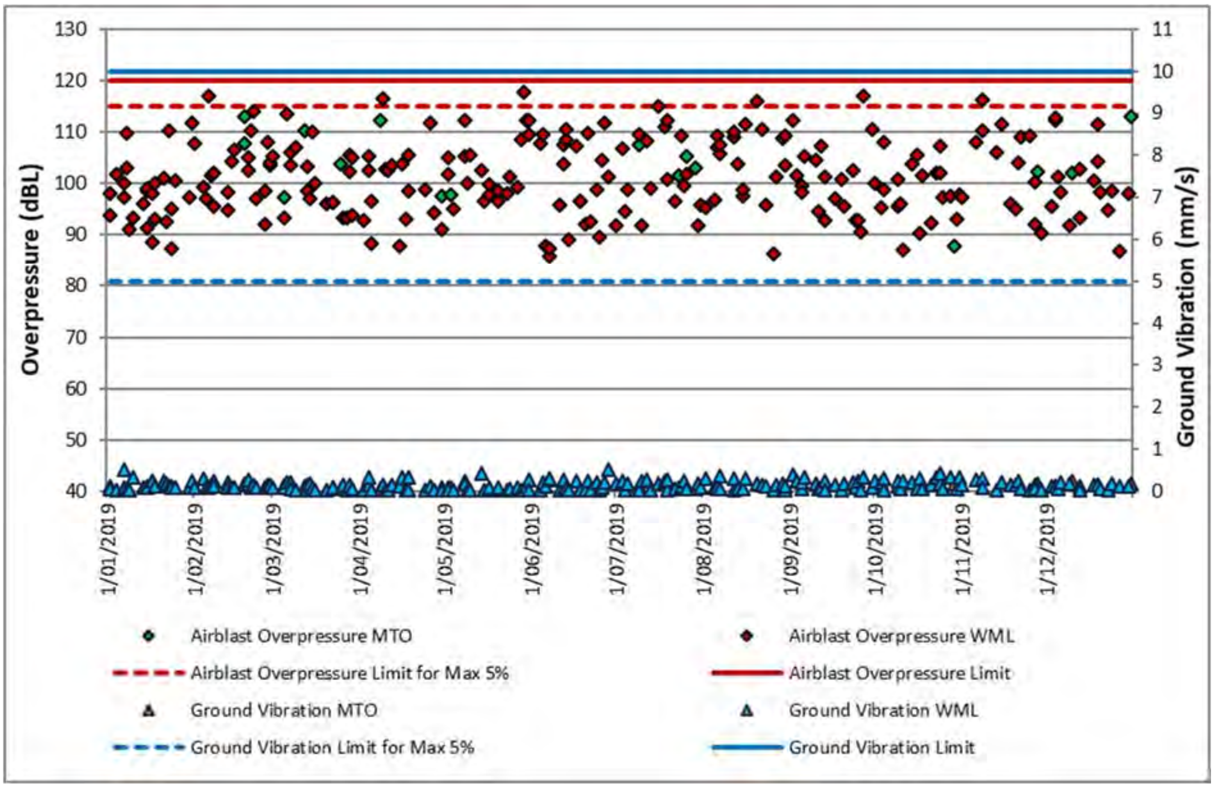


FIGURE 7: MTIE BLAST RESULTS

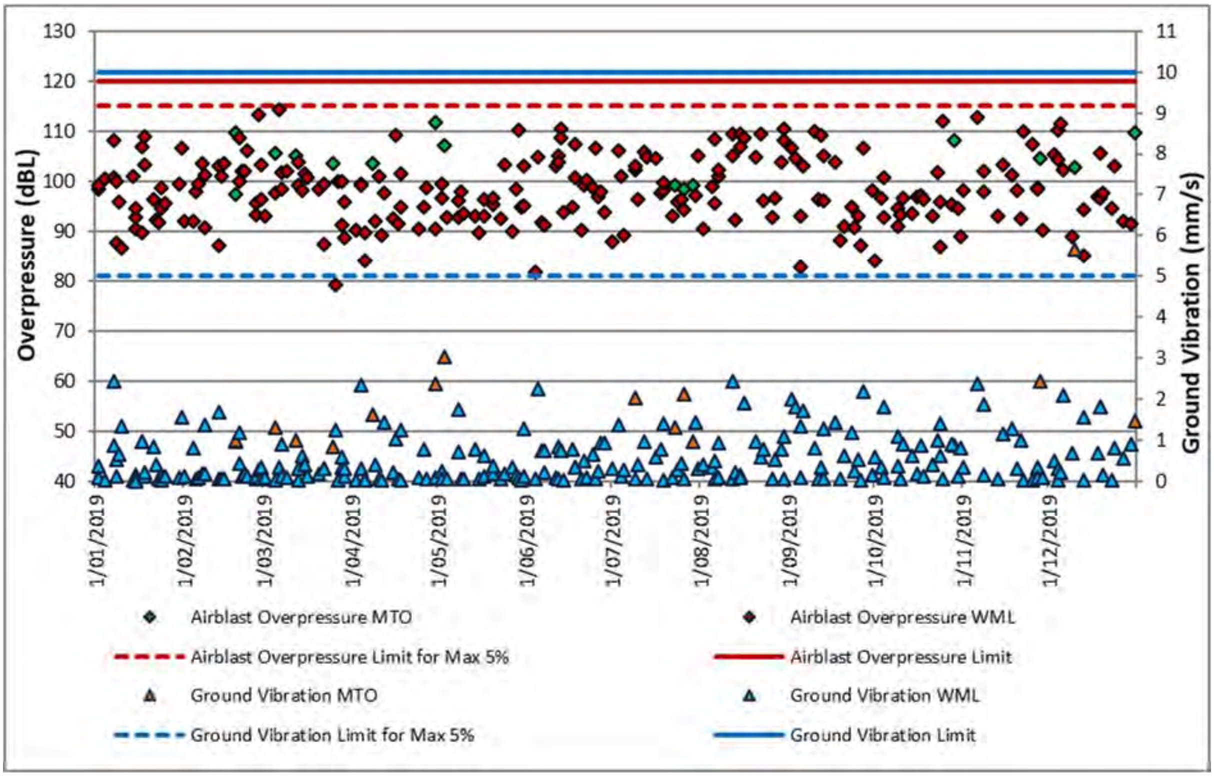


FIGURE 8: WOLLEMI PEAK ROAD BULGA BLAST RESULTS

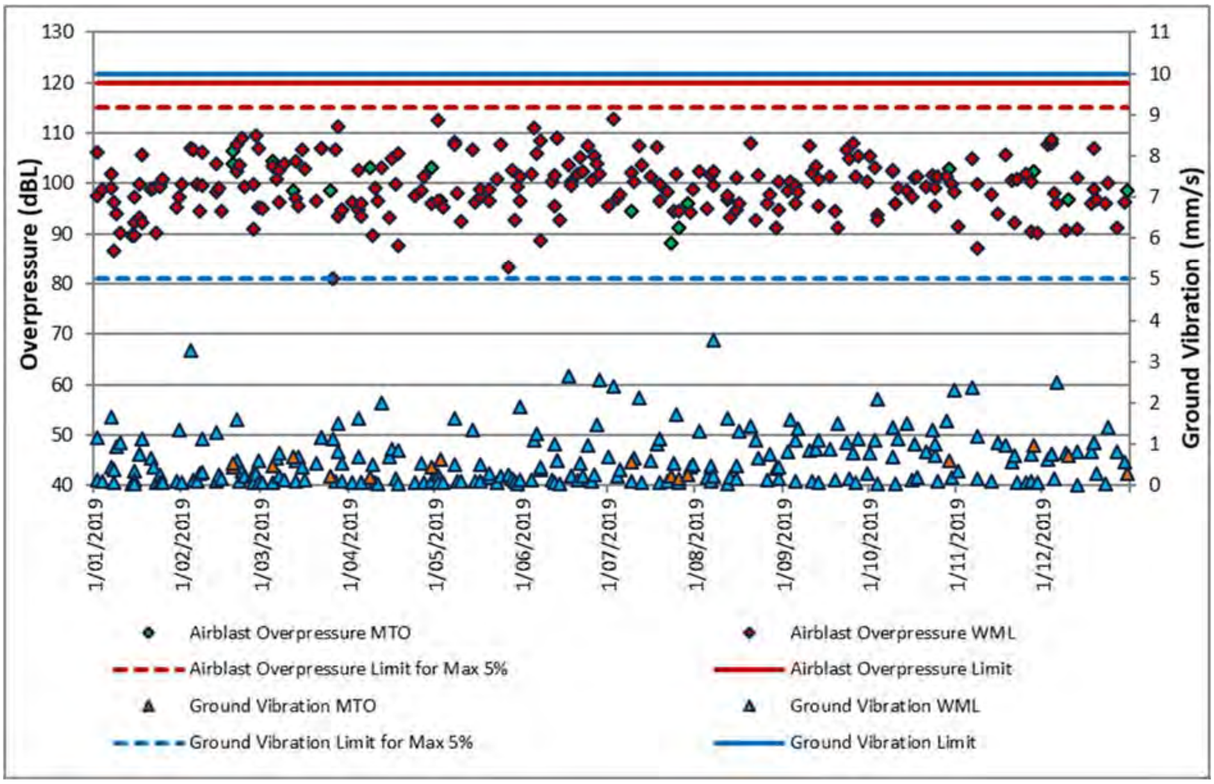


FIGURE 9: WAMBO ROAD BLAST RESULTS

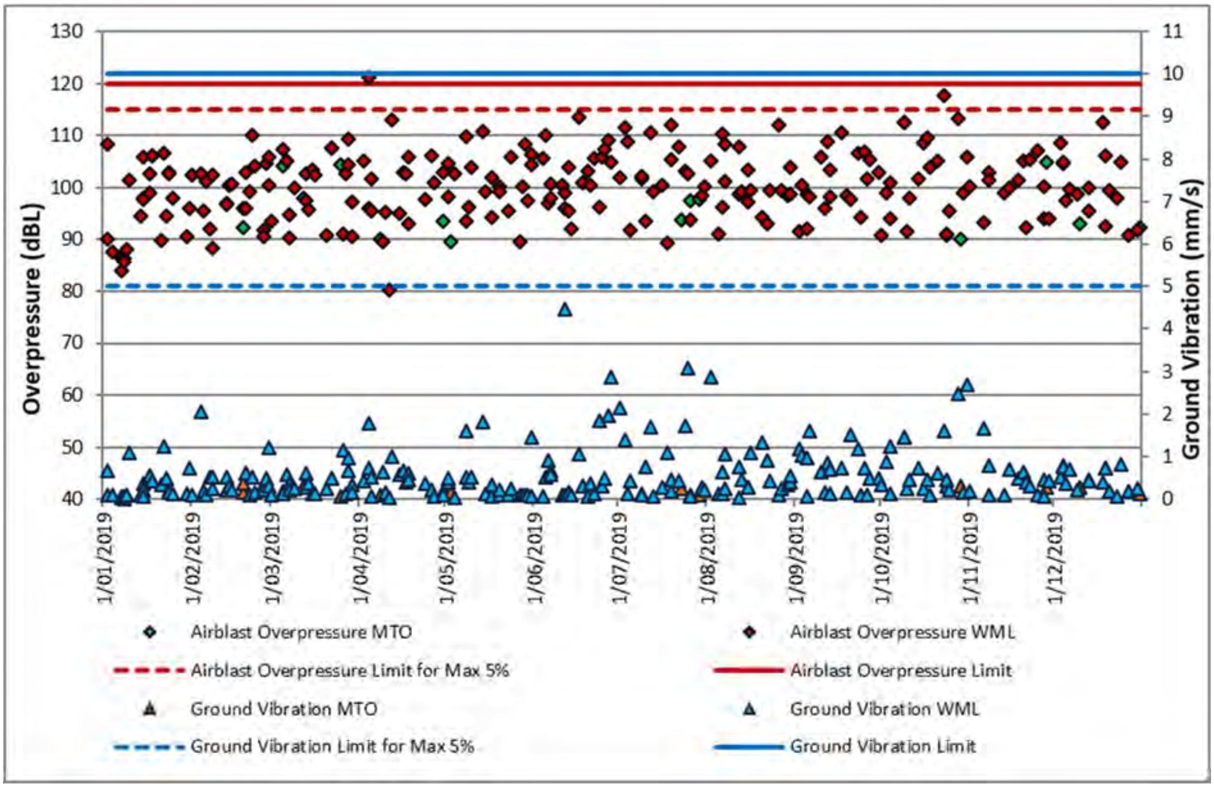


FIGURE 10: WARKWORTH BLAST RESULTS

6.3.2.1 Blast Fume Management

MTW operates a Post Blast Fume Generation Mitigation and Management Plan. This document outlines the practices to be utilised to reduce generation of post blast fume, and reduce potential offsite impact from any fume which may be produced. This includes risk assessment of the likelihood of fume production, specialised blasting design, appropriate product selection, on-bench water management, implementation of fume management zones and use of blasting permissions to identify likely path of any fume which may be produced.

All blasts are observed for fume and any fume produced is ranked according to the Australian Explosive Industry & Safety Group (AEISG) Scale. During 2019, no blasts produced visible post-blast fume with a post-blast ranking Level 4 or higher according to the AEISG Scale.

Rankings for visible blast fume according to the AEISG scale for shots fired during 2019 and comparison to rankings distribution during previous years is provided in **Table 6.6.**

TABLE 6.6 VISIBLE BLAST FUME RANKINGS ACCORDING TO THE AEISG COLOUR SCALE

AEISG Ranking	2019	2018	2017
0	269	280	329
1	16	26	31
2	7	15	25
3	1	2	2
4	0	0	1
5	0	0	0
Total*	293	323	378

** Where a number of individual blasts were fired as a blast event, fume was assessed for each individual blast pattern rather than for the event as a whole.*

6.3.2.2 Comparison of Monitoring Results Against Previous Years' Performance and EA Predictions

Blasting results recorded in 2019 are similar to results recorded in previous years and are generally consistent with EA predictions.

6.4 Air Quality

6.4.1 Air Quality Management

Air quality management at MTW is prescribed by the Air Quality Management Plan (available at http://insite.yancoal.com.au), the management plan:

- Describes procedures required to ensure compliance with the approval conditions relating to air quality including the measures that MTW will use to manage air quality;
- Details the management framework and mitigation actions to be taken while operating; and
- Provides a mechanism for assessing air quality monitoring results against the relevant impact assessment criteria.

6.4.1.1 Real-Time Air Quality Management

MTW's real-time air quality monitoring stations continuously log information and transmit data to a central database, generating alarms when particulate matter levels exceed internal trigger limits.

4,478 real-time alarms for air quality and wind conditions were received and acknowledged during 2019. In response, **6,762** hours of equipment downtime was recorded due to air quality management. A detailed breakdown of air quality related equipment stoppages (per month, per equipment type) is presented in **Figure 11**.

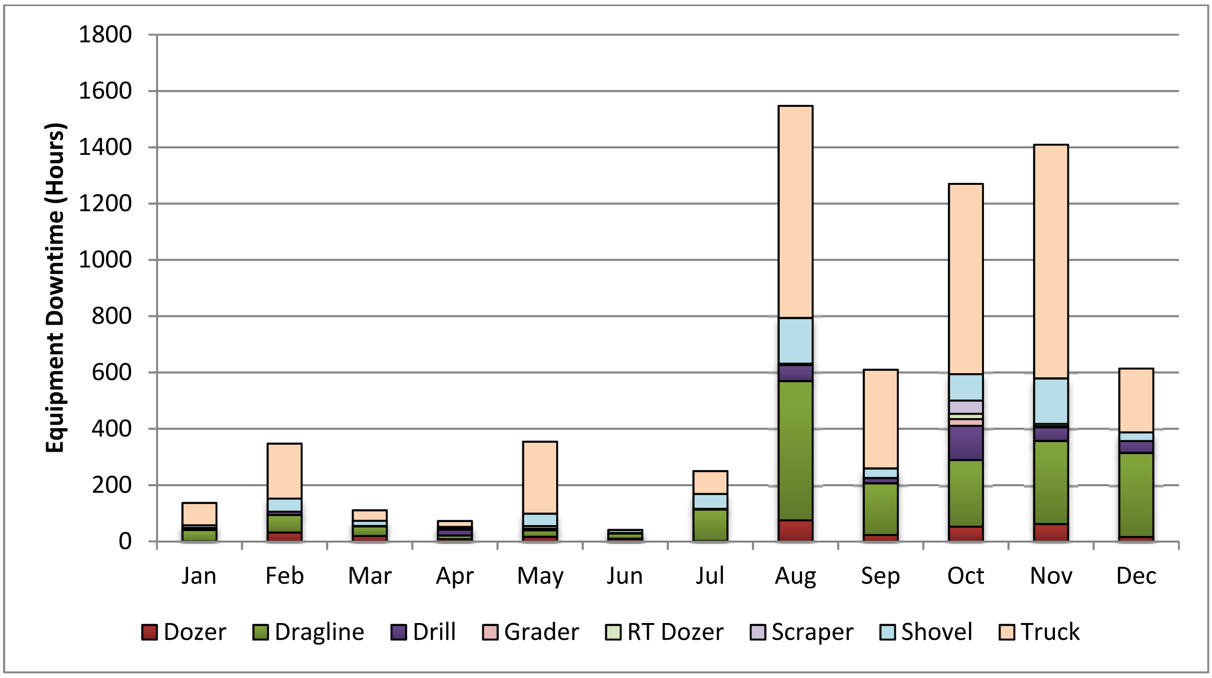


FIGURE 11: EQUIPMENT DOWNTIME FOR DUST MANAGEMENT BY MONTH (2019)

6.4.2 Air Quality Performance

6.4.2.1 Air Quality Monitoring

Air quality monitoring at MTW is undertaken in accordance with the MTW Air Quality Monitoring Programme and protocol for evaluating non-compliances. The monitoring network comprises an extensive array of monitoring equipment which is utilised to assess performance against the relevant conditions of MTW's approvals and EPL's. Air quality monitoring locations are shown in **Figure 12**. During 2019, MTW complied with all short term and annual average air quality criteria.

Air quality compliance criteria are shown in **Table 6.7,** along with a summary of MTW's performance against the criteria. Whilst MTW operates under two separate planning approvals the following compliance assessment has been undertaken on a 'whole of MTW site' basis, rather than individually assessing the contribution of each approval area to the measured results.

Air quality monitoring data is made publicly available through the MTW Monthly Environmental Monitoring Report and daily data can be accessed on http://insite.yancoal.com.au

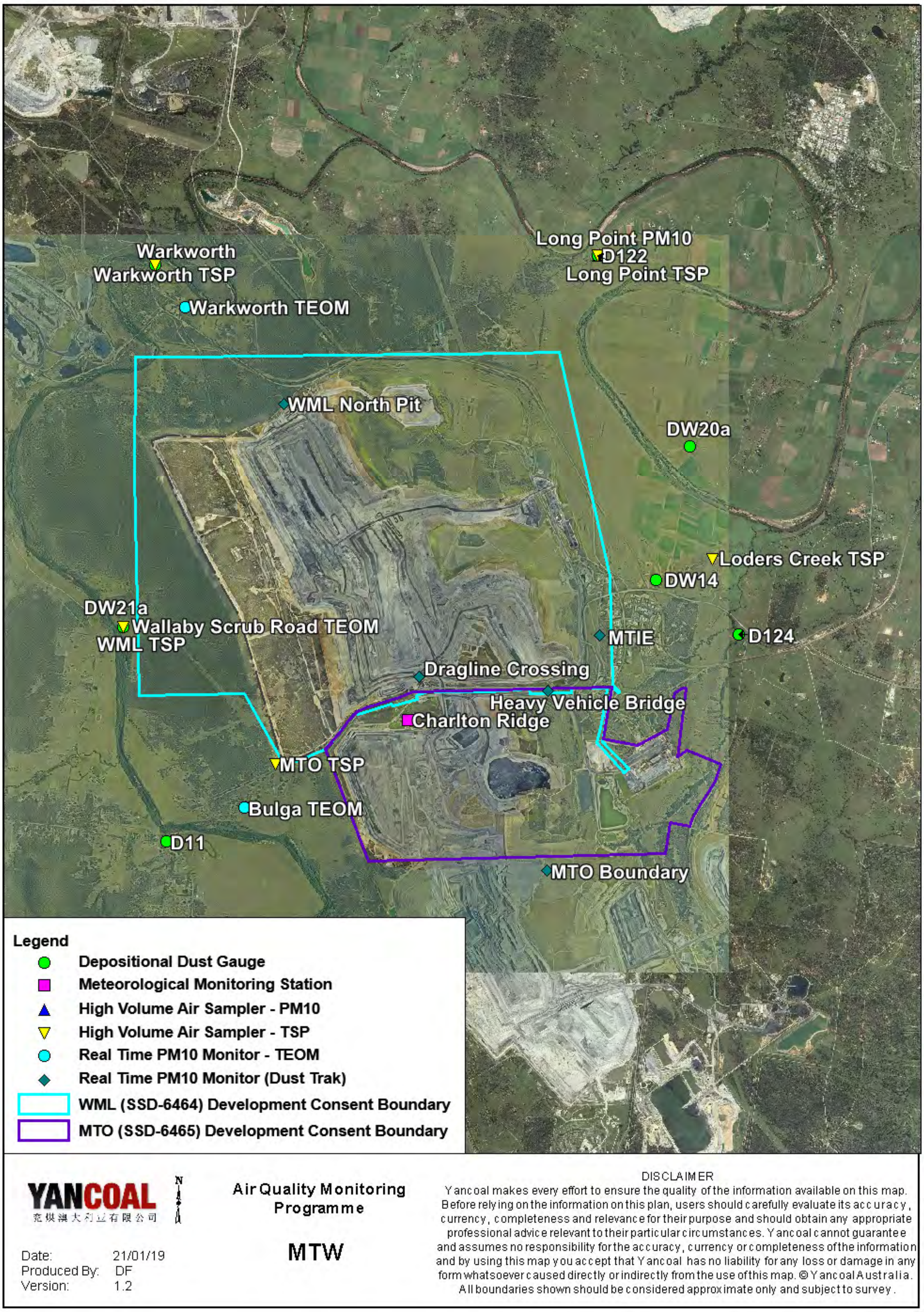


Figure 12: Air And Meteorological Monitoring Locations MTW 2019

TABLE 6.7 AIR QUALITY IMPACT ASSESSMENT CRITERIA AND 2019 COMPLIANCE ASSESSMENT

Pollutant	Criterion	Averaging Period	Compliance
Deposited Dust	4 g/m²/month	Maximum total deposited dust level	100%
	2 g/m²/month	Maximum increase in deposited dust level	100%
Total Suspended Particulate matter (TSP)	90 µg/m³	Long Term (Annual)	100%
Particulate matter <10µm (PM_{10})	30 µg/m³	Long Term (Annual)	100%
	50 µg/m³	Short Term (24 hour)	100%

6.4.2.2 Deposited Dust

Deposited dust is monitored at seven (7) locations situated on, or representative of privately-owned land generally in accordance with AS3580.10.1 (2003). The annual average insoluble matter deposition rates in 2019 compared with the impact assessment criterion and previous years' data is shown in **Figure 13.**

There was one exceedance of the long-term impact assessment criteria, for maximum total deposited dust level, recorded at the Warkworth monitoring location. An external consultant was engaged to conduct an investigation which determined maximum MTW contribution to be not more than 1.9g/m2/month, or 35% of the total level of 5.3g/m2/month at Warkworth. As per MTW's approved Air Quality Management Plan, this does not constitute non-compliance because the exceedance is not attributable to either of WML or MTO and no further action is required.

After analysis of the single exceedance, all annual average insoluble matter deposition rates recorded on privately owned land were compliant with the long-term impact assessment criteria of 4g/m2/month. All monitoring locations also demonstrated compliance with the maximum allowable insoluble solids increase criteria of 2g/m2/month (**Figure 14**).

It should be noted that during 2019, monthly dust deposition rates equal to or greater than the long-term impact assessment criteria of 4g/m2/month were recorded at multiple sites. Where field observations denote a sample as contaminated (typically with insects, bird droppings or vegetation), the results are excluded from Annual Average compliance assessment. Meteorological conditions and the results of nearby monitors for the sampling period are also considered when determining MTW's level of contribution to any elevated result. Details of excluded results are presented in the relevant MTW Monthly Environmental Monitoring Report. The graphs below illustrate a general trend in increased Depositional Dust in 2019 compared to 2018. This is consistent with well below average rainfall totals recorded in 2017 (444 mm), 2018 (457 mm) and 2019 (304 mm).

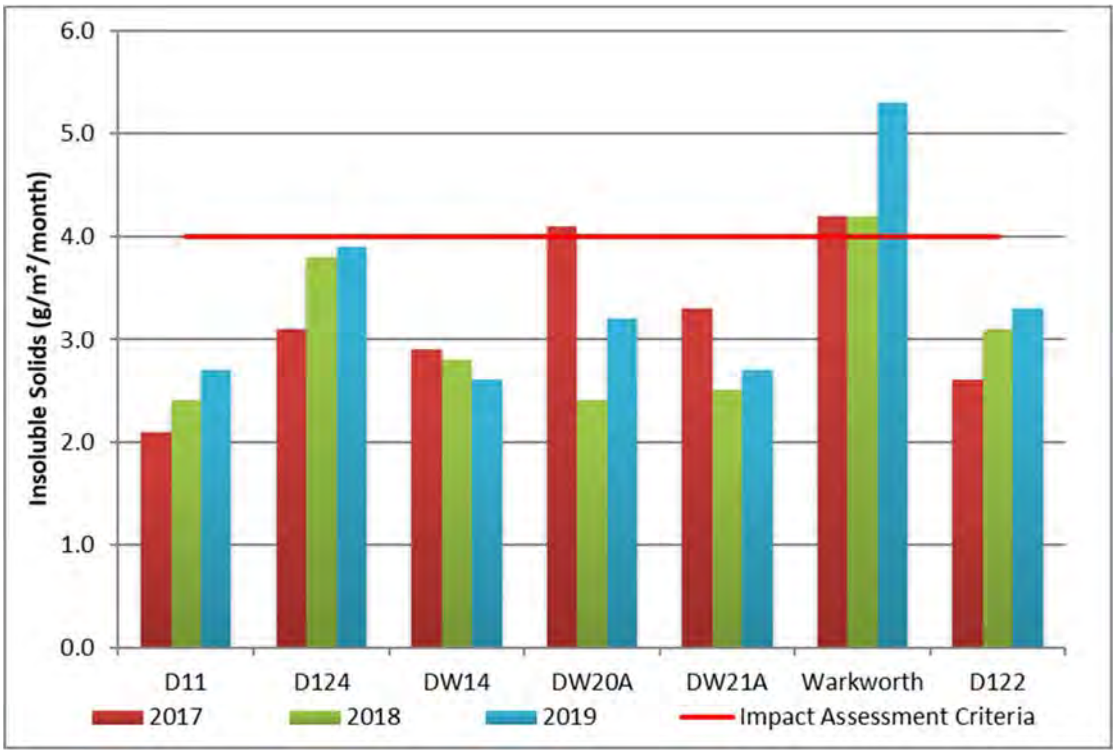


FIGURE 13: 2019 DEPOSITIONAL DUST RESULTS COMPARED AGAINST THE IMPACT ASSESSMENT CRITERIA AND PREVIOUS YEARS' RESULTS

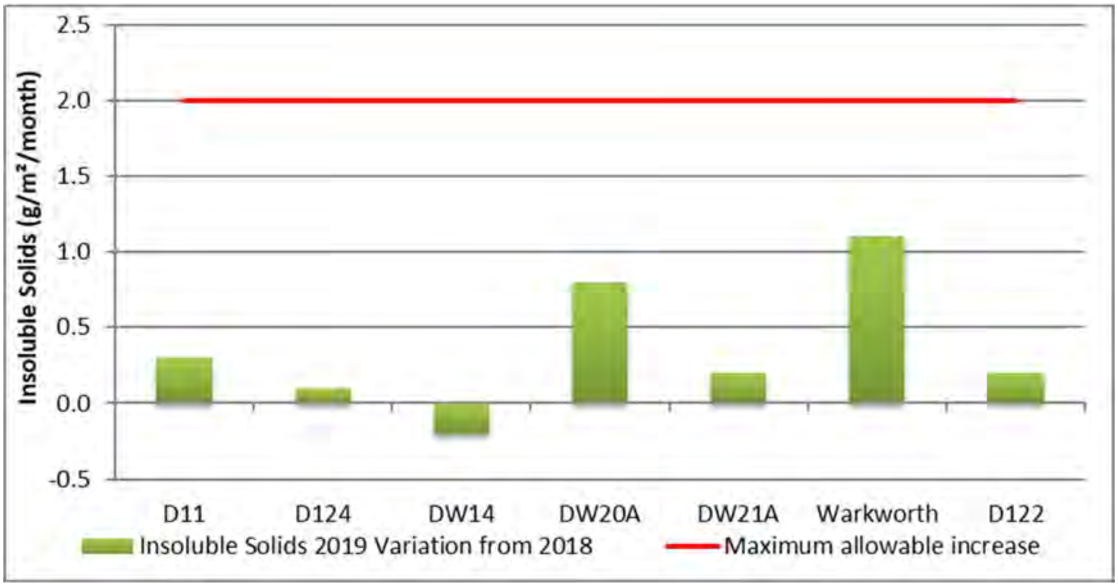


FIGURE 14: VARIATION IN INSOLUBLE SOLIDS DEPOSITION RATE FROM 2018 TO 2019 COMPARED AGAINST THE IMPACT ASSESSMENT CRITERIA

6.4.2.3 Total Suspended Particulates (TSP)

Total Suspended Particulates (TSP) are measured at five (5) locations situated on or representative of privately owned land in accordance with AS3580.9.3 (2003). Annual average TSP concentrations recorded in 2019 compared against the long-term impact assessment criterion and previous years' data, are shown **Figure 15**.

One high volume air sampler exceeded the annual TSP impact assessment criteria during the reporting period. This was investigated to determine the level of contribution from MTW activities in accordance with the compliance protocol outlined in the approved MTW Air Quality Management Plan. The recorded exceedance was determined to be compliant with the relevant criteria, as the measured result is not primarily attributable to MTW.

After analysis of the single exceedance, all annual average results were compliant with the impact assessment and land acquisition criteria.

A summary of the investigation undertaken for the annual TSP exceedance is provided in Table **6.8**

TABLE 6.8 ANNUAL TSP INVESTIGATION - 2019

Date	Site	Annual Average PM_{10} result (µg/m³)	Calculated Annual TSP (µg/m3)	Discussion
2019	Warkworth HVAS TSP	98.6	19.9*	An external consultant was engaged to investigate the exceedance. The investigation determined that contribution from MTW at the Warkworth monitor during the review period was relatively low. This was based on an analysis of meteorological data and position of the site in relation to MTW. As the measured result is not primarily attributable to MTW, it does not constitute non-compliance, as per MTW's approved Air Quality Management Plan. No further action is required.

* *MTW's estimated contribution to annual average TSP level (µg/m³), excluding "extraordinary event" days.*

During the reporting period, one (1) out of the 305 TSP measurements was not able to be collected on the scheduled sampling date (based on a sampling frequency of every six days) due to a power failure.

The annual average TSP concentrations recorded in 2019 are generally higher than those recorded in previous years, which is likely related to well below average rainfall for the year.

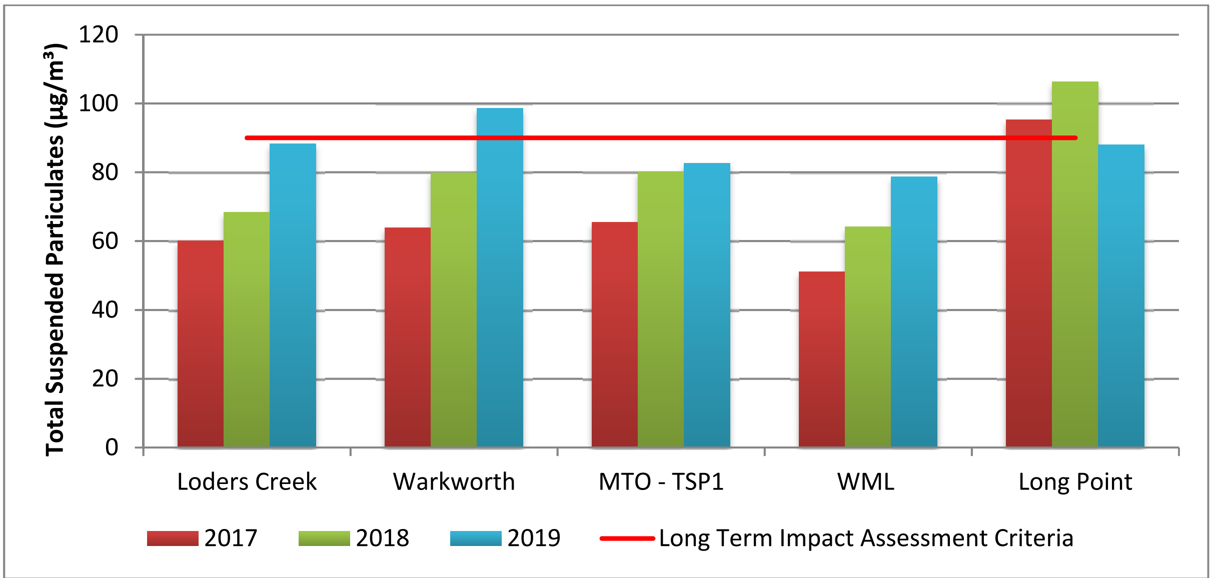


Figure 15: 2019 TSP Annual Average Compared Against the Impact Assessment Criteria and Previous Years' Results

6.4.2.4 Particulate Matter <10µm (PM10)

Compliance assessment for Particulate Matter <10µm (PM_{10}) is measured at five (5) locations on privately owned land in accordance with AS3580.9.6 (2003). During 2019, all short term and annual average results were compliant with the impact assessment criteria.

6.4.2.5 Short term PM10 impact assessment criteria

Monitoring results for PM_{10} (24 hour) collected through the High-Volume Air Sampler monitoring network are compared against the short-term impact assessment criteria (**Figure 16**). All 24hr average results recorded by MTW's surrounding network of TEOM monitors are presented on a quarterly basis in **Figure 17** to **Figure 20.**

The figures show that levels were elevated for an extended period from approximately late October 2019 until the end of the year. The elevated levels were primarily caused by smoke from bushfires which impacted the east coast of NSW at the end of 2019, as well as dust storms and generally elevated PM10 levels associated with hot, dry and windy days during drought conditions.

The DPIE provided MTW with a list of dates of "extraordinary events" for the Upper Hunter in 2019, as shown in **Table 6.9** below. Extraordinary events include bushfires, dust storms and/or regional dust events. As per MTW's Development Consents, the short and long term impact assessment criteria do not apply on days declared as extraordinary events.

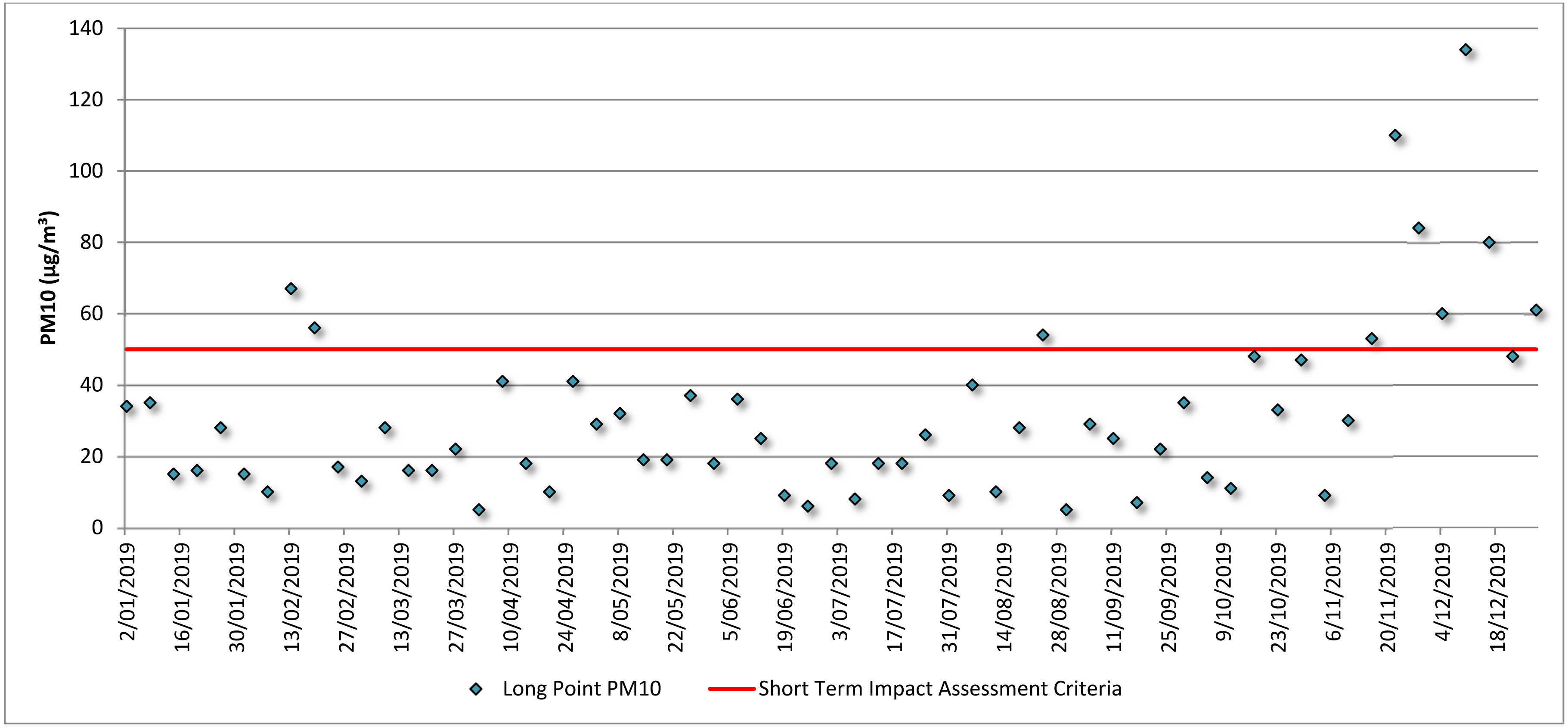


Figure 16: PM10 24Hr Monitoring Results (Measured by MTW PM10 HVAS Network)

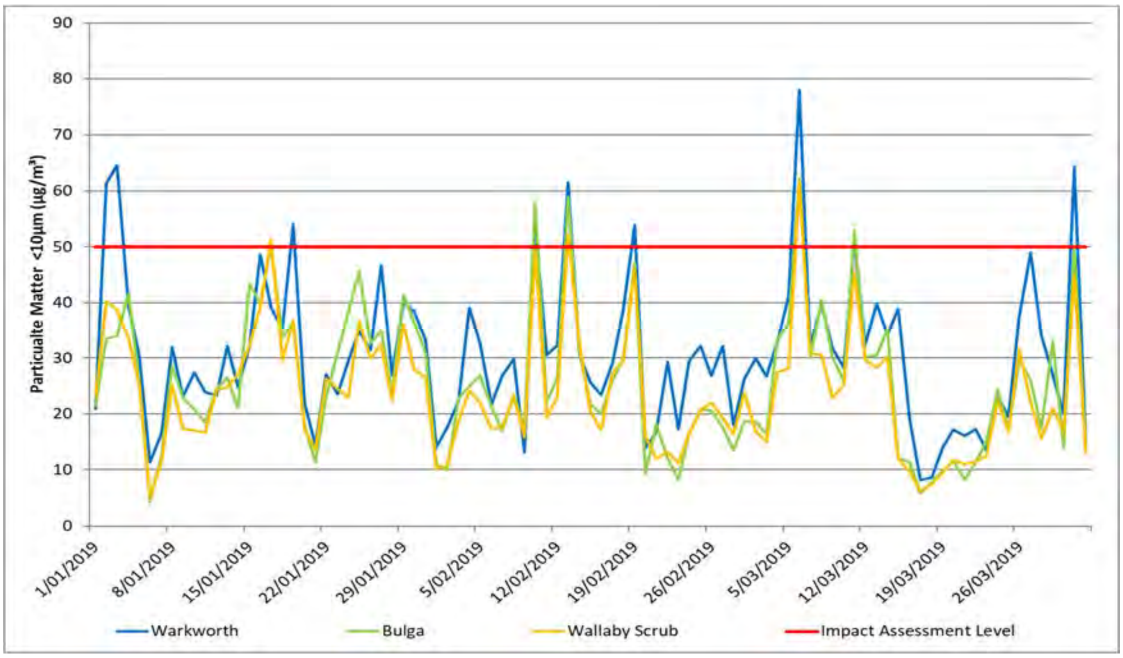


FIGURE 17: 24HR AVERAGE PM10 MEASURED AT TEOM MONITORS SURROUNDING MTW - QUARTER ONE 2019

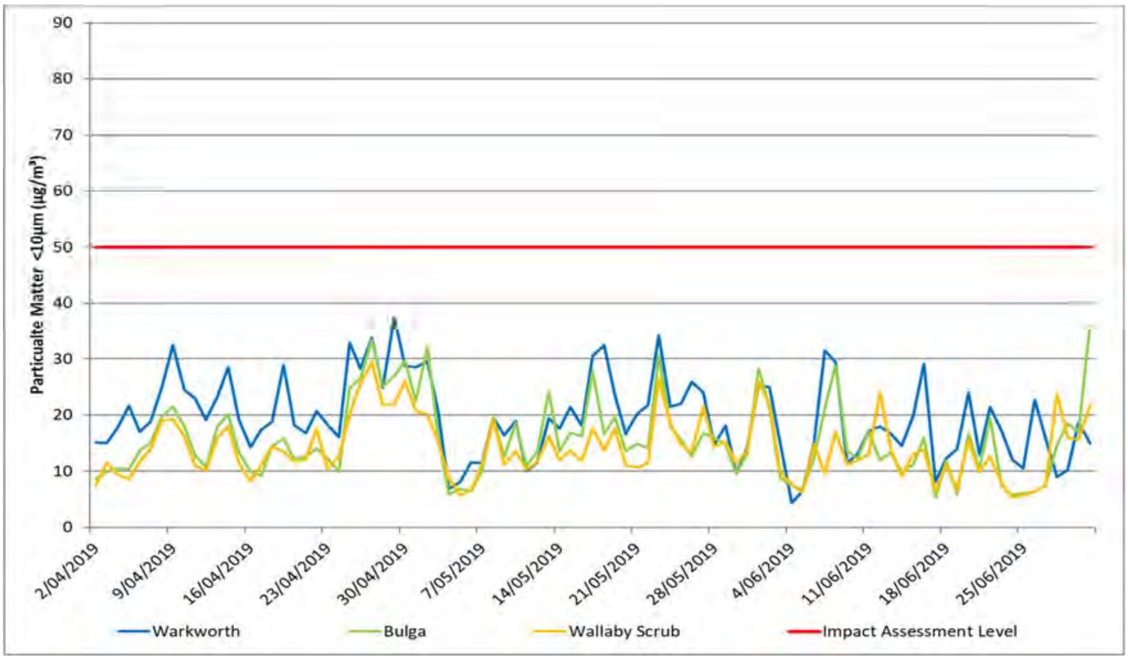


FIGURE 18: 24HR AVERAGE PM10 MEASURED AT TEOM MONITORS SURROUNDING MTW - QUARTER TWO 2019

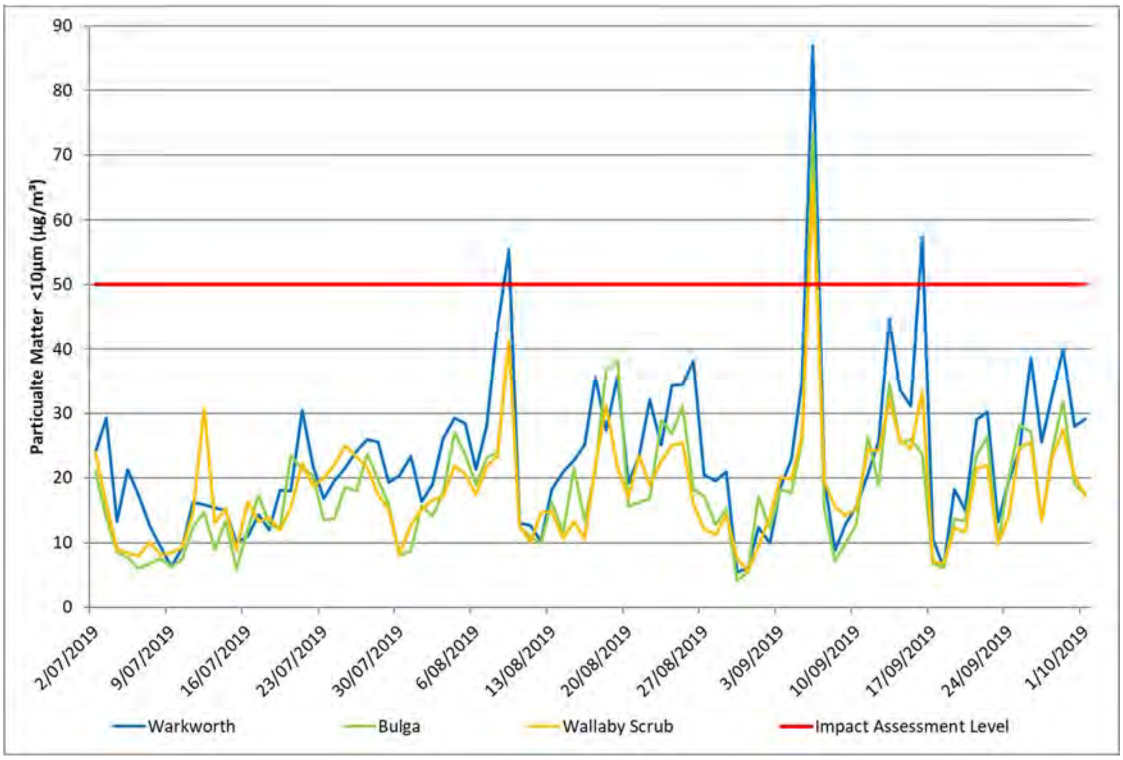


FIGURE 19: 24HR AVERAGE PM10 MEASURED AT TEOM MONITORS SURROUNDING MTW - QUARTER THREE 2019

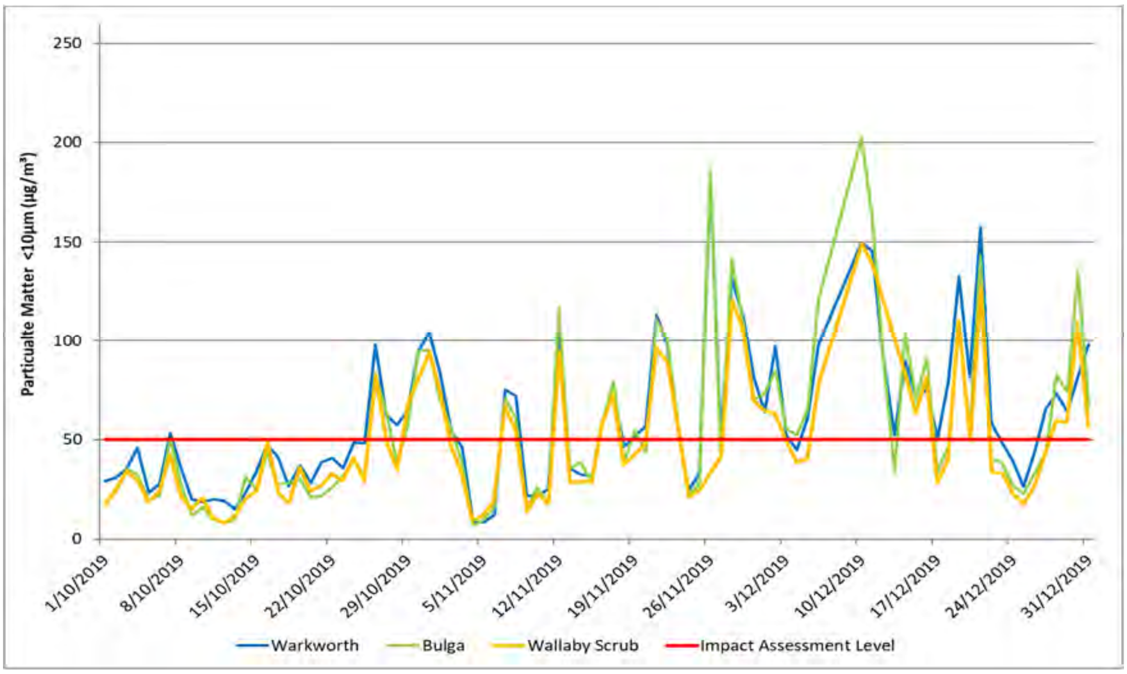


FIGURE 20: 24HR AVERAGE PM_{10} MEASURED AT TEOM MONITORS SURROUNDING MTW - QUARTER FOUR 2019

TABLE 6.9 EXTRAORDINARY EVENT DAYS

Month	Day(s)
Jan	16, 17
Feb	13, 19
Mar	6, 31
Apr	26
May	-
Jun	-
Jul	-
Aug	8, 9
Sep	6
Oct	7, 8, 18, 19, 24, 25, 26, 27, 28, 30, 31
Nov	1, 2, 7, 8, 12, 16, 17, 19, 20, 21, 22, 23, 26, 27, 28, 29, 30
Dec	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 27, 28, 29, 30, 31

Excluding "extraordinary event" days, one high volume air sample and 10 TEOM PM_{10} measurement results potentially exceeded the 24 hour short term impact assessment criteria during the reporting period. All exceedances were investigated to determine the level of contribution from MTW activities in accordance with the compliance protocol outlined in the MTW Air Quality Management Plan. MTW as not a significant contributor to these exceedances and therefore no non-compliances were recorded.

A summary of the investigations undertaken for each short term PM10 exceedance are provided in **Table 6.10**

TABLE 6.10 24 HOUR PM_{10} INVESTIGATIONS - 2019

Date	Site	24hr PM_{10} result (µg/m^3)	Estimated contribution from MTW (µg/m^3)	Discussion
02/01/2019	Warkworth TEOM	61.4	32.5	An analysis of meteorological data and background PM10 levels has determined the maximum potential MTW contribution to the result to be in the order of 32.5µg/m3 or ~53% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.

Date	Site	24hr PM_{10} result (µg/m^3)	Estimated contribution from MTW (µg/m^3)	Discussion
03/01/2019	Warkworth TEOM	64.5	33.3	An analysis of meteorological data and background PM10 levels has determined the maximum potential MTW contribution to the result to be in the order of 33.3µg/m3 or ~52% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.
19/01/2019	Warkworth TEOM	54.1	20.3	An analysis of meteorological data and background PM10 levels has determined the maximum potential MTW contribution to the result to be in the order of 20.3µg/m3 or ~38% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.
10/02/2019	Warkworth TEOM	53.9	23.4	An analysis of meteorological data has determined the maximum potential MTW contribution to the result to be in the order of 23.4µg/m3 or ~43% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.
10/02/2019	Bulga TEOM	58.0	22.2	An analysis of meteorological data has determined the maximum potential MTW contribution to the result to be in the order of 22.2µg/m3 or ~38% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.

Date	Site	24hr PM_{10} result ($\mu g/m^3$)	Estimated contribution from MTW ($\mu g/m^3$)	Discussion
11/03/2019	Warkworth TEOM	51.2	35.3	An analysis of meteorological data has determined the maximum potential MTW contribution to the result to be in the order of 35.3µg/m3 or ~69% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.
11/03/2019	Bulga TEOM	53.1	15.8	An analysis of meteorological data has determined the maximum potential MTW contribution to the result to be in the order of 15.8µg/m3 or ~30% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.
24/08/2019	Long Point HVAS PM_{10}	54.0	-	An analysis of meteorological data and background PM10 levels has determined the maximum potential MTW contribution to the result to be in the order of 25µg/m3 or ~47% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.
29/10/2019	Warkworth TEOM	64.7	38.4	An analysis of meteorological data has determined the maximum potential MTW contribution to the result to be in the order of 38.4µg/m3 or ~60% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.

Date	Site	24hr PM_{10} result ($\mu g/m^3$)	Estimated contribution from MTW ($\mu g/m^3$)	Discussion
29/10/2019	Bulga TEOM	56.8	27.8	An analysis of meteorological data has determined the maximum potential MTW contribution to the result to be in the order of 27.8µg/m3 or ~51% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.
29/10/2019	Wallaby Scrub Road TEOM	68.3	26.4	An analysis of meteorological data has determined the maximum potential MTW contribution to the result to be in the order of 26.4µg/m3 or ~39% of the measured result. As the calculated contribution was less than 75% of the measured result, MTW operations are not considered to be a significant contributor to the result, as described in the MTW Air Quality Management Plan.

6.4.2.6 Long term PM_{10} impact assessment criteria

Annual average PM_{10} concentrations have been compared with the long term PM_{10} impact assessment criterion and previous years' data (**Figure 21**). All annual average PM_{10} concentrations recorded on privately owned land (or representative of the nearest privately owned property) were compliant with the assessment criterion.

The Bulga, Wallaby Scrub Road and Warkworth monitoring locations recorded increases in annual average PM_{10} concentrations compared to 2018. This increase is considered largely attributable to bushfires (which impacted the east coast of NSW at the end of 2019), regional dust events and well below average rainfall.

The Long Point monitoring location recorded a decrease in annual average PM_{10} concentrations compared to 2018. This is considered to be related to the relocation of horses from the immediately adjacent paddock.

One high volume air sampler and one TEOM recorded a result above the annual PM_{10} impact assessment criteria during the reporting period. The results were investigated by an external consultant following identification of the exceedances to determine the levels of contribution from MTW activities in accordance with the compliance protocol outlined in the MTW Air Quality Management Plan. The results were determined to be compliant with the relevant criteria. A summary of the investigations undertaken are provided in **Table 6.11**.

TABLE 6.11 ANNUAL PM_{10} INVESTIGATION - 2019

Date	Site	Annual Average PM_{10} result ($\mu g/m^3$)	Calculated Annual PM_{10} ($\mu g/m^3$)	Discussion
2019	Long Point HVAS PM_{10}	31.3	1.8*	An external consultant was engaged to investigate the exceedance. The investigation determined that contribution from MTW at the Long Point monitor during the review period was relatively low. This was based on an analysis of meteorological data and position of the site in relation to MTW. As the measured result is not primarily attributable to MTW, it does not constitute non-compliance, as per MTW's approved Air Quality Management Plan and so no further action is required.
2019	Warkworth OEH TEOM	34.1	3.8*	An external consultant was engaged to investigate the exceedance. The investigation determined that contribution from MTW at the Warkworth OEH monitor during the review period was relatively low. This was based on an analysis of meteorological data and position of the site in relation to MTW. As the measured result is not primarily attributable to MTW, it does not constitute non-compliance, as per MTW's approved Air Quality Management Plan and so no further action is required.

* *MTW's estimated contribution to annual average PM10 level ($\mu g/m^3$), excluding "extraordinary event" days.*

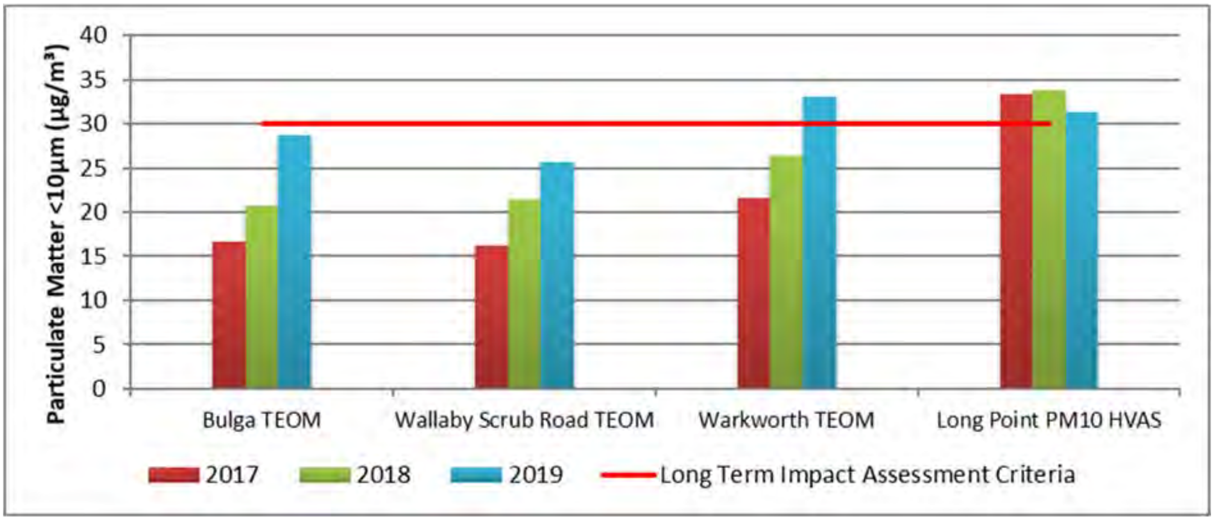


FIGURE 21: ANNUAL AVERAGE PM10 RESULTS 2017 TO 2019

6.4.2.7 Comparison of 2019 Air Quality data against EA predictions

Annual average PM_{10} results were above the modelled range for Year 3 of the development (nominally 2017) which is the mine plan year in the EA which provides the most appropriate comparison year. An analysis of 2019 meteorological and PM_{10} monitoring data was undertaken by an external consultant, which identified that the measured increases are largely related to elevated background levels and not primarily a direct result of MTW activity. Refer to **Table 6.12**

TSP annual averages at all monitoring locations were higher than modelled predictions for the Year 3 scenario. Refer to **Table 6.13.** The difference between modelled predictions and the measured results can be explained as a function of model inputs which do not account for TSP contribution from regional particulate events such as bushfires, stock movement, dust from local roads and driveways and agricultural activity.

TABLE 6.12 2019 PM10 ANNUAL AVERAGE RESULTS COMPARED AGAINST CUMULATIVE PREDICTIONS FOR YEARS 3 - WARKWORTH CONTINUATION EIS (2014).

Monitoring Location	Long Term (annual average) PM_{10} criteria	
	Year 3 EIS Prediction (µg/m³)	2019 Annual Average (µg/m³)
Bulga OEH TEOM	23	28.7
Wallaby Scrub Road TEOM	16	25.6
Warkworth OEH TEOM	30	34.1
Long Point PM_{10}	16	31.3

TABLE 6.13 2019 TSP ANNUAL AVERAGE RESULTS COMPARED AGAINST CUMULATIVE PREDICTIONS FOR YEAR 3 – WARKWORTH CONTINUATION EIS (2014).

Monitoring Location	Long Term (annual average) TSP criteria	
	Year 3 EIS Prediction (µg/m³)	2019 Annual Average (µg/m³)
MTO TSP1	52	82.6
Loders Creek TSP	43	88.4
WML- HV2a	39	78.7
Warkworth	65	98.6
Long Point	38	88.0

6.5 Heritage Summary

6.5.1 Heritage Management

During the reporting period, Aboriginal Cultural Heritage and Historic Heritage was managed in accordance with the sites approved Aboriginal Heritage and Historic Heritage Management Plans. A summary of the performance in each of these areas is outlined below.

6.5.2 Heritage Performance

6.5.2.1 Aboriginal Heritage

6.5.2.1.1 Aboriginal Heritage Activities

No Aboriginal cultural heritage assessments or salvage programs were required at MTW during the reporting period. Aboriginal cultural heritage was managed in accordance with the MTW Aboriginal Heritage Management Plan (AHMP) and the Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW (the Due Diligence Code).

There was one additional Aboriginal cultural heritage site identified during the reporting period. The site was identified by a MTW employee as part of the due diligence process associated with the sites ground disturbance approvals process. The site was barricaded and MTW arranged for an inspection by a qualified archaeologist to record and document the site. An AHIMS site card was developed and submitted in accordance with the provisions outlined in the ACHMP and the site was added to the MTW cultural heritage management GIS layer.

An AHMP compliance inspection covering the 2019 reporting period was undertaken on 2-3 March 2020. This inspection was conducted by representatives of the Aboriginal community, internal MTW personnel and a consultant archaeologist. A total of 57 Aboriginal cultural heritage sites were assessed during this program, with no adverse findings identified. The Aboriginal Heritage Management Plan Inspection report is shown in **Appendix 1**.

The Upper Hunter Valley Aboriginal Cultural Heritage Working Group (CHWG) is the primary forum for Aboriginal community consultation on matters pertaining to cultural heritage. The CHWG is comprised of representatives from MTW and Registered Aboriginal Parties (RAPs) from Upper Hunter Valley Aboriginal native title and community groups, corporations and individuals. There were no meetings of the CHWG during the reporting period. Meetings with the CHWG are planned for the next reporting period to discuss upcoming salvage programs and general cultural heritage management processes.

6.5.2.1.2 Audits and Incidents

During the reporting period there were 36 Ground Disturbance Permits (GDP's) assessed for cultural heritage management considerations at MTW. Ground disturbance works were conducted based on an Aboriginal cultural heritage sites avoidance policy so that no un-salvaged sites were impacted by these activities. There were no known incidents nor any unauthorised disturbance caused to Aboriginal cultural heritage sites at MTW during 2019.

6.5.2.2 Historic Heritage

6.5.2.2.1 Historic Heritage Activities

No historic heritage surveys or investigations were required at MTW in 2019.

An Historic Heritage Management Plan (HHMP) compliance inspection covering the 2019 reporting period was conducted on 4 March 2020. This inspection was conducted by a consultant archaeologist, assisted by representatives of the Community Heritage Advisory Group and internal MTW personnel. A total of 3 historic heritage sites were inspected during this program. The Historic Heritage Management Plan Inspection Report is shown in **Appendix 2**.

In 2012 the CHAG was established as a community consultation forum for matters pertaining to management of historic (non-Indigenous) heritage located on MTW lands. The CHAG is comprised of community representatives with particular knowledge and interests in the historic heritage of the region such as historical groups, individuals and local government.

The MTW Historic Heritage Conservation Fund (HHCF) was launched by Singleton Council in December 2018, in accordance with Schedule 17 of the HHMP, with four applications received. Singleton Council advise in their 2019 annual HHCF report, that Council in consultation their consultant Heritage Advisor reviewed the four applications with a recommendation put to the Singleton Heritage Advisory Council (SHAC) to fund one application. However, due to staff changes at Singleton Council, no applications were funded during 2019, and no further funding was advertised during 2019. MTW has consulted with Council during February 2020 on how the HHCF processes will be progressed to ensure the positive outcomes that the funding is intended to achieve can be realised in the Singleton area.

There were no incidents or any unauthorised disturbance caused to historic heritage sites at MTW during 2019.

6.6 Visual Amenity and Lighting

6.6.1 Visual Amenity and Lighting Management

MTW aims to minimise visual amenity impacts from its operations. Two of the main controls used are lighting management and visual screening.

6.6.2 Visual Amenity and Lighting Performance

6.6.2.1 Lighting

MTW aims to provide sufficient lighting for work to be undertaken safely, whilst minimising disturbance to neighbouring residents and public roads, particularly nearby residents in Bulga Village, Mount Thorley, Warkworth Village, Long Point, Milbrodale and vehicular traffic on the Putty Road and Golden Highway.

Actions undertaken in 2019 to manage lighting impacts at MTW included:

- Routine night shift inspections conducted by Community Response Officers to observe operating practices and to ensure lights are not shining towards nearby residential areas or affecting public roads;
- Yellow lights are used in preference to white lights in areas based on risk and external exposure;
- Alternate sheltered dumps are operated or work areas are shut down if lighting or visual amenity issues arise and cannot be sufficiently managed.

6.6.2.2 Visual Screening

Visual screening of MTW operations uses various methods to best suit the terrain and infrastructure constraints around the boundary of the mine.

Visual bunding has an immediate screening effect, providing complete screening in areas where vegetation would be inadequate to filter views or where additional height is required. Bunds may be vegetated where practicable and feasible for visual amenity and to mitigate erosion.

Built screens (i.e. solid fences or walls), may be used as an alternative when bunds and tree screens are not practicable. Temporary screens (i.e. fencing and shade mesh) may also be used as required for interim screening.

The Putty Road visual bund was extended to the west, to the junction of the Sealed Geo Road (former Wallaby Scrub Road), during 2019. Vegetation screening has also been planted during 2019 to the West of the former Wallaby Scrub Road to improve visual amenity for passing motorists. A section of deceased trees along the South Pit of Warkworth adjacent to the Putty Road were also removed in 2019 to improve visual amenity, with infill planting to occur in 2020 in this area.

6.7 Water

6.7.1 Water Management

An adaptive management approach is implemented at MTW to achieve the following objectives for water management:

- Fresh water usage is minimised;
- Impacts on the environment and MTW neighbours are minimised; and
- Interference to mining production is minimal.

This is achieved by:

- Preferentially using mine water for coal preparation and dust suppression where feasible;
- An emphasis on control of water quality and quantity at the source;
- Segregating waters of different quality where practical;
- Recycling on-site water;
- Ongoing maintenance and review of the water management system; and
- Releasing water to the environment in accordance with statutory requirements.

Plans showing the layout of all water management structures and key pipelines are shown in **Figure 22**. The MTW Water Management Plan contains further detail on management practices and is available on the webpage https://insite.yancoal.com.au.

Improvements to water management in 2019 have focused on mitigating the risk of unauthorised water releases from site. In addition to the existing management measures undertaken on site MTW commissioned a remote boundary dam monitoring system during the reporting period. The system was installed in December 2019 at Dams 46N, 43N, 51N, 52N, 53N and 50N. The new system allows for real time dam level information and photography to be captured at each location in real time. All information is captured is uploaded to a website repository that can be accessed by site personnel to assist with improving visibility and management at these locations. MTW will be monitoring the effectiveness of the new system in the next reporting period.

There were no new water storage facilities constructed during the reporting period. Capping of the sites Tailings Dam 2 (Dam 33N) continued during the reporting period.

There was one reportable water related incident during the reporting period. The incident involved the discharge of water from Dam 46N and Dam 53N as a result of a significant rain event on 30 March 2019. MTW reported the incident to the relevant authorities at the time and submitted incident reports in accordance with the site Development Consent and Environmental Protection Licence. Following an investigation by both the EPA and DPIE MTW was issued with a Penalty Notice for the discharge from Dam 46N and an Official Caution for the discharge from Dam 53N. Further details on this incident and the corrective actions taken by MTW to prevent a recurrence are provided in **Section 10**.

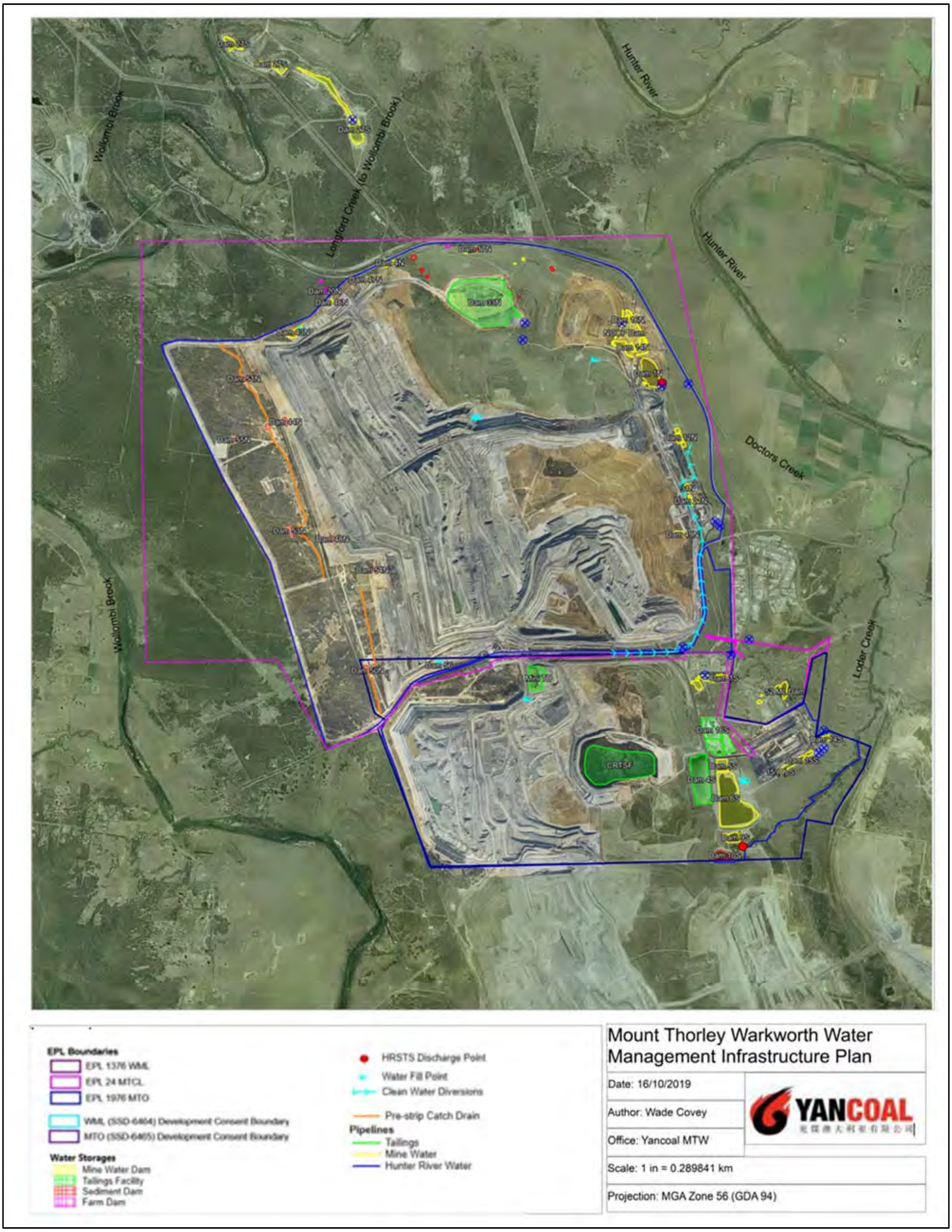


FIGURE 22: WATER MANAGEMENT INFRASTRUCTURE PLAN

6.7.2 Water Balance Performance

MTW uses a water balance to record and assess water flux, but also to forecast and plan water management needs. These annual site water balances are then compared to previous results. A 2019 static water balance for MTW is presented in **Table 6.14** and a simplified schematic of this balance is included in **Figure 23**. A salt flux schematic is shown **in Figure 24**.

TABLE 6.14 STATIC MODEL RESULTS, ANNUAL WATER BALANCE

Water Stream	Volume (ML) (% Total)
Inputs	
Rainfall Runoff	2,974 (39%)
Hunter River (MTJV supply scheme)	1,594 (21%)
Potable (Singleton Shire Council / trucked)	20 (<1%)
Groundwater	285 (4%)
Recycled to CHPP from tailings (not included in total)	6,536
Imported (LUG bore)	1731 (22%)
Imported (Hunter Valley Operations)	0 (0%)
Water from ROM Coal	1,024 (13%)
Total Inputs	**7,628**
Outputs	
Dust Suppression	3,325 (39%)
Evaporation – mine water dams	1,158 (14%)
Entrained in process waste	2,098 (25%)
Sharing with other mines	0 (0%)
Discharged (HRSTS)	0 (0%)
Water in coarse reject	685 (8%)
Water in product coal	1,105 (13%)
Miscellaneous use (wash-down etc.)	110 (1%)
Total Outputs	**8,481**
Change in storage	**(853)**

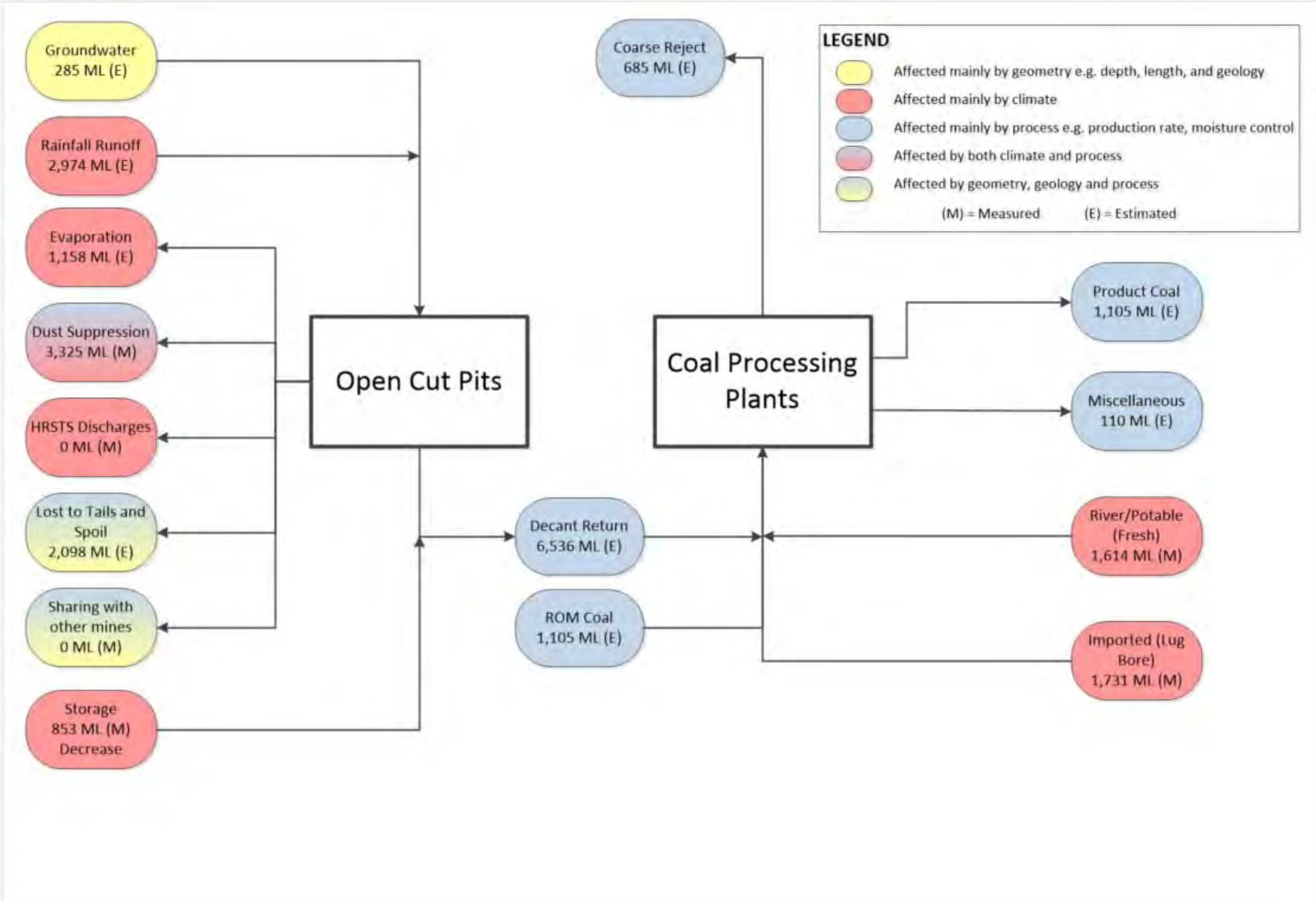


FIGURE 23: SCHEMATIC DIAGRAM MTW WATER FLUX

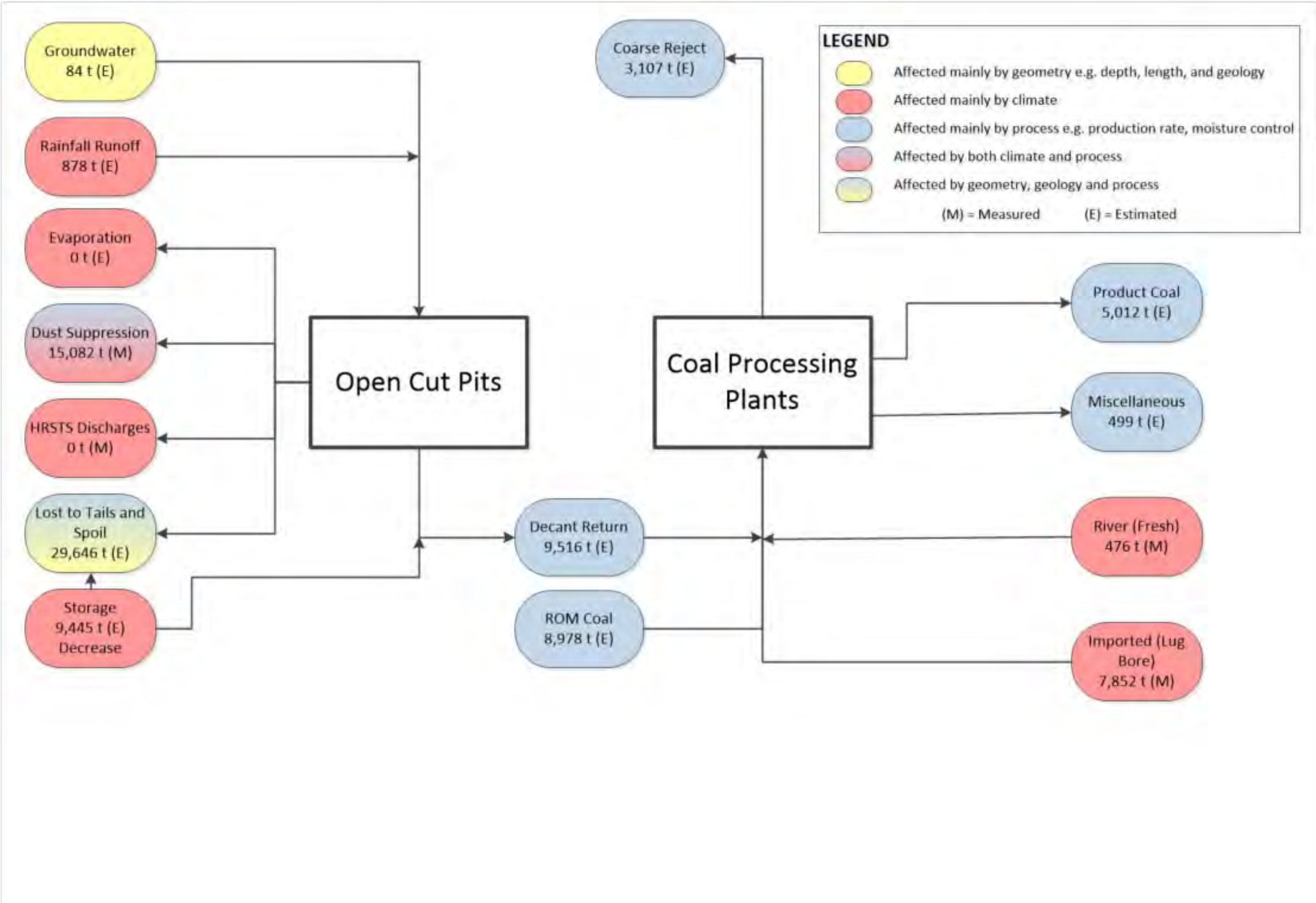


FIGURE 24: SCHEMATIC DIAGRAM MTW SALT FLUX

6.7.2.1 Water Inputs

A total of 303.8mm of rainfall was recorded at MTW in 2019 producing a calculated 2,974 ML of runoff from developed, disturbed and mining catchments. Water falling on clean water catchments is diverted off site into natural systems where possible. Rainfall runoff was the largest input to the site mine water balance in 2019 and comparable to the estimated runoff captured in the 2018 reporting period (3,698 ML) where the site recorded annual rainfall of 456.2mm.

As the site water inventory is drawn down, water is imported to meet site demand. During the reporting period 1,731 ML was imported from the LUG bore by MTW. This volume was an increase on the previous reporting period (875ML extracted), due to reliability improvements to the LUG infrastructure completed in 2019.

MTW also sources water from the Hunter River via the Mount Thorley Joint Venture (MTJV) water supply scheme. Singleton Shire Council holds the high security water licence on behalf of the scheme members. Singleton Shire Council maintains and operates the scheme to supply raw water to MTW, Glencore's Bulga Coal complex, and to meet Council's own needs. MTW's share of the MTJV allocation is 1,009 ML per water reporting year.

During the reporting period an additional 2,000 ML of high security water licenses were secured by MTW and a portion of this licence was transferred to the MTJV license to further supplement the operations water supply. It should be noted that due to the nature of the Water NSW reporting period, some temporary allocation assignments were executed in the 2019 AER reporting period, however, water was abstracted in the 2018 reporting period. A total of 1,594 ML of water was abstracted from the Hunter River during the reporting period for MTW operations.

Abstraction of 1,594 ML of water from the Hunter River in 2019 was slightly lower than the volume of water extracted in the previous reporting period. (1,768 ML extracted in 2018). Similar rainfall trends during this reporting period compared to the previous reporting period, indicate that rain events did not overcome the surface saturation threshold to generate runoff to replenish the site's water inventory.

Groundwater Licences under Part 5 of the Water Act 1912 are held for each mining excavation area, to account for passive take via seepage inflows. Water Licences held by MTW are detailed in **Table 3.5.**

Licence conditions require the volume and quality of water taken by the works to be measured and reported on an annual water calendar year basis (i.e. financial year). Groundwater inflows via pit wall seepage are at low rates, with a significant proportion evaporating at the coal face. The remainder reports to the pit floor, where it may accumulate along with direct rainfall, rainfall runoff and leakage from spoils. As a result, it is not possible to physically measure the volume of water taken by these groundwater licences, nor the quality of waters extracted via seepage to the pits.

6.7.2.2 Water Outputs

Significant water uses at MTW in 2019 were for dust suppression on haul roads, mining areas and coal stockpiles (3,325ML), evaporation from Dams (1,158ML) and water entrained in process waste (2,098ML). Water usage for dust suppression on haul roads slightly increased compared to the 2018 reporting period which may be attributed to dry climatic conditions during the reporting period and increased utilisation of contractor water carts for ancillary mining areas.

MTW participates in the Hunter River Salinity Trading Scheme (HRSTS), allowing discharge from licensed discharge points during declared discharge events associated with increased flow in the Hunter River. HRSTS discharges are undertaken in accordance with HRSTS regulations, EPL 1376 and EPL 1976.

MTW maintains two licensed HRSTS discharge monitoring locations:

- Dam 1N, located at WML North, which discharges to Doctor’s Creek; and
- Dam 9S, located at MTO South, which discharges to Loders Creek.

During the reporting period, MTW did not discharge under the HRSTS.

6.7.3 Surface Water Management

Surface water monitoring activities continued in 2019 in accordance with the MTW Water Management Plan and MTW Surface Water Monitoring Programme. MTW maintains a network of surface water monitoring sites located at selected site dams and surrounding natural watercourses as shown in **Figure 25**. Water quality monitoring is undertaken to verify the effectiveness of the water management system onsite, and to identify the emergence of potentially adverse effects on surrounding watercourses. Primary water storage dams are monitored routinely to verify the quality of mine water, used in coal processing, dust suppression, and other day to day activities around the mine.

Surface water monitoring data review involves a comparison of measured pH, EC and TSS results against internal trigger values which have been derived from the historical data set. The response to measured samples outside the trigger limits is detailed in the MTW Water Management Plan.

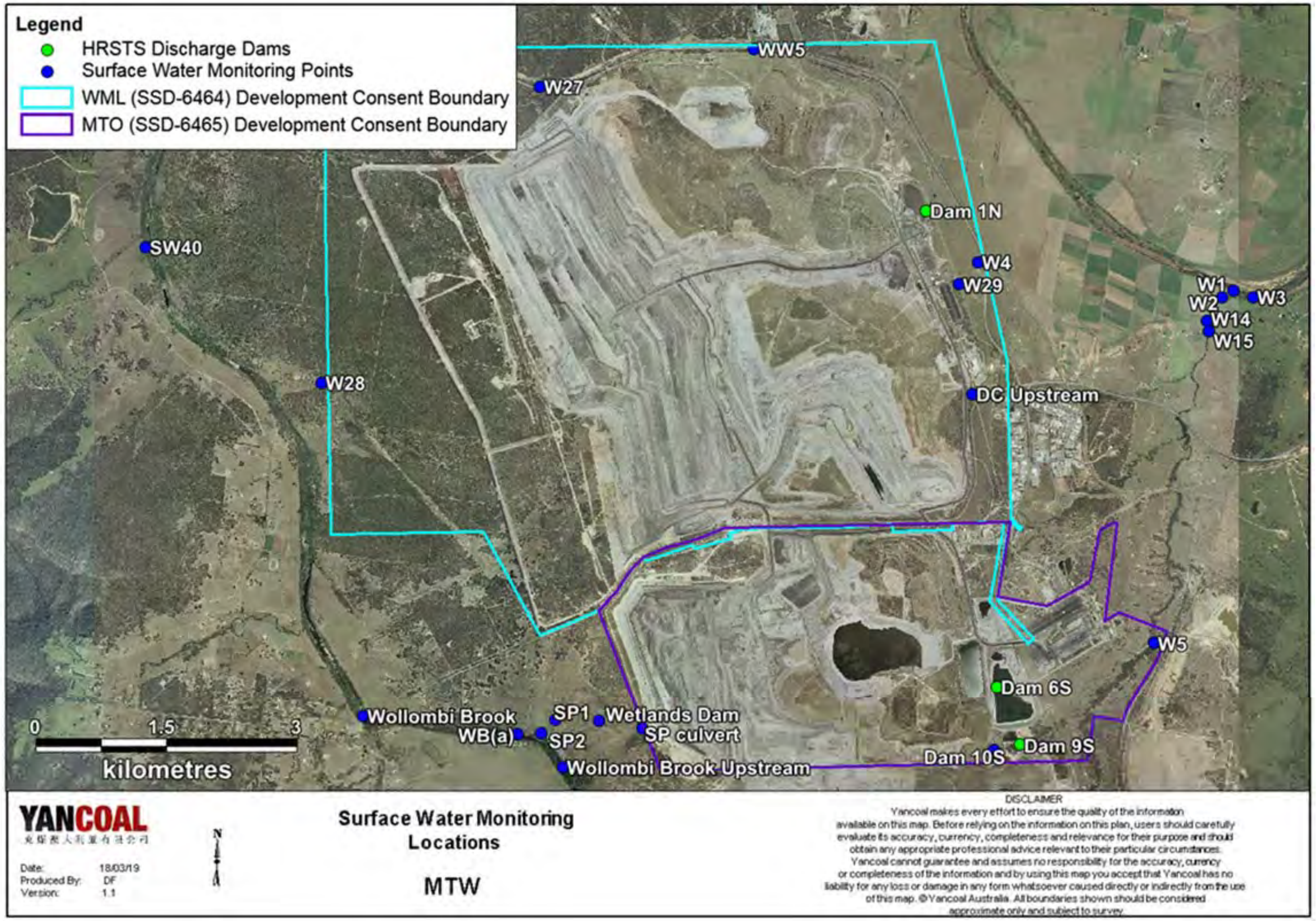


Figure 25: Surface Water Monitoring Points

6.7.4 Surface Water Performance

Routine surface water monitoring was undertaken from twelve (12) sites and rain event sampling was undertaken from thirteen (13) sites (see **Table 6.15** below). Sampling of surface waters was carried out in accordance with AS/NZS 5667.6 (1998). Analysis of surface water was carried out in accordance with approved methods by a NATA accredited laboratory.

Water quality is evaluated through the assessment of pH, Electrical Conductivity (EC) and Total Suspended Solids (TSS). All surface water sites were also sampled for comprehensive analysis annually. The sampling frequency for ephemeral water sites was modified in 2016, from quarterly to a rain-event trigger system in an effort to ensure samples taken were more representative of typical water quality for those streams (up to eight sampling events per annum can now be taken under the revised sampling protocol). Due to well below average rainfall during the reporting period, only two rain event sampling runs were completed in 2019. Low annual rainfall also resulted in lower data recovery in 2019 as multiple sites were recorded as dry during the monitoring events on multiple occasions. All required sampling and analysis was undertaken, except as detailed in **Table 6.15**. Trigger tracking results are described in **Table 6.16**.

TABLE 6.15 MTW WATER MONITORING DATA RECOVERY FOR 2019 (BY EXCEPTION)

Location	Data Recovery (%)	Comment
SP1	0%	Site recorded as dry in March
SP2	0%	Site recorded as dry in March
SP Culvert	50%	Site recorded as dry following first rain event in March
W14	50%	Site recorded as dry following first rain event in March
DC Upstream	50%	Site recorded as dry in March
W28	50%	Site recorded as dry following first rain event in March
Wetlands Dam	50%	Site recorded as dry following first rain event in March
W5	42%	Insufficient water for sampling from June to December
WW5	25%	Insufficient water for sampling in March, June and December
SW40	75%	Insufficient water for sampling in December
Dam 6S	92%	Insufficient water for sampling in July

Note: Missing data indicates that there was insufficient water to take a sample, or that there was no safe access.

A summary of all surface water monitoring results is provided in the MTW Monthly Environmental Monitoring Reports and can be viewed via MTW's Insite website (https://insite.yancoal.com.au/).

Figure 26 to **Figure 31** show long term water quality trends for the Hunter River, Wollombi Brook, other surrounding tributaries and site dams. Measurements of EC and pH were generally stable during the reporting period across the majority of sites and consistent with historical seasonal trends. Elevated EC levels were recorded at the Wollombi Brook and Wollombi Brook Upstream monitoring

sites during the reporting period. It is expected that the readings were a result of the prolonged dry climatic conditions with minimal flow recorded within Wollombi Brook during the reporting period and not related to mining impacts.

A number of TSS limits were triggered in the reporting period, which were generally associated with rainfall events or sampling from pooled section of watercourses; these are outlined below in **Table 6.16**. MTW undertook an investigation into the elevated TSS readings at W5 (Loder Creek) during the reporting period. The investigation concluded that the elevated results were most likely attributed to the sampling methodology at this location as samples were taken from a shallow pooled section on the creek bed. This sampling location was moved slightly downstream of this location to avoid this issue. Trigger tracking results are provided where three consecutive measurements of EC or pH are recorded. These are also provided in the Monthly reports provided on the MTW Insite website (https://insite.yancoal.com.au/).

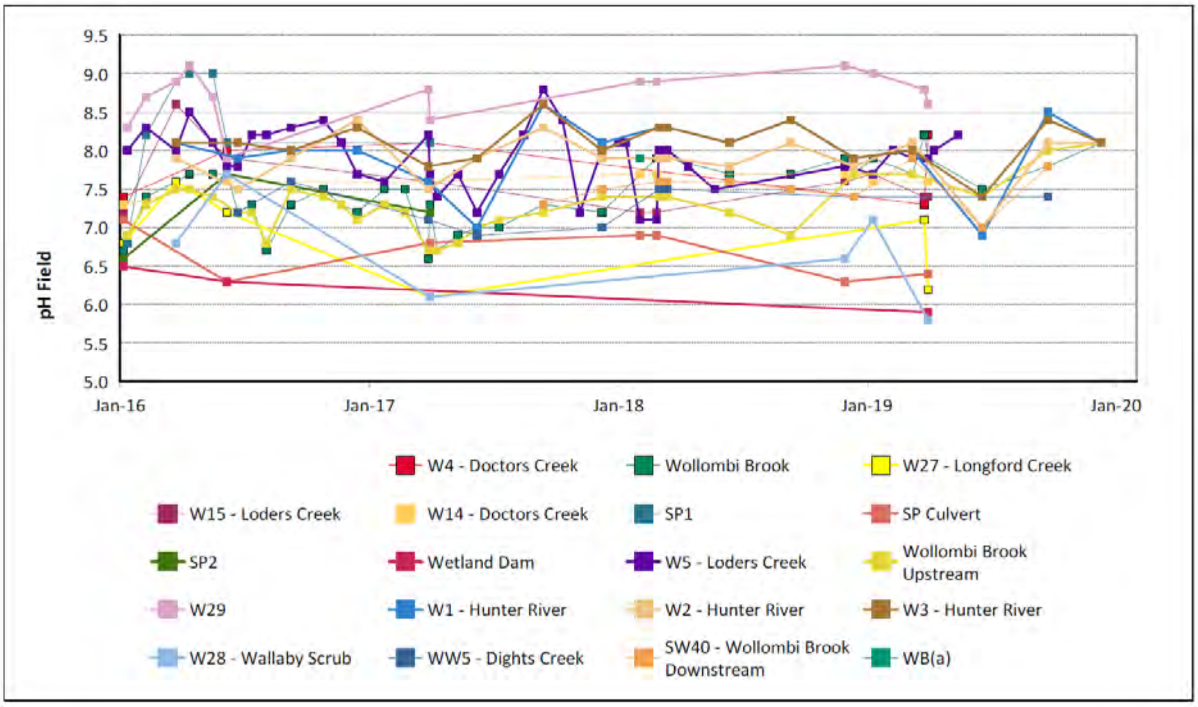
TABLE 6.16 SURFACE WATER MONITORING - TRIGGER TRACKING RESULTS

Site	Date	Trigger Limit	Action Taken in Response
W27	26/03/2019	EC –95th Percentile	Watching Brief* Note: Subsequent monitoring events have confirmed results are back within trigger limits. No further action required.
Wollombi Brook	08/03/2019	EC –95th Percentile	Watching Brief* Note: Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Wollombi Brook Upstream showing similar EC results and trends. Continue to watch and monitor.
Wollombi Brook	19/06/2019	EC –95th Percentile	Watching Brief* Note: Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Wollombi Brook Upstream showing similar EC results and trends. Continue to watch and monitor.
Wollombi Brook	23/09/2019	EC –95th Percentile	Watching Brief* Note: Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Wollombi Brook Upstream showing similar EC results and trends. Continue to watch and monitor. Investigation commenced.
Wollombi Brook	10/12/2019	EC –95th Percentile	Investigation Undertaken. Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Wollombi Brook Upstream showing similar EC results and trends. Continue to watch and monitor.
Wollombi Brook Upstream	08/03/2019	EC –95th Percentile	Watching Brief*

Site	Date	Trigger Limit	Action Taken in Response
Wollombi Brook Upstream	19/06/2019	EC –95th Percentile	Watching Brief* Note: Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Continue to watch and monitor.
Wollombi Brook Upstream	23/09/2019	EC –95th Percentile	Watching Brief* Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Wollombi Brook showing similar EC results and trends. Investigation commenced.
Wollombi Brook Upstream	10/12/2019	EC –95th Percentile	Investigation Undertaken. Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Wollombi Brook showing similar EC results and trends. Continue to watch and monitor.
SW40	08/03/2019	EC –95th Percentile	Watching Brief*
SW40	19/06/2019	EC –95th Percentile	Watching Brief* Note: Elevated EC is considered attributable to prolonged dry climatic conditions, and not related to mining related impacts. Wollombi Brook U/S showing similar EC results and trends. Results from subsequent monitoring events have confirmed results are back within trigger limits.
W1	19/06/2019	pH –5th Percentile	Watching Brief*
W2	19/06/2019	pH –5th Percentile	Watching Brief*
W3	19/06/2019	pH –5th Percentile	Watching Brief*
W4	26/03/2019	pH –5th Percentile	Watching Brief*
W27	31/03/2019	pH –5th Percentile	Watching Brief*
W28	31/03/2019	pH –5th Percentile	Watching Brief*
W1	19/06/2019	TSS – 50mg/L (ANZECC criteria)	Watching Brief*. Note: Unlikely to be associated with MTW mining related impacts.
W1	23/09/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Elevated TSS considered associated with recent rainfall and increased flow rate in the river at the time. Consistent with nearby W2 and W3 measurements. No signs of mining related impact.
W2	23/09/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Elevated TSS considered associated with recent rainfall and increased flow rate in the river at the time. Consistent with nearby W1 and W3 measurements. No signs of mining related impact.

Site	Date	Trigger Limit	Action Taken in Response
W2	10/12/2019	TSS – 50mg/L (ANZECC criteria)	Watching Brief*. Note: Unlikely to be associated with MTW mining related impacts. Elevated TSS results most likely attributable to sampling from slow flowing water following extended period of below average rainfall.
W3	19/06/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Elevated TSS considered associated with recent rainfall and increased flow rate in the river at the time. Consistent with nearby W1 and W2 measurements. No signs of mining related impact.
W3	23/09/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Elevated TSS considered associated with recent rainfall and increased flow rate in the river at the time. Consistent with nearby W1 and W2 measurements. No signs of mining related impact.
W4	31/03/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Field investigation did not identify any mining related sources of sediment. Elevated TSS results most likely attributable to high intensity rainfall event after prolonged dry period (52mm in 24 hours).
W5	09/01/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Field investigation did not identify any mining related sources of sediment. Elevated TSS results considered attributable to sampling from a pool of water with no flow.
W5	08/02/2019	TSS – 50mg/L (ANZECC criteria)	Field investigation did not identify any mining related sources of sediment. Elevated TSS results considered attributable to sampling from a pool of water with no flow.
W5	08/03/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Investigation did not identify any mining related sources of sediment. Elevated TSS results most likely attributable to sampling from a pool of water with no flow.
W14	31/03/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Field investigation did not identify any mining related sources of sediment. Elevated TSS results most likely attributable to high intensity rainfall event after prolonged dry period (52mm in 24 hours).
W15	31/03/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Field investigation did not identify any mining related sources of sediment. Elevated TSS results most likely attributable to high intensity rainfall event after prolonged dry period (52mm in 24 hours).

Site	Date	Trigger Limit	Action Taken in Response
W27	31/03/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Elevated TSS results most likely attributable to high intensity rainfall event after prolonged dry period (52mm in 24 hours). In addition, TSS results were potentially affected by turbid water associated with the overtopping of an MTW sediment dam as a result of greater than design rainfall on 30 March 2019. This is discussed further in Section 8.0.
W28	31/03/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Elevated TSS results most likely attributable to high intensity rainfall event after prolonged dry period (52mm in 24 hours). In addition, TSS results were potentially affected by turbid water associated with the overtopping of an MTW sediment dam as a result of greater than design rainfall on 30 March 2019. This is discussed further in Section 8.0.
SW40	23/09/2019	TSS – 50mg/L (ANZECC criteria)	Investigation undertaken. Note: Elevated TSS considered associated with recent rainfall (17-19 and 22 September) resulting in mobilisation of sediment after prolonged dry conditions. Unlikely to be associated with MTW mining related impacts. Continue to monitor.



Note: Missing data indicates that there was insufficient water to take a sample, or that there was no safe access.

FIGURE 26: WATERCOURSE pH TRENDS 2016 TO 2019

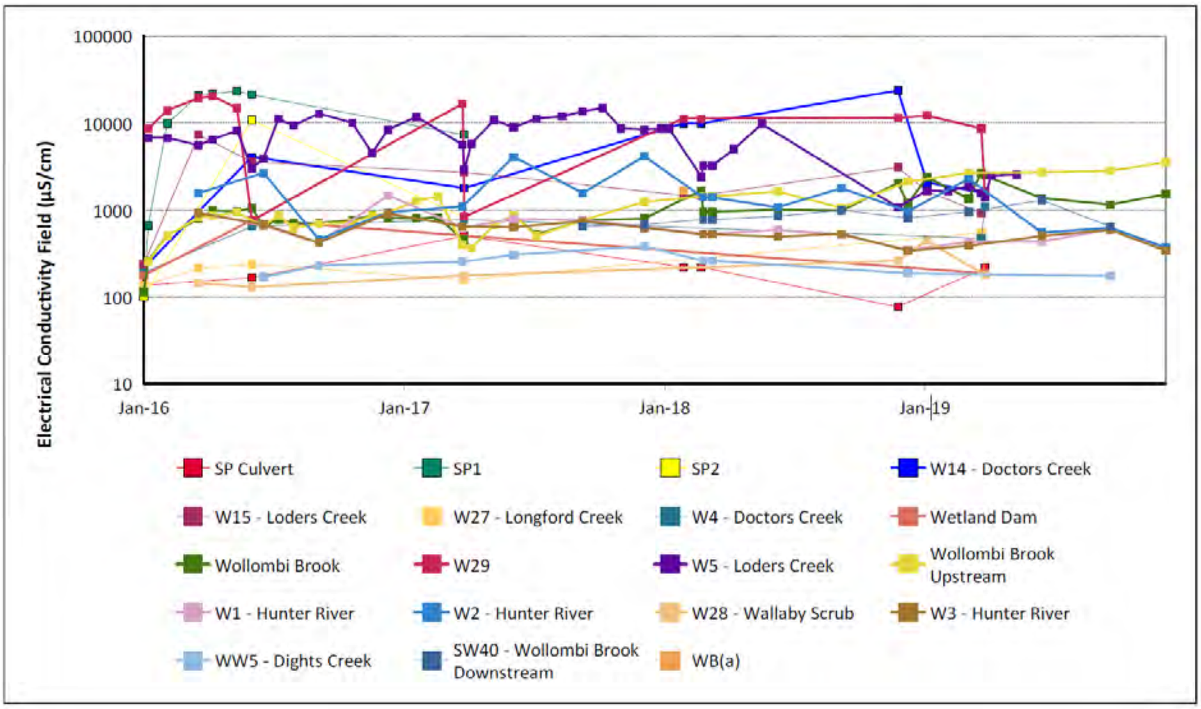


FIGURE 27: WATERCOURSE EC TRENDS 2016 TO 2019

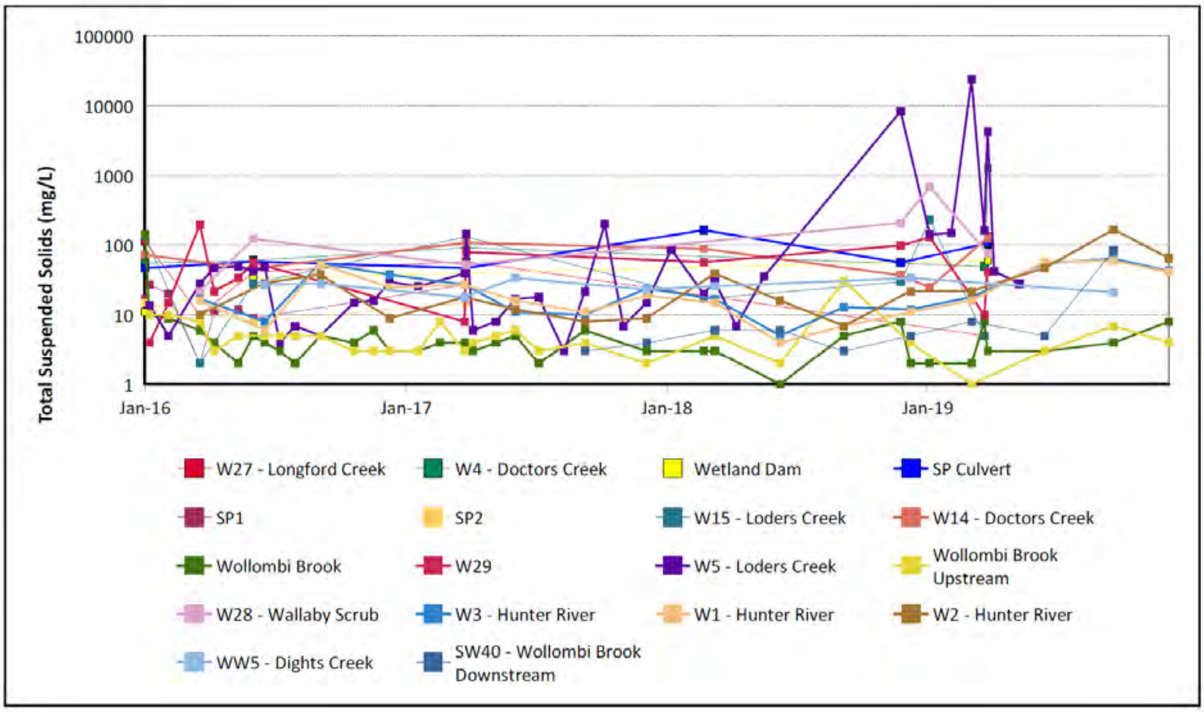


FIGURE 28: WATERCOURSE TSS TRENDS 2016 TO 2019

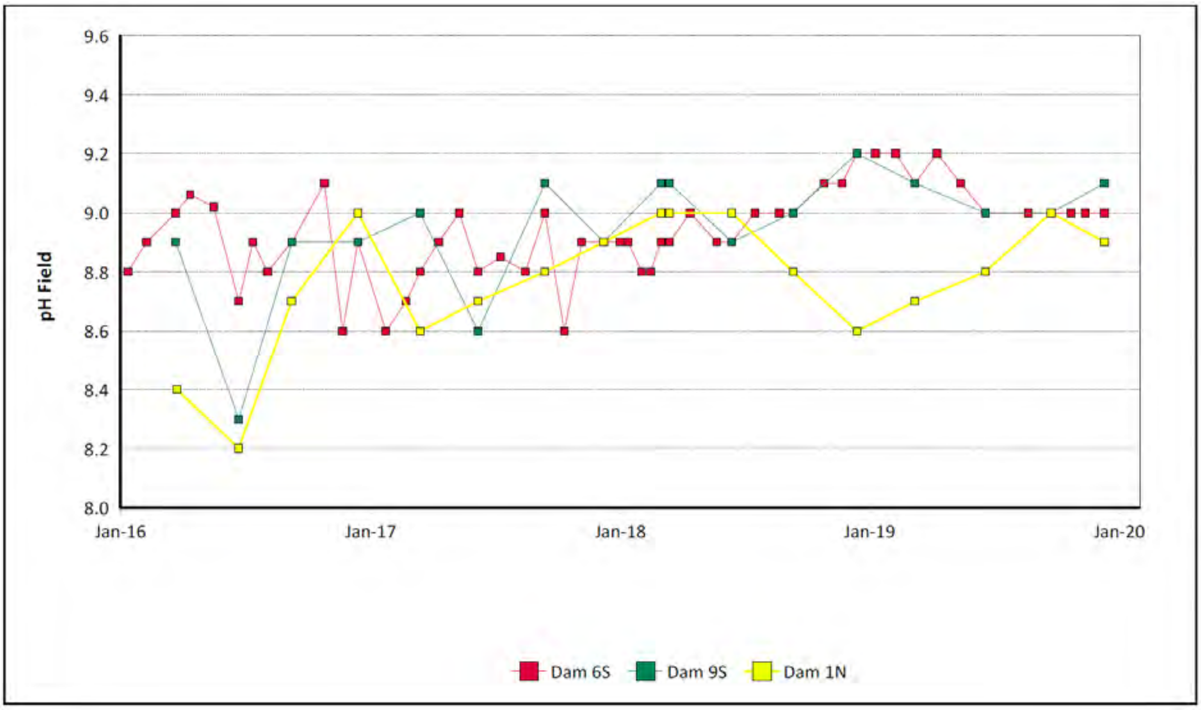


FIGURE 29: SITE DAMS PH TRENDS 2016 TO 2019

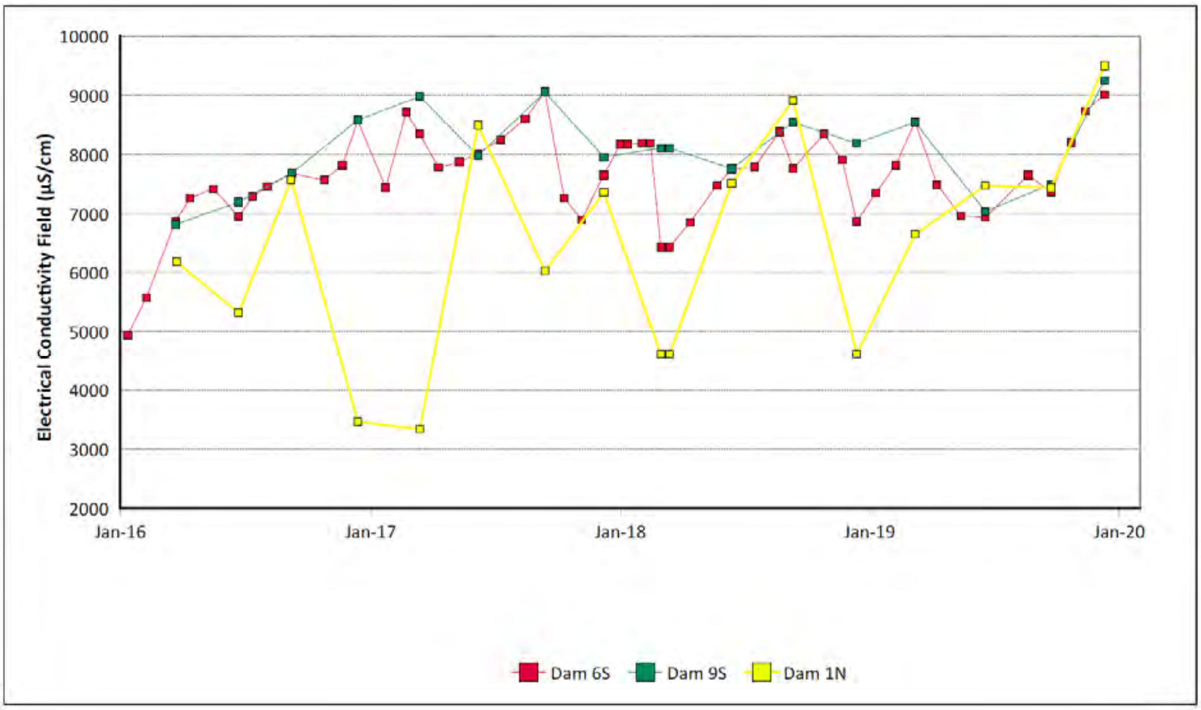


FIGURE 30: SITE DAMS EC TRENDS 2016 TO 2019

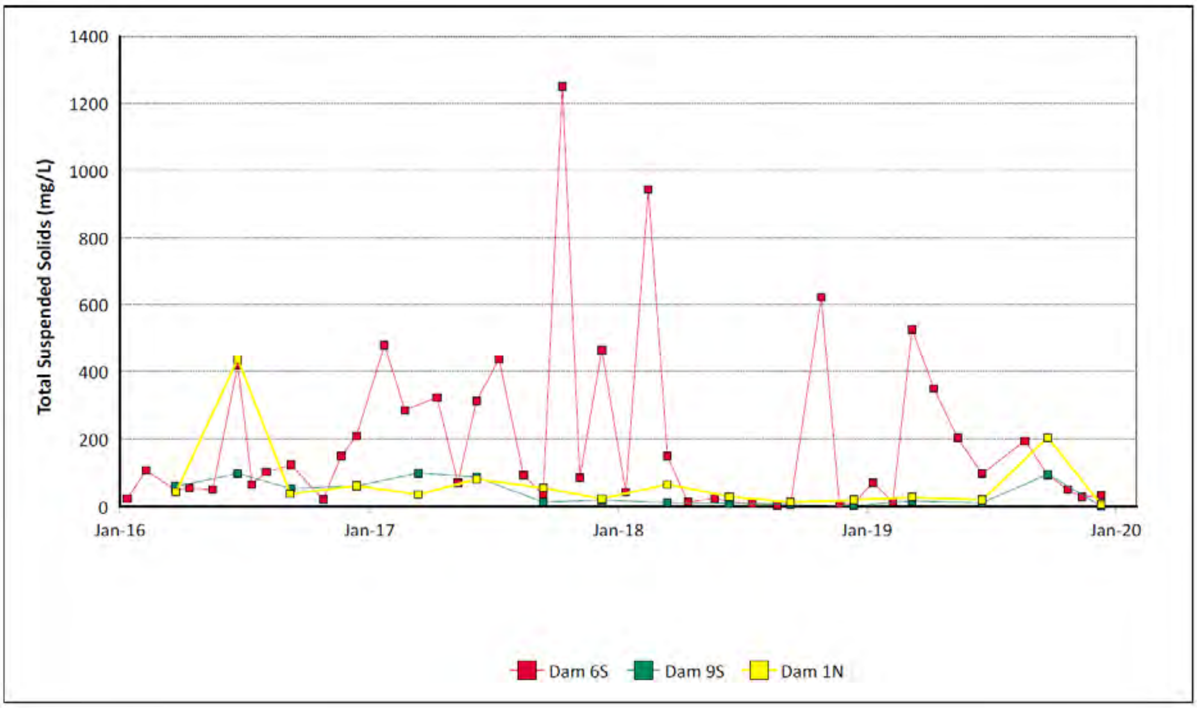


FIGURE 31: SITE DAMS TSS TRENDS 2016 TO 2019

6.7.4.1 Stream Health and Channel Stability

A programme to monitor and report on the stream and riparian vegetation health in Loders Creek and Wollombi Brook which may be potentially affected by the development commenced in 2016. The monitoring programme is conducted in conjunction with a similar programme managed by Bulga Surface Operations.

The annual monitoring program includes the following:

- Documenting locations and dimensions of significant erosive or depositional features;
- Photographs upstream, downstream, at both the left and right banks;
- Rating the site with the Ephemeral Stream Assessment protocol developed by the CSIRO to assess the erosional state of the creek at the monitoring location (a measure of channel stability);
- Rating the site with the Rapid Appraisal of Riparian Condition (RARC) protocol developed by Land & Water Australia. This assesses the ecological condition of riparian habitats using indicators that reflect functional aspects of the physical, community and landscape features of the riparian zone (a measure of stream health); and
- Taking measurements of the channel cross-sections (transects) for comparison purposes for any future monitoring.

A copy of the stream health and stability monitoring report is provided as **Appendix 3**. As outlined in the report, stream health and channel stability monitoring results in 2019 indicated that channel stability in Wollombi Brook had remained generally the same as the previous year's monitoring cycle

conditions and that the majority of Loders Creek displayed stable environments. Generally, the monitoring identified that both creeks have not significantly changed from what was observed during the previous survey. However, some evidence of minor erosion progression was observed at some of the monitoring points. Many sections of the local creeks experience active erosion as a result of natural influences and are not related to the development. This is exacerbated by dispersive sub-soils in some areas. Improvements were also identified during the 2019 survey, resulting from both natural occurrences as well as man-made upgrade works.

During the previous reporting period MTW undertook creek stability improvement works at its Mount Thorley Operations HRSTS discharge location to improve the stream health and channel stability in this location. This site had a classification of poor before the remediation works were completed. During the 2019 assessment, the site was classified as stabilising.

The 2019 stream health and stability assessment did not identify any direct impacts from MTW's current operations as contributing to a decline in stream health or channel stability. Despite this, MTW undertook an assessment of the LC3 stream monitoring location in the Loders Creek Cultural Heritage Conservation Area during the reporting period to assess whether improvement works are achievable in this zone. During the inspection, it was identified that the area is highly vegetated and that access into the affected zone was difficult without moderate levels of surface disturbance. It was also identified that the area was located within a sensitive cultural heritage management zone with cultural heritage sites in close proximity. MTW is committed to developing a remediation program for the LC3 location in the next reporting period in consultation with a qualified land regeneration consultant and in consultation with the relevant government and community stakeholders.

6.7.5 Groundwater Management

Groundwater monitoring activities were undertaken in 2019 in accordance with the MTW Water Management Plan and groundwater monitoring programme. The monitoring results are used to establish and monitor trends in physical and geochemical parameters of surrounding groundwater potentially influenced by mining.

The groundwater monitoring programme at MTW measures the quality of groundwater against background data, EIS predictions and historical trends. Ground water quality is evaluated through the parameters of pH, EC, and standing water level. A comprehensive suite of analytes are measured on an annual basis, including major anions, cations and metals. MTW modified its groundwater sampling methodology during the reporting period following a recommendation in the 2018 annual groundwater review undertaken by an independent groundwater consultant. Accordingly bore purging is undertaken across the monitoring network for routine samples (where infrastructure allows) to ensure a representative sample is collected in accordance with industry standards.

Groundwater monitoring data is reviewed on a quarterly basis. The review involves a comparison of measured pH and EC results against internal trigger values (5th and 95th percentile) which have been

derived from the historical data set. The response to results outside the trigger limits is detailed in the MTW Water Management Plan.

The monitoring locations are shown in **Figure 32** and the annual Ground Water Review report can be found in **Appendix 4.**

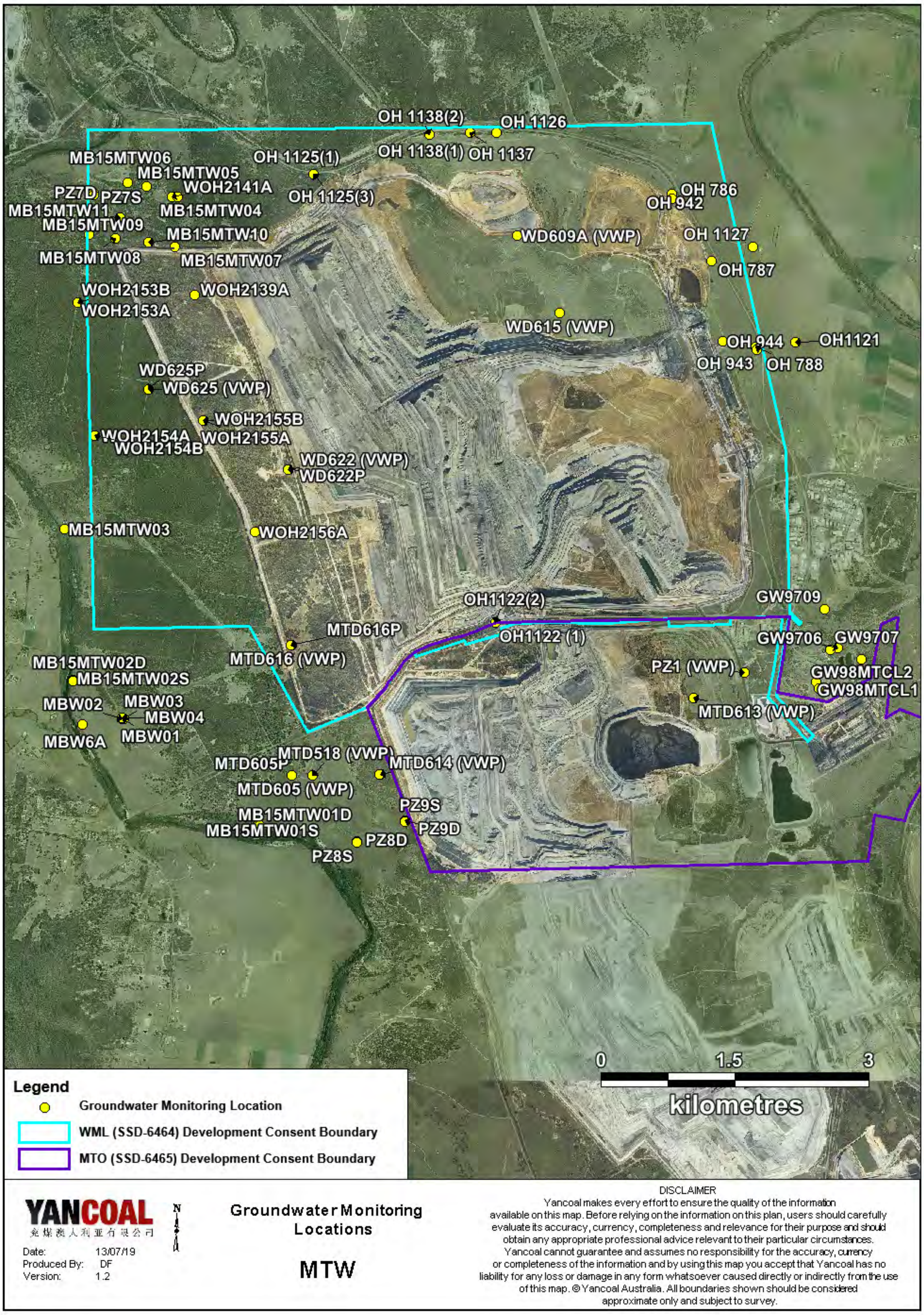


FIGURE 32: GROUNDWATER MONITORING NETWORK AT MTW IN 2019

6.7.6 Groundwater Performance

Sampling of ground waters was carried out on 275 occasions from 59 bores across MTW in accordance with AS/NZS 5667.6 (1998). Where laboratory analysis was undertaken, this was performed by a NATA accredited laboratory. Groundwater sampling and analysis was undertaken as required with the following exceptions detailed in **Table 6.17**.

TABLE 6.17 MTW WATER MONITORING DATA RECOVERY FOR 2019 (BY EXCEPTION)

Location	Data Recovery (%)	Comment
OH943	25%	Insufficient water for sampling in June, September and December
PZ9S	25%	Insufficient water for sampling in June, September and December
GW9709	75%	Insufficient water for sampling in December
MBW02	75%	No access possible in February due to a safety issue
OH1137	25%	Insufficient water for sampling in June, September and December
WOH2153B	25%	Insufficient water for sampling in February, May and August
WOH2156B	25%	Insufficient water for sampling in May, August and November
MB15MTW04	0%	Insufficient water for sampling in 2019
MB15MTW05	0%	Insufficient water for sampling in 2019
MB15MTW06	0%	Insufficient water for sampling in 2019
MB15MTW07	0%	Insufficient water for sampling in 2019
MB15MTW08	0%	Insufficient water for sampling in 2019
MB15MTW09	0%	Insufficient water for sampling in 2019

Location	Data Recovery (%)	Comment
MB15MTW10	0%	Insufficient water for sampling in 2019
MB15MTW11	0%	Insufficient water for sampling in 2019

A summary of the monitoring results for MTW Groundwater Sites is provided in the Monthly Environmental Monitoring Reports, available via MTW's Insite website (https://insite.yancoal.com.au).

The following sections present groundwater monitoring data in relation to the geographic locations and target stratigraphy for groundwater monitoring bores. Each location is discussed below, and a summary of monitoring data presented. Where monitoring results were recorded outside the internal trigger limit, these results are summarised in tables for each location.

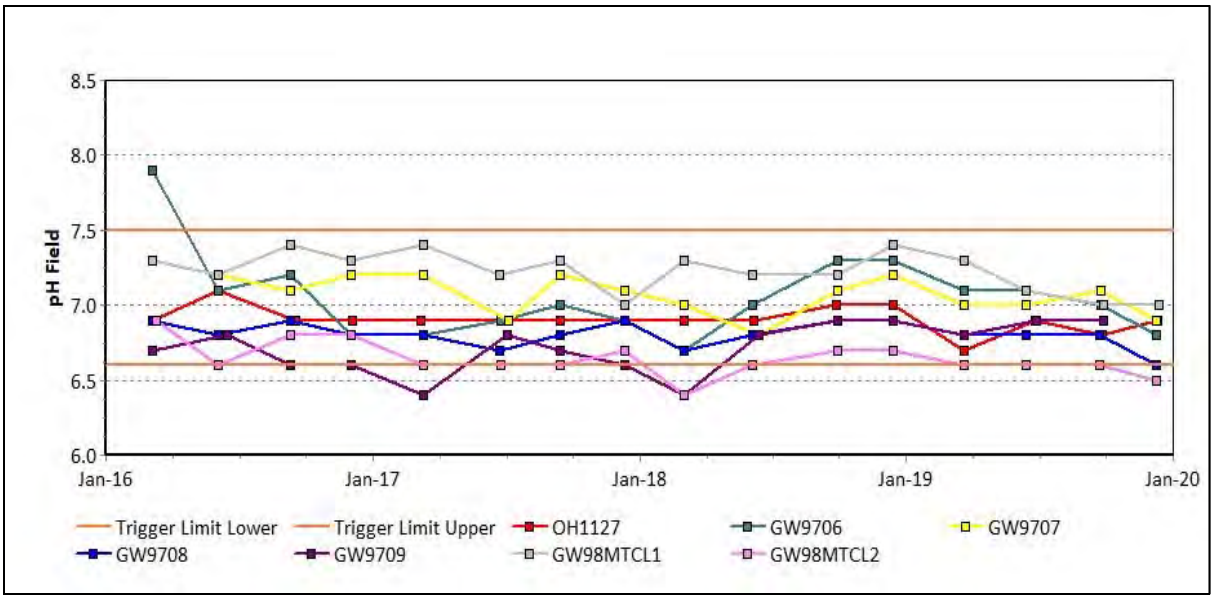
6.7.6.1 Bayswater Seam Bores

Groundwater monitoring in the Bayswater seam was undertaken from seven sites during 2019. A total of 27 samples were collected during the reporting period. The pH, EC and SWL trends for 2016 to 2019 for Bayswater groundwater bores are shown in **Figure 33** to **Figure 35** respectively. Trigger tracking results are given in **Table 6.18**. Results were generally stable and consistent with historical trends. Further detailed overview of monitoring results from these bores is provided in **Appendix 4**.

TABLE 6.18 BAYSWATER SEAM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

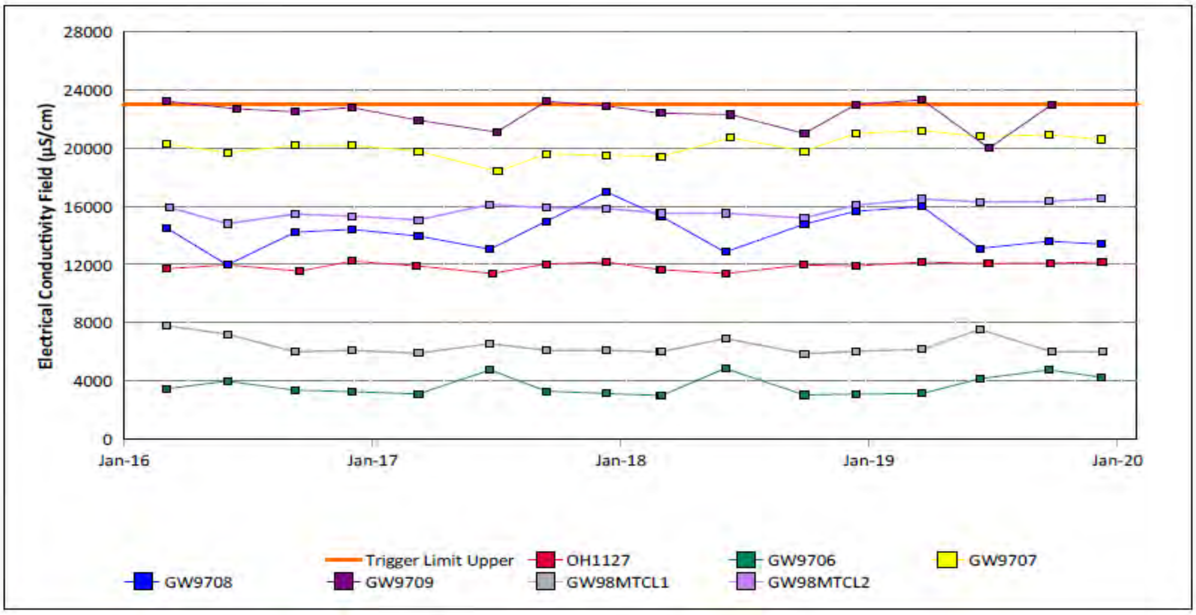
Location	Date	Trigger limit	Action taken in response
GW9709	21/03/2019	**EC – 95th percentile**	Watching Brief* Note: Monitoring result obtained in June 19 shows values back within trigger limits.
GW9709	27/09/2019	**EC – 95th percentile**	Watching Brief* Note: Elevated EC levels likely to be attributed to prolonged dry climatic conditions. Continue to monitor.
GW98MTCL2	09/12/2019	**pH – 5th percentile**	Watching Brief *

** = 1st/2nd trigger. Watching Brief established pending outcomes of subsequent monitoring events. No specific actions required*



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 33: BAYSWATER SEAM PH TRENDS 2016 TO 2019



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 34: BAYSWATER SEAM EC TRENDS 2016 TO 2019

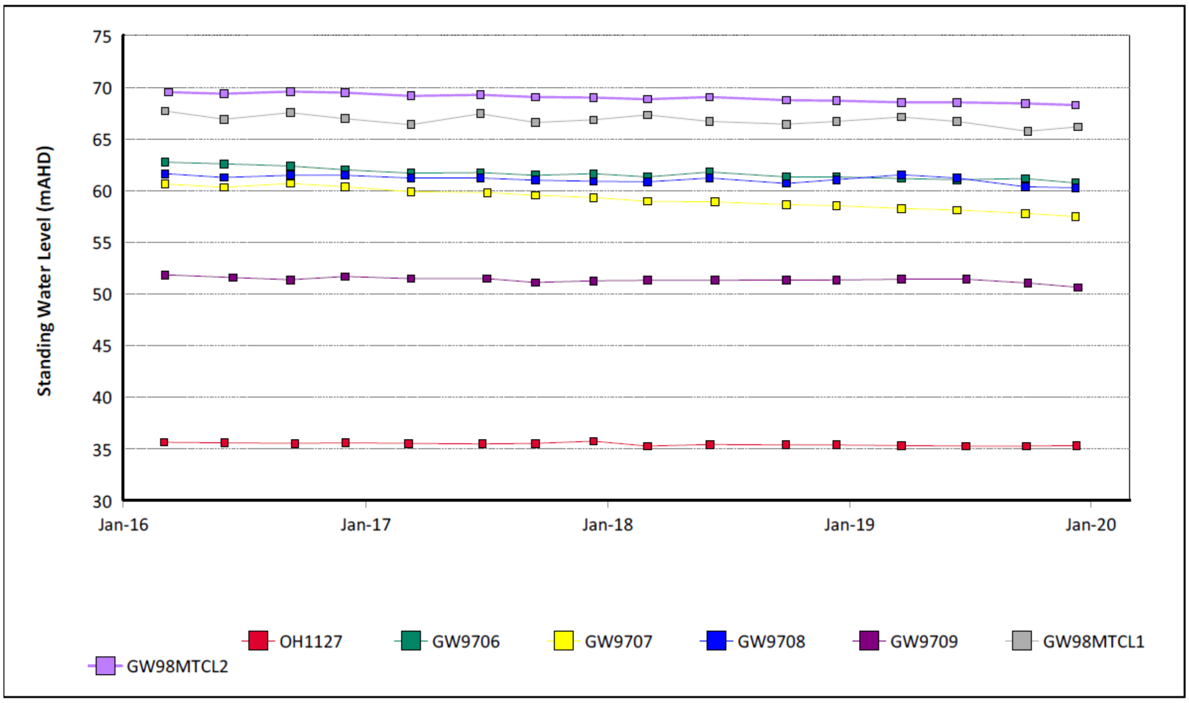


FIGURE 35: BAYSWATER SWL TRENDS 2016 TO 2019

6.7.6.2 Bowfield Seam Bores

Groundwater monitoring in the Bowfield seam was undertaken at one site during 2019. A total of 4 samples were collected during the reporting period. The pH, EC and SWL trends for 2016 to 2019 are shown in **Figure 36, Figure 37, Figure 38** respectively. Water quality results were similar to historical data throughout the reporting period. The SWL in Bore OH1125 decreased from 47.19 mAHD to 29.71 mAHD during the reporting period. This decline does correspond with the decrease in rainfall over the same period, however, Bore OH1125 is also located directly to the north of North Pit and the decline may be related to a drawdown into the active mine workings in North Pit. The trend may also be influenced by abstraction from LUG Bore located approximately 1.25 km to the north west. The LUG bore intersects the historical Lemington Underground workings, which mined through the deeper Mt Arthur Seam. The increased groundwater level drawdown observed over 2019 may therefore be a combination of the effects of mining of the North Pit and licenced abstraction from the LUG bore.

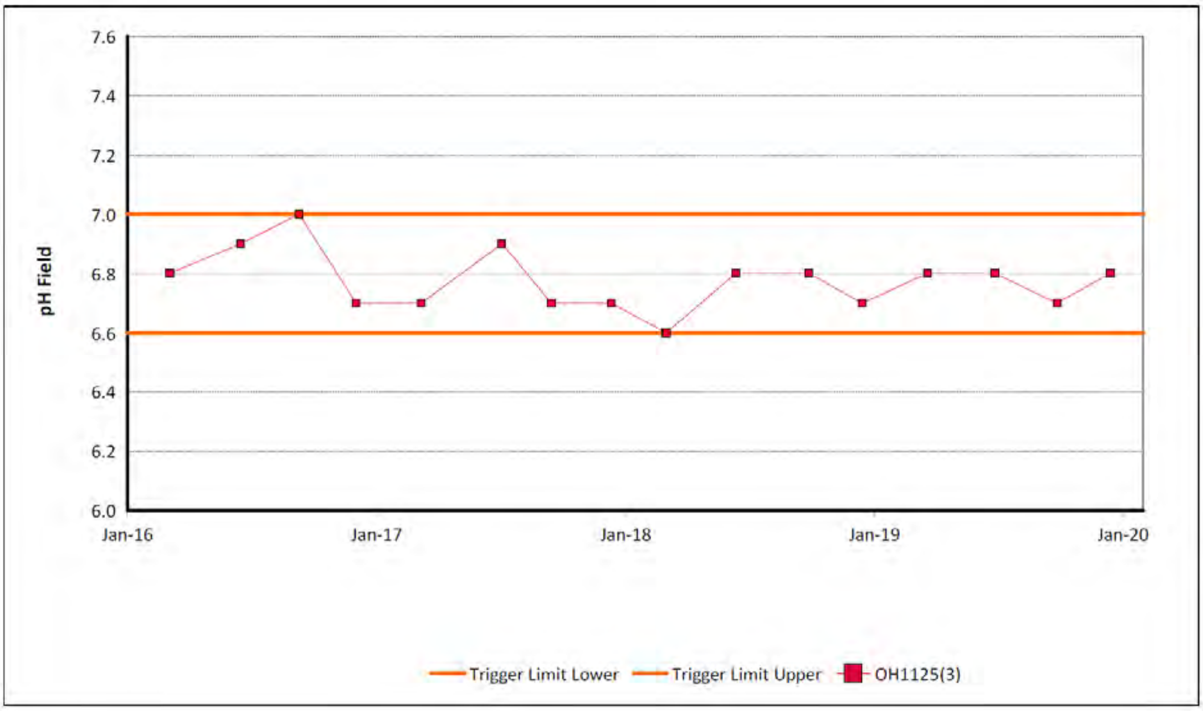


FIGURE 36: BOWFIELD SEAM PH TREND 2016 TO 2019

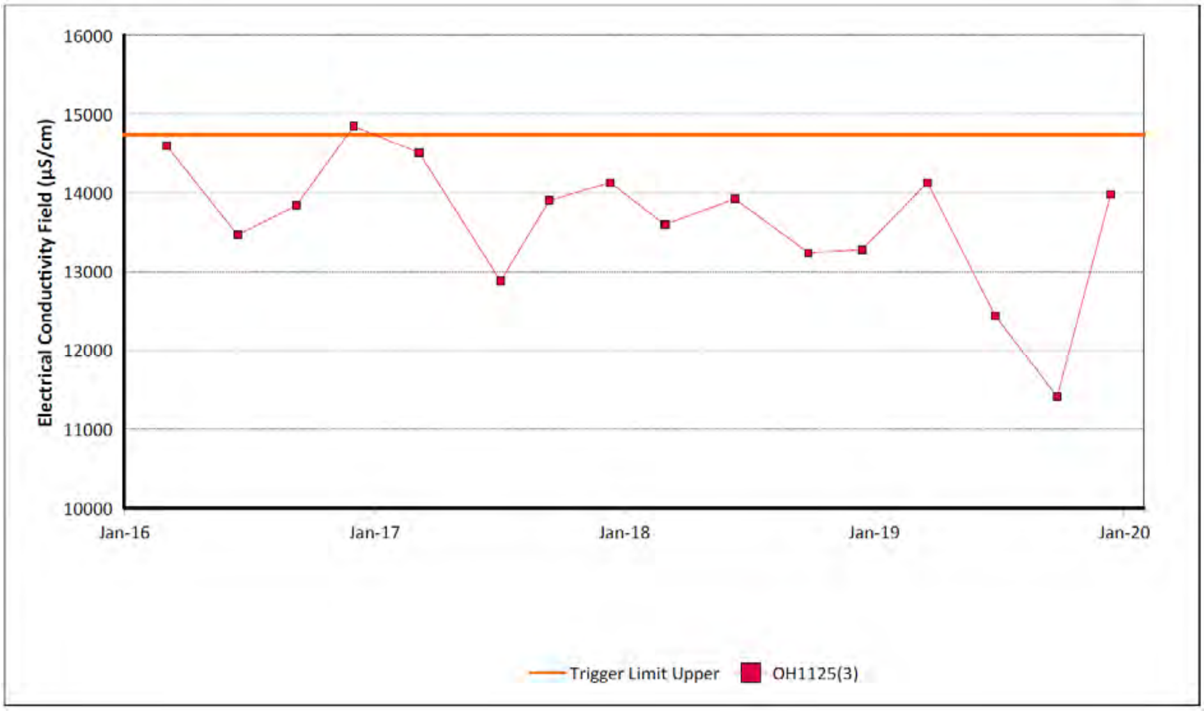


FIGURE 37: BOWFIELD SEAM EC TRENDS 2016 TO 2019

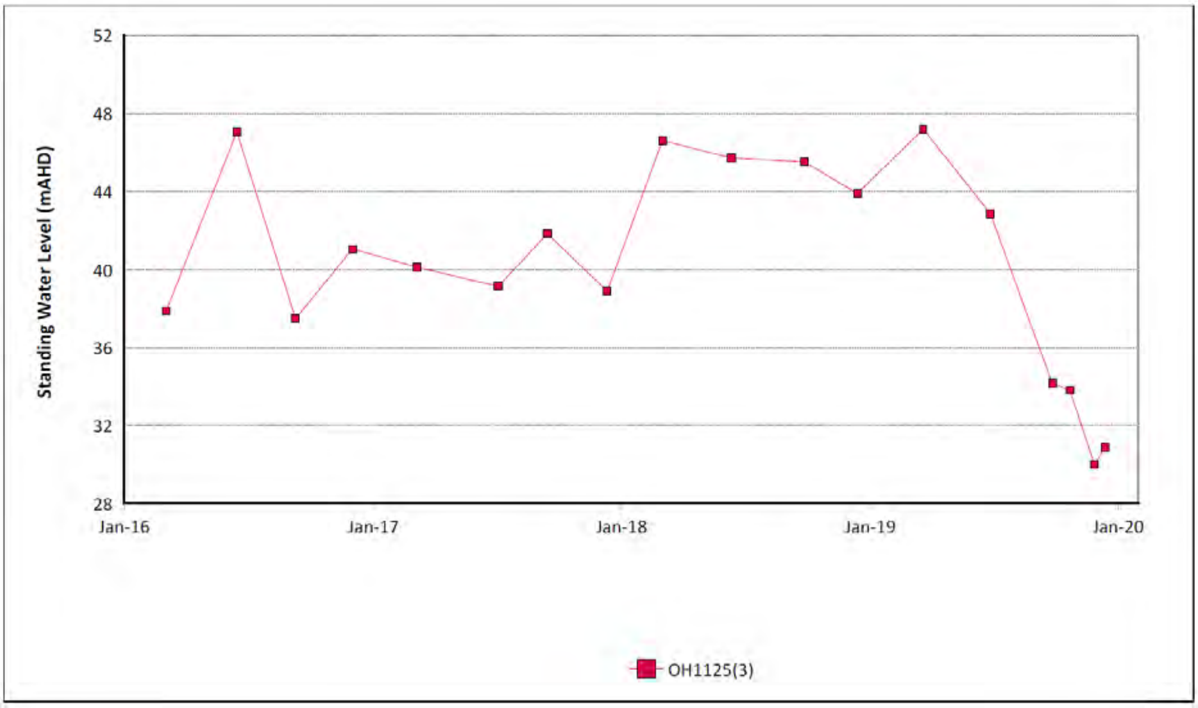


FIGURE 38: BAYSWATER SWL TRENDS 2016 TO 2019

6.7.6.3 Blakefield Seam Bores

Groundwater monitoring in the Blakefield seam was undertaken from three sites during 2019. A total of 20 samples were collected during the reporting period. The pH, EC and SWL trends for 2016 to 2019 are shown in **Figure 39, Figure 40** and **Figure 41** respectively. Water quality trends were generally steady with an increasing pH and EC trend observed in WOH2139A. The elevated EC is likely a result of the declining water levels due to depressurisation from the open cut operations.

Over 2019 groundwater levels generally declined within the Blakefield Seam bores OH1125 (1) and WOH2139A. Groundwater levels within OH1122 remained relatively stable throughout the reporting period. In response to the active mine progression Bore OH1125(1) recorded a 3.5 m decline, Bore WOH2139A recorded a 5.7 m decline and Bore OH1122(1) recorded a 0.2 m decline over 2019. The SWL results are described further in the Annual Groundwater Review (**Appendix 4**). Trigger tracking results are given in **Table 6.19**.

Table 6.19 Blakefield Seam Groundwater 2019 Internal Trigger Tracking

Location	Date	Trigger limit	Action taken in response
WOH2139A	22/01/2019 08/02/2019 21/03/2019 09/04/2019 14/05/2019 18/06/2019 16/07/2019 26/08/2019 26/09/2019 22/10/2019 26/11/2019 13/12/2019	**pH - 95th percentile**	Watching Brief* Investigation undertaken. pH values for WOH2139A considered to be associated with prolonged dry climatic conditions and are consistent with results obtained since 2017 at this location. Monitoring to be moved to quarterly.

** = 1st/2nd trigger. Watching Brief established pending outcomes of subsequent monitoring events. No specific actions required*

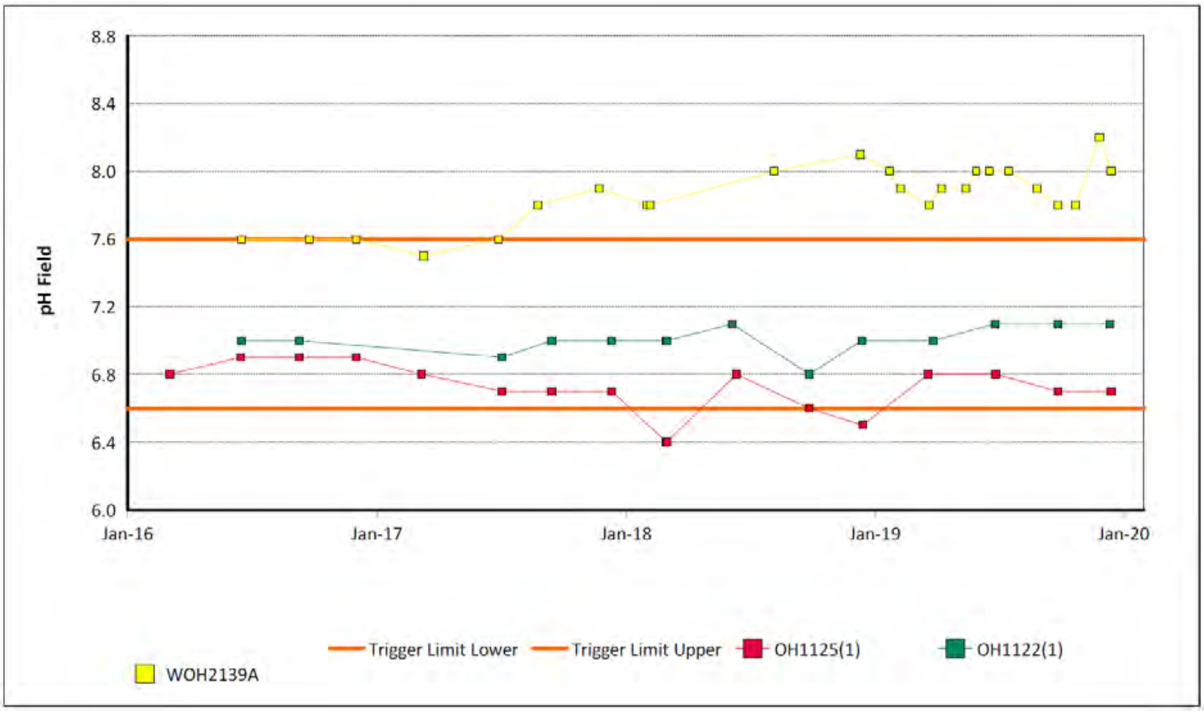


FIGURE 39: BLAKEFIELD SEAM GROUNDWATER PH TRENDS 2016 TO 2019

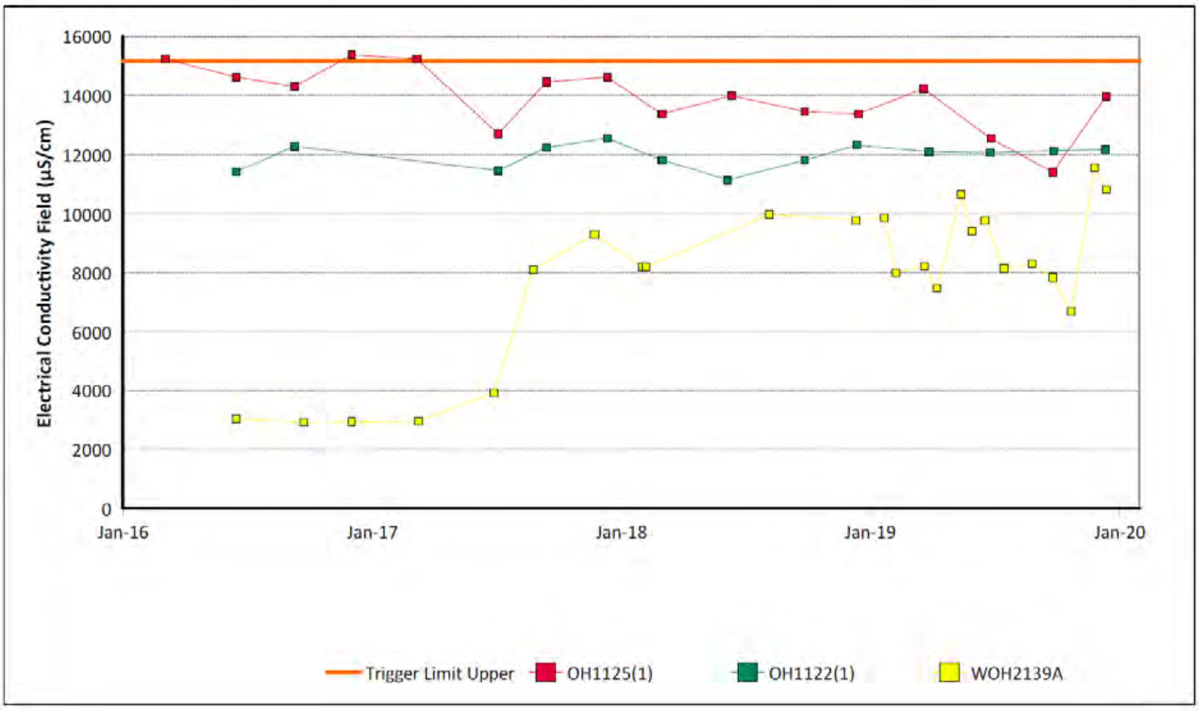


FIGURE 40: BLAKEFIELD SEAM GROUNDWATER EC TRENDS 2016 TO 2019

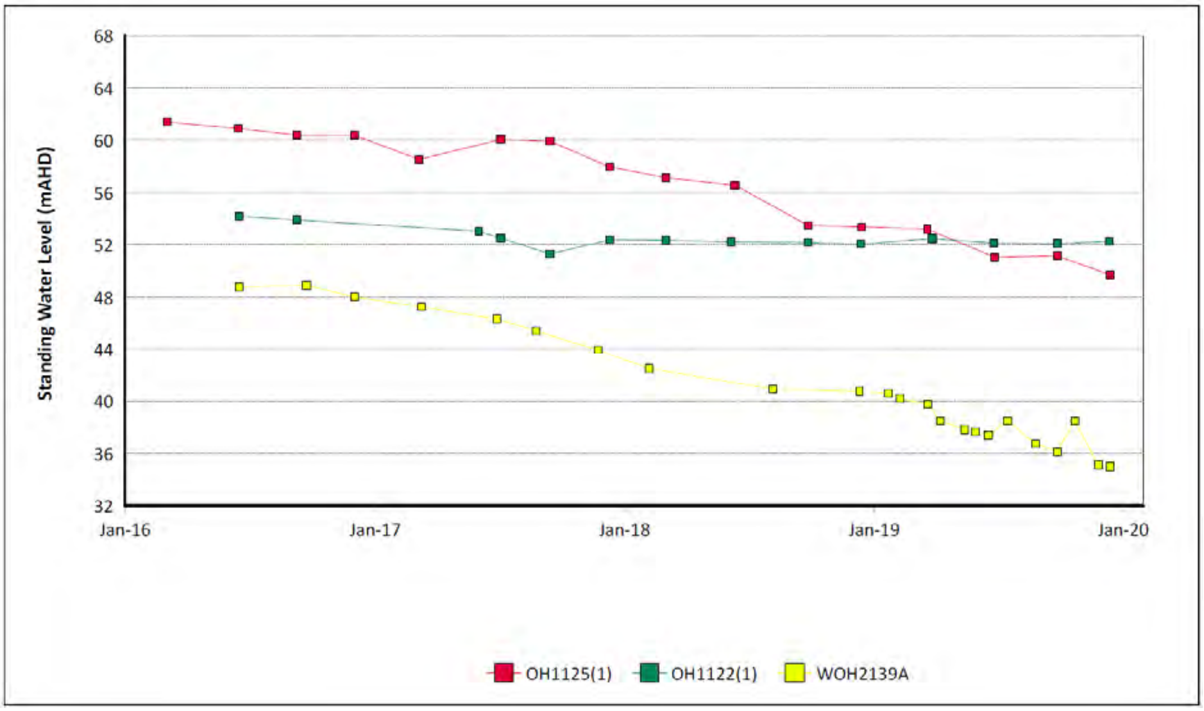


FIGURE 41: BLAKEFIELD SEAM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.4 Hunter River Alluvium Bores

Groundwater monitoring in the Hunter River Alluvium was undertaken from five sites during 2019. A total of 17 samples were collected during the reporting period. The pH, EC and SWL trends for 2016 to 2019 for Hunter River Alluvium groundwater bores are shown in **Figure 42** to **Figure 52**. Over the 2019 monitoring period bore OH788 recorded pH levels at and marginally below the lower trigger level of 7.1 throughout 2019. EC concentrations were also recorded above the trigger level of 11,742 µS/cm in Q2, Q3 and Q4.

Over 2019, all of the Hunter River Alluvium bores showed stable SWL results consistent with historical trends.

TABLE 6.20 HUNTER RIVER ALLUVIUM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

Location	Date	Trigger limit	Action taken in response
OH786	20/03/2019	**EC – 95th percentile**	Watching Brief* Note: Monitoring result obtained in June 19 was within trigger limits.
	26/09/2019		Watching Brief* Note: Elevated EC levels likely to be attributed to prolonged dry climatic conditions. Continue to monitor.
	10/12/2019		Watching Brief*
OH787	20/03/2019	**EC – 95th percentile**	Watching Brief* Note: Monitoring result obtained in June 19 and September shows values back within trigger limits.
	12/12/2019		Watching Brief*
OH942	20/03/2019	**EC – 95th percentile**	Watching Brief*
	26/06/2019		Watching Brief* Note: Monitoring result obtained in September 19 was within trigger limits. No further action required.
OH788	25/06/2019	**EC – 95th percentile**	Watching Brief* Note: Elevated EC levels likely to be attributed to prolonged dry climatic conditions. Continue to monitor.
	25/09/2019		Watching Brief* Note: Elevated EC levels likely to be attributed to prolonged dry climatic conditions. Continue to monitor.
	12/12/2019		Investigation Undertaken. Elevated EC levels likely to be attributed to prolonged dry climatic conditions.
OH788	25/09/2019	**pH – 5th percentile**	Watching Brief*

** = 1st/2nd trigger. Watching Brief established pending outcomes of subsequent monitoring events. No specific actions required*

FIGURE 42: HUNTER RIVER ALLUVIUM BORE OH786 PH TREND 2016 TO 2019

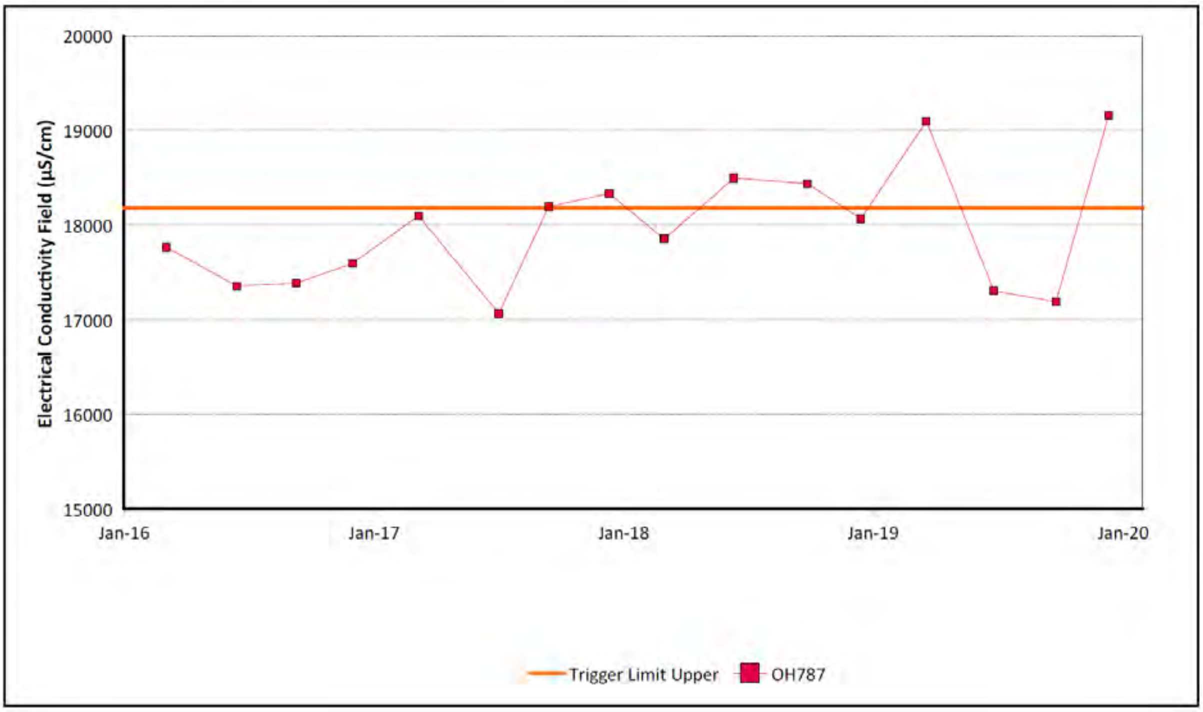


FIGURE 43: HUNTER RIVER ALLUVIUM BORE OH786 EC TREND 2016 TO 2019

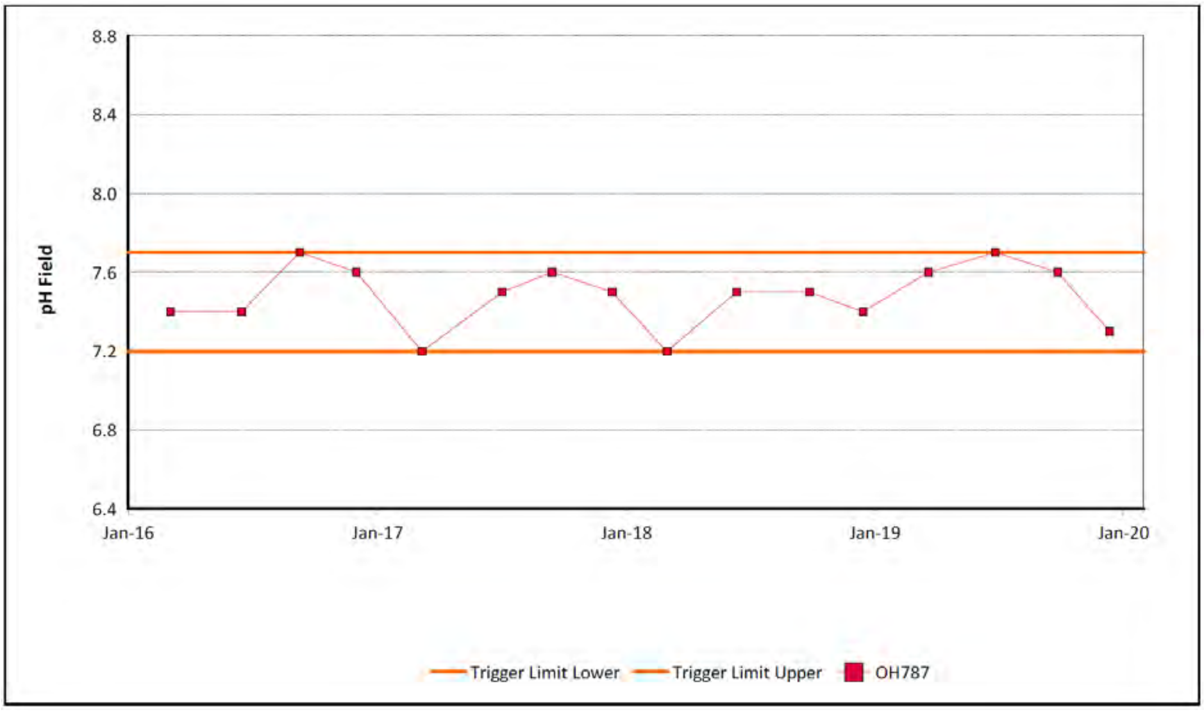


FIGURE 44: HUNTER RIVER ALLUVIUM BORE OH787 PH TREND 2016 TO 2019

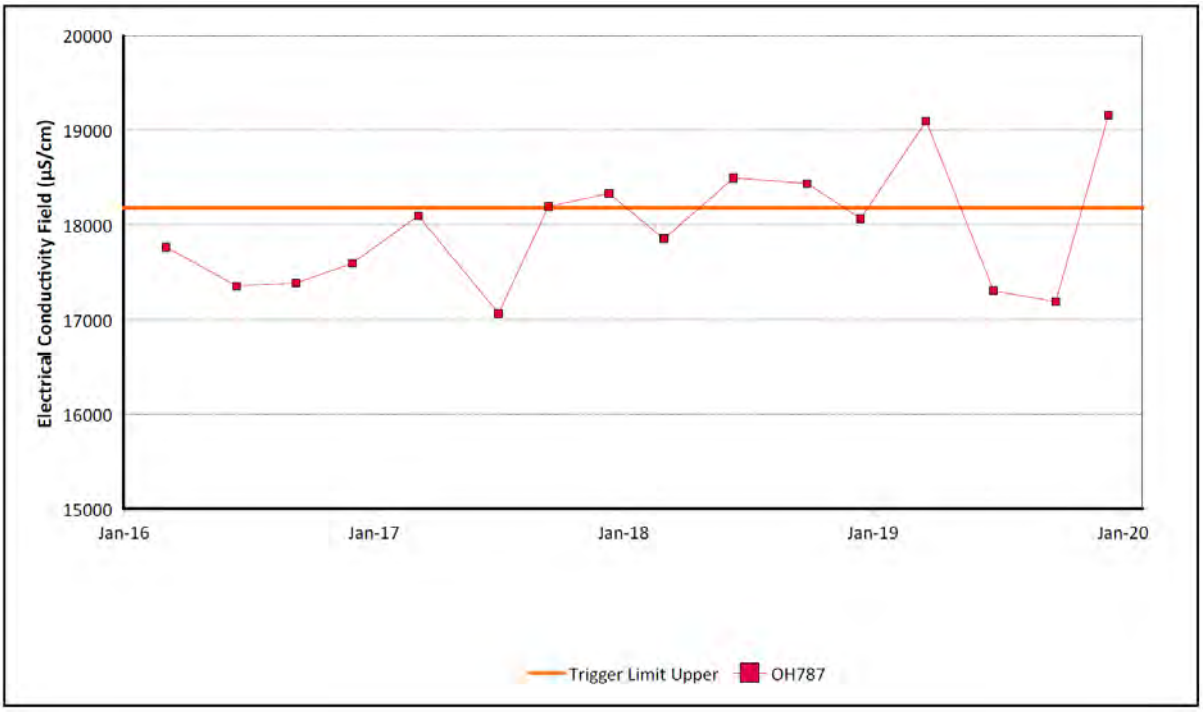


FIGURE 45: HUNTER RIVER ALLUVIUM BORE OH787 EC TREND 2016 TO 2019

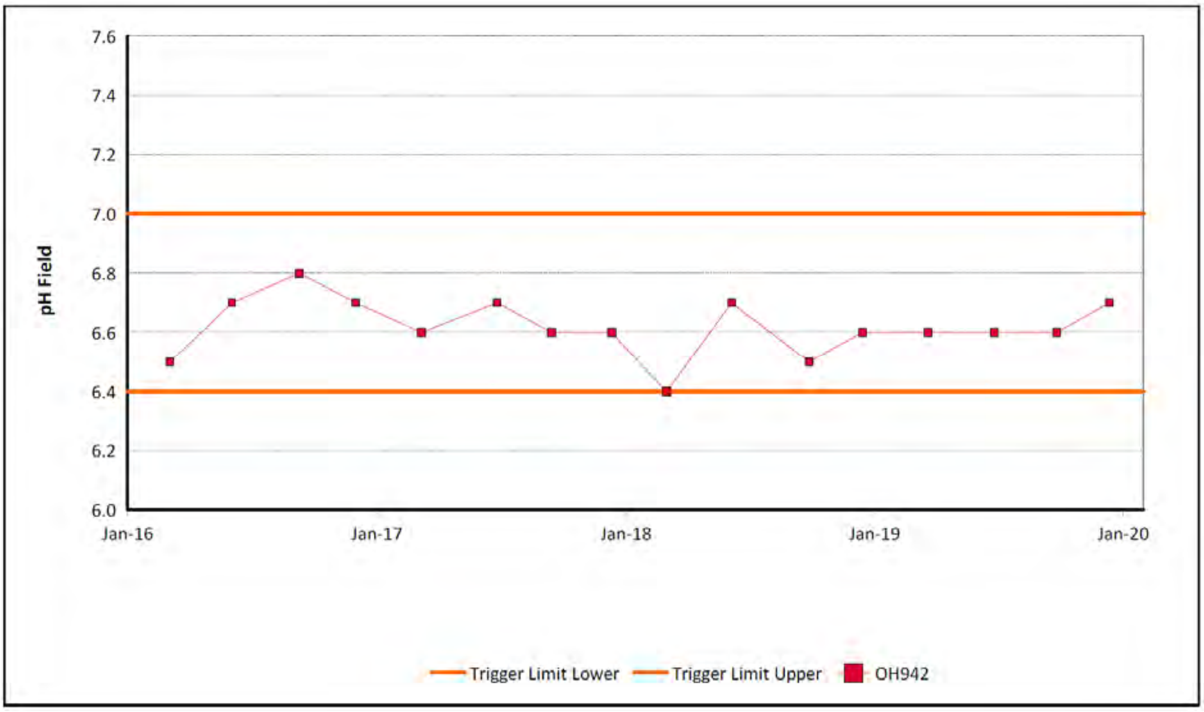


FIGURE 46: HUNTER RIVER ALLUVIUM BORE OH942 pH TREND 2016 TO 2019

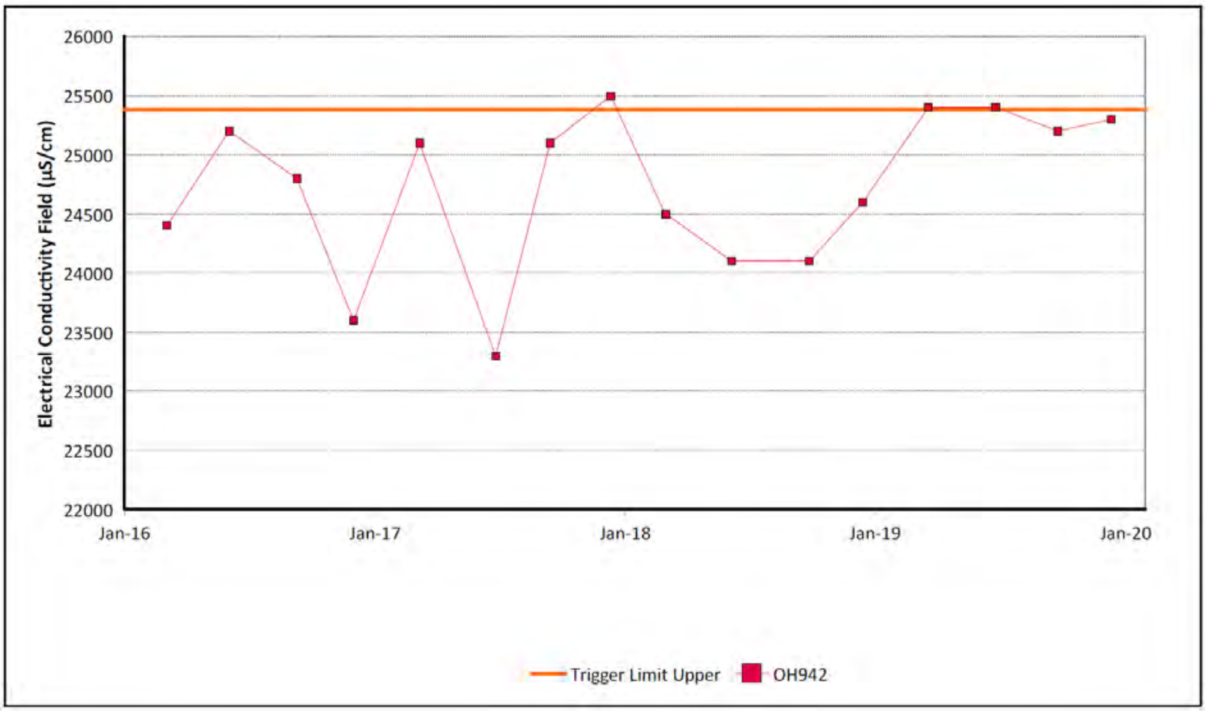
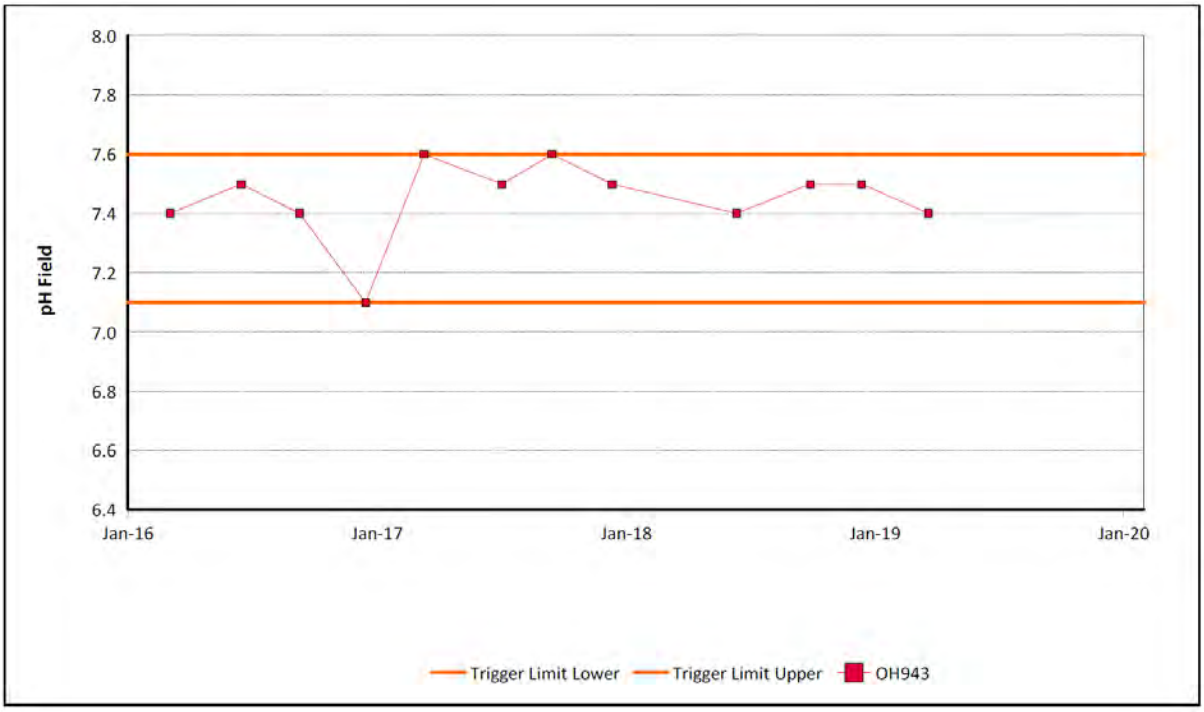
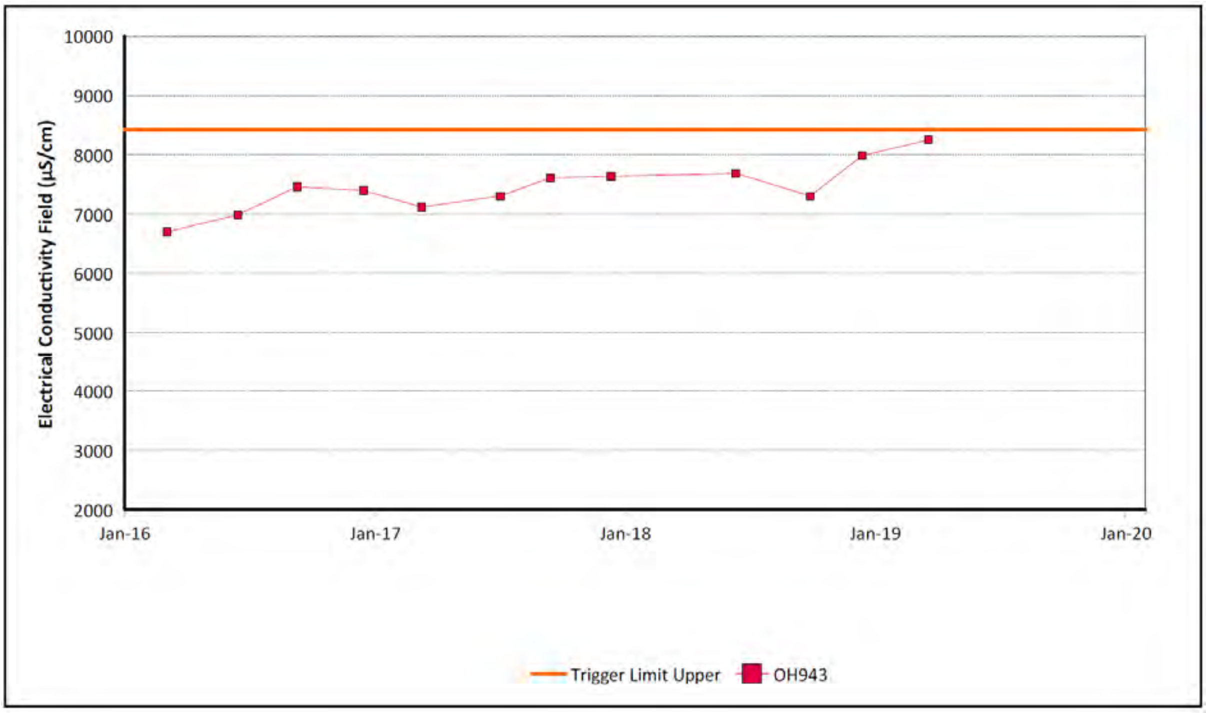


FIGURE 47: HUNTER RIVER ALLUVIUM BORE OH942 EC TREND 2016 TO 2019



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 48: HUNTER RIVER ALLUVIUM BORE OH943 PH TREND 2016 TO 2019



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 49: HUNTER RIVER ALLUVIUM BORE OH943 EC TREND 2016 TO 2019

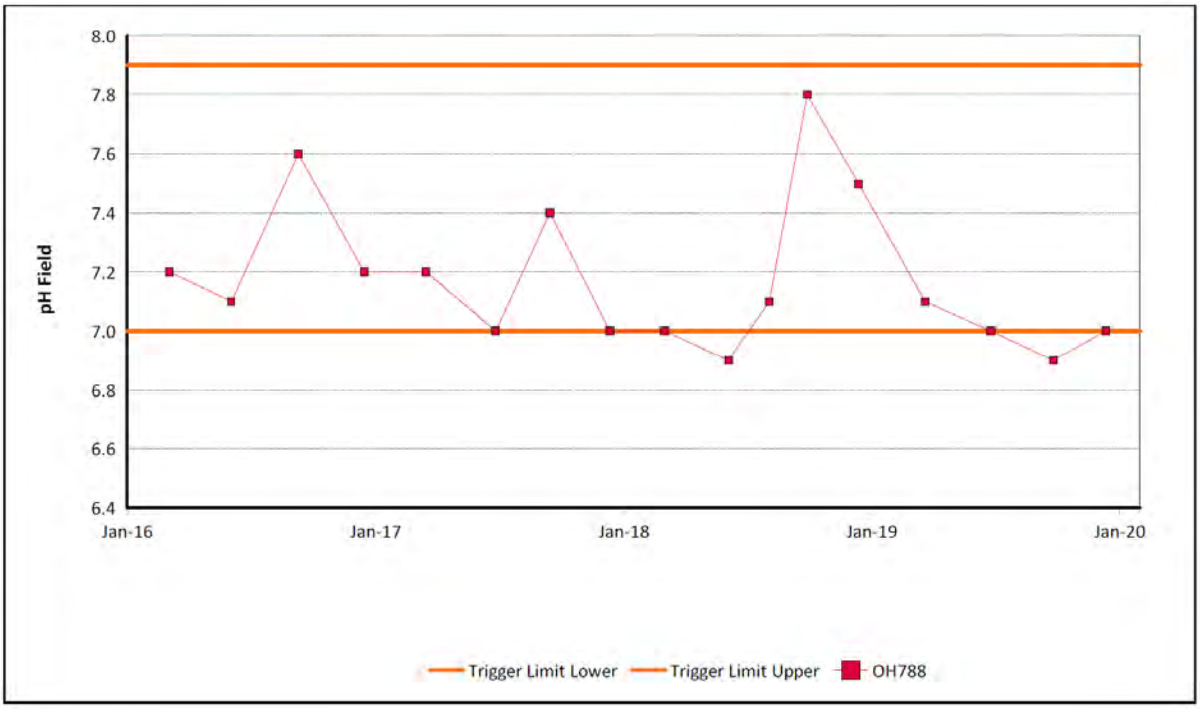


FIGURE 50: HUNTER RIVER ALLUVIUM BORE OH788 PH TREND 2016 TO 2019

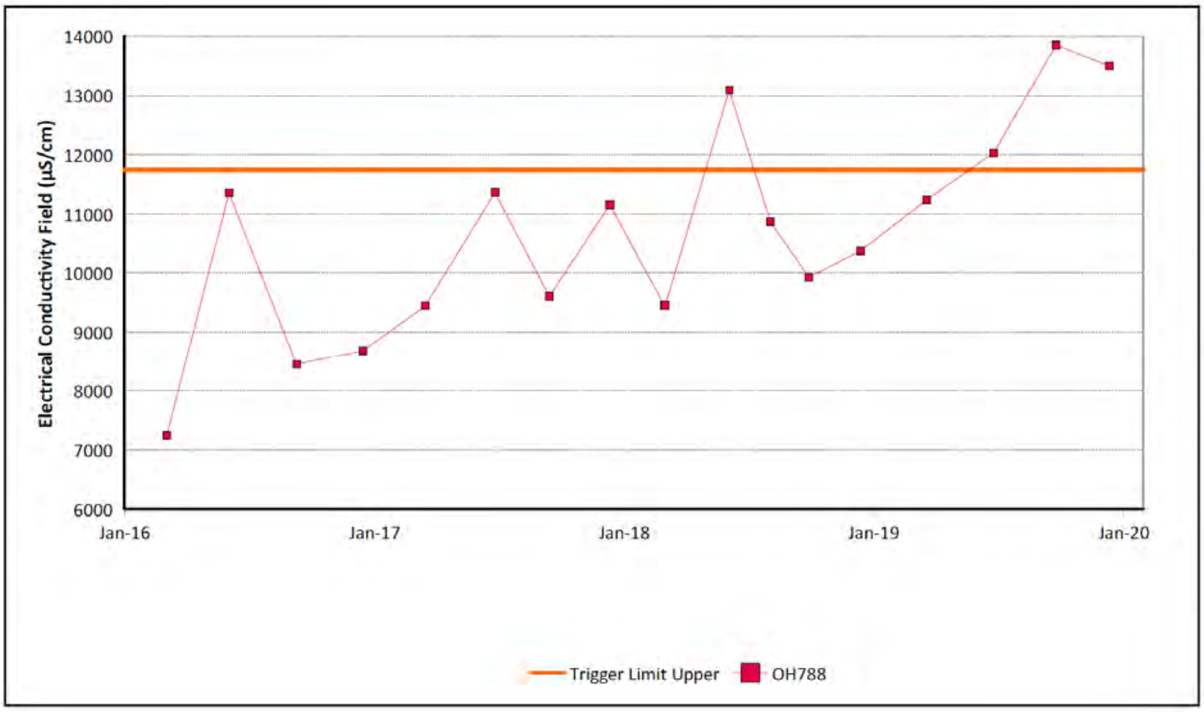


FIGURE 51: HUNTER RIVER ALLUVIUM BORE OH788 EC TREND 2016 TO 2019

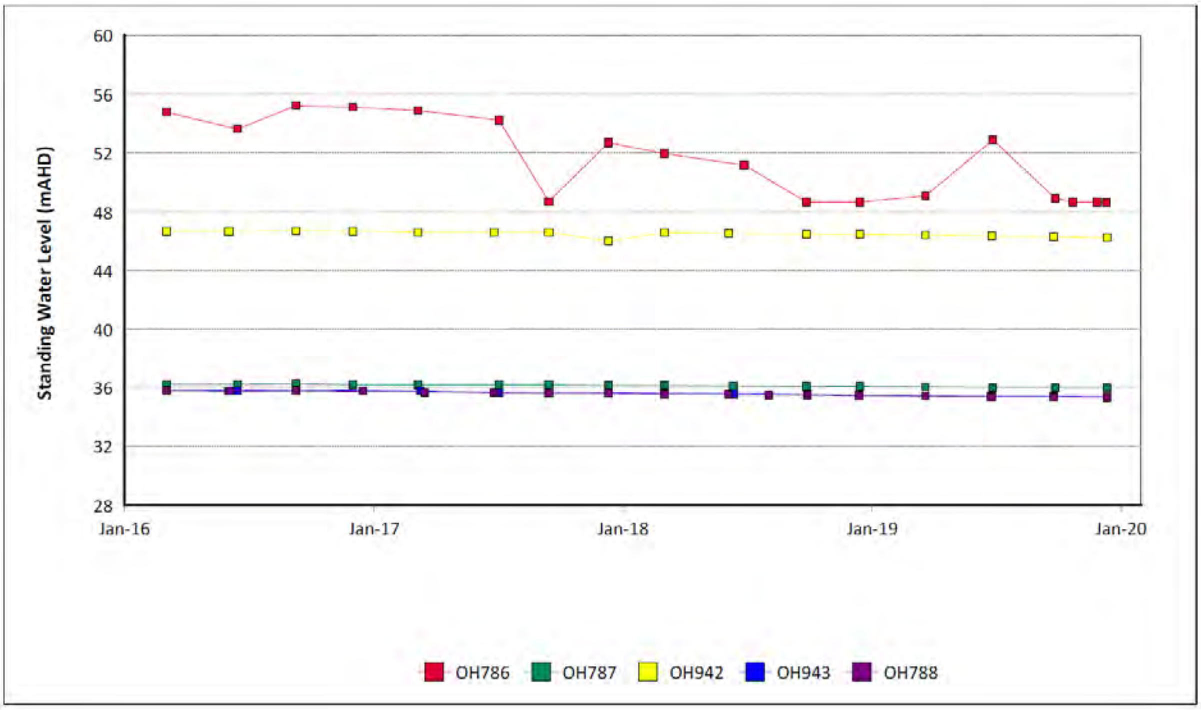


FIGURE 52: HUNTER RIVER ALLUVIUM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.5 Redbank Bores

Groundwater monitoring in the Redbank seam was undertaken from four sites during 2019. A total of 16 samples were collected during the reporting period. The pH, EC and SWL trends for 2016 to 2019 for Redbank seam groundwater bores are shown in **Figure 53**, **Figure 54** and **Figure 55** respectively. Water quality results across the Redbank seam bores were generally consistent with historical values.

A steady declining trend in SWL values at all monitoring sites continued during the reporting period. This was expected/predicted given the close proximity of the bores to MTW's operations at Warkworth which are progressing West. The depressurisation of the groundwater in this area was predicted as a result of mining.

TABLE 6.21 REDBANK SEAM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

Location	Date	Trigger limit	Action taken in response
WOH2153A	26/08/2019	**pH – 95th Percentile**	Watching Brief*
	26/11/2019		Watching Brief*
WOH2154A	01/03/2019	**pH – 5th Percentile**	Watching Brief* Note: Monitoring result obtained in May 19 shows values back within trigger limits. No further action required.

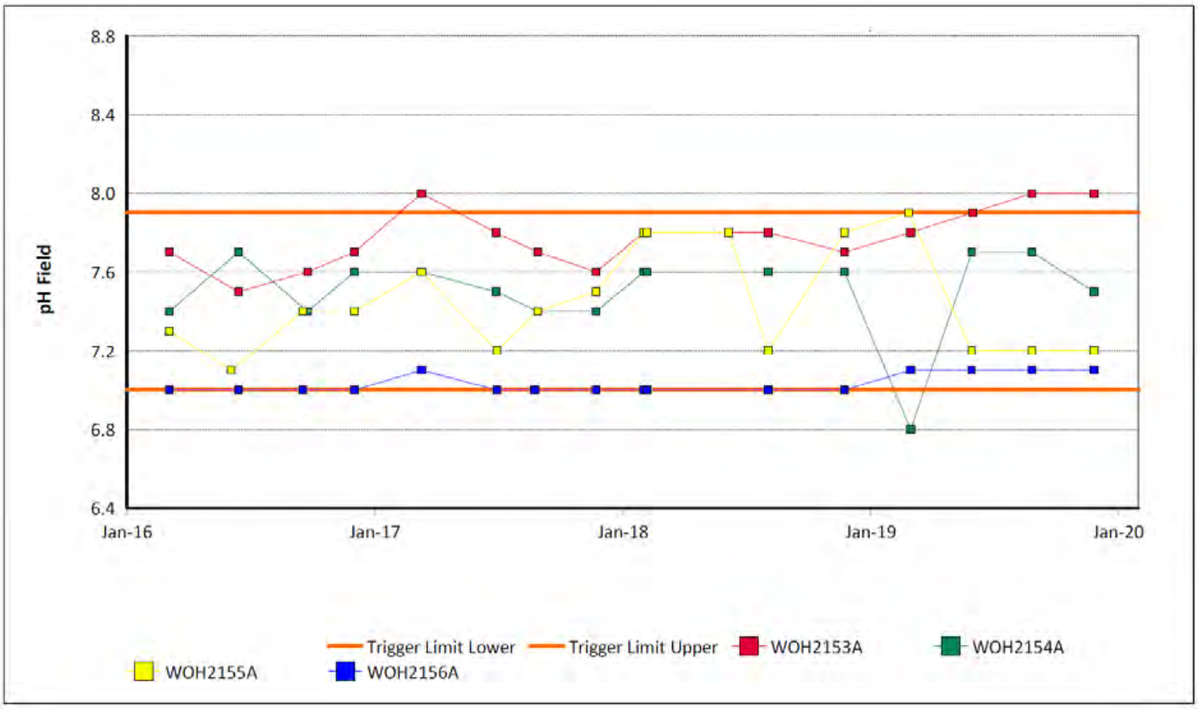


FIGURE 53: REDBANK SEAM GROUNDWATER PH TRENDS 2016 TO 2019

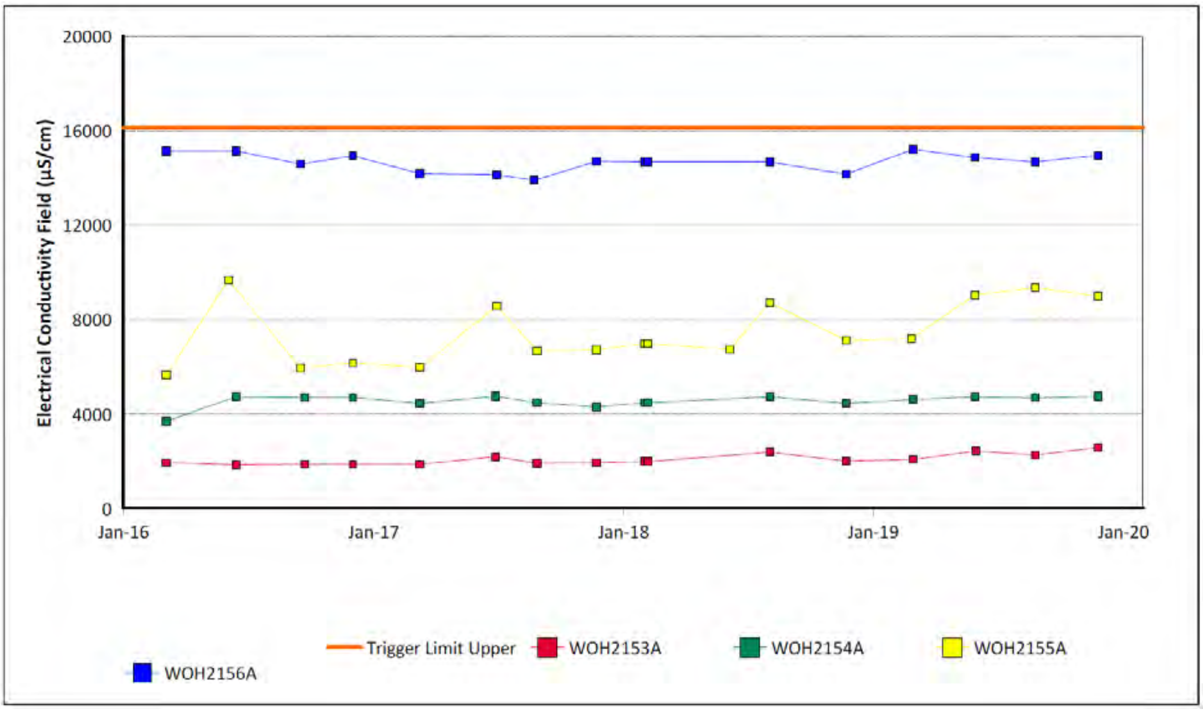


FIGURE 54: REDBANK SEAM GROUNDWATER EC TRENDS 2016 TO 2019

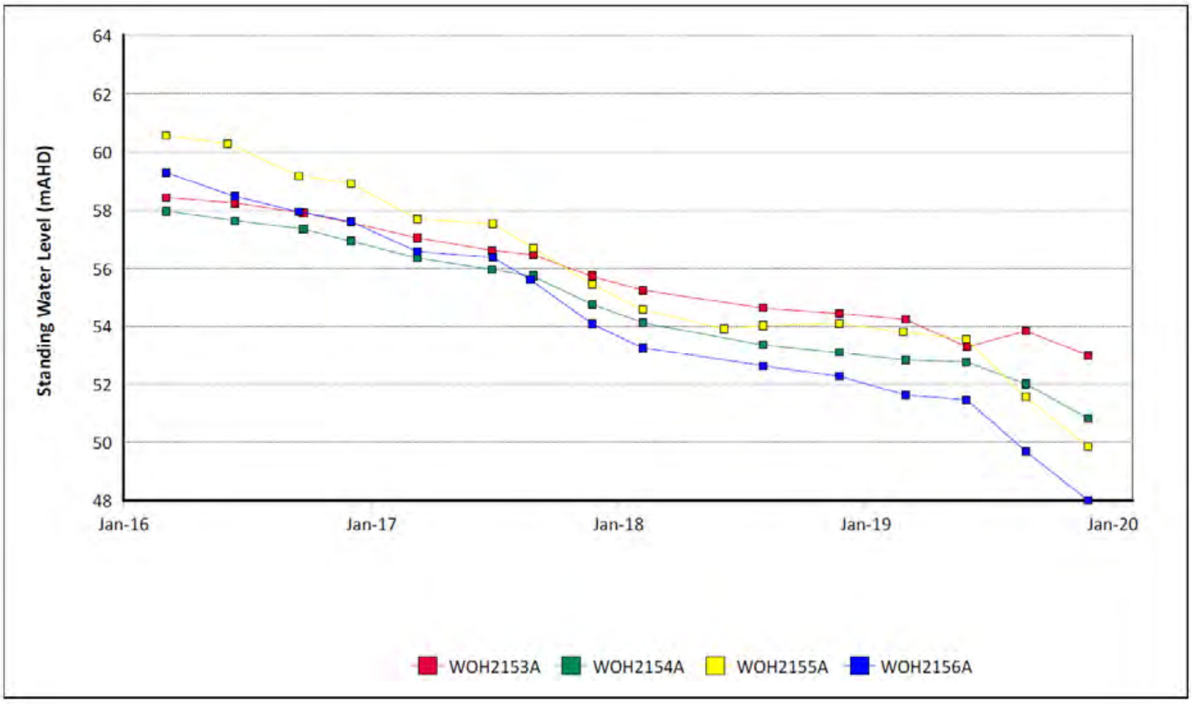


FIGURE 55: REDBANK SEAM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.6 Shallow Overburden Bores

Groundwater monitoring in the Shallow Overburden bores was undertaken from ten sites during 2019. A total of 39 samples were collected during the reporting period. The pH, EC and SWL trends for 2016 to 2019 for Shallow Overburden groundwater bores are shown in **Figure 56**, **Figure 57** and **Figure** 58 respectively.

Water levels and water quality were generally in line with historical values across these bores during the reporting period. Groundwater level trends for bores MTD605P, MTD614P, MTD616P, and MBW02 showed stable to slightly declining groundwater levels within the shallow overburden material. The exception to this were bores MTD616P and MTD614P in which slightly increasing groundwater levels were recorded. No land use changes or activities are known to have occurred near the bores that may have caused this rising trend.

TABLE 6.22 SHALLOW OVERBURDEN SEAM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

<table>
<tr><th>Location</th><th>Date</th><th>Trigger limit</th><th>Action taken in response</th></tr>
<tr><td>MTD605P</td><td>25/11/2019</td><td>EC – 95th percentile</td><td>Watching Brief*</td></tr>
<tr><td rowspan="3">MTD616P</td><td>27/05/2019</td><td rowspan="3">pH – 5th percentile</td><td>Watching Brief*</td></tr>
<tr><td>27/08/2019</td><td>Watching Brief*</td></tr>
<tr><td>25/11/2019</td><td>Investigation Undertaken.
Historically, fluctuations in pH at this location coincide with changes to the sampling methodology, from quarterly grab sampling to low flow pumping/purging prior to annual comprehensive sampling and analysis. A change to the sampling methodology implemented in 2019 i.e. low flow pumping/purging prior to all sampling and analysis, is considered the cause of the measured drop in pH.</td></tr>
<tr><td rowspan="4">MB15MTW01D</td><td>19/02/2019</td><td rowspan="4">pH – 5th percentile</td><td>Watching Brief*</td></tr>
<tr><td>27/05/2019</td><td>Watching Brief*</td></tr>
<tr><td>30/08/2019</td><td>Investigation undertaken.</td></tr>
<tr><td>27/11/2019</td><td>Note: pH values for MB15MTW01D consistent with prolonged dry weather and are consistent with results obtained over the last 24 months at this location.</td></tr>
</table>

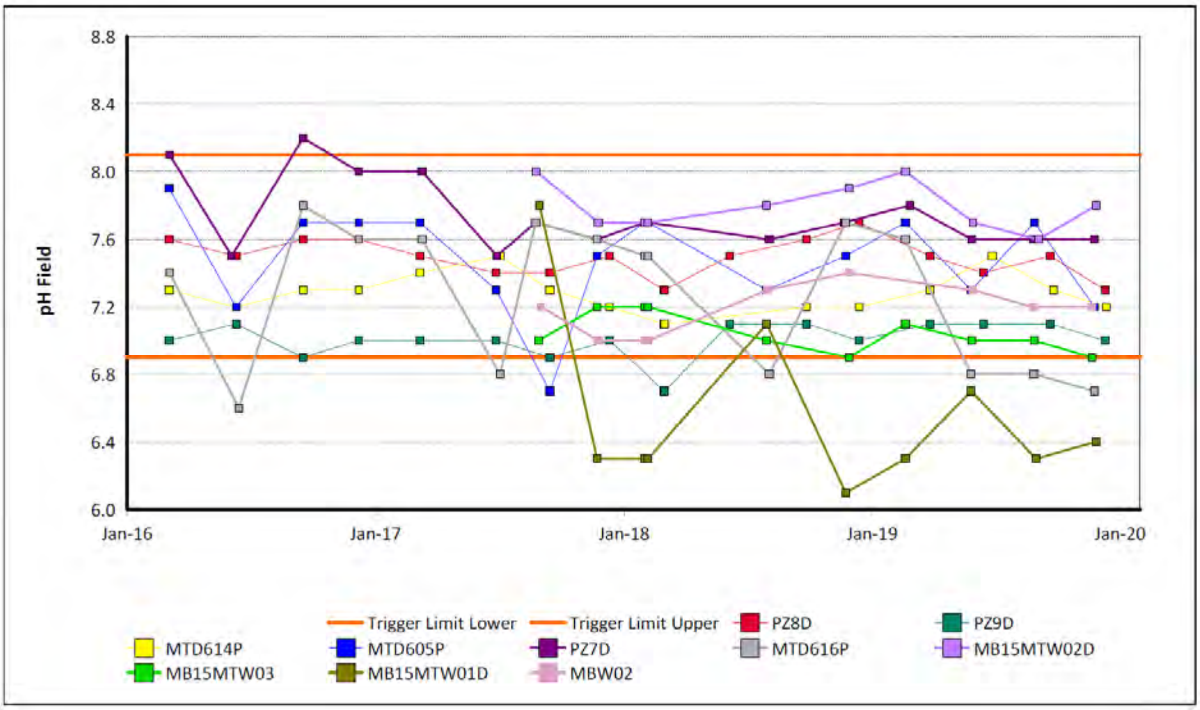


FIGURE 56: SHALLOW OVERBURDEN SEAM GROUNDWATER PH TRENDS 2016 TO 2019

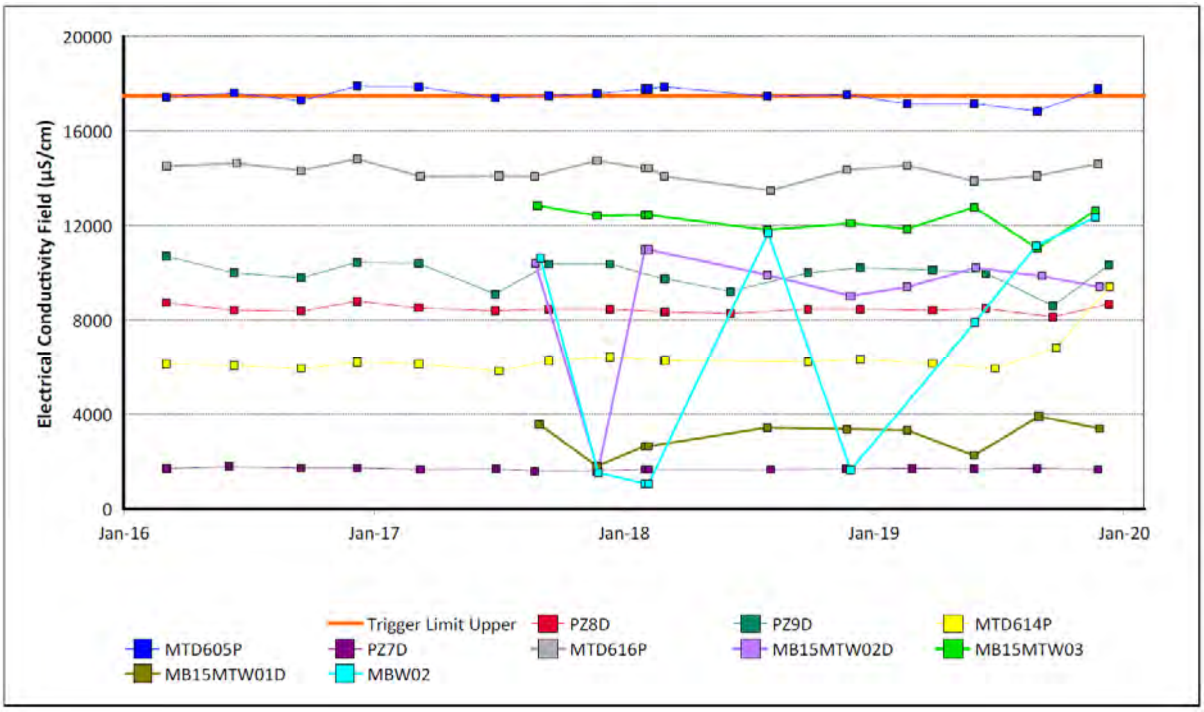


FIGURE 57: SHALLOW OVERBURDEN SEAM GROUNDWATER EC TRENDS 2016 TO 2019

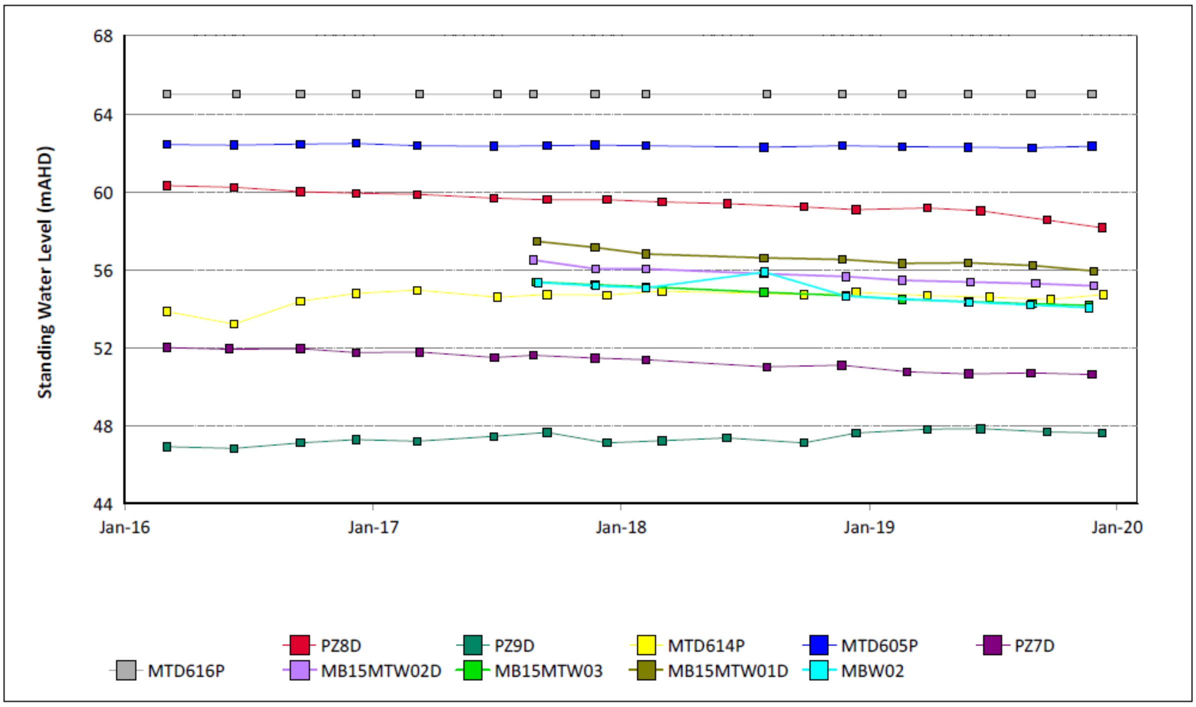


FIGURE 58: SHALLOW OVERBURDEN SEAM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.7 Vaux Seam Bores

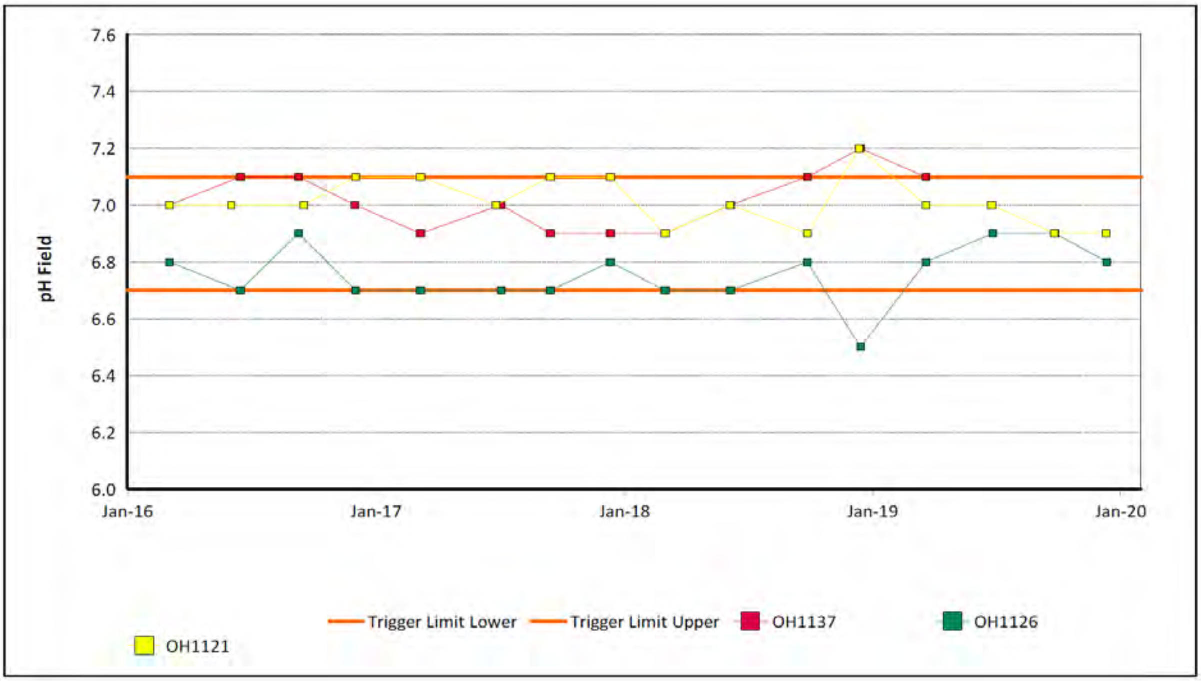
Groundwater monitoring in the Vaux Seam was undertaken from three sites during 2019; a total of 9 samples were collected. The pH, EC and SWL trends for 2016 to 2019 for Vaux groundwater bores are shown in **Figure 59**, **Figure 60** and **Figure 61** respectively. Bores OH1126 and OH1121 showed elevated EC results during the reporting period. It is likely that the values recorded are a result of the dry climatic conditions and the new sampling methodology that was adopted during the reporting period. Monitoring of these bores will continue in the next reporting period.

Historical groundwater level trends for the Vaux seam bores show that over 2019 groundwater elevations within the Vaux Seam, north of North Pit, (OH1126 and OH1137) ranged between 46.18 mAHD and 53.08 mAHD. Levels declined by up to 0.55 m with OH1137 reported as dry from September 2019. These trends are similar to trends observed within the Warkworth Seam, which may relate to depressurisation of the coal seams below the actively mined seams at MTW, or due to surrounding mine operations that target the Vaux Seam.

Groundwater levels within bore OH1121 remained stable over 2019.

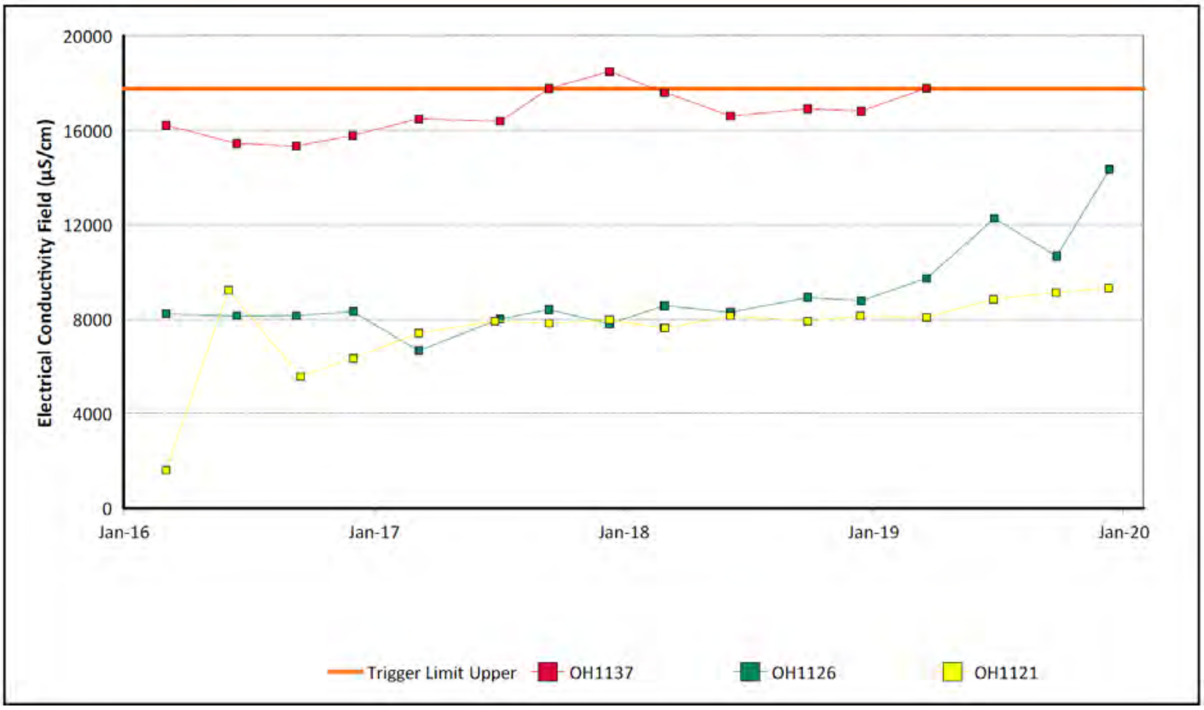
Table 6.23 Vaux Seam Groundwater 2019 Internal Trigger Tracking

Location	Date	Trigger limit	Action taken in response
OH1137	20/03/2019	**EC – 95th percentile**	Watching Brief* Note: Insufficient water volume recorded during sampling rounds in June and September 19. Continue to monitor.



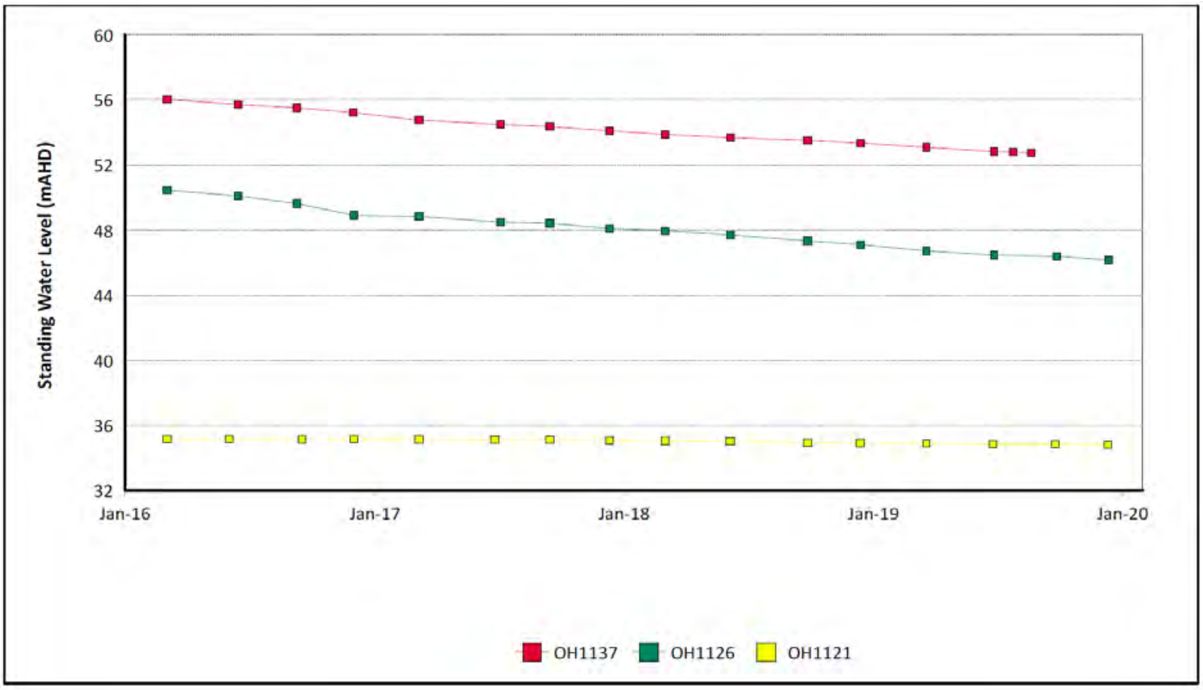
Note: Missing data indicates that there was insufficient water to take a sample.

Figure 59: Vaux Seam Groundwater pH Trends 2016 to 2019



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 60: VAUX SEAM GROUNDWATER EC TRENDS 2016 TO 2019



Note: Missing data indicates that there was insufficient water to take a sample.

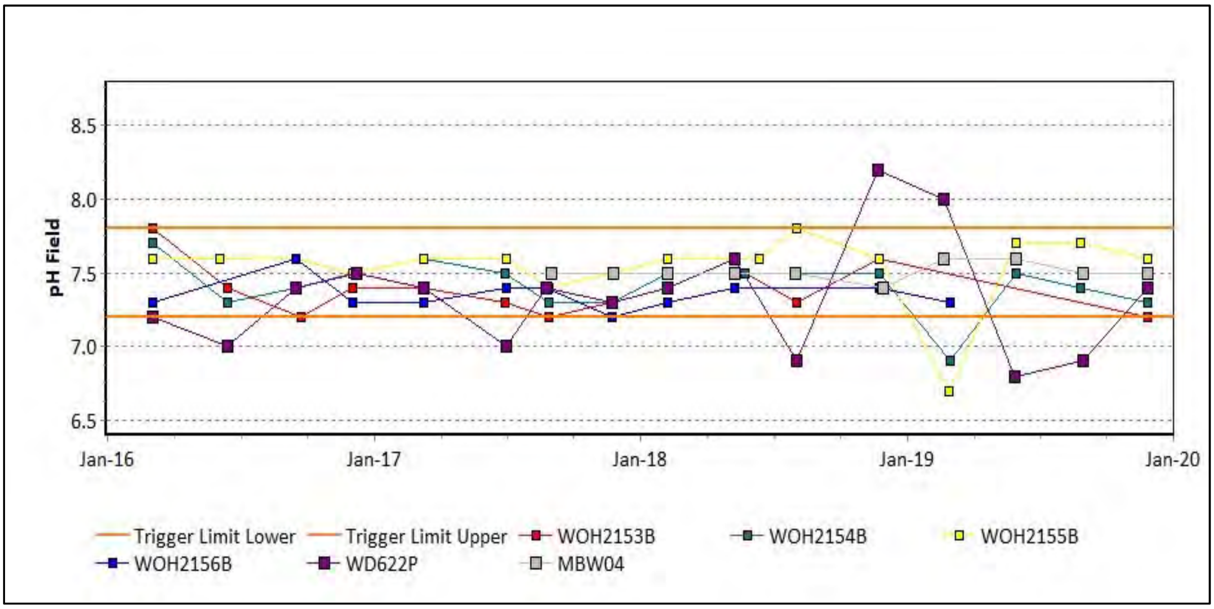
FIGURE 61: VAUX SEAM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.8 Wambo Seam Bores

Groundwater monitoring in the Wambo Seam was undertaken from six sites during 2019. A total of 18 samples were collected during the reporting period. The pH, EC and SWL trends for 2016 to 2019 for Wambo Seam groundwater bores are shown in **Figure 62, Figure 63** and **Figure 64** respectively. Over 2019 groundwater levels declined steadily in bores WOH2154B, WOH2153B, WOH2154B, WHO2155B and WOH2156B. WD622P showed an increased rate of drawdown. This bore is located less than 300m from the advancing West Pit highwall so this depressurisation is expected. Water quality results (with the exception of WD622P) were generally within trigger limits throughout the reporting period. WD622P experienced a declining trend in EC and an increasing trend in pH. It is likely that these water quality changes are a result of the reducing SWL at this location as a result of depressurisation from the open cut.

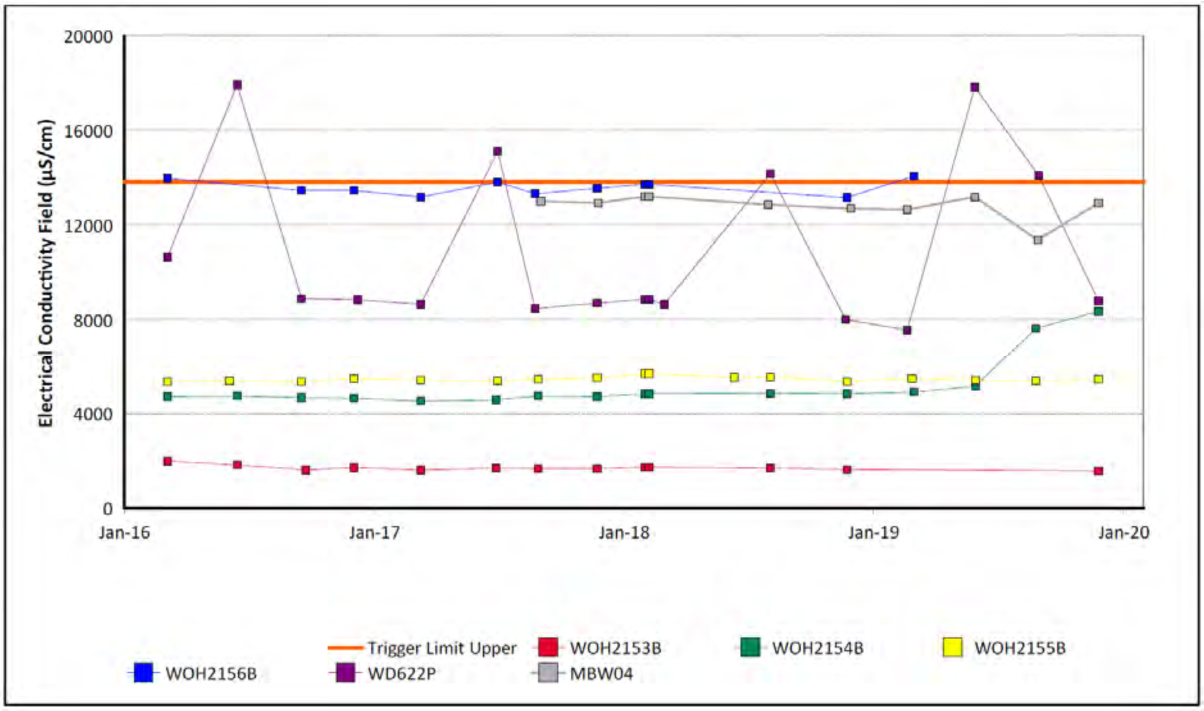
TABLE 6.24 MTW WAMBO SEAM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

Location	Date	Trigger limit	Action taken in response
WD622P	29/05/2019	**EC – 95th percentile**	Watching Brief* Note: Bore is located at edge of pre-strip area. Bore likely to influenced by active mining area.
	30/08/2019		
WD622P	19/02/2019	**pH – 95th percentile**	Watching Brief*
	29/05/2019	**pH – 5th percentile**	Watching Brief*
	30/08/2019		Investigation undertaken. Note: Fluctuating pH is considered to be attributable to coal seam depressurisation, as evidenced by historical trending of falling water level. This trend is consistent with the effects of nearby mining. Fluctuations also coincide with changes to the sampling methodology, from quarterly grab sampling to low flow pumping/purging prior to annual comprehensive sampling and analysis.
WOH2154B	01/03/2019	**pH – 5th percentile**	Watching Brief* Note: Monitoring result obtained in May 19 shows values back within trigger limits. No further action required.
WOH2155B	26/02/2019	**pH – 5th percentile**	Watching Brief* Note: Monitoring result obtained in May 19 shows values back within trigger limits. No further action required.
WOH2156B	01/03/2019	**EC – 95th Percentile**	Watching Brief* Note: Insufficient water volume recorded during sampling rounds in June and September 19.



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 62: WAMBO SEAM GROUNDWATER PH TRENDS 2016 TO 2019



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 63: WAMBO SEAM GROUNDWATER EC TRENDS 2016 TO 2019

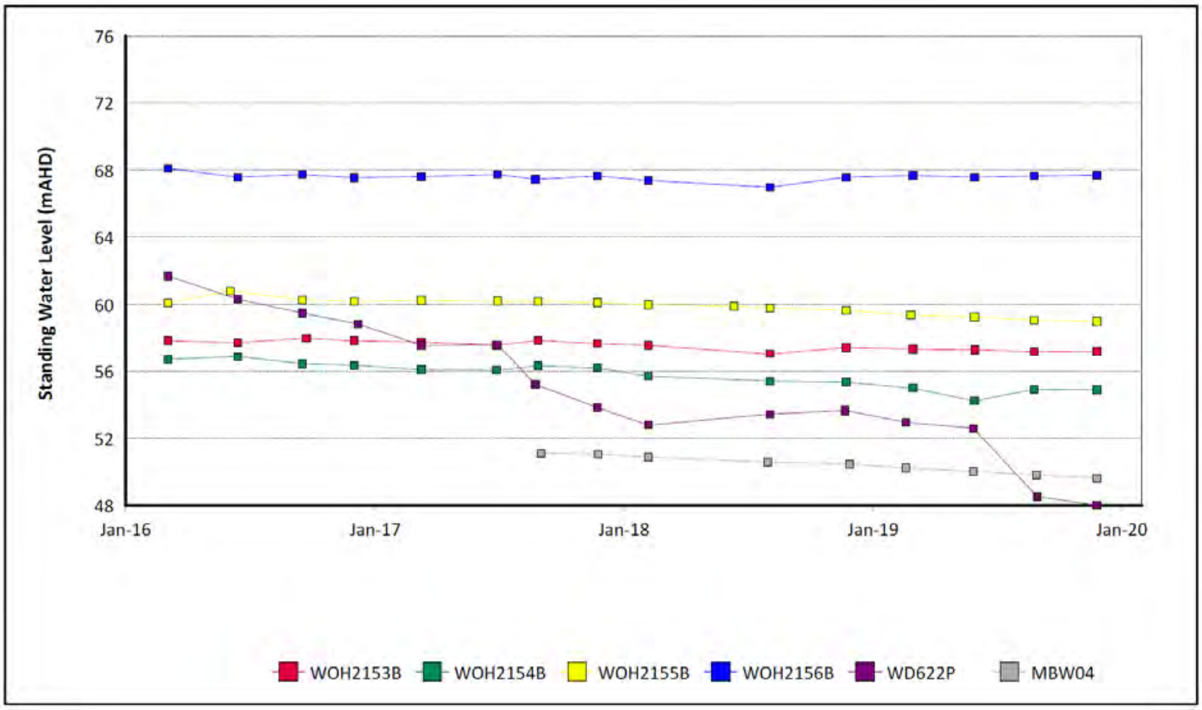


FIGURE 64: WAMBO SEAM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.9 Warkworth Seam Bores

Groundwater monitoring in the Warkworth Seam was undertaken from two sites during 2019; 24 samples were collected. The pH, EC and SWL trends for 2016 to 2019 for Warkworth seam bores are shown in

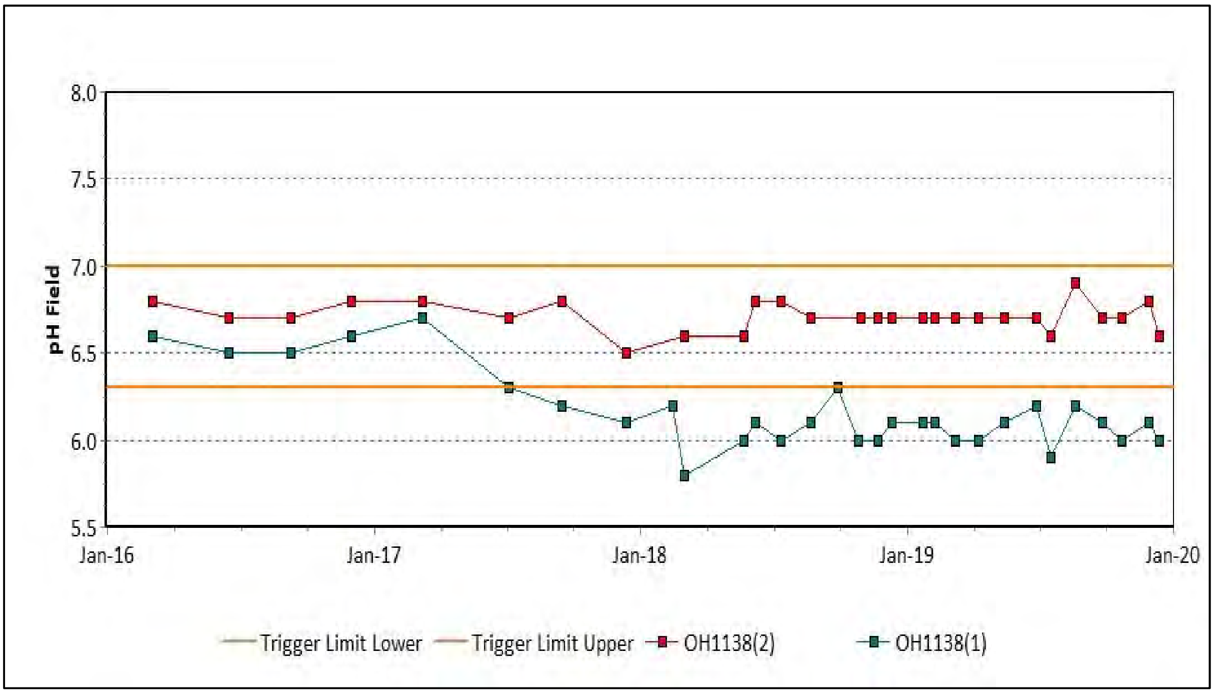


Figure 65, **Figure 66** and **Figure 67** respectively. The SWL in both bores reduced gradually over the reporting period in line with historical trends.

During the reporting period OH1138(1) exceeded trigger limits for declining pH and increasing EC. As outlined in **Appendix 4** it is expected that these results were most likely attributable to ongoing dry conditions. The decline may also be related to drawdown towards active mining within North Pit to the south-west as well as the new water quality sampling methodology and potential influences from the licenced abstraction of water from the LUG bore approximately 1.25km to the north-west .

TABLE 6.25 WARKWORTH SEAM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

Location	Date	Trigger limit	Action taken in response
OH1138(1)	22/01/2019 08/02/2019 08/03/2019 09/04/2019 14/05/2019 27/06/2019 16/07/2019 20/08/2019 26/09/2019 22/10/2019 27/11/2019 13/12/2019	**pH – 5th percentile**	Watching Brief* Note: pH values consistent with results obtained at this location since 2017. Continue to monitor on increased frequency.
OH1138(1)	09/04/2019 14/05/2019	**EC – 95th percentile**	Watching Brief* Note: Monitoring result obtained in June 19 shows values back within trigger limits.

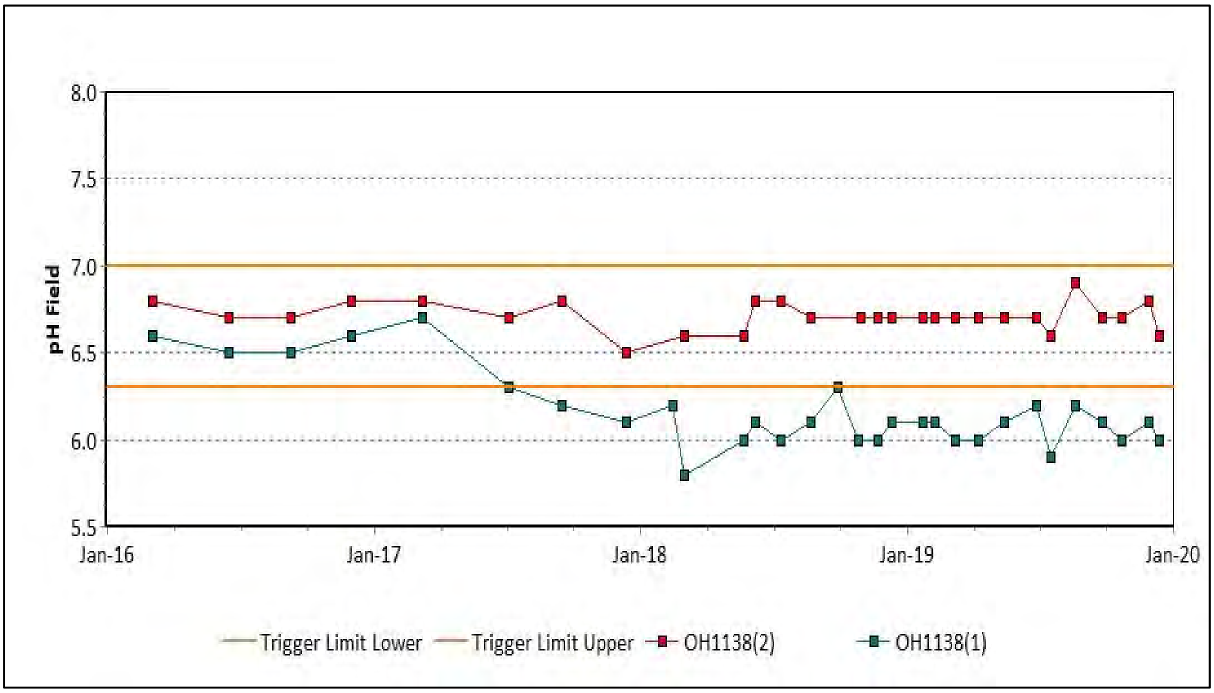


FIGURE 65: WARKWORTH SEAM GROUNDWATER PH TRENDS 2016 TO 2019

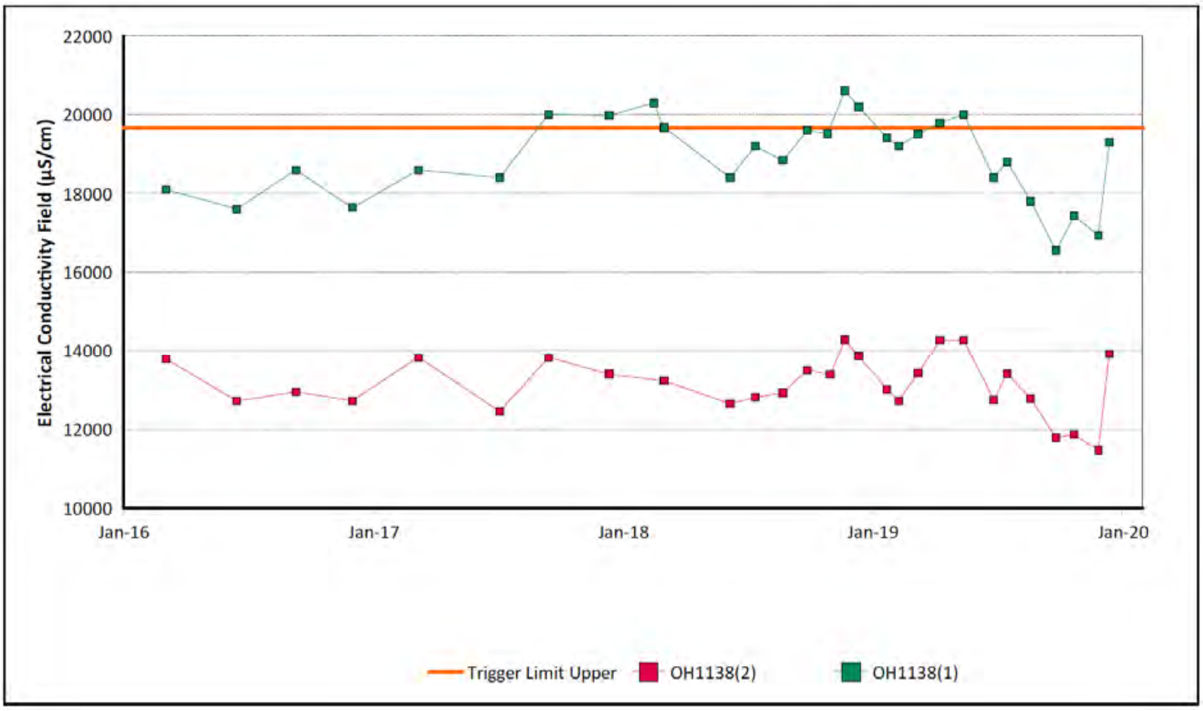


FIGURE 66: WARKWORTH SEAM GROUNDWATER EC TRENDS 2016 TO 2019

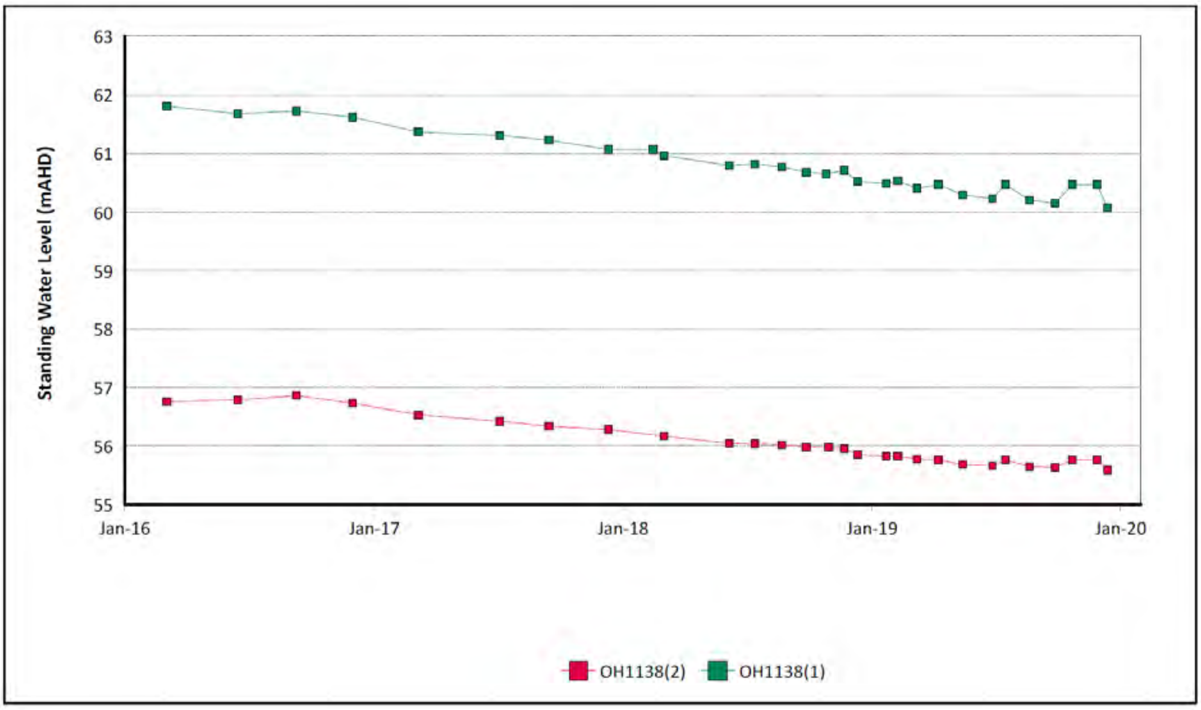


FIGURE 67: WARKWORTH SEAM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.10 Wollombi Brook Alluvium Bores

Groundwater monitoring in the Wollombi Brook Alluvium was undertaken from two sites during 2019; five samples were collected. The pH, EC and SWL trends for 2016 to 2019 are shown in **Figure 68** to **Figure 72** respectively. **Table 6.26** shows the Trigger summary.

Over 2019 the SWL in both bores declined in line with historical trends. The decline in water levels corresponds to the stream flow levels in the Wollombi Brook as a result is decreased rainfall over the period which has resulted in losing conditions. As outlined in **Appendix 4** the spikes in water quality across PZ8S and PZ9S are likely to be related to the bore being dry (at construction depth) and samples being influenced by localised rainwater at the base of each bore.

TABLE 6.26 WOLLOMBI BROOK ALLUVIUM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

Location	Date	Trigger limit	Action taken in response
PZ8S	10/12/2019	**pH – 5th Percentile**	Watching Brief*

FIGURE 68: WOLLOMBI BROOK ALLUVIUM GROUNDWATER PH TRENDS 2016 TO 2019

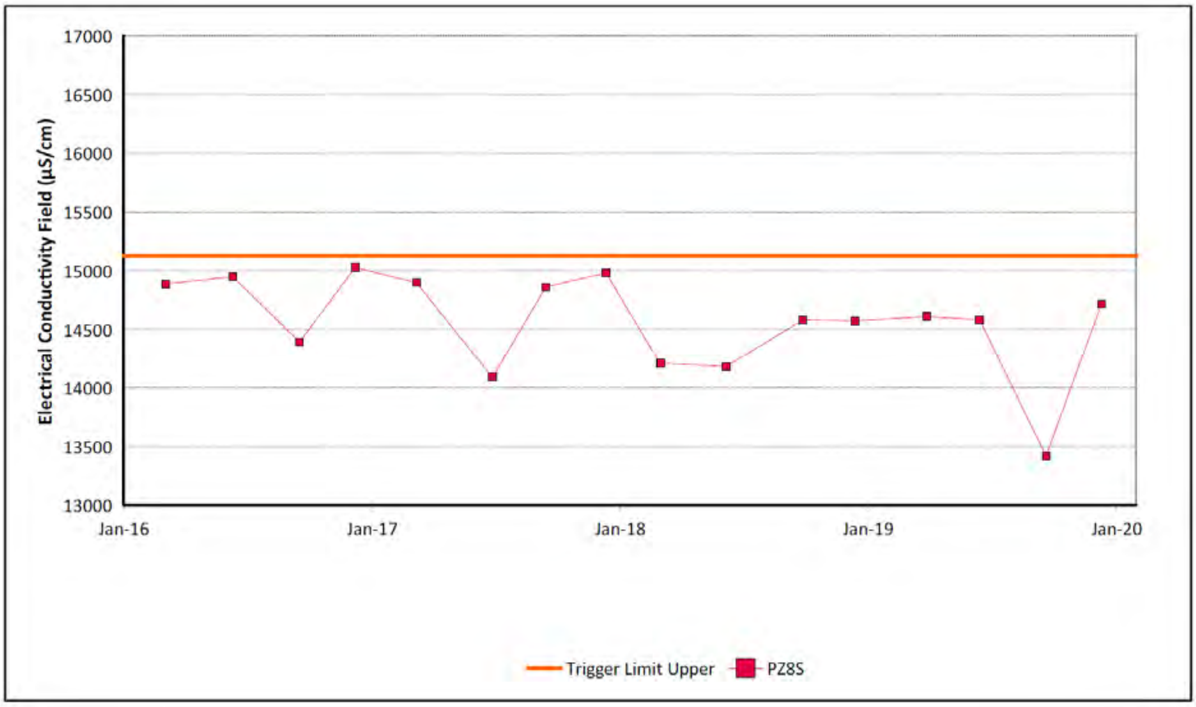
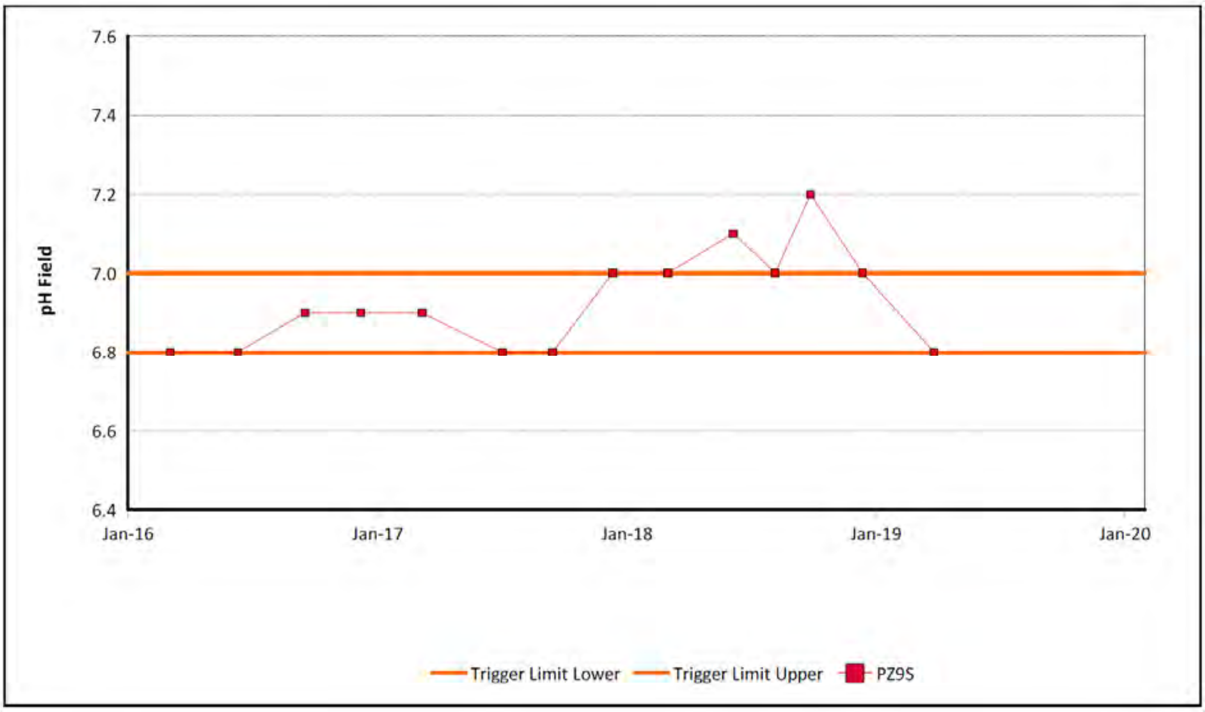
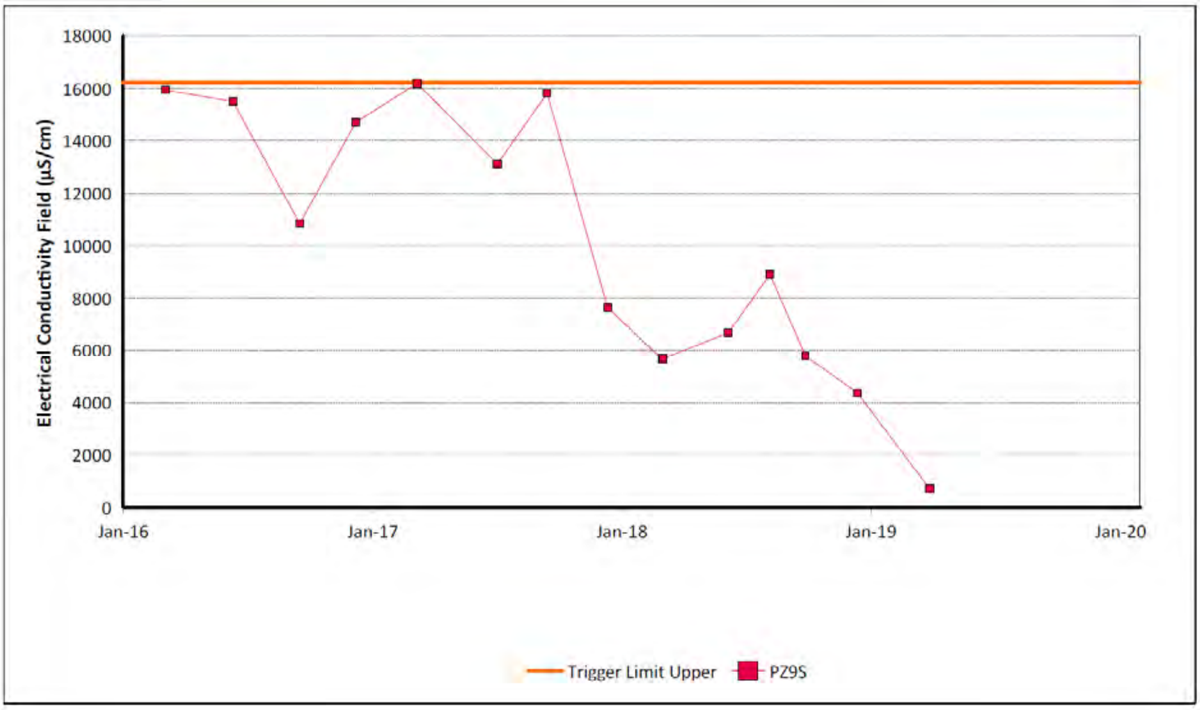


FIGURE 69: WOLLOMBI BROOK ALLUVIUM GROUNDWATER EC TRENDS 2016 TO 2019



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 70: WOLLOMBI BROOK ALLUVIUM GROUNDWATER pH TRENDS 2016 TO 2019



Note: Missing data indicates that there was insufficient water to take a sample.

FIGURE 71: WOLLOMBI BROOK ALLUVIUM GROUNDWATER EC TRENDS 2016 TO 2019

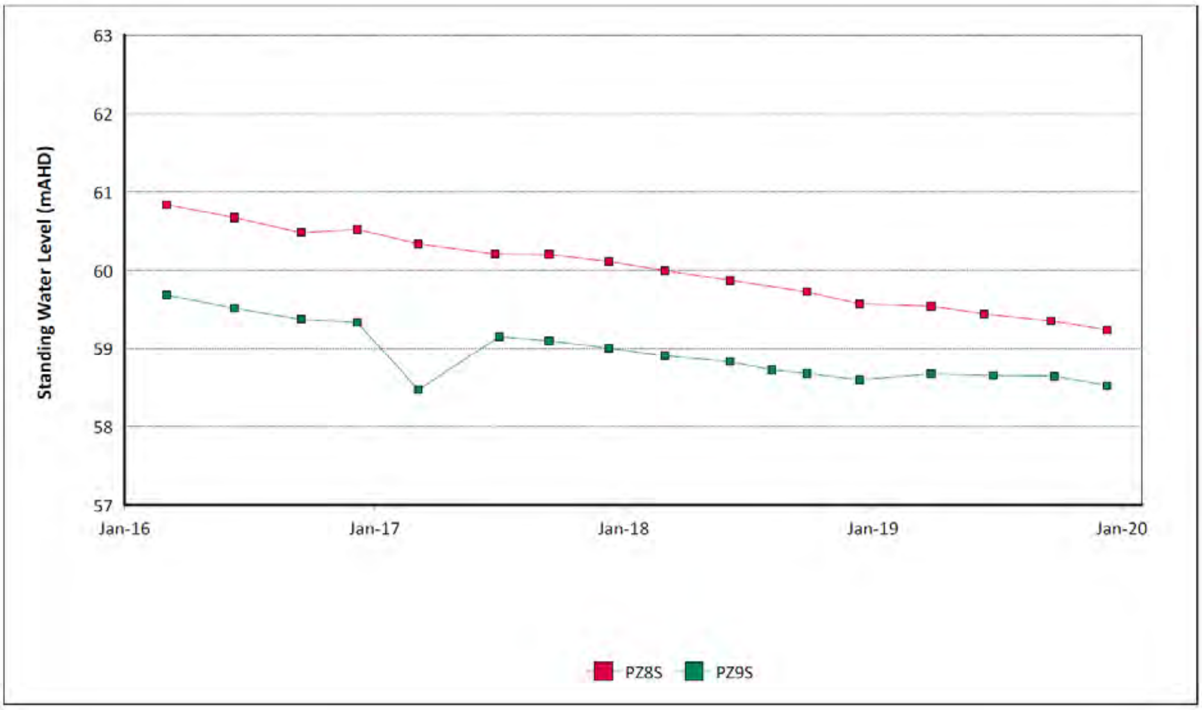


FIGURE 72: WOLLOMBI BROOK ALLUVIUM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.11 Woodlands Hill Seam Bores

Groundwater monitoring in the Woodlands Hill Seam was undertaken from one site during 2019; four samples were collected. The pH, EC and SWL trends for 2016 to 2019 are shown in **Figure 73** to **Figure 75** respectively. **Table 6.27** shows the Trigger Point summary. An erroneous pH reading (outside of trigger limits) was recorded during Q1 2019. The result was not consistent with historical values and was considered to be related to a field recording error.

TABLE 6.27 WOODLANDS HILL SEAM GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

Location	Date	Trigger limit	Action taken in response
WD625P	01/03/2019	**EC – 95th Percentile**	Watching Brief* Note: Monitoring result obtained in May 19 shows values back within trigger limits.
	30/08/2019		Watching Brief*
WD625P	01/03/2019	**pH – 5th Percentile**	Watching Brief*
	31/05/2019		Watching Brief* Note: Monitoring result obtained in May 19 shows values back within trigger limits. No further action required.

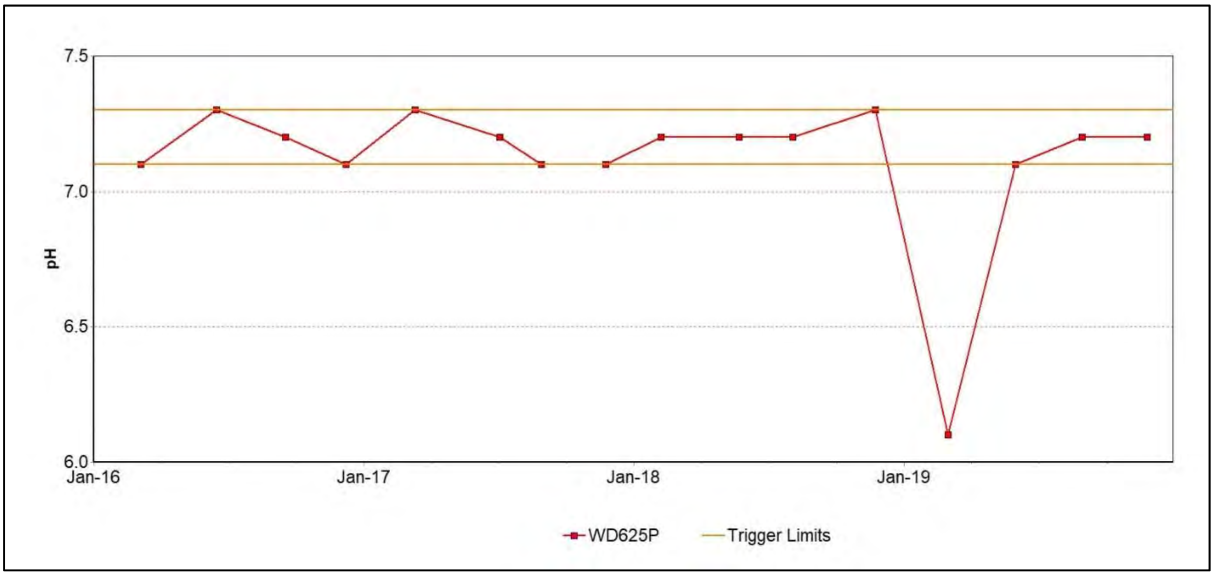


FIGURE 73: WOODLANDS HILL SEAM GROUNDWATER PH TRENDS 2016 TO 2019

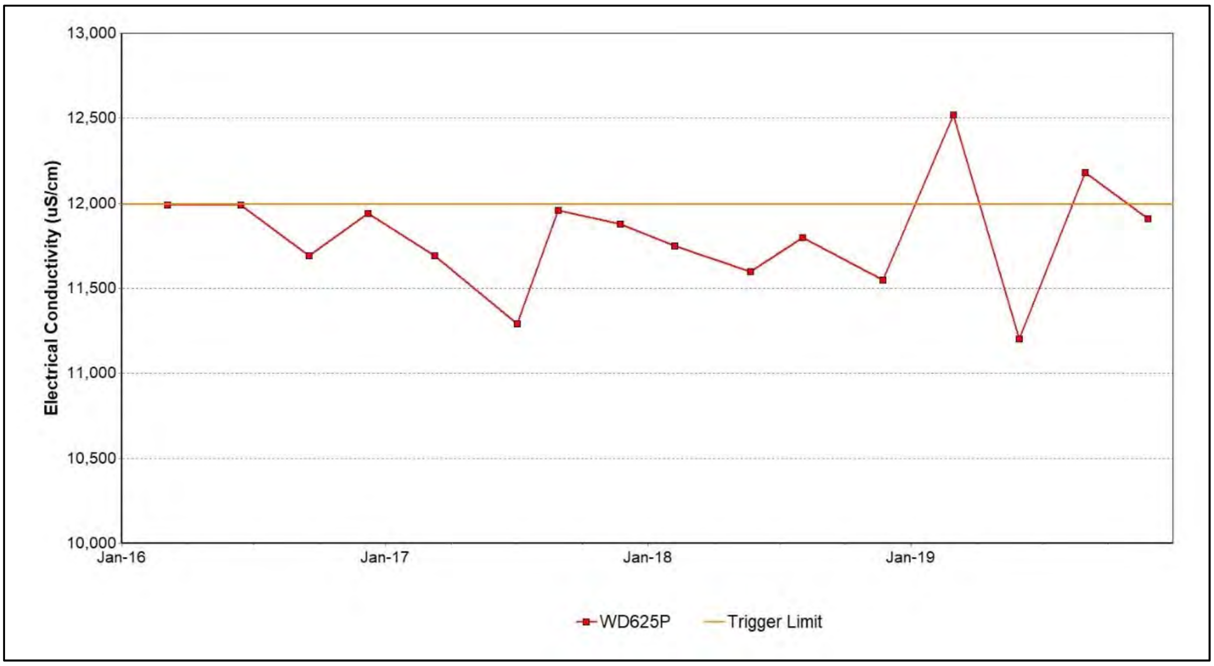


FIGURE 74: WOODLANDS HILL SEAM GROUNDWATER EC TRENDS 2016 TO 2019

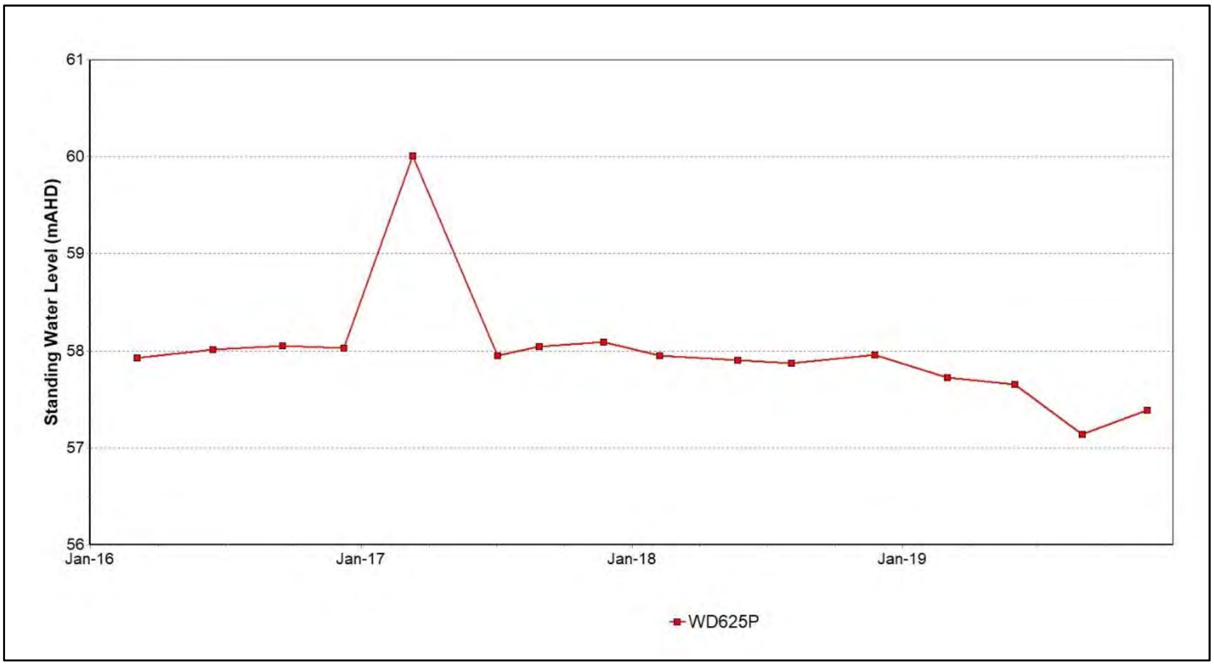


FIGURE 75: WOODLANDS HILL SEAM GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.6.12 Aeolian Warkworth Sands

Groundwater monitoring in the Aeolian Warkworth Sands was undertaken from one site during 2019; a total of four samples were collected. The pH, EC and SWL trends for 2016 to 2019 are shown in **Figure 76**, **Figure 77** and **Figure 78** respectively. Historical water level data for the bore shows a general decline in groundwater levels within the Warkworth Sands. This decline corresponds with the declining CRD trends however, the logger data does not show a response to the above average rainfall experienced in March 2019. Further investigation into the local ground conditions, condition of the nested bore and functionality of the bore loggers should be undertaken, to understand the interaction between the two bore depths. It is also noted that 2019 was the driest year on record from the sites weather station.

TABLE 6.28 AEOLIAN WARKWORTH SANDS GROUNDWATER 2019 INTERNAL TRIGGER TRACKING

Location	Date	Trigger limit	Action taken in response
PZ7S	27/08/2019	**pH – 5th Percentile**	Watching Brief*

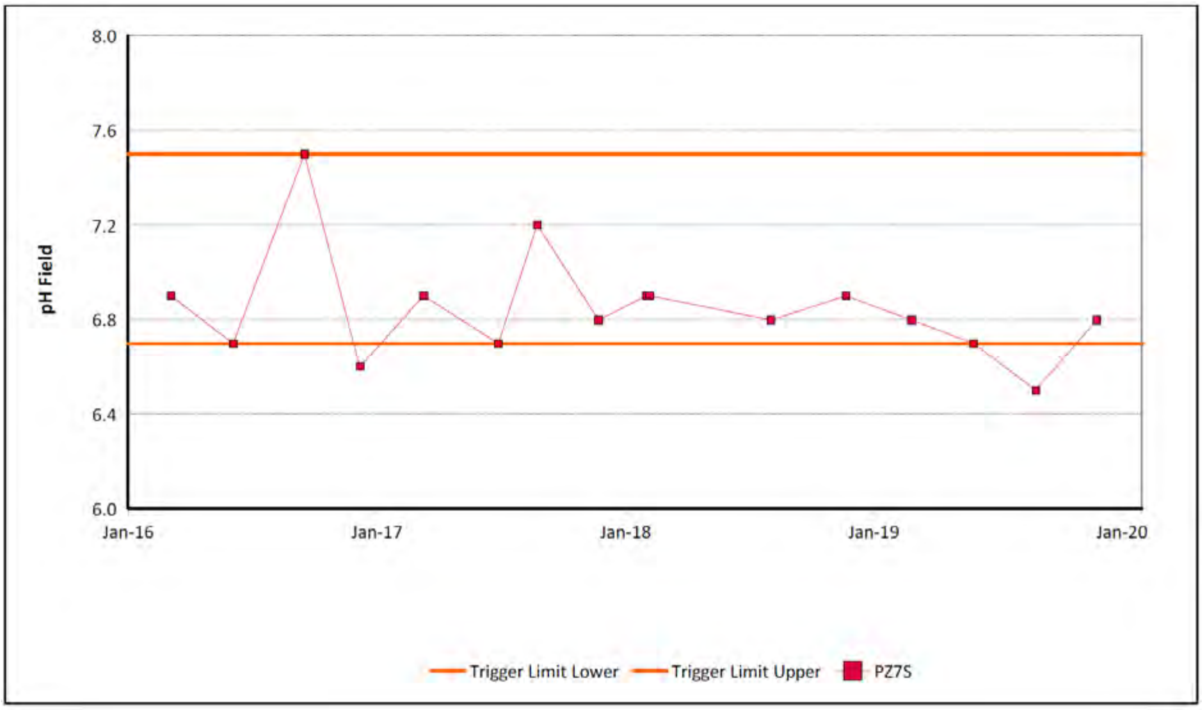


FIGURE 76: AEOLIAN WARKWORTH SANDS GROUNDWATER pH TRENDS 2016 TO 2019

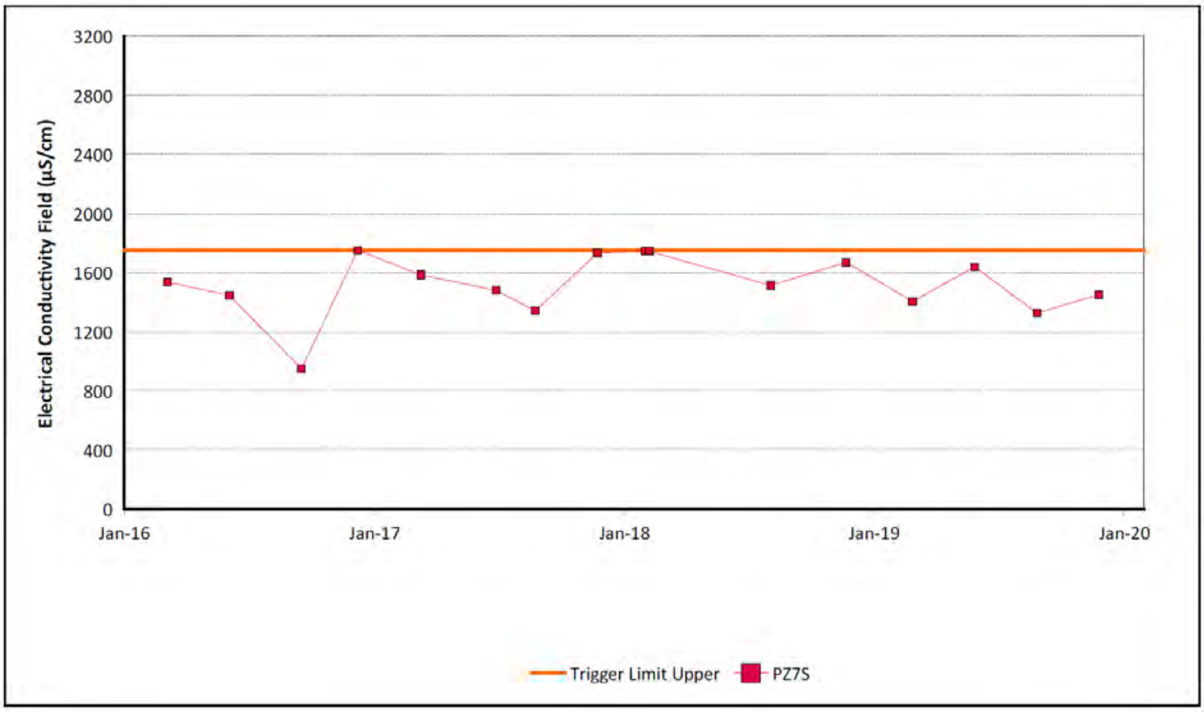


FIGURE 77: AEOLIAN WARKWORTH SANDS GROUNDWATER EC TRENDS 2016 TO 2019

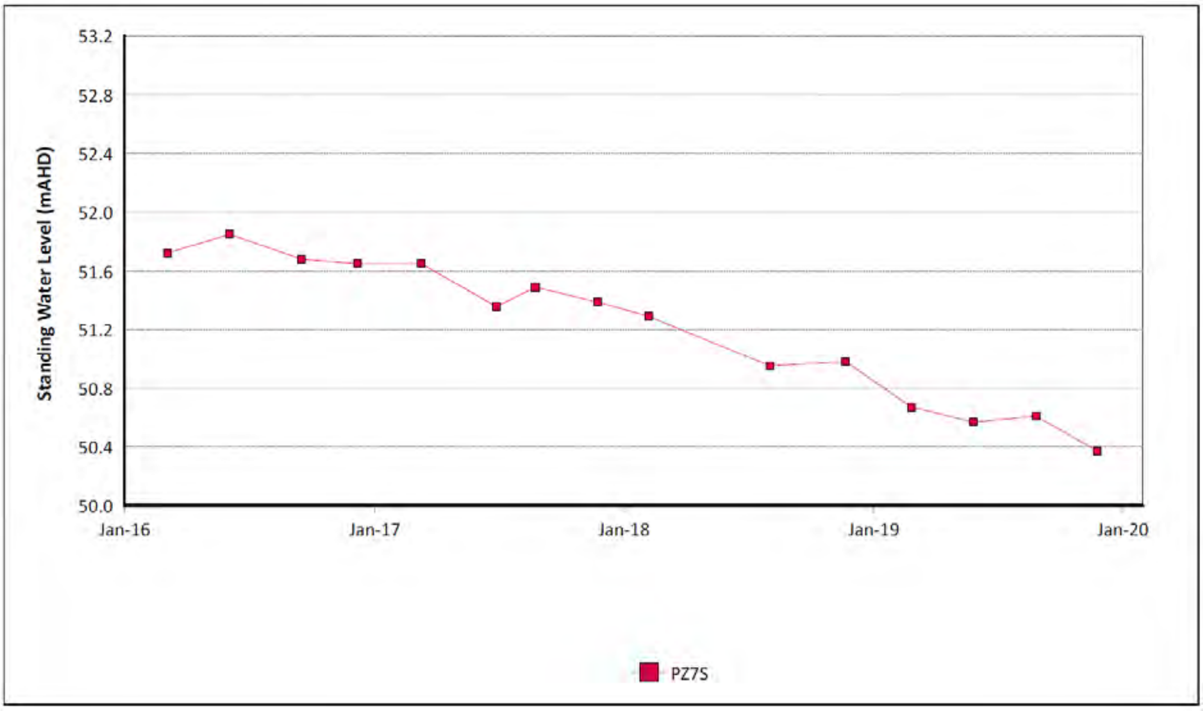


FIGURE 78: AEOLIAN WARKWORTH SANDS GROUNDWATER SWL TRENDS 2016 TO 2019

6.7.7 Audits and Reviews

Groundwater monitoring results are reviewed against the approved trigger limits within MTW's approved Water Management Plan on a quarterly basis by MTW. A comparison of the water quality information across MTW's monitoring bore network is provided graphically in **Figure 33** to **Figure 78.** The approved trigger limits are based on the historical water quality data as shown in the relevant site Environmental Impact Assessments. These trigger limits are updated annually based on collected site data as described in the MTW Water Management Plan. A summary of the management actions taken in response to any exceedances of the trigger limits during the period is provided in **Table 6.18** to **Table 6.28.**

An annual groundwater review was undertaken by an independent groundwater consultant. The scope of the review included an assessment of the water quality and groundwater levels recorded during the 2019 reporting period as well as a review of the historical results against the predictions in the site groundwater model. A copy of the full report is included in **Appendix 4.**

Key findings from the independent groundwater consultant's report were:

- Groundwater monitoring data indicates that, where saturated, water within the alluvium declined slightly, generally in line with climate and stream flow trends. Groundwater within the Permian coal measures remained relatively stable to slightly declining over 2019. Where observed, the decreasing elevations are believed to be attributed to depressurisation of the coal seams in relation to mining activities as well as below average rainfall. The groundwater drawdown appears to be in line with the predicted drawdown with the coal measures around active mine areas.
- The review of the sites groundwater model predictions against the historical site data generally showed that the model appeared to adequately replicate observed changes in groundwater levels during the 2019 reporting period. The review did however highlight some areas for improvement to further validate the current groundwater model, these items are included in the groundwater report in **Appendix 4**.
- Review of water quality results and comparison to trigger levels for EC and pH identified several trigger exceedances over 2019. It was identified that several bores exceeded triggers for EC and pH; however, 2019 readings were in line with historical trends for these bores. It is also noted that MTW changed its sampling methodology during the 2019 reporting period following recommendations in the 2018 review. It is recommended that a review of the trigger limits be undertaken in light of the revised sampling methodology. Groundwater quality trends outside of historical trends were observed for bore OH1138 and WOH2139A, which likely relate to declining groundwater levels. The decline in levels most likely relate to abstraction from the LUG Bore at Hunter Valley Operations to the north and the progression of mining activities associated with North Pit. Groundwater levels within the Warkworth Sands at PZ7S declined over the 2019, despite above average rainfall recorded in March 2019, similar to trends observed for bores in overburden. It is however noted that this

decline is in line with the dry climatic conditions. Further investigation into the ground conditions, bore construction and logger at PZ7S and PZ7D is recommended.

- Over 2019 monitoring of the groundwater bore network was generally conducted in accordance with the Groundwater Monitoring Program outlined within the WMP. Annual samples were collected in general accordance with relevant standards. The exception to this was generally for cases where the condition of the bores (i.e. 32 mm casing) inhibited the ability to collect representative samples. Grab samples have been taken for monitoring bores WOH1239A, WOH2141A, WOH2153A, WOH1254A, WOH2155A, WOH2156A, WD622P, MBW02 and MBW03 within the network. This approach is not in line with industry standards and may not provide a representative water quality sample. The justification for this methodology should be reviewed to determine if more suitable methods (i.e. full purge or low flow) can be applied. In addition, a review into the requirement of these bores for the collection of water quality data for the WMP should be undertaken. If it is found that the continued collection of water quality data is required from a bore and suitable sampling methods cannot be adopted to obtain a representative sample, then bore rectification works should be considered.
- Quantification of groundwater take was undertaken based on reported volumes estimated for approved operations by AGE (2015) and metered abstraction volumes from bores and surface water pumps. Based on this information, over the 2019 reporting year the total take under the Hunter Regulated water source was estimated at 1,597.5 ML. Total take from Hunter Unregulated water source was estimated at 11 ML and 270 ML from the North Coast Fractured and Porous Rock water source.
- Comparison of observed groundwater levels against predicted levels generated from the numerical groundwater model were made. Overall, the numerical model was found to have adequately replicated observed changes in groundwater levels for 2019. Where modelled and observed values were significantly different, it was largely found that the difference in values could be attributed to differences in actual and predicted site conditions (i.e. climatic conditions, changes to mine progression / activities etc). A number of recommendations therefore related to updating the model including a review of VWP data and construction, better matching of actual mine progression, inclusion of the LUG bore abstraction and current climate and streamflow trends.
- Overall, the current monitoring network and program is generally adequate for satisfying current monitoring requirements of the WMP. There is good spatial of coverage of monitoring locations across the site, with multiple bores and VWP sensors installed into each relevant aquifer unit.

Key recommendations from the independent groundwater consultant’s report include:

- Review the groundwater monitoring network and program to more clearly identify the purpose of each bore based on its location and construction, and align the compliance conditions to this purpose. This will include newly installed monitoring points and removal of bores/sensors from the program that have been identified as destroyed/erroneous;

- Check surveyed ground and casing elevations for bores, particularly the MB15MTW bores;
- Check VWP's and monitoring bore loggers are working correctly (i.e. check/replace batteries and logger depths) and install a site barometric logger for atmospheric compensation;
- Review of logger installation depths for bores PZ8D, PZ9S, PZ7S, PZ7D and MB15MTW02S. Review required to confirm that the reported installation depths are correct and to ensure loggers are suitably placed below the standing water level;
- Investigate ground conditions, bore construction and logger data for the Warkworth Sands and trends observed at bore PZ7S and PZ7D;
- Installation of data loggers within bores MB15MTW02D and PZ8S;
- Review geological and bore construction logs for bores OH943, OH944, OH788 and OH1121;
- Review site conditions around MTD616P and MTD614 to understand cause for rise in groundwater levels within shallow stratigraphy;
- Review of groundwater quality triggers to ensure they are reasonable and adequately capture historical trends for bores and account for changing climate conditions; and
- Update the site numerical groundwater model to account for climate trends, LUG bore abstraction and actual mine progression that have evolved since the initial model development

MTW modified its ground water quality sampling methodology for the 2019 reporting period as a direct result of the findings/recommendations outlined in the 2018 annual groundwater review. MTW now utilises a purging technique for the water quality sampling (where possible) rather than grab samples each quarter which has been undertaken historically.

In addition, MTW undertook a review of the trigger limits associated with MTW's groundwater monitoring bore network to better reflect individual bore trends. The updated trigger limits have been included within an updated Water Management Plan which was submitted to DPIE on 20 December 2019 for endorsement. Tracking against the revised trigger limits will be undertaken once the management plan has been endorsed.

7 REHABILITATION

7.1 Summary of Rehabilitation

A total of 82.7 ha of rehabilitation was undertaken during 2019 against a Mining Operations Plan (MOP) target of 82.1 ha.

Total disturbance undertaken during 2019 was 99.7 ha, which was higher than the MOP projection of 79.2 ha. The disturbance during 2019 was made up of 63.7 ha of new disturbance and 36.0 ha of disturbance of previously rehabilitated area.

TABLE 7.1 KEY REHABILITATION PERFORMANCE INDICATORS

Mine Area Type	Previous Reporting Period (Actual) Year 2018 (ha)	This Reporting Period (Actual) Year 2019 (ha)	Next Reporting Period (Forecast) Year 2020 (ha)
A. Total mine footprint[1]	3,879.6	3,881.2	3931.2
B. Total Active Disturbance[2]	2,546.5	2,579.8	2,584.9
C. Land being prepared for rehabilitation[3]	97.4	159.1	70
D. Land under active rehabilitation[4]	1,235.7	1142.3	1276.3
E. Completed rehabilitation[5]	0	0	0

*[1] **Total mine footprint** includes all areas within a mining lease that either have at some point in time or continue to pose a rehabilitation liability due to mining and associated activities. As such it is the sum of total active disturbance, decommissioning, landform establishment, growth medium development, ecosystem establishment, ecosystem development and relinquished lands (as defined in DRE MOP/RMP Guidelines). Please note that subsidence remediation areas are excluded.*

*[2] **Total active disturbance** includes all areas ultimately requiring rehabilitation such as: on-lease exploration areas, stripped areas ahead of mining, infrastructure areas, water management infrastructure, sewage treatment facilities, topsoil stockpiles areas, access tracks and haul road, active mining areas, waste emplacements (active/unshaped/in or out-of-pit), and tailings dams (active/unshaped/uncapped).*

*[3] **Land being prepared for rehabilitation** – includes the sum of mine disturbed land that is under the following rehabilitation phases – decommissioning, landform establishment and growth medium development (as defined in DRE MOP/RMP Guidelines).*

*[4] **Land under active rehabilitation** – includes areas under rehabilitation and being managed to achieve relinquishment – includes the following rehabilitation phases as described in the DRE MOP/RMP Guidelines – "ecosystem and land use establishment" and "ecosystem and land use sustainability" (revegetation assessed as showing signs of trending towards relinquishment OR infrastructure development).*

*[5] **Completed rehabilitation** – requires formal sign off by DRE that the area has successfully met the rehabilitation land use objectives and completion criteria.*

7.1.1 Management of Rehabilitation

Performance criteria for each rehabilitation phase is provided in detail in the MOP for MTW. The criteria have been developed so that the rehabilitation success can be quantitatively tracked as it progresses through the phases outlined below:

- Stage 1 – Decommissioning
- Stage 2 – Landform Establishment
- Stage 3 – Growing Media Development
- Stage 4 – Ecosystem and Land use Establishment
- Stage 5 – Ecosystem and Land use Sustainability
- Stage 6 – Rehabilitation Complete

The performance criteria are objective target levels or values that can be measured to quantitatively demonstrate the progress and ultimate success of a biophysical process. A monitoring methodology has been developed to measure the performance criteria outlined in the MOPs utilising a combination of tools that provide quantitative data to assess changes occurring over time.

The target levels or values have been based on monitoring results from reference sites and were detailed in the MOP Amendment A approved by Resources Regulator in December 2018. The results of the rehabilitation monitoring programme for native vegetation areas are compared against the target levels to determine if rehabilitation has been successful or if additional intervention is needed.

Ecologists from Niche Environment and Heritage commenced monitoring of rehabilitated land returned to native vegetation in 2015. The results of monitoring conducted in early and mid-2017 have been presented in previous MTW Annual Environmental Reviews (AER's). Monitoring has been conducted across 12 reference sites within the two target vegetation communities Central Hunter Grey Box-Ironbark Woodland EEC, and Ironbark-Spotted Gum-Grey Box Forest EEC. Previous monitoring programs have established 26 permanent monitoring transects across MTW rehabilitation areas with the majority of these sites having been revisited in successive years to provide information on the progression of sites over time.

The latest round of rehabilitation monitoring was conducted by Cumberland Plain Seeds in Autumn 2019, the results of this rehabilitation monitoring are presented in **Appendix 5** of this 2019 AER. The move to Autumn monitoring is to coincide with the flowering time for the bulk of the native grasses to make it easier to identify the native understorey species and therefore provide a more accurate and transparent assessment of the rehabilitation program. The 2019 monitoring program has established an additional 24 new monitoring sites at MTW.

Additional monitoring methods were incorporated into the 2017 program to measure the density, health and growth of canopy species. Sites have been selected to include rehabilitation of varying ages and different rehabilitation methods.

The key issues affecting successful rehabilitation at MTW and the control measures implemented to address these issues are listed below:

Issue 1 – Weed competition affecting native vegetation establishment.

Control Measures.
Use of mine spoil as growth medium to avoid use of weedy topsoils in rehabilitation. This technique has proven successful in establishing diverse native vegetation when combined with the use of composts and other ameliorants to improve the physical, chemical and nutritional quality of the mine spoil. Suitable alternative compost products have been sourced and trialled in 2019 in place of the Mixed Waste Compost, which was banned from use by the EPA in 2018.

Weed control on topsoil stockpiles.
Topsoil stockpiles established prior to 2011 were seeded with exotic pasture species to provide a suitable cover for erosion protection. These competitive exotic species are causing weed problems in rehabilitation areas when the soil from these stockpiles is used on areas being returned to native vegetation. MTW has a topsoil stockpile maintenance program in place to spray out the exotic pasture species and sow native species on these old stockpiles. Stockpiles may require a number of weed control passes to adequately reduce weed levels before sowing to native species. New topsoil stockpiles are being treated in much the same way as new rehabilitation areas, in terms of weed control and soil amelioration, before being sown to native species. Establishment of native species on topsoil stockpiles will reduce the presence of weeds and provide a soil seed bank in rehabilitation areas that contains seeds from desirable native species.

Pre- and post-sowing weed control in rehabilitation.
MTW has implemented an extensive weed control program in rehabilitation areas to reduce the amount of weeds and assist the establishment of native vegetation. This program involves the use of boom sprays for both pre-sowing and pre-emergent spray passes to control weeds volunteering from the topsoil. After the native species have germinated, a weed-wiper can be used to control weeds that are taller than the native species. Herbicide can be wiped onto the taller weeds without affecting the emerging native species. Crews using backpack sprays and Quikspray units are also used to selectively control weeds that are growing amongst desirable native species.

Issue 2 – **Topsoil/spoils prone to dispersion leading to surface crusting, erosion and poor vegetation establishment.**

Control Measures.
Addition of ameliorants to topsoil/spoil. MTW conducts soil testing on the topsoil/spoil material that is used in rehabilitation areas. Based on the results of the soil testing, ameliorants such as compost, gypsum, lime and fertilisers are then used to address the physical, chemical and nutritional deficiencies of the topsoil/spoil. Subsequent applications of ameliorants are undertaken as required to address poor performing rehabilitation areas with continuing soil quality issues.

Issue 3 – Lack of native seed in topsoil seed bank leading to poor vegetation establishment.

Control Measures.
Sourcing of diverse native seed mixes. MTW has generally found that the soil seed bank in topsoils from both stripping areas and topsoil stockpiles cannot be relied on to contain sufficient native seed propagules for successful native vegetation establishment in rehabilitation. MTW has established medium term contracts with seed suppliers to provide some security of supply to suppliers who are then able to collect and store sufficient quantities of seed to meet MTW's future demands. The seed supply contracts include quality assurance controls to ensure the seed being purchased is of suitable quality i.e. satisfactory provenance, correct species, high seed count and viability.

7.2 Decommissioning

Capping of the Interim Tailings Storage Facility continued during 2019 using breaker rock from the South CHPP. A capping of inert spoil will be placed over the breaker rock before rehabilitating the area.

During 2017, capping of Tailings Dam 2 commenced using small contractor-owned equipment to place selected mine spoil in layers across the tailings dam surface. Capping work was suspended during 2017 due to settlement cracking occurring in an area where the tailings surface had low strength. Stage 1 capping work has not been able to recommence during 2019 as geotechnical studies undertaken by Australian Tailings Consultants have determined that the tailings strength has not increased sufficiently to support the capping process. During the reporting period mine equipment has been able to complete capping on some areas where the Stage 1 capping had been finished. This has resulted in 2.2ha of rehabilitation being completed on the Tailings Dam 2 footprint. The other focus of activity during 2019 has been on pumping activities to keep the surface of the tailings storage facility dry. The aim of this work is to increase the strength of the top layer of the tailings to allow the Stage 1 capping work to recommence.

7.3 Rehabilitation Performance

Table 7.2 summarises actual rehabilitation and disturbance completed compared with the rehabilitation commitments in the MTW MOP. **Appendix 6** provides the Annual Rehabilitation Report Form, including rehabilitation progress for each domain through the rehabilitation phases.

The area of rehabilitation that was sown during the reporting period was 0.6ha above the MOP target for MTW. The area of rehabilitation disturbance however was more than the MOP target for MTW by 30.6ha, leading to a net rehabilitation result for 2019 that was 30.0ha behind the MOP commitment. The additional rehabilitation disturbance during 2019 was attributable to the re-classification of topsoil stockpiles in rehabilitation areas, that had been reported as rehabilitation, being re-classified as disturbed areas. The net rehabilitation result over the MOP period (2015 to 2019) is 347.8ha versus a MOP commitment of 383.4ha, lagging by 35.6ha.

The amount of new disturbance undertaken in 2018 was 10.1ha lower than the MOP projections. The cumulative new disturbance over the period of the current MOP is also 10.6ha lower than the projected disturbance.

The 2019 rehabilitation areas for MTW are shown in **Appendix 7.**

TABLE 7.2 REHABILITATION AND DISTURBANCE COMPLETED IN 2019

MOP	Pit Area	2019 Totals (ha)		Cumulative Totals During MOP Period* (ha)	
		Actual	MOP Commitment	Actual	MOP Commitment
Rehabilitation					
MTW	Mt Thorley	38.9	44.3	115.9	159.8
	Warkworth	43.8	37.8	270.8	319.5
	MTW Total	**82.7**	**82.1**	**469.4**	**479.3**
Rehabilitation Disturbance					
MTW	Mt Thorley	14.7	2.1	52.8	38.4
	Warkworth	21.3	3.3	68.8	57.5
	MTW Total	**36.0**	**5.4**	**121.6**	**95.9**
New Disturbance					
MTW	Mt Thorley	6.0	5.4	27.0	59.6
	Warkworth	57.7	68.4	350.9	328.9
	MTW Total	**63.7**	**73.8**	**377.9**	**388.5**
Net Rehabilitation (Rehabilitation minus Rehabilitation Disturbance)					

MTW	Mt Thorley	24.2	42.2	102.0	121.4
	Warkworth	22.5	34.5	245.8	262.0
	MTW Total	**46.7**	**76.7**	**347.8**	**383.4**

Note: Rehabilitation areas relate to areas at or past the phase of Ecosystem and Landuse Establishment.
** MOP Period is 2015 - 2021*

Progressive rehabilitation commitments are outlined in the Warkworth Continuation 2014 and Mt Thorley Operations 2014 Environmental Impact Statements. These documents modelled a total of 1,103 ha of rehabilitation to be completed by the end of 2017, and a further 505.8ha to be completed by the end of 2023. At the end of the reporting period there had been 1,282 hectares of rehabilitation completed across MTW, 179ha ahead of the EIS forecast for the end of 2017 and tracking well to achieve the forecast total rehabilitation area at the end of 2023.

7.4 Rehabilitation Programme Variations

An independent assessment was conducted in 2019 to assess the current status of active rehabilitation across the MTW site in response to two Notices of Direction issued by the NSW Resources Regulator on 5 July 2019. The project resulted in 1,067ha being classified in Ecosystem and Land Use Establishment phase and 140ha in the Growth Medium phase. No areas were deemed to have met the criteria for Ecosystem and Land Use Development phase, however some areas were tracking towards this phase and could achieve this phase in time with appropriate management. This represents a significant change in the classification of active rehabilitation at MTW with last year's AER reporting 1,067ha of rehabilitation in the Ecosystem and Land Use Development phase.
The change in rehabilitation classification has been reflected in this AER and will be incorporated in a MOP Amendment to be submitted to Resources Regulator by 31 March 2020.

7.5 Rehabilitation Trials

During 2018, a trial was undertaken on the CD Dump rehabilitation area of MTW to mainly compare the performance of an inoculated mineral fertiliser against that of Mixed Waste Compost as a soil ameliorant. The trial was conducted on plots that used both topsoil and mine spoil as the growth medium with the various treatments shown in the table below.

Monitoring of this trial was to be undertaken during 2019 to determine the relative effects of the various soil ameliorants but will be postponed until 2020 due to the continuing dry conditions experienced at MTW.

TABLE 7.3 SOIL AMELIORATION TREATMENTS USED FOR 2018 CD DUMP REHABILITATION TRIAL

Plot	Area ha	Growth Medium	Gypsum t/ha	Compost t/ha	Lime kg/ha	Fertiliser kg/ha
A1	0.95	Topsoil	0	50	300	300
A2	0.36	Topsoil	0	50	300	0
A3	0.28	Topsoil	0	50	0	400
A4	0.2	Spoil	0	50	300	0
A5	0.14	Spoil	0	50	300	300
B1	0.46	Topsoil	0	0	0	400
B2	0.29	Topsoil	0	0	300	300
B3	0.23	Topsoil	0	0	300	0
B4	0.2	Spoil	0	0	300	300
B5	0.2	Spoil	0	0	0	400
B6	0.18	Spoil	0	0	300	0
C1	4.31	Topsoil	10	100	0	0
C2	1.01	Spoil	10	100	0	0
Trial Total	**8.81**					

Bettergrow Biomulch Compost was trialled as a replacement for Mixed Waste Compost as a soil ameliorant in rehabilitation during the reporting period. Compost application rates for the Bettergrow Biomulch Compost were reduced to approximately 50t/ha (from 100t/ha used for the Mixed Waste Compost) to offset the increased cost of this compost. Germination and early establishment will be monitored in 2020 to determine the efficacy of the reduced application rates.

7.6 Rehabilitation Maintenance

Management of rehabilitated areas is undertaken as required or when issues are identified through monitoring, auditing or inspections. Rehabilitation maintenance activities are described further in the sections below.

Post rehabilitation broadacre weed control

Broadacre weed treatment within rehabilitation areas is undertaken using agricultural methods comprising boom sprays and wick wipers. In existing rehabilitation areas boom spraying is primarily used to manage cover crop and fallow areas prior to sowing to final native seed mixes. Pre-emergent application of herbicide is occasionally necessary to control emerging weeds in the period between sowing and germination of the desired plants. Wick wiping targets rapidly growing exotic grasses and other erect growing weeds in the period following native germination but while desirable species remain below the wiper target zone. During 2019 areas totalling 286.8ha of existing rehabilitation received boom spray and/or wick wiper treatment.

Hand spraying and manual removal of weeds is also undertaken in rehabilitation areas with establishing native vegetation. During 2019 areas totalling 171.5ha were treated using selective weed

control methods (i.e. backpack spray, Quikspray). The area of selective weed control increased significantly in 2019 (up from 37ha in 2018) in response to the changing rehabilitation methodology to move more quickly to sowing rehabilitation areas with the diverse native seed mixes.

Rehabilitation areas receiving weed control during 2019 are shown in **Figure 79** below. Note some areas may have received a combination of treatments during the reporting period.

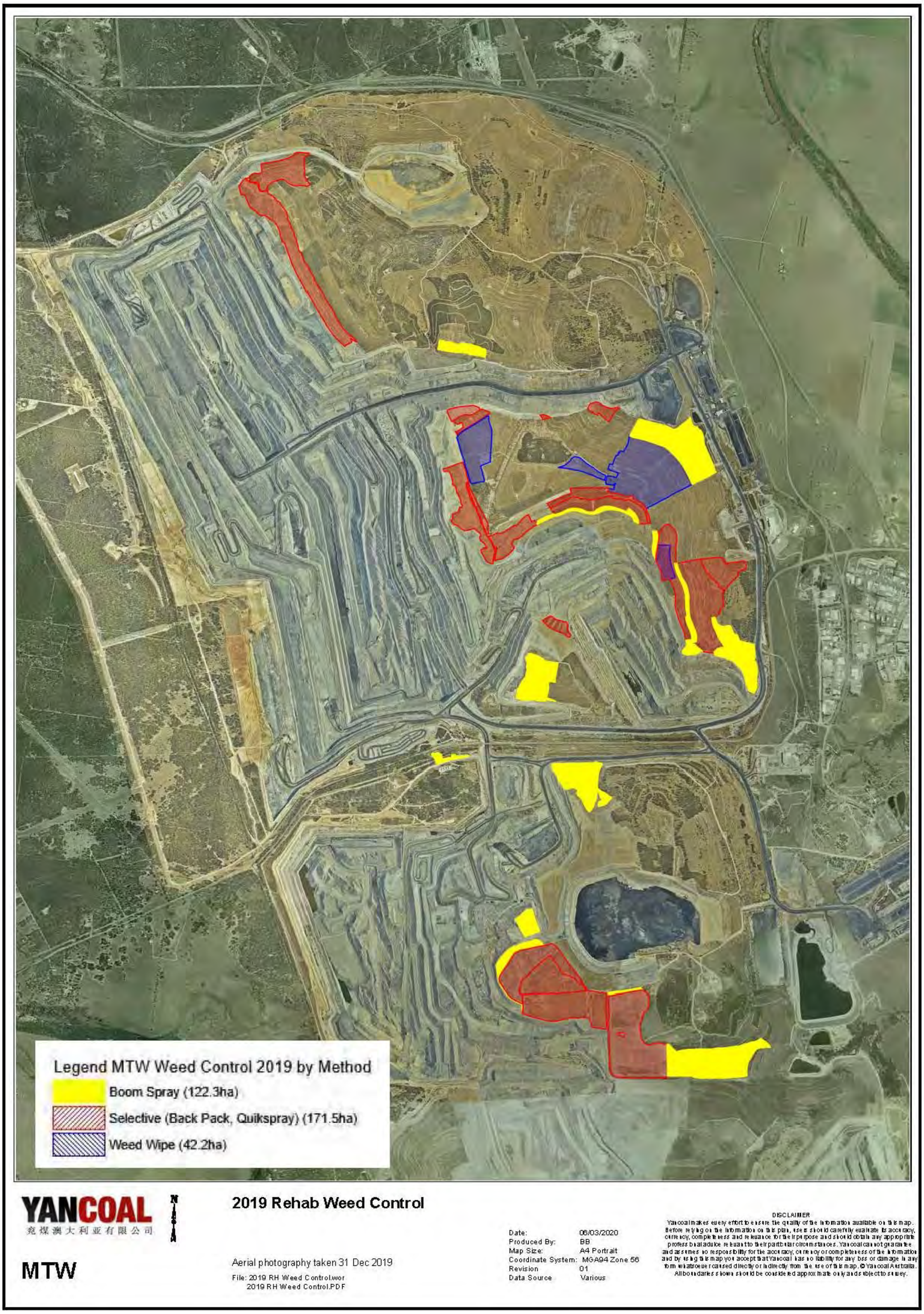


FIGURE 79: 2019 REHABILITATION WEED CONTROL LOCATIONS

7.7 Topsoil Management

Topsoil is managed according to MTW's Disturbance and Rehabilitation procedures. **Table 7.4** outlines the topsoil used and stockpiled during 2019. There was 68.5 ha of rehabilitation top soiled during 2019, using stockpiled and pre-stripped soil resources.

TABLE 7.4 SOIL MANAGEMENT

Soil Used this Period (m^3)	Soil Prestripped this Period (m^3)	Stockpile Inventory to Date (m^3)	Stockpile Inventory Last Report (m^3)
68,500	40,030	660,357	688,826

7.8 Tailings Management

Detail of capping activities on tailings storage facilities at MTW is covered in **Appendix 6**. Minimising the amount of standing water on tailings storage facilities, by managing the decant water, is important during and post tailings deposition to assist with closure of these facilities. Effective removal of decant water enables better consolidation of the tailings material, which in turn facilitates earlier capping and rehabilitation of the storage facility. **Table 7.5** outlines the current state of decant water pumping infrastructure across the active and inactive TSF's at MTW.

TABLE 7.5 TAILINGS MANAGEMENT

Facility	Status	Decant System
Centre Ramp TSF	Active	Decant pumps in place, regular pumping
Abbey Green South	Active	Decant pumps installed as required due to infrequent filling regime.
TD2	Inactive	Diesel Pump in place
Interim TSF	Inactive	Floating solar pump installed
Ministrip TSF	Inactive	Diesel Pump in place, pumping as required

7.9 Weed Control

7.9.1 Weed Treatment

The weeds identified at MTW occur primarily in areas that have been disturbed such as post mining rehabilitation areas, previous civil works areas, soil stockpiles, water management structure surrounds, and general areas of minor ground disturbance. A total of 87 days of weed management work was undertaken on site at MTW during 2019, with 230 ha of land treated, including maintenance of access tracks and 18 environmental monitoring points. The weeds targeted during the 2019 weed

management programme were based on the results of the 2018 weed survey. **Figure 80** illustrates the target species and weed treatment areas across MTW. Weed treatment areas are assessed following the completion of periods of work to determine the effectiveness of control works.

The species focussed on during treatment included:

- African boxthorn *(Lycium ferocissimum)*
- Galenia *(Galenia pubescens)*
- Green cestrum *(Cestrum parqui)*
- Lantana *(Lantana Camara)*
- Mother of millions *(Bryophyllum delagoense)*
- Opuntia (Pear) species (Tiger, Prickly and Creeping Pear)
- Saligna *(Acacia saligna)*
- Various grasses (Various spp)

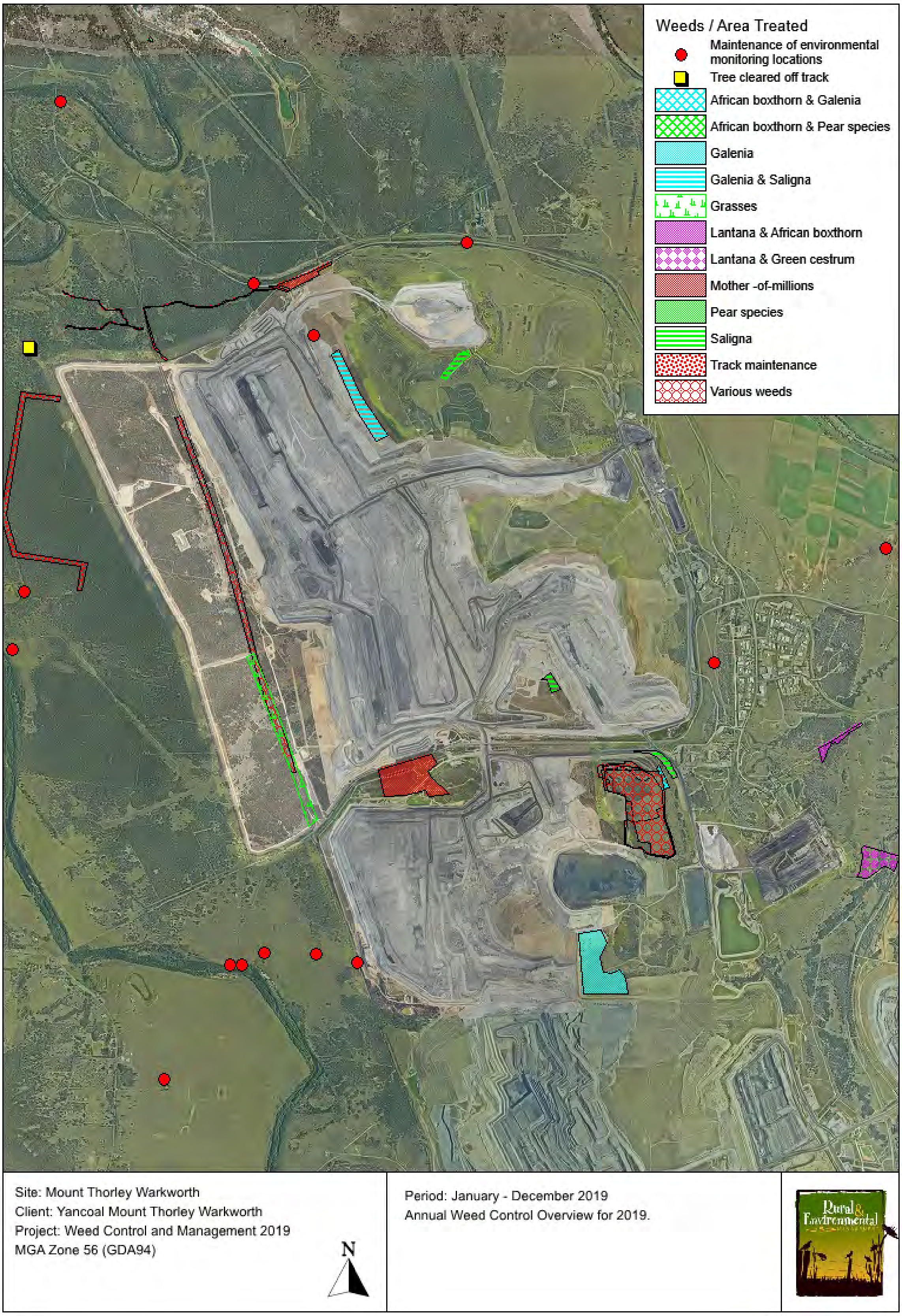


FIGURE 80: ANNUAL WEED CONTROL OVERVIEW FOR 2018

7.9.2 Annual Weed Survey

The management and control of weeds at MTW is governed by the Annual Weed Survey (AWS). The AWS lists Weeds of National Significance (WONS), noxious, environmental and other non-declared weed species identified across MTW, and provides a framework to allow for structured weed management and control across operational and non-operational areas of MTW.

The following summarises the results of the weed survey undertaken during December 2019, and is based upon the NSW Biosecurity Act 2015 which came into force from 1 July 2017 and repealed 14 Acts including the Noxious Weeds Act 1993. The new legislation has resulted in the development of the Hunter Regional Strategic Weed Management Plan 2017-2022 which covers the area occupied by MTW.

Eight WONS were identified during the survey, they included:

- African boxthorn *(Lycium ferocissimum)* State – Asset protection
- Bitou bush *(Chrysanthemoides monilifera subspecies rotundata)* State – Containment
- Fireweed *(Scenecio madagascariensis)* State – Asset protection/ Regional – additional species of concern
- Lantana *(Lantana camara)* State – Asset protection

Pear Species:

- Creeping pear *(Opuntia humifusa)* State – Asset protection
- Prickly pear *(Opuntia stricta)* State – Asset protection/ Additional species of concern
- Tiger pear *(Optunia aurantiaca)* State – Asset protection
- Velvety pear tree *(Opuntia tomentosa)* State – Asset protection

Thirteen other priority weeds were identified at MTW during the survey, including:

- African olive *(Olea europea subspecies cuspidae)* Regional – Asset protection
- African lovegrass *(Eragrostis curvulva)* Regional – Additional species of concern
- Balloon vine *(Cardiospermum grandiflorum)* Regional – Additional species of concern
- Blue heliotrope *(Heliotropium amplexicaule)* Regional – Additional species of concern
- Castor oil plant *(Ricinus communis)* General biosecurity duty
- Coolatai grass *(Hyparrhenia hirta)* Regional - Asset protection
- Galenia *(Galenia pubescens)* Regional – Additional species of concern
- Green cestrum *(Cestrum parqui)* Regional - Asset protection
- Mother of millions *(Bryophyllum delagonese)* Regional - Asset protection
- Pampas grass *(Cortaderia selloana)* Regional - Asset protection
- Saffron thistle *(Carthamus lanatus)* General biosecurity duty
- Bathurst burr *(Xanthium spinosum)* General biosecurity duty
- Noogoora burr *(Xanthium occidentale)* Regional Additional species of concern

Twelve weeds that are not officially declared or listed were also recorded at MTW including:

- Blackberry nightshade *(Solanum nigram)*
- Century plant *(Agave americana)*
- Golden wreath wattle or Saligna *(Acacia saligna)*
- Inkweed *(Phytolacca octandra)*
- Lambs tongue *(Verbascum Thapsus)*
- Mustard weed *(Sisymbrium sp)*
- Narrow leaved cotton bush *(Gomphocarpus fructicosus)*
- Paddy melon *(Cucumis myriocarpus)*
- Rhodes grass *(Chloris gayana Kunth)*
- Spiny Rush (Juncas acutus)
- Tree Tobacco (Nicotiana glauca)
- Wild Rose *(Rosa sp)*

Species identified during the 2019 survey will form the basis of ongoing weed management works during 2020.

7.10 Vertebrate Pest Management

As part of MTW's Vertebrate Pest Action Plan a baiting programme is carried out on a seasonal basis. Three 1080 ground baiting programmes consisting of approximately 60 bait sites utilising meat baits and ejector baits were undertaken during autumn and spring to target wild dogs and foxes. Baits were checked over a three-week period and replaced each week when taken.

Table 7.6 summarises the results from the programmes carried out at MTW during 2019 with baiting locations and results for the programmes are illustrated in **Figure 81** to **Figure 82**.

TABLE 7.6 VERTEBRATE PEST CONTROL SUMMARY

Season	1080 Baiting				Shooting		
	Total Lethal Baits Laid	Takes by Wild Dog	Takes by Fox	Takes by Feral Pigs	Feral Pigs	Hares	Foxes
Autumn	120	38	9	10	6	27	2
Spring	119	63	3	-	3	-	-
Total	**239**	**101**	**12**	**10**	**9**	**27**	**2**

Additional pest management programmes included:

- Feral pig 1080 baiting program carried out across MTW in autumn: 10 feral pigs poisoned.
- A cat trap was set in the North mining muster area in summer; one female cat and two kittens were trapped over a four-day period and euthanised at the local veterinary clinic.
- Opportunistic shooting of vertebrate pests.

MTW will continue to carry out quarterly vertebrate pest control programmes during 2020 to limit feral pest impacts on landholdings and surrounding neighbours.

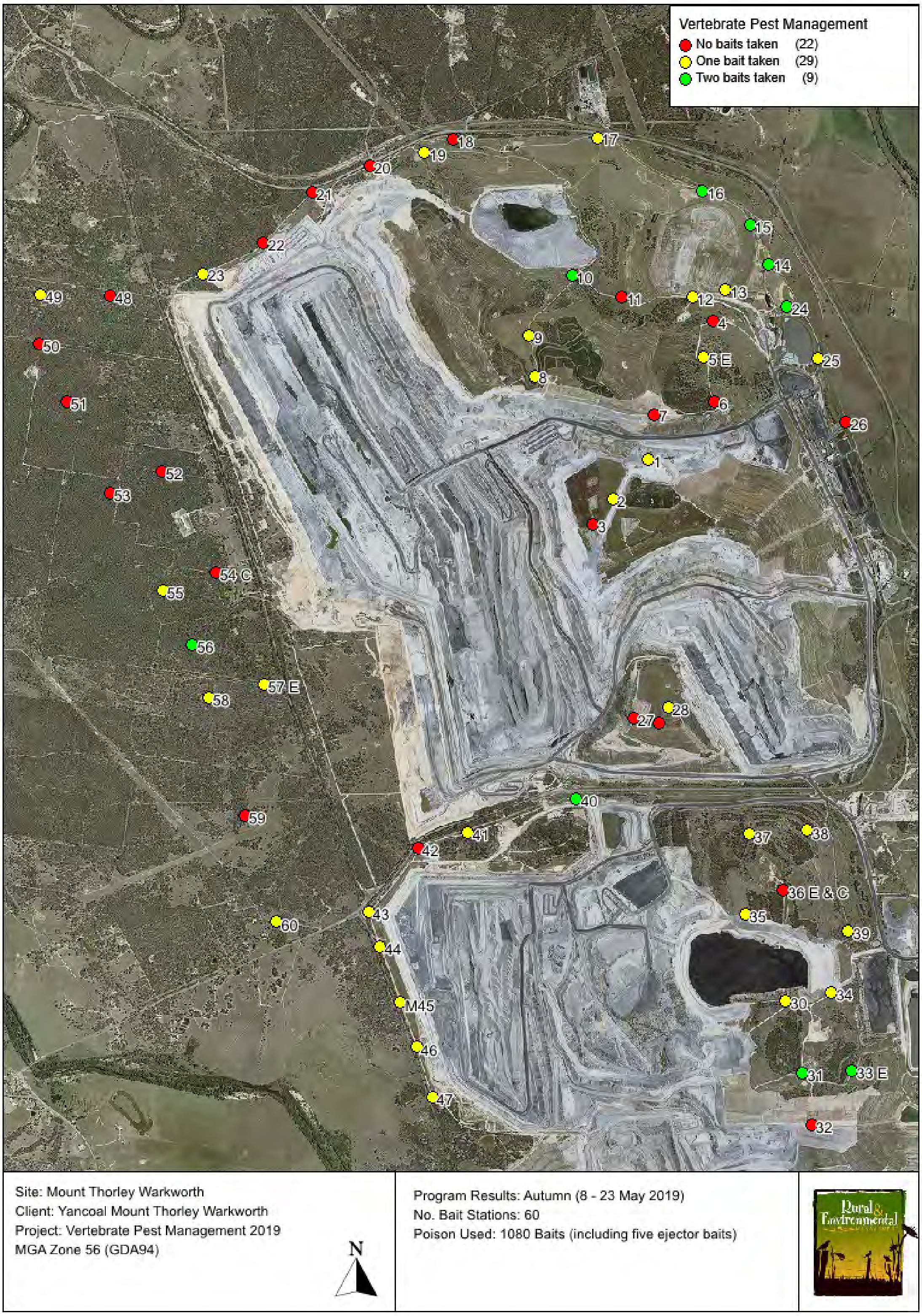


FIGURE 81: BAITING STATION LOCATIONS AND RESULTS AT MTW DURING AUTUMN 2019 VERTEBRATE PEST MANAGEMENT PROGRAMME

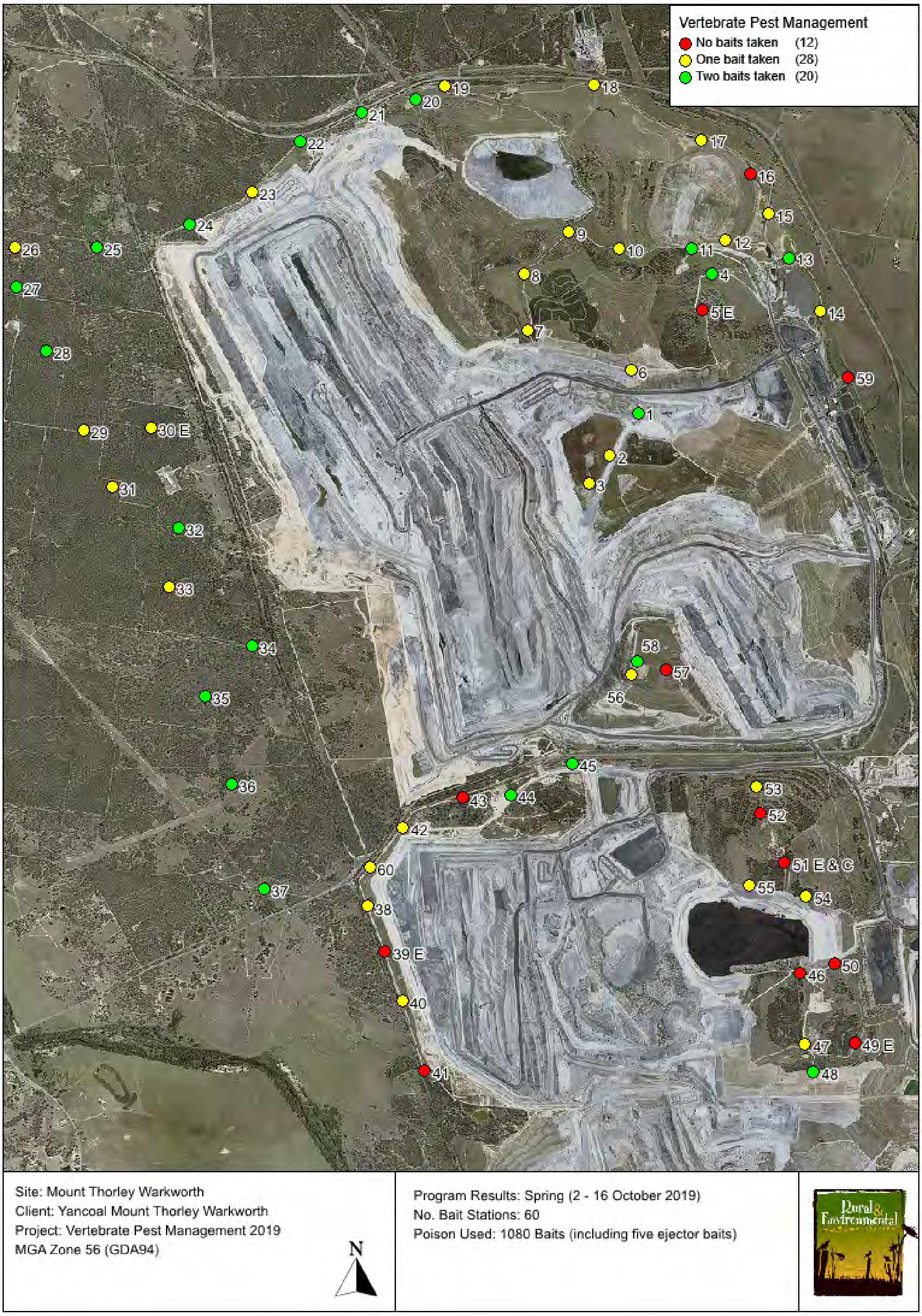


Figure 82: Baiting Station Locations and Results at MTW During Spring 2019 Vertebrate Pest Management Programme

7.11 Biodiversity Offsets

7.11.1 Management

MTW's impacts on biodiversity values are offset through the protection and management of Biodiversity Areas (BAs). The BA's that are related to MTW illustrated in **Figure 83** and listed in **Table 7.7.**

TABLE 7.7 MTW BIODIVERSITY AREAS

Biodiversity Areas	Area (ha)	Environmental Approvals				Offset Feature/s
		State		Federal		
		NSW 2014	NSW 2015	EPBC 2002/629	EPBC 2009/5081	
Southern	986	211	775		94	Warkworth Sands Woodland; Central Hunter Grey Box – Ironbark Woodland; Habitat for Swift Parrot, Regent Honeyeater, Southern Myotis and Large-eared Pied Bat.
Northern	341	39	302		341	Warkworth Sands Woodland; Central Hunter Grey Box – Ironbark Woodland; Habitat for Swift Parrot, Regent Honeyeater, Southern Myotis and Large-eared Pied Bat.
North Rothbury	41		41		41	North Rothbury Persoonia
Goulburn River (MTW Portion)	1,066		1,066	1,066		Central Hunter Valley Eucalypt Forest (CHVEF); Ironbark/Stringybark Communities; Box shrubby/grassy Woodlands; Habitat for Swift Parrot and Regent Honeyeater
Bowditch	602		602	520	82	CHVEF; Ironbark/Stringybark Communities; Habitat for Swift Parrot and Regent Honeyeater
Putty	383				383	CHVEF; Habitat for Swift Parrot and Regent Honeyeater
Seven oaks	519				519	CHVEF; Habitat for Swift Parrot and Regent Honeyeater
Condon View (MTW Portion)	345				345	CHVEF; Habitat for Swift Parrot and Regent Honeyeater

The MTW BA's are managed in accordance with site specific Offset Management Plans (OMPs). All of the OMPs are available on MTW's Insite website.

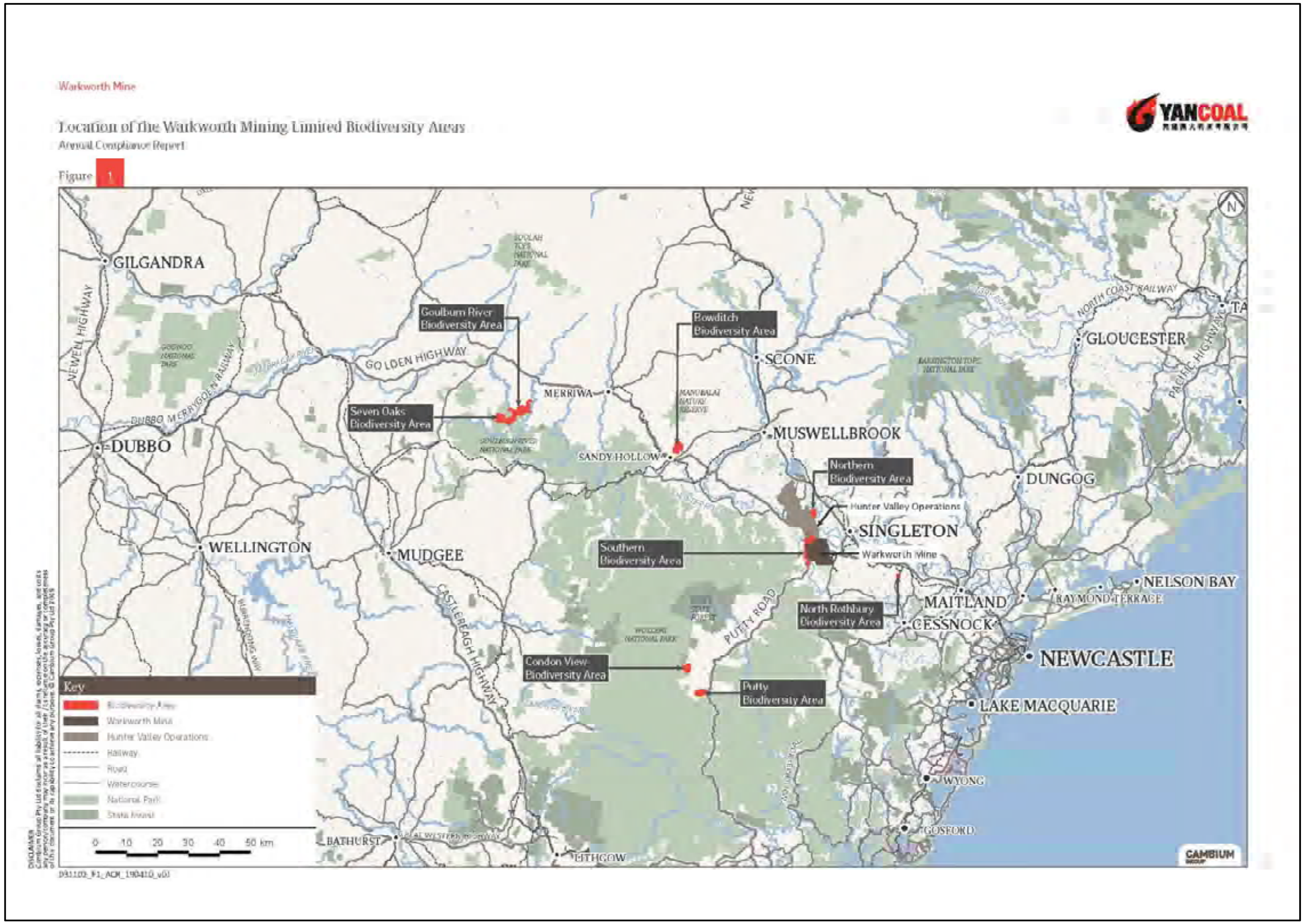


FIGURE 83: MTW BIODIVERSITY OFFSET LOCALITY MAP

7.11.2 Biodiversity Area Management Activities

The OMPs describe the Conservation Management Strategies. The following are the key actions completed throughout 2019 across all the BAs:

7.11.2.1 Weed Control

Weed control at the Local BAs targeted the following species:

- African boxthorn *(Lycium ferocissimum)*
- African lovegrass *(Eragrostis curvula)*
- African olive *(Olea europaea subsp. Cuspidate)*
- Blue heliotrope *(Heliotropium amplexicaule)*
- Bridal creeper *(Asparagus asparagoides)*
- Cats claw creeper *(Dolichandra unguis-cati)*
- Castor oil plant *(Ricinus communis)*
- Coolatai grass *(Hyparrhenia hirta)*
- Couch grass *(Cynodon dactylon)*
- Fireweed *(Scenecio madagascariensis)*
- Galenia *(Galenia pubescens)*
- Green cestrum *(Cestrum parqui)*
- Lantana *(Lantana camara)*
- Mother of millions *(Bryophyllum delagonese)*
- Natal grass *(Melinis repens)*
- Paterson's curse *(Echium plantagineum)*
- Prickly pear *(Opuntia stricta)*
- Tree of heaven *(Ailanthus altissima)*
- Tiger pear *(Optunia aurantiaca)*
- Tree pear *(Optunia tomentose)*

Weed control at the Regional BAs targeted the following species:

- Blackberry *(Rubus fruticosus)*
- Bridal creeper *(Asparagus asparagoides)*
- Caltrop *(Tribulus terrestris)*
- Farmers friends *(Bidens pilosa)*
- Fireweed *(Scenecio madagascariensis)*
- Galenia *(Galenia pubescens)*
- Green cestrum *(Cestrum parqui)*
- Lamb's ear *(Stachys byzantine)*
- Lamb's tongue *(Verbascum thapsus)*
- Lavender scallops *(Bryophyllum fedtschenkoi)*
- Narrow leaf cotton bush *(Gomphocarpus fructicosus)*
- Paddy's lucene *(Sida rhombifolia)*

- Prickly pear *(Opuntia stricta)*
- Scotch thistle *(Onopordum acanthium)*
- Stinging nettle *(Urtica dioica)*
- Tiger Pear *(Optunia aurantiaca)*
- Variegated thistle *(Silybum marianum)*
- Willlow *(Salix spp)*

7.11.2.2 Infrastructure Management and Improvement

Fence repairs were undertaken at the Southern and North Rothbury BAs. All tracks were maintained to reduce encroaching vegetation and improve access. Regular property inspections were undertaken on all BAs.

7.11.2.3 Fire Management

The MTW Biodiversity Area Bushfire Management Plan and the MTW Bushfire Management Plan were reviewed. Slashing of fire breaks was undertaken on the Goulburn River BA. Overall fuel load assessments were undertaken on the Regional BAs to identify current exposure to bushfire fuel hazard and implement a bushfire fuel hazard reduction program. Overall fuel load assessments for the Local BAs have been scheduled for 2020.

7.11.2.4 Strategic Grazing

No strategic grazing was undertaken in the BAs in 2019.

7.11.2.5 Vertebrate Pest Management

Two 1080 ground baiting programmes were undertaken across the Biodiversity Areas targeting wild dogs and foxes. Baits were checked over a three-week period and replaced each week when taken. Baiting was undertaken in autumn and spring and was undertaken in conjunction with neighbouring landholders where possible. **Table 7.8** summarises the results from the programmes carried out on the BA's during 2019.

TABLE 7.8 SUMMARY OF VERTEBRATE PEST MANAGEMENT 2019

Season	1080 Baiting			
	Total Lethal Baits Laid	Takes by Wild Dog	Takes by Fox	Takes by Feral Pigs
Autumn (Local BAs)	120	61	6	29
Spring (Local BAs)	120	77	2	0
Autumn (Regional BAs)	176	53	15	0
Spring (Regional BAs)	181	53	27	0
Total	**597**	**244**	**50**	**29**

Additional pest management programmes included:

- Feral pig 1080 baiting programme carried out across Northern and Southern BA in spring: 29 pigs poisoned.
    - Noisy Miner ground shoot at the Goulburn River BA to assist the survivability of the Regent Honeyeater: 353 Noisy Miners controlled under the Landholder's Licence to Harm Protected Animals (Biodiversity Conservation Act 2016). An additional programme undertaken by ANU/Birdlife Australia involved the implementation of direct nest protection measures including putting collars on nest trees to exclude possums and other predators and a cull of noisy miners and pied currawongs that occur within 200m of an active Regent Honeyeater nest.
- Opportunistic shooting of other vertebrate pests included 22 feral pigs, two foxes, seven rabbits, one feral cat, three deer and one wild dog.
- The Professional Wild Dog Controller Program has trapped and euthanised a total of 19 wild dogs on Yancoal land since July 2017. This is a four-year program with the primary goal to reduce the impacts of wild dog predation on livestock production, the social wellbeing of livestock producers, and native fauna, through professional and targeted control of problem dogs in the Upper Hunter district.

FIGURE 84: NEST PROTECTION MEASURES AT THE GOULBURN RIVER BIODIVERSITY AREA

Vertebrate pest management programmes will continue to be carried out during 2020 to limit feral pest impacts on landholdings and surrounding neighbours.

7.11.2.6 Seed Collection

Seed collection was undertaken by contractors in the Northern and Southern BAs during 2019, focussing on the Warkworth Sands Woodland (WSW), River Oak Forest and Ironbark vegetation community. Seed collection was also undertaken on the Goulburn River BA for Yellow Box – Grey Box – Red Gum grassy woodland and River Oak riparian woodland. Tube stock for 2019 plantings is currently being propagated from the seed collected.

7.11.2.7 Revegetation

MTW has committed to restoring the Endangered Ecological Communities of Warkworth Sands Woodland and Central Hunter Grey Box – Ironbark Woodland in the Southern and Northern Biodiversity Areas. Work commenced in 2014 and overall there is more than 500 hectares of grassland area to be planted and managed over 15 years to restore these Endangered Ecological Communities.

In 2019, restoration work included infill planting 129 ha of Central Hunter Grey Box – Ironbark Woodland and River Oak Forest in the Southern BA and with over 11,000 tube stock planted into rip lines. Infill of 9,100 tube stock was planted into Warkworth Sands Woodland plots in the Southern BA.

Infill planting also continued at the Northern BA with 3,000 tube stock planted into Warkworth Sands Woodland plots.
Planting at the Goulburn River Biodiversity area to increase the suitability of habitat for the Regent Honeyeater commenced with 17,000 tube stock planted in 2019 into the cleared areas of Yellow Box – Grey Box – Red Gum Grassy Woodland and riparian woodland areas. The site preparation for these sites included ripping by dozer, hand auguring and weed control. The team planted the seedlings into rip lines and hand planting areas. All plants were watered, fertilised and protected with a tree guard. The planting period saw well below average rainfall so additional watering was undertaken to assist plant establishment.

The next round of planting is planned for Autumn 2020 and will include 7ha of Warkworth Sands Woodland in the Northern BA with Warkworth Sand imported form areas ahead of mining at MTW. Additional infill of the Central Hunter Grey Box – Ironbark Woodland and River Oak Forest planting areas at the Southern BA will continue.
Supplementary infill planting to re-establish the cleared land in the Yellow Box – Grey Box – Red Gum Grassy Woodland to a Box Gum Grassy Woodland community will continue at the Goulburn River Biodiversity Area.

FIGURE 85: TUBE STOCK PLANTED INTO THE SOUTHERN BIODIVERSITY AREA

FIGURE 86: TUBE STOCK PLANTED INTO RIP LINES AT THE SOUTHERN BIODIVERSITY AREA

FIGURE 87: RIPPING BEING UNDERTAKEN IN THE GOULBURN RIVER BIODIVERSITY AREA

7.12 Audits and Reviews

The NSW Resources Regulator undertook an inspection of rehabilitation areas at MTW on 17 June 2019 which identified that there were ongoing delays in the progression of rehabilitation areas.

As a result of the above observation MTW was directed via two section 240 notices to undertake the following corrective action:

Conduct an independent review of rehabilitation progression which:

- Assesses the adequacy of progressive rehabilitation strategies and performance in implementation of those strategies to date. Provide a plan displaying the status of progressive rehabilitation

Outline any proposed measures or actions to improve progressive rehabilitation performance.

Response to corrective action:

- An independent review of rehabilitation progress was undertaken by Emergent Ecology and a report submitted to Resources Regulator on 30 September 2019. Resources Regulator issued two subsequent section 240 notices stating that the independent review had met the requirements of the original section 240 notices and directed MTW to submit a MOP amendment by 31 March 2020 incorporating the recommendations of the independent review.

The next MTW Independent Environmental Audit is due in **2020.**

8 COMMUNITY

8.1 Complaints

A total of 385 complaints were recorded during the reporting period, with an increase of approximately 10% compared to 2018. The 385 complaints were registered by approximately 50 people (some complainants remained anonymous), with just over 66% of complaints received from 7 individuals. Most complaints were received from residents in the Bulga area. A breakdown of complaints by type is shown in **Table 8.1.**

Noise remains of key concern for near neighbours. There has been a trending decrease (overall 41%) in noise complaints from 2017. The decrease experienced from 2017 is partially attributed to increased noise measurements undertaken by the Community Response Officers in 2018 and 2019 and corresponding mitigating actions taken where required.

Dust has emerged as a key concern for the community. 2019 showed an increase of complaints regarding dust by ~90% in comparison to 2018. This increase from 2018 can be partially attributed to below average rainfall in 2019 (304 mm), which is lower than 2018 (457 mm) and 2017 (444 mm). The average annual rainfall recorded at MTW's Charlton Ridge Meteorological station is 630mm, as calculated from 2007 to 2019 annual totals.

In summary:

- 35% reduction in noise complaints;
- Lighting and Water related complaint numbers have remained fairly consistent since 2017, although dust and blasting related complaints were higher than in 2017. An increase in dust complaints from 2017 is considered related to well below average rainfall, consecutively, from 2017 to 2019;
- Complaints in the "Other" category increased from 2017. Complaints in this category were in regards to pest management sightings, blasting information and notifications.

TABLE 8.1 SUMMARY OF COMPLAINTS BY TYPE FOR 2017 TO 2019

Complaint type	2019	2018	2017
Noise	112	171	191
Blasting	94	69	68
Dust	146	76	80
Lighting	27	32	33
Water	0	0	0
Other	6	3	10
Total	**385**	**351**	**382**

8.2 Review of Community Engagement

8.2.1 Communication

Members of the community are encouraged to contact MTW and engage in a way that suits them. Communication avenues in place to support MTW include:

- MTW free call Community Information Line (1800 727 745), which is advertised regularly in local newspapers and community newsletters;
- Online, via Insite website (www. insite.yancoal.com.au) with information about MTW including approvals documents, public reports, environmental monitoring results, blasting and road closures, and information about the MTW Community Consultative Committee (CCC) including the minutes of CCC meetings;
- MTW provide several avenues for community members to register enquiries or complaints, including via community information hotline and Environment and Community personnel;
- MTW maintains a 24 hour freecall environmental hotline (1800 656 892), which allows community members to register a concern or complaint at any time of the day or night, 365 days a year. The hotline is advertised in telephone directories, on the InSite website, regularly in local newspapers, and in MTW publications;
- MTW maintains a Blast Information Line (1800 099 669) which provides information on blasts and road closures;
- Near neighbour engagement, including proactive visits to neighbours surrounding MTW; and
- MTW also issues correspondence to specific community members who may be affected by certain changes, to inform of upcoming consultation activities and as a feedback mechanism.

A range of consultation and engagement activities were also completed, which included:

- Finalisation the MTW Social Impact Management Plan, and publishing on the MTW website. This plan collates together all commitments that were part of the Environmental Assessment for MTW's Continuation Project process and identifies where the company will undertake actions to mitigate some of the potential impacts in the area. The main topics include:-
  - Voluntary Planning Agreement;
  - Property Agreements Strategy, around acquisition and mitigation rights in the area.
  - Management of properties in and around Bulga that MTW has had to acquire.
  - Conservation funds and how MTW operate these.
  - Support for local Schools
  - Scholarships and Apprenticeships;
  - Acquisition of Commercial Facilities, for example the Bulga Tavern where MTW has worked to upgrade this facility to support the business sustainability;
  - Ongoing Community Support Program; and

    - the MTW CCC, which is identified as one of the primary communication areas where the company reports back through the CCC on how their business is performing.
- Engagement and consultation with near neighbours to provide project updates at key project milestones and activities, and in response to concerns/queries raised by individual near neighbours;
- Hosting the Bulga Rural Fire Service (RFS) for a further tour of the RFS access road (Watts Track) to review changes to the area and enable emergency service access to the area following the closure of Wallaby Scrub Road. The access road and entry protocol was approved by the RFS prior to road closure; and the
- MTW are supportive of the Upper Hunter Mining Dialogue School Tours program. Over two weeks in September, primary school children from St Catherine's Catholic College visited MTW to tour the operation.

MTW were also involved in various community events through sponsorship and participation.

8.2.2 Community Consultation Committee

The MTW CCC met on a quarterly basis to discuss our operations. The Committee is comprised of MTW representatives, community members and other key external stakeholders, including Singleton Council. The MTW CCC minutes were made available on the MTW Insite website (www. insite.yancoal.com.au). The community is invited to visit the MTW website to learn more about the MTW CCC, as well as other aspects of MTW operations and projects.

During the reporting period the CCC members were:

- Dr Col Gellatly - Independent Chair
- Cr Hollee Jenkins - Singleton Council Representative
- Mr Adrian Gallagher – Community Representative
- Mrs Christina Metlikovec – Community Representative (resigned 8 August 2019)
- Mr Graeme O'Brien – Community Representative
- Mr Ian Hedley – Community Representative
- Mr Stewart Mitchell – Community Representative

Company representatives attending the CCC included:

- Mr Jason McCallum - MTW General Manager
- Mr Gary Mulhearn – MTW Environment & Community Manager
- Mr David Bennett – MTW Mining Manager (and Acting General Manager)
- Mr Travis Bates – MTW Community Relations Specialist
- Ms Olivia Lane – MTW Environment & Community Coordinator
- Ms Aleisha Tindall – MTW Community Response Officer
- Mr Patrick Kirkwood – MTW Community Response Officer
- Mr Louis Fleming – MTW Community Response Officer

MTW advertised for new members to join the CCC over a period between 27 November 2019 to 17 January 2020, prompted by the resignation of Mrs Christina Metlikovec in August 2019. Advertisements were placed in the Singleton Argus Newspaper, in local businesses in Bulga, and at the Singleton Council offices. In addition, the local community near MTW were directly sent a letter advising that an opportunity to apply to join the MTW CCC was available. The outcome of the application process will be reported in the next Annual Review report.

8.2.3 Community Support and Development

In 2019, MTW continued its focus on ensuring the long-term sustainability of the communities in which it operates, through the facilitation of community development programmes such as:

- Voluntary Planning Agreement
- Mount Thorley Warkworth Community Support Program

8.2.3.1 Voluntary Planning Agreement

In 2019, MTW continued contributions to the voluntary planning agreement funds required by development consents SSD-6464 and SSD-6465, and as agreed with Singleton Council. During 2019, MTW contributed a further $800,000 excluding GST, bringing total VPA contributions at end of 2019 to $4.8M of the total commitment value of $11M.

Singleton Council operates the Mount Thorley Warkworth VPA Community Committee which discusses the Bulga Community Project Fund component of the VPA funds. During 2019, the committee was chaired by Mayor Sue Moore and includes senior staff from Council, community representatives, and a Yancoal representative. Pleasingly, there have been two projects approved in the Bulga area from the Bulga Community Project Fund which includes Bulga Recreation Grounds improvements and exercise equipment (which officially opened on 19 March 2020), and improvements to Bulga Hall (new media system).

8.2.3.2 MTW Community Support Program

In 2019 MTW continued implementation of the Yancoal Community Support Program (CSP). The CSP intends to make a genuine positive difference to the communities in which Yancoal operates. Applications for CSP partnerships are formally received once per funding year, with the first offer closing 31 January 2019 for the 2019 funding year, and a further offer closing 4 November 2019 for the 2020 funding year. MTW considers and supports applications for local donations and sponsorships that have a clear community benefit and are aligned with eh CSP guidelines.

In 2019, MTW supported $150,000 to 19 local projects and initiatives, including:

- University of Newcastle Scholarship Program
- University of Newcastle Upper Hunter Science and Engineering Challenge
- Rotary Club of Singleton on Hunter – 2019 Singleton Art Prize

- Singleton Schools Learning Community – Visible Wellbeing Project (Mental Health Program for teachers and students in all Singleton schools)
- Singleton Business Chamber – 2019 Singleton Business Excellence Awards
- Westpac Rescue Helicopter Service – Hunter Valley Mining Charity Rugby League Competition 2019
- Greta Branxton Rugby League – Sport Equipment
- Newcastle & Hunter Combined Schools ANZAC Service – 2019 Singleton ANZAC Service
- Singleton Theatrical Society – Platinum Sponsorship 2019 Production of 'Les Misérables'
- Mindaribba Warriors Rugby League –Bronze Sponsor
- Singleton District Girl Guides – Shade Shelters
- Singleton Council – Fireworks Display at 'Christmas on John Street 2019'. Sponsorship redirected to local Rural Fire Service organisations after cancellation of fireworks by Council.
- Singleton Rugby Club – Sponsorship towards defibrillator
- Singleton Golf Club Lady Members – Annual Ladies Day Open
- Wildlife Aid Inc - Support for Wildlife care and rescue
- Milbrodale Public School P&C Association - Family Fun Day 2019
- Northern Agriculture Association Inc - Gold Sponsorship - 2019 Singleton Show
- Mates in Mining – sponsorship
- Samaritans Foundation – Christmas Lunch in Singleton 2019

9 INDEPENDENT ENVIRONMENTAL AUDIT

There was no Independent Environmental Audit completed during the reporting period. An update of progress against the Action Plan developed in response to the 2017 Independent Environmental Audit is included in **Appendix 8**. The next MTW Independent Environmental Audit is due in 2020.

10 INCIDENTS AND NON-COMPLIANCE

A summary of the environmental incidents reported during 2019 are provided in **Table 10.1** below

TABLE 10.1 ENVIRONMENTAL INCIDENT SUMMARY 2019

Date	Incident Details	Follow up Actions
30 March 2019	Discharge from two boundary dams at Warkworth (Dam 46N and Dam 53N) as a result of a greater than design rainfall event. A total of 52mm of rainfall was recorded on the day of the incident. Notifications to the relevant regulatory authorities was undertaken, in accordance with the MTW Pollution Incident Response Management Plan (PIRMP).	Investigation undertaken by MTW into both discharges. MTW submitted an incident report to EPA and DPIE associated with the discharge event. Dewatering infrastructure upgraded on Dam 46N (Additional pump and dewatering pipeline) to improve the sites ability to control stormwater runoff during rainfall. Dam 46N was re-classified to a mine water dam in accordance with the site Water Management Plan. MTW installed a remote boundary dam monitoring system to assist with improving management of the sites remote boundary dams. MTW commissioned an external engineering assessment of its North Pit North water management zone to determine medium to long term actions that could be implemented to reduce the risk of future discharge events during significant rainfall. MTW is currently working through the recommendations from this review.
4 April 2019	A WML North Pit blast, N34-BFA-MD1 fired at approximately 01:09pm on 4 April 2019 recorded an airblast overpressure measurement of 121.2 dB(L) at the Warkworth monitoring location.	An external investigation was undertaken to determine the contribution of relevant factors affecting airblast overpressure to the air pressure level recorded at the Warkworth monitoring station. The investigation concluded that "The reason that the AOP level that resulted at the Warkworth monitoring station was greater

Date	Incident Details	Follow up Actions
		than predicted was due to the fact that the actual meteorological data, and hence the actual effects of meteorology, were different from that predicted." MTW are working with relevant stakeholders to enable the implementation of a real time model, which will use real time meteorological data from weather stations throughout the Hunter Valley to better determine the effect of possible overpressure enhancement. The exceedance was reported to the Department of Planning and Environment and the EPA on 5 April 2019. MTW also notified affected landowners in writing of the exceedance.
7 August 2019	At 13:49 on 7 August 2019 a blast identified as N39-GMB-PR4 was detonated in the North Pit of the Warkworth Mine. The resulting blast dust travelled to the east over land associated with Warkworth Coal Mine, Putty Road, and the Mount Thorley Industrial Estate before dissipating over farmland east of the licenced premises.	MTW has standard operating procedures to mitigate offsite blasting impacts and continues to apply these controls and manage all blast activities in accordance with approved licences and management plans. MTW has reviewed and implemented changes to the sites internal blast operating procedures based on wind speed and direction that could potentially result in a blast plume that does not dissipate prior to reaching the premises boundary in the direction of the Mt Thorley Industrial Estate.
31 December 2019	At the end of the 12 month 2019 calendar year, there were a total of 16 blast events at MTO, of which a single blast vibration result at the Wollemi Peak Road monitor was recorded in the range of 5-10mm/s (actual result 5.67mm/s). Due to the small number of blasts at MTO, this has resulted in 6.3% of blasts at the Wollemi Peak Road monitoring location being in the range of 5-10mm/s, which is greater than the requirements of development consent SSD-6465 which permits up to 5% of blasts to record in the range of 5-10mm/s.	An investigation of the individual result that was >5mm/s (5.67mm/s result recorded on 10 December 2019) was undertaken to determine the potential contributing factors affecting the ground vibration level recorded at the Wollemi Peak Road monitoring station. The investigation identified that ground conditions related to drought conditions and a presplit shot fired shortly after the main production shot, may have both contributed to the higher than predicted result. The blast design checklist has since been revised to reduce the potential for reoccurrence of a similar ground vibration result.

Date	Incident Details	Follow up Actions
		The exceedance was reported to DPIE and to the EPA (via the MTO Annual Return).

WML received two Penalty Notices for the water discharge incident dated 30 March 2019 during August 2019 and an official caution from the EPA in September 2019. One penalty notice was issued by the EPA for a breach of EPL 1376 and a second Penalty Notice was issued by DPIE for a breach of the Warkworth Development Consent. In addition to the follow up actions listed in **Table 10.1**, MTW submitted a revised water management plan for the operation to DPIE during the reporting period to address the incident investigation findings and regulatory feedback associated the water discharge incident.

WML received a Penalty Notice from DPIE in September 2019 in relation to the blast overpressure incident reported to the EPA and DPIE on 5 April 2019. Details of the incident are provided above. The Penalty Notice was in relation to failure to comply with Schedule 3, Condition 8 of Development Consent SSD-6464, for Warkworth mine. The recorded airblast overpressure result exceeded the blast criteria defined in Schedule 3, Condition 8 of 0% allowed to exceed 120 dBL.

11 ACTIVITIES TO BE COMPLETED IN THE NEXT REPORTING PERIOD

Yancoal will endeavour to carry out the following activities during the 2020 reporting period at Mount Thorley Warkworth, as outlined in **Table 11.1**.

TABLE 11.1 PROPOSED ACTIVITIES FOR 2020 REPORTING PERIOD

ID	Performance Area	Activities Proposed
1	Noise	• Maintain and continue sound power level testing of attenuated fleet; • Continue undertaking noise management and monitoring actions in accordance with the MTW Noise Management Plan
2	Blasting	• Review and revise the MTW Blast Management Plan for operational changes at MTW.
3	Air Quality	• Integration of additional "North Warkworth" meteorological station into MTW's monitoring network, to assist with decisions around blasting and water management. • Decommissioning of the Wallaby Scrub Road TEOM and integration of the new Wambo Road TEOM into MTW's air quality monitoring network, as approved in MTW's Air Quality Management Plan. The new monitoring location is considered to be more representative of air quality at receptor locations along Wambo Road.

ID	Performance Area	Activities Proposed
4	Aboriginal Cultural Heritage	• Ongoing Aboriginal archaeological and cultural heritage management activities will occur in 2020 in accordance with current management plans, to inform ongoing land management and development planning. This will include the relocation of the Site M grinding grooves from the Putty Road Storage facility to the WBACHCA & the salvage of those Aboriginal artefact sites located within the ACHMP Area in areas required for mine development. Condition monitoring of those sites peripheral to authorised disturbance areas will be conducted annually to ensure operational compliance with the ACHMP. • MTW will consult with its registered Aboriginal Parties regarding the ongoing management of the new artefact scatter site identified on Charlton Ridge during the 2019 reporting period. • The Hunter Valley Sands Bodies research study will be progressed, as will proactive management within the Wollombi Brook and Loders Creek Aboriginal Cultural Heritage Conservation Areas in accordance with the management plans for those areas. • Conservation Agreements for the Wollombi Brook and Loders Creek Aboriginal Cultural Heritage Conservation Areas will be progressed in 2020. • Relocation of the three cultural scar trees from the active mining area will be undertaken in consultation with the relevant stakeholders.
5	Historic Heritage	• Implementing the MTW complex-wide HHMP developed in accordance with the conditions of the Warkworth & Mount Thorley Development Consents, which will guide the management of historic heritage. • MTW is planning on undertaking an aerial drone review of the three historical heritage sites during the next reporting period to help inform management activities for the period.
6	Water	• Improving the general capacity of the site's water resources via construction and/or upgrades of approved tailings storage and water storage facilities. • Implementation of actions/recommendations from the annual groundwater review. • Develop an action plan to address the findings of the annual stream health assessment for Loders Creek. • Implement recommendations from NPN water management engineering assessment to reduce risks associated with stormwater management in this zone.

ID	Performance Area	Activities Proposed
7	Rehabilitation	• The rehabilitation monitoring programme will continue in 2020 for native vegetation rehabilitation areas. The monitoring program will be varied to align with changes to MOP performance criteria resulting from Independent Rehabilitation Review (Emergent Ecology 2019) recommendations. • Maintenance activities are planned to result in approximately 80ha of rehabilitation, currently in the initial stage of cover cropping, being seeded with the full native seed mixes. Weed spraying (boom and spot spraying) and weed wiping will be conducted in establishing rehabilitation areas as required to control both noxious and environmental weeds that are likely to impact on successful rehabilitation being achieved. It is planned that 64ha of new rehabilitation will be undertaken at MTW during 2020. • Native woodland seed mixes will be revised based on recommendations from the Independent Rehabilitation Review. • Habitat augmentation measures, such as the construction of habitat ponds and the placement of salvaged logs in rehabilitation areas. • Capping of Tailings Dam 2 will be progressed during 2020 in accordance with the revised capping methodology developed by Australian Tailings Consultants. The capping method being utilised on TD2 was reviewed and updated following settlement cracking of the capping layer in an area of TD2 in 2017. • Capping of the Interim TSF will continue during 2020 using breaker rock from the South CHPP as the initial capping layer.

ID	Performance Area	Activities Proposed
8	Biodiversity Management	• Planting works will continue to restore Warkworth Sands Woodland and Central Hunter Grey Box – Ironbark Woodland in the Northern and Southern BAs. Supplementary planting to re-establish the cleared land in the Yellow Box – Grey Box – Red Gum Grassy Woodland to a Box Gum Grassy Woodland community and increase the suitability of habitat for the Regent Honeyeater in the River Oak riparian woodland will continue at the Goulburn River Biodiversity Area. • Conservation management actions will be undertaken across the BAs in 2020 in accordance with the Offset Management Plans, these will include weed management in autumn and spring. Vertebrate pest management including 1080 ground baiting programmes to target wild dogs and foxes scheduled for autumn and spring across all BAs and a noisy miner control in the regent honeyeater breeding area at the Goulburn River BA. Rapid Condition Assessment, Overall Fuel Load Assessments and property Inspections will be undertaken across all BAs. Bird Assemblage Monitoring and Habitat Restoration Monitoring is scheduled to be undertaken across all BAs. Infrastructure improvement including fence repairs and track maintenance will be undertaken as required. • Progress the securing of biodiversity offset areas using the methods detailed in the relevant state and federal biodiversity approvals.
9	Community Engagement	• Continued operation of the Community Consultation Committee. • Implementation of the MTW Social Impact Management Plan (which outlines specific and general stakeholder engagement and consultation requirements).
10	Community Development	• Implementation of the Yancoal Community Support Program (CSP) during 2020 after closing date in November 2019, and seeking applications from the local community for 2021 funding. The CSP program will provide an opportunity for multiple site or group-wide investment in larger, long-term, capacity building projects that make a positive difference. Focus areas include health, social and community, environment, education and training.

Appendix 1:

Aboriginal Heritage Management Plan Compliance Inspection Report

Mount Thorley Warkworth
Aboriginal Heritage Management Plan
2019 Compliance Audit Inspection

Report prepared for

Yancoal Australia, Mount Thorley Warkworth

March 2020

Joel Deacon

ARROW HERITAGE SOLUTIONS

Introduction

Yancoal Australia (Yancoal) manage the Mount Thorley Warkworth (MTW) mining complex located in the Hunter Valley, approximately 8km south-west of Singleton. Approval for the continuation & expansion of the mine was granted on 26th November 2015 under two separate project approvals: the Warkworth Continuation Project Approval (SSD-6464) & the Mount Thorley Operations Project Approval (SSD-6465).

Pursuant to Condition 43 of the Warkworth Continuation Project Approval, & Condition 28 of the Mount Thorley Operations Project Approval, Yancoal developed a MTW Aboriginal Heritage Management Plan (AHMP) to cover both mining operations, which was originally approved by the Department of Planning & Environment on 29th May 2017. This AHMP sets out the principles, processes & measures through which Aboriginal cultural heritage will be managed within the AHMP Area. This includes a commitment (Provision 24) to conduct annual AHMP compliance inspections with members of the Aboriginal community, through the auspices of the MTW Aboriginal Cultural Heritage Working Group (CHWG), throughout the life of operations. The purpose of the compliance inspections is to afford the Aboriginal stakeholders & MTW:

- the opportunity to visit mine operations and mine areas to inspect the operational compliance with AHMP provisions & Ground Disturbance Permit procedures;
- to inspect and monitor the condition and management of various sites over time; and
- to review the effectiveness and performance of AHMP provisions in the management of cultural heritage at the mine.

These compliance inspections are conducted at least annually. Due to the number of Aboriginal cultural heritage sites within the AHMP area & the time foreseen to inspect all sites, it is not feasible to inspect every site during the same field trip. Therefore, a regular, rolling program of compliance inspections has been implemented that will visit all sites at each location periodically. A record will be kept of each compliance inspection against each Aboriginal cultural heritage site, so that it can be ensured that each site is inspected regularly.

Proposed Activity and Project Brief

The compliance inspections involved the following elements:

- A number of Aboriginal cultural heritage (ACH) sites were visited and AHMP compliance inspection proformas were completed for each noting the outcomes of the inspections including evidence of compliance and non-compliance with AHMP provisions, recommendations on modifications and improvements to management provisions, recommendations on corrective actions, and other comments associated with AHMP provisions;
- A photographic record of the inspected ACH sites; and
- Specific inspection of a recent new find to see an example of the implementation of AHMP procedures.

Timing & Personnel

The 2019 MTW AHMP compliance inspection program was conducted on Monday 2nd and Tuesday 3rd March 2020. The personnel involved in these inspections were:

Name	Position/Organisation
Joel Deacon	Archaeologist, Arrow Heritage Solutions
Wade Covey	Environment and Community Coordinator, MTW
Maree Waugh	CHWG representative
Katrina Cavanagh	CHWG representative

Arrow Heritage Solutions were engaged as independent heritage consultants to conduct the AHMP compliance inspections, and Joel Deacon acted as technical advisor and author of this report. MTW's Environment and Communities Co-ordinator Wade Covey arranged the compliance inspection programs and escorted the field team. Representatives of the Wattaka Cultural Consultants and Wallangan participated in the field work program.

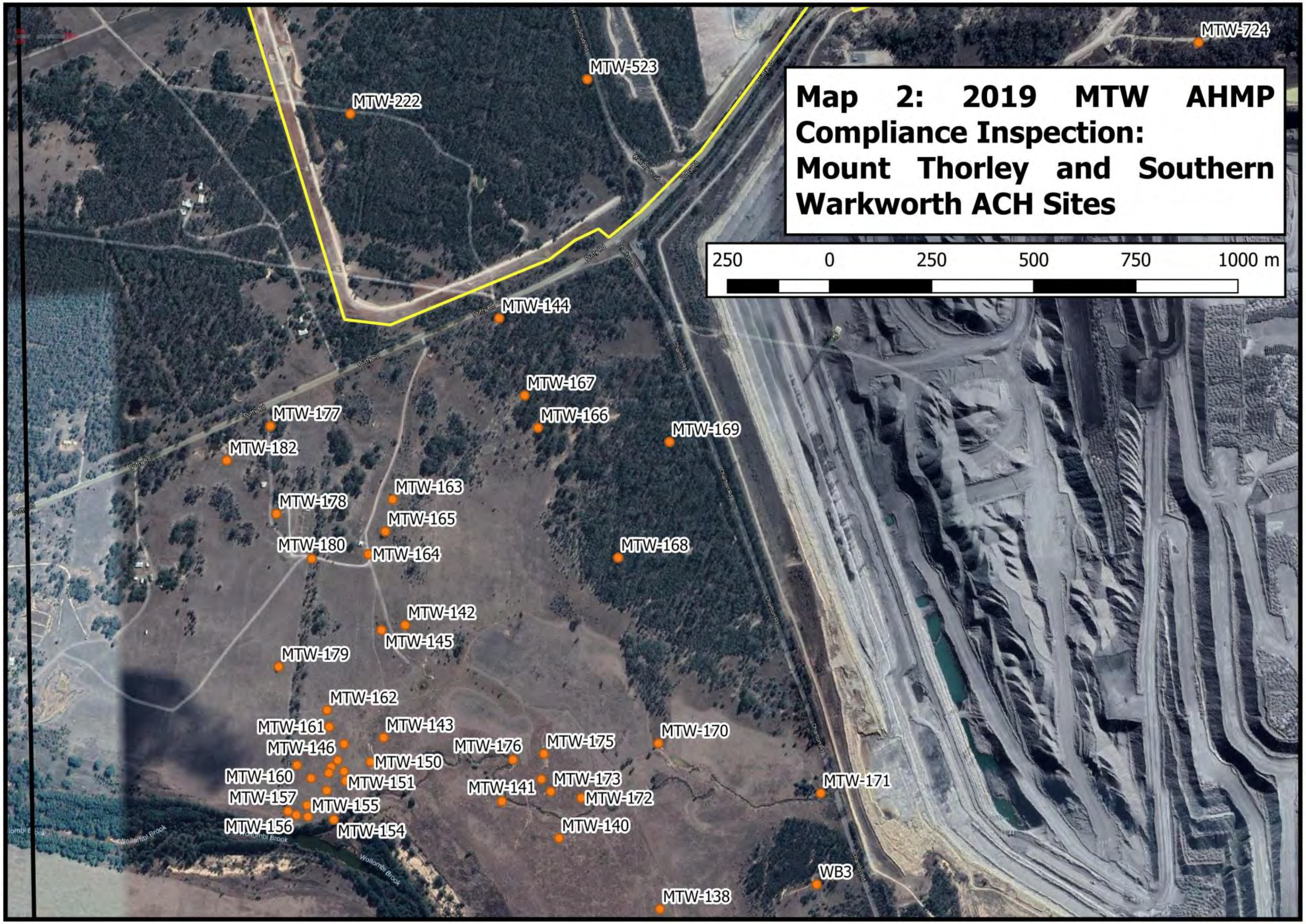
MTW AHMP Compliance Inspection

A total of 58 Aboriginal heritage sites were inspected across both the Warkworth and the Mount Thorley mining sites (see Maps 1 and 2). The area at Warkworth was selected for inspection as this is adjacent to current development areas and is being frequently accessed for a variety of activities. The sites inspected at Mount Thorley are located within an environmental offset area south of Putty Rd and west of Charlton Rd and, although generally protected from any possible ground disturbing activities, do have the potential to be affected by erosion and other environmental factors

Results

Table 1 summarises the results of the 2019 MTW compliance inspection and summarises the information recorded on the individual proforma inspection sheets. Using a mobile mapper pre-loaded with the GIS co-ordinates for each Aboriginal heritage site, the field team travelled to each location and attempted to re-locate each site. Sometimes this was not possible due to poor ground surface visibility, a result which in itself was not overly significant as long as it was determined that the vicinity had not been inadvertently disturbed. The presence and condition of barricading or fencing was noted, as well as the presence and nature of various potential site disturbing factors (e.g. erosion, animal, human). General observations of each site were made if necessary, and, based on information provided for all the above factors, management recommendations were discussed and agreed by the field team for each site.

Map 1: 2019 MTW AHMP Compliance Inspection: Northern Warkworth ACH Sites
250 0 250 500 750 1000 m
MTW-80
WS7;
MTW-86
MTW-90
MTW-72
MTW-71
MTW-89
MTW-69
MTW-70
MTW-8
MTW-4


Map 2: 2019 MTW AHMP Compliance Inspection: Mount Thorley and Southern Warkworth ACH Sites
250 0 250 500 750 1000 m
MTW-724
MTW-523
MTW-222
MTW-144
MTW-167
MTW-166
MTW-169
MTW-177
MTW-182
MTW-163
MTW-178
MTW-165
MTW-180
MTW-164
MTW-168
MTW-142
MTW-145
MTW-179
MTW-162
MTW-161
MTW-143
MTW-146
MTW-176
MTW-175
MTW-170
MTW-150
MTW-160
MTW-151
MTW-141
MTW-173
MTW-171
MTW-157
MTW-155
MTW-172
MTW-156
MTW-154
MTW-140
WB3
MTW-138

Site Name	Date	Mine	Site re-identified?	Site intact?	Site fenced/ barricaded?	Fencing/ barricading intact?	Natural erosion	Livestock damage	Human disturbance	Animal disturbance	Pests & weeds	General observations	Management recommendations
MTW-138	3/3/20	MTO	Yes	Yes	Yes	No	No	No	No	No	No	-	Rebarricade and add signage
MTW-140	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-141	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-142	2/3/20	MTO	Yes	Yes	Yes	No	Yes	No	No	No	No	Artefacts noted 10m south of current barricading	Rebarricade and extend extent by 10m south, add signage
MTW-143	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-144	2/3/20	MTO	Yes	Yes	Yes	No	No	No	No	No	No	-	Install new signage
MTW-145	2/3/20	MTO	Yes	Yes	Yes	No	Yes	No	No	No	No	Artefacts noted 10m south of current barricading	Rebarricade and extend extent by 10m south, add signage
MTW-146	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-147	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-148	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-149	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-150	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-151	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-152	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-153	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-154	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-155	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-156	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.

Site Name	Date	Mine	Site re-identified?	Site intact?	Site fenced/ barricaded?	Fencing/ barricading intact?	Natural erosion	Livestock damage	Human disturbance	Animal disturbance	Pests & weeds	General observations	Management recommendations
MTW-157	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-158	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-159	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-160	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-161	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-162	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-163	2/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	-	Add signage
MTW-164	2/3/20	MTO	Yes	Yes	Yes	No	No	No	No	No	No	-	Rebarricade and extend 5m to north, add signage
MTW-165	2/3/20	MTO	Yes	Yes	Yes	No	No	No	No	No	No	-	Rebarricade and add signage
MTW-166	2/3/20	MTO	No	Yes	Yes	Yes	No	No	No	No	No	-	Nil
MTW-167	2/3/20	MTO	No	Yes	Yes	No	No	No	No	No	Ants nest	-	Rebarricade and add signage
MTW-168	2/3/20	MTO	Yes	Yes	Yes	No	No	No	No	No	No	-	Add new sign
MTW-169	3/3/20	MTO	Yes	Yes	Yes	No	No	No	No	No	No	-	Rebarricade and add signage
MTW-170	3/3/20	MTO	Yes	Yes	Yes	No	Some erosion	No	No	No	No	-	Rebarricade and add signage
MTW-171	3/3/20	MTO	No	Yes	Yes	No	On creek bank	No	No	No	No	-	Rebarricade
MTW-172	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-173	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-174	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-175	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.
MTW-176	3/3/20	MTO	No	Yes	Yes	No	No	No	No	No	No	In cluster of sites that was formerly barricaded. Star pickets remain, barricading deteriorated. Within environmental offset.	Consider rebarricading if ground disturbance activities are planned in this area in the future.

Site Name	Date	Mine	Site re-identified?	Site intact?	Site fenced/ barricaded?	Fencing/ barricading intact?	Natural erosion	Livestock damage	Human disturbance	Animal disturbance	Pests & weeds	General observations	Management recommendations
MTW-177	2/3/20	MTO	No	Yes	Yes	No	No	No	On old track	No	No	-	Rebarricade and add signage
MTW-178	2/3/20	MTO	No	Yes	Yes	No	No	No	Rubbish ditch	No	No	-	Add signage
MTW-179	2/3/20	MTO	Yes	Yes	Yes	No	No	No	No	No	No	-	Rebarricade
MTW-180	2/3/20	MTO	No	Yes	Yes	Yes	No	No	Near track	No	No	-	Add signage
MTW-182	3/3/20	MTO	No	Yes	Yes	Yes	No	No	No	No	No	-	Nil
MTW-222	2/3/20	WML	Yes	Yes	Yes	Yes	No	No	No	No	No	-	Salvage in medium term
MTW-4	2/3/20	WML	No	Yes	Yes	No	No	No	No	No	No	Very low visibility, barricading deteriorated	Re-barricade and add sign in short term; salvage in medium term
MTW-523	2/3/20	WML	Yes	Yes	Yes	Yes	No	No	No	No	No	Fallen scarred tree in very deteriorated state	Relocation to be attempted in consultation with CHWG
MTW-69	2/3/20	WML	No	Yes	No	-	No	No	No	No	No	-	Install barricading and signage in short term; salvage in medium term
MTW-70	2/3/20	WML	Yes	Yes	Yes	Yes	No	No	No	No	No	-	Add signage to barricading, have arborist assess for removal options
MTW-71	2/3/20	WML	Yes	Yes	Yes	Yes	No	No	No	No	No	-	Add signage to barricading in short term; salvage in medium term
MTW-72	2/3/20	WML	Yes	Yes	Yes	No	No	No	Yes – on old track	No	No	-	Install barricading and signage in short term; salvage in medium term
MTW-724	2/3/20	MTO	Yes	Yes	Yes	Yes	No	No	No	No	No	RAPs pleased with operation of AHMP Chance Finds procedure	Enclose barricading in short term; salvage in medium term
MTW-8	2/3/20	WML	Yes	Yes	Yes	Yes	No	No	No	No	No	Scarred tree in very deteriorated state	Rebarricade; Relocation to be attempted in consultation with CHWG
MTW-80	2/3/20	WML	Yes	Yes	Yes	Yes	No	No	No	No	No	Scarred tree	Relocate in consultation with CHWG
MTW-86	2/3/20	WML	No	Yes	Yes	No	No	No	No	No	No	-	Re-barricade and add sign in short term; salvage in medium term
MTW-89	2/3/20	WML	Yes	Yes	No	-	No	No	Yes – on old track	No	No	-	Install barricading and signage in short term; salvage in medium term
MTW-90	2/3/20	WML	No	Yes	No	-	No	No	Yes – on old track	No	No	-	Install barricading and signage in short term; salvage in medium term
WB3	3/3/20	MTO	Yes	Yes	No	-	No	No	No	No	No	Artefact located at 317593e 6385352n	Move site point to co-ordinates
WS7	2/3/20	WML	No	Yes	Yes	Yes	No	No	No	No	No	-	Remove barricading from branches in short term; salvage in medium term

Table 1: Results of 2019 MTW AHMP Compliance Inspection

Aboriginal Site Management Recommendations

Management recommendations were provided for the majority of the Aboriginal heritage sites visited during the 2019 compliance inspection. At some sites, more than one management action was recommended. The nature of these recommendations are described below.

Install or reinstall/repair barricade, wire and/or signage

Sites: MTW-4; 8; 69; 71; 72; 86; 89; 90; 138; 142; 144; 145; 163-5; 167-71; 177-80; WS7

The majority of ACH sites inspected had barricading installed that had deteriorated and required mending or reinstalling. It is recommended that barricading, fencing and signage at these sites be re-installed/repaired to prevent inadvertent disturbance.

Example of dilapidated barricading

Consider rebarricading if activity increases in the area

Sites: MTW-140; 141; 143; 146-62; 172-6

There are several sites located south of Putty Rd within an environmental offset area with limited access or activity. These sites had previously been barricaded as two large complexes but this barricading has since deteriorated, although the star pickets remain in place. As these areas are already afforded a high degree of protection by virtue of them being inside the offset area, rebarricading is not necessary at this point in time. However, it is recommended that the star pickets remain in place so that barricading could be reinstalled if activities increase in the area in the future.

Salvage in consultation with CHWG

Sites: MTW-4; 69; 71; 72; 86; 89; 90; 222; 724; WS7

There are a number of sites that are located within future planned disturbance areas, or are already in close proximity to work areas. These sites should be salvaged prior to works in the area to prevent inadvertent disturbance. There were no objections raised to this recommendation by the RAPs in the field, and further planning and salvage should be done in conjunction with the CHWG.

Remove and relocate scarred trees

Sites: MTW-8; 70; 80; 523

Four scarred trees are located within the approved future mining area at MTW. With the exception of MTW-70, these trees have been visited by an arborist to assess the best method of removal and relocation, and general plans developed. MTW-70 should also be assessed for removal and relocation. These scarred trees have been visited by RAPs during this compliance inspection and during other inspections and assessments. Their removal and the arborist's plans should be discussed with the CHWG, as well as the location to where they will be relocated – the Wollombi Brook ACH Conservation Area has been suggested.

Scarred tree MTW-8

Scarred tree MTW-70

Scarred tree MTW-80

Scarred tree MTW-523

Update site co-ordinates

Sites: WB3

Limited information is on file regarding ACH site WB3, which was recorded off Charlton Rd several decades ago when GIS/GPS equipment was less advanced and accurate than today. Previous inspections have failed to relocate the site, however, during the current compliance inspection a silcrete flaked piece was identified near to the registered co-ordinates (317593e 6385352n). It is recommended that the site record be relocated to these co-ordinates within the MTW GIS system.

Silcrete flaked piece from WB3

Charlton Ridge New Find – MTW-724

During the compliance inspection, the field team visited the location of a newly identified site on Charlton Ridge. In October 2019, during a routine inspection for a ground disturbance permit, a member of the MTW Environment and Community team discovered a potential Aboriginal stone artefact in an undisturbed area adjacent the sites meteorological station on Charlton Ridge. There were no Aboriginal heritage sites recorded in the area.

In accordance with Provision 37 of the MTW AHMP – 'Discovery of New Finds', the find was reported internally and an archaeologist was engaged to assess the find. A follow up inspection confirmed the presence of two mudstone flakes at the location. These artefacts were subsequently barricaded and the site registered with AHIMS and on the MTW GIS system.

The RAPs participating in the compliance inspection were pleased with MTW's response to the chance find and the application of the measures implemented in accordance with the approved AHMP. Particular mention was made regarding the benefit of education amongst mine-site personnel to assist with identify Aboriginal stone artefacts, with this example serving to avoid harm to unknown ACH material. The RAP's recommended that the barricading at this site be extended to further protect the extent of the site until it could be salvaged. It was also recommended that the find be communicated to the CHWG during the next meeting.

Conclusions and Recommendations

The 2019 AHMP compliance inspection has been conducted as per the procedures outlined in the AHMP. No unauthorised site disturbances or AHMP non-compliances were observed during the inspection, and no issues were raised by the CHWG representatives present. A number of recommendations have been made to enhance or assist with the management of ACH at MTW:

1. **Install or reinstall/repair barricade, wire and/or signage at sites MTW-4; 8; 69; 71; 72; 86; 89; 90; 138; 142; 144; 145; 163-5; 167-71; 177-80; and WS7;**
2. **Consider rebarricading if activity increases in the area sites MTW-140; 141; 143; 146-62; and 172-6 if activity increases in their vicinity;**
3. **Discuss and plan the salvage with CHWG of sites: MTW-4; 69; 71; 72; 86; 89; 90; 222; 724; and WS7;**
4. **In consultation with the CHWG and an arborist, remove and relocate scarred trees MTW-8; 70; 80; and 523, considering the Wollombi Brook ACH Conservation Area as a relocation destination; and**
5. **Update the site co-ordinates within the MTW ACH GIS of site WB3 to those noted in the report.**
6. **Increase the extent of the barricade around the new find at Charlton Ridge (MTW-724).**

Appendix 2:

Historic Heritage Management Plan Compliance Inspection Report

Mount Thorley Warkworth
Historic Heritage Management Plan
2019 Compliance Audit Inspection

Report prepared for

Yancoal Australia, Mount Thorley Warkworth

March 2020

Joel Deacon

ARROW
HERITAGE SOLUTIONS

Introduction

Yancoal Australia (Yancoal) manage the Mount Thorley Warkworth (MTW) mining complex located in the Hunter Valley, approximately 8km south-west of Singleton. Approval for the continuation & expansion of the mine was granted on 26 November 2015 under two separate project approvals: the Warkworth Continuation Project Approval (SSD-6464) & the Mount Thorley Operations Project Approval (SSD-6465).

Pursuant to Condition 46 of the Warkworth Continuation Project Approval, Yancoal have developed an MTW Historic Heritage Management Plan (HHMP) that covers the whole MTW mining complex. The MTW HHMP was approved by the Department of Planning & Environment on 11 October 2017 and sets out the principles, processes & measures through which historic heritage will be managed within the HHMP Area. This includes the commitment (Provision 19) to conduct annual HHMP compliance inspections with members of the community through the auspices of the Community Heritage Advisory Group (CHAG). The purpose of the HHMP compliance inspections is to:

a. inspect areas and sites to assess compliance with the provisions of the HHMP;
b. inspect and monitor the condition and management of various sites; and
c. review the effectiveness and performance of the HHMP provisions in the management of historic heritage at MTW.

Proposed Activity and Project Brief

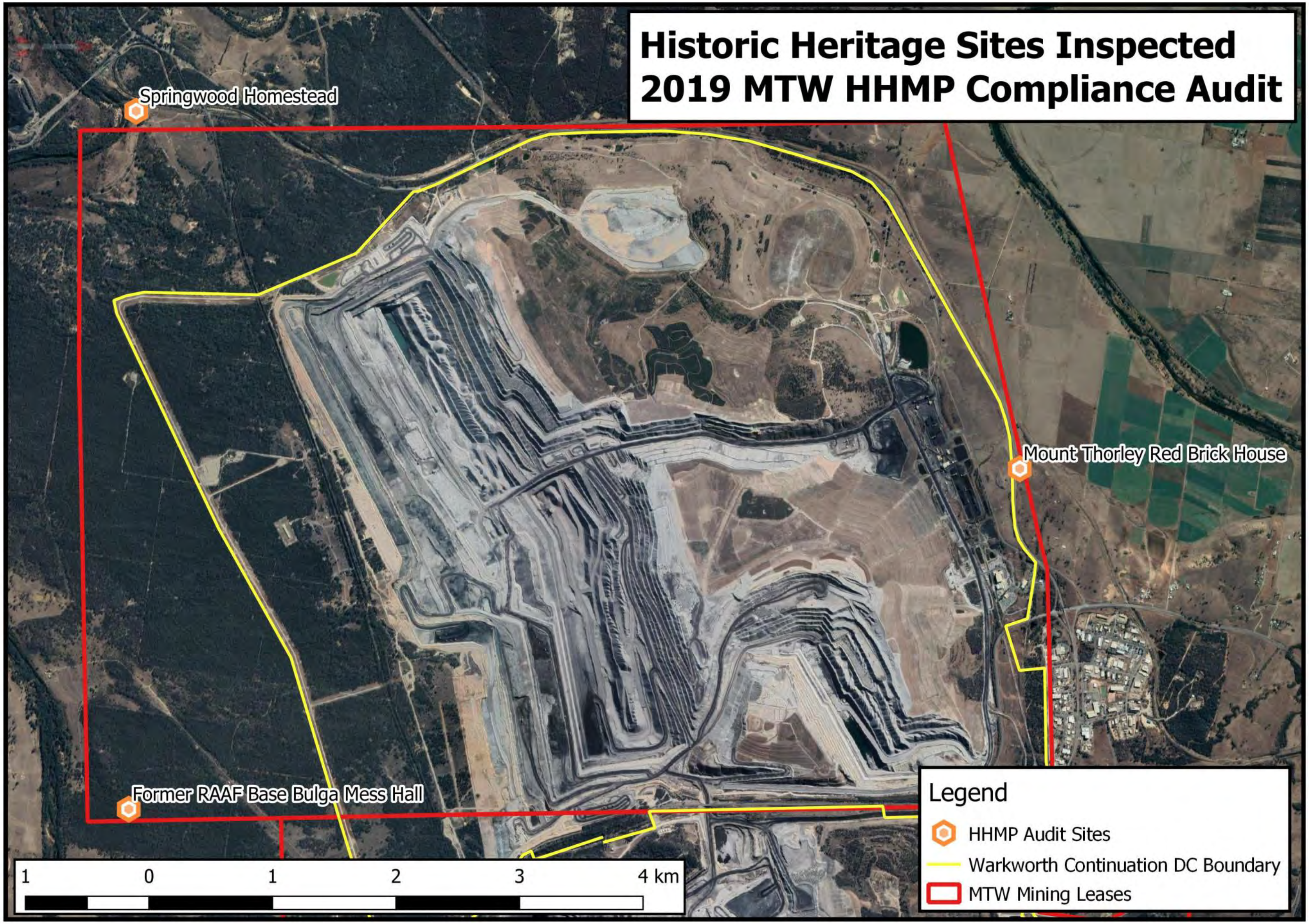
The following historic sites (shown in the map below) within the MTW HHMP area were to be inspected to assess compliance with actions listed in the HHMP and specific Conservation Management Plans (CMP), and a detailed photographic record for each site was collated to add to the previous photographic data:

- Former RAAF Base Bulga Mess Hall
- Springwood Homestead
- Mount Thorley Brick Farm House

Timing & Personnel

The 2019 MTW HHMP compliance inspection was conducted on Wednesday 4 March 2020. The personnel involved in this inspection were:

Name	Position/Organisation
Joel Deacon	Archaeologist, Arrow Heritage Solutions
Wade Covey	Environment and Community Coordinator, MTW
Neville Hodkinson	CHAG representative
Stewart Mitchell	CHAG representative
Wesley Warren	CHAG representative



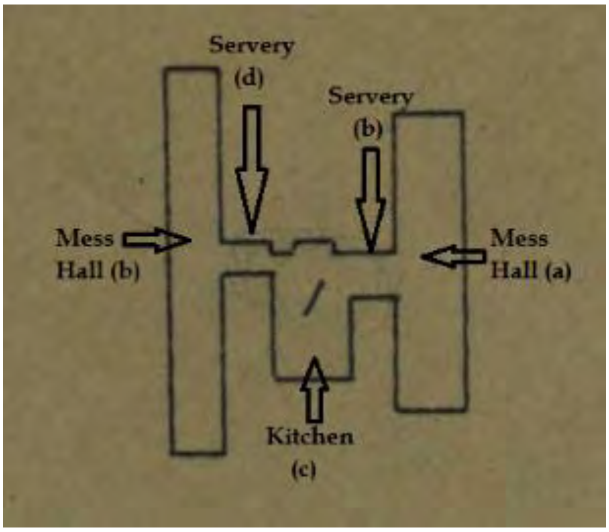
Historic Heritage Sites Inspected
2019 MTW HHMP Compliance Audit
Springwood Homestead
Mount Thorley Red Brick House
Former RAAF Base Bulga Mess Hall
1
0
1
2
3
4 km
Legend
HHMP Audit Sites
Warkworth Continuation DC Boundary
MTW Mining Leases

Arrow Heritage Solutions were engaged as independent heritage consultants to conduct the HHMP compliance inspection, and Joel Deacon acted as technical advisor and author of this report. MTW's Environment and Community Coordinator arranged the compliance inspection program and escorted the field team. Neville Hodkinson, Stewart Mitchell and Wesley Warren participated in the inspection as representatives of the CHAG forum.

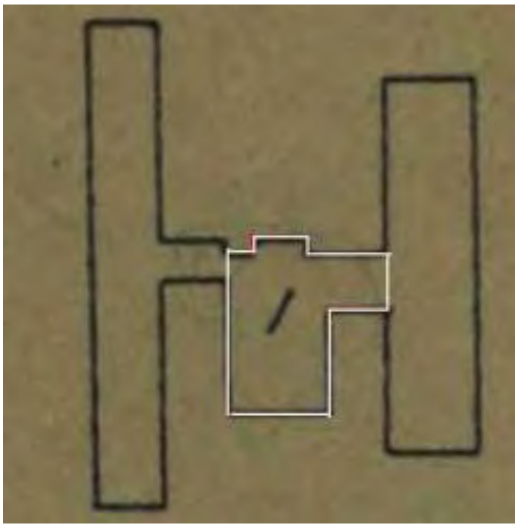
Former RAAF Base Bulga Mess Hall

Following the Japanese attack on Pearl Harbour in December 1941, plans were approved to expand existing RAAF bases and establish new ones, including a number of sites in the Hunter Valley. Bulga was identified as a potential site for an operational base and the area was officially taken over by the RAAF on 12 June 1942 for use as a relief landing strip. By July 1943 the site was completed, including the kitchen and mess hall, however, by January 1944 the use of the site was limited due to the decreasing threat of attack. A 1946 condition report noted this building as deteriorating. In January 1953, the building was noted as missing a few sheets of iron and windows.

The building sits in the former camp area west of the north-south runway. It was originally irregular in plan comprising a central kitchen area measuring 13.4 x 8.8m, with long rectangular mess halls to the east and west, connected by a servery on either side. The remnant structure today comprises the kitchen building and the foundation of one of the serveries (see below).



Original layout of building



Remaining structure

The remnant building is "L" shaped in plan with brick and concrete footings. During the original assessment conducted by ERM in November 2012 (which informed the CMP) the building was noted as being in poor condition with trees physically impacting on the building fabric, and some minor settlement issues resulting in cracking and failing brickwork. The western section of the building was the most intact part, retaining the original timber frame, corrugated asbestos cement roof sheeting and walls clad with corrugated iron sheeting.

The building is currently structurally unsound, with a large tree impacting on the roof and a number of timber elements either missing or in a deteriorated state. Corrugated asbestos roof sheeting is also missing in some places, and damaged and in poor condition where it remains. Much of the corrugated iron sheeting is corroded. Brickwork is also cracking in a number of locations resulting in significant movement outward, loss of mortar and loss of bricks along the southern and eastern elevations.

View to mess from south-east (2012)

Remnant kitchen area (2012)

As a result, a number of structural recommendations were outlined by ERM in the CMP developed for the site in 2012. These recommendations were not intended to return the building to a serviceable state, rather they seek to do the minimum required to allow safe access to the building to prevent significant damage, and also allow safe access for asbestos removal and internal inspection of the building in the short to medium term.

CMP Requirements

Short to medium term structural recommendations included:

a) **Remove fallen tree branch.** The tree branch impacting on the roof of the building should be removed, using an external mobile elevated platform or boom lift;
b) **Temporary propping.** The building should be temporarily propped and supported as per Bligh Tanner plans SK 1.0 A and SK 2.0 A (contained within the CMP) to allow for safe access into the building and more detailed inspection of the structure.
c) **Asbestos Removal.** Asbestos removal should be completed by a licensed asbestos removal specialist, include the roof sheeting, all asbestos dust and fibres, and loose fragments that are known to exist in the remaining area.
d) **Stabilise framework and replace roof.** Any structural roof members that are destabilized once the roof sheeting is removed are to be secured as required. Side walls which lose stiffness once the roof sheeting has been removed are to be propped temporarily until the new roof has been replaced.
e) **Archaeological clean-up.** Asbestos removal and clean-up should be supervised by a historical archaeologist to ensure any identified items of significance are retained.
f) **Further building inspection.** A structural engineer should complete a building inspection to identify structural repairs and stability requirements with four weeks of the building being cleaned up and decontaminated from asbestos.

Following the internal inspection of the building noted in (f) above, further advice may be provided regarding medium to long term recommendations. Due to the lack of integrity of the building, recommendations are unlikely to be directed at restoration of the building, but more towards retaining the remnant structure in a safe environment and reducing further deterioration. Repair drawings have been provided in the CMP to remedy any major cracking in the brickwork or where sections of brickwork have either partially collapsed or broken away from the wall.

Photographic Comparison 2012 – 2018 - 2020

During the inspection of the Former RAAF Base Bulga Mess Hall for this report, a number of photographs were taken from the same angles and of the same features as were taken during the ERM 2012 assessment and archival recording as well as during the 2018 HHMP compliance inspection. These photographs provide a visual baseline condition assessment of the building, and also allow a comparative analysis of the deterioration levels over the last six to eight years. These photographs are set out below, along with comments pertinent to management recommendations.

2012	2018	2020
		
East elevation **2012-18:** no discernible change – note fallen branch from tree on western side. **2018-20:** no discernible change – fallen branch has moved.		

2012	2018	2020
		
View to north-east elevation **2012-18:** roof over open kitchen area has deteriorated, causing severe lean on far wall. **2018-20:** top of far wall now collapsed.		
		
South-east elevation **2012-18:** evidence of increased bow to southern wall. **2018-20:** bow in wall appears to have increased.		

<table>
<tr><th>2012</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">South elevation
2012-18: evidence of increased bow to southern wall and missing panel above entry.
2018-20: increased bow to southern wall.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">West elevation
2012-18: shows deterioration of roofing members above open kitchen area and leaning north wall, and further collapse of asbestos roof due to fallen dead tree.
2018-20: top of north wall now collapsed, further damage to roof with branch now fallen to ground.</td></tr>
</table>

<table>
<tr><th>2012</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">North elevation
2012-18: no discernible change.
2018-20: top of north wall now collapsed.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">North-east elevation
2012-18: difficult to discern change.
2018-20: difficult to discern change.</td></tr>
</table>

2012	2018	2020
		
Concrete and brick foundation at east side of building **2012-18:** difficult to discern change. **2018-20:** no discernible change.		
		
View to building interior from north-east **2012-18:** shows collapse of remnant roofing members above open kitchen area. **2018-20:** further minor deterioration of asbestos sheeting panelling.		

<table>
<tr><th>2012</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Grease trap at south end of building
2012-18: shows bow to south wall.
2018-20: shows increased bow to south wall.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Storage area at south end of building
2012-18: further slight collapse of storage area.
2018-20: shows loosening of corrugated iron wall sheeting due to bowing in wall.</td></tr>
</table>

2012	2018	2020
		
Windows and entry at west elevation **2012-18:** shows large trunk/branch portions of tree collapsed on roof, which has destroyed roof ventilator. **2018-20:** shows majority of branches fallen from roof, leaving increased damage to sheeting.		
		
Timber window detail, west elevation **2012-18:** no discernible change. **2018-20:** no discernible change.		

2012	2018	2020
		
Showing cylindrical ventilator and damage to roof, view from west **2012-18:** shows significant roof damage from fallen dead tree, including to ventilator. **2018-20:** shows increased damage to roof sheeting from fallen branch.		
		
Detail of north-west elevation **2012-18:** shows increased collapse over open kitchen area, as well as new damage to brick foundation at north-west corner. **2018-20:** shows fallen top of north wall plus increased (animal?) damage to brick foundation at north-western corner.		

<table>
<tr><th>2012</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Showing interior damage at kitchen at north end of building
2012-18: shows increased collapse over and accumulation of debris within open kitchen area. Note also severe lean to north wall.
2018-20: shows collapsed top of north wall and collapse of remaining full cross-beam.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Showing interior damage at kitchen at north end of building
2012-18: shows increased collapse over and accumulation of debris within open kitchen area. Note also severe lean to north wall.
2018-20: shows collapsed top of north wall and collapse of remaining full cross-beam.</td></tr>
</table>

2012	2018	2020
		
View to interior of south end of building, view from east **2012-18:** shows increased collapse over open kitchen area. **2018-20:** shows further minor deterioration of asbestos panelling.		

2012	2018	2020
		

Showing stove at kitchen at north end
2012-18: note the remaining two stove doors have become unhinged and build up of debris from collapsed roof.
2018-20: stove now obscured by collapsed north wall.

2012	2018	2020
		

View to interior, showing west entry to building
2012-18: no discernible change.
2018-20: no discernible change.

2012	2018	2020
		
Showing west interior space **2012-18:** no discernible change. **2018-20:** no discernible change.		
		
Damaged brick foundation at south-east corner **2012-18:** no discernible increase to cracked brick foundation. **2018-20:** further cracking of foundation (to left of shot) and some slumping of corner bricks.		

2012	2018	2020
		
Detail of damaged brick foundation **2012-18:** some further collapse of concrete/cement above brick foundation. **2018-20:** some slumping outwards of corner brick foundation.		
		
View to interior of building, looking north from south entry **2012-18:** no discernible change. **2018-20:** no discernible interior change, but shows collapsed north wall.		

2012	2018	2020
		
View to interior of building from entry at west **2012-18:** no discernible change. **2018-20:** no discernible change.		
		
Showing interior of building, viewed from north-west corner **2012-18:** shows collapsed roofing members above open kitchen area and accumulation of debris. **2018-20:** shows collapsed north wall across stove and additional fallen roof member.		

2012	2018	2020
		

Showing interior of building, viewed from north-west corner
2012-18: shows collapsed roofing members above open kitchen area and accumulation of debris.
2018-20: shows additional collapsed roofing member.

The comparative photographs above show the changes at the building over the past eight years. During this time, and with an emphasis on the last two years, apart from the general deterioration of the panelling and timber within the 75 year old mess hall, the more significant changes can be summarised as:

- The collapsed dead tree on western side of asbestos roof has now fallen to the ground, but damage has been caused to sheeting and roofing members, as well reducing structural stability of southern wall, which shows an increase in bowing since the 2018 inspection;
- Due to the complete collapse of remaining roofing members over the open kitchen area the top portion of the northern wall has now failed and fallen inside the building footprint; and
- Increased damage to brick foundation in north-west corner, and new slumping of south-west foundation corner.

Recommendations

High Priority Actions

1. If not already conducted, have an asbestos expert assess and develop a clean up and disposal plan to deal with both the broken fragments and intact asbestos sheeting;
2. Remove any remaining tree branches from the roof. In addition, to prevent similar damage in the future, serious consideration should be given to removing or lopping those trees that are located close enough to the building that they may cause damage if they fall or drop large branches;

High Priority Actions to Follow Actions 1 & 2

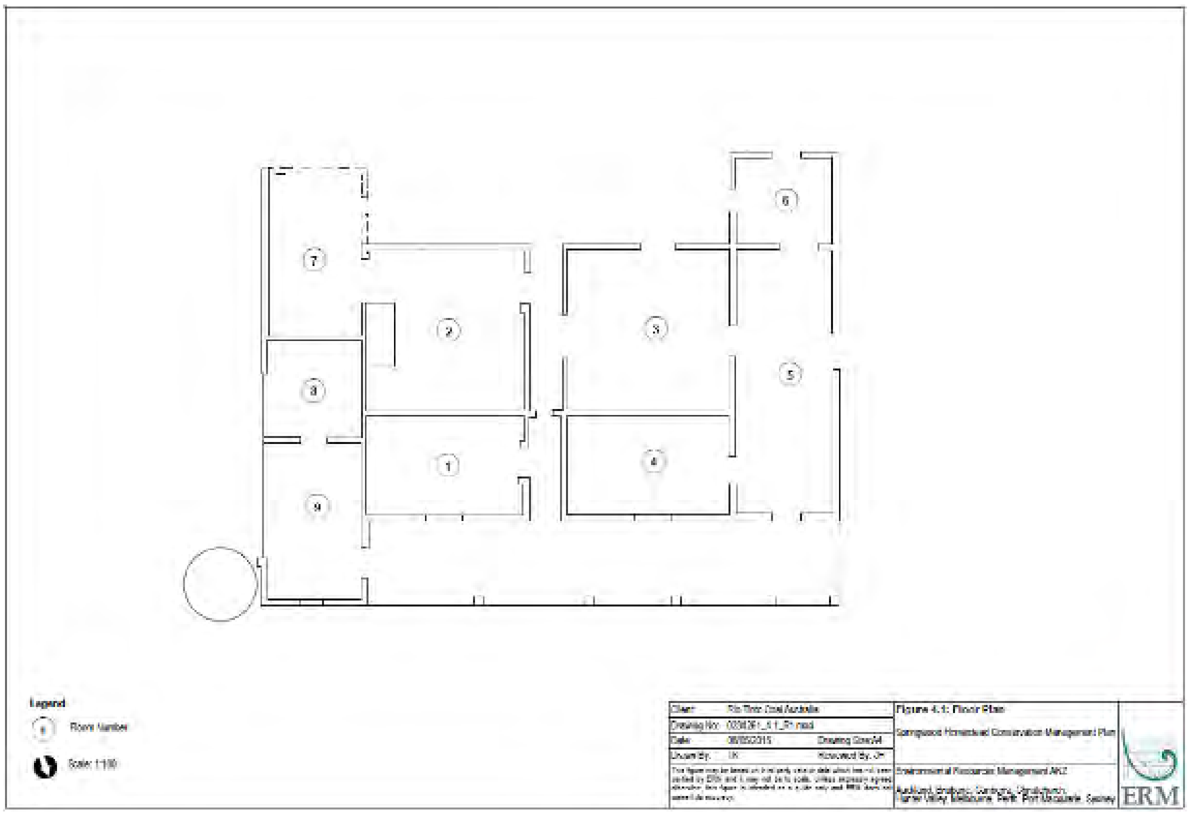
3. Pending the results of the asbestos assessment, the building and surrounds should be thoroughly cleaned of asbestos and other rubbish material. An archaeologist should be present to collect any items of historic importance or that relate to the original fabric of the building. These can be stored inside the building and potentially re-used during further stabilization programs;
4. Pending the results of the asbestos assessment, any parts of the building framework, such as roofing members of walls should be stabilized and propped, using the Bligh Tanner plans as a guide;
5. A structural engineer should then inspect the building before any further works are commenced to make further recommendations on stability requirements and structural repairs. These further works should aim to reduce the likelihood and extent of any further deterioration at the site rather than seek to rebuild or renovate as it is unlikely that there would be any valid or appropriate option to re-use the site; and

Ongoing

6. Continue the photographic monitoring program at the building using the views and locations previously catalogued so that any future changes to the building can be documented.
7. Consider using drone technology to undertake an aerial assessment of the site to determine any further actions required in areas that cannot be inspected from the ground.

Springwood Homestead

Based on historical research, Springwood Homestead is likely to have been constructed c.1860, and displays many characteristics of late Old Colonial Georgian and Victorian Georgian architecture, including an original shingle broken-backed roof, fanlights or transom lights, panelled doors and under-roof verandahs. The homestead is low-set, constructed in vertical timber slabs and built around a four room square core, as shown in the plan below (taken from ERM's 2015 CMP).



Springwood Homestead in 2012

Given that Springwood Homestead is timber framed and in direct contact with the ground, it is remarkable that it is still standing and in a generally stable condition, with most roof rafters appearing to be still in place. Although the building fabric is generally intact there are a number of areas where the level of structural damage to the roof, wall and flooring members is high. The majority of the damage has occurred from termites and fungal decay, resulting in localised collapse of outer external walls and roof structures. Within the CMP developed for the site by ERM in 2015, a number of stabilisation measures have been recommended that will assist to reduce the extent of damage, however a return to a habitable state is not planned.

CMP Recommendations

Although many recommendations are made within the CMP, the more important management measures have been incorporated within a conservation works schedule that covers the following issues:

- Drainage and weatherproofing;
- Asbestos;
- Vegetation;
- Termites and vermin;
- Building fabric; and
- Structural capacity and wind loads.

The works schedule prioritises the required conservation works and are presented with technical specifications from a structural engineer. Those measures that attend to the buildings structural integrity are the focus of the schedule.

High Priority

a) Remove debris from roof using a cherry picker or similar;
b) Remove tree from eastern elevation and stabilize building in this location;
c) Remove vine from eastern wall using combination of pruning and herbicide;
d) Remove tree from south-west corner and stabilize building in this location;
e) Prune all overhanging branches and maintain regular maintenance program; and
f) Reinstate southern verandah and roof to match northern elevation.

Moderate to Low Priority

g) Place treated plywood sheeting over door openings;
h) Prune trees, spray weeds and slash grass;
i) Clean up of site surrounds, overseen by archaeologist;
j) Clean up of building interior, overseen by archaeologist;
k) Refix loose ceiling boards, retaining evidence of fabric if unable to fix;
l) Refix loose and dislodged slabs and plates; and
m) Place treated plywood sheeting over openings and undertake repairs to windows.

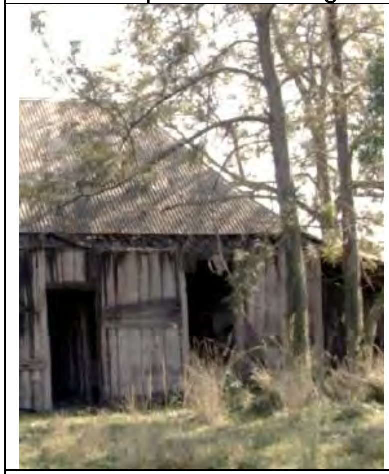
Photographic Comparison 2014 – 2018 - 2020

During the inspection of Springwood Homestead for this report, a number of photographs were taken from the same angles and of the same features as were taken during the 2018 HHMP compliance inspection and the ERM 2014 assessment that informed the 2015 CMP. These photographs provide a visual baseline condition assessment of the building, and also allow a comparative analysis of the changes over the last six years. These photographs are set out below, along with comments pertinent to management recommendations.

2014	2018	2020
		
Northern entrance **2014-8:** further deterioration of overlaid weatherboard. **2018-20:** No major increase in deterioration.		

2014	2018	2020
		
Eastern elevation **2014-8:** no discernible change. **2018-20:** roof slumping appears to have increased.		
		
Looking towards south-west corner from east **2014-8:** no discernible change to tree impact, but note missing vertical slabs from southern wall. **2018-20:** no major increase in deterioration.		

2014	2018	2020
		
Looking towards south-west corner from south-west **2014-8:** no discernible change to tree impact, but note missing vertical slabs from southern wall. **2018-20:** no discernible change, but vine still growing.		
		
Southern elevation **2014-8:** vertical timber slabs have been removed from southern wall. **2018-20:** possible deterioration of shingles at roof edge, and missing panels from above back door.		

<table>
<tr><th>2014</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Southern elevation
2014-8: vertical timber slabs have been removed from southern wall.
2018-20: panels missing from above back door.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Southern elevation
2014-8: vertical timber slabs have been removed from southern wall.
2018-20: possible deterioration of shingles at roof edge, and missing panels from above back door.</td></tr>
</table>

<table>
<tr><th>2014</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Southern elevation
2014-8: vertical timber slabs have been removed from southern wall.
2018-20: possible deterioration of shingles at roof edge, and missing panels from above back door.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Southern elevation doorway
2014-8: door has been removed.
2018-20: no discernible change.</td></tr>
</table>

<table>
<tr><th>2014</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">South-eastern corner
2014-8: vertical slabs have been removed causing further collapse of roof.
2018-20: further deterioration of eastern wall.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Eastern side
2014-8: debris has been cleaned and stored and a weed removal program conducted. The house area has also been fenced.
2018-20: further deterioration of eastern wall and regrowth of weeds.</td></tr>
</table>

2014	2018	2020
		
Room 2 interior **2014-8:** increased debris caused by removal of southern wall. **2018-20:** no discernible change.		
		
Room 4 ceiling **2014-8:** no discernible change. **2018-20:** no discernible change.		

2014	2018	2020
		
South-west corner **2014-8:** shows removal of vertical slabs from southern wall. **2018-20:** no discernible change.		
		
Northern elevation **2014-8:** further deterioration of weatherboard panelling. **2018-20:** no discernible change, though termite activity present.		

2014	2018	2020
		

South-east corner
2014-8: shows removal of vertical slabs from southern wall and further collapse of roof.
2018-20: further roof slumping and deterioration of eastern wall.

2014	2018	2020
		
Eastern elevation **2014-8:** possible further collapse of crossbeam and guttering. **2018-20:** tree continues to impact eastern roof line.		

2014	2018	2020
		
Northern elevation **2014-8:** slumping of verandah along edge beam. **2018-20:** no discernible change.		

<table>
<tr><th>2014</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">View of south-west corner from south
2014-8: shows removal of vertical slabs from southern wall as well as some increase in vegetation growth.
2018-20: no discernible change but continuing vegetation impacts.</td></tr>
</table>

The comparative photographs above show the changes at the building over the past six years. During this time, and with an emphasis on the last two years, the more significant changes are:

- The removal of all of the vertical timber slabs from the southern wall continue to have a negative impact on the structural integrity of this side of the building and also allow weather and its associated adverse impacts into the building;
- The continued growth of trees and vines are also having impacts on structural stability in the south-western corner and along the eastern roof line; and
- Noticeable increase in termite activity.

It was noted during the 2018 inspection that some management measures had been implemented, including the removal of weeds and vegetation from around the homestead, the clean up of debris from around the exterior of the building, and the erection of fencing.

Recommendations

Management recommendations have been prioritised as high or moderate importance, and high priority recommendations should be actioned as soon as possible, after which the conservation works schedule within the CMP can be re-evaluated and amended by a structural engineer prior to further works being commenced.

High Priority

1. Remove the trees and vines currently impacting the building at the eastern elevation and south-west corner, and treat to prevent regrowth. Coincident with this removal, acrow props should be installed where appropriate, i.e. where the trees themselves have been supporting the building structure, and as per the structural engineer's instructions at Annex B of the CMP;
2. Once vegetation has been removed, clean all debris from the roof and prune (or consider the removal of) all other trees in close vicinity of the building with potential to drop leaf/branch litter on roof;
3. Clear the surroundings of the building of rubbish, overgrowth and weeds in the accompaniment of an archaeologist to ensure any items of historical relevance are salvaged and stored within the homestead;
4. Due to the damage caused by the removal of the vertical slabs, once the items above are complete, a structural engineer should then re-inspect the building before any further works are commenced to make further recommendations on stability requirements and structural repairs; and
5. Implement a termite and pest control regime at the building.

Moderate Priority

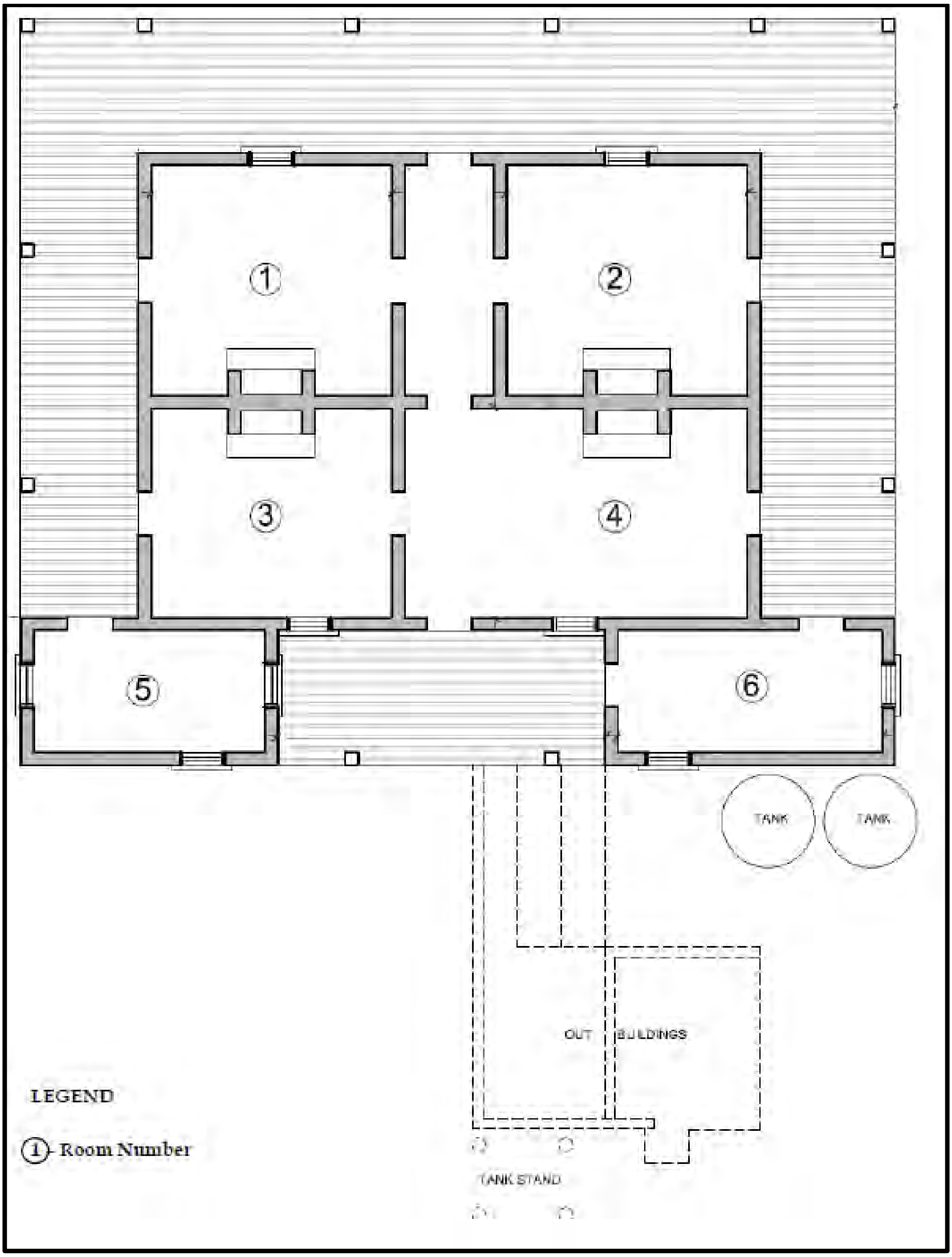
Once the high priority recommendations have been attended to, the structural engineer may recommend different or additional measures than originally put forward. Notwithstanding these, the following moderate priority measures are recommended to attain compliance with the CMP and enhance the condition of the homestead:

1. Due to their propensity to harbour termites and transfer infestation to the building, remove all peppercorn trees from around the building;
2. Future condition inspections should photograph the building using the photograph views and locations presented above so that any changes to the building can be documented in subsequent inspections;
3. Implement and maintain a regular vegetation maintenance program;

4. Pending structural engineer's advice, reinstate southern wall, verandah and roof to match northern elevation.
5. Pending reconstruction of southern wall, place treated plywood sheeting over door and window openings;
6. Clean up of building interior, overseen by archaeologist;
7. Pending structural engineer's advice, refix loose ceiling boards and loose and dislodged wall slabs and plates, retaining evidence of fabric if unable to fix;
8. Ensure the minor recommendations and 'policies' listed throughout Section 7 of the CMP are considered in the future management of the homestead; and
9. Give consideration to an archaeological excavation and research program at the site, with possible community involvement, to explore the areas of archaeological potential identified in the CMP.
10. Consider using drone technology to undertake an aerial assessment of the site to determine any further actions required in areas that cannot be inspected from the ground.

Mount Thorley Brick Farm House

The Mount Thorley Brick Farm House is located off the Golden Highway opposite the MTW coal handling and preparation plant, c.10km south-west of Singleton. The portion of land on which the house sits was purchased by Eliza Glass in 1870 and the physical attributes of the house, which display characteristics of Victorian Georgian architecture, suggest that it was constructed during the following decade. The building is roughly square in plan, with four principal rooms flanking a central hallway.



Floor plan of Mount Thorley Brick Farm House, north up (from ERM 2015 CMP)

The masonry structure of the building is sound, however, it was noted as being in poor physical condition in 2015 (when a CMP was developed for the site by ERM), with a collapsed verandah roof, missing or loose roof sheeting, missing or collapsed verandah posts, and floorboards and areas affected by termites. The conservation works schedule within the CMP considered the following issues at Mount Thorley Brick Farm House:

- Drainage and weather-proofing;
- Asbestos;
- Vegetation;
- Termites and vermin;
- Building fabric; and
- Structural capacity and wind loads.

Recommendations were made within the CMP's conservation works schedule to address the elements above, a number of which were completed by the proponent prior to the 2018 compliance inspection. These works included:

- Removal and safe storage of verandah;
- Initial vegetation clearing;
- Sheeting and sealing of all window and door openings;
- Clean up of scattered debris surrounding building; and
- Repair of loose roof sheeting and patching of holes.

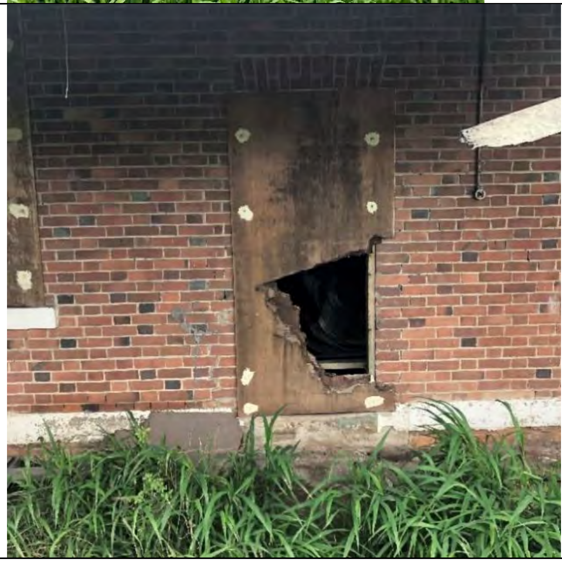
Mount Thorley Brick Farm House (2012)

Photographic Comparison 2015 – 2018 - 2020

During the inspection of the Mount Thorley Brick Farm House for this report, a number of photographs were taken from the same angles and of the same features as were taken during the 2018 HHMP compliance inspection and the ERM 2015 assessment that informed the CMP. These photographs provide a visual baseline condition assessment of the building, and also allow a comparative analysis of the changes over the last five years. These photographs are set out below, along with comments pertinent to management recommendations.

2015	2018	2020
		
View of north-west corner (verandah focus) **2015-8:** verandah removed and stored inside building **2018-20:** no discernible change		

2015	2018	2020
		
View of northern side (surrounding vegetation focus) **2015-8:** grass vegetation slashed around building **2018-20:** vegetation has regrown around building		

2015	2018	2020
		
		

View of door and window panelling
2015-8: sheeting installed on all openings, however some repair required
2018-20: some repair of paneling required

2015	2018	2020
		

View of rear of building (focus on debris)
2015-8: debris has been cleared and stacked
2018-20: vegetation has regrown around building and stacked debris

View of rear of building (focus on debris)
2015-8: debris has been cleared and stacked
2018-20: vegetation has regrown around building and stacked debris

2015	2018	2020
		

View of north-west roof corner (focus on damaged roof)
2015-8: roofing sheets have been replaced and holes patched
2018-20: some minor roof holes and lifted sheeting noted

2015	2018	2020
		
		

View of eastern verandah (focus on verandah floor)
2015-8: posts and sheeting removed, damaged boards remain exposed
2018-20: damaged boards remain and vegetation growth throughout

2015	2018	2020
		

View of rear of building (focus on skillion roof)
2015-8: skillion roof and rafters have collapsed
2018-20: no discernible change

View of north-east of building (focus on top of wall)
2015-8: wall element has collapsed bricks stacked under window)
2018-20: no discernible change

2015	2018	2020
		

View of north-east of building (focus on skillion roof)
2015-8: roof framing, sheeting and guttering has collapsed
2018-20: no discernible change

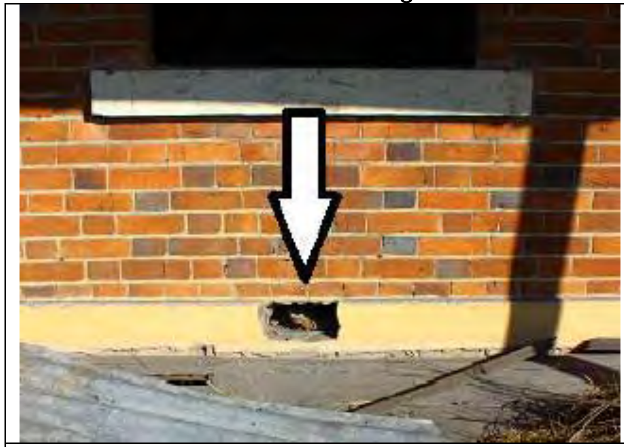
View of rear of building (focus on guttering)
2015-8: main roof holes repaired but northern section of skillion roof collapsed and guttering unchanged
2018-20: no discernible change, however vegetation regrowth evident

2015	2018	2020
		

View of north-east corner of building (focus wall below window)
2015-8: bricks from roof above stacked in front of required repointing, window sheeting removed
2018-20: no discernible change

View of south-east of building (focus on top of wall)
2015-8: no discernible change
2018-20: no discernible change

<table>
<tr><th>2015</th><th>2018</th><th>2020</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">View of eastern verandah (focus on dwarf wall wall)
2015-8: debris cleared from verandah, no change to dwarf wall
2018-20: no discernible change</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">View of ventilation grilles
2015-8: grilles not replaced
2018-20: no discernible change</td></tr>
</table>

2015	2018	2020
		

View of southern chimney
2015-8: no discernible change
2018-20: no discernible change

Recommendations

The comparative photographs above show the changes at the building over the past five years. During this time, and with an emphasis on the last two years, the more significant changes are:

- Significant regrowth of vegetation around the building;
- Considerable damage and exposure to the rear of the building;
- Loose, damaged and removed window and door sheeting; and
- Some new roof holes and loose sheeting.

While many of the high and moderate priority recommended actions within the CMP conservation works schedule have been completed in the past, the 2019 inspection has identified that some items need renewed attention. The recommendations outlined below are required to minimise the risk of further deterioration in the building structure.

High Priority

1. Implement a regular vegetation slashing and maintenance schedule for the building surrounds, ensuring all debris is clear from ground-level ventilation openings;
2. Replace any damaged plywood door/window coverings and ensure all coverings are tightly attached;
3. Patch fix any new damage to roofing sheets;
4. Implement a termite inspection regime and treat as required, giving consideration to removing the peppercorn trees surrounding the building;
5. If any asbestos or fibrous cement sheeting remains at the property, engage an asbestos removalist to remove as required;

Moderate Priority

6. After the next vegetation slashing campaign, check that all debris surrounding the house has been removed. If this has not occurred, remove all debris, ensuring an archaeologist is on hand to identify and catalogue any early architectural fittings or rare pieces of joinery that should be retained for future restoration purposes;
7. Reinstall verandah, including verandah decking and northern brick dwarf wall, re-using original material where possible, as per recommendations M5, M6 and L1 in the CMP conservation works schedule;
8. As the roof above Room 6 has collapsed, salvage any reusable masonry or timber and set aside within room. Engage a structural engineer to advise on feasibility of reconstructing the roof. (NB. Recommendation M9 in the CMP conservation works schedule erroneously refers to Room 5 rather than Room 6 as shown in the photograph);
9. Replace gutters around the house to match existing materials and ogee profile. Install new down-pipes and ensure they are discharging away from the building.
10. Repoint mortar joints with lime based mortar on brickwork below Room 6 eastern elevation window sill, on northern wall of room 5 and all chimneys;
11. Install new ventilation grilles to existing ground level openings; and
12. Future condition inspections should photograph the building using the photograph views and locations presented above so that any changes to the building can be documented in subsequent inspections.
13. Consider using drone technology to undertake an aerial assessment of the site to determine any further actions required in areas that cannot be inspected from the ground.

Appendix 3:

Annual Stream Health and Stability Report

2019 STREAM HEALTH AND STABILITY REPORT

Mount Thorley Warkworth

SLR Ref: 630.12941-R01
Version No: -v0.2
March 2020

SLR

PREPARED BY

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BASIS OF REPORT

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
630.12941-R01-v0.1	19 December 2019	Stephane Peignelin / Samuel McDonald	Paul Delaney	Paul Delaney
630.12941-R01-v0.2	11 March 2020	Stephane Peignelin / Samuel McDonald	Paul Delaney	Paul Delaney

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FIGURES

APPENDICES

1 Introduction

SLR Consulting Australia Pty Ltd (SLR) was previously engaged in December 2017 by Bulga Surface Operations (BSO) and Mount Thorley Warkworth (MTW) to conduct channel stability and stream health monitoring of creeks adjacent to the mine sites. An integrated channel monitoring program was developed as both mines discharge into the same drainage lines (e.g. Loder Creek). The monitoring program includes channel stability and stream health assessments at six specific monitoring points (two of which are only specific to BSO and one point which is only specific to MTW). In addition it also includes a visual inspection of Loder Creek from the Hunter River to the MTW discharge point to identify any areas of increased erosion.

SLR was subsequently engaged to undertake the 2018 and 2019 annual channel stability and stream health monitoring to identify any changes to the creeks including any new erosion features in accordance with regulatory requirements. This report has been specifically prepared for the MTW monitoring points and should be read in conjunction with the 2017 and 2018 reports for better understanding.

MTW advise there have been nil discharge events from the MTW discharge point between the 2018 stream health monitoring event and the 2019 monitoring event. There has been 283 mm of rainfall recorded within the on-site rainfall gauge for the period November 2018 to October 2019. In comparison, the Bureau of Meteorology shows an average of 502 mm at Singleton (Singleton STP 61397) for the same period. This indicates that this round of monitoring was subjected to a significantly drier year than what occurs on average within the region.

2 METHODOLOGY

In accordance with the accepted scope of works the following procedure was undertaken at each monitoring site:

1. Documenting locations and dimensions of significant erosive or depositional features;
2. Photographs upstream, downstream and at both banks;
3. Rating the site with the Ephemeral Stream Assessment protocol developed by the CSIRO to assess the erosional state of the creek at the monitoring location (a measure of channel stability);
4. Rating the site with the Rapid Appraisal of Riparian Condition protocol developed by Land & Water Australia. This assesses the ecological condition of riparian habitats using indicators that reflect functional aspects of the physical, community and landscape features of the riparian zone (a measure of stream health); and
5. Taking measurements of the channel cross-sections (transects) for comparison purposes for any future monitoring.

2.1 Rapid Appraisal of Riparian Condition (RARC)

The RARC is an assessment method incorporating indicators of geophysical and biological properties and processes which are likely to provide reliable estimates of ecological condition in riverine ecosystems (Land & Water Australia, 2005). The RARC index is made up of five sub-indices, each with a number of indicator variables which can be seen in **Table 1** below.

Table 1 Summary table of indicators, functions and components assessed in the RARC (Land and Water Australia, 2005)

Functions of the riparian zone at different levels of organisation	Components of the riparian ecosystem that perform those functions	Indicators of the functions used in the RARC
Physical:		
Reduction of erosion of banks	Roots, ground cover	Vegetation cover*
Sediment trapping	Roots, fallen logs, ground cover	Canopy cover, fallen logs, ground cover vegetation, leaf litter cover
Controlling stream microclimate/ discharge/water temperatures	Riparian forest	Canopy cover
Filtering of nutrients from upslope	Vegetation, leaf litter	Ground cover vegetation, leaf litter cover
Community:		
Provision of organic matter to aquatic food chains	Vegetation	Vegetation cover*, leaf litter cover
Retention of plant propagules	Fallen logs, leaf litter	Fallen logs, leaf litter cover
Maintenance of plant diversity	Regeneration of dominant species, presence of important species, dominance of natives *versus* exotics	Native canopy and shrub regeneration, grazing damage to regeneration, reeds, native vegetation cover*
Provision of habitat for aquatic and terrestrial fauna	Fallen logs, leaf litter, standing dead trees/hollows, riparian forest, habitat complexity	Fallen logs, leaf litter cover, standing dead trees, hollows, vegetation cover*, number of vegetation layers
Landscape:		
Provision of biological connections in the landscape	Riparian forest (cover, width, connectedness)	Vegetation cover*, width of riparian vegetation, longitudinal continuity of riparian vegetation, proximity to other habitat
Provision of refuge in droughts	Riparian forest	Vegetation cover*

* Vegetation cover = canopy, understorey and ground cover

In accordance with previous annual stream health surveys undertaken at the site classifications have been assigned based on the total score as assessed by the RARC methodology. It is useful to compare this total score over time to see how the biodiversity and functionality of the riparian zone is progressing at each of the monitoring points. **Table 2** below outlines these classifications.

Table 2 Summary RARC Classification System

RARC Total Score	Classification
40-50	Excellent
35-39	Good

RARC Total Score	Classification
30-34	Average
25-29	Poor
<25	Very Poor

2.2 CSIRO Ephemeral Stream Assessment

The CSIRO *Ephemeral Stream Assessment* procedures (CSIRO, date unknown) were used to assess the channel stability of the creeks in the vicinity of the MTW Mine. The assessment uses four main classes of indicators to evaluate the degree of stream-bed condition:

1. The type and condition of the vegetation present, if any;
2. The shape and profile of the drainage line and type of materials on the drainage line floor;
3. The nature of the drainage line wall materials; and
4. The nature of the stream bank bordering flats and/or slopes and regulation of lateral flow into the drainage line.

The indicators produce a rating based on a scoring system, and the combined total of the indicators rank each location from very actively eroding through to very stable as shown in **Table 3.** This enables an assessment to be made as to whether the section of creek has changed since previous rounds of annual monitoring.

Table 3 Classification of different drainage line states (CSIRO)

Activity Rating (%)	Classification	Discussion of Classification
80 +	Very Stable	Drainage line is very stable and likely to be in original form. It is able to withstand all flow velocities that have previously occurred in this area and only minimal monitoring is required, predominantly after high flow events, to ensure condition does not deteriorate.
70-80	Stable	Drainage line is stable. It is important to assess this zone in relation to the other classifications and define whether this zone is moving from potentially stabilising to a more stable form, or if it is deteriorating from a very stable form. The nature of this relationship will identify the type of monitoring required.
60-69	Potentially Stabilising	Drainage line is potentially stabilising. Ongoing monitoring is required while rehabilitation works are not needed in the immediate future.

Activity Rating (%)	Classification	Discussion of Classification
50-59	Active	Drainage line is actively eroding and remedial actions are required. It is important to classify if erosion is caused primarily by upstream flows, lateral flows or unstable wall materials so that appropriate rehabilitation can be carried out.
< 50	Very Active	Drainage line is very actively eroding and immediate remedial actions are required. It is important to classify if erosion is caused primarily by upstream flows, lateral flows or unstable wall materials so that appropriate rehabilitation can be carried out.

Table Source: CSIRO Ephemeral Stream Assessment (CSIRO, date unknown)

2.3 Transects at Monitoring Points

Transect data is collected at the monitoring points to provide a representation of the drainage line profile. The transect assessment allows for simple identification of any deposition of sediments within the channel bed or scouring of the banks by comparison with profile measurements on a yearly basis.

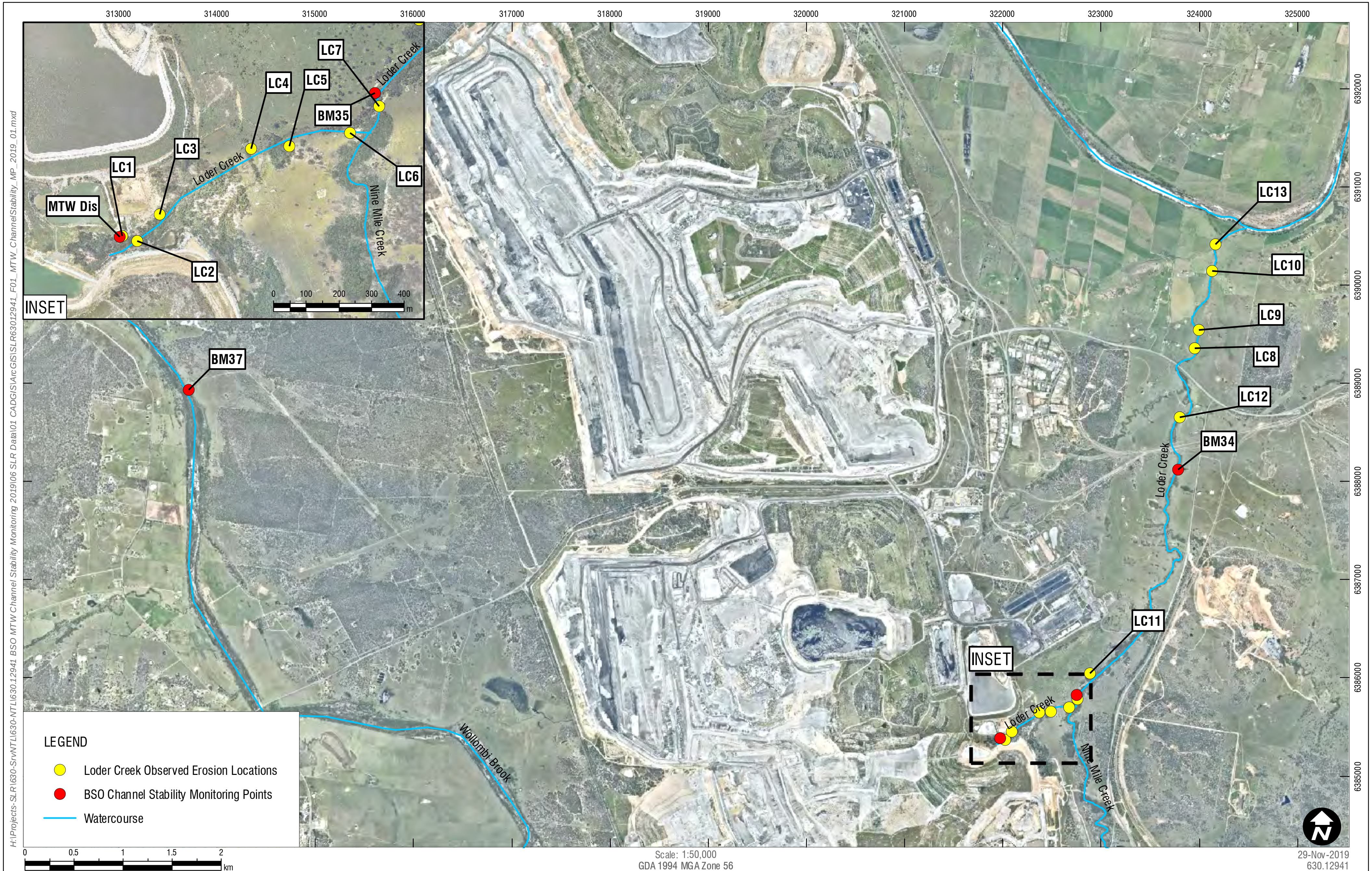
The transect assessment is undertaken by extending a tape measure laterally across the drainage line to two permanently fixed posts which are located within the riparian zone. A survey staff is then used to measure the vertical distance between the tape and the ground surface at approximately 0.5 m increments or at points which capture any sudden changes in channel geometry (e.g. steep channel banks).

2.4 Visual Assessment of Loder Creek

A visual inspection of Loder Creek from the Hunter River to the MTW discharge point was undertaken to identify any areas of increased erosion. Where erosion was observed within this reach of Loder Creek the following were recorded:

- Documented locations and dimensions of notable erosive or depositional features;
- Photos so that comparisons could be made in future surveys; and
- Rating the site with the *Ephemeral Stream Assessment* protocol developed by the CSIRO to assess the erosional state of the creek at the monitoring location.

Any visible changes that occurred since the preceding inspection will be documented by comparison to the photos taken during the previous surveys.



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MTW Channel Stability Monitoring Points - 2019

FIGURE 1

3 Results

3.1 Channel Stability / Stream Health Monitoring Site Results

3.1.1 MTW Dis (321966 E 6385379 N)

This monitoring point is located at the Mount Thorley discharge point. This section of creek has been upgraded and now includes rock armouring of the creek bed as well as jute mesh and seeding of both banks. Overall, the creek stability at this location has improved from the previous monitoring cycle and is now stabilising.

The banks are characterised by patches of scattered eucalypts with Bull Oak (*Allocasuarina luehmannii*) and Swamp Oak (*Casuarina glauca*) dominating the canopy. The understorey is sparse consisting mainly of Acacia shrubs scattered on the bank. Very little groundcover was observed with most areas consisting of bare earth especially around jute mesh. It should be noted there is very little diversity in either canopy or groundcover species. Both banks of the creek contain an almost continuous band of riparian vegetation in widths less than 40m wide with the exception of the cleared area where construction works have occurred. Exotic grass and bare soil (mine workings and vehicle tracks) surround riparian vegetation. Debris such as leaf litter and small numbers of fallen logs are evident. Linkage to larger areas of native vegetation is absent. Regeneration of native canopy species is evident across the site. The channel of the creek line contained dense native *Juncus* spp.

RARC Stream Health Assessment Classification – **Poor**

CSIRO Ephemeral Stream Assessment Classification – **Potentially Stabilising**

Photos taken at the established photo points for this monitoring point are shown in Plate 1 to Plate 4.

Plate 1 Right Bank

Plate 2 Upstream

Plate 3 Downstream

Plate 4 Left Bank

For the purpose of monitoring any changes to the creek, a creek line transect was established. The transect is shown in **Figure 2** and was taken from left to right looking downstream. It can see from this transect that the channel hasn't changed significantly since the previous monitoring cycle. It should also be noted that as part of the upgrade works, the peg on the left bank was removed which explains why this round of monitoring shows a shorter length of transect. Difference in the data appears to be within the expected transect accuracy tolerances, and it is not possible to discern if there has been bed erosion across at transect location.

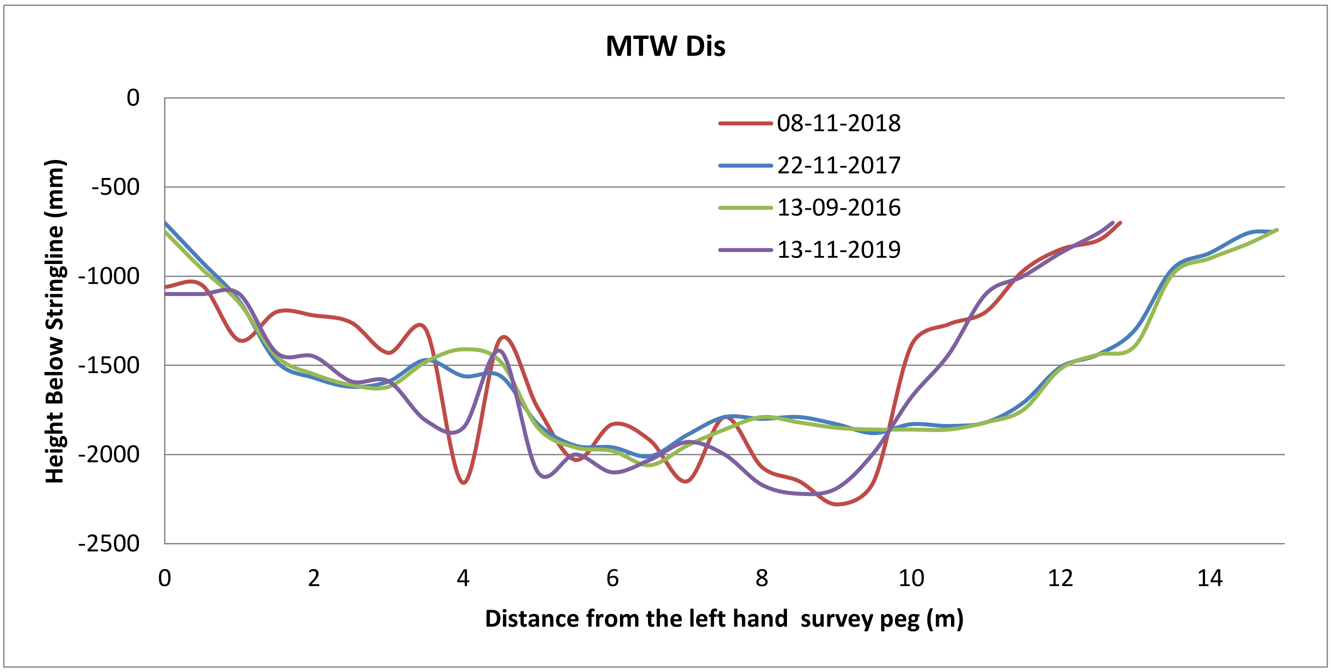

Figure 2 MTW Dis Transect Results

3.1.2 BM35 (322746 E 6385819 N)

The channel at this location was observed to have a good coverage of long grass across the bed. The left bank also appears stable with good grass coverage. The right bank contains some lateral erosion (approximately 0.5m

high) at the top of the bank. The lateral erosion is forming some rill/gully erosion down this bank, however the rest of the right bank appears to be stable with good grass coverage. Overall, this location shows similar conditions to the previous monitoring cycle.

The creek banks are characterised by Swamp Oak (*Casuarina glauca*) with scattered eucalypts upslope. Both banks of the creek contained an almost continuous band of riparian vegetation in widths mostly around 15m wide with one patch downstream extending to 40m wide. The understory consisted of weeds including Lantana, Paddy's Lucerne and Rhodes Grass. Exotic pastures surrounded riparian vegetation and linkage to other areas of native vegetation was absent. The channel of the creek line contained dense native *Typha* spp. with exotic grasses. Regenerating canopy tree (mostly *Casuarina glauca*) species were abundant.

RARC Stream Health Assessment Classification – **Poor**

CSIRO Ephemeral Stream Assessment Classification – **Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 5 to 9.

Plate 5 Right Bank

Plate 6 Upstream

Plate 7 Downstream

Plate 8 Left Bank

Plate 9 Erosion (top of right bank)

For the purpose of monitoring any changes of the creek, a creek line transect was established. The transect is shown in **Figure 3** and was taken from left to right looking downstream. It suggests that no significant scouring has occurred on the banks or creek bed since the previous monitoring cycles. Difference in the data appears to be within the expected transect accuracy tolerances.

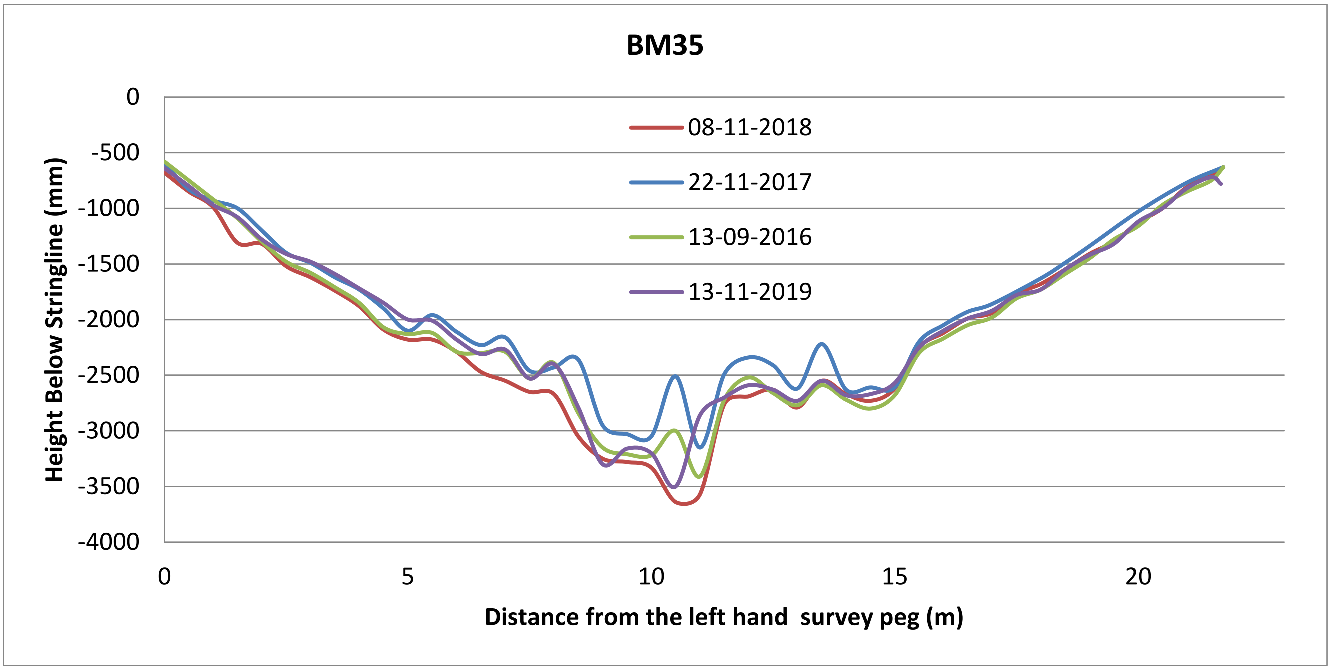

Figure 3 BM35 Transect Results

3.1.3 BM34 (323779 E 6388119 N)

The creek bed at this monitoring point is covered by reeds and is stable. Both the left and right banks have good grass coverage and appear to be stable with gentle-moderate slopes. The creek upstream and downstream of the monitoring point also appears to be stable. The creek has a very slight meander at this monitoring point. Overall this location has remained the same as the previous monitoring cycle conditions.

The banks were characterised by dense Swamp Oak (*Casuarina glauca*), tall River Oak *(Casuarina cunninghamia)* with scattered eucalypts. The creek is congested with *Juncus spp* and *Phragmites australis.* The understory contained high levels of weed infestation. Lantana, Paddy's Lucerne and in particular African Boxthorn were abundant below the canopy particularly upstream of the monitoring point. It should be noted that there has been a slight increase in the density of African Boxthorn since the 2018 monitoring event. Native Weeping Grass (*Microlaena stipoides*) was present in small patches beneath the denser canopy areas. Both banks of the creek contained an almost continuous band of riparian vegetation in widths less than 30m wide. Exotic pastures surrounded riparian vegetation and linkage to other areas of native vegetation was absent. Regenerating canopy tree (mostly *Casuarina glauca*) species were abundant. BM34 increased from the upper range of 'poor' to the lower range of 'average' due to an increase in canopy cover.

RARC Stream Health Assessment Classification – **Poor**

CSIRO Ephemeral Stream Assessment Classification – **Stable**

Photos taken at the established photo points for this monitoring point are shown in Plates 10 to 13.

Plate 10 Right Bank

Plate 11 Upstream

Plate 12 Downstream

Plate 13 Left Bank

For the purpose of monitoring any changes of the creek, a creek line transect was established. The transect is shown in **Figure 4** and was taken from left to right looking downstream. It suggests that no significant scouring has occurred on the banks or creek bed since the previous monitoring cycles. Difference in the data appears to be within the expected transect accuracy tolerances at most locations. The data also suggests that across the bed and right hand bank it is likely that there has been erosion over the past 3 years.

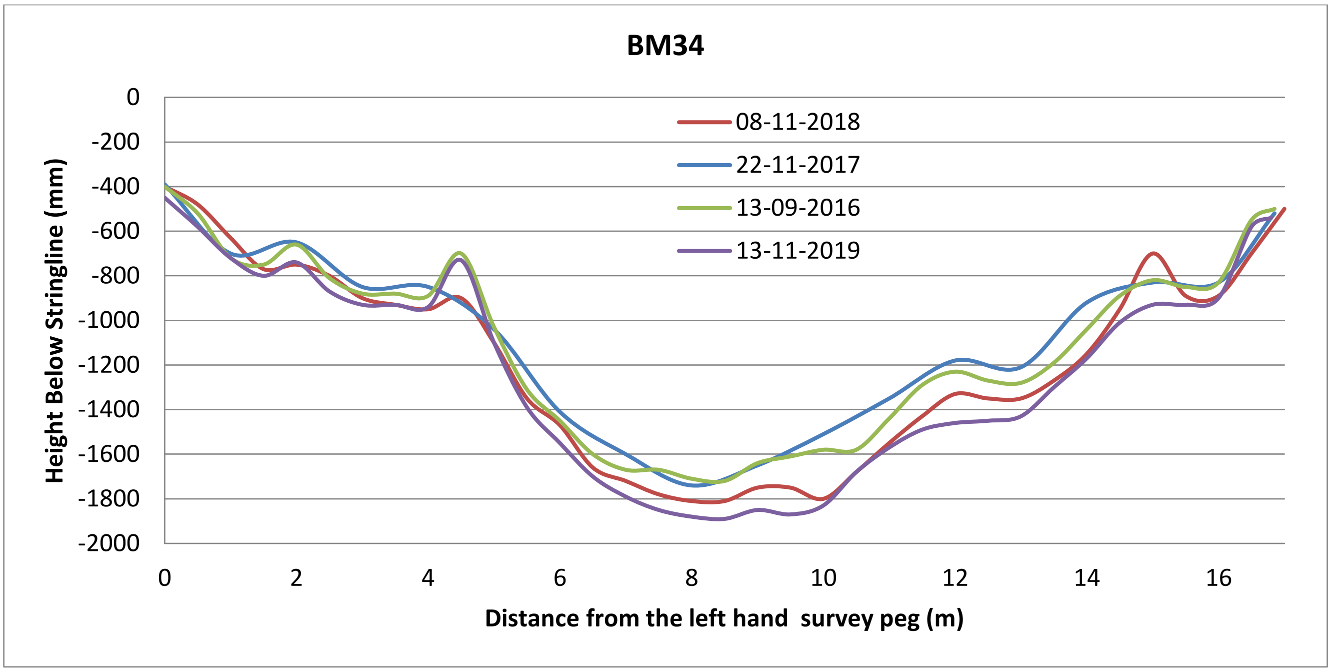

Figure 4 BM34 Transect Results

3.1.4 BM37 (313709 E 6388933 N)

Monitoring point BM37 is the only monitoring point that is located on Wollombi Brook Wollombi Brook is a large tributary of the Hunter River, with channel widths ranging from 10m to 60m. Generally Wollombi Brook has flowing water in it except during extreme drought periods. Water was observed to be ponding but not flowing at the time of the inspection. Both the left and right banks appeared to be generally stable with both banks containing trees. The right bank is steeper than the left bank with a moderate slope and a height of approximately 2m. A pipe outlet exists immediately downstream of the monitoring point on the eastern bank and has scoured out the bank slightly with some exposed moderately dispersive soils (approximately 0.3m high). Some wombat holes were also observed on the eastern bank. Overall this location has remained the same as the previous monitoring cycle conditions.

At sample site BM37, only the eastern side of Wollombi Brook was surveyed, as the width and depth of the stream prevented transects being extending across the full width of the stream. Riparian vegetation along a 280 meter reach of the stream was surveyed, with four parallel transects established across the riparian zone upstream and downstream of the sample site (marker point). Generally only a thin band (of between 5m to 15m in width) of native riparian forest exists along the banks of the stream. The innermost parts of the riparian zone, extending over a series of steep terraced banks, comprise of a narrow band of modified open forest of mainly Swamp Oak (*Casuarina glauca*), River Oak (*Casuarina cunninghamiana*) and occasional Cabbage Gum *Eucalyptus amplifolia*. The lower bank edges contain patches of dense reeds, including *Typha orientalis*, *Phragmites australis* and the exotic *Juncus acutus*. Patches of Parramatta Green Wattle *Acacia parramattensis*, as well as juvenile (or early mature) eucalypts and casuarinas, form a mid-canopy in places; however, generally the vegetation lacks a shrub layer. Leaf litter, as well as exotic grasses and herbs, dominates the ground layer, with common species being Paddy's Lucerne *Sida rhombifolia*, Panic Veldt Grass *Ehrharta erecta* and Common Sowthistle *Sonchus oleraceus*. The native Weeping Grass (*Microlaena stipoides*) occurs occasionally in shaded bank areas.

Upslope of this vegetation, extending to the outer parts of the riparian zone, the forest canopy gives way to cleared land comprising with exotic pasture grass, supporting a range of common exotic grasses and herbs, including African Lovegrass *Eragrostis curvula*, Narrow-leafed Carpet Grass *Axonopus fissifolius*, Couch *Cynodon dactylon* and several other species. No significant change was noted.

RARC Stream Health Assessment Classification – **Poor**

CSIRO Ephemeral Stream Assessment Classification – **Potentially Stabilising**

Photos taken at the established photo points for this monitoring point are shown in Plates 14 to 19.


Plate 14 Right Bank

Plate 15 Upstream


Plate 16 Downstream

Plate 17 Left Bank

Plate 18 Erosion

Plate 19 Erosion

3.2 Loders Creek Erosion Visual Assessment

3.2.1 LC1 (321974 E 6385382 N)

The erosion at LC1 has been remediated as part of upgrade work on the Mount Thorley discharge point. The works undertaken at this erosion site included rock armouring of the creek bed as well as jute mesh and seeding of both banks. Overall, this location has improved greatly from the previous monitoring cycle and is now considered stable.

CSIRO Ephemeral Stream Assessment Classification – **Stable**

Photos taken at the established photo points for this monitoring point are shown in Plates 20 to 23.

Plate 20 Right Bank

Plate 21 Upstream

Plate 22 Downstream

Plate 23 Left Bank

3.2.2 LC2 (322019 E 6385367 N)

The erosion observed at LC2 included a steep near vertical section of exposed dispersive material (approximately 2m high) on the right bank. This area appeared to be actively eroding including some areas immediately downstream. However, this monitoring location appears to be similar to what was observed in the 2018 survey. A tree was observed to have fallen over at this section of the exposed creek bank. The creek bed and left bank appear to be stable at this location.

CSIRO Ephemeral Stream Assessment Classification – **Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 24 to 26.

Plate 24 Upstream

Plate 25 Downstream

Plate 26 Erosion

3.2.3 LC3 (322087 E 6385446 N)

This location is positioned at a small channel entry point to Loders Creek (on the left bank). The channel appears to be stable, however the confluence point has some significant erosion with some slight undercutting and tunnelling of the dispersive soil. Overall, this monitoring location appears very similar to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Very Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 27 to 30.

Plate 27 Upstream

Plate 28 Downstream

Plate 29 Erosion

Plate 30 Tunnel Erosion

3.2.4 LC4 (322367 E 6385647 N)

LC4 is located under a powerline in an area where it appears that vegetation has been maintained within the powerline easement. The near vertical left bank on the outside of the creek meander is about 4-5m high and has some exposed dispersive material (approximately 1m high) near the top of the bank however this erosion has shown signs of potentially stabilising. The right bank is much flatter and appears to be stable, as does the creek bed. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Potentially Stabilising**

Photos taken at the established photo points for this monitoring point are shown in Plates 31 to 33.

Plate 31 Right Bank

Plate 32 Left Bank

Plate 33 Downstream

3.2.5 LC5 (322484 E 6385655 N)

LC5 is located in a historic diversion of Loders Creek. The erosion observed at LC5 included erosion extending up the right bank approximately 20-30m. The area has 0.5-1.0m high steep exposed walls surrounding 5m of exposed soil. The creek bed and left bank appear to be stable. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 34 to 37.

Plate 34 Right Bank

Plate 35 Upstream


Plate 36 Downstream

Plate 37 Erosion (top of right bank)

3.2.6 LC6 (322670 E 6385697 N)

The erosion observed at LC6 included significant lateral erosion near the top of the right bank. This erosion was approximately 1m high with an alluvial fan extending approximately 2m from the near vertical bank. The rest of the right bank appears to stable as does the creek bed and the left bank. Overall, this monitoring location appears similar to the previous monitoring cycle. The active erosion appears to be primarily the result of a historic disturbance of the top of the right bank which has exposed the highly dispersive soils at this location.

CSIRO Ephemeral Stream Assessment Classification – **Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 38 to 40.


Plate 38 Right Bank

Plate 39 Erosion

Plate 40 Erosion

3.2.7 LC7 (322759 E 6385778 N)

The erosion observed at LC7 included an area of active erosion of a steep comprising exposed dispersive clay material (approximately 0.8m high) on the right bank, however this erosion is not laterally extensive. The erosion appears to have been caused by lateral flow across the bare banks in the area. The right bank appears to be stable downslope of the eroded area, as does the creek bed and the left bank. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 41 to 45.

Plate 41 Right Bank

Plate 42 Upstream

Plate 43 Downstream

Plate 44 Left Bank

Plate 45 Erosion

3.2.8 LC8 (323948 E 6389351 N)

The erosion observed at LC8 included significant erosion of the left bank (approximately 0.8m high with the overall bank at approximately 2.5m high) at a location with a slight meander in the creek as shown on Plate 57. The erosion has some minor undercutting with a section of vertical banks partly stabilised by tree roots. The soil appears be alluvial and not particularly dispersive. Trees at this location are at risk of falling over due to loss of support. The creek bed and right bank appear to be stable. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Potentially Stabilising**

Photos taken at the established photo points for this monitoring point are shown in Plates 46 to 49.

Plate 46 Right Bank

Plate 47 Upstream

Plate 48 Downstream

Plate 49 Left Bank

3.2.9 LC9 (323996 E 6389540 N)

The erosion observed at LC9 included some loss of exposed slightly dispersive material on the right bank which may have been caused by livestock in the area. This bank is about 2m high and has about 0.8m of exposed soil. The area appears to be stabilising. The creek bed and the left bank appear to be stable. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Potentially Stabilising**

Photos taken at the established photo points for this monitoring point are shown in Plates 50 to 53.


Plate 50 Right Bank

Plate 51 Upstream


Plate 52 Downstream

Plate 53 Left Bank

3.2.10 LC10 (324131 E 6390142 N)

The erosion observed at LC10 is located immediately downstream of a concrete lined chute. The soil is alluvial and non-dispersive. The erosion has been created from scouring of the right bank during large flow events with the upstream chute increasing the velocity of the water to this downstream section of channel. This scouring has exposed some tree roots of some of the trees that line the creek bank. The creek has steep slopes on both banks (approximately 4m high). The creek is generally stable upstream and downstream except for some cattle tracks immediately upstream on the right bank. Limited vegetation exists in the creek bed. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Potentially Stabilising**

Photos taken at the established photo points for this monitoring point are shown in Plates 54 to 57.

Plate 54 Right Bank

Plate 55 Upstream

Plate 56 Downstream

Plate 57 Left Bank

3.2.11 LC11 (322881 E 6386043 N)

The erosion observed at LC11 includes some significant tunnelling and active erosion on the left bank with exposed vertical dispersive soil. Potential causes for this erosion include wombat holes as well as the presence of a contour bank overflow (which is located immediately upslope of the erosion). Trees were observed on both banks and creek bed. The creek bed and the right bank both show stable conditions. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 58 to 61.

Plate 58 Upstream

Plate 59 Downstream

Plate 60 Erosion

Plate 61 Erosion (Top)

3.2.12 LC12 (323802 E 6388650 N)

The erosion observed at LC12 includes some erosion (approximately 2m high) on the left bank with exposed vertical dispersive soil. It is likely that this erosion was at least partially caused by a fallen tree at the monitoring point location. The left bank at the monitoring point is significantly higher than the right bank. The creek bed and the right bank both show stable conditions. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Potentially Stabilising**

Photos taken at the established photo points for this monitoring point are shown in Plates 62 to 65.


Plate 62 Right Bank

Plate 63 Upstream


Plate 64 Downstream

Plate 65 Left Bank

3.2.13 LC13 (324160 E 6390408 N)

LC13 includes some erosion extending for approximately 5m on the steep left bank with exposed soil which doesn't appear to be highly dispersive. This erosion was most likely caused by livestock tracks observed upstream and downstream of the monitoring location or a localised slope failure. The creek and the right bank both show stable conditions. Overall, this monitoring location has shown similar conditions to the previous monitoring cycle.

CSIRO Ephemeral Stream Assessment Classification – **Active**

Photos taken at the established photo points for this monitoring point are shown in Plates 66 to 69.

Plate 66 Right Bank

Plate 67 Upstream

Plate 68 Downstream

Plate 69 Left Bank

4 Summary of Results

Monitoring Site	RARC Stream Heath Assessment Classification			CSIRO Ephemeral Stream Assessment Classification			Primary Cause of Erosion
	2017	2018	2019	2017	2018	2019	
MTW Dis	Poor	Poor	Poor	Active	Potentially Stabilising	Potentially Stabilising	Lateral Inflows
BM35	Poor	Poor	Poor	Active	Active	Active	Unstable Wall Materials
BM34	Poor	Poor	Average	Very Stable	Stable	Stable	NA
BM37	Average	Poor	Poor	Stable	Stable	Potentially Stabilising	NA
LC1	NA	NA	NA	Active	Stable	Stable	NA
LC2	NA	NA	NA	Active	Active	Active	Unstable Wall Materials
LC3	NA	NA	NA	Very Active	Very Active	Very Active	Upstream Flows
LC4	NA	NA	NA	Potentially Stabilising	Potentially Stabilising	Potentially Stabilising	Unstable Wall Materials
LC5	NA	NA	NA	Potentially Stabilising	Active	Active	Unstable Wall Materials
LC6	NA	NA	NA	Active	Active	Active	Unstable Wall Materials
LC7	NA	NA	NA	Active	Active	Active	Lateral Inflows

Monitoring Site	RARC Stream Heath Assessment Classification			CSIRO Ephemeral Stream Assessment Classification			Primary Cause of Erosion
	2017	2018	2019	2017	2018	2019	
LC8	NA	NA	NA	Potentially Stabilising	Potentially Stabilising	Potentially Stabilising	Upstream Flows
LC9	NA	NA	NA	Potentially Stabilising	Potentially Stabilising	Potentially Stabilising	Unstable Wall Materials
LC10	NA	NA	NA	Potentially Stabilising	Active	Potentially Stabilising	Upstream Flows
LC11	NA	NA	NA	Active	Active	Active	Wombat Activity, Contour Bank Overflows
LC12	NA	NA	NA	Active	Active	Potentially Stabilising	Fallen Tree
LC13	NA	NA	NA	Active	Active	Active	Livestock Tracks

5 Conclusion and Recommendations

MTW advise there have been nil discharge events from the MTW discharge point between the 2018 stream health monitoring event and the 2019 monitoring event. There has been 283 mm of rainfall recorded within the on-site rainfall gauge for the period November 2018 to October 2019. In comparison, the Bureau of Meteorology shows an average of 502 mm at Singleton (Singleton STP 61397) for the same period. This indicates that this round of monitoring was subjected to a significantly drier year than what occurs on average within the region.

The results of this monitoring survey indicate that both stream health and channel stability fluctuate over different sections of Loder Creek. The survey identified that some sections of Loder Creek are currently eroding and are vulnerable to further erosion with areas of significant erosion observed. These areas are generally associated with exposed dispersive sub-soils, which hamper vegetation establishment by the development of a hard surface crust when the soil is dry, and the 'melting' nature of the soil when wet.

The survey identified that the majority of Loder Creek displayed stable environments. Generally the monitoring identified that the creeks have not significantly changed from what was observed during the 2018 survey, however some evidence of minor erosion progression were observed at some of the monitoring points. Many sections of the creek experience active erosion as a result of natural influences. Improvements were also identified during the 2019 survey, resulting from both natural occurrences as well as man-made upgrade works.

In one instance, the CSIRO rating has downgraded from what was observed during the 2018 inspection although the observed conditions were similar. This is largely related to the subjectivity using the methodology proposed by CSIRO and therefore is subjected to change where there is a change in assessor.

The RARC stream health assessment identified that the monitoring points on Loder Creek were classified as poor and average. It should be noted that BM34 situated on Loder Creek increased from the upper range of 'poor' to the lower range of 'average' due to an increase in canopy cover. The single monitoring point on Wollombi Brook was classed as poor with little change observed since monitoring in 2018.

It is recommended that MTW adopt a risk based approach to determine whether mitigation measures and/or improvement works are required at the monitoring points where erosion was observed. Different remediation measures may be utilised depending on the type of erosion that has occurred (as listed in **Section 4**).

For example, erosion caused by lateral flows and unstable wall materials may be remediated by re-grading the batter slope (as required) to a maximum gradient of 3(H):1(V), ripping the soil and then seeding with a suitable vegetation species. Gypsum may also be used as a soil ameliorant and applied at a rate of 1kg/m^2. Bunding may also be used to control upslope lateral flows. Creek erosion caused by the shear stresses associated with the upstream flows may be remediated by armouring of the creek bed / banks (i.e. rock, jute mesh, erosion blanket etc), as was observed to have been implemented by MTW at location MTW Dis during the 2018 survey.

6 References

Land & Water Australia (2005), Rapid Appraisal Of Riparian Condition – Version Two (River and Riparian Technical Guideline No. 4a)

Commonwealth Scientific and Research Organisation (CSIRO) (date unknown) - Ephemeral Stream Assessment, date accessed 14/09/09,

http://www.cse.csiro.au/research/ras/efa/resources/ephemeraldrainagelineassessment.pdf

APPENDIX A

Rapid Appraisal of Riparian Conditions

Rapid Appraisal of Riparian Condition

Site Number:	MTW DIS

Site:	**Mount Thorley Discharge**	**GPS start:**	**See figure**
Date:	**13/11/2019** **Observer:** **SM**	**GPS end:**	

Longitudinal continuity of riparian canopy vegetation (>5m wide)

Map	Score
	2

0 = <50%, 1 = 50-64%, 2 = 65-79%, 3 = 80-94%, 4 = >95% vegetated bank;

with ½ point subtracted for each significant discontinuity (>50m long)

Width of riparian canopy vegetation

Transect	Channel Width (CW)	Vegetation Width (VW)	Score
1	3	75	4
2	3	15	2
3	5	45	4
4	7	55	4
Average			3.5

Channel <10m wide: 0 = VW <5m, 1 = VW 5-9m , 2 = VW 10-19m, 3 = VW 20-39m, 4 = VW >40m

Channel >10m wide: 0 = VW/CW <0.5, 1 = VW/CW 0.5-0.9, 2 = VW/CW 1-1.9, 3 = VW/CW 2-3.9, 4 = VW/CW >4

Proximity

Score
1

Nearest patch of native vegetation >10ha:

0 = >1km, 1 = 200m-1km, 2 = contiguous,

3 = contiguous with patch >50ha

Vegetation cover: Canopy >5m, Understorey 1-5m, Ground cover <1m

Transect	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
1	3	3	1	1	2	1	3
2	2	2	0	0	2	1	3
3	2	2	1	1	2	1	3
4	2	2	1	1	2	1	3
Average	2.25	2.25	0.75	0.75	2	1	3

Canopy and ground cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Understorey cover: 0 = none, 1 = 1-5%, 2 = 6-30%, 3 = >30%

Debris

Transect	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
1	3	3	0	0	1
2	3	3	1	0	1
3	3	3	0	0	0
4	3	3	0	0	0
Average	3	3	0.25	0	0.5

Leaf litter & native leaf litter cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Standing dead trees (>20cm dbh) & hollow-bearing trees: 0 = absent, 1 = present

Fallen logs (>10cm diameter): 0 = none, 1 = small quantities, 2 = abundant

Features

Transect	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
1	1	0	1	2
2	1	0	1	2
3	1	0	1	2
4	1	0	1	2
Average	1	0	1	2

Regeneration <1m tall: 0 = none, 1 = scattered, and 2 = abundant, with ½ point subtracted for grazing damage

Reeds & large tussock grasses: 0 = none, 1 = scattered, and 2 = abundant

Calculation of scores

Site Number:	MTO DIS

Longitudinal continuity of riparian canopy vegetation

Score
2

Width of riparian canopy vegetation

Average	3.5

Proximity

Score
1

Vegetation cover

	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
Average	2.25	2.25	0.75	0.75	2	1	3

Debris

	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
Average	3	3	0.25	0	0.5

Features

	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
Average	1	0	1	2

TOTALS

Site:	Habitat	Cover	Natives	Debris	Features	Total
(out of)	11	12	9	10	8	50
	6.5	8	4	6.75	4	29.25

Rapid Appraisal of Riparian Condition

Site Number: **BM34**

Site:	**Loaders Creek**	**GPS start:**	**see figure**
Date:	**14-11-2019** **Observer:** **SM**	**GPS end:**	

Longitudinal continuity of riparian canopy vegetation (>5m wide)

Map	Score
	4

0 = <50%, 1 = 50-64%, 2 = 65-79%, 3 = 80-94%, 4 = ≥95% vegetated bank;

with ½ point subtracted for each significant discontinuity (>50m long)

Width of riparian canopy vegetation

Transect	Channel Width (CW)	Vegetation Width (VW)	Score
1	6	25	3
2	6	20	3
3	6	15	2
4	6	15	2
Average			2.5

Channel ≤10m wide: 0 = VW <5m, 1 = VW 5-9m , 2 = VW 10-19m, 3 = VW 20-39m, 4 = VW ≥40m

Channel >10m wide: 0 = VW/CW <0.5, 1 = VW/CW 0.5-0.9, 2 = VW/CW 1-1.9, 3 = VW/CW 2-3.9, 4 = VW/CW ≥4

Proximity

Score
2

Nearest patch of native vegetation >10ha:

0 = >1km, 1 = 200m-1km, 2 = contiguous,

3 = contiguous with patch >50ha

Vegetation cover: Canopy >5m, Understorey 1-5m, Ground cover <1m

Transect	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
1	3	3	2	0	3	2	3
2	2	2	2	0	3	2	3
3	3	3	2	0	3	2	3
4	3	3	2	0	3	2	3
Average	2.75	2.75	2	0	3	2	3

Canopy and ground cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Understorey cover: 0 = none, 1 = 1-5%, 2 = 6-30%, 3 = >30%

Debris

Transect	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
1	1	1	0	0	0
2	1	1	0	0	0
3	1	1	0	0	0
4	1	1	0	0	0
Average	1	1	0	0	0

Leaf litter & native leaf litter cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Standing dead trees (>20cm dbh) & hollow-bearing trees: 0 = absent, 1 = present

Fallen logs (>10cm diameter): 0 = none, 1 = small quantities, 2 = abundant

Features

Transect	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
1	1	1	1	2
2	1	1	1	2
3	1	1	1	2
4	1	1	1	2
Average	1	1	1	2

Regeneration <1m tall: 0 = none, 1 = scattered, and 2 = abundant, with ½ point subtracted for grazing damage

Reeds & large tussock grasses: 0 = none, 1 = scattered, and 2 = abundant

Calculation of scores

Site Number:	BM34

Longitudinal continuity of riparian canopy vegetation

Score
4

Width of riparian canopy vegetation

Average	2.5

Proximity

Score
2

Vegetation cover

	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
Average	2.75	2.5	2	0	3	2	3

Debris

	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
Average	1	1	0	0	0

Features

	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
Average	1	1	1	2

TOTALS

Site:	Habitat	Cover	Natives	Debris	Features	**Total**
(out of)	11	12	9	10	8	50
	8.5	10.75	4.5	2	5	30.75

Rapid Appraisal of Riparian Condition

Site Number: BM35

Site:	Loaders Creek	**GPS start:**	See figure
Date:	13-11-2019 **Observer:** SM	**GPS end:**	

Longitudinal continuity of riparian canopy vegetation (>5m wide)

Map	Score
	3

0 = <50%, 1 = 50-64%, 2 = 65-79%, 3 = 80-94%, 4 = ≥95% vegetated bank;

with ½ point subtracted for each significant discontinuity (>50m long)

Width of riparian canopy vegetation

Transect	Channel Width (CW)	Vegetation Width (VW)	Score
1	5	18	2
2	5	25	3
3	5	30	3
4	5	60	4
Average			3

Channel ≤10m wide: 0 = VW <5m, 1 = VW 5-9m , 2 = VW 10-19m, 3 = VW 20-39m, 4 = VW ≥40m

Channel >10m wide: 0 = VW/CW <0.5, 1 = VW/CW 0.5-0.9, 2 = VW/CW 1-1.9, 3 = VW/CW 2-3.9, 4 = VW/CW ≥4

Proximity

Score
1

Nearest patch of native vegetation >10ha:

0 = >1km, 1 = 200m-1km, 2 = contiguous,

3 = contiguous with patch >50ha

Vegetation cover: Canopy >5m, Understorey 1-5m, Ground cover <1m

Transect	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
1	2	2	2	0	2	0	3
2	2	2	2	0	2	0	3
3	3	3	2	0	2	0	3
4	3	3	2	0	1	0	3
Average	2.5	2.5	2	0	1.75	0	3

Canopy and ground cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Understorey cover: 0 = none, 1 = 1-5%, 2 = 6-30%, 3 = >30%

Debris

Transect	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
1	3	3	0	0	1
2	3	3	0	0	1
3	3	3	0	0	0
4	3	3	0	0	1
Average	3	3	0	0	0.75

Leaf litter & native leaf litter cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Standing dead trees (>20cm dbh) & hollow-bearing trees: 0 = absent, 1 = present

Fallen logs (>10cm diameter): 0 = none, 1 = small quantities, 2 = abundant

Features

Transect	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
1	1	1	1	2
2	1	1	1	2
3	1	1	1	2
4	1	1	1	2
Average	1	1	1	2

Regeneration <1m tall: 0 = none, 1 = scattered, and 2 = abundant, with ½ point subtracted for grazing damage

Reeds & large tussock grasses: 0 = none, 1 = scattered, and 2 = abundant

Calculation of scores

Site Number:	BCC01

Longitudinal continuity of riparian canopy vegetation

Score
3

Width of riparian canopy vegetation

Average	3

Proximity

Score
1

Vegetation cover

	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
Average	2.25	2.25	2	0	2	0	3

Debris

	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
Average	3	3	0	0	0

Features

	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
Average	1	1	1	2

TOTALS

Site:	Habitat	Cover	Natives	Debris	Features	Total
(out of)	11	12	9	10	8	50
	7	9.25	2.25	6	5	29.5

Rapid Appraisal of Riparian Condition

Site Number: BM37

Site:	Wollomi Brook	**GPS start:**	See figure
Date:	13/11/2019 **Observer:** SM	**GPS end:**	

Longitudinal continuity of riparian canopy vegetation (>5m wide)

Map	Score
	3

0 = <50%, 1 = 50-64%, 2 = 65-79%, 3 = 80-94%, 4 = ≥95% vegetated bank;

with ½ point subtracted for each significant discontinuity (>50m long)

Width of riparian canopy vegetation

Transect	Channel Width (CW)	Vegetation Width (VW)	Score
1	20	15	1
2	10	17	2
3	20	20	4
4	10	35	3
Average			2.5

Channel ≤10m wide: 0 = VW <5m, 1 = VW 5-9m , 2 = VW 10-19m, 3 = VW 20-39m, 4 = VW ≥40m

Channel >10m wide: 0 = VW/CW <0.5, 1 = VW/CW 0.5-0.9, 2 = VW/CW 1-1.9, 3 = VW/CW 2-3.9, 4 = VW/CW ≥4

Proximity

Score
2

Nearest patch of native vegetation >10ha:

0 = >1km, 1 = 200m-1km, 2 = contiguous,

3 = contiguous with patch >50ha

Vegetation cover: Canopy >5m, Understorey 1-5m, Ground cover <1m

Transect	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
1	2	2	2	1	3	1	3
2	2	2	2	1	3	1	3
3	2	2	2	1	3	1	3
4	2	2	2	1	3	1	3
Average	2	2	2	1	3	1	3

Canopy and ground cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Understorey cover: 0 = none, 1 = 1-5%, 2 = 6-30%, 3 = >30%

Debris

Transect	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
1	2	2	0	0	0
2	2	2	0	0	1
3	2	2	0	0	0
4	2	2	0	0	1
Average	2	2	0	0	0.5

Leaf litter & native leaf litter cover: 0 = none, 1 = 1-30%, 2 = 31-60%, 3 = >60%

Standing dead trees (>20cm dbh) & hollow-bearing trees: 0 = absent, 1 = present

Fallen logs (>10cm diameter): 0 = none, 1 = small quantities, 2 = abundant

Features

Transect	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
1	0	0	1	2
2	0	0	1	2
3	0	0	1	2
4	0	0	1	2
Average	0	0	1	2

Regeneration <1m tall: 0 = none, 1 = scattered, and 2 = abundant, with ½ point subtracted for grazing damage

Reeds & large tussock grasses: 0 = none, 1 = scattered, and 2 = abundant

Calculation of scores

Site Number:	BM37

Longitudinal continuity of riparian canopy vegetation

Score
3

Width of riparian canopy vegetation

Average	2.5

Proximity

Score
2

Vegetation cover

	Canopy	Native canopy	Understorey	Native understorey	Ground cover	Native ground cover	# layers
Average	2	2	2	1	3	1	3

Debris

	Leaf litter	Native leaf litter	Standing dead trees	Hollow-bearing trees	Fallen logs
Average	2	2	0	0	0.5

Features

	Native canopy species regeneration	Native understorey regeneration	Large native tussock grasses	Reeds
Average	0	0	1	2

TOTALS

Site:	Habitat	Cover	Natives	Debris	Features	Total
(out of)	11	12	9	10	8	50
	7.5	10	4	4.5	3	29

APPENDIX B

CSIRO Ephemeral Stream Assessment Database

BSO MTW CSIRO Ephemeral Stream Assessment Database

Site Number	Distance US/DS from Survey Peg (m)	Date of Monitoring	Nov-18	Nov-19
		Assessor	SLR	SLR
		Channel Characteristic	**Rating**	**Rating**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	3	3
		Shape of D/L Cross-Section	3	3
		Longitudinal Morphology	3	3
		Particle Size of Materials on Floor	1	1
LC1	0m (At Survey Peg)	Nature of D/L Wall Materials	3	3
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	3	3
		Sum of Ratings	**23**	**23**
		Activity Rating	**72**	**72**
		Classification	**Stable**	**Stable**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	1	1
		Shape of D/L Cross-Section	2	2
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
LC2	0m (At Survey Peg)	Nature of D/L Wall Materials	1	1
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**18**	**18**
		Activity Rating	**56**	**56**
		Classification	**Active**	**Active**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	1	1
		Shape of D/L Cross-Section	2	1
		Longitudinal Morphology	2	1
		Particle Size of Materials on Floor	1	1
LC3	0m (At Survey Peg)	Nature of D/L Wall Materials	1	1
		Nature and Shape of Bank Edge	3	3
		Nature of Lateral Flow Regulation	2	2
		Sum of Ratings	**15**	**13**
		Activity Rating	**47**	**41**
		Classification	**Very Active**	**Very Active**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	3	3
		Shape of D/L Cross-Section	3	2
		Longitudinal Morphology	3	3
		Particle Size of Materials on Floor	1	1
LC4	0m (At Survey Peg)	Nature of D/L Wall Materials	1	1
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**22**	**21**
		Activity Rating	**69**	**66**
		Classification	**Potentially Stabilising**	**Potentially Stabilising**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	2	2
		Shape of D/L Cross-Section	2	2
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
LC5	0m (At Survey Peg)	Nature of D/L Wall Materials	2	2
		Nature and Shape of Bank Edge	3	3
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**19**	**19**
		Activity Rating	**59**	**59**
		Classification	**Active**	**Active**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	2	2
		Shape of D/L Cross-Section	2	2
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
LC6	0m (At Survey Peg)	Nature of D/L Wall Materials	1	1
		Nature and Shape of Bank Edge	3	3
		Nature of Lateral Flow Regulation	3	3
		Sum of Ratings	**17**	**17**
		Activity Rating	**53**	**53**
		Classification	**Active**	**Active**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	1	1
		Shape of D/L Cross-Section	2	2
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
LC7	0m (At Survey Peg)	Nature of D/L Wall Materials	2	2
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	2	2
		Sum of Ratings	**17**	**17**
		Activity Rating	**53**	**53**
		Classification	**Active**	**Active**
		Vegetation on D/L Floor	2	2
		Vegetation on D/L Walls	1	1
		Shape of D/L Cross-Section	3	3
		Longitudinal Morphology	3	3
		Particle Size of Materials on Floor	1	1
LC8	0m (At Survey Peg)	Nature of D/L Wall Materials	2	2
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**20**	**20**
		Activity Rating	**63**	**63**
		Classification	**Potentially Stabilising**	**Potentially Stabilising**
		Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	3	3
		Shape of D/L Cross-Section	3	3

LC9	0m (At Survey Peg)	Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
		Nature of D/L Wall Materials	3	2
		Nature and Shape of Bank Edge	3	4
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**22**	**22**
		Activity Rating	**69**	**69**
		Classification	**Potentially Stabilising**	**Potentially Stabilising**
LC10	0m (At Survey Peg)	Vegetation on D/L Floor	1	1
		Vegetation on D/L Walls	1	1
		Shape of D/L Cross-Section	2	2
		Longitudinal Morphology	2	1
		Particle Size of Materials on Floor	1	3
		Nature of D/L Wall Materials	4	4
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**19**	**20**
		Activity Rating	**59**	**63**
		Classification	**Active**	**Potentially Stabilising**
LC11	0m (At Survey Peg)	Vegetation on D/L Floor	3	2
		Vegetation on D/L Walls	1	2
		Shape of D/L Cross-Section	2	3
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
		Nature of D/L Wall Materials	1	2
		Nature and Shape of Bank Edge	3	3
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**17**	**19**
		Activity Rating	**53**	**59**
		Classification	**Active**	**Active**
LC12	0m (At Survey Peg)	Vegetation on D/L Floor	2	2
		Vegetation on D/L Walls	2	2
		Shape of D/L Cross-Section	3	3
		Longitudinal Morphology	2	3
		Particle Size of Materials on Floor	1	1
		Nature of D/L Wall Materials	2	2
		Nature and Shape of Bank Edge	3	3
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**19**	**20**
		Activity Rating	**59**	**63**
		Classification	**Active**	**Potentially Stabilising**
LC13	0m (At Survey Peg)	Vegetation on D/L Floor	1	1
		Vegetation on D/L Walls	2	1
		Shape of D/L Cross-Section	3	2
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
		Nature of D/L Wall Materials	2	3
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**19**	**18**
		Activity Rating	**59**	**56**
		Classification	**Active**	**Active**
MTW Dis	0m (At Survey Peg)	Vegetation on D/L Floor	1	1
		Vegetation on D/L Walls	2	2
		Shape of D/L Cross-Section	3	3
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	3	3
		Nature of D/L Wall Materials	3	3
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	2	2
		Sum of Ratings	**20**	**20**
		Activity Rating	**63**	**63**
		Classification	**Potentially Stabilising**	**Potentially Stabilising**
BM34	0m (At Survey Peg)	Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	3	3
		Shape of D/L Cross-Section	5	5
		Longitudinal Morphology	3	3
		Particle Size of Materials on Floor	1	1
		Nature of D/L Wall Materials	3	3
		Nature and Shape of Bank Edge	3	3
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**25**	**25**
		Activity Rating	**78**	**78**
		Classification	**Stable**	**Stable**
BM35	0m (At Survey Peg)	Vegetation on D/L Floor	3	3
		Vegetation on D/L Walls	2	2
		Shape of D/L Cross-Section	2	2
		Longitudinal Morphology	2	2
		Particle Size of Materials on Floor	1	1
		Nature of D/L Wall Materials	2	2
		Nature and Shape of Bank Edge	3	3
		Nature of Lateral Flow Regulation	3	3
		Sum of Ratings	**18**	**18**
		Activity Rating	**56**	**56**
		Classification	**Active**	**Active**
BM37	0m (At Survey Peg)	Vegetation on D/L Floor	1	1
		Vegetation on D/L Walls	3	3
		Shape of D/L Cross-Section	4	4
		Longitudinal Morphology	3	3
		Particle Size of Materials on Floor	1	1
		Nature of D/L Wall Materials	3	2
		Nature and Shape of Bank Edge	4	4
		Nature of Lateral Flow Regulation	4	4
		Sum of Ratings	**23**	**22**
		Activity Rating	**72**	**69**
		Classification	**Stable**	**Potentially Stabilising**

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Appendix 4:

Annual Ground Water Review Report

MOUNT THORLEY WARKWORTH ANNUAL GROUNDWATER REVIEW 2019

2019 Annual Groundwater Review

Prepared for:

Yancoal Mount Thorley Warkworth Australia
PO Box 267
SINGLETON NSW 2330

SLR Ref: 620.12289.40000-R05
Version No: -v2.0
March 2020

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DOCUMENT CONTROL

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620.12289.40000-R05-v2.0	26 March 2020	Duncan Dawson	Claire Stephenson	Claire Stephenson
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DOCUMENT REFERENCES

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APPENDICES

1 Introduction

1.1 Overview

The Mount Thorley Warkworth (MTW) mining complex is located approximately 15 km south-west of Singleton, NSW. As part of compliance with mine approval conditions, routine groundwater monitoring is conducted across MTW, and the data reviewed and analysed on an annual basis. The annual groundwater review is required for:

- Warkworth Mine in accordance with Condition 25 of the Warkworth Consent (SSD 6464) Statement of Commitments; and
- Mt Thorley Mine in accordance with Condition 27 of Development Consent (SSD 6465)

MTW commissioned SLR Consulting Pty Ltd (SLR) to review the groundwater monitoring data for the 2019 calendar year. This report presents groundwater monitoring data collected at the MTW complex and discusses the impact of mining on the groundwater regime.

1.2 Scope

The scope of work for this review included analysis of monitoring data and reporting. This report presents:

- Site background:
  - Legislative requirements and conditions relevant to groundwater;
  - Mine activities over reporting period;
  - Hydrogeological regime; and
  - Groundwater monitoring network and program.
- Data review:
  - Review and illustration (i.e. hydrographs) of groundwater level trends;
  - Review and illustration (i.e. hydrographs) of groundwater quality trends; and
  - Comparison of water level and quality trends to relevant trigger levels and natural trends (i.e. surface water levels and rainfall).
- Review of numerical groundwater model predictions and comparison to observed groundwater levels.
- Discussion of groundwater impacts and compliance over the reporting period and provision of recommendations (where required).

2 MTW Complex

The following section provides a summary of known activities conducted across the complex that relate to the annual groundwater review. The general site layout is presented in **Figure 2-1**.

2.1 Mine Operations

Table 2-1 presents a summary of mine areas across MTW and activities conducted over 2019.

Table 2-1 Summary of MTW Activities

Mine Area	Site	2019 Activities
North Pit	Warkworth	Mining progressed to the west, mining down to the Mt Arthur Seam.
West Pit	Warkworth	Mining progressed to the west, mining down to the Mt Arthur Seam.
South Pit	Warkworth	No active mining, rehabilitation works in place.
Loders Pit	Mt Thorley	Mining continued within the existing footprint down to the Redbank Seam.
Abby Green Pit	Mt Thorley	No mining active, rehabilitation works in place.

A range of tailings storage facilities (TSF) are present across MTW, as summarised in **Table 2-2**.

Table 2-2 Summary of approved tailings storage facilitates at MTW

Area	Location	Status
Tailings Dam 1 (Dam 32N)	North Pit – Warkworth. Tailings dam located overlying spoil, within backfilled pit.	Inactive, tailings dam rehabilitated.
Tailings Dam 2 (Dam 33N)	North Pit – Warkworth. Tailings dam located overlying spoil, within backfilled pit.	Inactive, excess standing water actively decanted in 2017 and rehabilitation commenced. Capping of the tailings dam continued during the period.
Centre Ramp Tailings Dam (Dam 17S)	Loders Pit – Mt Thorley. Tailings dam located overlying spoil, within backfilled pit.	Active
Abbey Green Tailings Dam (Dam 4S)	Abbey Green – Mt Thorley. Tailings dam located overlying spoil, within backfilled pit.	Active
Mini-strip Tailings Dam	Loders Pit – Mt Thorley. Tailings dam located overlying spoil, within backfilled pit.	Inactive, excess standing water actively decanted. Rehabilitation works in progress
Loders Pit North	Loders Pit- Mount Thorley. Tailings dam located in-pit.	Approved TSF not yet developed.

Main road
Major watercourses
MTW Infrastructure
Mine Areas
Open Cut
Underground

Sheet Size : A4

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Mt Thorley Warkworth
2019 Annual Groundwater Review
Locality Map

Figure 2-1

2.2 Groundwater Impacts

Groundwater impacts associated with the approved operations are presented within the:

- Warkworth Mine Modification Groundwater Impact Assessment (AGE, 2013);
- Warkworth Continuation 2014 Groundwater Assessment (AGE, 2014a);
- Mount Thorley Operations 2014 Groundwater Assessment (AGE, 2014b);
- Mount Thorley and Warkworth Mines, Long Term Approvals Model Update (AGE, 2015).

The most recent groundwater assessment that captures operations across MTW was the Long Term Approvals Model Update (AGE, 2015). The groundwater assessment involved updating the numerical groundwater model developed in 2014 as part of the continuation projects. Updates included recalibration of the model to site observations and updating the mine plans. AGE (2015) reported on predicted impacts associated with approved operations. The approved operations included mining at North Pit, West Pit and Loders Pit until 2035, as well as surrounding non-MTW mining operations (i.e. Wambo). Groundwater conditions and groundwater response to approved mining, as reported by AGE (2015), indicated:

- Groundwater within the hard rock units (i.e. Whittingham Coal Measures) is directly intercepted by approved operations at MTW, with a peak take of 275 ML/year predicted for Warkworth and 298 ML/year predicted for Mt Thorley;
- Groundwater within the confined to semi-confined Permian coal measures became depressurised around the area of active mining;
- There is no direct interception of groundwater within the ‘highly productive’ alluvium for active mine operations at MTW;
- With depressurisation of the coal measures, the model predicted a reduction in upward seepage to the ‘highly productive’ alluvium along the Hunter River and Wollombi Brook, referred to as ‘indirect take’. Peak indirect take:
  - From the Wollombi Brook alluvium (Hunter Unregulated) was predicted to be 16.7 ML/year for Warkworth and 11.3 ML/year for Mt Thorley;
  - From the Hunter River alluvium (Hunter Regulated) was predicted to be 3.5 ML/year for Warkworth and 0.6 ML/year for Mt Thorley;

Groundwater licenses have been obtained for the approved operations, as discussed in **Section 2.3**. Management and monitoring requirements of potential groundwater related impacts from approved operations are captured within the development consent conditions. These conditions are addressed within the site Water Management Plan (WMP), which was updated in September 2018. Further discussion on the monitoring and management requirements is included within **Section 5.**

2.3 Groundwater Licensing

Under the *Water Act 1912* and *Water Management Act 2000*, adequate water licences are required for approval of the mine developments. Groundwater licenses held for MTW are outlined in **Table 2-3**. Water licence details have been obtained from the WMP.

Table 2-3 MTW Groundwater Licenses

License Number	Description	WSP	Water Source - Management Zone	Approved Extraction (ML)
40464 20AL218784	Mt Thorley Excavations	North Coast Fractured and Porous Rock	Permian Coal Seams	180
40465 20AL218785	Warkworth Excavations			750
18558 20AL208627	-	Hunter Unregulated and Alluvial Water Sources	Lower Wollombi Brook Water Source	50
18469 20AL218784	-			245
19022 20AL209903	Sandy Hollow Creek		Singleton Water Source	60
10543 20AL201239	To Oakhampton Rail Bridge	Hunter River Regulated Water Source	Zone 2b Hunter River from Wollombi Brook Junction to downstream extent of the Hunter Regulated River	1,009
963 20AL201242	Warkworth Farm – Hunter River Pump			243
971 20AL201258				270
1008 20AL201341				243
995 20AL201302	Appledale Farm – Hunter River Pump			243
1009 20AL201343				435
969 20AL201254	-		Zone 1b Hunter River from Goulburn River Junction to Glennies Creek Junction	39

2.4 Groundwater Conditions

In accordance with the development consent approval conditions and statement of commitments (SOC) to the 2014 continuation project approval, Yancoal are required to prepare and implement a WMP to the satisfaction of the Director-General. **Table 2-4** presents a summary of the relevant groundwater conditions and SOC's from the 2018 WMP. The table identifies where the conditions relating to routine groundwater monitoring for 2019 have been addressed.

Table 2-4 Groundwater Conditions within WMP

Condition	Details	Where Addressed
Sch. 3, Cond. 24 for Mt Thorley (SSD-6465) Sch. 3, Cond. 26 for Warkworth (SSD-6464)	Design, install and maintain emplacements to prevent offsite migration of saline groundwater seepage	See **Section 6** for discussion of groundwater quality. WMP and surface water review
Sch. 3, Cond. 25(b) for Mt Thorley (SSD-6465) Sch. 3, Cond. 27(b) for Warkworth (SSD-6464)	Groundwater Management Plan, which includes detailed baseline data on groundwater levels, yield and quality in the region, and privately-owned groundwater bores, that could be affected by the development	See WMP. As per WMP, no privately-owned groundwater bores on non-mine owned land were identified as having groundwater levels decline by over 2 m due to the approved operations.
Sch. 3, Cond. 25(b) for Mt Thorley (SSD-6465) Sch. 3, Cond. 27(b) for Warkworth (SSD-6464)	Groundwater Management Plan, which includes groundwater assessment criteria, including trigger levels for investigating any potentially adverse groundwater impacts	See **Section 5.3** for triggers and **Section 6.3** for discussion on site water quality results against trigger levels.
Sch. 3, Cond. 25(b) for Mt Thorley (SSD-6465) Sch. 3, Cond. 27(b) for Warkworth (SSD-6464)	Groundwater Management Plan which includes a program to monitor and report on:	
	Groundwater inflows to the open cut pits;	See WMP
	The seepage/leachate from water storages, emplacements, backfilled voids and final voids;	See WMP and surface water review and see **Section 6** for discussion of groundwater quality.
	The impacts of the development on: • regional and local (including alluvial) aquifers; • groundwater supply of potentially affected landowners; • groundwater dependent ecosystems and riparian vegetation; • base flows to Loders Creek (Mt Thorley) and Wollombi Brook (Warkworth);	See **Section 6** for discussion on groundwater monitoring results for 2019. As per WMP, no privately-owned bores identified as potentially impacted. See ecology review for discussion on ecosystems and vegetation.

Condition	Details	Where Addressed
Sch. 3, Cond. 25(b) for Mt Thorley (SSD-6465) Sch. 3, Cond. 27(b) for Warkworth (SSD-6464)	Groundwater Management Plan which includes a plan to respond to any exceedances of the groundwater assessment criteria;	Trigger exceedances are discussed in **Section 6.**
Sch. 3, Cond. 25(b) for Mt Thorley (SSD-6465) Sch. 3, Cond. 27(b) for Warkworth (SSD-6464)	Groundwater Management Plan which includes a program to validate the groundwater model for the development, including an independent review of the model with every independent environmental audit, and compare the monitoring results with modelled predictions.	Numerical model last updated in 2015 as discussed in **Section 2.2**. Comparison between observed and modelled groundwater levels undertaken in **Section 6.5.**.
SOC Warkworth Continuation 2014 EIS Table 22.1 Groundwater	Updates to current groundwater monitoring programme: • installation of nested monitoring bores along the Wollombi Brook (PZ10, PZ11, PZ12); and • installation of monitoring bores with the Warkworth Sands system as part of an update to the existing Warkworth Sands Ephemeral Perched Aquifer Management Plan within the MTW WMP.	Bores installed in 2016, see **Section 5** for details on the monitoring program.
	Mine seepage monitoring programme: • recording of the time, location and estimated volume of any unexpected increased groundwater outflow from the highwall and endwall; • measurement of water pumped from the mine, preferably using flow meters or other suitable gauging apparatus; • correlation of rainfall records with mine seepage records so groundwater and surface water can be separated;	See mine water balance and surface water review.
	Data management and reporting: • establishment of trigger levels; • quarterly review of groundwater levels and field water quality against trigger levels, with site-specific investigations initiated; • formal review of depressurisation of coal measures and alluvium would be undertaken annually by a suitably qualified hydrogeologist; • annual reporting (including all water level and water quality data); and • all groundwater data being stored in a database customised for MTW with suitable QA/QC controls.	Quarterly reviews conducted as part of routine groundwater monitoring by external contractors AECOM. Review of groundwater level and quality changes presented in **Section 6**. Data stored within database held by Yancoal.
	Future model iterations: • assess the validity of the model predictions every three years; and • incorporate into the model and revise predictions, if required.	Model predictions assessed in **Section 6.5.**
	Licensing: • retain and obtain appropriate water licences, as required, to account for modelled take.	**Section 2.3** and **Section 6.4**

Condition	Details	Where Addressed
SOC Mount Thorley Operations 2014 EIS Table 21.1 Groundwater	A site specific investigation into trigger level exceedance would be undertaken if: • professional judgement determines that the single deviation or a developing trend could result in environmental harm; or • three consecutive measurements exceed trigger values.	See **Section 6.3** for discussion on site water quality results against trigger levels.
	Data management and reporting: • establishment of trigger levels; • quarterly review of groundwater levels and field water quality against trigger levels, with site specific investigations initiated; and • all groundwater data being stored in a database customised for MTW with suitable QA/QC controls.	Trigger levels presented in **Section 5.3**. Quarterly reviews conducted as part of routine groundwater monitoring by external contractors AECOM. Data stored within database held by Yancoal.
	Licensing: • retain and obtain appropriate water licences, as required, to account for modelled take.	**Section 2.3**

Groundwater monitoring is to be conducted in accordance with the Groundwater Monitoring Program (GMP) outlined within Appendix C of the WMP. The program outlines groundwater monitoring frequency, parameters to be tested and groundwater triggers for electrical conductivity (EC) and pH. Further discussion on the GMP and triggers is included in **Section 5**.

3 Hydrogeological Setting

This section presents a brief summary of the hydrogeological setting for MTW. This includes discussion on climate, terrain, drainage, geology and groundwater bearing units.

3.1 Climate, Terrain and Drainage

3.1.1 Climate

The climate of the MTW region can be classed as temperate and is characterised by hot summers and mild dry winters. Rainfall data from the Bureau of Meteorology (BoM) Station 61191 Bulga South was used as this provides the longest record of data in the area from 1959 to present. **Table 3-1** shows the average monthly rainfall calculated since 1959 and for the year 2019.

Table 3-1 Long Term Average and 2019 Climate Data

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average Historical	86.6	84.2	66.7	45.9	40.3	44.1	30.0	34.2	38.5	54.3	61.8	71.5	**656.6**
2019 Rainfall	59.6	21.0	145.6	3.4	11.8	6.4	13.4	21.8	21.4	4.4	30.8	0.2	**339.8**

A cumulative rainfall departure (CRD) plot is provided as **Figure 3-1** to illustrate long term climate trends in the MTW area, based on average monthly rainfall data. The CRD graphically shows trends in recorded rainfall compared to long-term averages (1959 to present) and provides a historical record of relatively wet and dry periods. A rising trend in slope in the CRD graph indicates periods of above average rainfall, whilst a declining slope indicates periods when rainfall is below average. A level slope indicates average rainfall conditions.

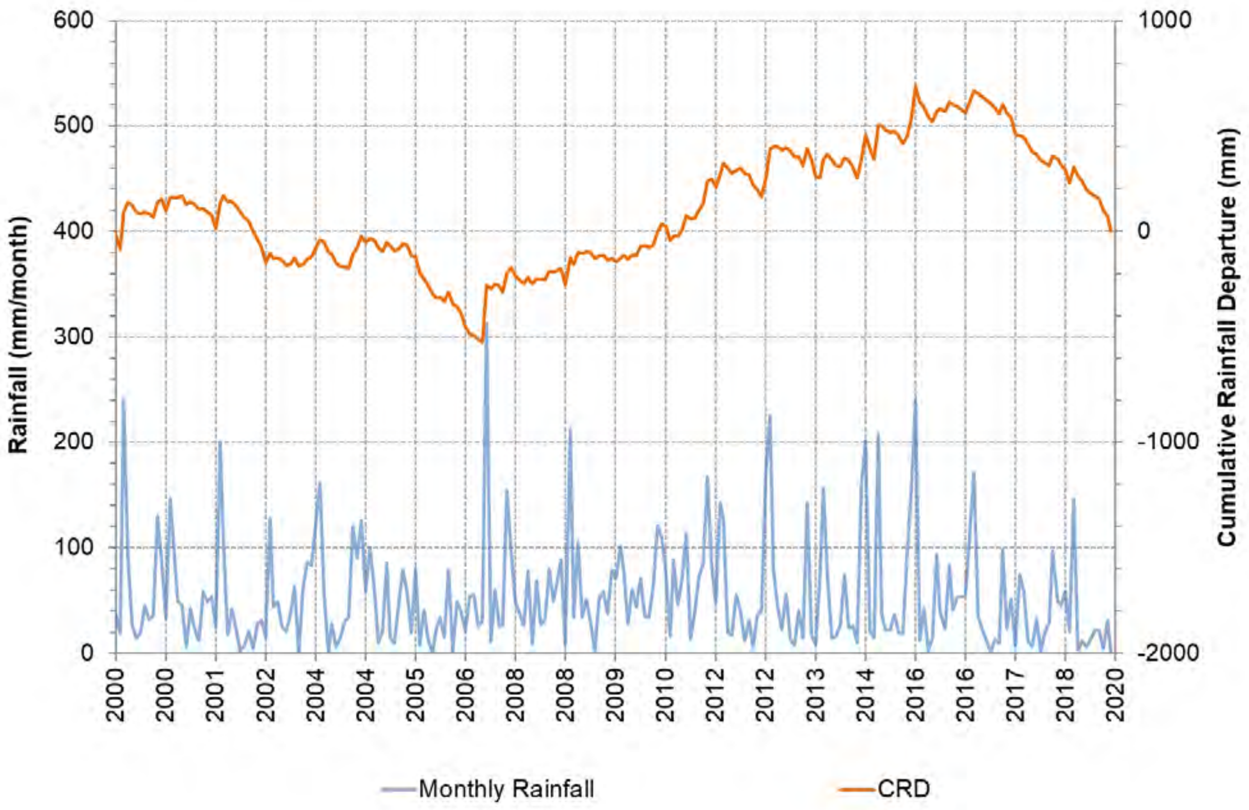


Figure 3-1 Cumulative Rainfall Departure and Monthly Rainfall

As shown in **Figure 3-1**, the region has generally experienced below average rainfall from 2016. Over 2019 rainfall was well below historical average for all months, except for March where 145.6 mm of rainfall was recorded, which was 78.9 mm above average.

3.1.2 Terrain and Drainage

Ground elevations at MTW range between 35 m Australian Height Datum (mAHD) along the Hunter River alluvial plains to 100 mAHD west of MTW. Minor ephemeral drainage features are also present around MTW (i.e. Loders Creek, Sandy Hollow Creek, Doctors Creek), draining into the Hunter River.

Real time stream flow data is monitored along the Hunter River and Wollombi Brook at NSW Department of Primary Industries (DPI) Water gauging stations via the Hunter Integrated Telemetry System (HITS). Time series river water elevations (mean level above zero gauge elevation) is presented in **Figure 3-2** for three HITS stations (Hunter River @ Mason Dieu, Hunter River @ Long Point and Wollombi Brook @ Warkworth).

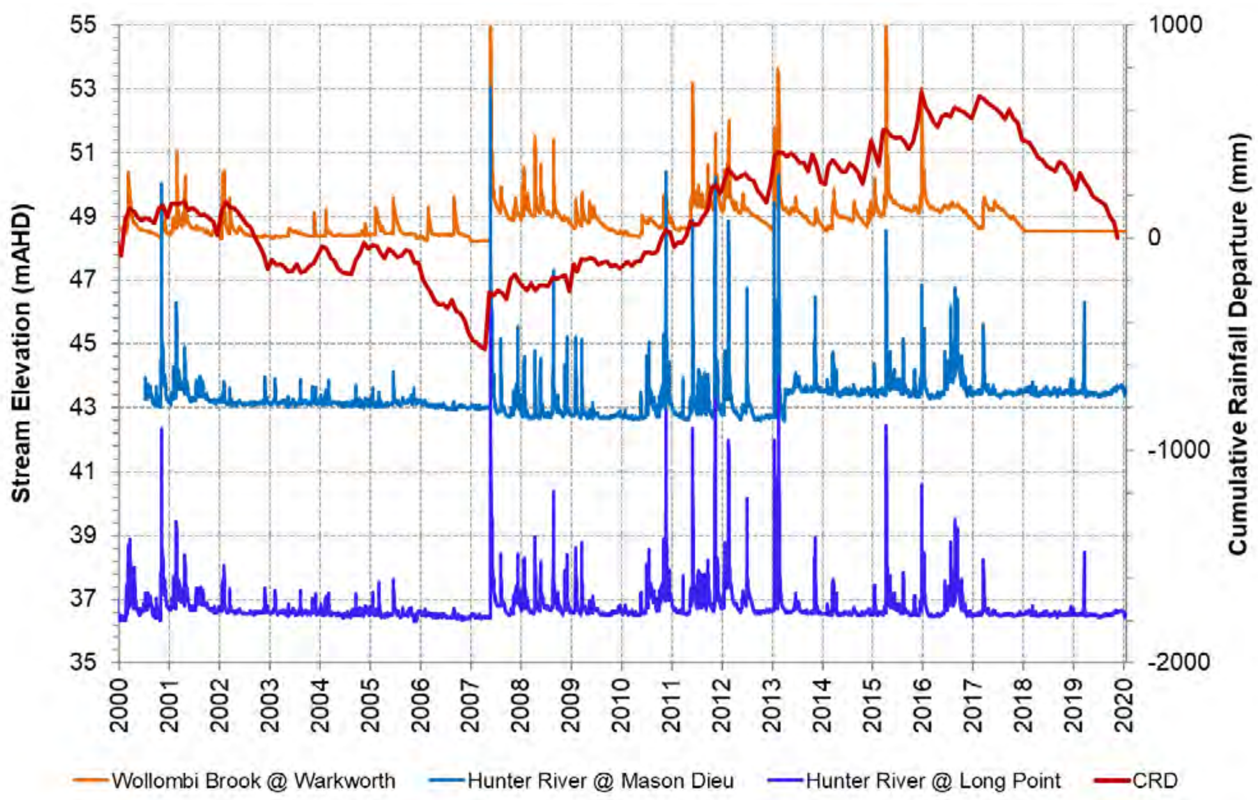


Figure 3-2 Surface Water Levels

As shown in **Figure 3-2**, over 2019 stream elevations within the Hunter River remained stable ranging between 36.43 mAHD and 38.49 mAHD at Long Point and between 43.32 mAHD and 46.32 mAHD at Mason Dieu. Glenbawn Dam is located approximately 135 km upstream of the project area. Daily regulated releases of the dam storage are undertaken to maintain flow and environmental quality of the Hunter River. Given the low rainfall recorded over 2019, the consistent elevations observed at both gauging stations are likely to be largely due to these storage releases. This is supported by the spike in elevation seen in April 2019 in contrast to the negligible rainfall (3.4 mm) recorded over the same period.

Figure 3-2 shows that over 2019, stream elevations within Wollombi Brook were recorded consistently at 48.5 mAHD. The zero gauge for Warkworth station (Station 210004) is 47.755 mAHD, meaning that water levels were recorded above the zero gauge over 2019 at 0.78 m. The stability of the water level over 2019 suggests pooled water has been measured rather than changes in stream elevations. Time series data of total rainfall against discharge volumes for Wollombi Brook is presented in **Figure 3-3**. The graph shows that since August 2017 no discharge volumes have been recorded within the brook, suggesting that that over 2019 Wollombi Brook did not flow, which is consistent with the observed water levels.

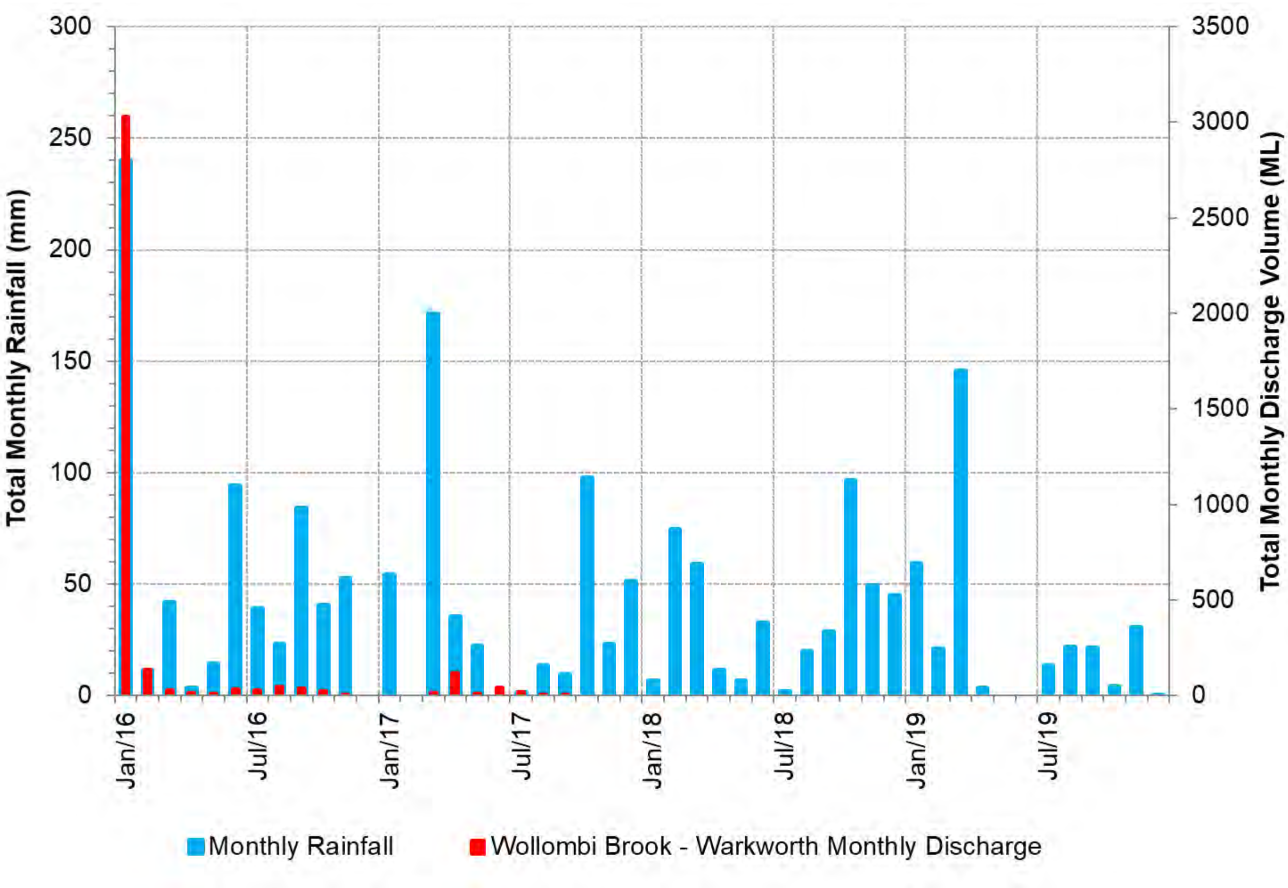


Figure 3-3 Wollombi Brook Monthly Surface Water Flow Volumes vs Monthly Rainfall

3.2 Geology

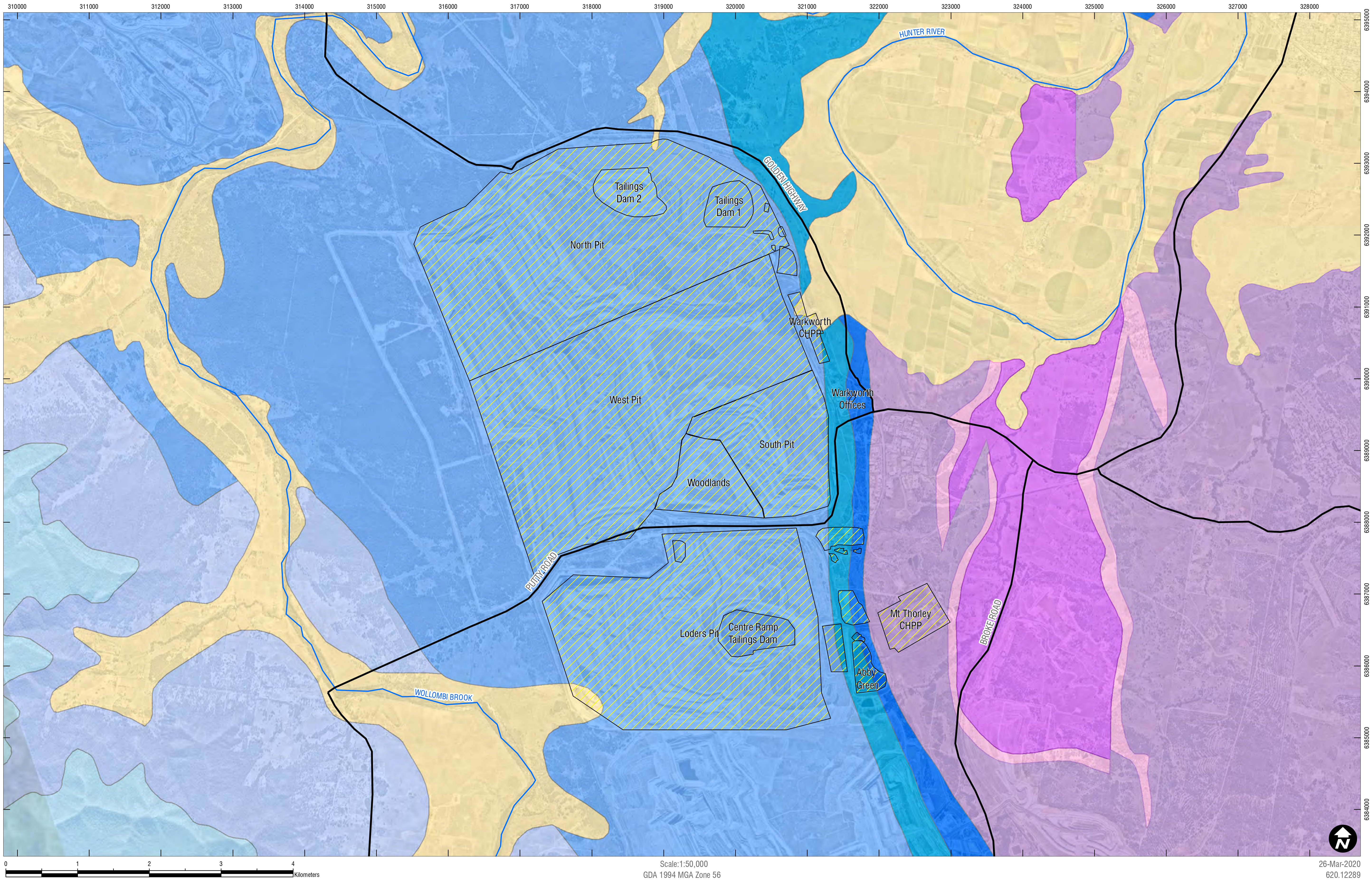
MTW lies within the Hunter Coalfields, which are dominated by the Permian aged Whittingham Coal Measures of the Sydney Basin. The Whittingham Coal Measures are made up of the Jerrys Plains Sub-group and Vane Sub-group. These units comprise economic coal seams along with overburden and interburden consisting of sandstone, siltstone, tuffaceous mudstone and conglomerate. The Whittingham Coal Measures are truncated to the east by the Hunter-Mooki Thrust Fault and occur at MTW as stratified (layered) sequences that dip at a shallow angle (2^0 to 5^0) to the south-west. The coal seams subcrop to the east of MTW.

Along the Hunter River and Wollombi Brook thin Quaternary alluvial deposits unconformably overlie the Permian strata. The alluvial deposits comprise surficial fine grained sediments (i.e. silts and clays). Along major watercourses (i.e. Hunter River and Wollombi Brook) the surficial sediments overlie basal sands and gravels.

Table 3-2 presents a summary of site geology and **Figure 3-4** presents a map of the geology of the MTW site and surrounds.

Table 3-2 MTW Generalized Stratigraphy

Age	Stratigraphic Unit		Description
Cainozoic	Quaternary sediments - alluvium (Qa)	Surficial alluvium (Qhb)	Shallow sequences of clay, silty sand and sand.
		Productive basal sands/gravel (Qha)	Basal sands and gravels along major watercourses (i.e. Hunter River).
	Silicified weathering profile (Czas)		Silcrete
	Alluvial terraces (Cza)		Silt, sand and gravel
Jurassic	Volcanics (Jv)		Flows, sills and dykes
Permian	Whittingham Coal Measures	Jerrys Plains Sub-group (Pswj)	Coal bearing sequences interbedded with sandstone and siltstone. Coal seams (youngest to oldest) include Whybrow Seam, Redbank Creek Seam, Wambo Seam, Whynot Seam, Blakefield Seam, Glen Munro Seam, Woodlands Hill Seam, Arrowfield Seam, Bowfield Seam, Warkworth Seam, Mt Arthur Seam, Piercefield Seam, Vaux Seam, Broonie Seam and Bayswater Seam.
		Archerfield Sandstone	Lithic sandstone marker bed.
		Vane Sub-group (Pswv)	Coal bearing sequences interbedded with sandstone and siltstone. Coal seams (youngest to oldest) include Lemington Seam, Pikes Gully Seam, Arties Seam, Liddell Seam, Barrett Seam and Hebden Seam.



H:\Projects-SLR\620-BNE\620-BNE\620.12289 Warkworth GW\06 SLR Data\01 CADGIS\ArcGIS\2019 AEMR\SLR620122289_2019_AEMR_F03_4_Geology_001.mxd

- MTW Infrastructure
- Main road
- Major watercourses

Hunter Coalfields 100k Geology

- Qa - Quaternary Alluvium
- Rn - Narrabean Group
- Psl - Newcastle Coal Measures
- Pswj - Jerrys Plains Subgroup
- Pms - Muree Sandstone
- Pswv - Archerfield Ss. Vane Subgroup
- Pswc - Saltwater Creek Formation
- Pmm - Mulbring Siltstone
- Pmb - Branxton Formation

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Mt Thorley Warkworth
2019 Annual Groundwater Review
Surface Geology

Figure 3-4

4 Groundwater Units

The principal groundwater units at MTW and its immediate surrounds are the productive alluvium associated with the Hunter River and Wollombi Brook, the Permian coal seams of the Whittingham Coal Measures and associated regolith material. Description of the groundwater units was derived from historical groundwater assessment reports, discussed in **Section 2.2**.

4.1 Regolith

Regolith material has been identified in the east of the project area overlying the Permian coal measures to depths of around 5 m. The material is clay rich comprising clays, sandy clays and minor clay sands with permeability of around 3.3 x 10^{-5} m/day to 9.5 x 10^{-3} m/day. The material has previously been categorised as alluvium. The regolith is recharged by rainfall infiltration and potential seepage from mine infrastructure.

4.2 Alluvium

The Quaternary alluvium is an unconfined groundwater system that is recharged by rainfall infiltration, streamflow and upward leakage from the underlying stratigraphy, particularly in undisturbed areas (i.e. away from active mining). The potentiometric surface and flow direction within the alluvium is a subdued reflection of topography. Groundwater within the Hunter River alluvium flows in a southerly direction, while water within the Wollombi Brook alluvium flows in a north to north-easterly direction towards the Hunter River.

Regionally, the Hunter River and Wollombi Brook are predominantly gaining water from the surrounding alluvium, as well as from rainfall and regulated flow (i.e. dam releases). However, there are also areas where the rivers recharge the underlying alluvium. These losing conditions can occur around areas of active mining, where the hydraulic gradient is increased due to depressurisation of the underlying coal measures. Losing conditions also occur within the more topographically elevated tributaries of the main water courses, where the water table is deeper and not connected directly to the streams.

While “less productive” groundwater within the surficial alluvium (Qhb **Table 3-2**) does not meet the ANZECC (2000) water quality guidelines for stock water supply, the “highly productive” alluvium (basal sands and gravels (Qha **Table 3-2**)) is considered suitable for stock water supply from a water quality perspective. However, most agricultural producers (crop and cattle) utilise surface water resources (Hunter River and Wollombi Brook) in preference to alluvial groundwater.

Aeolian sands referred to as the Warkworth Sands are present north to north-west of North Pit, and within a small area to the south-west of Loders Pit. The Warkworth Sands comprise fine grained sands to a thickness of approximately 3 m. The unit overlies clay rich regolith material, which apparently forms a perched aquifer recharged from rainfall infiltration (AGE, 2014a). The Warkworth Sands supports woodland (Warkworth Sands Woodland), which is classified as an Endangered Ecological Community (EEC) under the *Threatened Species Conservation Act* 1995 and Critically Endangered (CE) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

4.3 Permian Coal Measures

The Whittingham Coal Measures outcrop across the north to east of MTW. The coal measures form unconfined groundwater systems at outcrop, becoming semi-confined to confined as they dip towards the south-west.

Recharge occurs from direct rainfall to the ground surface, infiltrating into the formations through the thin soil cover and weathered profile. The coal measures also occur at subcrop in localised zones beneath alluvium associated with the Hunter River and Wollombi Brook, where the unit is recharged by downward seepage where gradients promote this flow.

The coal seams are typically moderately to slightly permeable, whilst the hydraulic conductivity of the interburden material is generally less than coal seams but is more variable, depending on the predominance of fractures in the rock mass. The hydraulic conductivity of the coal seams generally decreases with depth due to the closure of the cleats with increasing stratigraphic pressure. Conglomerates and weathered sandstone can be present to depths of around 16 m, and exhibit hydraulic conductivity of around 1.2×10^{-3} m/day to 9.5×10^{-2} m/day.

The direction of groundwater flow for the Whittingham Coal Measures is influenced by the local geomorphology and structural geology, as well as the long history of mining within the region which has significantly altered groundwater flow paths within the Permian units. Groundwater flow in the Permian aquifers on a regional scale follows the regional topography, flowing in a north-easterly direction. However, on a local scale groundwater levels show drawdown impacts associated with the extensive active mining areas. Groundwater discharge from the Whittingham Coal Measures currently occurs as discharge to active mining and abstraction bores, as well as upward seepage to the Quaternary alluvium where hydraulic gradients promote this flow.

There is no significant usage of groundwater from the Permian coal measures, likely due to the poor quality that generally exceeds ANZECC (2000) water quality guidelines for stock supply, and presence of perennial surface water flows (Hunter River and Wollombi Brook) and the more productive alluvial aquifer.

5 Groundwater Monitoring

5.1 Groundwater Monitoring Program

Groundwater monitoring is conducted at MTW in accordance with the MTW WMP. The monitoring results are used to establish and monitor trends in physical and geochemical parameters of surrounding groundwater potentially influenced by mining.

The monitoring program at MTW measures the Standing Water Level (SWL) in monitoring bores, reported as elevation (mAHD). The data is compared against background data, EIS predictions and historical trends as a means of assessing MTW related impacts to the quantity of groundwater in the various aquifers. The monitoring program at MTW also assesses the quality of groundwater against background data and historical trends. Groundwater quality is evaluated through the parameters of pH and EC. On a periodic basis (nominally once per annum) a comprehensive suite of analytes is measured, including major anions, cations and metals. Prior to sampling for comprehensive analysis, bore purging is undertaken to ensure a representative sample is collected.

Groundwater quality monitoring data is reviewed on a quarterly basis. The review involves a comparison of measured pH and EC results against internal trigger values which have been derived from the historical data set. Trigger limits are calculated as the 95th percentile maximum value (EC and pH) and the 5th percentile minimum value (pH only) from data collected since 2011. Trigger levels have been set based on target stratigraphy. A site specific investigation will be initiated where three consecutive measurements of EC or pH exceed trigger values or where professional judgement determines that a single deviation or a developing trend could result in environmental harm.

The groundwater monitoring network has been installed progressively over the life of the operations at MTW and acquired through land purchase. In relation to the WMP the groundwater monitoring network at MTW comprises 60 open standpipe bores installed into various geologic units. As outlined within the WMP, bores are grouped based on geology, as summarised below:

- Regolith;
- Hunter River alluvium;
- Wollombi Brook alluvium;
- Aeolian Warkworth Sands;
- Whittingham Coal Measures:
    - Redbank Seam;
    - Wambo Seam;
    - Blakefield Seam;
    - Woodlands Hill Seam;
    - Bowfield Seam;
    - Warkworth Seam;
    - Vaux Seam; and
    - Bayswater Seam.
- Shallow Overburden

In addition, 10 vibrating wire piezometers (VWP's) with a total of 36 sensors are present across the site. However, based on discussion with site personnel and review of the data it is understood some of the VWP sensors may not be fully operational due to a range of factors (i.e. batteries). Details of each of the MTW monitoring bores as well as each bore's respective monitoring program are provided in **Appendix A** and the location of the bores are presented in **Figure 5-1**.

In Q1 and Q2 2019 an additional four VWPs were installed at MTW as part of ongoing site investigations. These bores are not included within the compliance network within the WMP, but details on the bores are presented in **Table 5-1** below for background reference.

Table 5-1 2019 VWP Construction Details Summary

<table>
<tr><th>Bore ID</th><th>Easting(s) GDA94 z56</th><th>Northing(s) GDA94 z56</th><th>Ground RL (m AHD)</th><th>Sensor Depth (m bTOC)</th><th>Target Aquifer</th><th>Comments</th></tr>
<tr><td>LD603_P1</td><td rowspan="6">321198</td><td rowspan="6">6386574</td><td rowspan="6">90.87</td><td>275.17</td><td>Below Bayswater</td><td rowspan="6">P1 - not currently connected</td></tr>
<tr><td>LD603_P2</td><td>268.29</td><td>Bayswater Seam</td></tr>
<tr><td>LD603_P3</td><td>191.65</td><td>Vaux Seam</td></tr>
<tr><td>LD603_P4</td><td>148.7</td><td>Mt Arthur Seam</td></tr>
<tr><td>LD603_P5</td><td>79.95</td><td>Mt Arthur Seam Overburden</td></tr>
<tr><td>LD603_P6</td><td>37.3</td><td>Spoil</td></tr>
<tr><td>WD646R_P1</td><td rowspan="6">316795</td><td rowspan="6">6392767</td><td rowspan="6">99.590</td><td>359.53</td><td>Below Bayswater Seam</td><td rowspan="6">P1 - not currently connected.

P2 - potential sensor failure following installation.</td></tr>
<tr><td>WD646R_P2</td><td>340.72</td><td>Bayswater Seam</td></tr>
<tr><td>WD646R_P3</td><td>304.8</td><td>Bayswater/Vaux Interburden</td></tr>
<tr><td>WD646R_P4</td><td>261.35</td><td>Vaux Seam</td></tr>
<tr><td>WD646R_P5</td><td>181.76</td><td>Mt Arthur Seam</td></tr>
<tr><td>WD646R_P6</td><td>72.97</td><td>Mt Arthur Overburden</td></tr>
<tr><td>WD645_P1</td><td rowspan="5">319108</td><td rowspan="5">6390127</td><td rowspan="5">157.49</td><td>311.99</td><td>Below Bayswater Seam</td><td rowspan="5"></td></tr>
<tr><td>WD645_P2</td><td>295.52</td><td>Bayswater Seam</td></tr>
<tr><td>WD645_P3</td><td>249.22</td><td>Bayswater/Vaux Interburden</td></tr>
<tr><td>WD645_P4</td><td>219.85</td><td>Vaux Seam</td></tr>
<tr><td>WD645_P5</td><td>205.36</td><td>Base of spoil</td></tr>
<tr><td>MTD650_P1</td><td rowspan="5">317618</td><td rowspan="5">6385929</td><td rowspan="5">75.21</td><td>423.77</td><td>Below Bayswater Seam</td><td rowspan="5"></td></tr>
<tr><td>MTD650_P2</td><td>403.86</td><td>Bayswater Seam</td></tr>
<tr><td>MTD650_P3</td><td>376.02</td><td>Bayswater/Vaux Interburden</td></tr>
<tr><td>MTD650_P4</td><td>341.23</td><td>Vaux Seam</td></tr>
<tr><td>MTD650_P5</td><td>297</td><td>Mt Arthur Seam</td></tr>
</table>

As outlined in **Appendix A**, full laboratory water quality analysis is required to be conducted for 60 of bores, on an annual basis. The full water quality analysis includes:

- Total dissolved solids (TDS);
- Major ions (Ca, Cl, K, Na, SO_4 (or S), CO_3);
- Total alkalinity, bicarbonate alkalinity, carbonate alkalinity, hydroxide alkalinity; and
- Total metals (Al, As, B, Cd, Cu, Hg, Mg, Ni, Pb, Se, and Zn.

Six of the 60 bores are also analysed for total metals Mo, V and Cr, as shown in **Appendix A.** Discussion on the groundwater monitoring network is presented in **Section 6**.

5.2 Groundwater Monitoring Methodology

MTW engages field contractors AECOM to carry out sampling and analysis. Sampling is required to be undertaken in accordance with relevant Australian Standards and other regulatory guidelines. Samples are analysed by laboratories that are National Association of Testing Authorities (NATA) accredited or equivalent for the parameters being analysed.

The WMP documents that sampling is to be undertaken in accordance with AS 5667.1:-1998, *Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples and AS 5667.11-1998, Guidance on Sampling of Groundwaters*. Groundwater bores are purged prior to sample extraction for all samples requiring comprehensive laboratory analysis.

From review of the contractors sampling field sheets, it is understood that the quarterly and annual groundwater samples for the majority of bores are collected following purging either by using a Solinist low flow pump or bailer (3x casing volumes where possible) and water levels and field parameters (i.e. EC and pH) monitored. This approach is considered consistent with *AS 5667.1:-1998.* For bores with 25 mm and 32 mm casing, it is understood that the sample is collected following the purging using a bailer with a one-way check valve at the bottom of the bailer. Bores are purged until the field parameters stabilise and then they are sampled.

For the remaining bores (WOH1239A, WOH2141A, WOH2153A, WOH1254A, WOH2155A, WOH2156A, WD622P, MBW02 and MBW03) it is understood that the quarterly and annual groundwater samples are collected as grab samples using a disposable bailer. As outlined within *AS 5667.11-1998*, mineral material can accumulate within boreholes. Therefore, to collect representative groundwater samples the bore should be purged (4 to 6 times the well volume) and water quality parameters stabilised before sampling.

H:\Projects-SLR\620-BNE\620-BNE\620.12289 Warkworth GW\06 SLR Data\01 CADGIS\ArcGIS\2019 AEMR\SLR62012289_2019_AEMR_F04_1_GWMonitoring_001.mxd

0 1 2 3 4 Kilometres

Scale: 1:75,000
GDA 1994 MGA Zone 56

26-Mar-2020

Main road
Major watercourses
Groundwater Monitoring Points
MTW Infrastructure

Sheet Size : A4

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Mt Thorley Warkworth
2019 Annual Groundwater Review
Groundwater Monitoring Network

Figure 4-1

5.3 Groundwater Triggers

The WMP includes groundwater assessment criteria, including water quality trigger levels for investigating potentially adverse groundwater impacts. Trigger levels were established for EC based on the 95th percentile of baseline data, and the trigger levels for pH based on the 5th and 95th percentiles, as presented in the 2018 WMP and summarized in **Table 5-2**.

Groundwater quality readings from the site monitoring bores have been compared to the relevant trigger levels in **Section 6.3**.

Table 5-2 Groundwater Quality Triggers by Location

Location	Target Seam/ Stratigraphy	EC (95th) µS/cm	pH (5th)	pH (95th)
OH786	Regolith*	950	6.8	7.7
OH787	Regolith*	18,185	7.2	7.7
OH788	Hunter River Alluvium	11,742	7.0	7.9
OH942	Regolith*	25,380	6.4	7.0
OH943	Hunter River Alluvium	8,415	7.1	7.6
PZ7S	Aeolian Warkworth Sands	1,752	6.7	7.5
PZ8S	Wollombi Brook Alluvium	15,126	6.5	7.0
PZ9S	Wollombi Brook Alluvium	16,202	6.8	7.0
PZ7D	Shallow Overburden	17,490	6.9	8.1
PZ8D	Shallow Overburden	17,490	6.9	8.1
PZ9D	Shallow Overburden	17,490	6.9	8.1
MTD616P	Shallow Overburden	17,490	6.9	8.1
MTD614P	Shallow Overburden	17,490	6.9	8.1
MBW02	Shallow Overburden	17,490	6.9	8.1
MB15MTW01D	Shallow Overburden	17,490	6.9	8.1
MTD605P	Shallow Overburden	17,490	6.9	8.1
MB15MTW02D	Shallow Overburden	17,490	6.9	8.1
MB15MTW03	Shallow Overburden	17,490	6.9	8.1
WD625P	Woodlands Hill / Whybrow	11,996	7.1	7.3
WOH2153A	Redbank	16,123	7.0	7.9
WOH2154A	Redbank	16,123	7.0	7.9
WOH2155A	Redbank	16,123	7.0	7.9
WOH2156A	Redbank	16,123	7.0	7.9
WOH2153B	Wambo	13,843	7.2	7.8
WOH2154B	Wambo	13,843	7.2	7.8
WOH2155B	Wambo	13,843	7.2	7.8
WOH2156B	Wambo	13,843	7.2	7.8
WD622P	Wambo	13,843	7.2	7.8

Location	Target Seam/ Stratigraphy	EC (95th) µS/cm	pH (5th)	pH (95th)
MBW04	Wambo	13,843	7.2	7.8
WOH2139A	Blakefield	15,161	6.6	7.6
OH1122 (1)	Blakefield	15,161	6.6	7.6
OH1125 (1)	Blakefield	15,161	6.6	7.6
OH1125 (3)	Bowfield	14,696	6.6	7.0
OH1138 (1)	Warkworth	19,657	6.3	7.0
OH1138 (2)	Warkworth	19,657	6.3	7.0
OH1121	Vane Subgroup†	17,745	6.7	7.1
OH1126	Vaux	17,745	6.7	7.1
OH1137	Vaux	17,745	6.7	7.1
OH1127	Vane Subgroup†	22,991	6.6	7.5
GW 9706	Bayswater	22,991	6.6	7.5
GW 9707	Bayswater	22,991	6.6	7.5
GW 9708	Bayswater	22,991	6.6	7.5
GW 9709	Bayswater	22,991	6.6	7.5
GW98MTCL1	Bayswater	22,991	6.6	7.5
GW98MTCL2	Bayswater	22,991	6.6	7.5

Note: ** Bore located outside extent of mapped alluvium and bore logs and site geology shows the bore actually intersects regolith material not Hunter River Alluvium as categorised within WMP*

† Bore located outside extent of mapped Jerry's Plains Subgroup and likely intersects underlying Vane Subgroup as per 1:25k geological mapping

5.4 Trigger Investigations

As part of the annual review of groundwater level and quality trends for 2018, SLR (2019) identified several readings outside of the trigger threshold range for water quality (EC and pH) and water levels where further investigation was required. A summary of these and works undertaken to investigate the trends is included below:

- Bore PZ9S recorded pH at or above the trigger threshold of 7.0. The pH readings coincided with a general decline in groundwater level and SLR (2019) indicated it may relate to sampling methodology and influence from sediment at the base of the bore. Review of sampling methodology to ensure representative samples were collected was recommended.
- Bore OH1138(1) recorded pH below the trigger threshold of 6.3 over 2018 and EC above 19,657 µS/cm. The bore is constructed as a nested monitoring point with 32 mm PVC to 42.8 m depth screened within the Warkworth Seam. The bore recorded a general rise in EC over time with a decline in groundwater levels. The decline in levels was identified as potentially relating to abstraction from the Lemington Underground (LUG) Bore 1.25 km to the north west, which abstracts from the abandoned Lemington Underground board and pillar workings that were mined into the Mt Arthur Seam.

6 Monitoring Results

6.1 Data Recovery and Network Review

Over 2019, groundwater monitoring was carried out at 60 monitoring bores across MTW. No water level or quality data was collected from ten of the monitoring bores over 2019 due to them being dry. The bores and sites with a data capture rate of less than 100 per cent are outlined in **Table 6-1**.

Table 6-1 Groundwater Monitoring Data Recovery

Location	Type	Data Recovery	Comments
OH943	WQ	0%	Insufficient water for field test and lab sample – March, June, September & December 2019
OH944	WL and WQ	0%	Bore dry over 2019
OH786	WQ	75%	Insufficient water for lab sample – June 2019 (field results only)
PZ9S	WQ	75%	Insufficient water for field test and lab sample – June, September & December 2019
MBW02	WL and WQ	75%	No access – February 2019
MB15MTW04	WL and WQ	0%	Bore dry over 2019
MB15MTW05	WL and WQ	0%	Bore dry over 2019
MB15MTW06	WL and WQ	0%	Bore dry over 2019
MB15MTW07	WL and WQ	0%	Bore dry over 2019
MB15MTW08	WL and WQ	0%	Bore dry over 2019
MB15MTW09	WL and WQ	0%	Bore dry over 2019
MB15MTW10	WL and WQ	0%	Bore dry over 2019
MB15MTW11	WL and WQ	0%	Bore dry over 2019
GW9709	WQ	75%	Insufficient water for field test – December 2019
OH1125 (2)	WL and WQ	0 %	Bore dry over 2019
OH1137	WL and WQ	75% (WL) / 25% (WQ)	Bore blocked – June 2019, Bore dry – September & December 2019
WHO2154B	WQ	0%	Bore blocked – March 2019, Insufficient Water for lab sample and field test – May, August and November 2019
WOH2156B	WQ	75%	Insufficient water for lab sample and field test – May, August & November 2019

Groundwater levels are recorded by site VWP's and data loggers installed in select monitoring bores. Level data was successfully downloaded from nine of the VWP sites and 18 of the loggers. Sites where data collection issues have been encountered are outlined in **Table 6-2.** Further work to check the VWP's and monitoring bore loggers are working correctly (i.e. check / replacing batteries and logger depths) is ongoing.

Table 6-2 Logger Data Recovery

Bore ID	Serial Number	Comments
PZ8S		No logger installed in bore
PZ8D	2053696	Data erroneous after February 2019 (data does not match manual dip measurements). It is suspected that the logger install depth may be different to the reported depth or that the logger has failed – further investigation required to confirm logger depth and status.
PZ9S	2053704	Water level below base of logger therefore the logger is only recording atmospheric pressure – recommend logger be lowered if sufficient water present above base of bore.
PZ7S	2016488	2019 data does not match manual dip measurements. It is suspected that the logger install depth may be different to the reported depth – further investigation required to confirm logger depth.
PZ7D	2053695	2019 data does not match manual dip measurements. It is suspected that the logger install depth may be different to the reported depth – further investigation required to confirm logger depth.
MB15MTW02S	2053694	2019 data does not match manual dip measurements. It is suspected that the logger install depth may be different to the reported depth – further investigation required to confirm logger depth.
MB15MTW02D	2039901	Erroneous data from June 2019. Logger to be replaced during next quarterly monitoring event.

Table 6-3 VWP Data Recovery

Location	Sensor (s)	Comments
WD622	1 to 5	Data erroneous – potential sensor failure
MTD518	1 to 3	Data gap between March and July 2019 following removal of logger. Logger replaced in July 2019 and all sensors appear to be recording correctly.
PZ2	1 & 2	No longer exists
MTD605	3, 5 & 6	Data potentially erroneous – calculated SWL elevation above VWP surface elevation. Sensor 5 data erroneous from 01/11/19 – potential sensor failure Sensor 6 data erroneous from 23/06/19 – potential sensor failure
MTD613	1	Erroneous data between June and August 2019, however sensor appears to be working correctly after this period.
MTD614	3 to 5	Data erroneous – potential sensor failure
WD462	1 to 3	Sensor data not collected.
PZ1	1 & 2	Sensor 2 logger replaced in June 2019. Sensor 1 and 2 depths and calibration details unknown

Overall, the current monitoring network and program is generally adequate for satisfying current monitoring requirements of the WMP. There is good spatial of coverage of monitoring locations across the site, with multiple bores and VWP sensors installed into each relevant aquifer unit when take into account the installation of additional VWP's in 2019. It is recommended that the Groundwater Management Plan be updated to incorporate these additional VWP's, remove destroyed/erroneous monitoring points and to more clearly identify the purpose of each bore based on its location and construction. Compliance conditions should also be updated to align with the revised network and identified purpose of bores.

6.2 Water Levels

A summary of the water level results is provided for each of the main water bearing units (regolith, alluvium and Permian coal measures) below. Routine water level readings for 2019 are presented in **Appendix B**.

6.2.1 Regolith

In the 2018 annual environmental monitoring report (SLR, 2019) a review of the construction depths for bores previously identified as intersecting the Hunter River Alluvium in the WMP was undertaken. The review found that three bores (OH786, OH787 and OH942) are in fact screened within regolith material meaning surficial clays and shallow deeply weathered Permian coal measures.

Over 2019, groundwater within the regolith bores occurred at depths of between 2.75 m and 13.96 m below surface. **Figure 6-4** presents the historical groundwater levels for all three regolith bores, along with rainfall trends (CRD) and stream elevations recorded at the Hunter River stream gauges at Mason Dieu and Long Point.

The greatest fluctuations in water level were recorded for bore OH786 which intersects the shallow regolith east of TD1 and Dam 1N. Flunctuations in groundwater levels within OH786 have fluctuated over time but generally show a decline since 2016. This may relate to climate trends and reduced rainfall recharge, or potentially relate to cessation of storage within TD1 from 2012 and water storage in Dam 1N. The adjacent bore OH942 is installed approximatley 6 m deeper into the weatherd Permian Coal Measures and recorded stable groundwater levels. This indicates the recharge source is largely restricted to the shallow regolith.

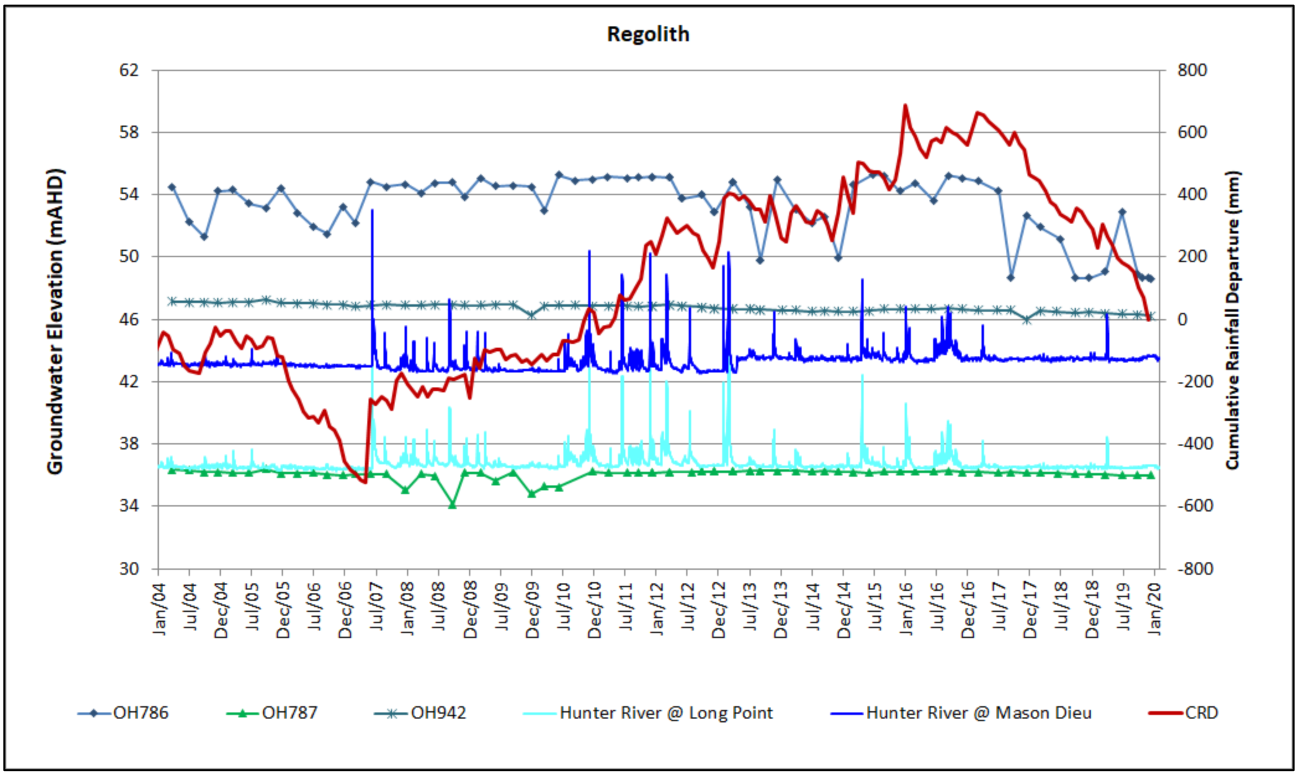


Figure 6-1 Groundwater Levels – Regolith

6.2.2 Alluvium

Groundwater level trends are discussed below for the Warkworth Sands, alluvium along the Hunter River and alluvium along Wollombi Brook.

6.2.2.1 Warkworth Sands

Bores within the Warkworth Sands include PZ7S and MB15MTW04 to MB15MTW11. All bores within the Warkworth Sands are equipped with dataloggers that are set to record groundwater levels on a six hourly basis. Levels have been compensated using barometric levels recorded at the MTW site. Barometric levels used to compensate the 2018 data was sourced from the neighbouring Bulga Mine which resulted in a degree of 'noise' in the readings.

Bore PZ7 is a nested bore with screen within the Warkworth Sands to 11.1 m depth (PZ7S), and screen within the shallow overburden material at 30.5 m depth (PZ7D). Historical water level data for the bores is presented in **Figure 6-2**. **Figure 6-2** shows that groundwater elevations within the coal measures at PZ7D have historically been slightly higher than levels in the overlying Warkworth Sands, indicating a potential upward gradient. Since 2016 this gradient has reduced, with levels within the Warkworth Sands and shallow overburden showing similar elevations and trends. **Figure 6-2** shows that over 2019 groundwater levels within the Warkworth Sands and shallow overburden material at PZ7S and PZ7D generally declined. This trend appears to correspond with the general decline in rainfall over this period; however, the logger data does not show a response to the above average rainfall experienced in March 2019. Further investigation into the local ground conditions, condition of the nested bore and functionality of the bore loggers should be undertaken, to understand the interaction between the two bore depths.

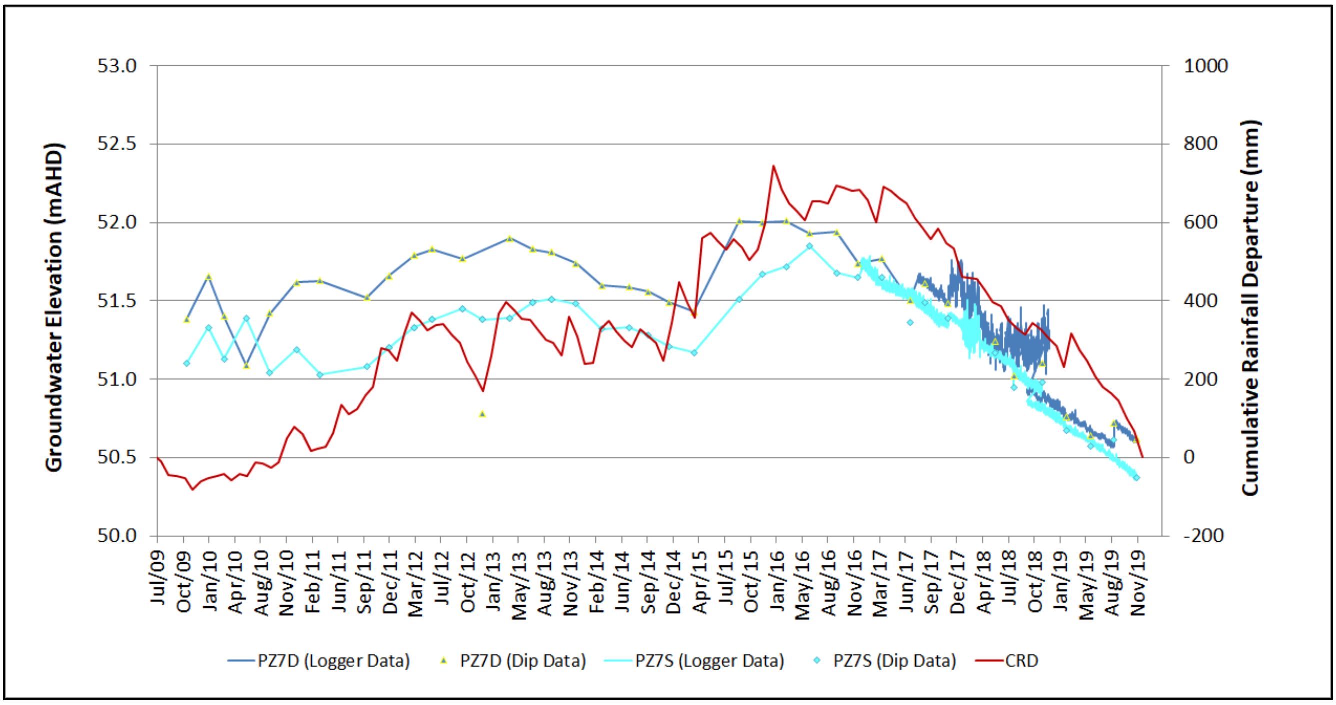


Figure 6-2 Groundwater Levels – Warkworth Sands Bore PZ7S and PZ7D

Bores MB15MTW04 to MB15MTW11 were generally recorded as dry since construction in 2016. An exception to this was bore MB15MTW06, which has historically shown a groundwater level response to rainfall events (**Figure 6-3)**. Bore MB15MTW06 was generally recorded as dry throughout 2019, which generally corresponds with the below average rainfall recorded during this period, except for the above average rainfall in March 2019 (**Figure 6-3**). Further review into the groundwater conditions associated with the Warkworth Sands is recommended.

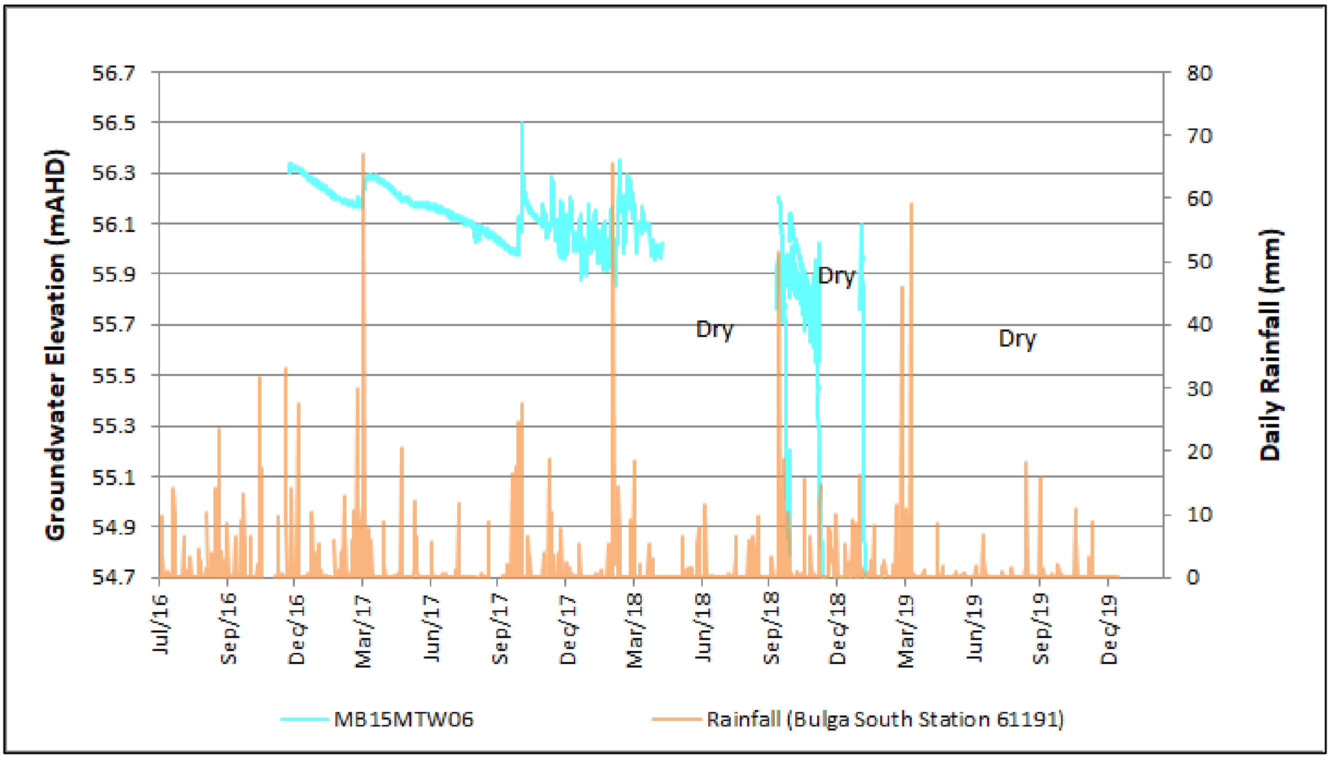


Figure 6-3 Groundwater Levels – Warkworth Sands Bore MB15MTW06

6.2.2.2 Hunter River Alluvium

Three bores within the monitoring network intersect alluvium along the Hunter River, these are OH788, OH943 to OH944. Over 2019, bore OH944 was dry, with water levels recorded at or below the base of the bore. According to available bore construction details, bore OH944 is apparently 8.2 m deep and historical monitoring records detail the bore has often been dry or had insufficient water present to sample since 2011.

Of the bores with water present, alluvial groundwater occurred at depths of between 9.47 m and 9.61 m below surface over 2019. **Figure 6-4** presents the historical groundwater levels for all three Hunter River alluvium bores, along with rainfall trends (CRD) and stream elevations recorded at the Hunter River stream gauges at Mason Dieu and Long Point. As shown in **Figure 6-4**, groundwater levels have remained relatively stable at bores OH788 and OH943 since monitoring commenced in 2004, with less than 0.5 m variation in levels recorded. There is a very slight decline since 2016 recorded for both bores that may relate to the below average rainfall period. However, historical readings show no correlation with rainfall trends and no response to peak rainfall periods. It is recommended that the construction and geology at the two bores be reviewed to verify they do intersect alluvium.

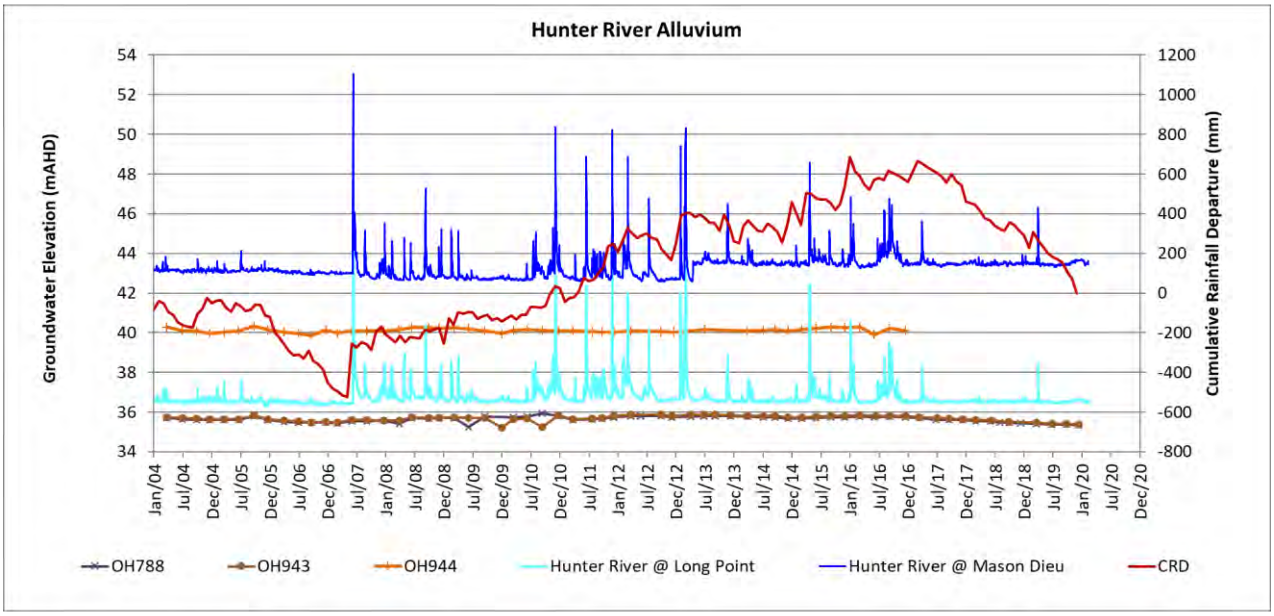


Figure 6-4 Groundwater Levels – Hunter River Alluvium

6.2.2.3 Wollombi Brook Alluvium

Five bores intersect the alluvium along the Wollombi Brook: G3, PZ8S, PZ9S, MB15MTW01S, and MB15MTW02S. Each of the bores is nested with a deeper bore screened within the underlying overburden material of the Permian coal measures.

Groundwater level trends for bores west of MTW (MB15MTW01 and MB15MTW02) are presented in **Figure 6-5,** which includes rainfall trends (CRD) and stream elevations for Wollombi Brook as recorded at Bulga. Groundwater levels at the two locations are recorded with data loggers and manual dip readings. It should be noted that due to data logger failure groundwater level data for MB15MTW02D is only accurate up to June 2018. Any data recorded after June 2018 has not been included within this review. Manual dip readings have therefore been used instead, to provide a basic indication of changes to groundwater levels. Manual dip readings have also been plotted alongside the logger data for MB1MTW02S. The reason for this is that following review of the logger data, the readings between March and May 2019 were found to be erroneous with record levels approximately 0.5m lower than recorded before and after this period. It is believed that this difference is likely to have been due to a change in the logger depth placement. The logger data has therefore been adjusted to account for the difference in logger depth over this period. Lastly, it should be noted that the 'noisy' data observed for all bores throughout 2018 is due to the use of barometric data from the neighbouring Bulga mine during this period.

Bores MB15MTW01 and MB15MTW02 are located adjacent to Wollombi Brook. **Figure 6-5** shows that over 2019 alluvial groundwater elevations along Wollombi Brook were below stream elevations, indicating losing conditions. Groundwater levels within the alluvium and shallow overburden steadily declined over 2019. Trends between the alluvium and underlying shallow overburden material follow similar trends along Wollombi Brook. This contrasts with observations further away from the Wollombi Brook, as discussed below.

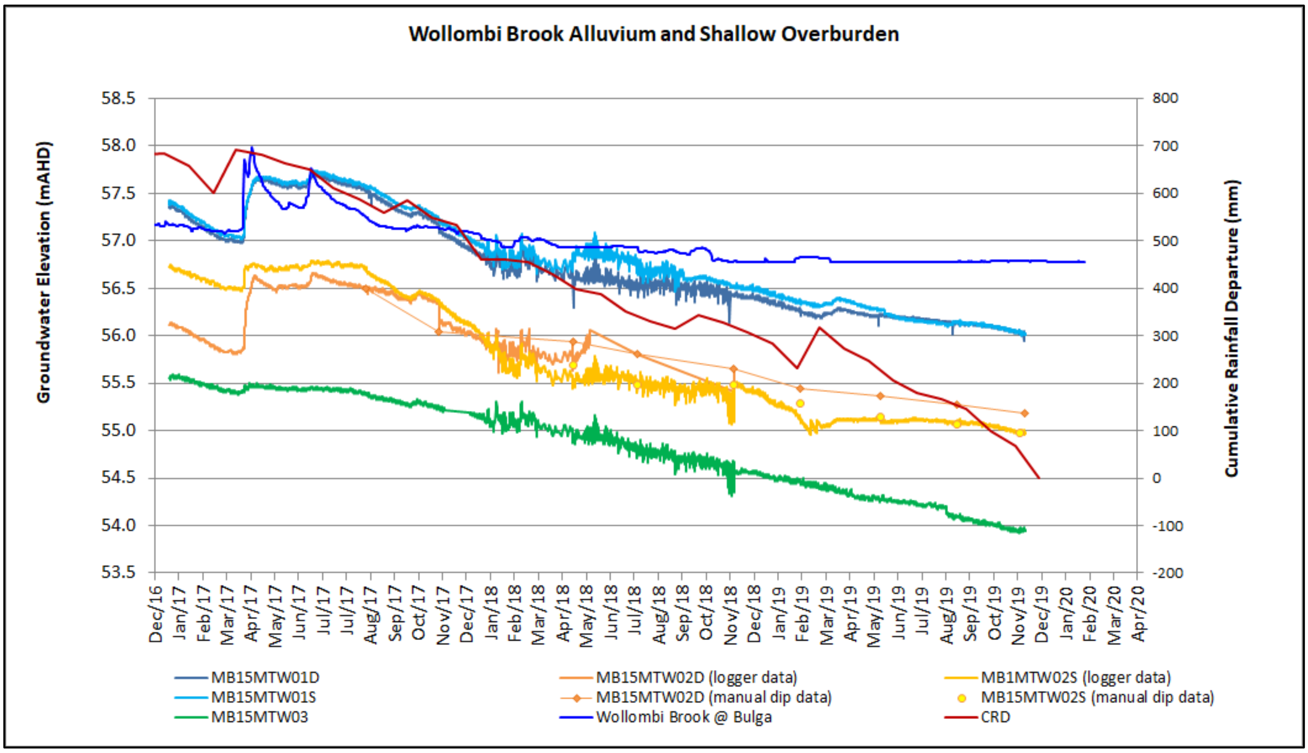


Figure 6-5 Groundwater Levels – Wollombi Brook Alluvium MB15MTW01 and MB15MTW02

Groundwater level trends for bores over 600 m from Wollombi Brook, at the south-western end of site (PZ8 and PZ9), are presented in **Figure 6-6**. Trends for the MB15MTW alluvial bores are also included for comparison. The graph also includes rainfall trends (CRD) and stream elevations for Wollombi Brook as recorded at Bulga. As with the bores adjacent to Wollombi Brook, **Figure 6-6** shows a general decline in groundwater levels within the alluvium following rainfall trends, with a slight rise following the March 2019 above average rainfall event.

Figure 6-6 shows that alluvial groundwater elevations are higher than the underlying overburden material, indicating a downward flow gradient. The exception to this is bore site MB15MTW02 where the alluvial groundwater elevations are marginally lower than the underlying overburden material, indicating a potential upward flow gradient. It is also noted that groundwater levels within shallow overburden bore PZ9D declined from commencement of monitoring in 2009 to 2016. Between 2016 and 2017 groundwater levels gradually rose before becoming more stable over 2019. Bore PZ9D is positioned closest to the active operations at Loders Pit. Therefore, the decline in groundwater levels within the shallow overburden material likely reflects depressurisation from mining, as predicted as part of the mine approvals (AGE, 2014b). Both PZ9S and PZ9D are shallow, at 7 m and 24 m depth, respectively. Therefore, the difference in groundwater trends highlights limited vertical hydraulic connection between the Permian coal measures and surficial sediments at this location. Overburden bore PZ8D also recorded a decline in levels between June and December 2019, which is not observed in PZ8S alluvial bore. The bores are located approximately 800 m from Loders Pit and the decline in the overburden likely reflects depressurisation from mining, as predicted by AGE (2014b).

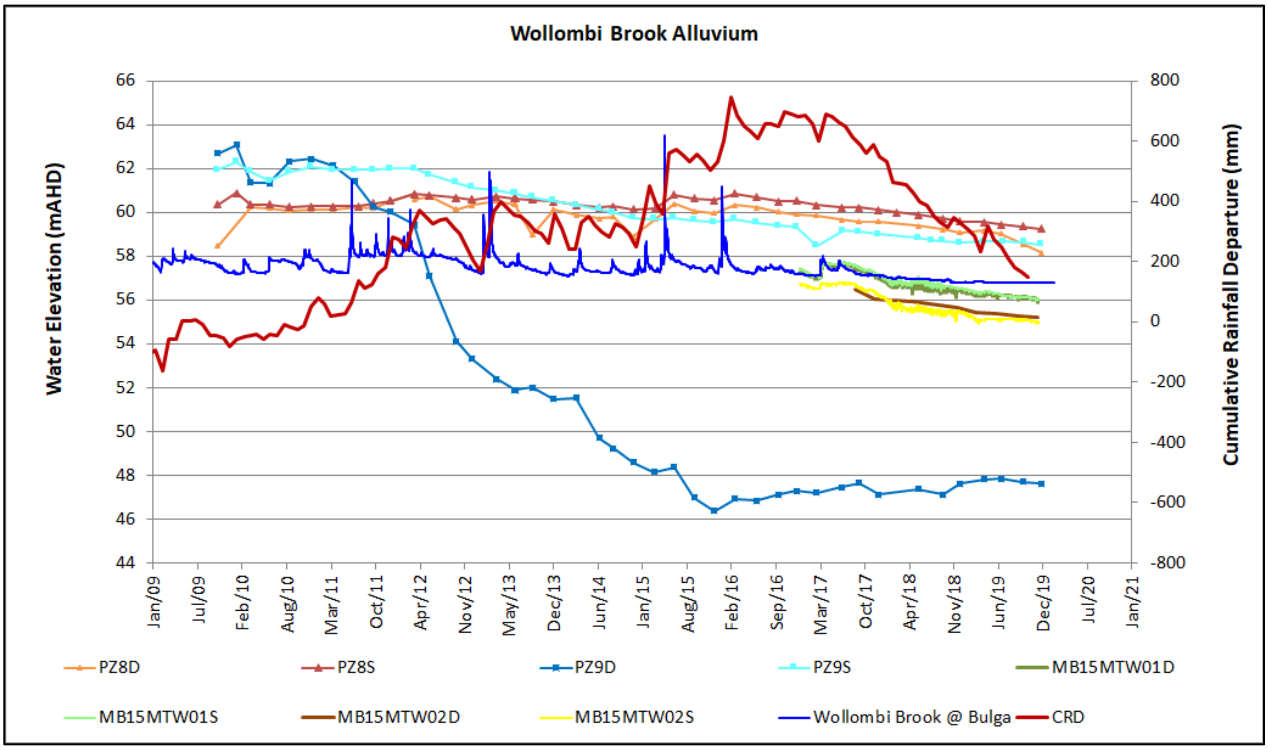


Figure 6-6 Groundwater Levels – Wollombi Brook Alluvium Bores PZ8, PZ9, MB15MTW01 and MB15MTW02

6.2.3 Permian Coal Measures

Groundwater level trends for the Permian coal measures are discussed in stratigraphic order in **Section 6.2.3.1** to **Section 6.2.3.9** below. This includes further discussion on the shallow overburden, shallow coal seams (Whybrow, Redbank Creek and Wambo seams), Blakefield Seam, Bowfield Seam, Warkworth Seam, Vaux Seam and Bayswater Seam.

6.2.3.1 Shallow Overburden

Ten monitoring bores intersect the shallow overburden material, PZ7D, PZ8D, PZ9D, MTD605P, MTD614P, MTD616P, MBW02, MB15MTW01D, MB15MTW02D, and MB15MTW03. Groundwater level trends for bores nested with alluvial bores (PZ7D, PZ8D, PZ9D, MB15MTW01D, and MB15MTW02D) are discussed in **Section 6.2.1**. Trends for bore MB15MTW03 are also presented in **Figure 6-5** of **Section 6.2.1**, as the bore is located along Wollombi Brook. **Figure 6-5** showed a general decline in groundwater levels at MB15MTW03 over 2019. The trends were similar to what was observed within the upstream alluvial bores, but with a more muted response to streamflow changes and no visible response in groundwater levels to the March 2019 above average rainfall event.

Groundwater level trends for bores MTD605P, MTD614P, MTD616P, and MBW02 are presented in **Figure 6-7**. **Figure 6-7** shows stable to slightly declining groundwater levels within the shallow overburden material. The exception to this is bore MTD616P in which slightly increasing groundwater levels were recorded. No land use changes or activities are known to have occurred near the bore that may have caused this rising trend. Further investigation into site conditions around MTD616P should be undertaken to confirm this.

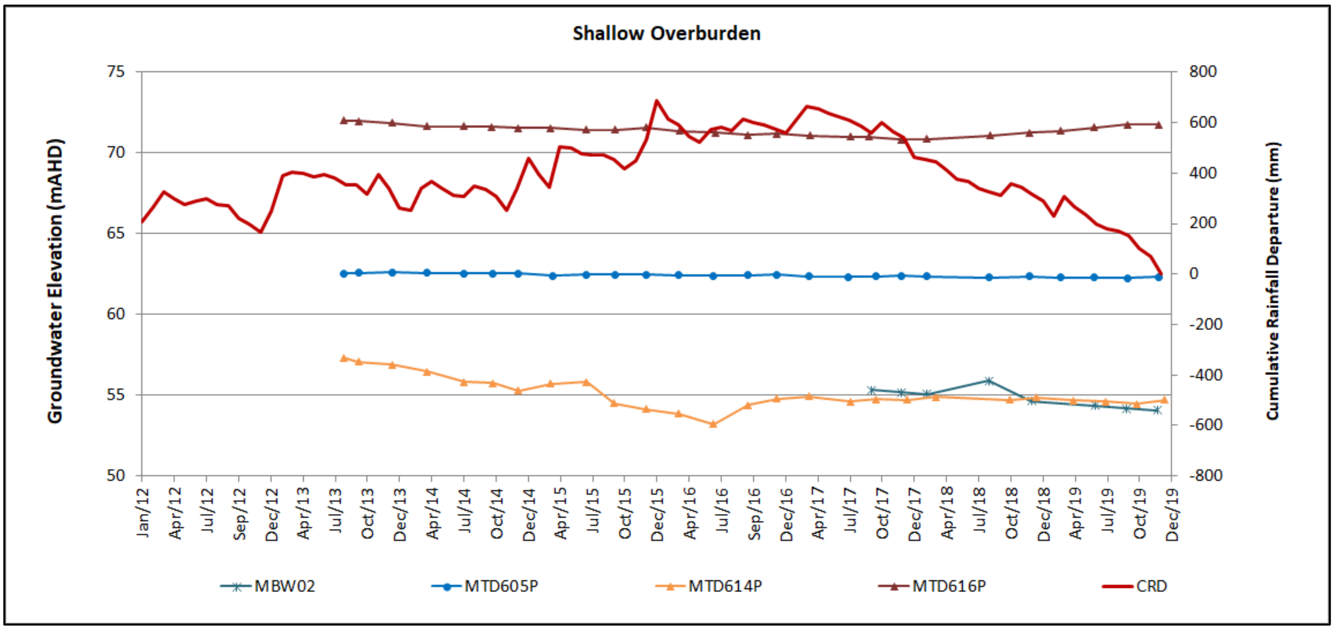


Figure 6-7 Hydrograph of Shallow Permian Coal Measures

6.2.3.2 Whybrow, Redbank Creek and Wambo Seams

Historical groundwater level trends for bores intersecting the shallow coal seams (Whybrow, Redbank Creek and Wambo seams) are presented in **Figure 6-8**. The graph shows that over 2019 groundwater elevations ranged between 46.6 mAHD and 67.7 mAHD. Over 2019 groundwater levels generally declined in bores WD622P, WOH2154B, WOH2155A, WOH2153A, WOH2154A, and WOH2156A. With the exception of bore WOH2153A, the rate of groundwater level decline increased from May 2019. Over 2019 groundwater elevations in WD622P, decreased from 52.96 m AHD to 46.56 m AHD; in WOH2154B decreased from 54.97 m AHD to 53.81 m AHD; in WOH2155A from 53.55 m AHD to 49.85 m AHD; and from WOH2156A from 51.63 m AHD to 47.75 m AHD. Bores WOH2154A, WOH2155A and WOH2156A all target the Redbank Creek Seam with WD622P and WOH2154B targeting the Wambo Seam. WD622P, is located within 300 m of the highwall at West Pit, with the remaining bores approximately 750m west of the North and West Pits. The increased decline in groundwater levels are therefore likely to be a response to the depressurisation of the coal seams as a result of mining operations. Groundwater levels remained relatively stable at bores WOH2153B, WOH2155B and WD625P, which are all located approximately 1 km west of Warkworth operations. Groundwater elevations were found to slightly increase throughout 2019 in WOH2156B.

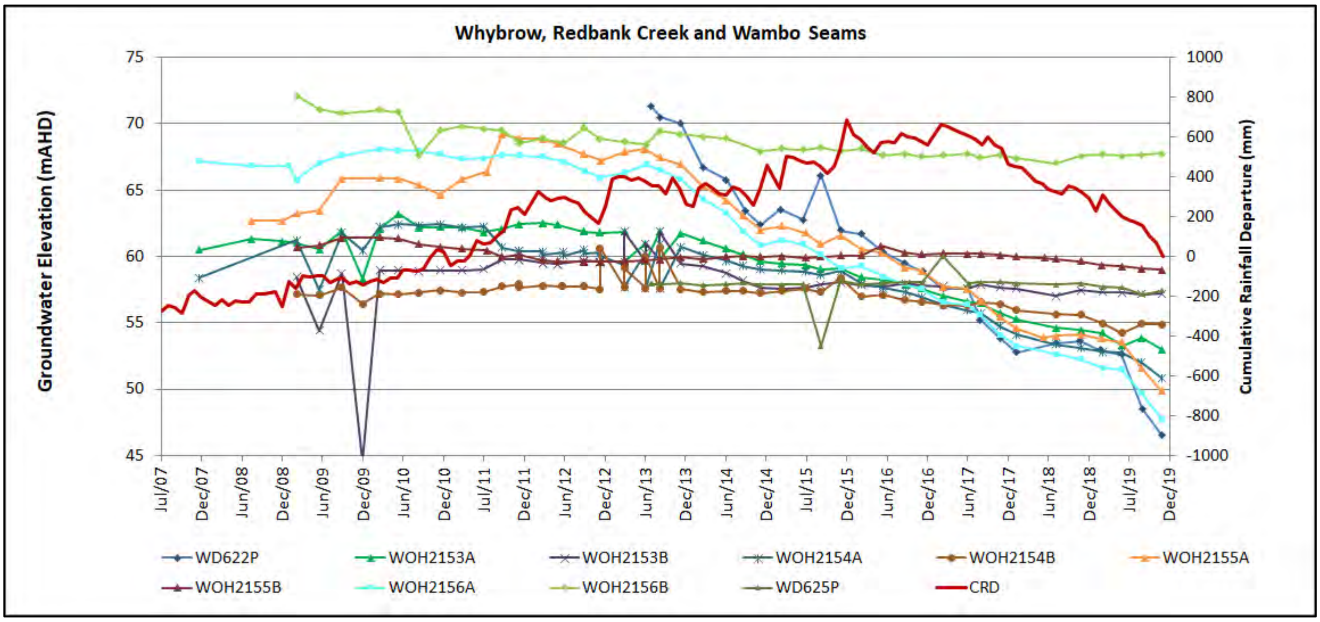


Figure 6-8 Hydrograph of Whybrow, Wambo and Redbank Creek Seams

Groundwater level trends for VWP sensors installed within the Whybrow and Wambo seams are presented in **Figure 6-9** and **Figure 6-10** respectively. The graphs show that over 2019 groundwater elevations within both seams declined, with a steeper decline again observed within the Wambo Seam from May 2019. This corresponds with the monitoring bore data and is likely due to depressurisation of the seams from mining of West Pit and Loders Pit to the east.

In the 2018 annual environmental monitoring review it was found that the MTD614 sensor installed within the Whybrow Seam (sensor 1) recorded increasing groundwater elevations, this in contrast to the other Whybrow Seam sensors where declining elevations have been recorded. MTD614 is located directly to the west of Loders Pit which is actively mined down to the deeper Woodlands Hill Seam. The active mining should in theory result in lowering of groundwater levels through depressurisation. It was suggested that the increase in groundwater elevations may indicate that the sensor is not working correctly. Review of the 2019 data found that groundwater elevations recorded MTD614 (sensor 1) continued to increase until August after which they began to decrease. Review of the raw sensor data suggests that the sensor and logger are working correctly, with pressure and temperature readings relatively consistent since installation. This trend is also consistent with trends for nearby shallow overburden bore MTD616P.

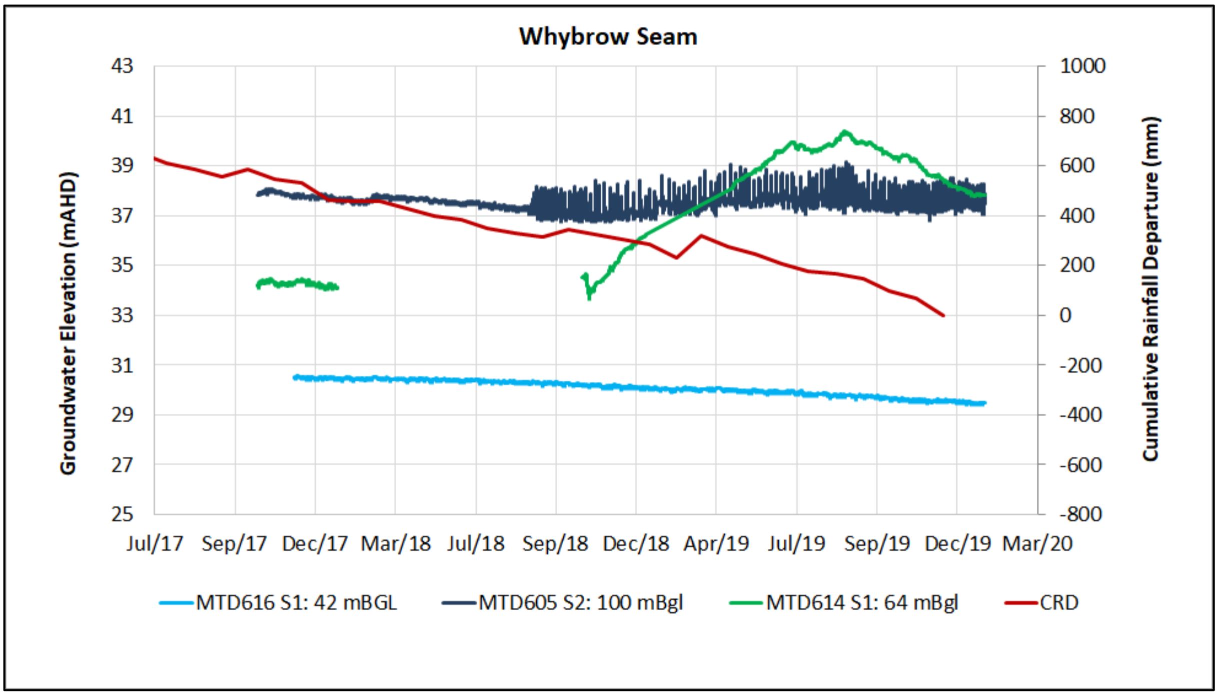


Figure 6-9 VWP Hydrograph of Whybrow Seam

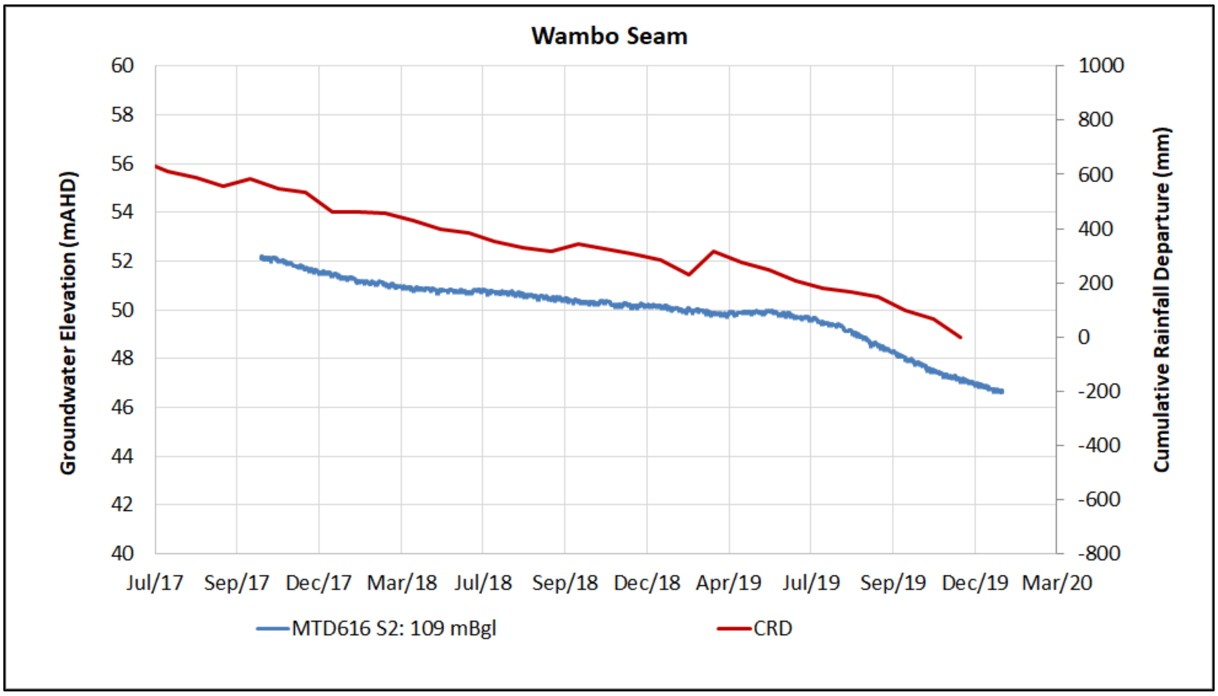


Figure 6-10 VWP Hydrograph of Wambo Seam

6.2.3.3 Blakefield Seam

Historical groundwater level trends for bores intersecting the Blakefield Seam are presented in **Figure 6-11**. The graph shows that over 2019 groundwater elevations ranged between 34.9 mAHD and 53.16 mAHD. Over 2019 groundwater levels generally declined within the Blakefield Seam in bores OH1125 (1) and WOH2139A. Groundwater levels within OH1122 remained relatively stable throughout 2019. In response to mine progression Bore OH1125(1) recorded a 3.5 m decline, Bore WOH2139A recorded a 5.7 m decline and Bore OH1122(1) recorded a 0.2 m decline over 2019.

Groundwater level trends for VWP sensors installed within the Blakefield Seam are presented in **Figure 6-12**. The graph shows that over 2019 groundwater elevations within the seam slightly declined. This corresponds with the monitoring bore data and is likely due to depressurisation of the seams from expansion of West Pit to the east.

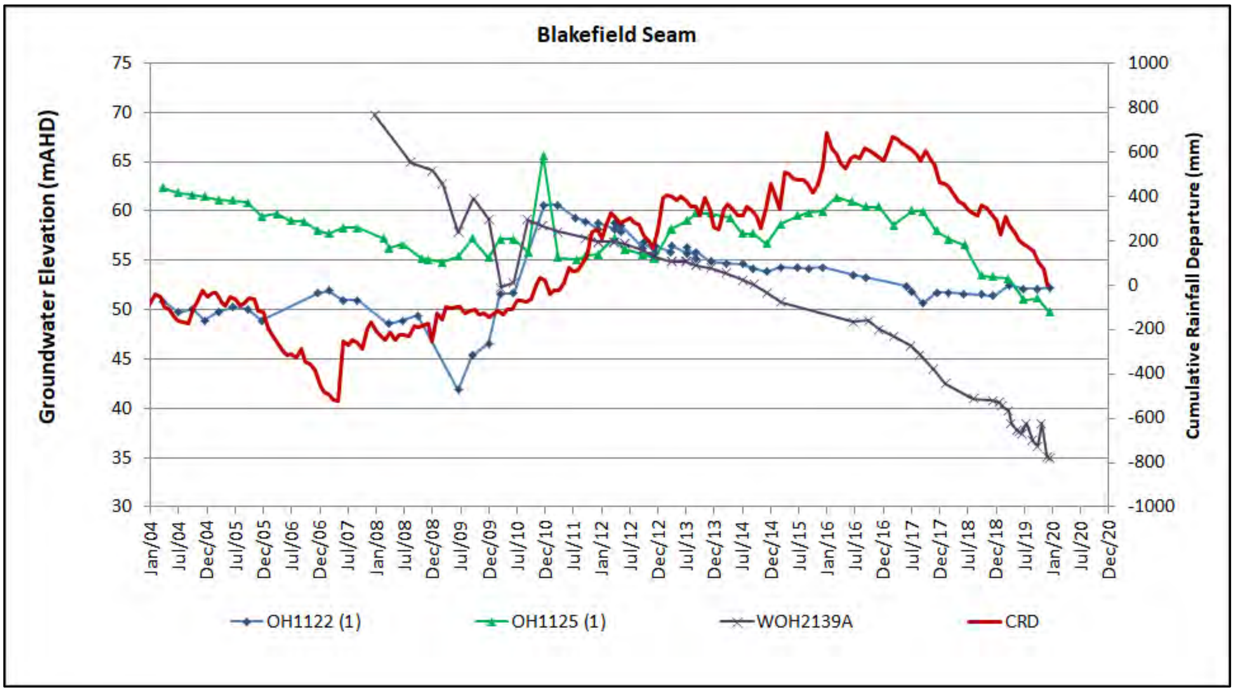


Figure 6-11 Hydrograph of Blakefield Seam

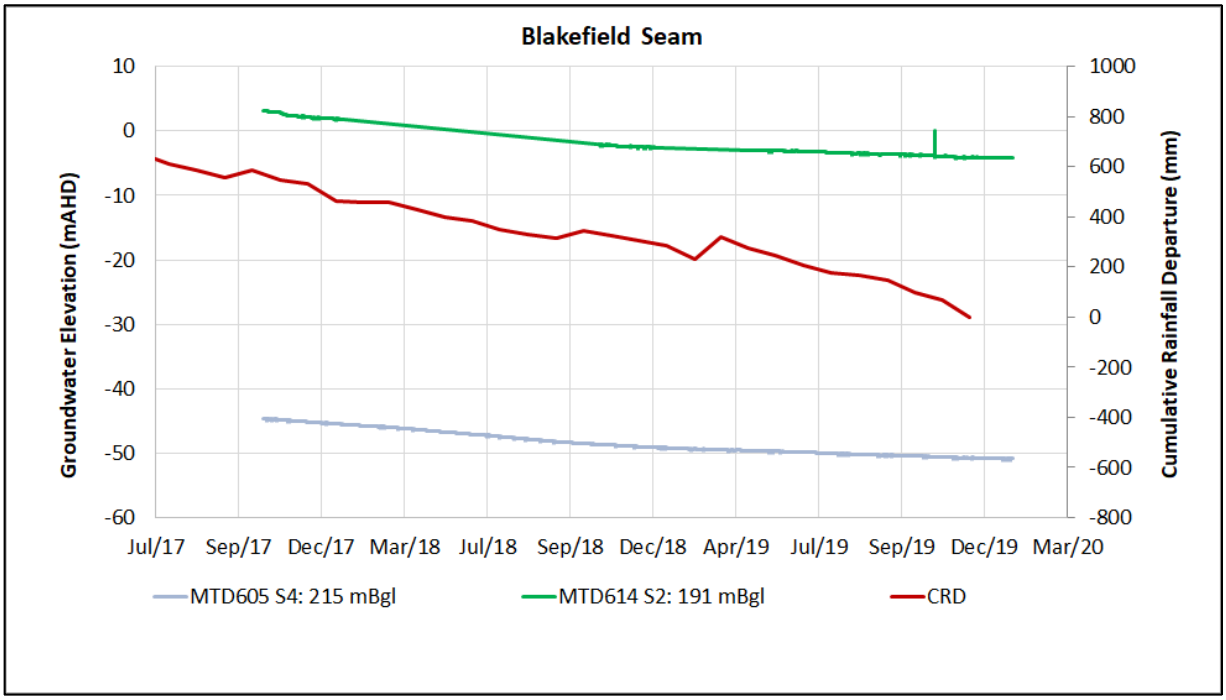


Figure 6-12 VWP Hydrograph of Blakefield Seam

6.2.3.4 Woodlands Hill Seam

Groundwater level trends for VWP sensors installed within the Woodlands Hill Seam are presented in **Figure 6-13**. The graph shows that over 2019 groundwater elevations within the seam at VWP WD625 were variable, whereas at VWP MTD616 groundwater elevations slightly declined. MTD616 is located to the north west of Loders Pit and west of West Pit. The decreasing groundwater elevations are likely due to dewatering of the coal seam from mining of these pits.

WD625 is located to the west of North Pit and recorded variable but generally decreasing groundwater elevations over 2019. The cause of these fluctuations is unclear but may relate to underground mine and water storage activities at Wambo.

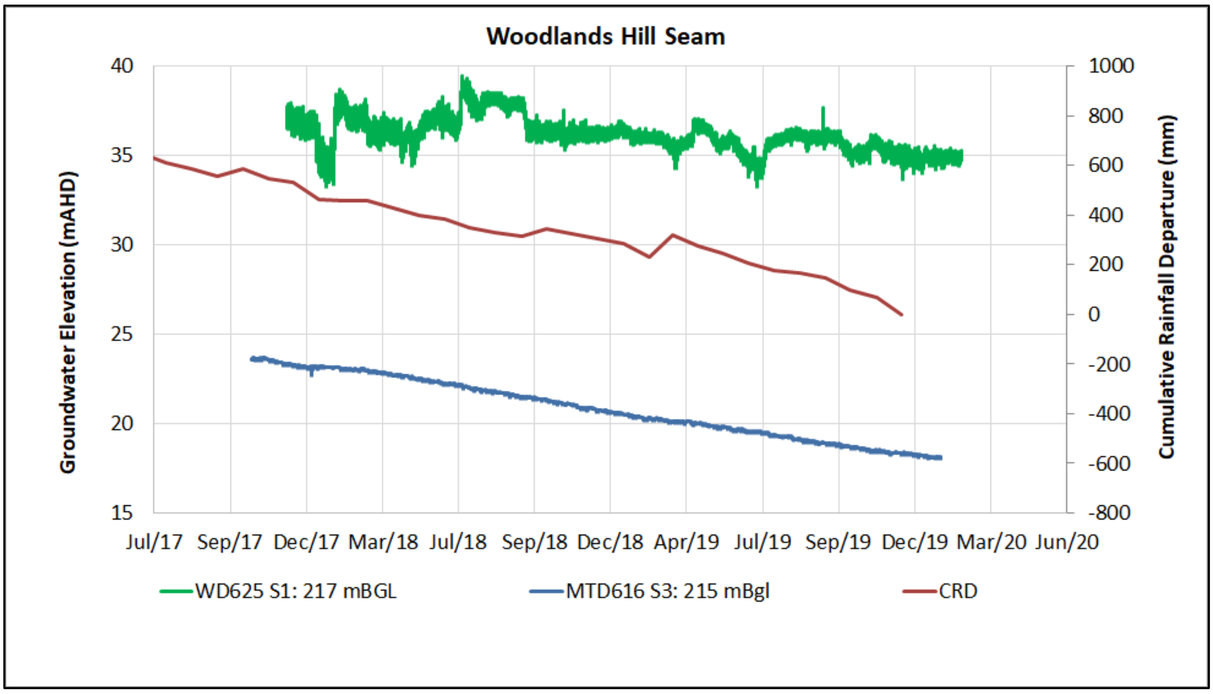


Figure 6-13 VWP Hydrograph of Woodlands Hill Seam

6.2.3.5 Bowfield Seam

Historical groundwater level trends for bores intersecting the Bowfield Seam are presented in **Figure 6-14**. The graph shows that over 2019 groundwater elevations in Bore OH1125(3) decreased from 47.19 mAHD to 29.71 mAHD, corresponding to the decrease in rainfall over this period. Bore OH1125(3) is located directly to the north of North Pit and the decline may relate to drawdown towards active mining within the pit to the south. The trend may also be influenced by abstraction from LUG Bore located approximately 1.25 km to the north west. The LUG bore intersects the historical Lemington Underground workings, which mined through the deeper Mt Arthur Seam. The increased groundwater level drawdown observed over 2019 may therefore be a combination of the effects of mining of the North Pit and licenced abstraction from the LUG bore.

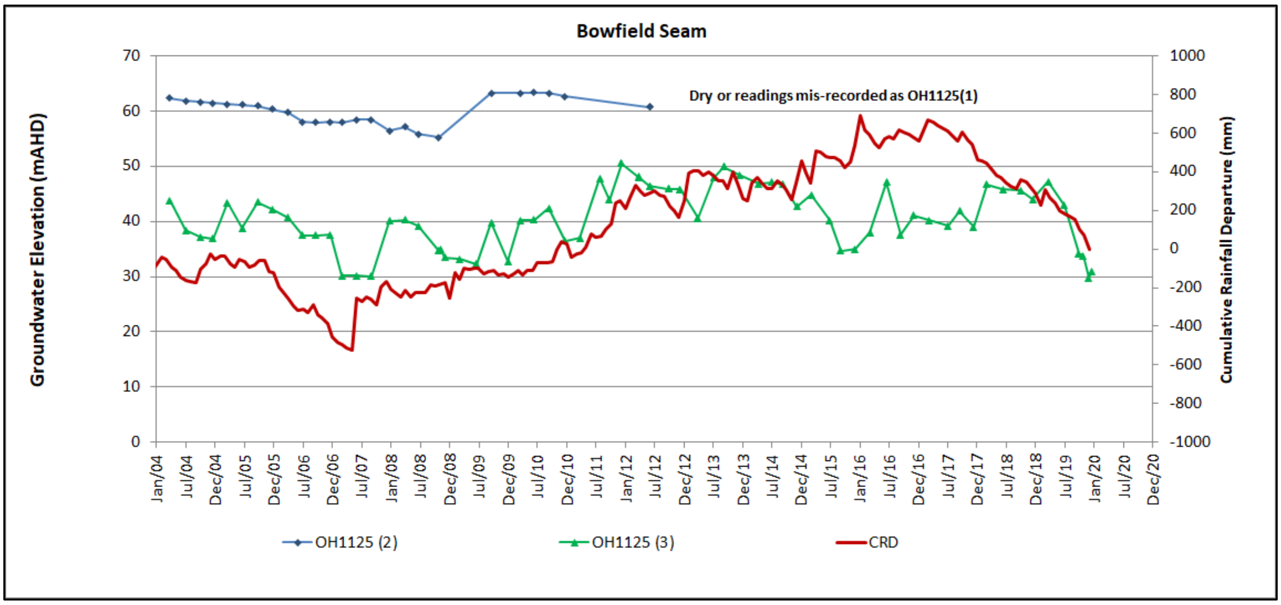


Figure 6-14 Hydrograph of Bowfield Seam

6.2.3.6 Warkworth Seam

Historical groundwater level trends for bores intersecting the Warkworth Seam at bore OH1138 at two intervals (1 and 2) are presented in **Figure 6-15**. The graph shows that over 2019 groundwater elevations ranged between 55.59 mAHD and 60.53 mAHD and level declined by up to 0.46 m. The bore is located north of North Pit and the decline may relate to drawdown towards active mining within the pit to the south-west. The trend may also be influenced by abstraction from LUG Bore approximately 1.25 km to the north-west.

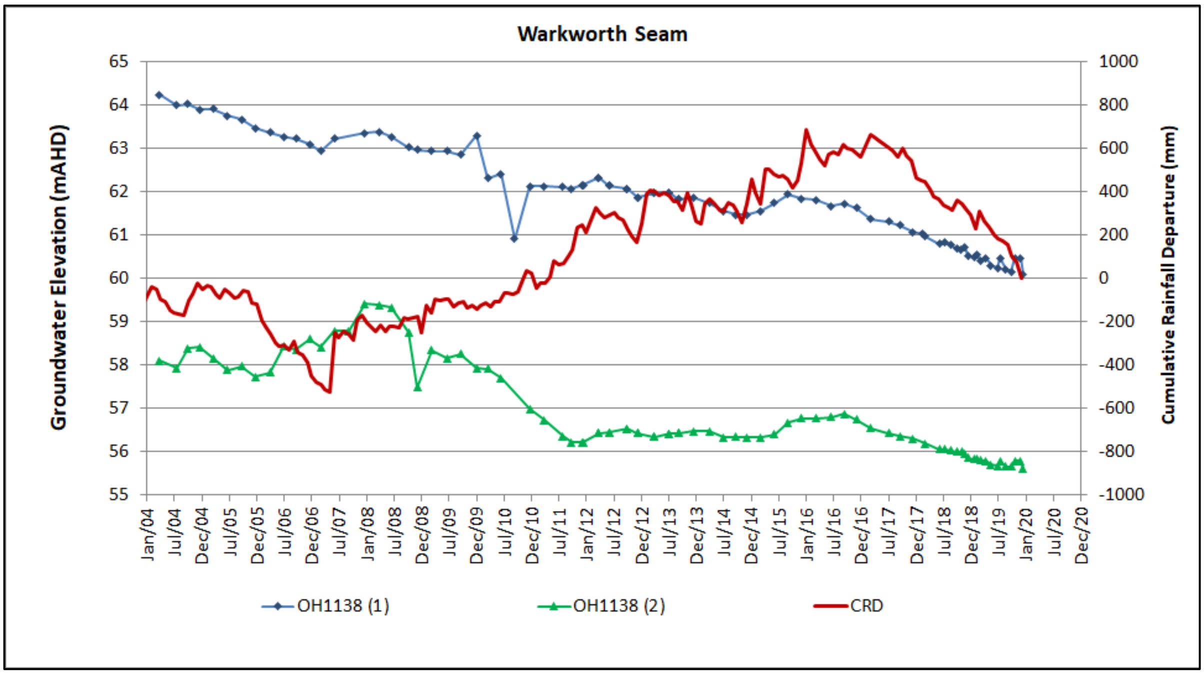


Figure 6-15 Hydrograph of Warkworth Seam

6.2.3.7 Mt Arthur and Piercefield Seams

Historical groundwater level trends for VWP sensors intersecting the Mt Arthur and Piercefield coal seams are presented in **Figure 6-16** and **Figure 6-17** respectively. At MTD605 water level data is only available up to November 2019. After this period the data is erroneous, suggesting that the sensor has failed.

Figure 6-16 shows that over 2019 groundwater elevations within the Mt Arthur Seam ranged between 1.84 mAHD and 34.59 mAHD with a groundwater level decline of up to 2.48 m observed. The large difference in groundwater elevations is related to the difference in sensor elevations across the VWPs. The accuracy of the MTD605 sensor data has previously been questioned due to the low elevations recorded. The sensor calibration details and reported construction depths have been confirmed which suggests a long term issue with the sensor prior to failure. Although the accuracy of the groundwater elevations for MT605 are questionable, the decreasing trend in water level corresponds with the MTD616 readings.

The decreasing elevations within VWP MTD605 and MTD616 are likely to be due to the depressurisation of coal seams related to West Pit and Loders Pit. The stable elevations observed in WD625 suggest that depressurisation of the coal seams associated with North Pit are not influencing groundwater levels within the Mt Arthur seam at this location.

Figure 6-17 shows that over 2019 groundwater elevations within the Piercefield Seam increased from a low of 25.04 mAHD in February 2019 to 25.71 mAHD in December 2019 (0.67 m). VWP WD615 is located along the southern boundary of North Pit, within a rehabilitated area of the pit. The VWP sensor is located in the seam underlying the mined coal seam at this location. The increase in groundwater elevation within the Piercefield Seam is potentially an indication of recharge from the overlying spoil as groundwater recovery takes place in the rehabilitated areas.

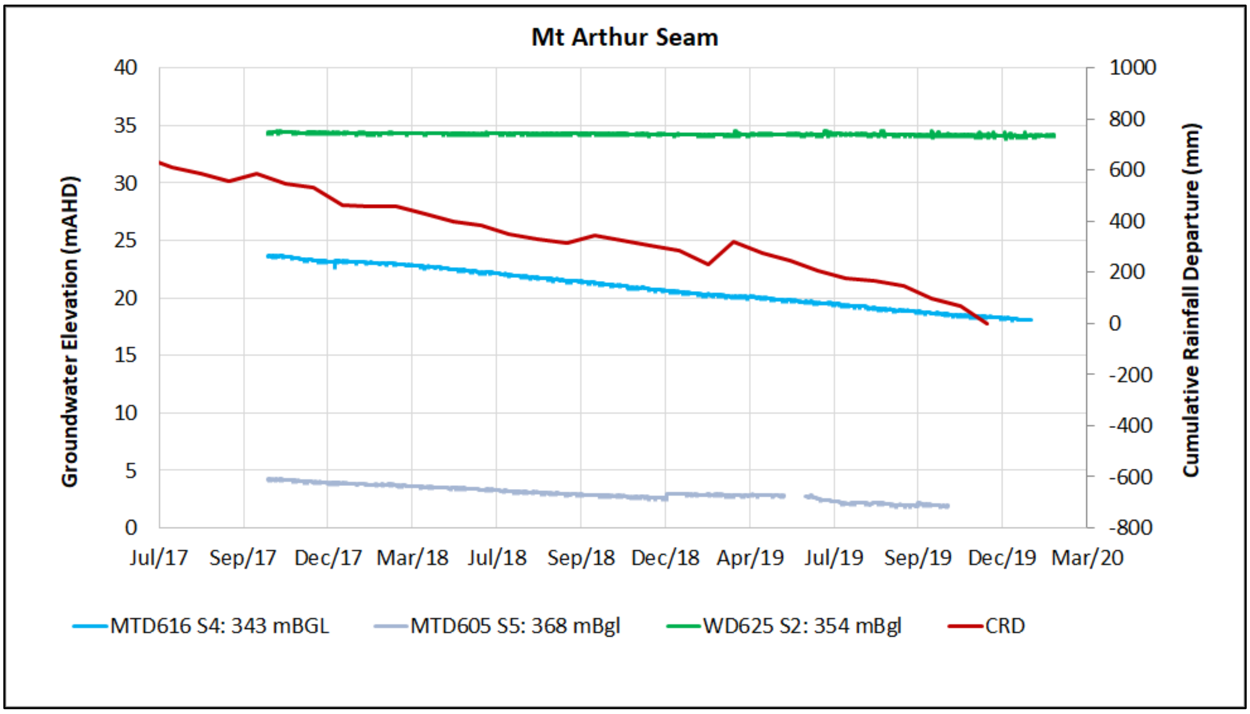


Figure 6-16 VWP hydrograph of Mt Arthur Seam

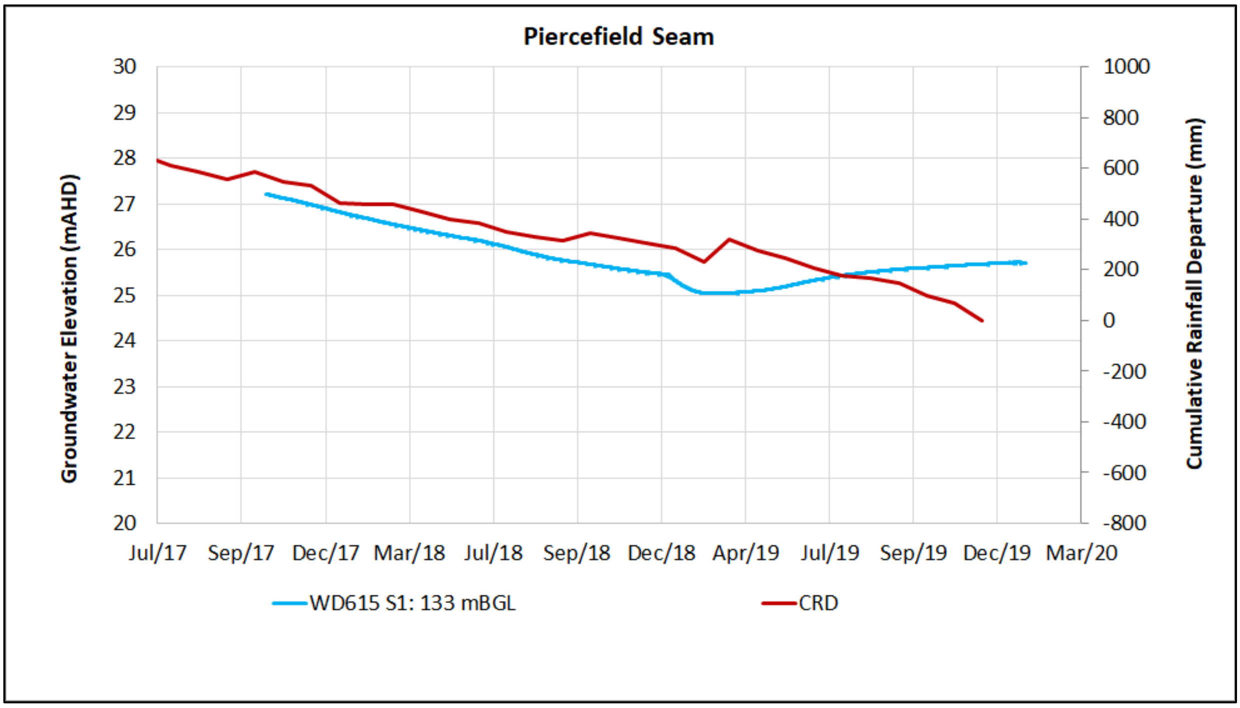


Figure 6-17 VWP hydrograph of Piercefield Seam

6.2.3.8 Vaux Seam

Historical groundwater level trends for bores intersecting the Vaux Seam around MTW are presented in **Figure 6-18**. The graph shows that over 2019 groundwater elevations within the Vaux Seam, north of North Pit, (OH1126 and OH1137) ranged between 46.18 mAHD and 53.08 mAHD. Levels declined by up to 0.55 m with OH1137 reported as dry from September 2019. These trends are similar to trends observed within the Warkworth Seam, which may relate to depressurisation of the coal seams below the actively mined seams at MTW, or due to surrounding mine operations that target the Vaux Seam.

Groundwater levels within bore OH1121 remained stable over 2019. This bore is located upgradient (east) of MTW and is reported in the WMP to intersect the shallow Vaux Seam (20 m depth). However, upon review of the geology map (**Figure 3-4**) the Jerry's Plains Subgroup that the Vaux Seam is within is not present at this location. Therefore, the condition and construction details of the bore should be further reviewed.

Groundwater level trends for VWP sensors installed within the Vaux Seam are presented in **Figure 6-19**. Although the sensor for MTD605 appears to have failed in June 2019, the graph shows that over 2019 groundwater elevations were relatively stable. WD625 is located to the west of North Pit, MTD605 is located to the west of Loders Pit and MTD616 is located to the south west of West Pit. The VWP data therefore suggests that over 2019 groundwater levels within the Vaux Seam were not influenced by mine operations at these locations.

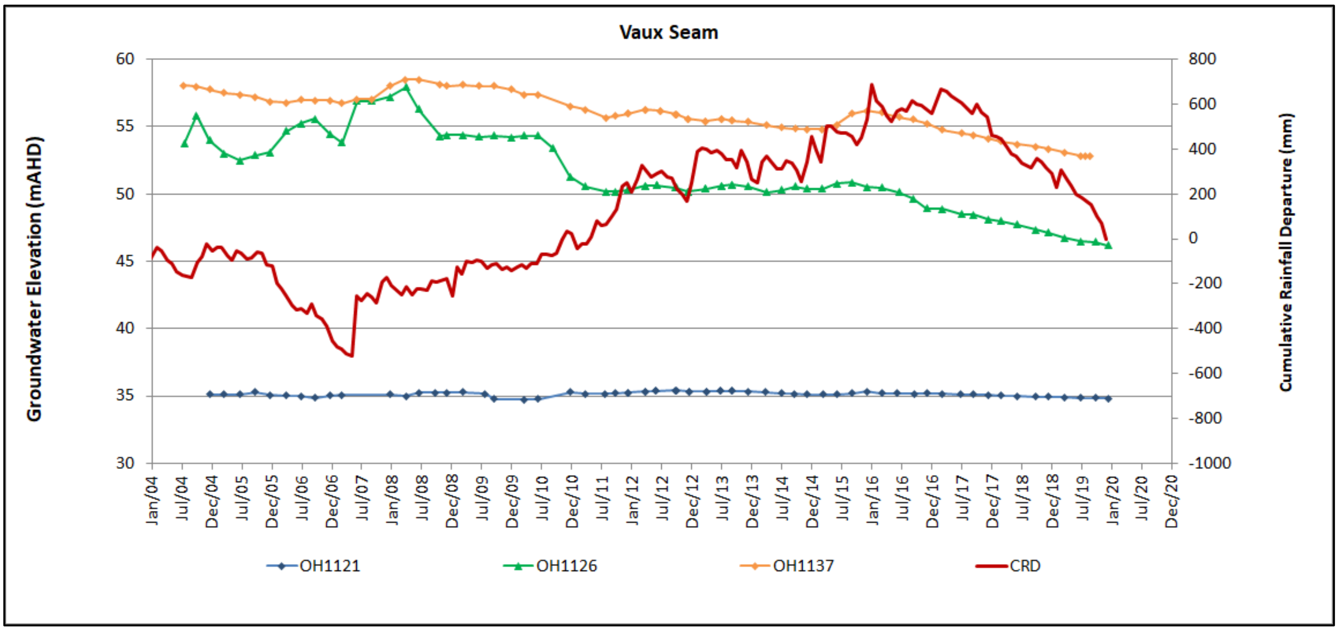


Figure 6-18 Hydrograph of Vaux Seam

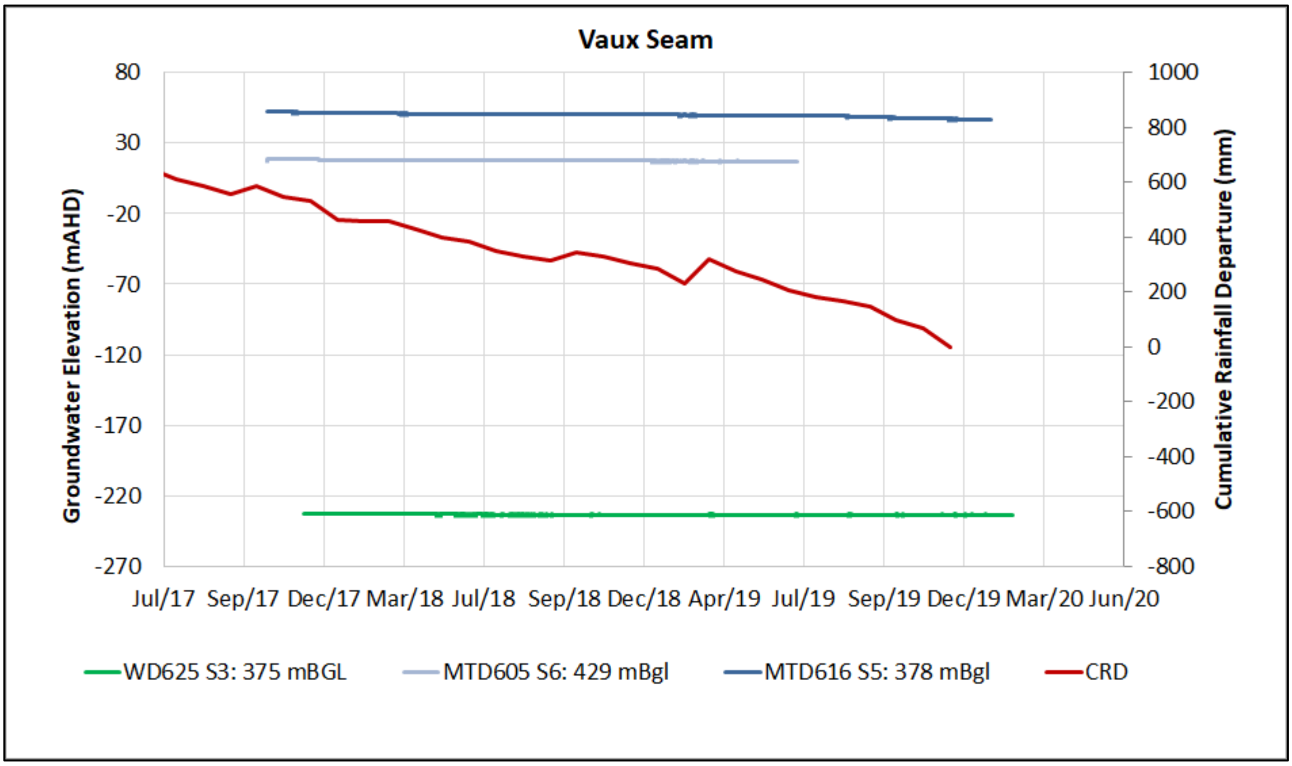


Figure 6-19 VWP hydrograph of Vaux Seam

6.2.3.9 Bayswater Seam

Historical groundwater level trends for bores intersecting the Bayswater Seam around MTW are presented in **Figure 6-20**. The graph shows that over 2019 groundwater levels remained relatively stable, with elevations ranging between 35.25 mAHD and 68.55 mAHD. All bores presented in **Figure 6-20** are located to the south east of South Pit.

Groundwater level trends for VWP sensors installed within the Bayswater Seam are presented in **Figure 6-21**. The graph shows that over 2019 groundwater elevations were relatively stable. The exception to this is WD615 where groundwater elevations increased. With the exception of WD615 all VWP locations are located to the west of the main mine pits (North Pit, West Pit and Loders Pit). WD615 is located in the east of the North Pit. As observed within the Vaux Seam, the groundwater levels reported suggest that mine operations are not impacting groundwater levels within the Bayswater Seam at the VWP monitoring locations. The increase in groundwater elevations observed in WD615 corresponds with the increasing elevations observed within the Piercefield Seam at the same location. The increase may again be an indication of recovering groundwater levels within rehabilitated areas of the North Pit resulting in recharge to the underlying coal seams

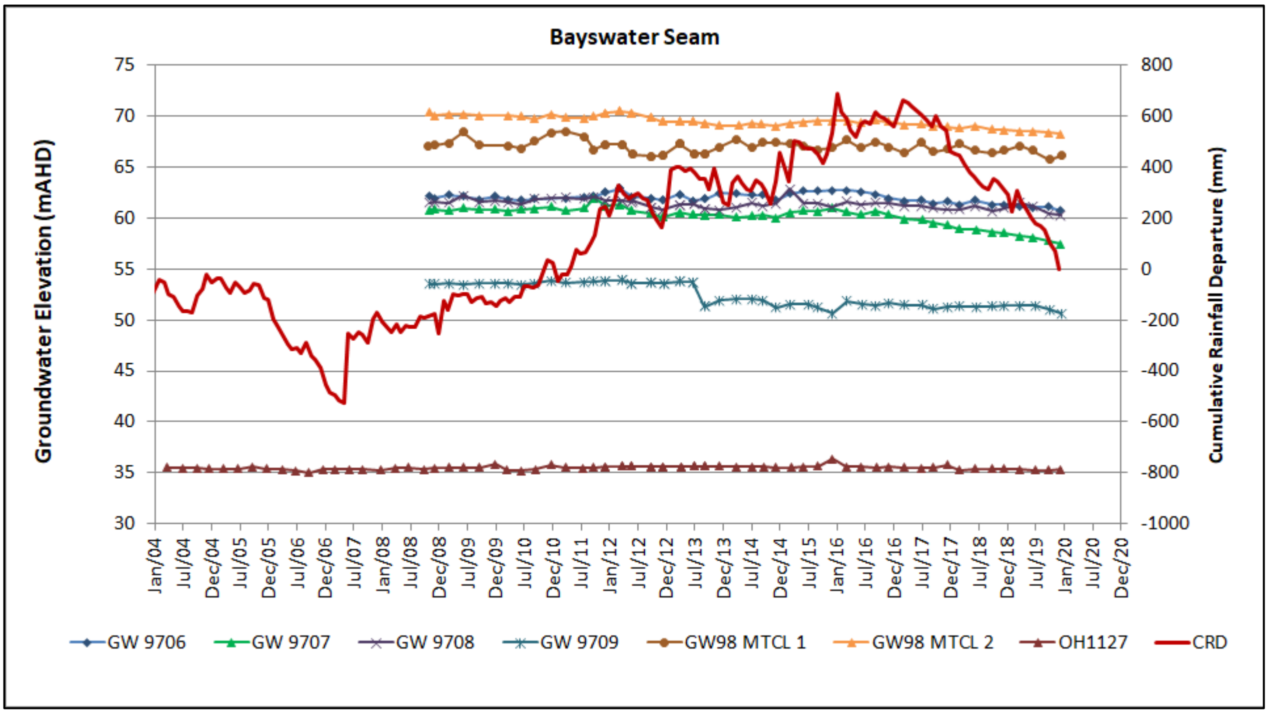


Figure 6-20 Hydrograph of Bayswater Seam

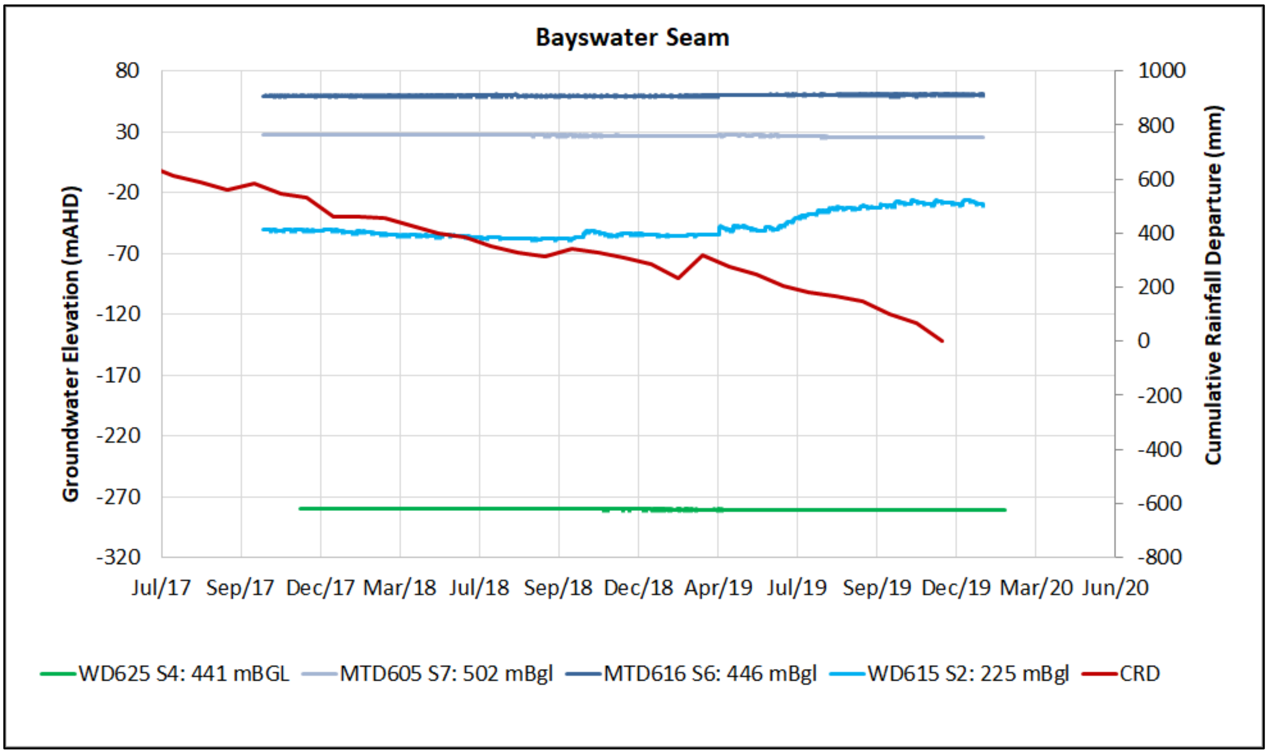


Figure 6-21 VWP hydrograph of Bayswater Seam

6.3 Water Quality

A summary of the water quality results is provided for each of the main water bearing units (alluvium and Permian coal measures) below. Routine EC and pH readings and historical trends are presented in **Appendix B** and **Appendix C**, respectively.

6.3.1 Regolith

Over the 2019 monitoring period, the following triggers were exceeded for the bores within the regolith:

- Bore OH786 recorded EC above the trigger level of 950 µS/cm in Q1, Q3 and Q4;
- Bore OH787 recorded EC levels above the trigger level of 18,185 µS/cm in Q1 and Q4, and pH equal to the trigger level of 7.7 in Q2.
- Bore OH942 recorded EC levels marginally above the trigger level of 25,380 µS/cm in Q1 and Q2, with EC levels below the trigger level in Q3 and Q4. .

As discussed in **Section 5.3**, bores OH786 and OH787 recorded EC above the trigger threshold in 2018, and again in 2019. Previous investigations by AGE (2014b) indicates potential for seepage from TD1 and TD2.

Historical EC readings for OH787 since 2015 show regular fluctuations of between 17,070 µS/cm and 18,150 µS/cm. The 2019 readings of up to 19,160 µS/cm are therefore slightly above historical levels. This trend may relate to the area having received below average rainfall over most of 2019. Bore OH787 recorded groundwater levels of between 13.90 m and 13.96 m depth, which are above the reported base of the bore (15.05 m depth). Available construction details indicate the screen extends to 12.1m. This difference in reported bore depths may suggest that a sump exists, potentially influencing results. A review of the bore condition and construction is required to verify the bore depth.

Historical EC readings for OH786 between 2012 and 2018 show regular fluctuations of between 440 µS/cm and 1,435 µS/cm. The 2019 readings of up to 2,760 µS/cm are therefore slightly above historical levels. This trend may relate to the area having received below average rainfall over most of 2019. Bore OH786 recorded groundwater levels of between 2.75 m and 7.02 m depth, which are above the reported base of the bore (7.1 m depth). Review of data shows that elevated EC concentrations correspond to events where water levels are reported close to the total bore depth. In addition review of sampling comments shows that during these events the presence of suspended solids in the purge water has been noted. It is therefore likely that the exceedances of the EC trigger level is a result of sediment within the collected sample influencing results rather than an indication of long term increasing trends.

6.3.2 Alluvium

Over 2019, routine monitoring of EC and pH was conducted for most alluvial monitoring bores on a quarterly basis. Exceptions to this were:

- OH944 was recorded as dry throughout 2019;
- OH943 and PZ9S were recorded as having insufficient water for sampling from March 2019; and
- Bores targeting the Warkworth Sands MB15MTW04 to MB15MTW11 were recorded as dry throughout 2019.

Alluvial groundwater quality over 2019 ranges between the different units, as discussed below:

- Warkworth Sands: EC ranges between 1,328 µS/cm and 1,641 µS/cm and pH ranges between 6.5 and 6.8 for bore PZ7S.
- Hunter River: EC ranges between 8,250 µS/cm and 13,850 µS/cm and pH ranges between 6.9 and 7.4;
- Regolith: EC ranges between 845 µS/cm and 25,400 µS/cm and pH ranges between 6.6 and 7.7; and
- Wollombi Brook: EC ranges between 715 µS/cm and 14,710 µS/cm and pH ranges between 6.2 and 7.6

Discussion in water quality trends and triggers is included for each alluvial unit from **Section 6.3.2.1** to **Section 6.3.2.3**.

Full water quality analysis was conducted for the site alluvial bores in accordance with the WMP. Exceptions to this include bores MB15MTW04 to MB15MTW10 and OH944 (dry throughout 2019), MB15MTW11 (could not be accessed) and OH786, OH943, and PZ9S (insufficient water available for sampling).

Full water quality data is presented in **Appendix D** and summarised below:

- Total aluminium: values ranged from below the limit of reporting (LOR) 0.01 mg/L to 0.85 mg/L (PZ7S);
- Total arsenic: values ranged from below the LOR of 0.001 mg/L to 0.004 mg/L (MB15MTW02S);
- Total cadmium: all values were recorded as below the LOR of 0.0001 mg/L;
- Total copper: values ranged from below the LOR of 0.001 mg/L to 0.02 mg/L (PZ8S);
- Total lead: concentrations below the limit of reporting of less than 0.001 mg/L, except for bores PZ7S and OH787 that recorded total lead concentrations of 0.01 mg/L and 0.003 mg/L respectively;
- Total nickel: values ranged from below the LOR of 0.001 mg/ to 0.087 mg/L (MB15MTW02S);
- Total selenium: all concentrations were below the LOR of 0.01 mg/L;
- Total zinc: concentrations generally below the limit of reporting or less than 0.01 mg/L, except for bores OH787, MB15MTW01S, and PZ8S that recorded total selenium concentrations of 0.087 mg/L, 0.01 mg/L and 0.013 mg/L respectively;
- Total boron: concentrations were variable ranging from below the LOR to 0.12 mg/L (OH787); and
- Total mercury: all concentrations were reported below the LOR of 0.001 mg/L with the exception of bore OH942 which recorded a total mercury concentration of 0.0007 mg/L.

6.3.2.1 Warkworth Sands

Over the 2019 monitoring period, the following triggers were exceeded for the bores within the Warkworth Sands alluvium:

- Bore PZ7S recorded a pH of 6.5 in Q3 which is marginally below the lower trigger level of 6.7.

Over 2019 the SWL in bore PZ7S decreased from 7.77 m to 8.07 m, and the depth of PZ7S is reported as 11.3 m. pH levels have fluctuated within PZ7S since 2012 and therefore the Q3 result is consistent with historic variations.

6.3.2.2 Hunter River Alluvium

Over the 2019 monitoring period, the following triggers were exceeded for the bores within the Hunter River alluvium:

- Bore OH788 recorded pH levels at and marginally below the lower trigger level of 7.1 throughout 2019. EC concentrations were also recorded above the trigger level of 11,742 µS/cm in Q2, Q3 and Q4.

Over 2019 SWL in bore OH788 was relatively stable ranging between 9.96 m to 10.03 m. The depth of bore OH788 is reported as 22.1 m with the screen depth reported as 21.6 m. Following recommendations made in the 2018 AEMR, the sampling methodology for the quarterly monitoring changed from a grab sample to low flow. The increase in EC concentrations observed over 2019 may be as a result of this change. Lower than average rainfall over 2019 may also contribute to an increase in EC concentrations within the Hunter River Alluvium with resulting in reduced recharge and therefore less fresh water entering the system.

6.3.2.3 Wollombi Brook Alluvium

Over the 2019 monitoring period, the following triggers were exceeded for the bores within the Woollombi Brook alluvium:

- Bore PZ9S recorded pH levels at the lower trigger limit of 6.8 in Q1; and.
- Bore PZ8S recorded pH levels below the trigger limit of 6.5 in Q4;

Over 2019 SWL in bore PZ9S decreased from 6.76 m to 6.91 m, and the depth of PZ9S is reported as 6.9 m. Through Q2 to Q4 insufficient water was available to undertake field testing. In addition, the Q1 sample recorded an EC concentration of 715 µS/cm which is significantly fresher than the EC concentration reported in the PZ8S bore. Based on this it is anticipated that the bore in Q1 may have been dry and the results likely reflect water within a sump at the base of the bore

6.3.3 Permian Coal Measures

Routine monitoring of EC and pH was conducted for all monitoring bores intersecting the Permian coal measures and overburden material on a quarterly basis over 2019. Exceptions to this include:

- OH1125(2) which could not be sampled as the bore was dry over 2019;
- OH1137 which was dry in Q2, Q3, and Q4;
- WOH2153B which was blocked in Q1 and had insufficient water for sampling in Q2 and Q3;
- WOH2156B which had insufficient water for sampling in Q2, Q3, and Q4;
- GW9709 had insufficient water for sampling in Q4; and
- MBW02 which could not be accessed in Q1.

Over 2019 groundwater within the shallow overburden material of the Permian coal measures recorded EC of between 1,664 µS/cm and 17,780 µS/cm and pH ranges between 6.3 and 8.0.

Over 2019 groundwater within the Permian coal measures recorded EC between 1,592 µS/cm and 23,300 µS/cm and pH ranges between 5.9 and 8.2.

In accordance with the WMP full water quality analysis was conducted for the bores targeting the Permian coal measures. Exceptions to this include OH1125(2) which could not be sampled as the bore was dry over 2019; OH1137 which was blocked; and WOH2153B and WOH2156B which had insufficient water for sampling. Full water quality data is presented in **Appendix D** and summarised below:

For bores within the shallow overburden:

- Total aluminium: concentrations ranged from 0.02 mg/L to 5.22 mg/L (MB15MTW01D);
- Total arsenic: concentrations ranged from below the LOR of 0.001 mg/L to 0.014 mg/L (PZ8D);
- Total cadmium: all bores reported concentrations which were below the LOR of 0.0001 mg/L;
- Total copper concentrations ranged from below the LOR of 0.001 mg/L to 0.012 mg/L (PZ8D);
- Total lead concentrations ranged from below the LOR of 0.001 mg/L to 0.034 mg/L (PZ8D);
- Total nickel concentrations ranged from below the LOR of 0.001 mg/L to 0.007 mg/L (MB15MTW02D);
- Total selenium: concentrations were below the LOR of 0.01 mg/L for all bores;
- Total zinc: concentrations ranged from below the LOR of 0.005 mg/L to 0.062 mg/L (MB15MTW02D);
- Total boron: concentrations ranged from 0.08 mg/L to 0.31 mg/L (MTD605P); and
- Total mercury: concentrations were below the LOR of 0.0001 mg/L for all bores.

For bores within the Permian Coal Measures:

- Total aluminium: concentrations ranged from 0.01 mg/L to 5.58 mg/L (WOH2154B);
- Total arsenic: concentrations ranged from below the LOR of 0.001 mg/L to 0.004 mg/L (OH1138(2));
- Total cadmium: concentrations ranged from below the LOR of 0.0001 mg/L to 0.0008 mg/L (OH1138(1));
- Total copper concentrations ranged from below the LOR of 0.001 mg/L to 0.04 mg/L (OH1138(2));
- Total lead concentrations ranged from below the LOR of 0.001 mg/L to 0.017 mg/L (OH1138(2) and OH1126);
- Total nickel concentrations ranged from below the LOR of 0.001 mg/L to 0.02 mg/L (OH1138(1));
- Total selenium: concentrations were below the LOR of 0.01 mg/L for all bores;
- Total zinc: concentrations ranged from below the LOR of 0.005 mg/L to 0.494 mg/L (WOH2154B);
- Total boron: concentrations ranged from below the LOR of 0.05 mg/L to 0.46 mg/L (GW9707); and
- Total mercury: concentrations were below the LOR of 0.0001 mg/L for all bores with the exception of (OH1138(1)) which recorded a concentration of 0.0018 mg/L.

6.3.3.1 Shallow Overburden Trigger Exceedances

Over the 2019 monitoring period, the following triggers were exceeded for bores within the shallow overburden.

- Bore MTD605P recorded an EC of above the trigger level of 17,490 in Q4;
- Bore MTD616P recorded a PH of below the lower trigger level of 6.9 in Q2, Q3, and Q4;
- Bore MB15MTW01D recorded a PH of below the lower trigger level of 6.9 throughout 2019.

6.3.3.2 Permian Coal Measures Trigger Exceedances

Over the 2019 monitoring period, the following triggers were exceeded for bores within the Permian coal measures.

- Bore WD625P recorded pH values at and below the lower trigger level of 7.1 in Q1 and Q2 and EC concentrations above the trigger level of 11,996 µS/cm in Q1 and Q3;
- Bore WOH2153A recorded pH values at and above the upper trigger level of 7.9 in Q2, Q3 and Q4;
- Bore WHO2154A recorded a pH value below the lower trigger level of 7.2 in Q1;
- Bore WHO2155A recorded a pH value at the upper trigger level of 7.9 in Q1;
- Bore WOH2153B recorded a pH value at the lower trigger level of 7.2 in Q4;
- Bore WHO2154B recorded a pH value below the lower trigger level of 7.2 in Q1;
- Bore WHO2155B recorded a pH value below the lower trigger level of 7.2 in Q1;
- Bore WOH2156B recorded an EC concentration above the trigger level of 13,843 µS/cm in Q1;
- Bore WD622P recorded pH values above the upper trigger level of 7.9 in Q1 and at and below the lower trigger level of 7.2 in Q2 and Q3. EC concentrations were also recorded above the trigger level of 13,843 µS/cm in Q2 and Q3;
- Bore WOH2139A recorded pH values at and above the upper trigger level of 7.6 from Q1 to Q4;
- Bore OH1138 (1) recorded pH values below the lower trigger value of 6.3 from Q1 to Q4;
- Bore OH1137 recorded a pH value at the trigger level of 7.1 and an EC concentration marginally above the trigger level of 17,745 µS/cm in Q1;
- Bore GW9709 recorded EC concentrations marginally above the trigger level of 22,991 µS/cm in Q1 and Q3;
- Bore GW98MCTL2 recorded pH at or below the lower trigger level of 6.6 throughout the whole of 2019;

Further discussion of EC and pH trends for bores WOH2139A and OH1138(1) is included below.

Bore WOH2139A is located directly west of North Pit and intersects the Blakefield Seam with a depth of 98 m. Additional to the quarterly monitoring events bore WOH2139A was monitored every month throughout 2019. All pH results were above the upper trigger limit throughout 2019. This is consistent with historical results since October 2017. EC concentrations for bore WOH2139A were within trigger limits throughout 2019; however, a significant increase in EC concentrations was also observed from October 2017. Comparison of the data shows that pH values and EC concentrations are generally inversely proportional to water levels, increasing as water levels decrease and vice versa. The trends for pH and EC in comparison to the SWL in the bore are presented in **Figure 6-22** and **Figure 6-23**. Given the proximity of WOH2139A to North Pit, the changes in water quality in relation to changes in water levels is expected.

The EC concentrations and pH values for bore WOH2139A are not consistent with those recorded in the other monitoring bores intersecting the Blakefield Seam (OH1122 (1) and OH1125 (1)). Within the monitoring network bore OH1125 (1) is located directly to the north of the North Pit, with bore OH1122 (1) located directly to the south of the West Pit. Review of historical and 2019 water quality data shows that the pH values and EC concentrations within these bores are similar and are therefore potential more representative of the Blakefield Seam. A review of the construction details and lithological logs for each bore should be undertaken to confirm that each bore is targeting the Blakefield Seam. In addition, review of sampling techniques shows that WOH2139A is a grab sample whereas bore OH1122 (1) is sampled using full purge techniques. The difference in techniques may therefore result in the variability in quality observed between the bores.

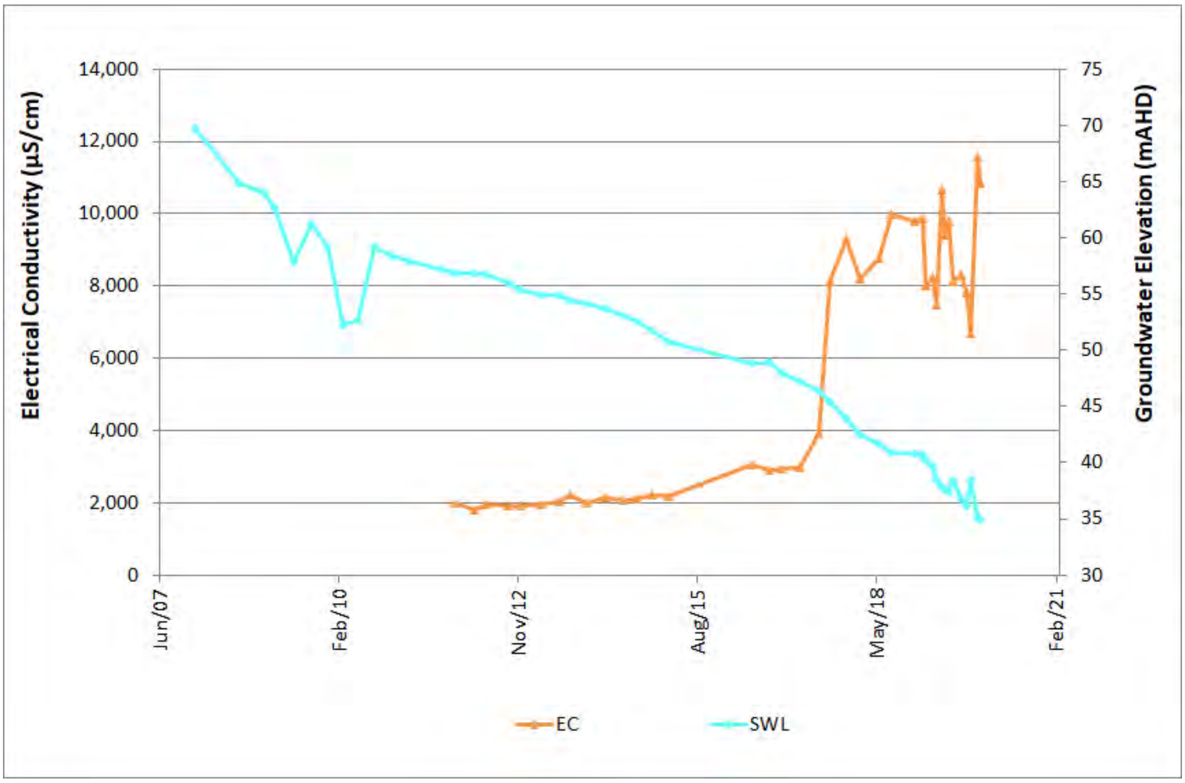


Figure 6-22 Electrical Conductivity and SWL Trends at WOH2139A

Figure 6-23 pH and SWL Trends at WOH2139A

Bore OH1138 is constructed as a nested bore with two sections of 32 mm PVC casing within the one hole, both of which target the shallow Warkworth Seam. OH1138(1) is apparently screened from 20.8 m to 24.8 m depth and OH1138(2) is apparently screened from 38.8 m to 42.8 m depth. The bores are located on the north side of North Pit.

Additional to the quarterly monitoring events bore OH1138(1) was monitored monthly throughout 2019. pH over 2019 was variable and consistently below the lower pH trigger threshold, with readings ranging between 5.9 (July 2019) to 6.2 (August 2019). Except for monitoring results from April 2019 and May 2019 EC concentrations were within trigger levels. pH and EC concentrations for bore OH1138 (2) were within trigger limits throughout 2019.

Trends in water quality for the two bores are presented in **Figure 6-24**. The graph shows that over 2019 pH readings in bore OH1138 (1) were generally stable with small variations from month to month. Overall pH was lower than historic trends in bore OH1138 (1) and similar to historic trends in bore OH1138 (2). The graph includes available water quality data for adjacent surface water dam 27N, which shows no clear correlation to trends in OH1138.

Figure 6-24 shows that over 2019, trends in EC concentrations in both bore OH1138 (1) and OH1138 (2) were similar, with concentrations initially increasing until July 2019, decreasing until October 2019 and then increasing again across the rest of the year. Over 2019, the trigger level of 19,657 µS/cm was exceeded in bore OH1138 (1) in April and May. The graph includes available water quality data for adjacent surface water dam 27N, which shows no clear correlation to trends in OH1138. **Figure 6-25** shows that EC concentrations have fluctuated in OH1138 (1) since 2013, with no apparent correlation with the observed decline in groundwater levels.

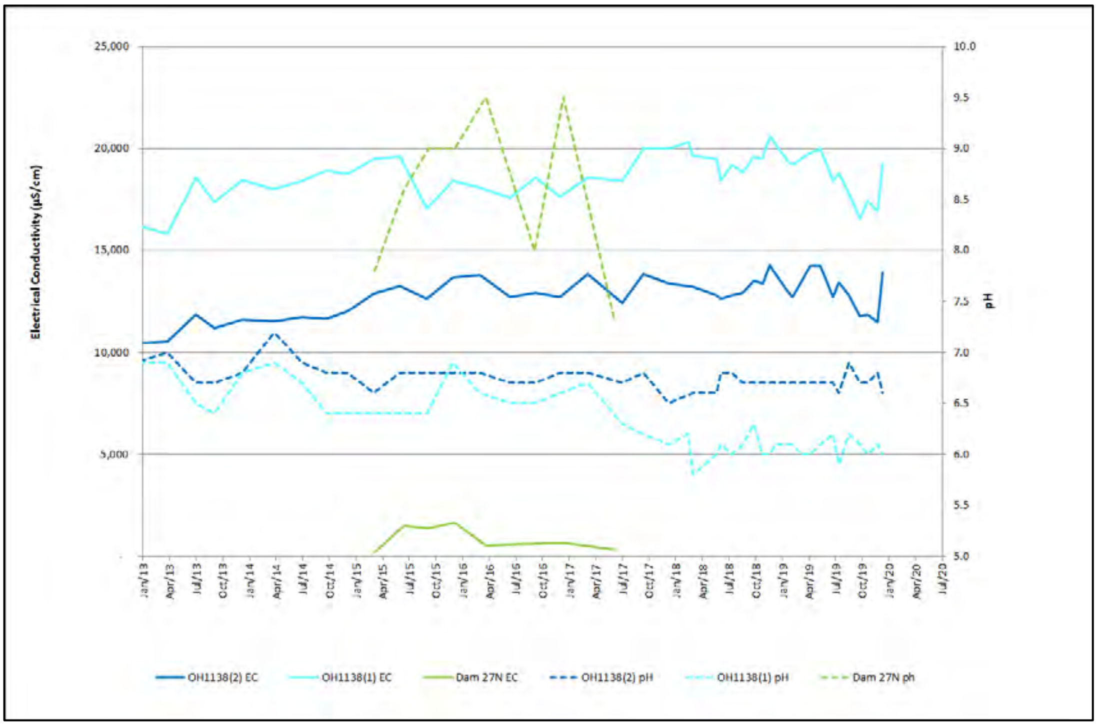


Figure 6-24 Water Quality Trends at OH1138(1) and OH1138(2)

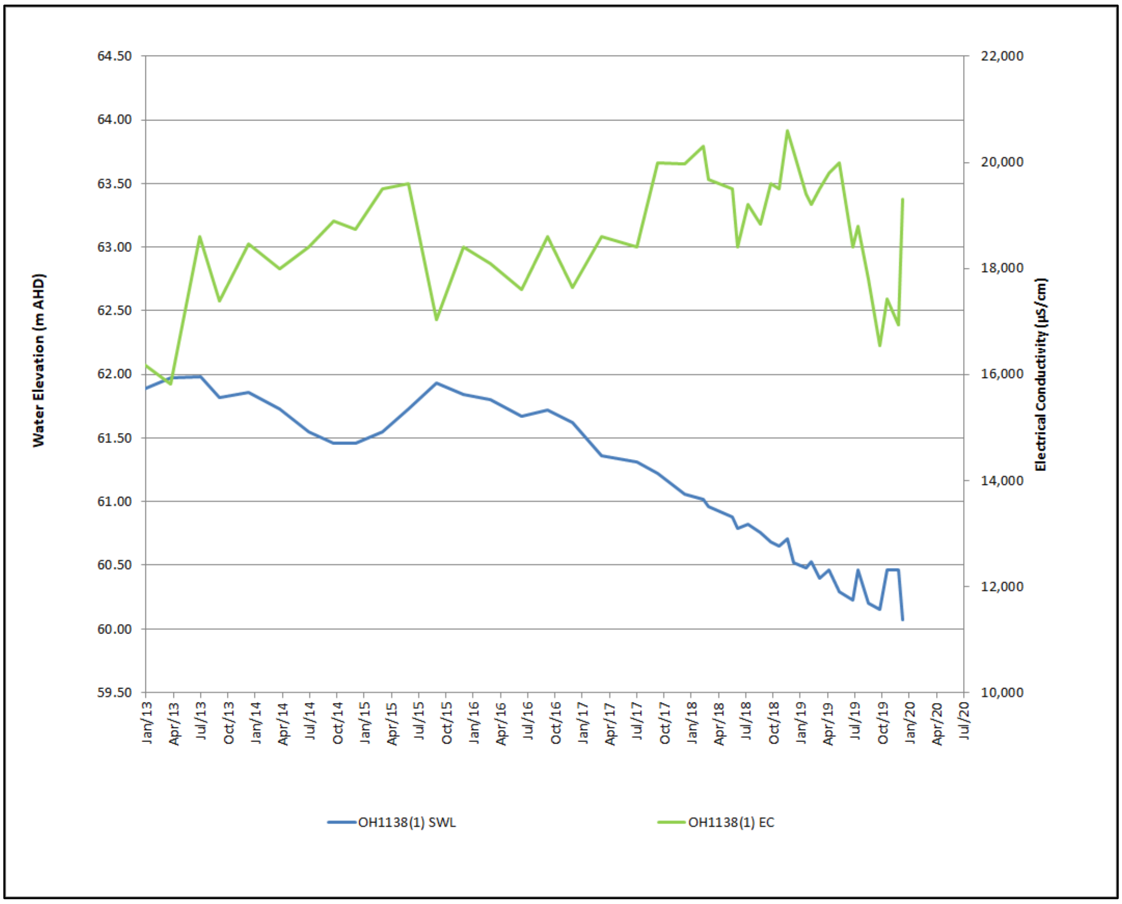


Figure 6-25 Electrical Conductivity and SWL Trends at OH1138(1)

6.4 Groundwater Take

Interception of groundwater occurs at site due to a range of activities, including direct interception of groundwater with mining activities, and indirect interception via induced inter-formation flows due to depressurisation of the Permian coal measures. Each activity and the estimated groundwater take for the various water sources. is discussed below. Note, the information presented does not capture the full mine water balance but only a summary of available information provided to SLR.

6.4.1 Groundwater Inflows to Mine Operations

A numerical groundwater model was developed for MTW and updated by AGE (2015). The model was calibrated up to 2014 conditions and replicates mine progression to year 2035. As discussed in **Section 2.2**, AGE (2015) present predicted groundwater take (direct and indirect) from the various groundwater sources. AGE (2015) report that MTW operations were predicted to intercept up to approximately 500 ML of water from the North Coast Fractured and Porous Rock water source. AGE (2015) report that the predicted indirect interception of water, via inter-formational flows due to depressurisation of the Permian coal measures, for 2019 was approximately:

- 3.5 ML from the Hunter River Regulated Water Source;
- 11 ML from the Hunter Unregulated and Alluvial Water Sources; and
- 270 ML from the North Coast Fractured and Porous Rock water source.

6.4.2 Surface Water Abstraction

Over 2019, surface water was abstracted from the Hunter River in accordance with licence conditions. Metered volumes recorded by Yancoal show 1,594 ML of water was pumped from the Hunter River over the 2019 calendar year.

6.4.3 Groundwater Abstraction

Lemington Underground (LUG) bore is an abstraction bore at the Hunter Valley Operations. The bore is constructed into the abandoned LUG mine void underlying HVO and is licensed to take up to 1,800 ML of water from the North Coast Fractured and Porous Rock aquifer (WAL 39798) per water year (July to June). The licenses are held by HVO but utilised by MTW as part of a water sharing agreement.

The bore is equipped with a flow meter, with total monthly abstraction documented. Based on the flow volumes recorded from July 2018 to June 2019 a total of 1,315 ML of water was abstracted from the LUG bore, which is within the licensed allocation of 1,800 ML/year.

6.4.4 Summary of Water Take For 2019

Water take from the various groundwater and surface water sources associated with MTW are presented in **Table 6-4** for the 2019 calendar year. Abstraction volumes from the LUG bore are not presented within **Table 6-4** as they are reported through HVO's licencing and reporting processes.

Table 6-4 Predicted Groundwater Take (ML) for 2019

	Hunter Regulated	Hunter Unregulated	North Coast Fractured and Porous Rock
Mt Thorley Pit Excavation	~0.5	~5.0	~110
Warkworth Pit Excavation	~3.0	~6.0	~160
Surface Water Abstraction	1,594	0	-
Total	**1,597.5**	**11**	**~270**

As shown in **Table 6-4**, over the 2019 reporting year the total take under the Hunter River Regulated water source was estimated at 1,597.5 ML, total take from Hunter Unregulated water source was estimated at 11 ML and 270 ML from the North Coast Fractured and Porous Rock water source. These volumes are within the licensed volumes (see **Section 2.3**) for each water source.

6.5 Verification Model Predictions

In accordance with Schedule 3 Condition 26(b) (Mount Thorley SSD 6465) and Condition 27 (b) (Warkworth SSD 6464), the WMP includes requirements to review the numerical groundwater model every 3 years, comparing monitoring results with modelled predictions. The original numerical groundwater model for MTW was developed in 2014 as part of the Continuation Project (AGE, 2014a and AGE, 2014b). The model was developed using MODFLOW-SURFACT code to simulate groundwater response to mining over time. The model comprises 16 layers with 98,644 cells (76,089 active) per model layer. The numerical groundwater model was updated in 2015 by AGE (2015), with changes made to the model design (i.e. mine progress, extent of alluvium, flood levee and final void) and the hydraulic parameters recalibrated.

SLR were provided with the AGE (2015) numerical groundwater model predictions, which have been graphed against observed groundwater levels at the site in **Appendix E**. Review of the trends has identified that the predicted groundwater level trends generally correspond to trends within observed data. However, at a few of the bores and VWP sensors the model predicted less drawdown than observed, as discussed below:

- GW9707, GW9708, and GW9709 – groundwater observations recorded a decline from 2017 and through 2019 compared to stable levels within the model. The model replicated the bores as being within layer 16 (basement) but construction details indicate the bores are within the shallow (<30 m deep) weathered Bayswater Seam.
- OH1123 – groundwater observations indicate a rapid decline in groundwater levels from 2014, while the model predicted a more gradual decline in groundwater levels. The difference appears to relate to actual mine progression, model cell discretisation and influence from abstraction from LUG Bore not captured in the model.
- OH1126, OH1137, and OH1138 – the bores intersect shallow (13 m to 53 m depth) Permian coal measures (Warkworth Seam and Vaux Seam) to the north of North Pit. The bores record a general decline in groundwater levels since 2008, while the model predicted a rise in groundwater levels. This difference may relate to how the model replicates recovery within the rehabilitated spoil at North Pit. The difference may also relate to influence of licenced groundwater abstraction from the Lemington Underground Bore that is not replicated within the model.

- WDH462_P1 – is a VWP sensor that targets the Vaux Seam to the west of North Pit, which is mined down to the shallow Mt Arthur Seam. The bore recorded a decline in groundwater levels since 2011, while the model predicted a rise in groundwater levels. As outlined within the AGE (2014a) groundwater assessment report, this likely relates to depressurisation of the seams below the base of the pit as well as cumulative impacts from surrounding operations.
- WOH2153A, WOH2154A, WOH2155A, and WOH2156A – all four bores are reported to intersect the Redbank Creek Seam at depths of between 30 m and 70 m. This seam is not present within the numerical groundwater model; therefore, the bores are represented in the model as intersecting the lower permeability interburden material in Layer 4.
- Recent trends in observed data vary from modelled at VWP's WD625_P3, WD615_P2, MTD605_P2, MTD605_P3, MTD605_P6, MTD605_P7, MTD613, MTD518, and WD609. The observed data appears inconsistent with historical trends and may reflect errors in data conversion.
- Groundwater level drawdown is observed in bores WOH2153A, WOH2154A, WOH2155A, and WOH2156A above predictive results. In contrast bore PZ9D was predicted to have higher drawdown than observed. The cause for discrepancy may relate to changes in mine scheduling and how pre-stripping and backfilling was captured within the model.

Overall, the numerical model appears to adequately replicate observed changes in groundwater levels for 2019 at most bores. However, work should be conducted to further refine the model predictions, as follows:

- Better match between actual mine progression and predicted mine progression (including spoil emplacement) for operations at MTW and surrounding mine operations;
- Include the licenced groundwater abstraction from LUG bore within the model;
- Include current climate and streamflow trends, as well as incorporate data from recently installed bores (i.e. MB15MTW bores);
- Review calibrated parameters for spoil and vertical hydraulic conductivity within the Permian coal measures;
- Review monitoring bore construction details and confirm water bearing zones being monitored;
- Review the model structure and compare to the site geological model and available drill data; and
- Review data collected from VWPs including construction details and calibration certificates.

7 Conclusions and Recommendations

7.1 Conclusions

This annual groundwater review covers data collected over 2019 and was completed in compliance with:

- Warkworth Mine in accordance with Schedule 3 Condition 27 of the Warkworth Consent (SSD 6464); and
- Mt Thorley Mine in accordance with Schedule 3 Condition 25 of Development Consent (SSD 6465)

Over 2019 operations across MTW included active mining at North Pit, Loders Pit and West Pit. Tailings Dam 1 has been rehabilitated, and Tailings Dam 2 undergoing rehabilitation.

Review of climate data indicates that, with the exception of March (145.6mm), over 2019 the region generally experienced below average rainfall, and no flow has been recorded along Wollombi Brook.

The groundwater bore network at MTW has been installed progressively over the life of the operations and acquired through land purchase. In accordance with the WMP 60 open standpipe bores require routine SWL and quality monitoring. The WMP also requires routine SWL monitoring of 10 VWPs, however based on discussion with site personnel and review of the data it is understood some of the VWP sensors may not be fully operational due to a range of factors (i.e. batteries, pressurisation of sensors above their working limit). To ensure that water level data continues to be collected across all aquifer units a review of all bores and VWPs in which logger / sensor failures have been reported should be undertaken. The review should include an assessment into whether the faulty logger / sensor can be repaired or whether replacement / rectification works are required.

Available VWP and monitoring bore logger data was reviewed to assess trends in groundwater levels over 2019. The data indicates that where saturated, water within the alluvium declined slightly, generally in line with climate and stream flow trends. Groundwater within the Permian coal measures remained relatively stable to slightly declining over 2019. Where observed, the decreasing elevations are believed to be attributed to depressurisation of the coal seams in relation to mining activities. The groundwater drawdown appears in line with the predicted drawdown with the coal measures around active mine areas.

As per the WMP, pH and EC concentrations are monitored on a quarterly basis at nominated bores, with a larger suite of analytes reviewed annually. Review of water quality results and comparison to trigger levels for EC and pH identified several trigger exceedances over 2019. It was identified that several bores exceeded triggers for EC and pH; however, 2019 readings were in line with historical trends for these bores. It is also noted that MTW changed its sampling methodology during the 2019 reporting period following recommendations in the 2018 review. It is recommended that a review of the trigger be undertaken in light of the revised sampling methodology. Groundwater quality trends outside of historical trends were observed for bore OH1138 and WOH2139A, which likely relate to declining groundwater levels. The decline in levels may relate to abstraction from the LUG Bore at Hunter Valley Operations to the north and the progression of mining activities associated with North Pit. Groundwater levels within the Warkworth Sands at PZ7S declined over the 2019, despite above average rainfall recorded in March 2019, similar to trends observed for bores in overburden. Further investigation into the ground conditions, bore construction and loggers at PZ7S and PZ7D is recommended.

Over 2019 monitoring of the groundwater bore network was generally conducted in accordance with the GMP outlined within the WMP. Following recommendations made in the previous Annual Review, quarterly sampling methodologies were changed in 2019 to be in general accordance with relevant standards. Annual samples were also collected in general accordance with relevant standards. The exception to this was generally for cases where the condition of the bores (i.e. 32 mm casing) inhibited the ability to collect representative samples. Grab samples have been taken for monitoring bores WOH1239A, WOH2141A, WOH2153A, WOH1254A, WOH2155A, WOH2156A, WD622P, MBW02 and MBW03 within the network. This approach is not in line with industry standards and may not provide a representative water quality sample. The justification for this methodology should be reviewed to determine if more suitable methods (i.e. full purge or low flow) can be applied. A review into the requirement of these bores for the collection of water quality data for the WMP should be undertaken. If it is found that the continued collection of water quality data is required from a bore and suitable sampling methods cannot be adopted, then bore rectification works should be considered.

Over 2019 water level and water quality readings were not taken at 19 bore locations due to a range of factors, such as dry or blocked bore conditions and access restrictions.

Quantification of groundwater take was undertaken based on reported volumes estimated for approved operations by AGE (2015) and metered abstraction volumes from bores and surface water pumps. Based on this, over the 2019 reporting year the total take under the Hunter Regulated water source was estimated at 1,597.5 ML. Total take from Hunter Unregulated water source was estimated at 11 ML and 270 ML from the North Coast Fractured and Porous Rock water source.

Comparison of observed groundwater levels against predicted levels generated from the numerical groundwater model were made. Overall, the numerical model was found to have adequately replicated observed changes in groundwater levels for 2019. Where modelled and observed values were significantly different, it was largely found that the difference in values could be attributed to differences in actual and predicted site conditions (i.e. climatic conditions, changes to mine progression / activities etc). A number of recommendations are therefore related to updating the model including a review of VWP data and construction, better matching of actual mine progression, inclusion of the LUG bore abstraction and the inclusion of current climate and streamflow trends.

Overall, the current monitoring network and program is generally adequate for satisfying current monitoring requirements of the WMP. There is good spatial of coverage of monitoring locations across the site, with multiple bores and VWP sensors installed into each relevant aquifer unit. To ensure this is maintained a network review should be undertaken with the purpose of identifying existing monitoring infrastructure that may need rectification or replacement due to potential impacts from current and future mining.

7.2 Recommendations

Based on review of the available data for 2019, the following recommendations have been made:

- Review the groundwater monitoring network and program to more clearly identify the purpose of each bore based on its location and construction, and align the compliance conditions to this purpose. Including inclusion of newly installed monitoring points and removal of bores/sensors from the program that have been identified as destroyed/erroneous;
- Check surveyed ground and casing elevations for bores, particularly the MB15MTW bores;
- Check VWP's and monitoring bore loggers are working correctly (i.e. check/replace batteries and logger depths) and install a site barometric logger for atmospheric compensation;
- Installation of data loggers within bores MB15MTW02D and PZ8S;

- Review of logger installation depths for bores PZ8D, PZ9S, PZ7S, PZ7D and MB15MTW02S. Review required to confirm that the reported installation depths are correct and to ensure loggers are suitably placed below the standing water level;
- Investigate ground conditions, bore construction and logger data for nested bore PZ7S and PZ7D;
- Review geological and bore construction logs and geology for bores OH943, OH944, OH788, OH1121;
- Review site conditions around MTD616P and MTD614 to understand cause for rise in groundwater levels within shallow stratigraphy;
- Review of groundwater quality triggers to ensure they are reasonable and adequately capture historical trends for bores and account for changing climate conditions; and
- Continue to update the numerical groundwater model to more account for climate trends and actual mine progression activities that have evolved since the initial model development.

8 References

Australasian Groundwater and Environmental Consultants 2013, *Warkworth Mine Modification Groundwater Impact Assessment*, Appendix C in Warkworth Modification 6 Environmental Assessment, prepared for EMGA Mitchell McLennan, August 2013.

Australasian Groundwater and Environmental Consultants 2014a, *Warkworth Continuation 2014 Groundwater Assessment*, prepared for EMGA Mitchell McLennan, May 2014.

Australasian Groundwater and Environmental Consultants 2014b, *Mount Thorley 2014 Groundwater Assessment*, prepared for EMGA Mitchell McLennan, May 2014.

Australasian Groundwater and Environmental Consultants 2015, *Mount Thorley and Warkworth Mines, Long Term Approvals Model Update*, February 2015.

SLR Consulting 2019, *Mt Thorley Warkworth Annual Groundwater Review*, prepared for Yancoal.

APPENDIX A

Groundwater Monitoring Program

ID	Easting	Northing	Top of Casing Elevation (mAHD)	Bore Depth (m bTOC)	Geology	Groundwater Monitoring Program			
						Water Level	EC	pH	Full WQ
OH786a	320542	6392674	55.7	7.1	Regolith	Q	Q	Q	A
OH787	320982	6391921	50.0	12.1	Regolith	Q	Q	Q	A*
OH788	321482	6390967	45.4	22.1	Hunter River Alluvium	Q	Q	Q	A
OH942	320536	6392622	55.8	13.2	Regolith	Q	Q	Q	A*
OH943	321476	6390963	45.0	9.9	Hunter River Alluvium	Q	Q	Q	A
OH944	321113	6391035	47.9	8.2	Hunter River Alluvium	Q	Q	Q	A
G3(2)	317787	6385253	73.0	4.1	Wollombi Brook Alluvium				
PZ8S	317002	6385411	65.8		Wollombi Brook Alluvium	Q	Q	Q	A
PZ9S	317542	6385642	65.4	6.9	Wollombi Brook Alluvium	Q	Q	Q	A
MB15MTW01S	315909	6385605			Wollombi Brook Alluvium	Q	Q	Q	A
MB15MTW02S	313823	6387224			Wollombi Brook Alluvium	Q	Q	Q	A
MBW01	314379	6386796	62.4	11.0	Alluvium	Q	Q	Q	A
PZ7S	314055	6392671	58.4	11.1	Aeolian Warkworth Sands	Q	Q	Q	A
MB15MTW04	314993	6392645		6.5	Warkworth Sands	Q	Q	Q	A
MB15MTW05	314645	6392758		6.9	Warkworth Sands	Q	Q	Q	A
MB15MTW06	314438	6392801		6.9	Warkworth Sands	Q	Q	Q	A
MB15MTW07	314965	6392085		6.8	Warkworth Sands	Q	Q	Q	A
MB15MTW08	314296	6392182		6.8	Warkworth Sands	Q	Q	Q	A
MB15MTW09	313995	6392219		3.1	Warkworth Sands	Q	Q	Q	A
MB15MTW10	314667	6392134		3.7	Warkworth Sands	Q	Q	Q	A
MB15MTW11	314352	6392417		6.9	Warkworth Sands	Q	Q	Q	A
PZ7D	314057	6392684	58.4	30.5	Shallow Overburden	Q	Q	Q	A
PZ8D	317001	6385418	65.8	37.0	Shallow Overburden	Q	Q	Q	A
PZ9D	317541	6385652	65.5	24.0	Shallow Overburden	Q	Q	Q	A
MTD616P	316269	6387618	77.8	29.0	Shallow Overburden	Q	Q	Q	A
MTD614P	317259	6386175	72.6	30.0	Shallow Overburden - Conglomerate	Q	Q	Q	A
MBW02	314373	6386798	62.6	60.4	Shallow Overburden	Q	Q	Q	A
MB15MTW01D	315910	6385604			Shallow Overburden? Alluvium?	Q	Q	Q	A
MTD605P	316279	6386156	77.4	42.0	Shallow Overburden - sandstone	Q	Q	Q	A
MB15MTW02D	313823	6387219			Shallow Overburden? Alluvium?	Q	Q	Q	A
MB15MTW03	313722	6388917		22.7	Shallow Overburden - Wollombi alluvium?	Q	Q	Q	A
WD625P	314669	6390487	76.4	31.0	Whybrow Seam	Q	Q	Q	A
WOH2153A	313881	6391429	68.3	42.6	Redbank Crk Seam	Q	Q	Q	A
WOH2154A	313976	6389990	68.9	69.4	Redbank Crk Seam	Q	Q	Q	A
WOH2155A	315278	6390138	74.6	46.0	Redbank Crk Seam	Q	Q	Q	A
WOH2156A	315874	6388866	80.4	31.5	Redbank Crk Seam	Q	Q	Q	A
WOH2153B	313881	6391429	68.3	62.4	Wambo Seam	Q	Q	Q	A
WOH2154B	313976	6389990	68.9	98.0	Wambo Seam	Q	Q	Q	A
WOH2155B	315278	6390138	74.6	73.1	Wambo Seam	Q	Q	Q	A
WOH2156B	315874	6388866	80.4	80.1	Wambo Seam	Q	Q	Q	A
WD622P	316229	6389585	84.5	55.0	Wambo Seam	Q	Q	Q	A
MBW04	314368	6386800	62.4	162.0	Wambo	Q	Q	Q	A
WOH2139A	315249	6391511	91.7	96.0	Blakefield	Q	Q	Q	A*
OH1122 (1)	318545	6387886	100.6	49.6	Blakefield Seam	Q	Q	Q	A*
OH1122 (2)	318545	6387886	100.6	112.6	Woodlands Hill Seam				
OH1122 (3)	318545	6387886	100.6	152.6	Bowfield Seam				
OH1125 (1)	316511	6392875	86.2	40.0	Blakefield	Q	Q	Q	A*

ID	Easting	Northing	Top of Casing Elevation (mAHD)	Bore Depth (m bTOC)	Geology	Groundwater Monitoring Program			
						Water Level	EC	pH	Full WQ
OH1125 (2)	316511	6392875	86.2	25.3	Unknown - Blakefield?	Q	Q	Q	A*
OH1125 (3)	316511	6392875	86.2	62.7	Bowfield Seam	Q	Q	Q	A*
OH1138 (1)	317835	6393346	70.7	24.8	Warkworth Seam	Q	Q	Q	A
OH1138 (2)	317835	6393346	70.7	42.8	Warkworth Seam	Q	Q	Q	A
OH1121	321902	6391030	45.6	20.3	Vane Subgroup	Q	Q	Q	A
OH1126	318586	6393387	64.5	52.5	Vaux	Q	Q	Q	A
OH1137	318266	6393377	67.9	17.8	Vaux	Q	Q	Q	A
OH1127	321444	6392097	51.2	29.0	Vane Subgroup	Q	Q	Q	A
GW 9706	322404	6387589	64.2	21.2	Bayswater	Q	Q	Q	A
GW 9707	322319	6387569	63.9	21.0	Bayswater	Q	Q	Q	A
GW 9708	322158	6387209	73.1	29.6	Bayswater	Q	Q	Q	A
GW 9709	322251	6388026	60.3	21.0	Bayswater	Q	Q	Q	A
GW98MTCL1	322188	6387032	77.8	19.7	Bayswater	Q	Q	Q	A
GW98MTCL2	322669	6387462	79.5	27.6	Bayswater	Q	Q	Q	A
WOH2141A	314989	6392647	91.6	45.6	Whynot Seam	Q	Q	Q	A
PZ1_VW1	321350	6387310	72.1	41.0	Mt Arthur Seam (Shallow)	Q			
PZ1_VW2	321350	6387310	72.1	42.0	Mt Arthur Seam (Deep)	Q			
PZ2_VW1	321445	6387218	68.1	48.6	Mt Arthur Seam (Shallow)	Q			
PZ2_VW2	321445	6387218	68.1	49.6	Mt Arthur Seam (Deep)	Q			
WD609A	318803	63922	129.9	110.0	Spoil	Q			
WD615_P1	319281	6391347	160.0	133.0	Piercefield Seam	Q			
WD615_P2	319281	6391347	160.0	225.0	Bayswater Seam	Q			
WD625_P1	314663	6390483	76.4	217.0	Woodlands Hill	Q			
WD625_P2	314663	6390483	76.4	354.0	Mt Arthur Seam	Q			
WD625_P3	314663	6390483	76.4	375.0	Vaux Seam	Q			
WD625_P4	314663	6390483	76.4	441.0	Bayswater Seam	Q			
WD622_P1	316236	6389588	84.5	54.0	Wambo Seam	Q			
WD622_P2	316236	6389588	84.5	165.0	Woodlands Hill Seam	Q			
WD622_P3	316236	6389588	84.5	314.0	Mt Arthur Seam	Q			
WD622_P4	316236	6389588	84.5	334.0	Vaux Seam	Q			
WD622_P5	316236	6389588	84.5	408.0	Bayswater Seam	Q			
MTD616_P1	316274	6387621	77.7	42.0	Whybrow Seam	Q			
MTD616_P2	316274	6387621	77.7	109.0	Wambo Seam	Q			
MTD616_P3	316274	6387621	77.7	215.0	Woodlands Hill Seam	Q			
MTD616_P4	316274	6387621	77.7	343.0	Mt Arthur Seam	Q			
MTD616_P5	316274	6387621	77.7	378.0	Vaux Seam	Q			
MTD616_P6	316274	6387621	77.7	446.0	Bayswater Seam	Q			
MTD613 (VWP)	320778	6387025	150.5	384.0	Broonie/Bayswater Seam?	Q			
MTD605_P1	316512	6386159	77.1	58.0	Weathered OB over Whybrow	Q			
MTD605_P2	316512	6386159	77.1	100.0	Whybrow Seam	Q			
MTD605_P3	316512	6386159	77.1	149.0	IB btw Wambo and Whynot	Q			
MTD605_P4	316512	6386159	77.1	215.0	Blakefield Seam	Q			
MTD605_P5	316512	6386159	77.1	368.0	Mt Arthur Seam	Q			
MTD605_P6	316512	6386159	77.1	429.0	Vaux Seam	Q			
MTD605_P7	316512	6386159	77.1	502.0	Bayswater Seam	Q			
MTD614_P1	317265	6386174	72.4	64.0	Whybrow Seam	Q			
MTD614_P2	317265	6386174	72.4	191.0	Glen Munro Seam	Q			
MTD614_P3	317265	6386174	72.4	342.0	Mt Arthur Seam	Q			
MTD614_P4	317265	6386174	72.4	383.0	Vaux Seam	Q			

ID	Easting	Northing	Top of Casing Elevation (mAHD)	Bore Depth (m bTOC)	Geology	Groundwater Monitoring Program			
						Water Level	EC	pH	Full WQ
MTD614_P5	317265	6386174	72.4	453.0	Bowfield Seam	Q			
WD456 (VWP)			100.6		Bayswater Seam	Q			
WD462_P1	315529	6391358	101.7	354.6	Vaux Seam	Q			
WD462_P2	315529	6391358	101.7	354.6	Bowfield Seam	Q			
WD462_P3	315529	6391358	101.7	354.6	Woodlands Hill Seam	Q			
MTD517_P1	317521	6386147	77.3		Mt Arthur Seam	Q			
MTD517_P2	317521	6386147	77.3		Woodlands Hill Seam	Q			
MTD517_P3	317521	6386147	77.3		Wambo Seam	Q			
MTD518_P1	316512	6386156	80.0		Mt Arthur Seam	Q			
MTD518_P2	316512	6386156	80.0		Blakefield/Woodlands Hill Seam	Q			
MTD518_P3	316512	6386156	80.0		Wambo Seam	Q			
MBW03	314387	6386794	62.4	84.2	Whybrow Seam	Q	Q	Q	A
MBW6A						Q	Q	Q	A

Notes:

TOC – top of casing
Q – Quarterly
A – Annual
 # Comprehensive analysis includes metals Mo, V and Cr

APPENDIX B

Groundwater Level and Quality Readings 2019

Bore ID	Target Geology	EC Trigger 95th	pH Trigger 5th –95th		Q1				Q2				Q3				Q4			
					SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC
OH786	Regolith	950	6.8	7.7	6.6	49.1	7.2	**1510**	2.8	52.9	7.1	845	6.7	48.9	7.1	**1920**	7.0	48.6	7.5	**2760**
OH787	Regolith	18185	7.2	7.7	13.9	36.1	7.6	**19100**	14.0	36.0	7.7	17310	14.0	36.0	7.6	17190	14.0	36.0	7.3	**19160**
OH788	Hunter River Alluvium	11742	7.1	7.9	1	35.4	7.1	11240	1	35.4	**7.0**	**12030**	1	35.4	**6.9**	**13850**	1	35.4	**7.0**	**13500**
OH942	Regolith	25380	6.4	7	9.3	46.4	6.6	**25400**	9.4	46.3	6.6	**25400**	9.5	46.3	6.6	25200	9.5	46.2	6.7	25300
OH943	Hunter River Alluvium	8415	7.1	7.6	9.6	35.5	7.4	8250	9.6	35.4			9.6	35.4			9.7	35.4		
OH944	Hunter River Alluvium																			
G3(2)	Wollombi Brook Alluvium																			
PZ8S	Wollombi Brook Alluvium	15200	6.5	7	6.2	59.5	6.6	14610	6.3	59.4	6.7	14580	6.4	59.4	6.8	13420	6.5	59.2	**6.2**	14710
PZ9S	Wollombi Brook Alluvium	16140	6.8	7	6.8	58.7	6.8	715	6.8	58.7		0	6.8	58.6			6.9	58.5		0
MB15MTW01S	Wollombi Brook Alluvium				6.9	56.4	**6.7**	**1533**	7.1	56.3	**6.9**	**3730**	7.1	56.3	**6.7**	**2160**	7.1	56.2	**6.6**	**2320**
MB15MTW02S	Wollombi Brook Alluvium				6.8	55.3	**7.6**	**2610**	7.0	55.2	**6.8**	**3840**	7.1	55.1	**6.8**	**3980**	7.1	55.0	**6.8**	**4000**
PZ7S	Aeolian Warkworth Sands				5.9	56.5	**7.5**	**16690**	5.9	56.5	**7.3**	**18200**	6.0	56.4	**7.4**	**15430**	6.1	56.3	**7.3**	**17580**
MBW01	Alluvium	1752	6.7	7.5	7.8	50.7	6.8	1407	7.9	50.6	6.7	1641	7.8	50.6	**6.5**	1328	8.1	50.4	6.8	1451
MB15MTW04	Warkworth Sands																			
MB15MTW05	Warkworth Sands																			
MB15MTW06	Warkworth Sands																			
MB15MTW07	Warkworth Sands																			
MB15MTW08	Warkworth Sands																			
MB15MTW09	Warkworth Sands																			
MB15MTW10	Warkworth Sands																			
MB15MTW11	Warkworth Sands																			

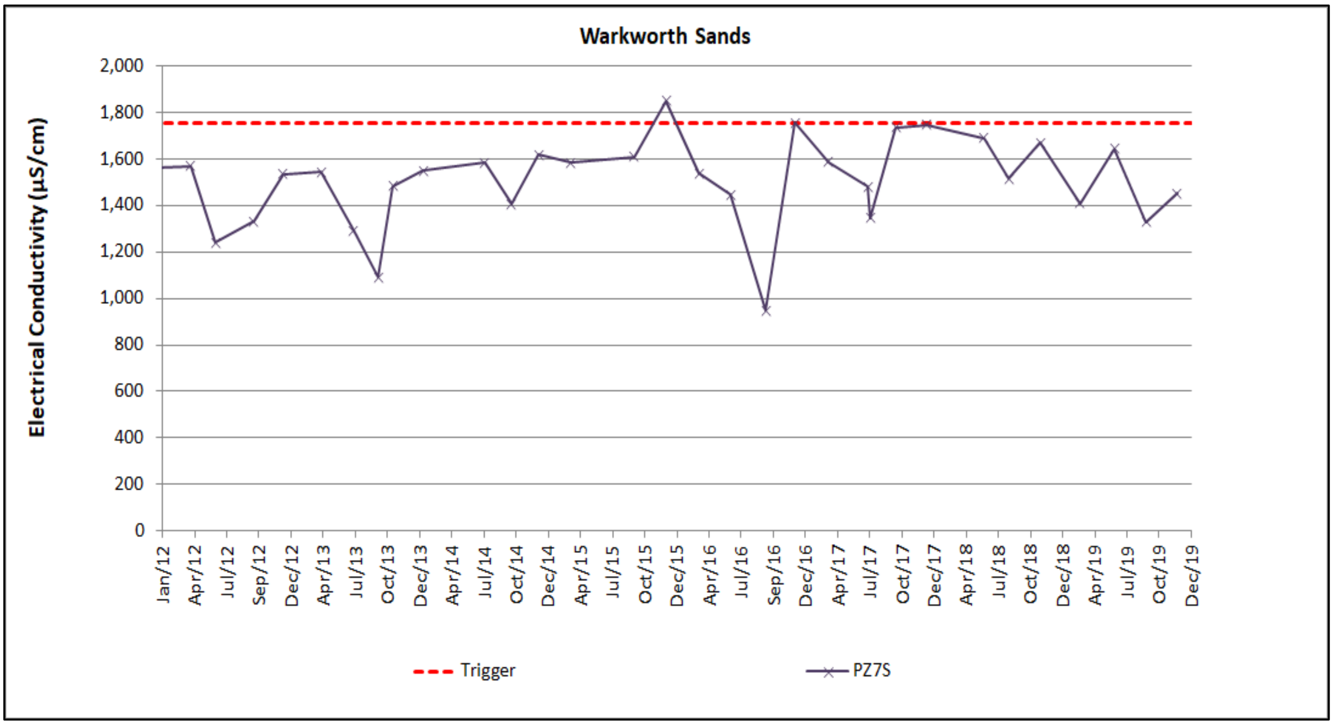
Bore ID	Target Geology	EC Trigger 95th	pH Trigger 5th –95th		Q1				Q2				Q3				Q4			
					SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC
PZ7D	Shallow Overburden	17490	6.9	8.1	7.7	50.8	7.8	1710	7.8	50.6	7.6	1686	7.7	50.7	7.6	1710	7.8	50.6	7.6	1664
PZ8D	Shallow Overburden	17490	6.9	8.1	6.6	59.2	7.5	8410	6.8	59.0	7.4	8500	7.2	58.5	7.5	8130	7.6	58.2	7.3	8670
PZ9D	Shallow Overburden	17490	6.9	8.1	17.7	47.8	7.1	10110	17.7	47.8	7.1	9970	17.8	47.7	7.1	8600	17.9	47.6	7.0	10330
MTD616P	Shallow Overburden	17490	6.9	8.1	6.5	71.4	7.6	14540	6.2	71.6	**6.8**	13880	6.1	71.8	**6.8**	14100	6.1	71.8	**6.7**	14600
MTD614P	Shallow Overburden - Conglomerate	17490	6.9	8.1	17.9	54.7	7.3	6160	18.0	54.6	7.5	5940	18.1	54.5	7.3	6840	17.9	54.7	7.2	9390
MBW02	Shallow Overburden	17490	6.9	8.1					8.3	54.3	7.3	7910	8.4	54.2	7.2	11150	8.6	54.1	7.2	12340
MB15MTW01D	Shallow Overburden?	17490	6.9	8.1	7.0	56.3	**6.3**	3330	7.0	56.4	**6.7**	2250	7.1	56.2	**6.3**	3900	7.4	55.9	**6.4**	3400
MTD605P	Shallow Overburden - sandstone	17490	6.9	8.1	15.1	62.3	7.7	17130	15.1	62.3	7.3	17130	15.1	62.3	7.7	16840	15.0	62.3	7.2	**17780**
MB15MTW02D	Shallow Overburden?	17490	6.9	8.1	6.6	55.4	8.0	9400	6.6	55.4	7.7	10200	6.7	55.3	7.6	9850	6.8	55.2	7.8	9400
MB15MTW03	Shallow Overburden?	17490	6.9	8.1	6.4	54.5	7.1	11860	6.6	54.4	7.0	12760	6.7	54.2	7.0	11030	6.8	54.1	6.9	12640
WD625P	Whybrow Seam	11996	7.1	7.3	18.7	57.7	**6.1**	**12520**	18.8	57.7	7.1	11200	19.3	57.1	7.2	**12180**	19.0	57.4	7.2	11910
MBW03	Whybrow Seam				8.0	54.4	**7.4**	**9680**	8.1	54.3	**7.3**	**9940**	8.2	54.2	**7.2**	**8980**	8.3	54.1	**7.3**	**9790**
WOH2153A	Redbank Crk Seam	16123	7	7.9	14.0	54.2	7.8	2080	15.0	53.3	7.9	2410	14.4	53.8	**8.0**	2260	15.3	53.0	**8.0**	2550
WOH2154A	Redbank Crk Seam	16123	7	7.9	16.1	52.8	**6.8**	4610	16.1	52.8	7.7	4730	16.9	52.0	7.7	4680	18.1	50.8	7.5	4750
WOH2155A	Redbank Crk Seam	16123	7	7.9	20.7	53.8	7.9	7200	21.0	53.6	7.2	9050	23.0	51.6	7.2	9350	24.7	49.9	7.2	9000
WOH2156A	Redbank Crk Seam	16123	7	7.9	28.8	51.6	7.1	15210	28.9	51.5	7.1	14860	30.7	49.7	7.1	14680	32.6	47.8	7.1	14960
WOH2153B	Wambo Seam	13843	7.2	7.8	10.9	57.3			11.0	57.3			11.1	57.2			11.1	57.2	7.2	1592
WOH2154B	Wambo Seam	13843	7.2	7.8	13.7	55.0	**6.9**	4910	14.4	54.2	7.5	5170	13.7	54.9	7.4	7620	13.8	54.9	7.3	8360
WOH2155B	Wambo Seam	13843	7.2	7.8	15.2	59.4	**6.7**	5490	15.3	59.3	7.7	5430	15.5	59.1	7.7	5390	15.6	59.0	7.6	5440
WOH2156B	Wambo Seam	13843	7.2	7.8	12.7	67.7	7.3	**14080**	12.8	67.6			12.7	67.7			12.7	67.7		
WD622P	Wambo Seam	13843	7.2	7.8	31.5	53.0	**8.0**	7560	31.9	52.6	**6.8**	**17830**	35.9	48.5	**6.9**	**14100**	37.9	46.6	7.4	8780

Bore ID	Target Geology	EC Trigger 95th	pH Trigger 5^{th} –95^{th}		Q1				Q2				Q3				Q4			
					SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC	SWL mbTOC	SWL mAHD	pH	EC
MBW04	Wambo	13843	7.2	7.8	12.2	50.2	7.6	12650	12.4	5	7.6	13190	12.6	49.8	7.5	11380	12.8	49.6	7.5	12930
WOH2139A	Blakefield	15161	6.6	7.6	52.0	39.7	**7.8**	8230	54.1	37.7	**8.0**	9420	55.0	36.8	**7.9**	8320	56.6	35.1	**8.2**	11550
OH1122 (1)	Blakefield Seam	15161	6.6	7.6	48.7	52.5	7.0	12090	49.1	52.1	7.1	12060	49.1	52.1	7.1	12130	48.9	52.3	7.1	12160
OH1125 (1)	Blakefield	15161	6.6	7.6	33.0	53.2	6.8	14230	35.2	51.0	6.8	12540	35.1	51.1	6.7	11410	36.5	49.7	6.7	13970
OH1125 (2)	Unknown	14696	6.6	7																
OH1125 (3)	Bowfield Seam	14696	6.6	7	39.0	47.2	6.8	14130	43.3	42.8	6.8	12440	52.0	34.2	6.7	11410	55.3	30.9	6.8	13980
OH1138 (1)	Warkworth	19657	6.3	7	10.3	60.4	**6.0**	19500	10.5	60.2	**6.2**	18400	10.6	60.2	**6.1**	16550	10.7	60.1	**6.0**	19300
OH1138 (2)	Warkworth	19657	6.3	7	14.9	55.8	6.7	13420	15.1	55.7	6.7	12730	15.1	55.6	6.7	11780	15.1	55.6	6.6	13920
OH1121	Vane Subgroup	17745	6.7	7.1	10.8	34.9	7.0	8100	10.8	34.9	7.0	8860	10.8	34.8	6.9	9150	10.8	34.8	6.9	9320
OH1126	Vaux	17745	6.7	7.1	17.8	46.7	6.8	9750	18.0	46.5	6.9	12280	18.1	46.4	6.9	10670	18.3	46.2	6.8	14360
OH1137	Vaux	17745	6.7	7.1	14.8	53.1	7.1	**17790**	15.0	52.8										
OH1127	Vane Subgroup	22991	6.6	7.5	15.9	35.3	6.7	12190	15.9	35.3	6.9	12080	16.0	35.3	6.8	12120	15.9	35.3	6.9	12170
GW 9706	Bayswater	22991	6.6	7.5	3.1	61.1	7.1	3160	3.2	61.1	7.1	4170	3.1	61.1	7.0	4790	3.5	60.7	6.8	4250
GW 9707	Bayswater	22991	6.6	7.5	5.7	58.2	7.0	21200	5.8	58.1	7.0	20800	6.1	57.8	7.1	20900	6.5	57.5	6.9	20600
GW 9708	Bayswater	22991	6.6	7.5	11.6	61.5	6.8	15990	11.9	61.2	6.8	13120	12.8	60.4	6.8	13600	12.9	60.3	6.6	13420
GW 9709	Bayswater	22991	6.6	7.5	8.9	51.4	6.8	**23300**	8.9	51.4	6.9	20000	9.3	51.1	6.9	**23000**	9.7	50.6		
GW98MTCL1	Bayswater	22991	6.6	7.5	10.7	67.1	7.3	6180	11.1	66.7	7.1	7560	12.0	65.7	7.0	6020	11.6	66.2	7.0	6010
GW98MTCL2	Bayswater	22991	6.6	7.5	10.9	68.6	6.6	16510	11.0	68.5	6.6	16300	11.1	68.4	6.6	16360	11.2	68.3	**6.5**	16540
WOH2141A	Whynot Seam				43.9	47.7	**7.7**	**10260**	44.2	47.4	**7.8**	**10220**	44.3	47.3	**7.8**	**10220**	44.4	47.2	**7.8**	**10390**
MBW6A					8.3		**6.6**	**990**	8.3		**6.7**	**968**	8.3		**6.3**	**924**	8.4		**6.4**	**953**

Note: *SWL – standing water level*
mbTOC – meters below top of casing
NS – Casing elevation not surveyed

APPENDIX C

Groundwater Quality Graphs



Warkworth Sands
Electrical Conductivity (µS/cm)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
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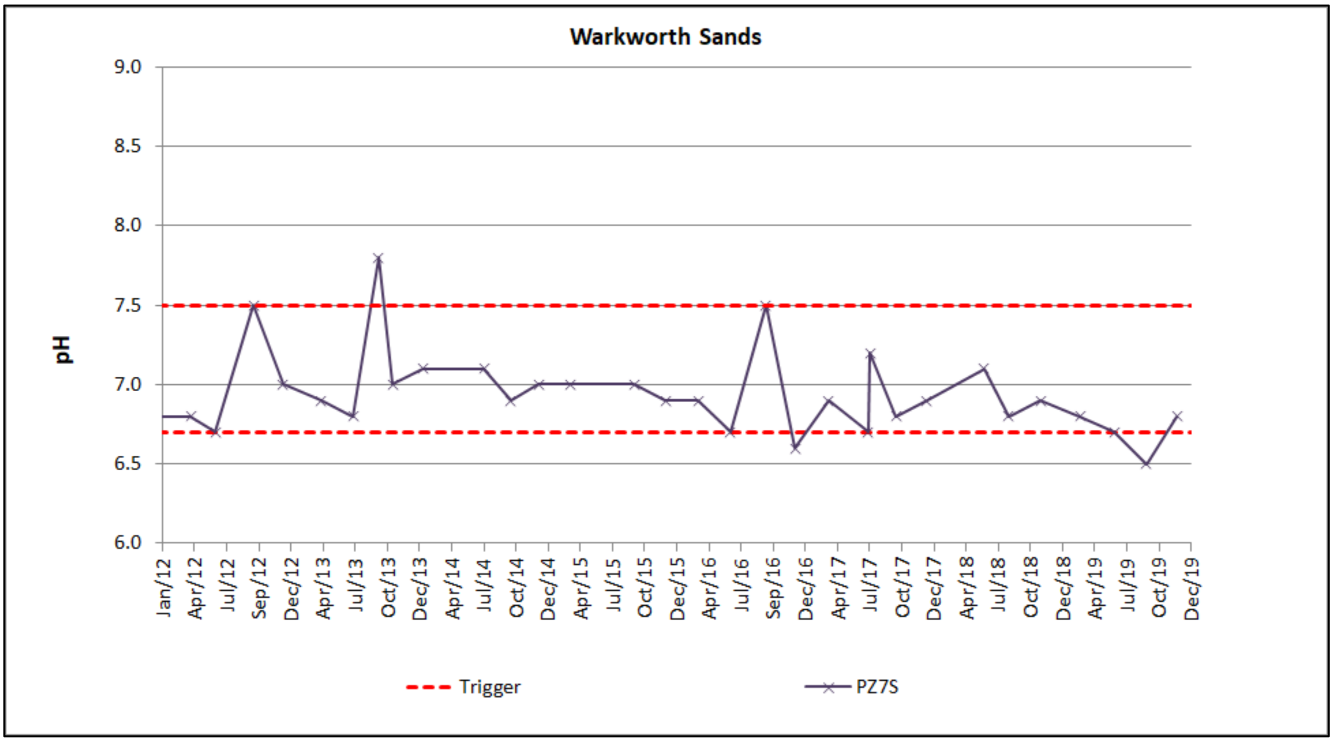
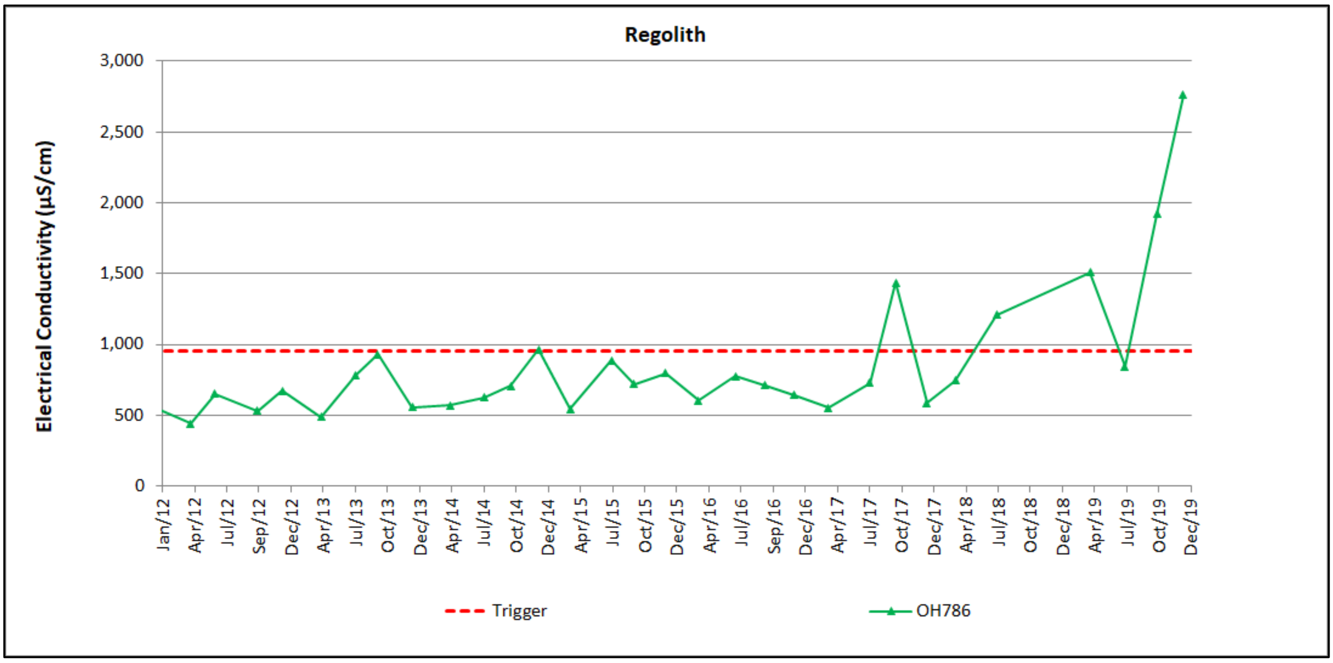
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
PZ7S



Warkworth Sands
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
PZ7S


Regolith
Electrical Conductivity (µS/cm)
3,000
2,500
2,000
1,500
1,000
500
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
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Apr/18
Jul/18
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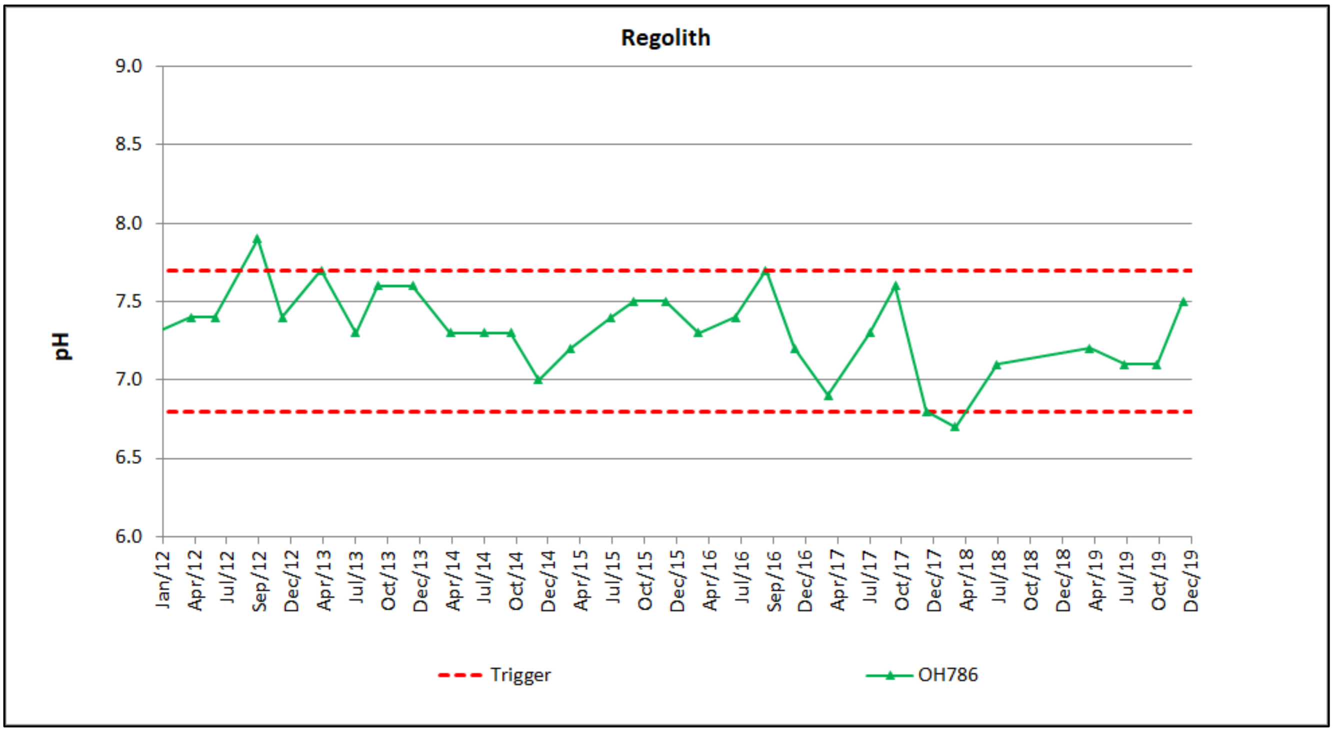
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH786


Regolith
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
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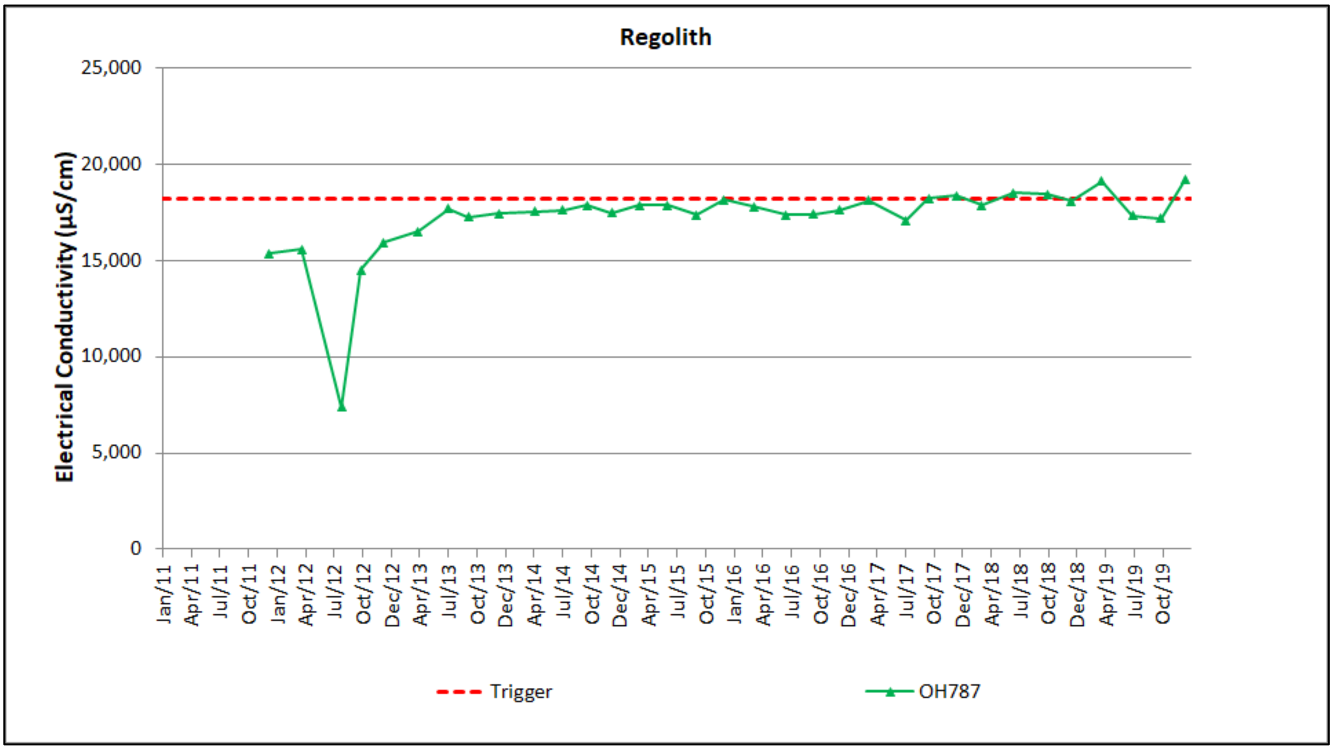
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH786


Regolith
Electrical Conductivity (µS/cm)
25,000
20,000
15,000
10,000
5,000
0
Jan/11
Apr/11
Jul/11
Oct/11
Jan/12
Apr/12
Jul/12
Oct/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Jan/16
Apr/16
Jul/16
Oct/16
Dec/16
Apr/17
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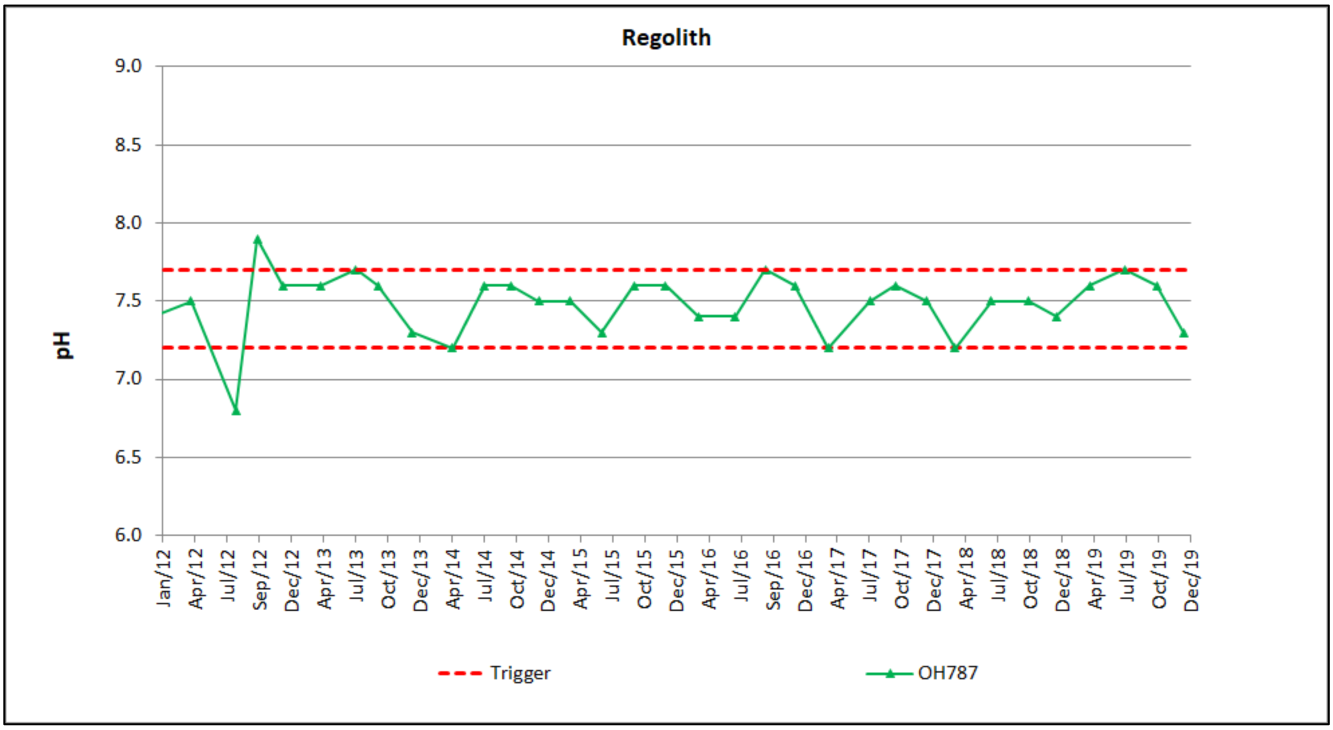
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Trigger
OH787


Regolith
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
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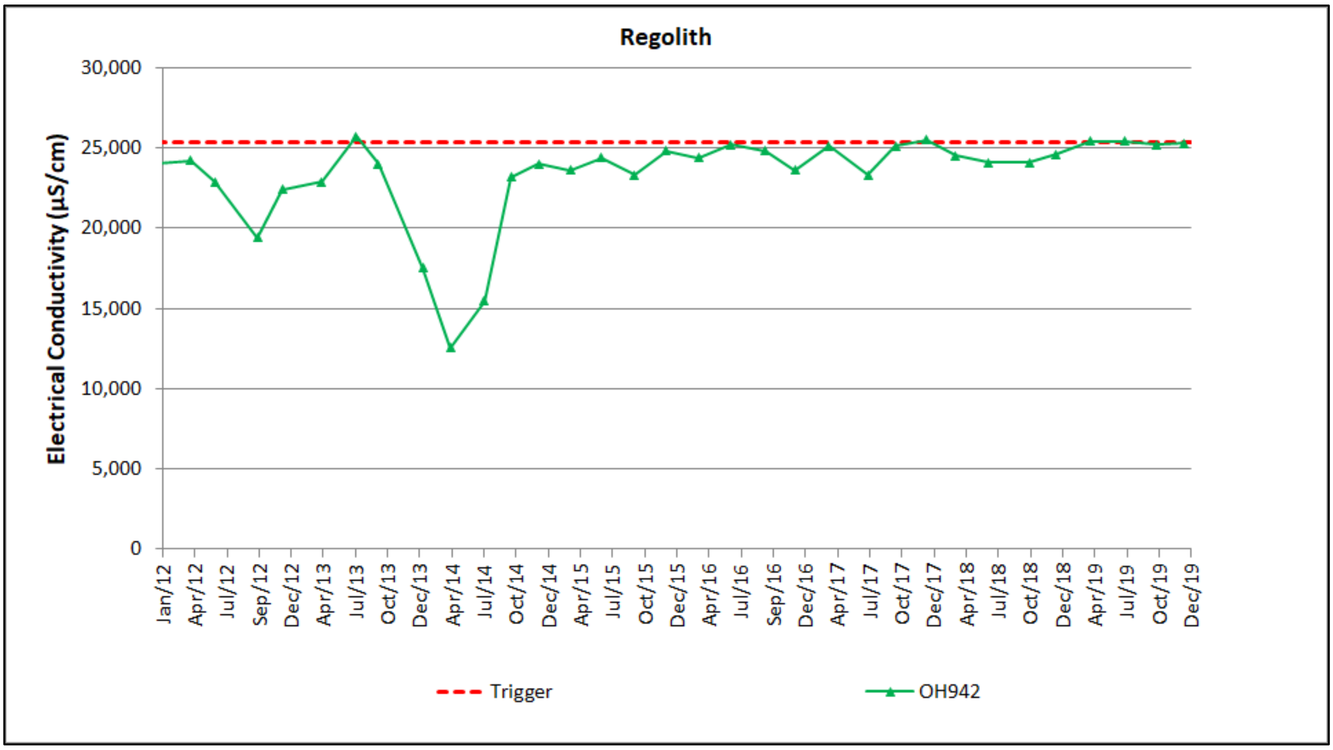
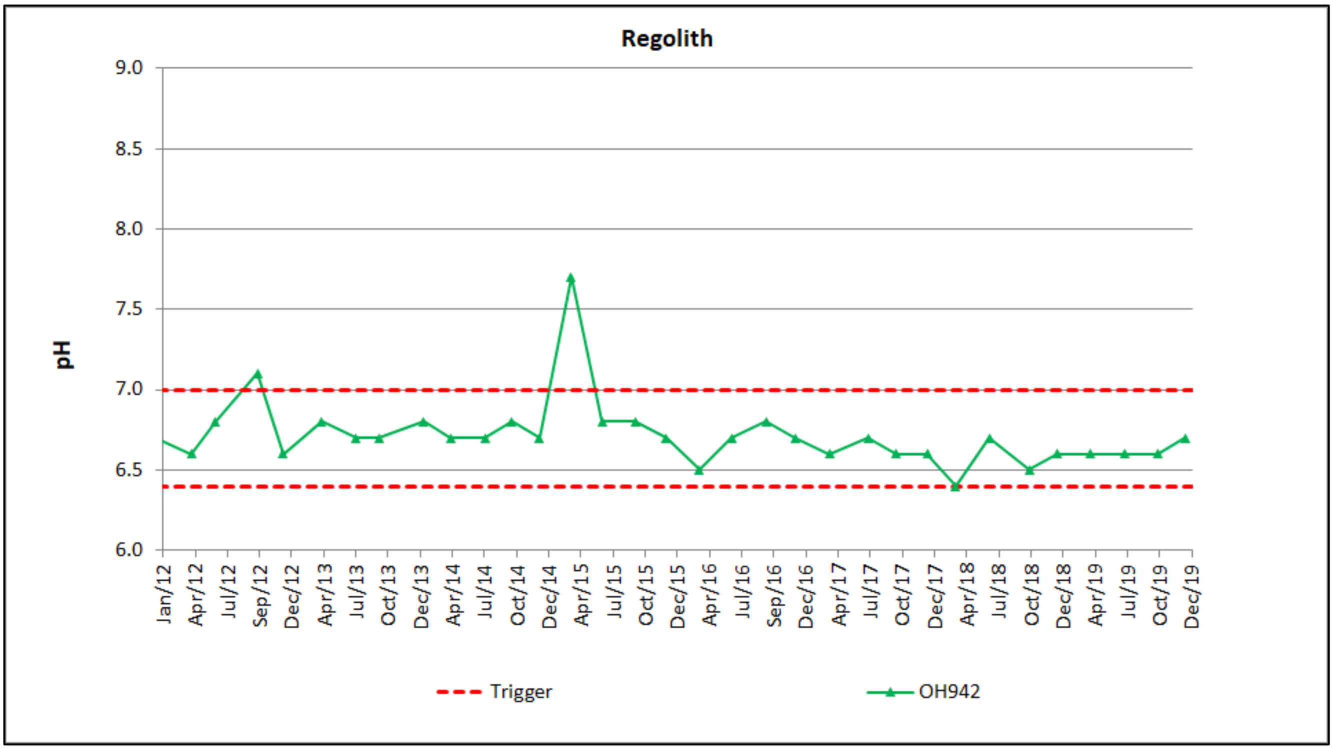
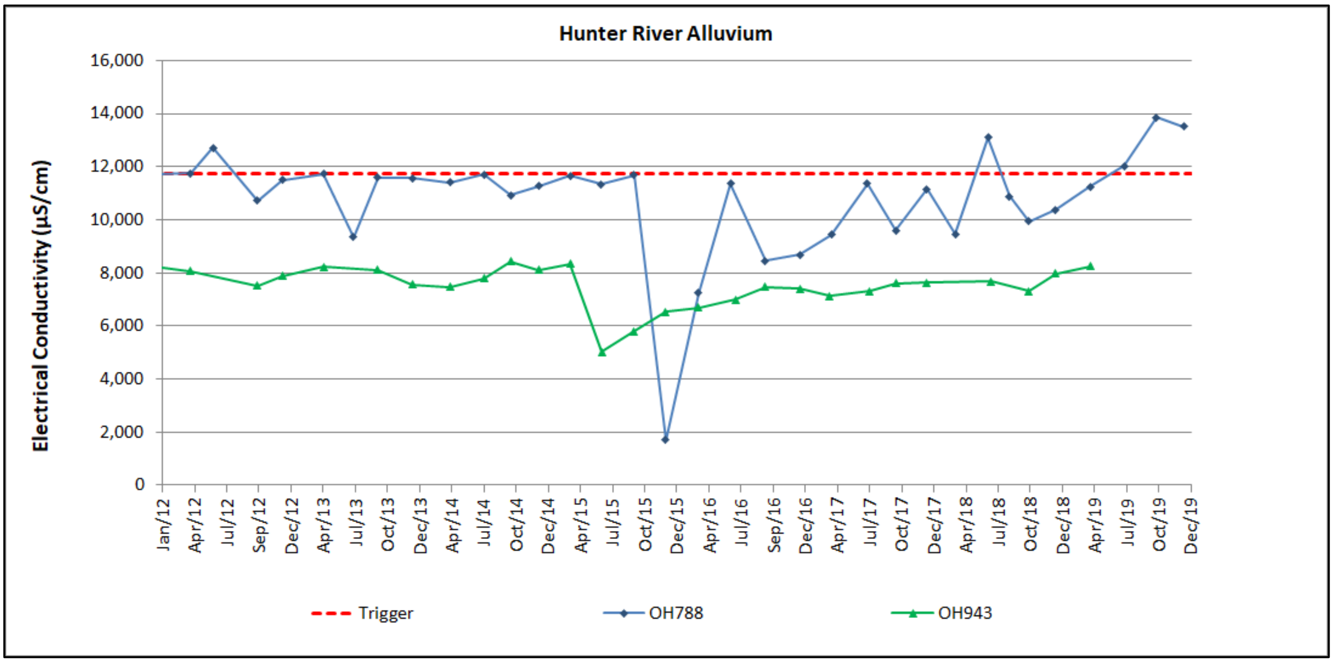
Oct/19
Dec/19
Trigger
OH787


Regolith
Electrical Conductivity (µS/cm)
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
OH942


Regolith
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
OH942


Hunter River Alluvium
Electrical Conductivity (µS/cm)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
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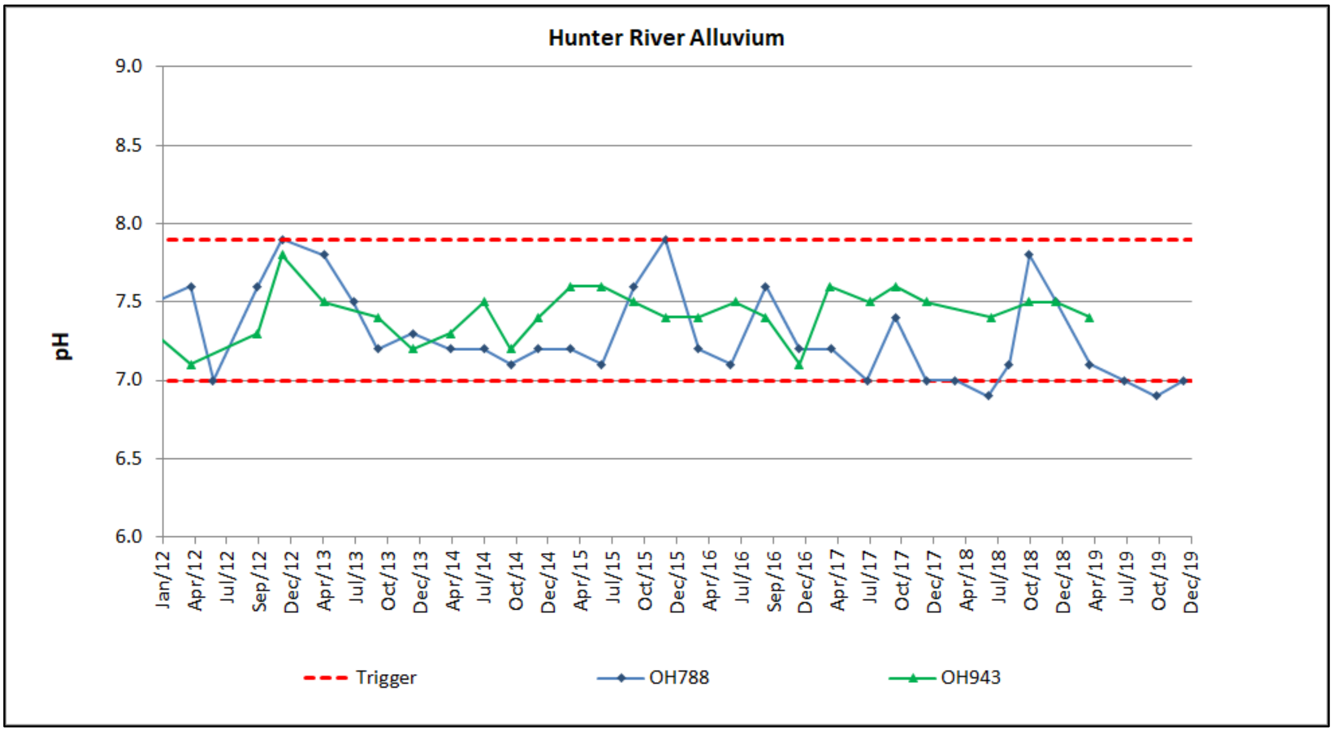
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH788
OH943


Hunter River Alluvium
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
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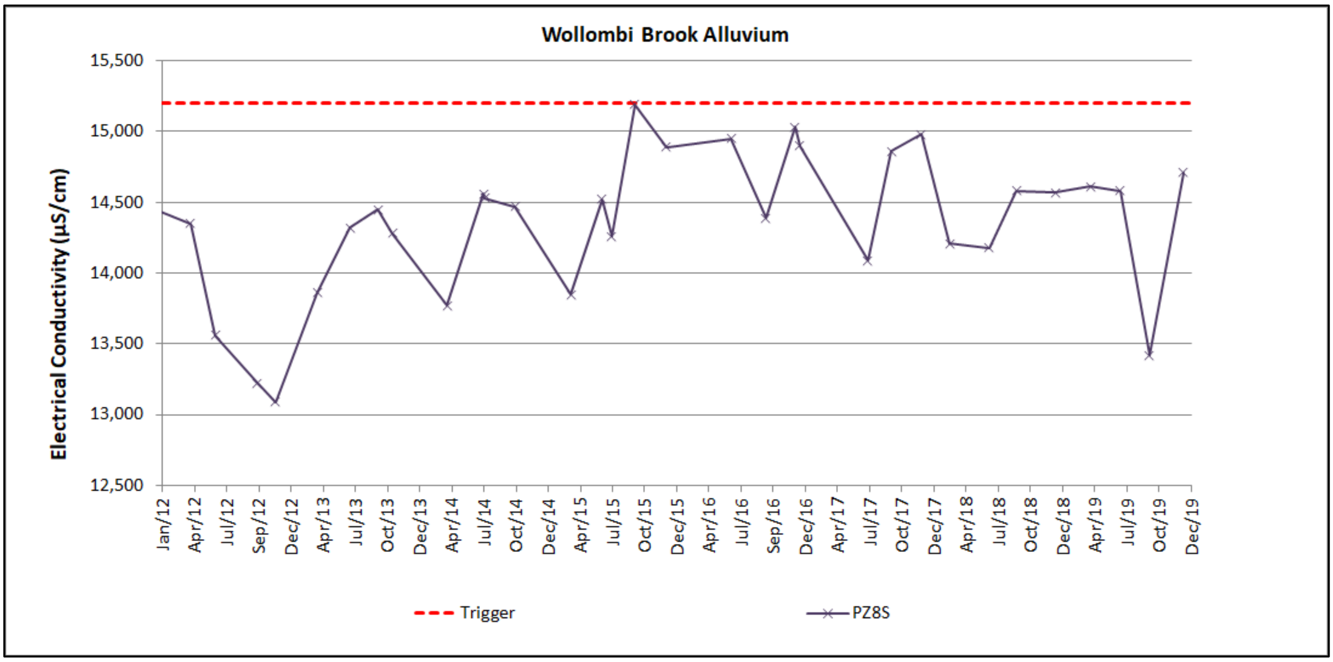
Oct/19
Dec/19
Trigger
OH788
OH943


Wollombi Brook Alluvium
Electrical Conductivity (µS/cm)
15,500
15,000
14,500
14,000
13,500
13,000
12,500
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
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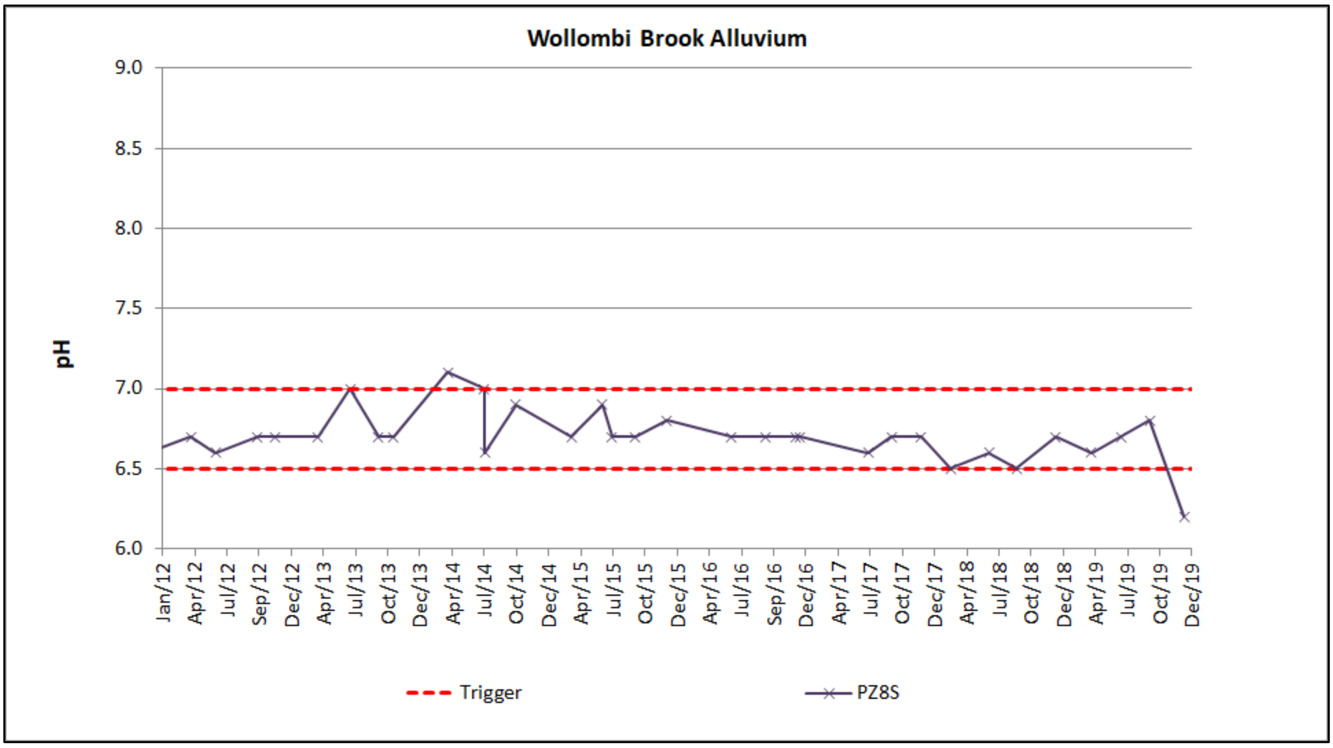
Jul/19
Oct/19
Dec/19
Trigger
PZ8S


Wollombi Brook Alluvium
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
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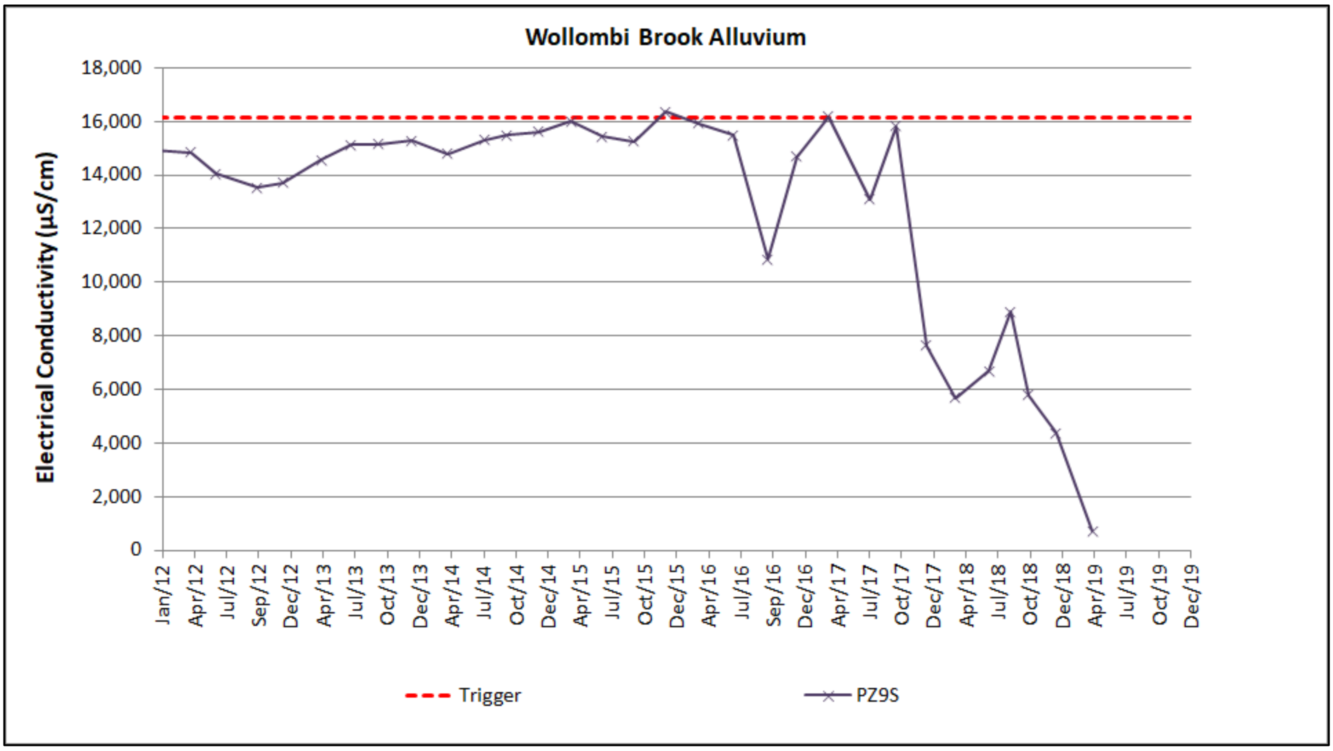
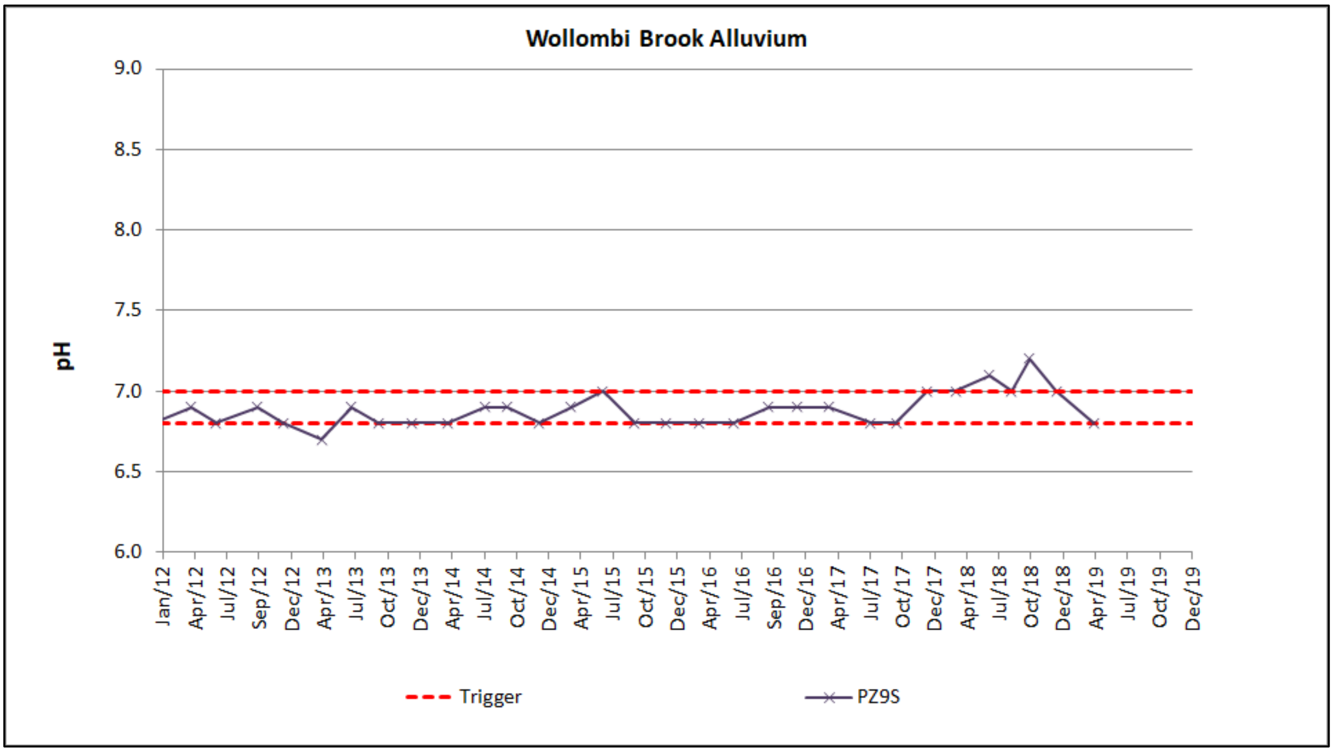
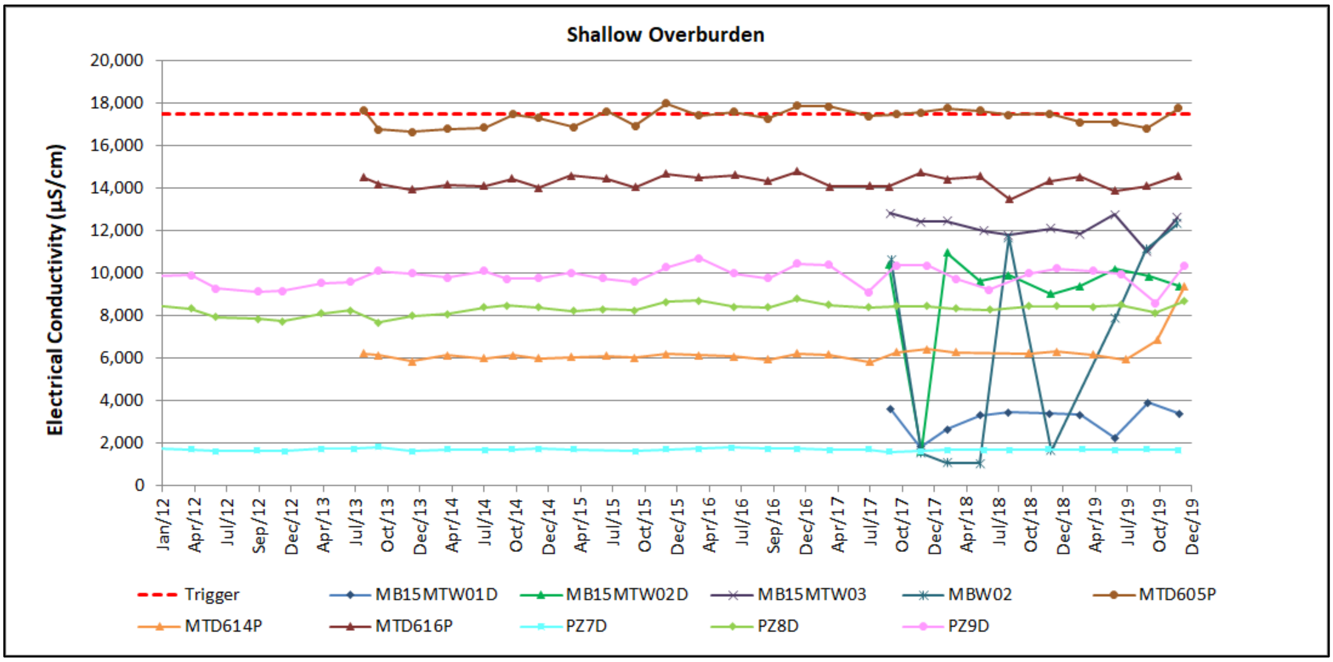
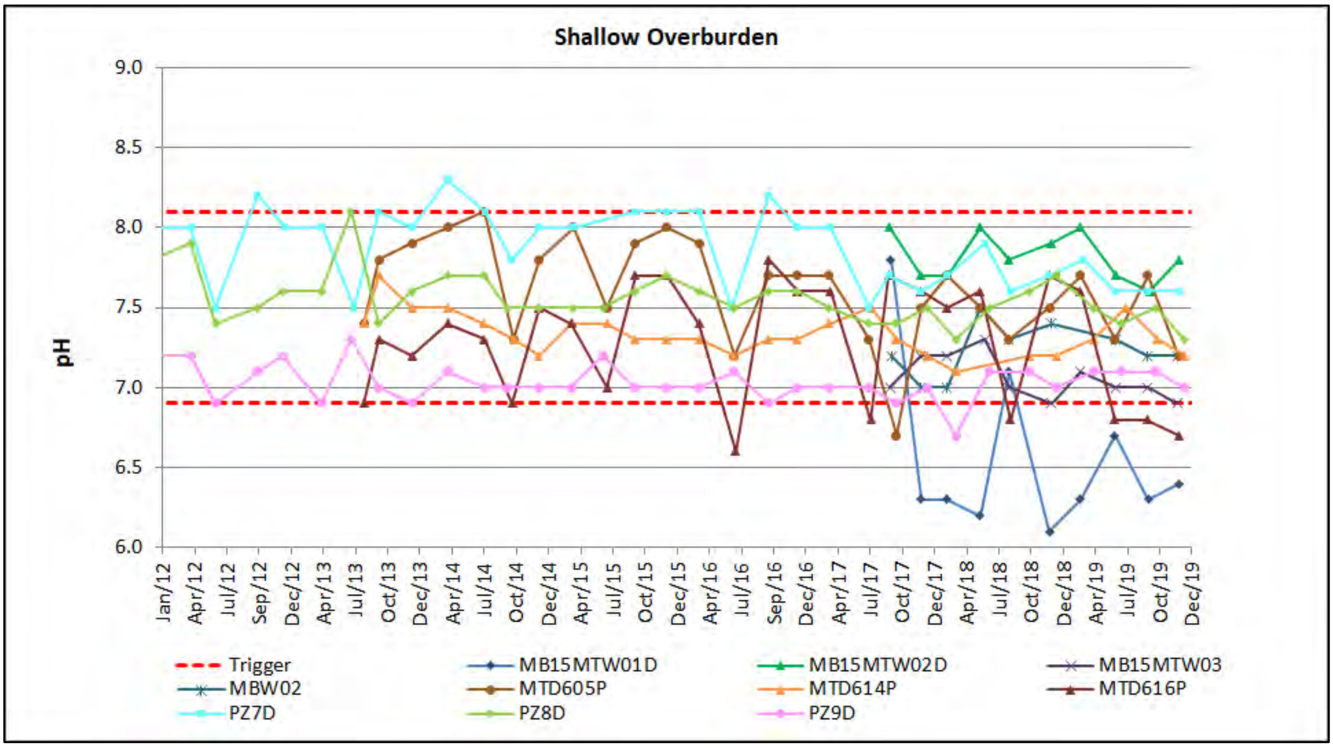
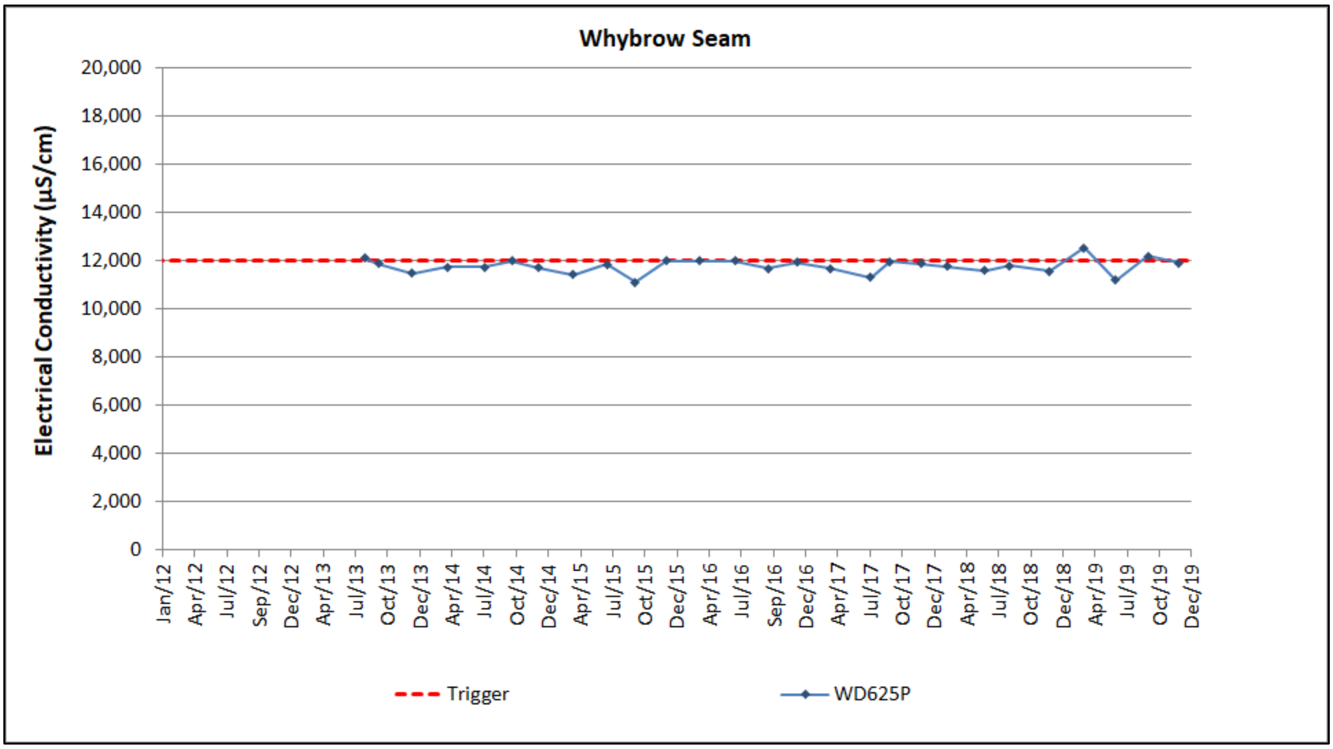
Oct/19
Dec/19
Trigger
PZ8S

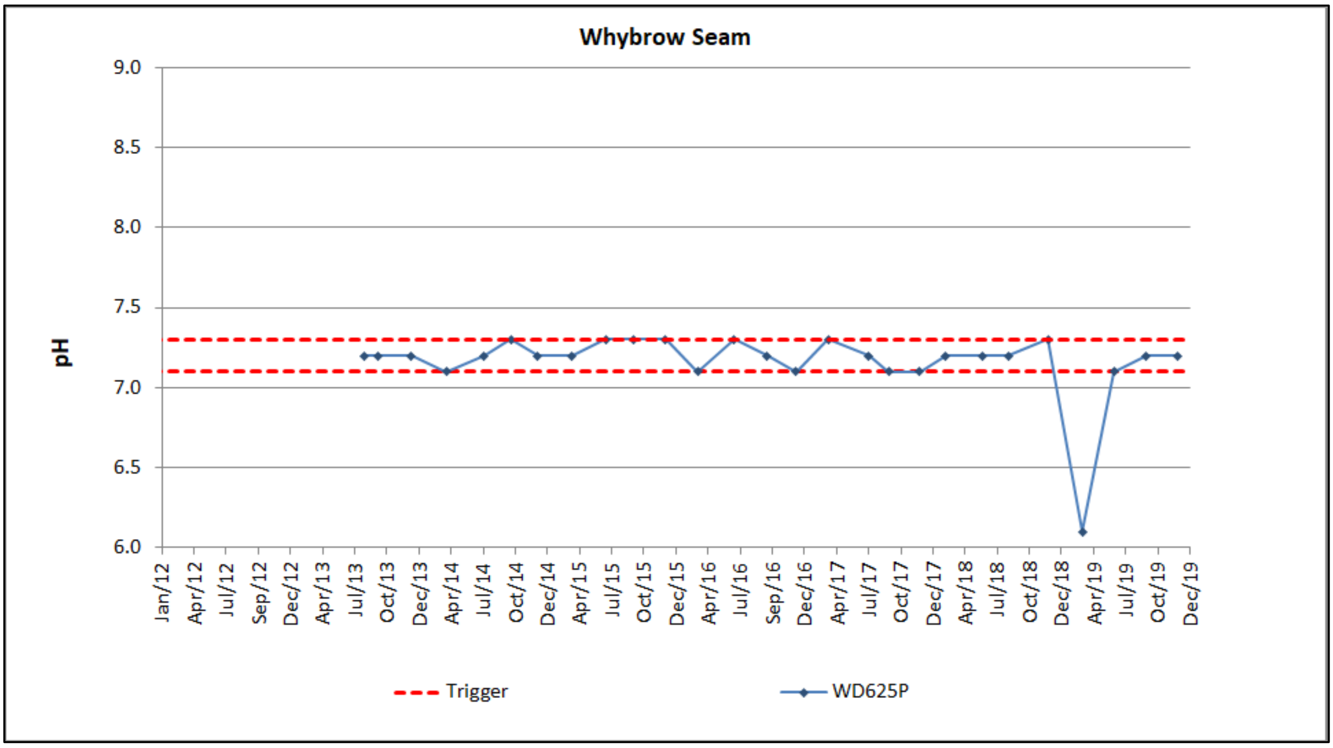

Wollombi Brook Alluvium
Electrical Conductivity (µS/cm)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
PZ9S


Wollombi Brook Alluvium
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
PZ9S


Shallow Overburden
Electrical Conductivity (µS/cm)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
MB15MTW01D
MB15MTW02D
MB15MTW03
MBW02
MTD605P
MTD614P
MTD616P
PZ7D
PZ8D
PZ9D


Shallow Overburden
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
MB15MTW01D
MB15MTW02D
MB15MTW03
MBW02
MTD605P
MTD614P
MTD616P
PZ7D
PZ8D
PZ9D


Whybrow Seam
Electrical Conductivity (µS/cm)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
WD625P


Whybrow Seam
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
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Apr/18
Jul/18
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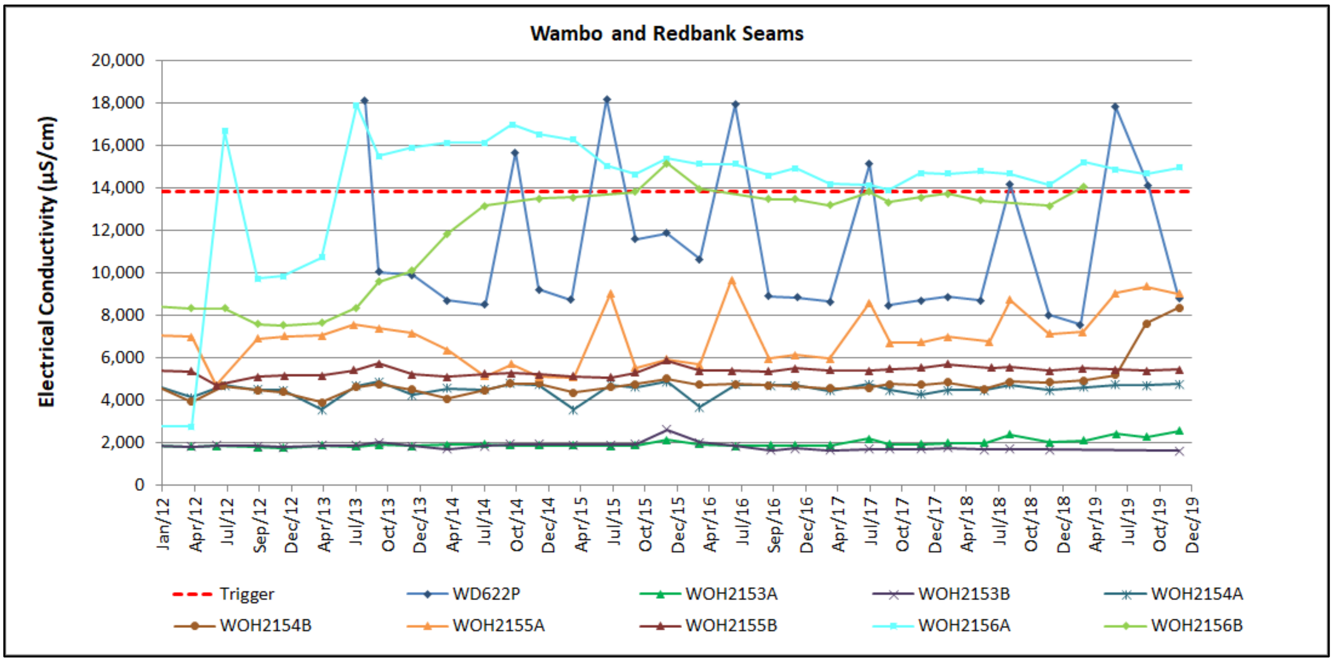
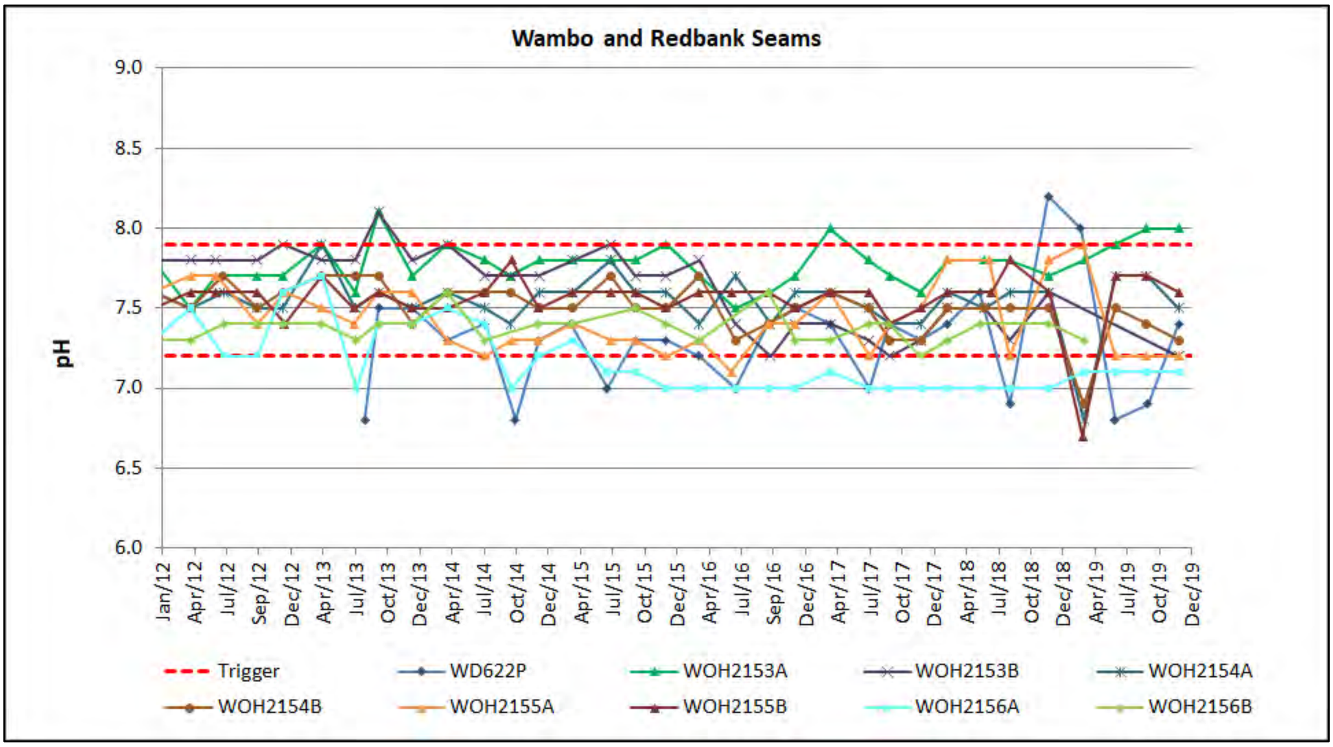
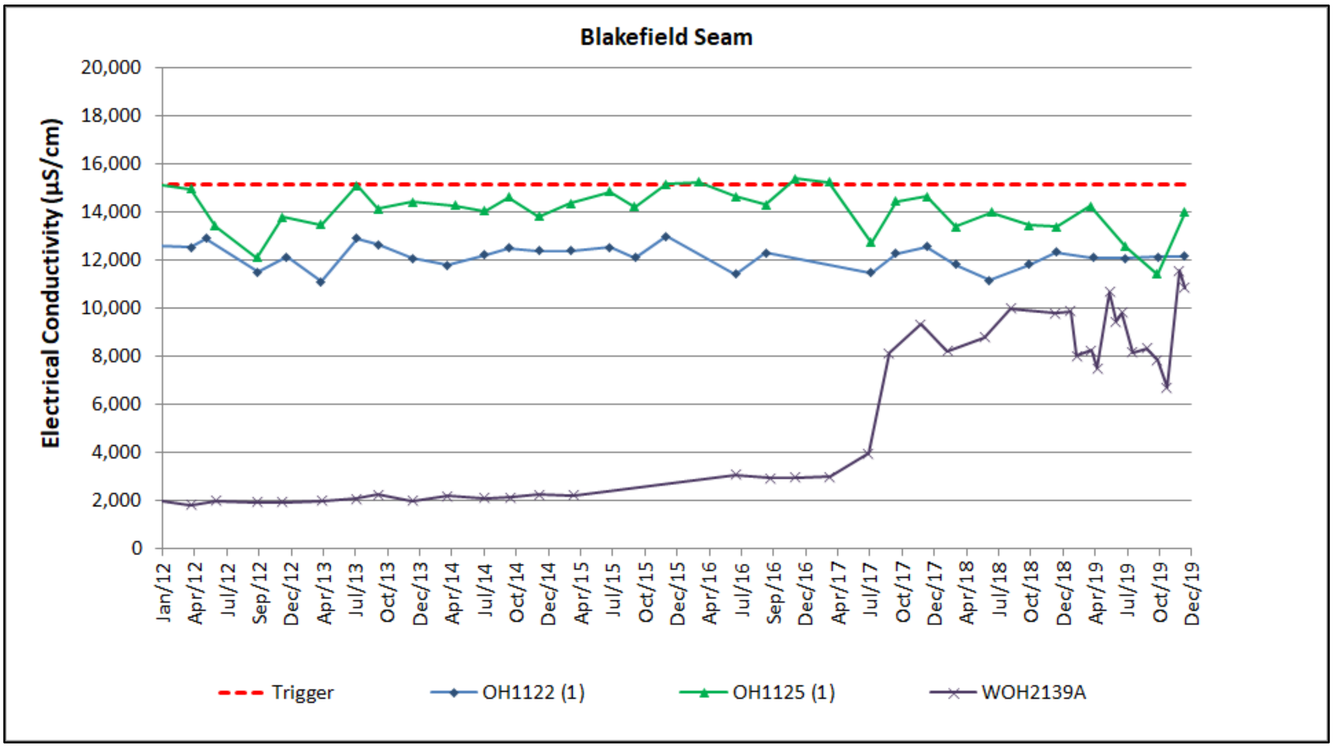
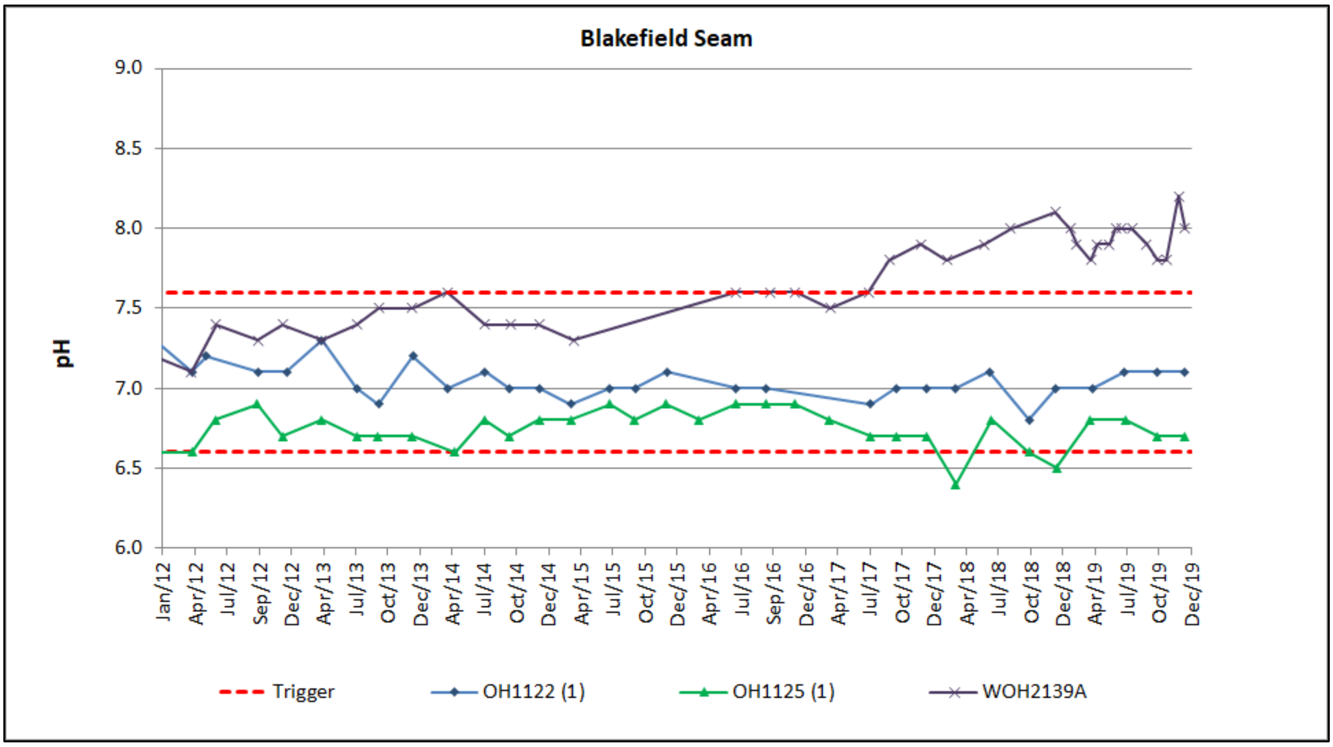
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
WD625P


Wambo and Redbank Seams
Electrical Conductivity (µS/cm)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
WD622P
WOH2153A
WOH2153B
WOH2154A
WOH2154B
WOH2155A
WOH2155B
WOH2156A
WOH2156B

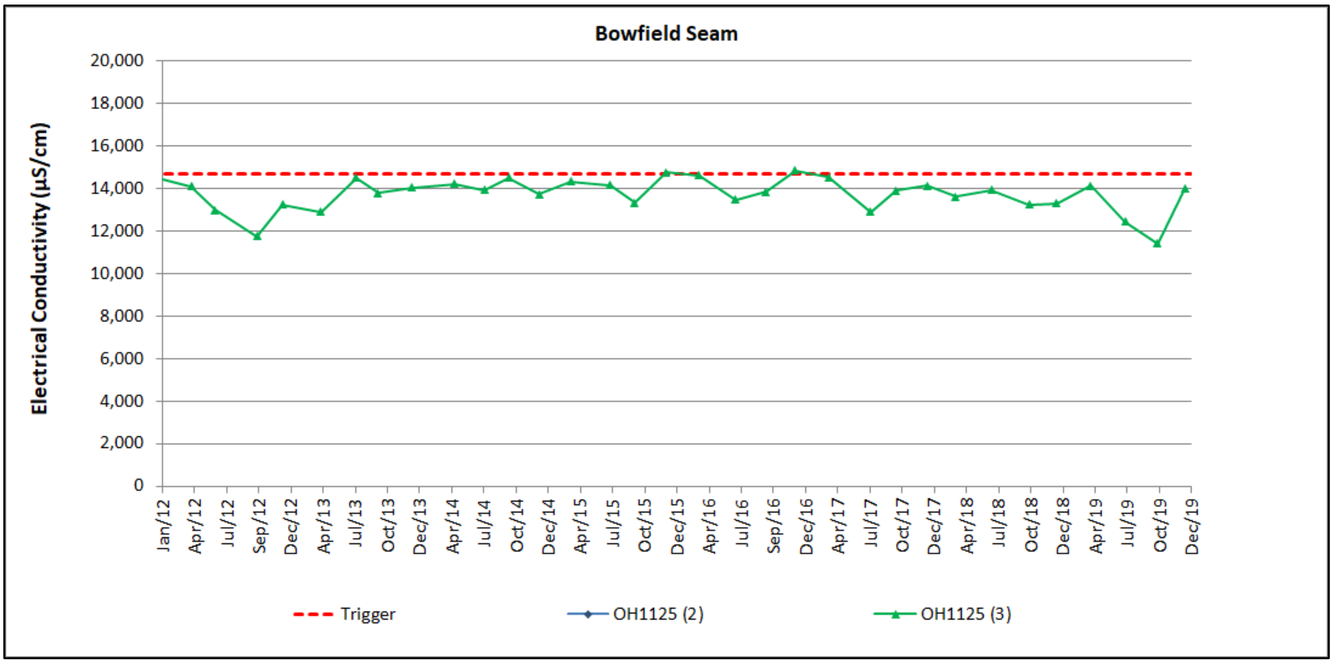

Wambo and Redbank Seams
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
WD622P
WOH2153A
WOH2153B
WOH2154A
WOH2154B
WOH2155A
WOH2155B
WOH2156A
WOH2156B



Blakefield Seam
Electrical Conductivity (µS/cm)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
OH1122 (1)
OH1125 (1)
WOH2139A



Blakefield Seam
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
OH1122 (1)
OH1125 (1)
WOH2139A


Bowfield Seam
Electrical Conductivity (µS/cm)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
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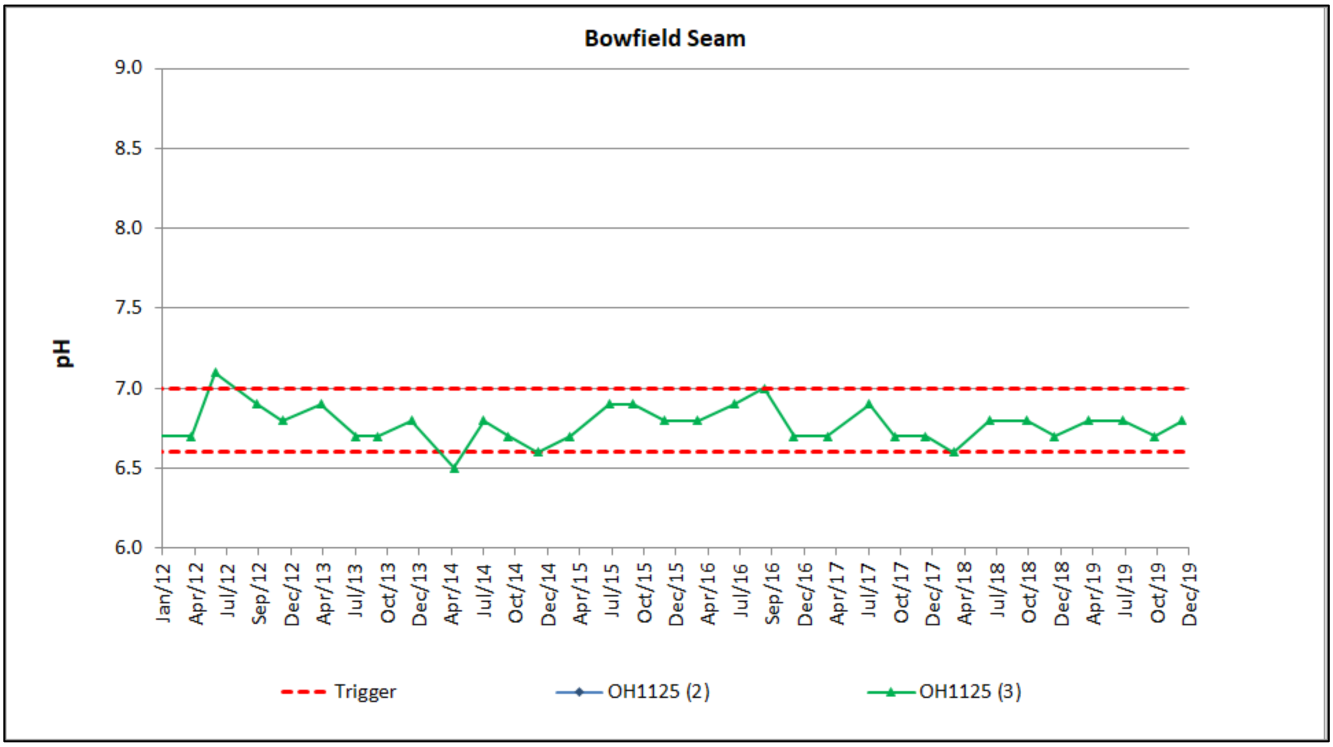
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH1125 (2)
OH1125 (3)


Bowfield Seam
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
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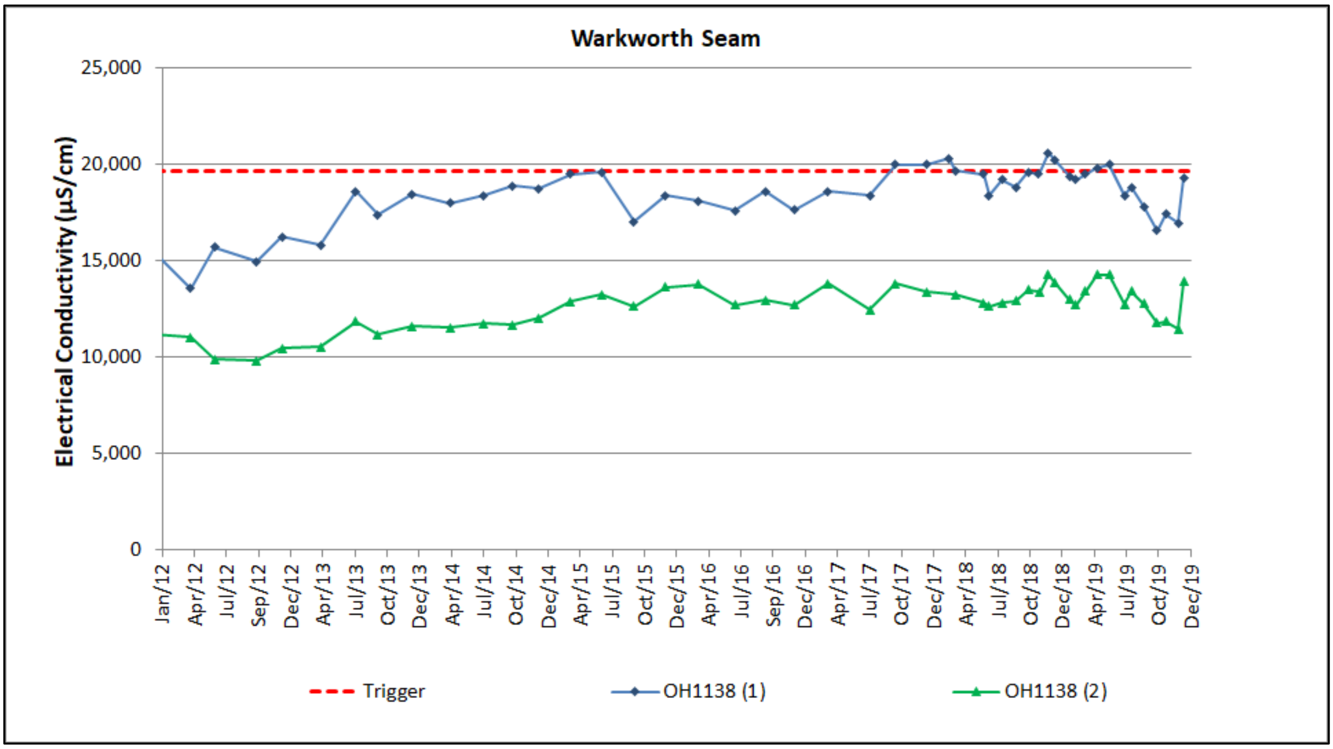
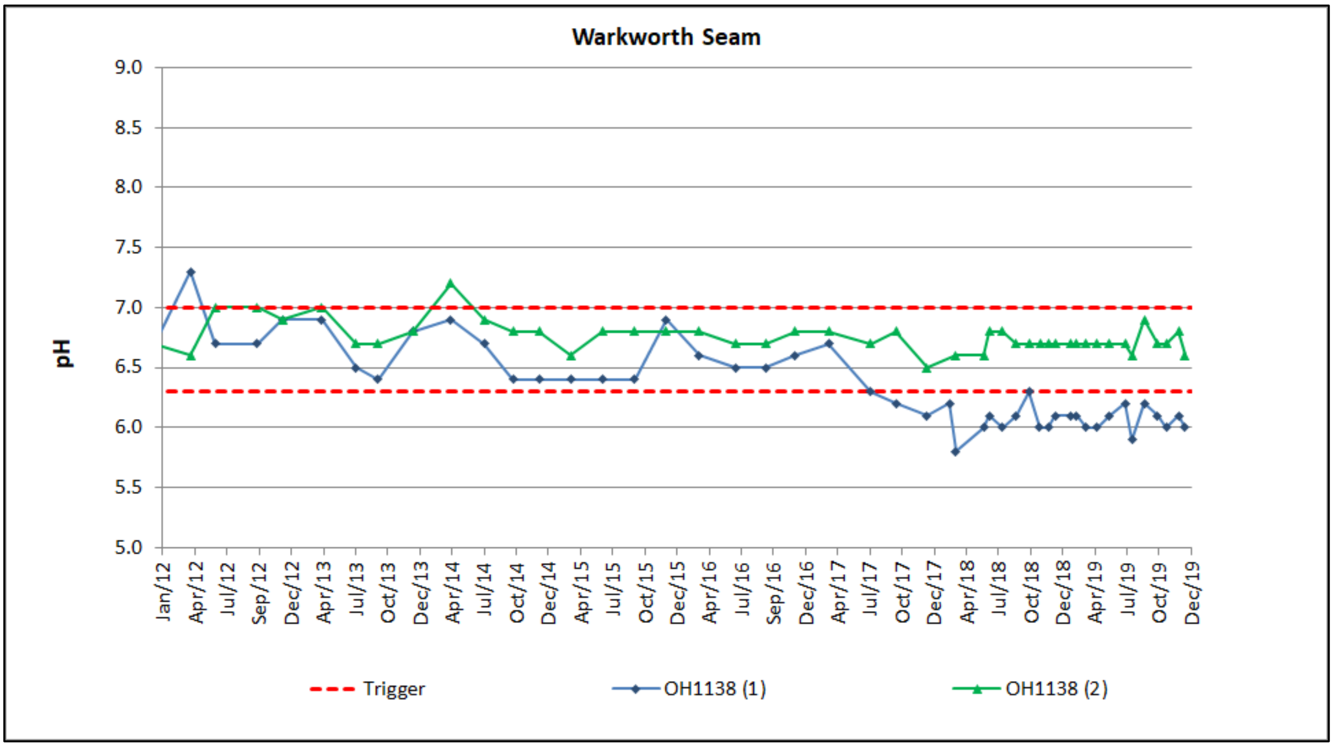
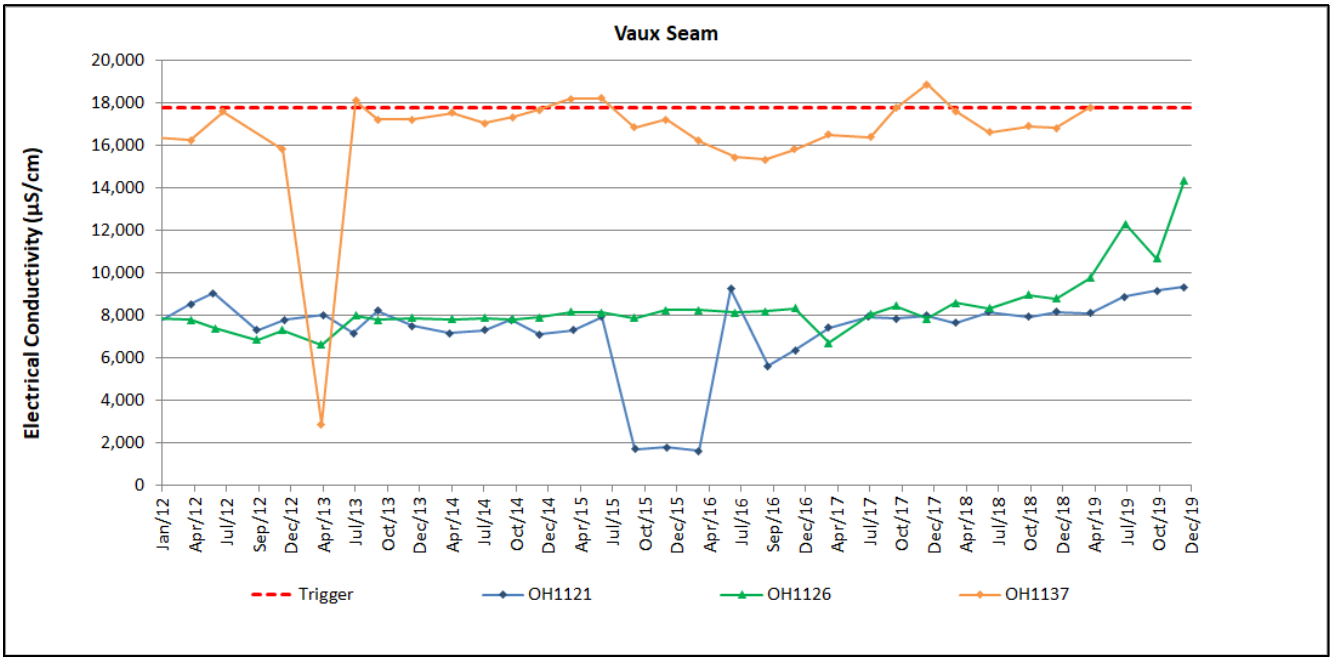
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH1125 (2)
OH1125 (3)

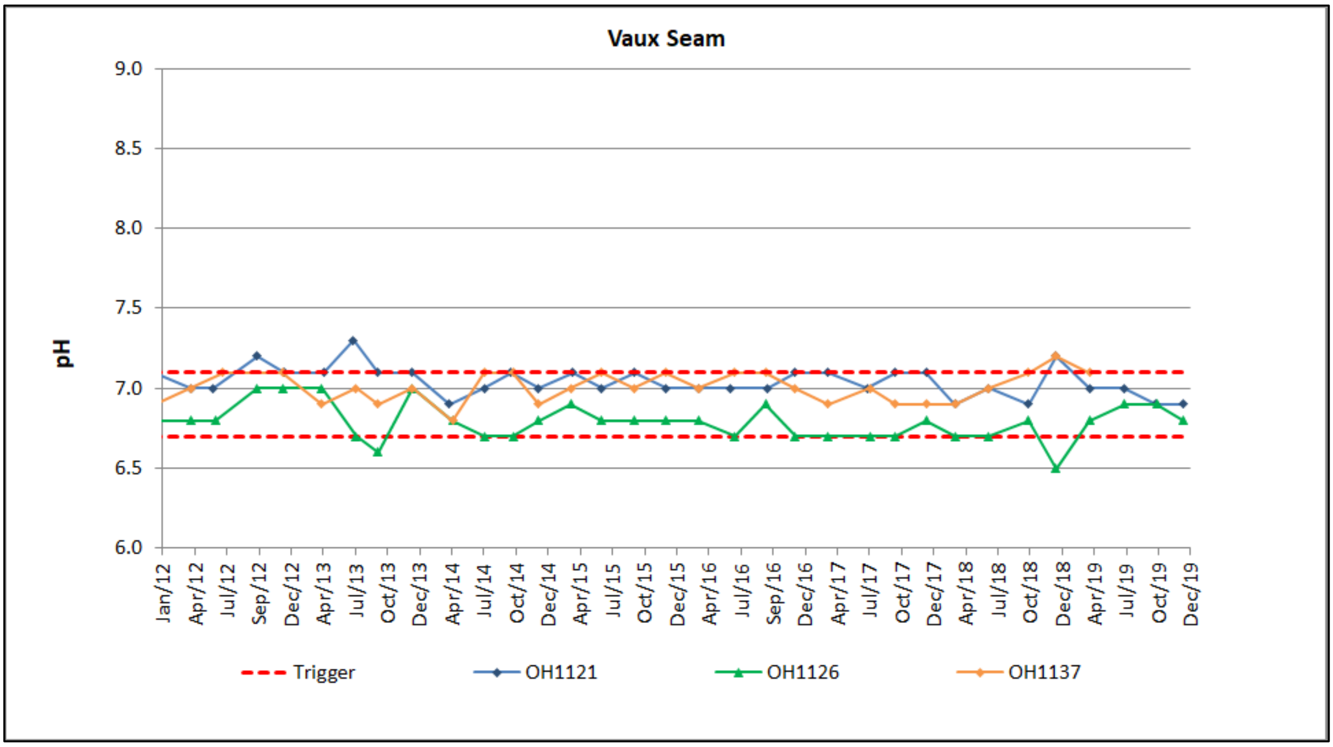


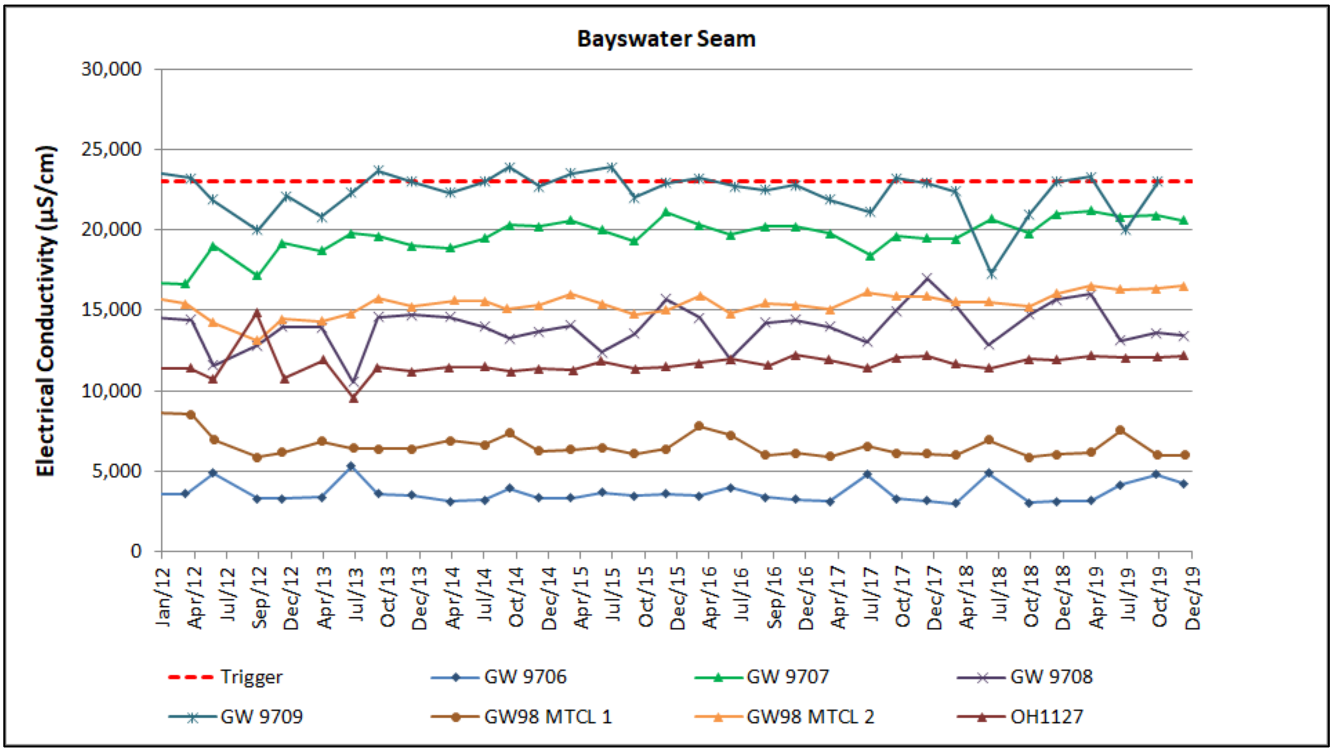
Warkworth Seam
Electrical Conductivity (µS/cm)
25,000
20,000
15,000
10,000
5,000
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH1138 (1)
OH1138 (2)



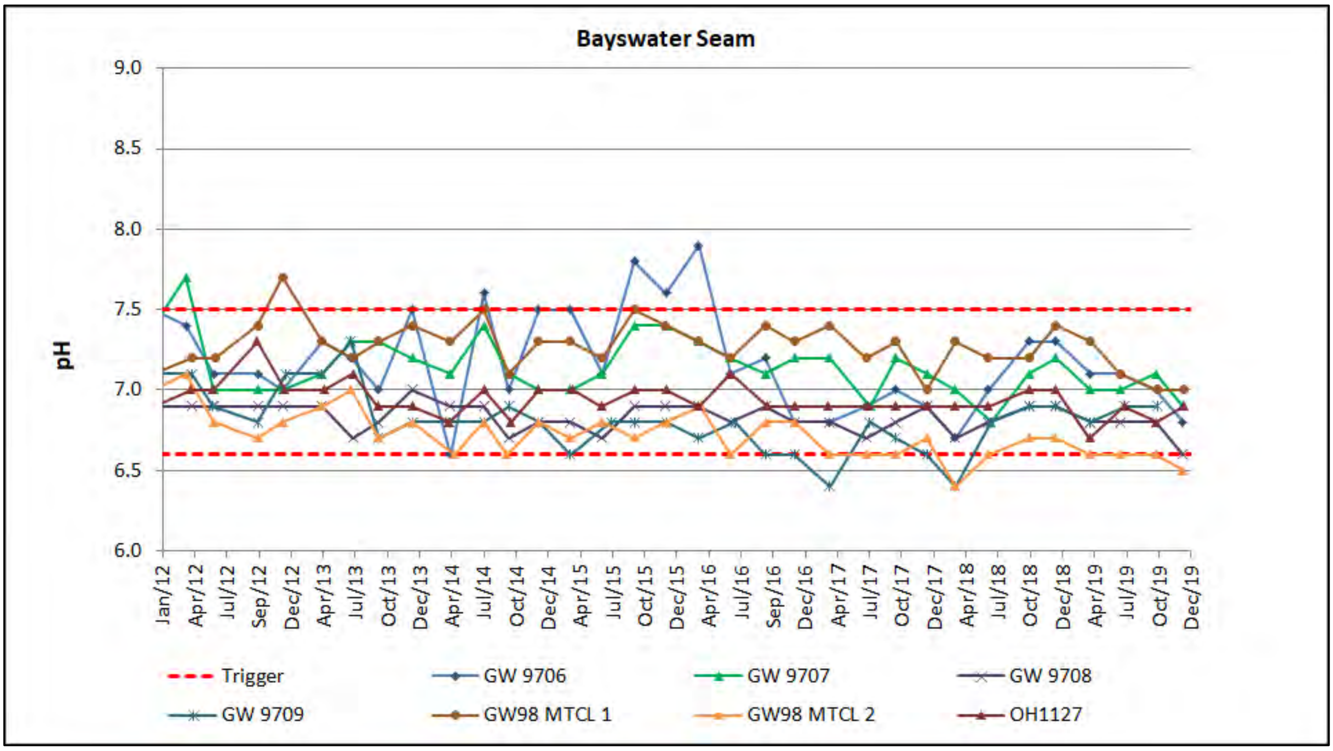
Warkworth Seam
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH1138 (1)
OH1138 (2)


Vaux Seam
Electrical Conductivity (µS/cm)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH1121
OH1126
OH1137


Vaux Seam
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12
Apr/12
Jul/12
Sep/12
Dec/12
Apr/13
Jul/13
Oct/13
Dec/13
Apr/14
Jul/14
Oct/14
Dec/14
Apr/15
Jul/15
Oct/15
Dec/15
Apr/16
Jul/16
Sep/16
Dec/16
Apr/17
Jul/17
Oct/17
Dec/17
Apr/18
Jul/18
Oct/18
Dec/18
Apr/19
Jul/19
Oct/19
Dec/19
Trigger
OH1121
OH1126
OH1137



Bayswater Seam
Electrical Conductivity (µS/cm)
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
GW 9706
GW 9707
GW 9708
GW 9709
GW98 MTCL 1
GW98 MTCL 2
OH1127



Bayswater Seam
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan/12 Apr/12 Jul/12 Sep/12 Dec/12 Apr/13 Jul/13 Oct/13 Dec/13 Apr/14 Jul/14 Oct/14 Dec/14 Apr/15 Jul/15 Oct/15 Dec/15 Apr/16 Jul/16 Sep/16 Dec/16 Apr/17 Jul/17 Oct/17 Dec/17 Apr/18 Jul/18 Oct/18 Dec/18 Apr/19 Jul/19 Oct/19 Dec/19
Trigger
GW 9706
GW 9707
GW 9708
GW 9709
GW98 MTCL 1
GW98 MTCL 2
OH1127

APPENDIX D

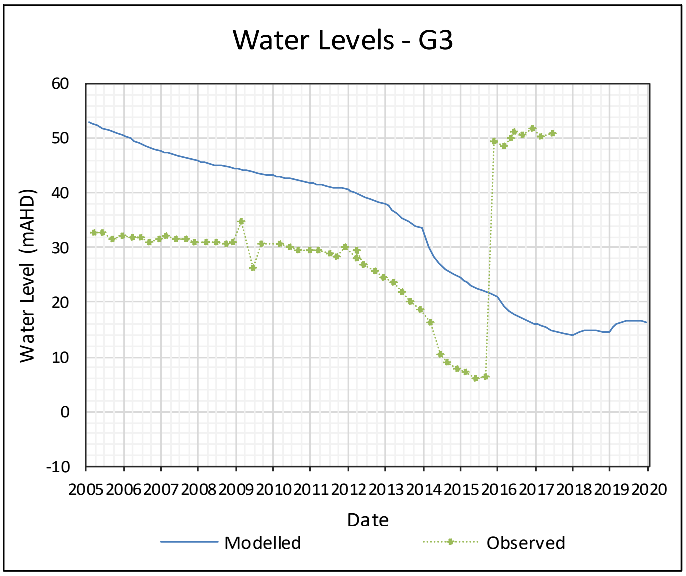
Full Water Quality Data 2019

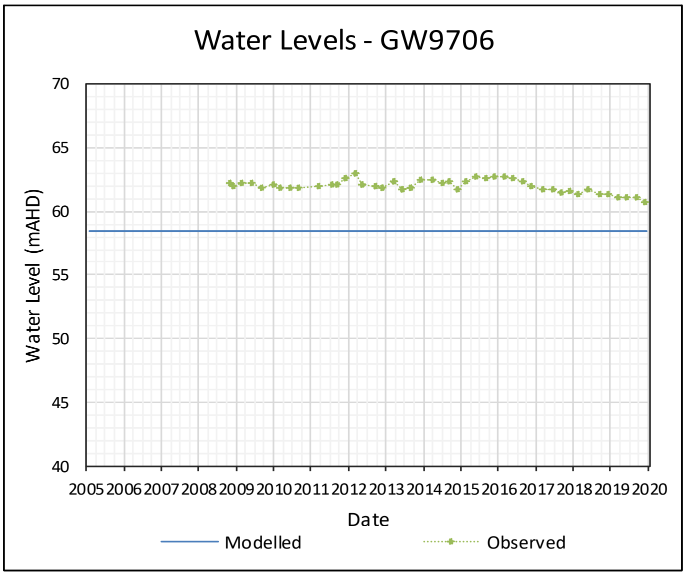
Station	Geology	Time	Date	SWL RL Calc	pH Field	EC Field (uS/cm (25TRef))	Water Temp (Deg C)	Comment	TDS - Total (mg/l)	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Acidity as CaCO3	SO4 - Total (mg/l)	Cl- (mg/l)	Ca - Total (mg/l)
PZ7S	Aeolian Warkworth Sands	8:25	28-05-19	50.57	6.7	1,641	17.2		838	<1	<1	415	415		22	269	59
MB15MTW04	Warkworth Sands	10:50	28-05-19					Dry									
MB15MTW05	Warkworth Sands	11:00	28-05-19					Dry									
MB15MTW06	Warkworth Sands	11:10	28-05-19					Dry									
MB15MTW07	Warkworth Sands	11:20	31-05-19					Dry									
MB15MTW08	Warkworth Sands	11:10	31-05-19					Dry									
MB15MTW09	Warkworth Sands	11:25	31-05-19					Dry									
MB15MTW10	Warkworth Sands	11:15	31-05-19					Dry									
MB15MTW11	Warkworth Sands	10:25	31-05-19					No Access - Fallen Tree									
OH786	Regolith	12:40	27-06-19	52.90	7.1	845	20.5	Purged 14/06/2019. Insufficent water- field results only									
OH787	Regolith	12:50	27-06-19	36.01	7.7	17,310	20.1	Purged 14/06/2019	11300	<1	<1	1180	1180	50	322	5530	87
OH788	Hunter River Alluvium	12:30	25-06-19	35.38	7.0	12,030	19.5		6810	<1	<1	1040	1040		362	3310	88
OH943	Hunter River Alluvium	12:40	25-06-19	35.40				Insufficient water									
OH944	Hunter River Alluvium	13:30	25-06-19					Dry									
MB15MTW01S	Wollombi Brook Alluvium	0.3611	43612	56.258	6.9	3730	21.4		1380	<1	<1	59	59		64	674	53
MB15MTW02S	Wollombi Brook Alluvium	0.4167	43615	55.15	6.8	3840	19.9		2120	<1	<1	290	290		17	1060	65
PZ8S	Wollombi Brook Alluvium	0.3576	43630	59.44	6.7	14580	20.1		8730	<1	<1	581	581		558	4940	110
PZ9S	Wollombi Brook Alluvium	0.5694	43643	58.65				Purged 14/06/2019. Insufficient water following purge									
MBW01	Alluvium	11:10	29-05-19	56.48	7.3	18,200	20.6		11000	<1	<1	1380	1380		510	5590	43
MB15MTW01D	Shallow Overburden? Alluvium?	9:50	27-05-19	56.35	6.7	2,250	20.4		2010	<1	<1	363	363		141	1010	31
MB15MTW02D	Shallow Overburden? Alluvium?	8:25	30-05-19	55.37	7.7	10,200	19.8		6280	<1	<1	2000	2000		9	2420	47
MB15MTW03	Shallow Overburden - Wollombi alluvium	13:00	28-05-19	54.37	7.0	12,760	19.3		7660	<1	<1	926	926		368	4010	196
MBW02	Shallow Overburden	11:15	29-05-19	54.34	7.3	7,910	17.5	DTW Checked	4770	<1	<1	1150	1150		<1	1940	42
MTD605P	Shallow Overburden - sandstone	10:30	27-05-19	62.27	7.3	17,130	20		11400	<1	<1	2050	2050		788	4820	45
MTD614P	Shallow Overburden - Conglomerate	13:50	27-06-19	54.59	7.5	5,940	19.7	Purged 14/06/2019	3630	<1	<1	1440	1440		100	991	52
MTD616P	Shallow Overburden	13:00	27-05-19	71.58	6.8	13,880	20.6		8980	<1	<1	1310	1310		472	4620	104
PZ7D	Shallow Overburden	9:10	28-05-19	50.64	7.6	1,686	19.3		901	<1	<1	440	440		30	282	20
PZ8D	Shallow Overburden	9:10	14-06-19	59.01	7.4	8,500	22.3		4610	<1	<1	1810	1810		47	1800	35
PZ9D	Shallow Overburden	10:35	14-06-19	47.84	7.1	9,970	21.4		5720	<1	<1	876	876		412	3060	167
GW 9706	Bayswater	10:25	13-06-19	61.06	7.1	4,170	21.4		2270	<1	<1	502	502		881	600	96
GW 9707	Bayswater	11:10	13-06-19	58.12	7.0	20,800	22.6		16100	<1	<1	758	758		5370	5400	429
GW 9708	Bayswater	12:20	13-06-19	61.21	6.8	13,120	22.9		11200	<1	<1	682	682		5020	1950	494
GW 9709	Bayswater	13:20	27-06-19	51.44	6.9	20,000	19.6	Purged 13/06/2019	18100	<1	<1	772	772		6960	5210	607
GW98 MTCL 1	Bayswater	13:20	13-06-19	66.68	7.1	7,560	22.9		4150	<1	<1	875	875		783	1460	67
GW98 MTCL 2	Bayswater	9:25	13-06-19	68.51	6.6	16,300	21.7		12600	<1	<1	653	653		4440	4060	646
OH1127	Vane Subgroup	10:05	26-06-19	35.28	6.9	12,080	20.3		7170	<1	<1	1900	1900		<1	3080	147
OH1122 (1)	Blakefield Seam	12:20	26-06-19	52.13	7.1	12,060	20.8		6610	<1	<1	1420	1420		532	3260	112
OH1125 (1)	Blakefield	11:10	27-06-19	51.02	6.8	12,540	20.4		8940	<1	<1	918	918	83	730	4160	320
OH1125 (3)	Bowfield Seam	11:30	27-06-19	42.84	6.8	12,440	20.9		9100	<1	<1	872	872	90	725	4050	323
WOH2139A	Blakefield	12:30	30-05-19	37.65	8.0	9,420	20.1		5280	<1	<1	954	954		<1	2750	9
WOH2153A	Redbank Crk Seam	9:30	31-05-19	53.29	7.9	2,410	18.5		1420	<1	<1	909	909		23	242	2
WOH2154A	Redbank Crk Seam	13:20	30-05-19	52.76	7.7	4,730	19.6		2760	<1	<1	958	958		144	937	4
WOH2155A	Redbank Crk Seam	11:50	30-05-19	53.55	7.2	9,050	19.8		5730	<1	<1	918	918		763	2280	42
WOH2156A	Redbank Crk Seam	11:15	30-05-19	51.47	7.1	14,860	19		9580	<1	<1	1160	1160		958	4280	113
OH942	Regolith	11:10	26-06-19	46.34	6.6	25,400	20.2		17500	<1	<1	605	605		954	7710	173
OH1125 (2)	Unknown - Blakefield?	11:20	27-06-19					Dry									
OH1121	Vane Subgroup	13:45	25-06-19	34.85	7.0	8,860	20.6		4600	<1	<1	673	673		240	2720	179
OH1126	Vaux	10:10	27-06-19	46.49	6.9	12,280	20.5		7110	<1	<1	799	799	66	757	3750	141
OH1137	Vaux?	10:00	27-06-19	52.84				Blocked									
OH1137	Vaux?	12:30	25-07-19	52.79				Results checked following annual sampling in June 2019. Foot valve sampling scheduled for further investigation.									
OH1137	Vaux?	12:05	20-08-19	52.77				DTB ammended. Foot valve and tubing installed									
MBW04	Wambo Seam	11:30	29-05-19	50.03	7.6	13,190	18.3	DTW Checked	7870	<1	<1	1710	1710		248	3620	67
WD622P	Wambo Seam	8:20	29-05-19	52.59	6.8	17,830	21.1		11300	<1	<1	1040	1040		1370	5430	152
WOH2153B	Wambo Seam	9:35	31-05-19	57.29				Insufficient Water									
WOH2154B	Wambo Seam	13:25	30-05-19	54.22	7.5	5,170	18.6		2910	<1	<1	974	974		157	1160	14
WOH2155B	Wambo Seam	11:45	30-05-19	59.25	7.7	5,430	18.6		2970	<1	<1	1040	1040		262	1050	21
WOH2156B	Wambo Seam	11:10	30-05-19	67.57				Insufficient Water	533	0	0	132	132		32	180	9.9
OH1138 (1)	Warkworth Seam	8:15	27-06-19	60.23	6.2	18,400	16.7		11800	<1	<1	231	231		407	6460	154
OH1138 (2)	Warkworth Seam	8:35	27-06-19	55.66	6.7	12,730	17.7		8790	<1	<1	683	683		639	4370	552
MBW03	Whybrow Seam	11:20	29-05-19	54.31	7.3	9,940	19.5	Suspended Solids	5730	<1	<1	2050	2050		<1	1980	37
WD625P	Whybrow Seam	10:10	31-05-19	57.65	7.1	11,200	17.9		6390	<1	<1	1220	1220		263	3640	67
WOH2141A	Whynot Seam	10:20	28-05-19	47.41	7.8	10,220	20.4		5920	<1	<1	1160	1160		<1	3030	15
MBW6A	0	10:15	29-05-19		6.7	968	19.4		475	<1	<1	120	120		31	226	10

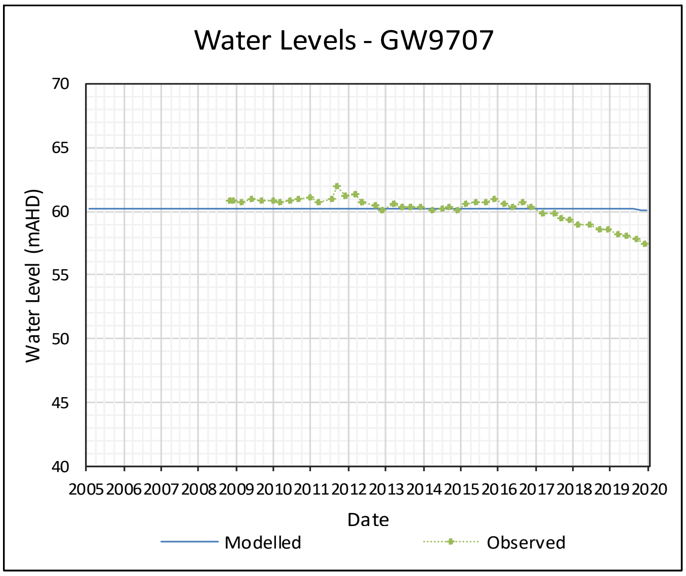
Station	Geology	Time	Date	SWL RL Calc	pH Field	EC Field (uS/cm (25TRef))	Water Temp (Deg C)	Comment	TDS - Total (mg/l)	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Acidity as CaCO3	SO4 - Total (mg/l)	Cl- (mg/l)	Ca - Total (mg/l)
PZ7S	Aeolian Warkworth Sands	8:25	28-05-19	50.57	6.7	1,641	17.2		838	<1	<1	415	415		22	269	59
MB15MTW04	Warkworth Sands	10:50	28-05-19					Dry									
MB15MTW05	Warkworth Sands	11:00	28-05-19					Dry									
MB15MTW06	Warkworth Sands	11:10	28-05-19					Dry									
MB15MTW07	Warkworth Sands	11:20	31-05-19					Dry									
MB15MTW08	Warkworth Sands	11:10	31-05-19					Dry									
MB15MTW09	Warkworth Sands	11:25	31-05-19					Dry									
MB15MTW10	Warkworth Sands	11:15	31-05-19					Dry									
MB15MTW11	Warkworth Sands	10:25	31-05-19					No Access - Fallen Tree									
OH786	Regolith	12:40	27-06-19	52.90	7.1	845	20.5	Purged 14/06/2019. Insufficent water- field results only									
OH787	Regolith	12:50	27-06-19	36.01	7.7	17,310	20.1	Purged 14/06/2019	11300	<1	<1	1180	1180	50	322	5530	87
OH788	Hunter River Alluvium	12:30	25-06-19	35.38	7.0	12,030	19.5		6810	<1	<1	1040	1040		362	3310	88
OH943	Hunter River Alluvium	12:40	25-06-19	35.40				Insufficient water									
OH944	Hunter River Alluvium	13:30	25-06-19					Dry									
MB15MTW01S	Wollombi Brook Alluvium	0.3611	43612	56.258	6.9	3730	21.4		1380	<1	<1	59	59		64	674	53
MB15MTW02S	Wollombi Brook Alluvium	0.4167	43615	55.15	6.8	3840	19.9		2120	<1	<1	290	290		17	1060	65
PZ8S	Wollombi Brook Alluvium	0.3576	43630	59.44	6.7	14580	20.1		8730	<1	<1	581	581		558	4940	110
PZ9S	Wollombi Brook Alluvium	0.5694	43643	58.65				Purged 14/06/2019. Insufficient water following purge									
MBW01	Alluvium	11:10	29-05-19	56.48	7.3	18,200	20.6		11000	<1	<1	1380	1380		510	5590	43
MB15MTW01D	Shallow Overburden? Alluvium?	9:50	27-05-19	56.35	6.7	2,250	20.4		2010	<1	<1	363	363		141	1010	31
MB15MTW02D	Shallow Overburden? Alluvium?	8:25	30-05-19	55.37	7.7	10,200	19.8		6280	<1	<1	2000	2000		9	2420	47
MB15MTW03	Shallow Overburden - Wollombi alluvium	13:00	28-05-19	54.37	7.0	12,760	19.3		7660	<1	<1	926	926		368	4010	196
MBW02	Shallow Overburden	11:15	29-05-19	54.34	7.3	7,910	17.5	DTW Checked	4770	<1	<1	1150	1150		<1	1940	42
MTD605P	Shallow Overburden - sandstone	10:30	27-05-19	62.27	7.3	17,130	20		11400	<1	<1	2050	2050		788	4820	45
MTD614P	Shallow Overburden - Conglomerate	13:50	27-06-19	54.59	7.5	5,940	19.7	Purged 14/06/2019	3630	<1	<1	1440	1440		100	991	52
MTD616P	Shallow Overburden	13:00	27-05-19	71.58	6.8	13,880	20.6		8980	<1	<1	1310	1310		472	4620	104
PZ7D	Shallow Overburden	9:10	28-05-19	50.64	7.6	1,686	19.3		901	<1	<1	440	440		30	282	20
PZ8D	Shallow Overburden	9:10	14-06-19	59.01	7.4	8,500	22.3		4610	<1	<1	1810	1810		47	1800	35
PZ9D	Shallow Overburden	10:35	14-06-19	47.84	7.1	9,970	21.4		5720	<1	<1	876	876		412	3060	167
GW 9706	Bayswater	10:25	13-06-19	61.06	7.1	4,170	21.4		2270	<1	<1	502	502		881	600	96
GW 9707	Bayswater	11:10	13-06-19	58.12	7.0	20,800	22.6		16100	<1	<1	758	758		5370	5400	429
GW 9708	Bayswater	12:20	13-06-19	61.21	6.8	13,120	22.9		11200	<1	<1	682	682		5020	1950	494
GW 9709	Bayswater	13:20	27-06-19	51.44	6.9	20,000	19.6	Purged 13/06/2019	18100	<1	<1	772	772		6960	5210	607
GW98 MTCL 1	Bayswater	13:20	13-06-19	66.68	7.1	7,560	22.9		4150	<1	<1	875	875		783	1460	67
GW98 MTCL 2	Bayswater	9:25	13-06-19	68.51	6.6	16,300	21.7		12600	<1	<1	653	653		4440	4060	646
OH1127	Vane Subgroup	10:05	26-06-19	35.28	6.9	12,080	20.3		7170	<1	<1	1900	1900		<1	3080	147
OH1122 (1)	Blakefield Seam	12:20	26-06-19	52.13	7.1	12,060	20.8		6610	<1	<1	1420	1420		532	3260	112
OH1125 (1)	Blakefield	11:10	27-06-19	51.02	6.8	12,540	20.4		8940	<1	<1	918	918	83	730	4160	320
OH1125 (3)	Bowfield Seam	11:30	27-06-19	42.84	6.8	12,440	20.9		9100	<1	<1	872	872	90	725	4050	323
WOH2139A	Blakefield	12:30	30-05-19	37.65	8.0	9,420	20.1		5280	<1	<1	954	954		<1	2750	9
WOH2153A	Redbank Crk Seam	9:30	31-05-19	53.29	7.9	2,410	18.5		1420	<1	<1	909	909		23	242	2
WOH2154A	Redbank Crk Seam	13:20	30-05-19	52.76	7.7	4,730	19.6		2760	<1	<1	958	958		144	937	4
WOH2155A	Redbank Crk Seam	11:50	30-05-19	53.55	7.2	9,050	19.8		5730	<1	<1	918	918		763	2280	42
WOH2156A	Redbank Crk Seam	11:15	30-05-19	51.47	7.1	14,860	19		9580	<1	<1	1160	1160		958	4280	113
OH942	Regolith	11:10	26-06-19	46.34	6.6	25,400	20.2		17500	<1	<1	605	605		954	7710	173
OH1125 (2)	Unknown - Blakefield?	11:20	27-06-19					Dry									
OH1121	Vane Subgroup	13:45	25-06-19	34.85	7.0	8,860	20.6		4600	<1	<1	673	673		240	2720	179
OH1126	Vaux	10:10	27-06-19	46.49	6.9	12,280	20.5		7110	<1	<1	799	799	66	757	3750	141
OH1137	Vaux?	10:00	27-06-19	52.84				Blocked									
OH1137	Vaux?	12:30	25-07-19	52.79				Results checked following annual sampling in June 2019. Foot valve sampling scheduled for further investigation.									
OH1137	Vaux?	12:05	20-08-19	52.77				DTB ammended. Foot valve and tubing installed									
MBW04	Wambo Seam	11:30	29-05-19	50.03	7.6	13,190	18.3	DTW Checked	7870	<1	<1	1710	1710		248	3620	67
WD622P	Wambo Seam	8:20	29-05-19	52.59	6.8	17,830	21.1		11300	<1	<1	1040	1040		1370	5430	152
WOH2153B	Wambo Seam	9:35	31-05-19	57.29				Insufficient Water									
WOH2154B	Wambo Seam	13:25	30-05-19	54.22	7.5	5,170	18.6		2910	<1	<1	974	974		157	1160	14
WOH2155B	Wambo Seam	11:45	30-05-19	59.25	7.7	5,430	18.6		2970	<1	<1	1040	1040		262	1050	21
WOH2156B	Wambo Seam	11:10	30-05-19	67.57				Insufficient Water	533	0	0	132	132		32	180	9.9
OH1138 (1)	Warkworth Seam	8:15	27-06-19	60.23	6.2	18,400	16.7		11800	<1	<1	231	231		407	6460	154
OH1138 (2)	Warkworth Seam	8:35	27-06-19	55.66	6.7	12,730	17.7		8790	<1	<1	683	683		639	4370	552
MBW03	Whybrow Seam	11:20	29-05-19	54.31	7.3	9,940	19.5	Suspended Solids	5730	<1	<1	2050	2050		<1	1980	37
WD625P	Whybrow Seam	10:10	31-05-19	57.65	7.1	11,200	17.9		6390	<1	<1	1220	1220		263	3640	67
WOH2141A	Whynot Seam	10:20	28-05-19	47.41	7.8	10,220	20.4		5920	<1	<1	1160	1160		<1	3030	15
MBW6A	0	10:15	29-05-19		6.7	968	19.4		475	<1	<1	120	120		31	226	10

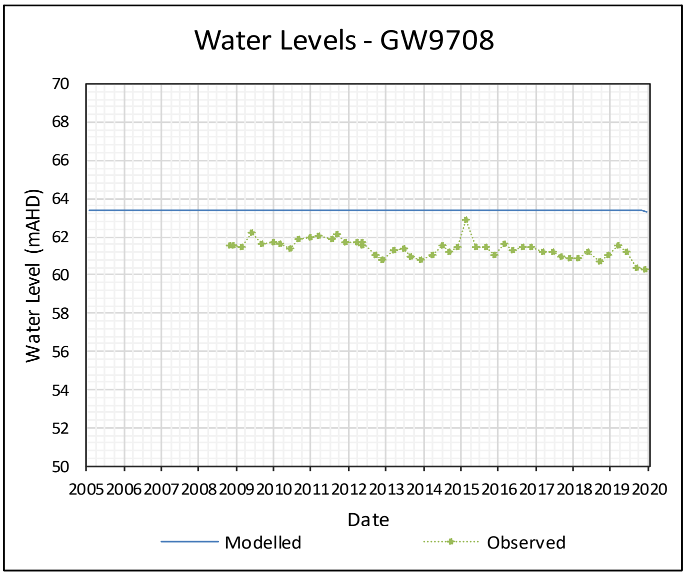
APPENDIX E

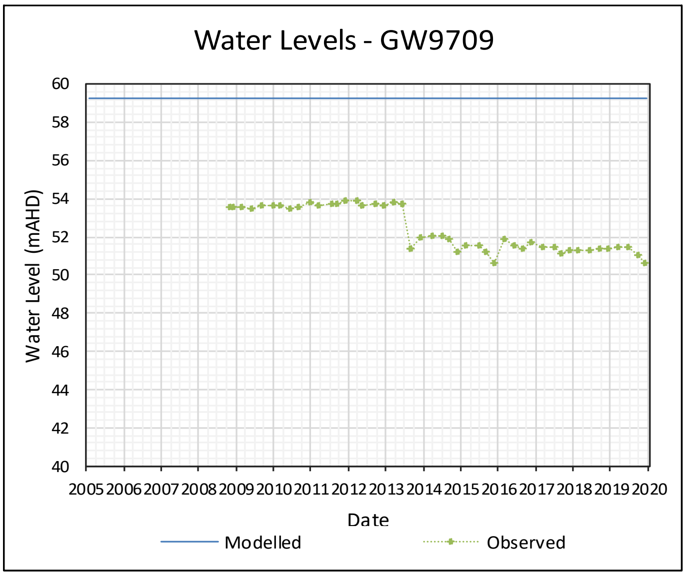
Model Verification Hydrographs

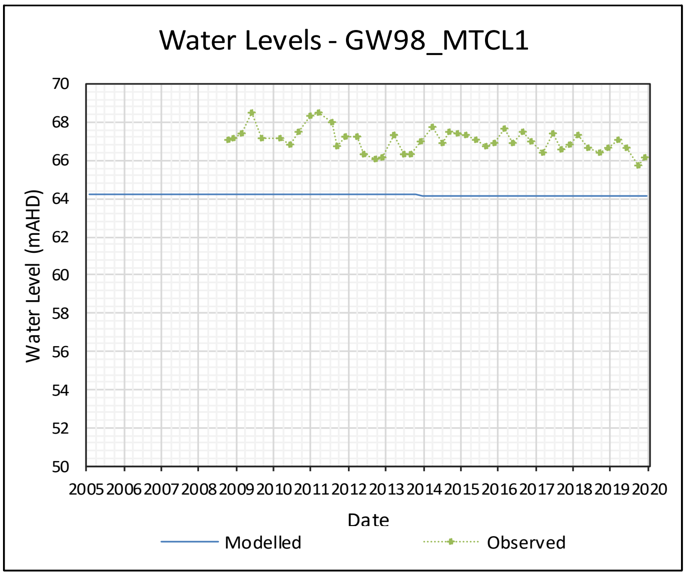

Water Levels - G3
Water Level (mAHD)
Date
Modelled
Observed

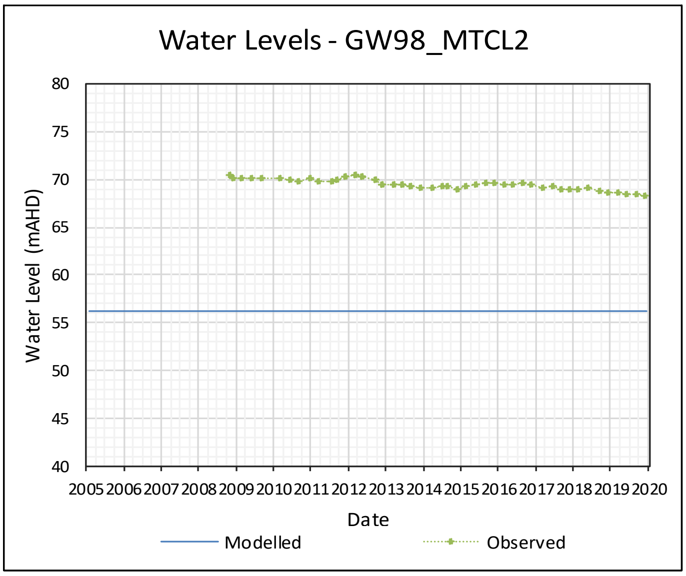

Water Levels - GW9706
Water Level (mAHD)
Date
Modelled
Observed

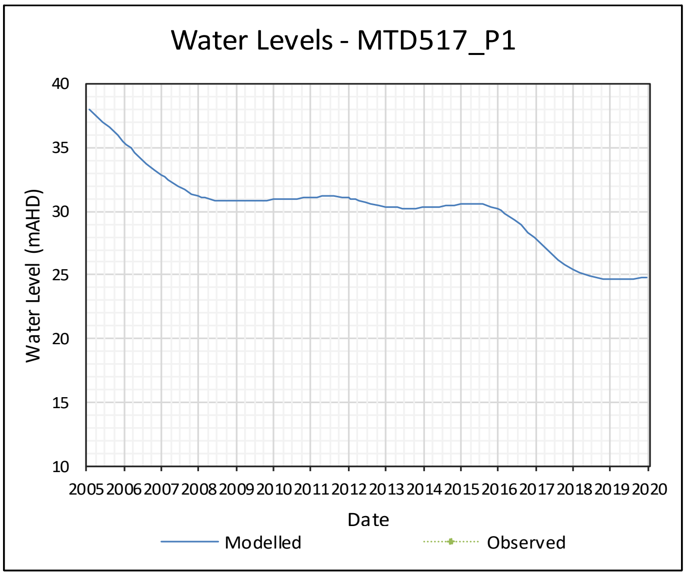

Water Levels - GW9707
Water Level (mAHD)
Date
Modelled
Observed

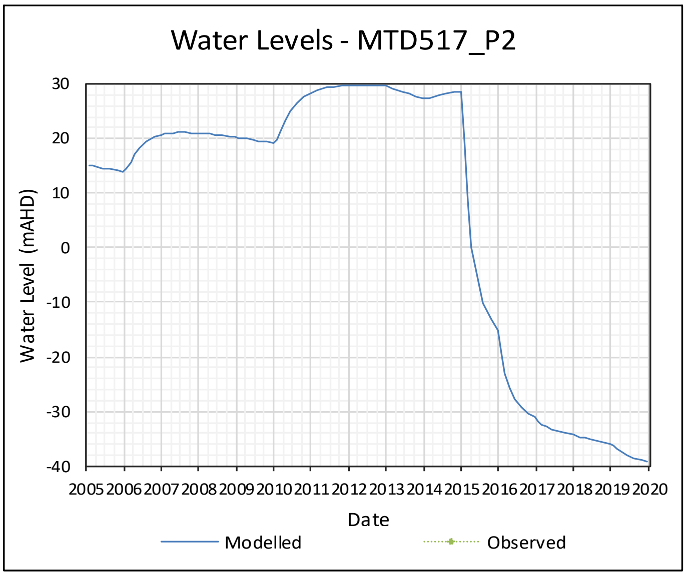

Water Levels - GW9708
Water Level (mAHD)
Date
Modelled
Observed

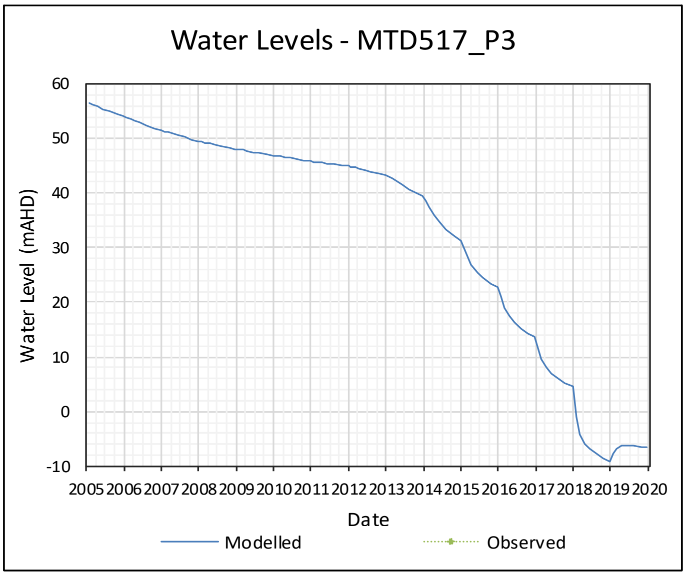

Water Levels - GW9709
Water Level (mAHD)
Date
Modelled
Observed

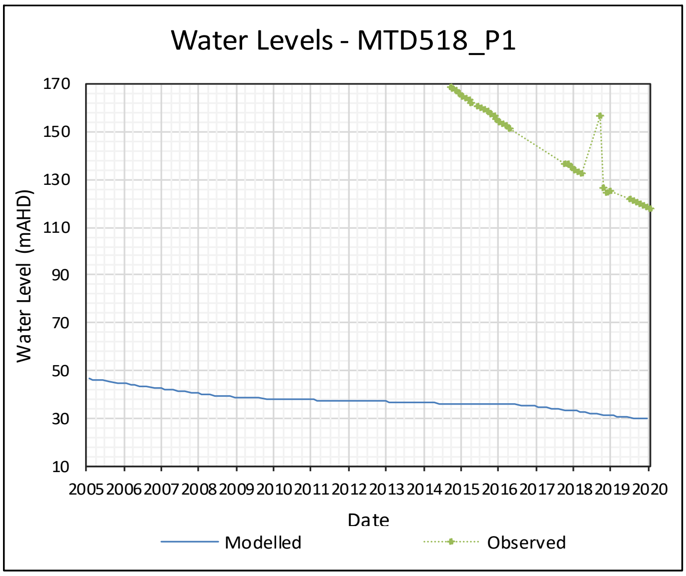

Water Levels - GW98_MTCL1
Water Level (mAHD)
Date
Modelled
Observed

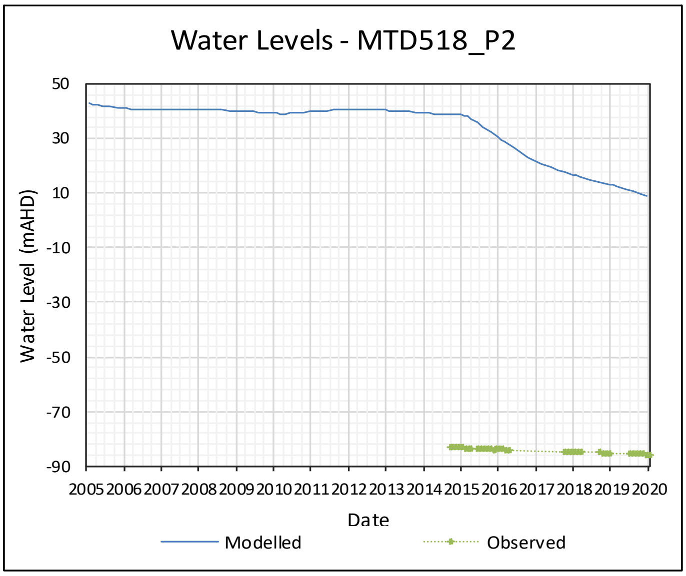

Water Levels - GW98_MTCL2
Water Level (mAHD)
80
75
70
65
60
55
50
45
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

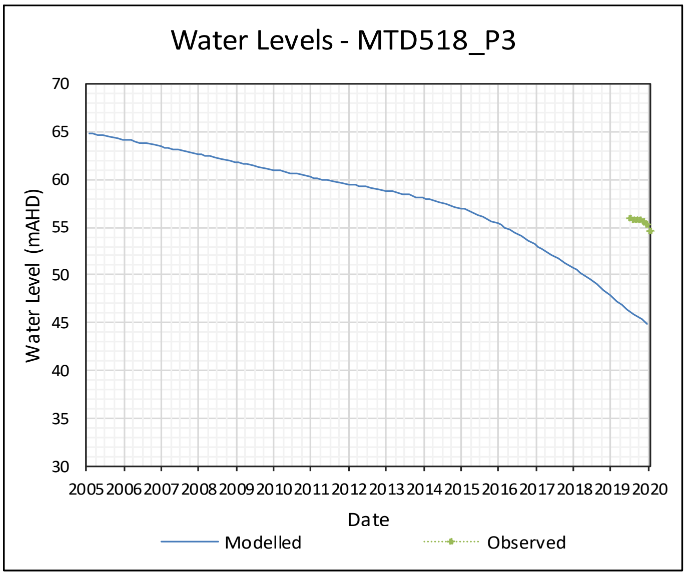

Water Levels - MTD517_P1
Water Level (mAHD)
40
35
30
25
20
15
10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

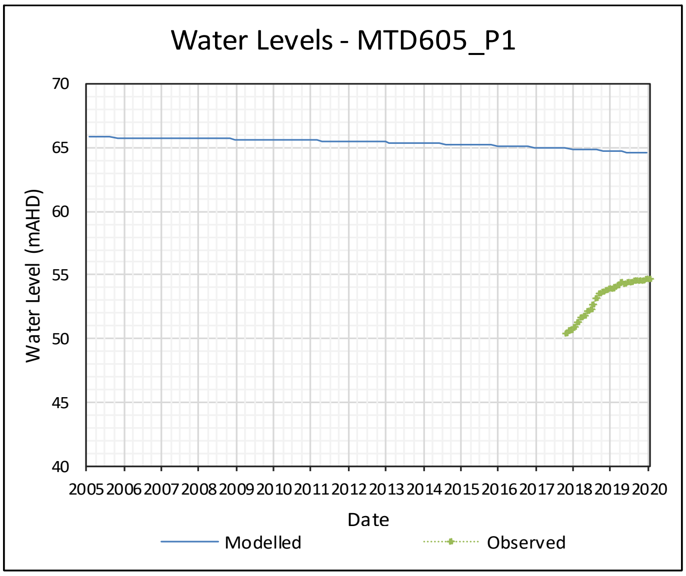

Water Levels - MTD517_P2
Water Level (mAHD)
30
20
10
0
-10
-20
-30
-40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

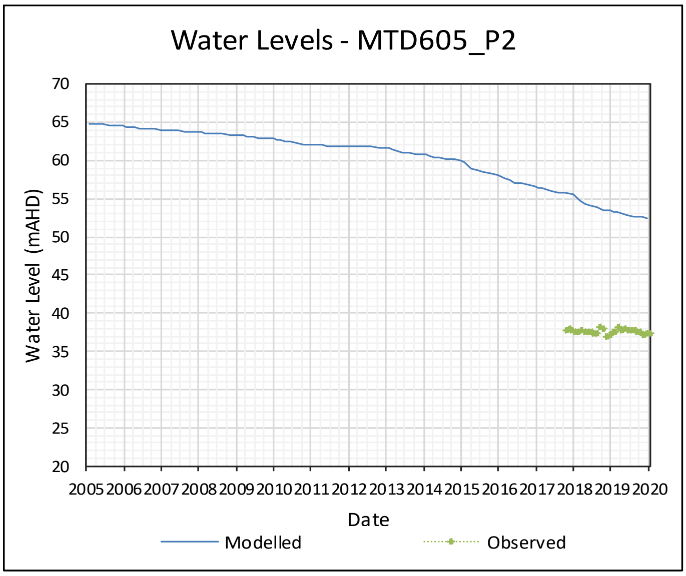

Water Levels - MTD517_P3
Water Level (mAHD)
60
50
40
30
20
10
0
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

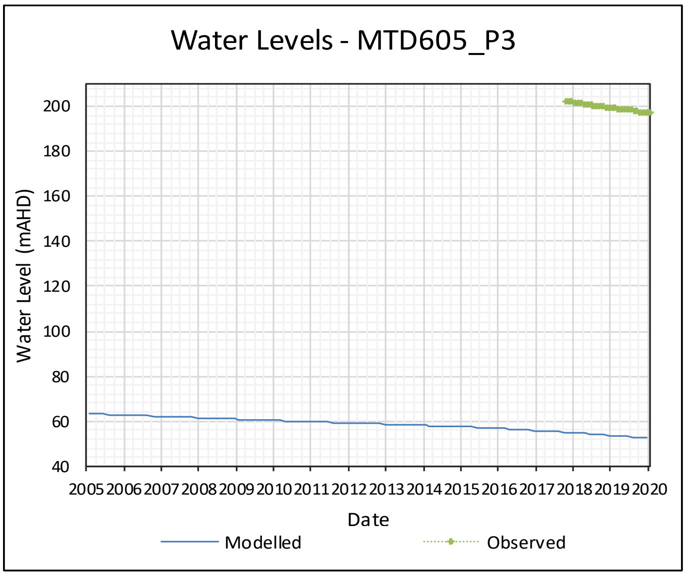

Water Levels - MTD518_P1
Water Level (mAHD)
170
150
130
110
90
70
50
30
10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

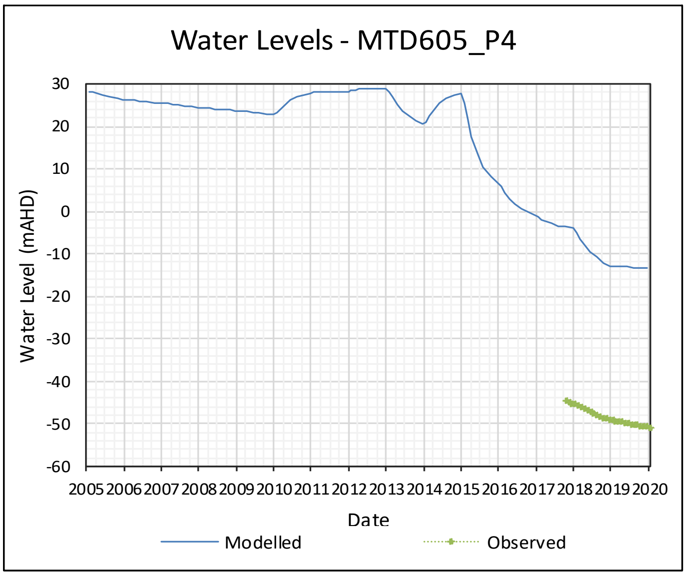

Water Levels - MTD518_P2
Water Level (mAHD)
50
30
10
-10
-30
-50
-70
-90
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

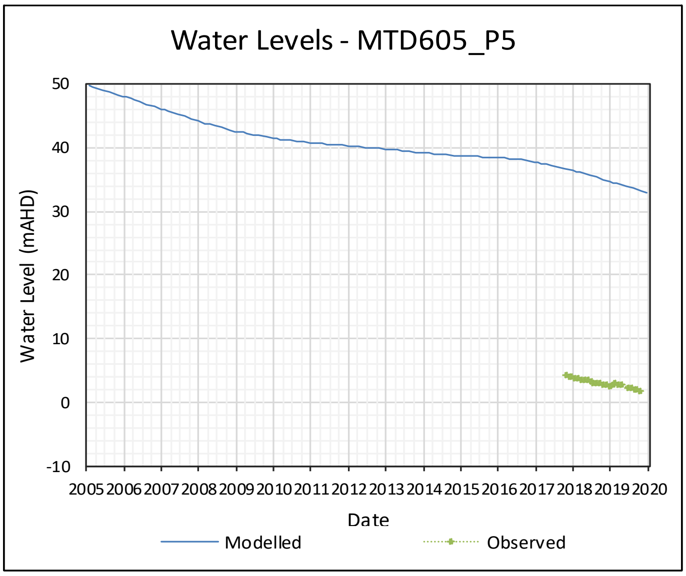

Water Levels - MTD518_P3
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

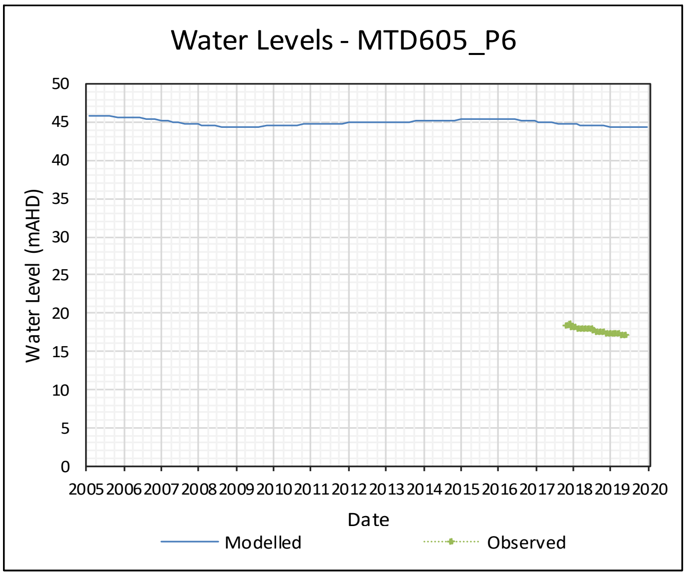

Water Levels - MTD605_P1
Water Level (mAHD)
70
65
60
55
50
45
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

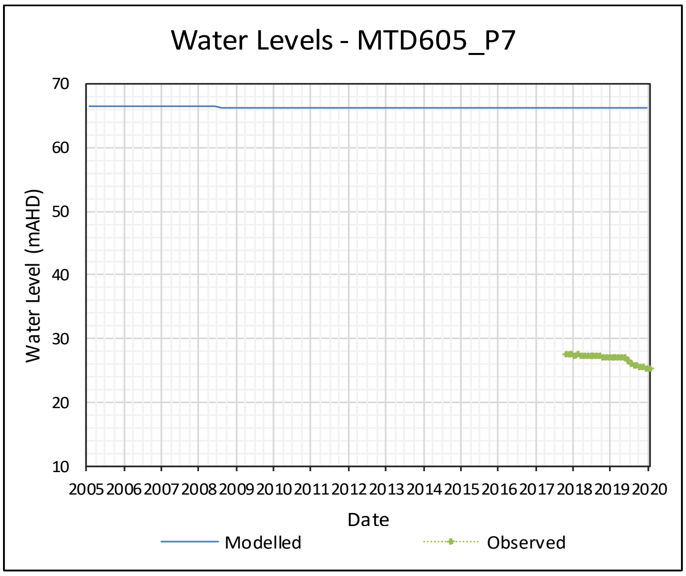

Water Levels - MTD605_P2
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
25
20
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

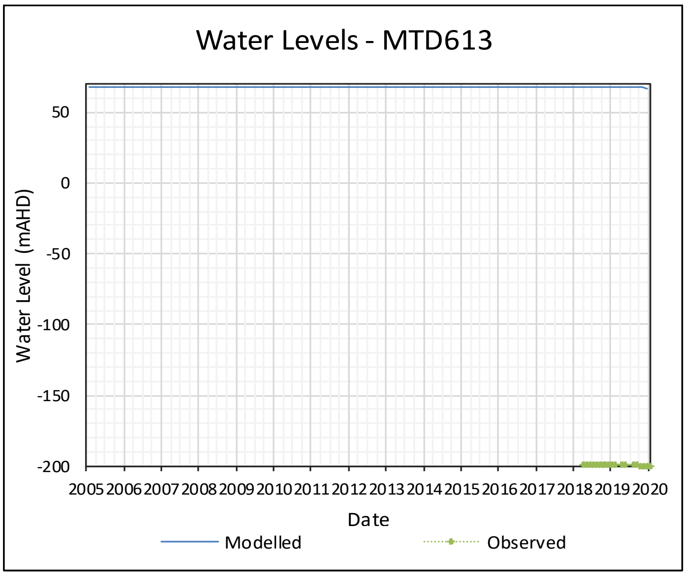

Water Levels - MTD605_P3
Water Level (mAHD)
200
180
160
140
120
100
80
60
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

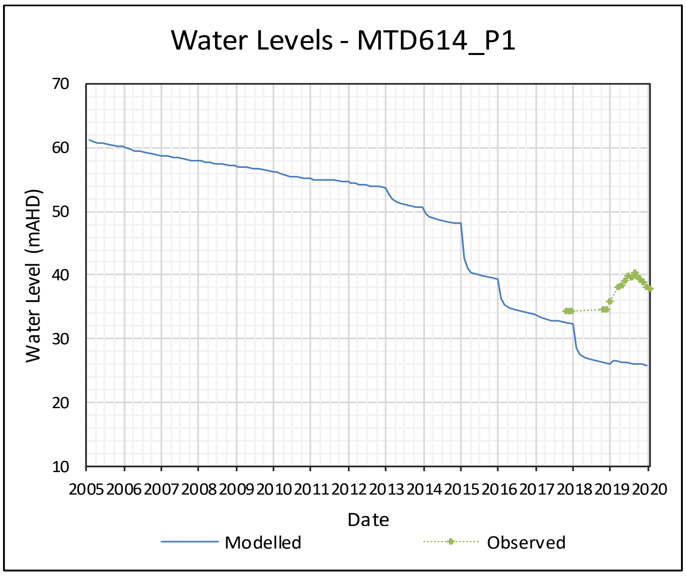

Water Levels - MTD605_P4
Water Level (mAHD)
30
20
10
0
-10
-20
-30
-40
-50
-60
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

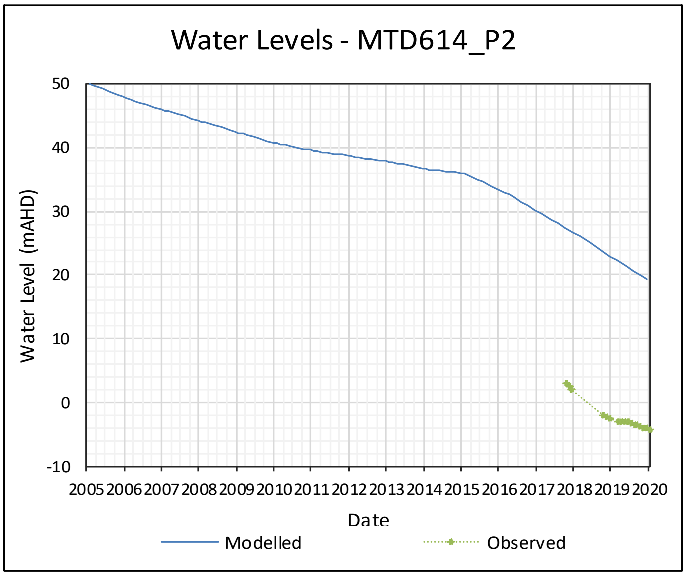

Water Levels - MTD605_P5
Water Level (mAHD)
50
40
30
20
10
0
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

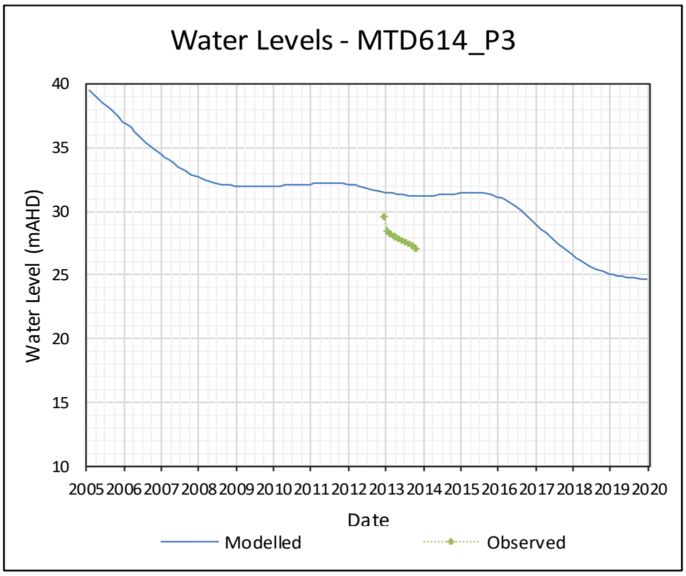

Water Levels - MTD605_P6
Water Level (mAHD)
Date
Modelled
Observed

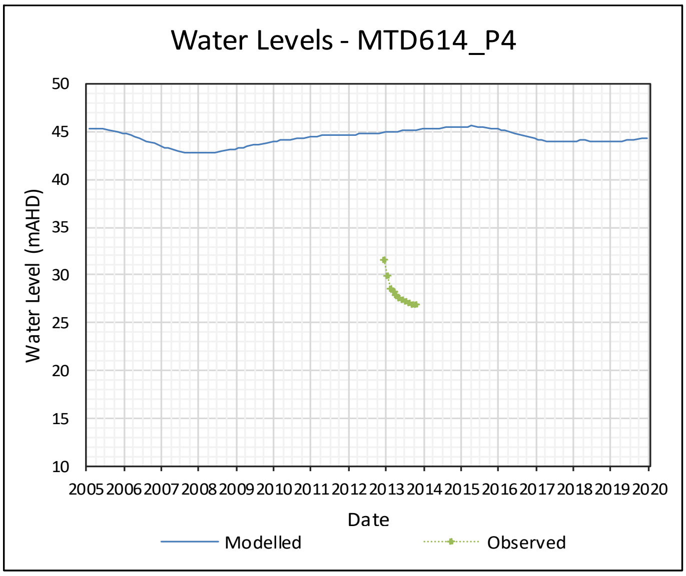

Water Levels - MTD605_P7
Water Level (mAHD)
Date
Modelled
Observed

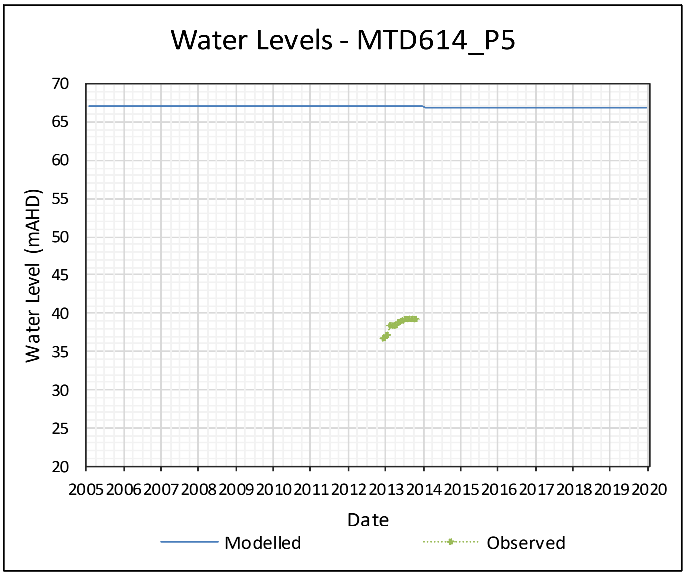

Water Levels - MTD613
Water Level (mAHD)
Date
Modelled
Observed

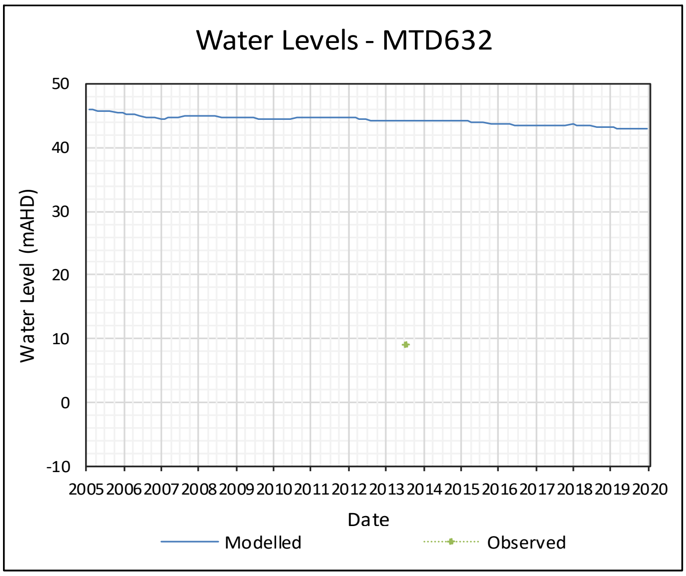

Water Levels - MTD614_P1
Water Level (mAHD)
Date
Modelled
Observed

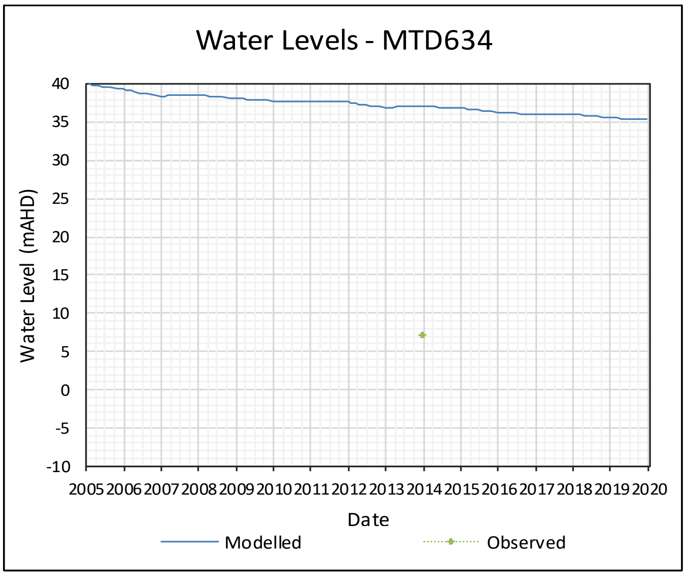

Water Levels - MTD614_P2
Water Level (mAHD)
Date
Modelled
Observed

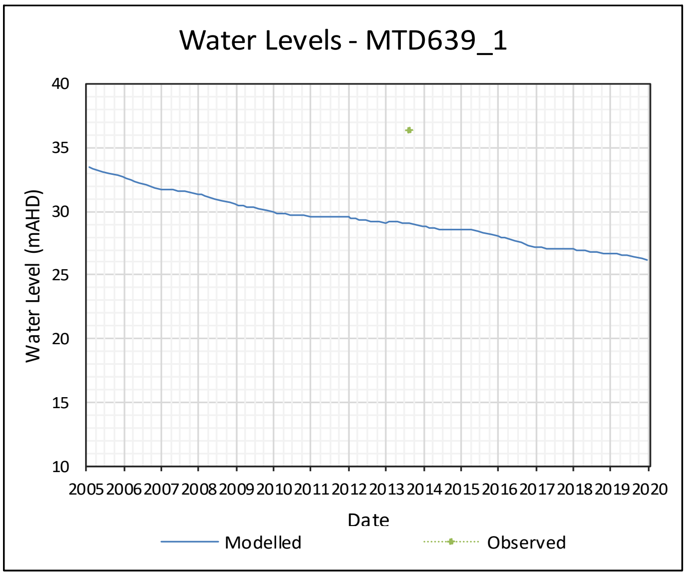

Water Levels - MTD614_P3
Water Level (mAHD)
Date
Modelled
Observed

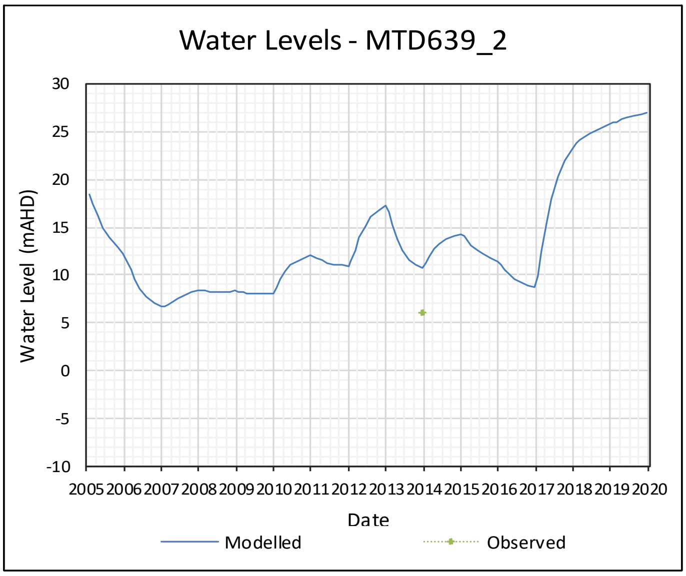

Water Levels - MTD614_P4
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

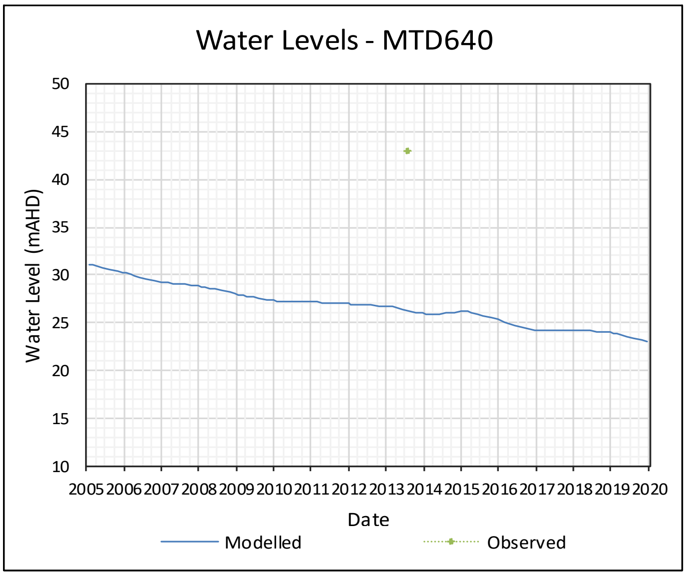

Water Levels - MTD614_P5
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
25
20
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

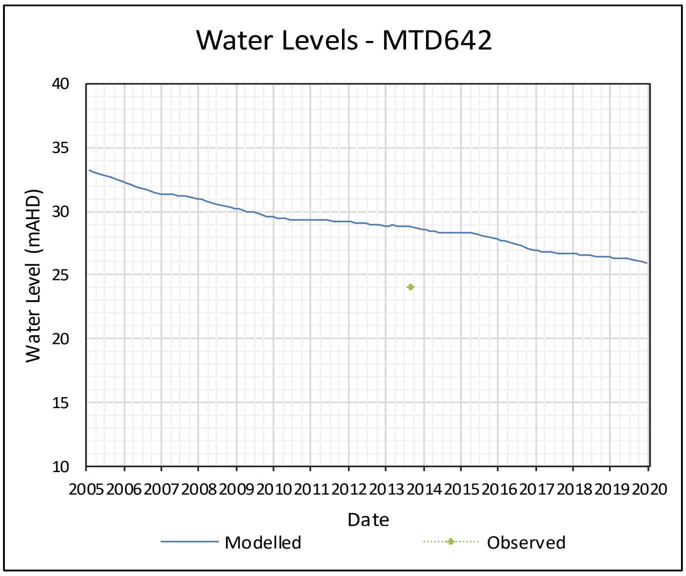

Water Levels - MTD632
Water Level (mAHD)
50
40
30
20
10
0
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

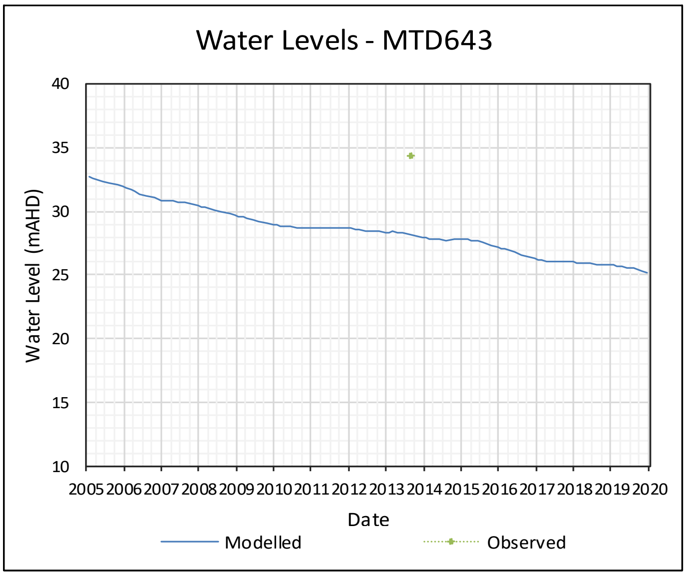

Water Levels - MTD634
Water Level (mAHD)
40
35
30
25
20
15
10
5
0
-5
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

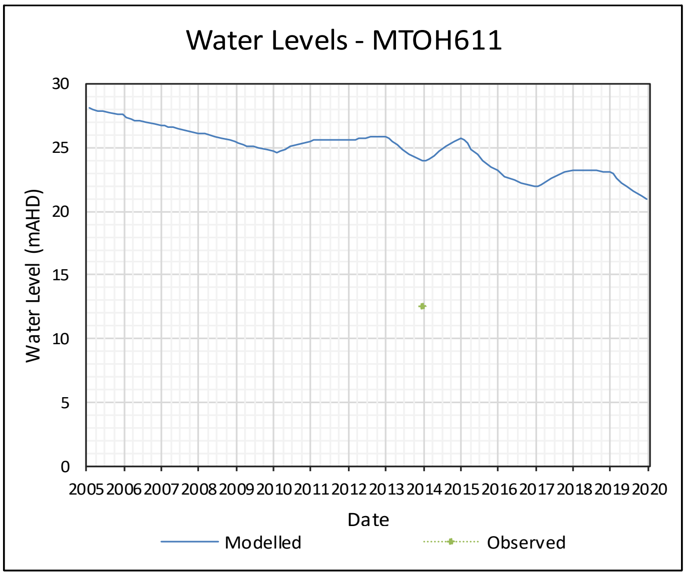

Water Levels - MTD639_1
Water Level (mAHD)
40
35
30
25
20
15
10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

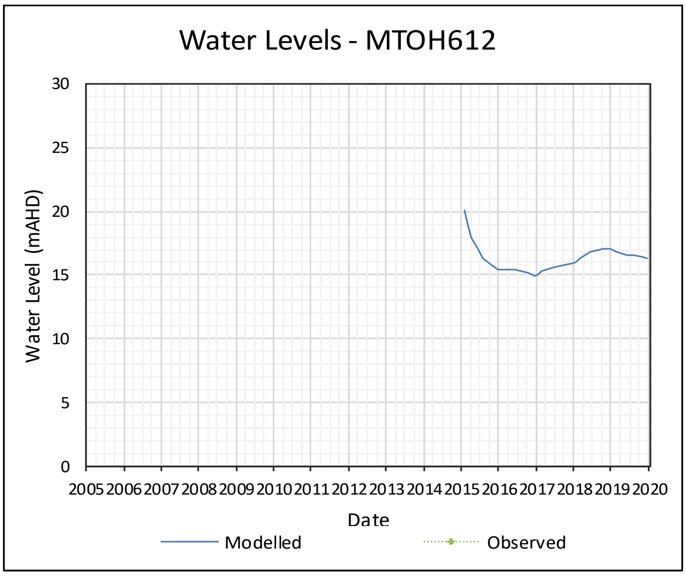

Water Levels - MTD639_2
Water Level (mAHD)
30
25
20
15
10
5
0
-5
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

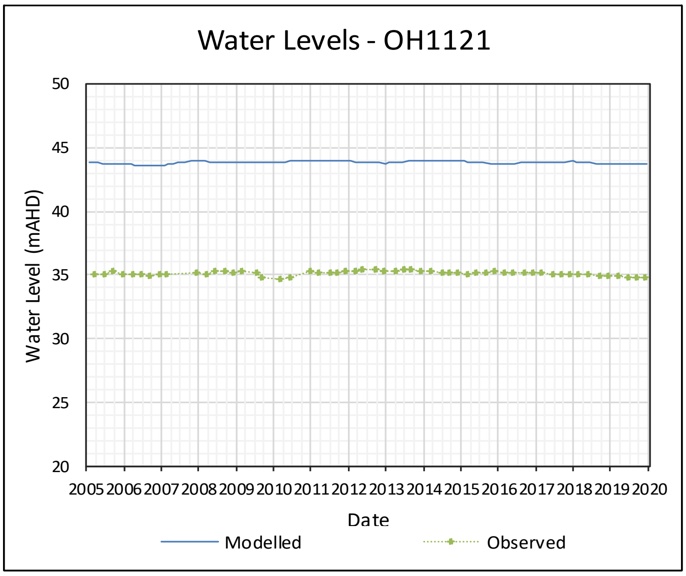

Water Levels - MTD640
Water Level (mAHD)
Date
Modelled
Observed

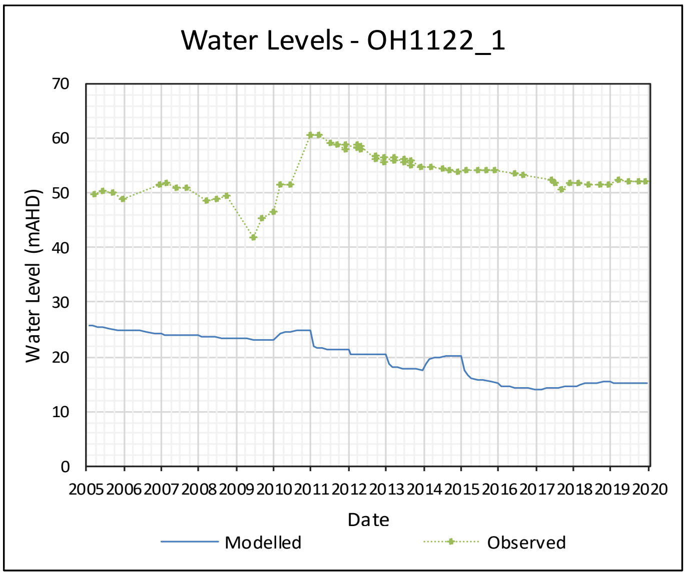

Water Levels - MTD642
Water Level (mAHD)
Date
Modelled
Observed

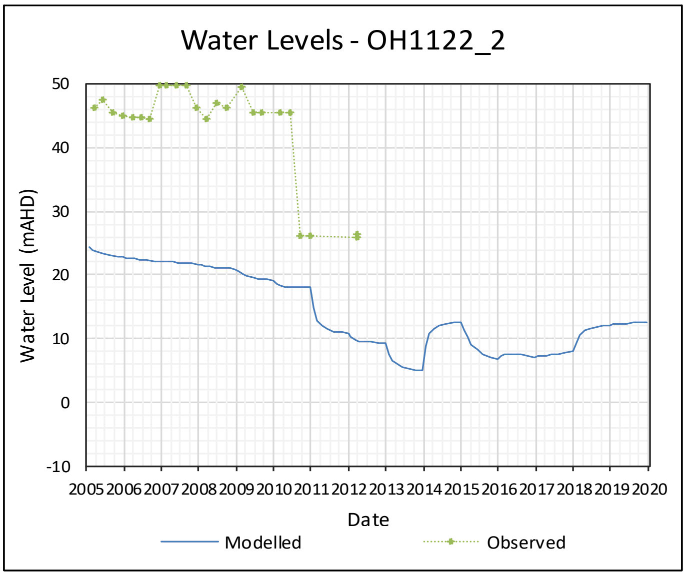

Water Levels - MTD643
Water Level (mAHD)
Date
Modelled
Observed

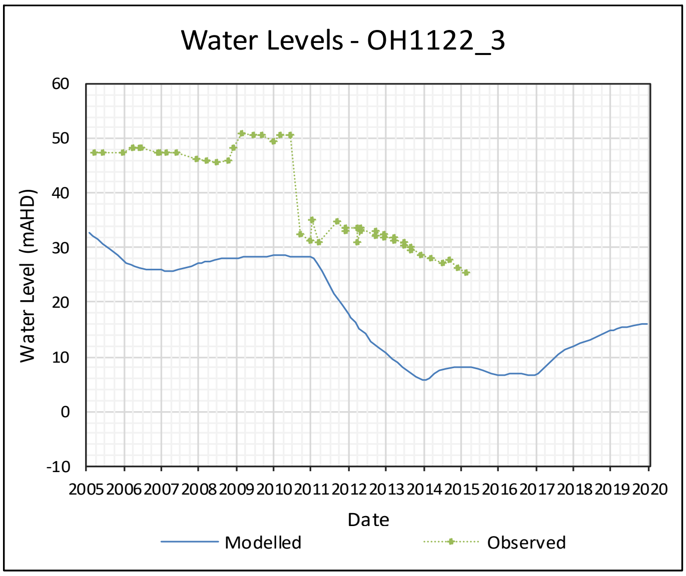

Water Levels - MTOH611
Water Level (mAHD)
Date
Modelled
Observed

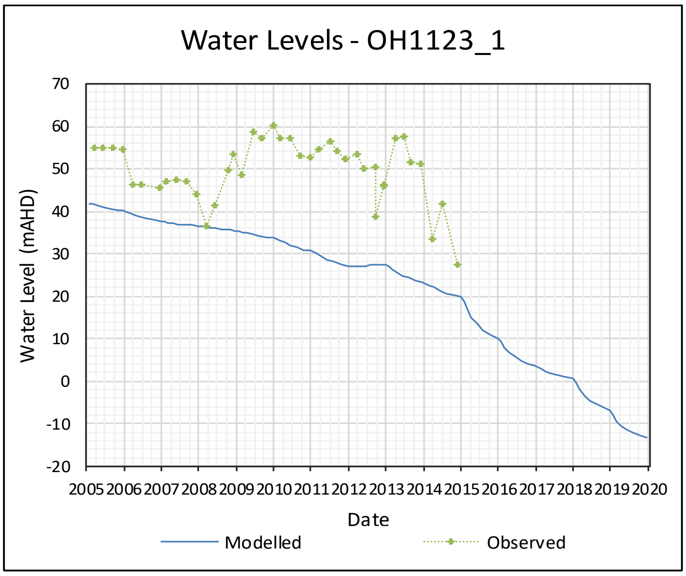

Water Levels - MTOH612
Water Level (mAHD)
Date
Modelled
Observed

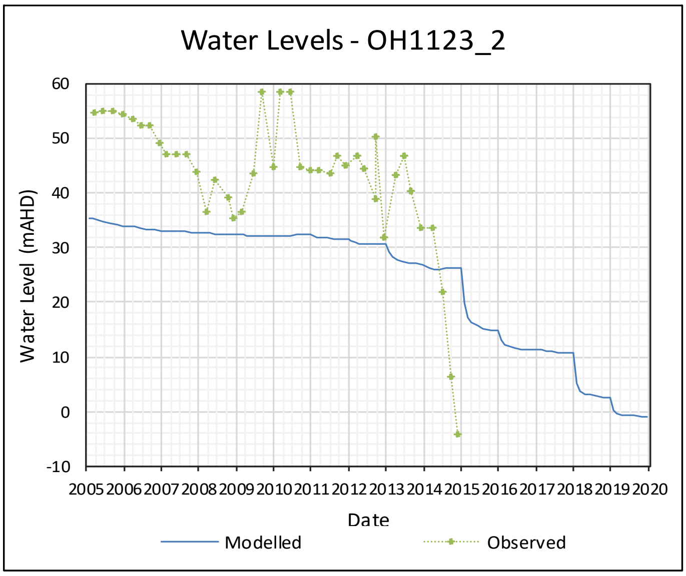

Water Levels - OH1121
Water Level (mAHD)
Date
Modelled
Observed

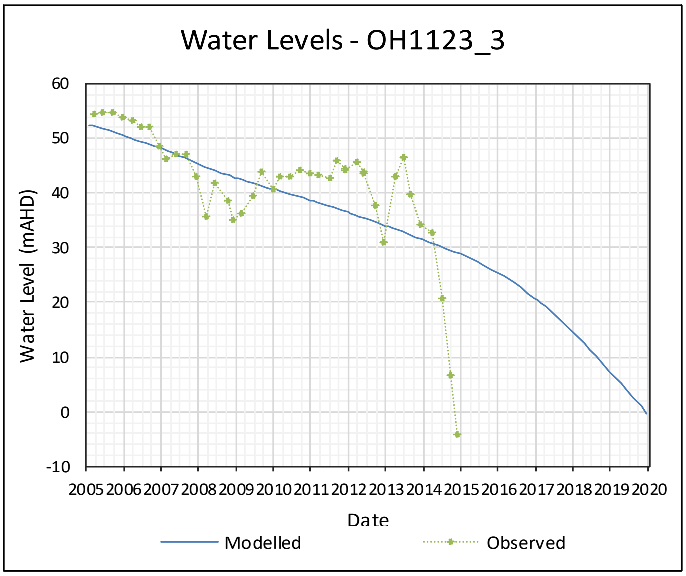

Water Levels - OH1122_1
Water Level (mAHD)
Date
Modelled
Observed

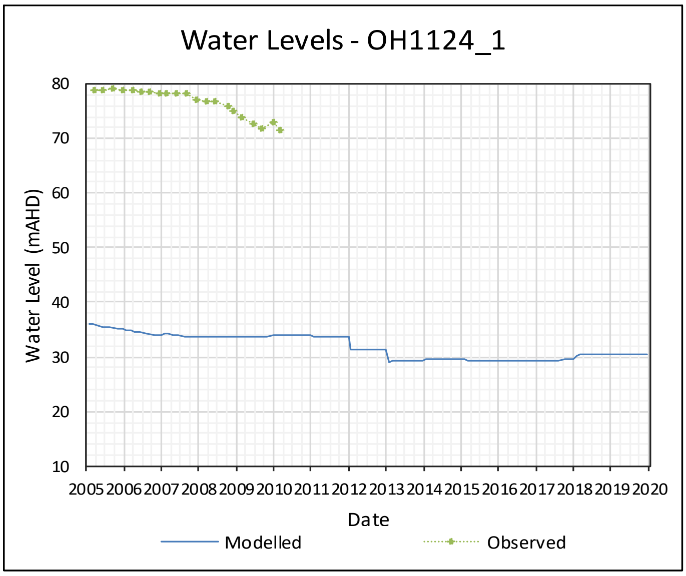

Water Levels - OH1122_2
Water Level (mAHD)
Date
Modelled
Observed

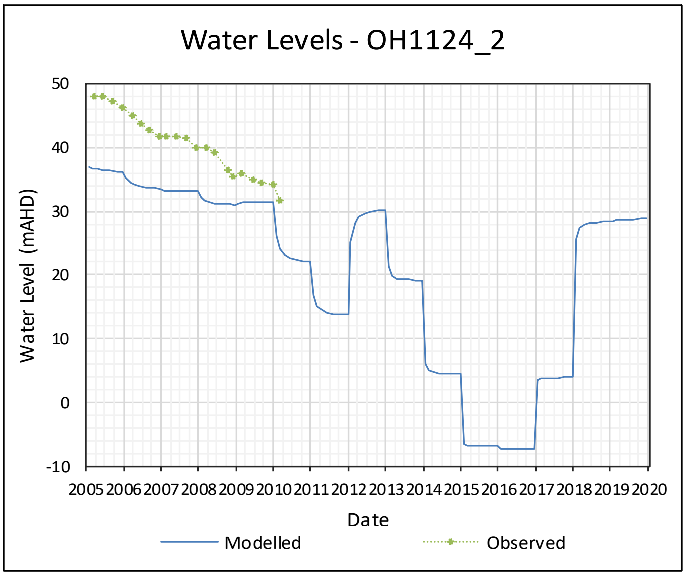

Water Levels - OH1122_3
Water Level (mAHD)
Date
Modelled
Observed

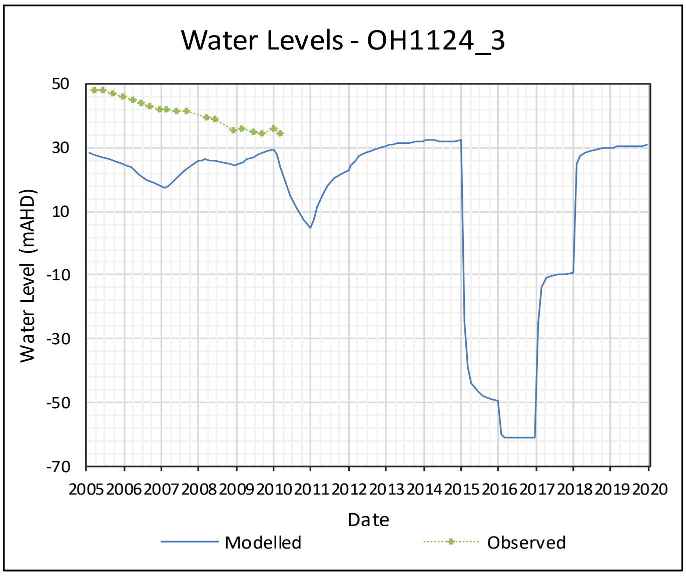

Water Levels - OH1123_1
Water Level (mAHD)
Date
Modelled
Observed

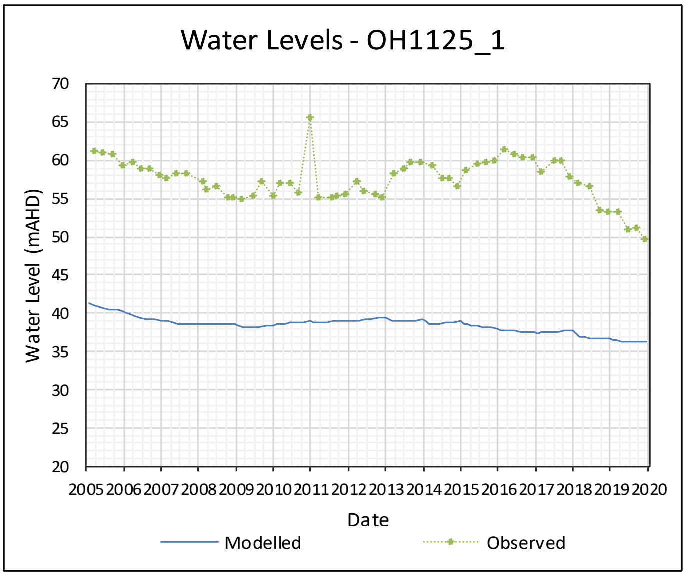

Water Levels - OH1123_2
Water Level (mAHD)
Date
Modelled
Observed

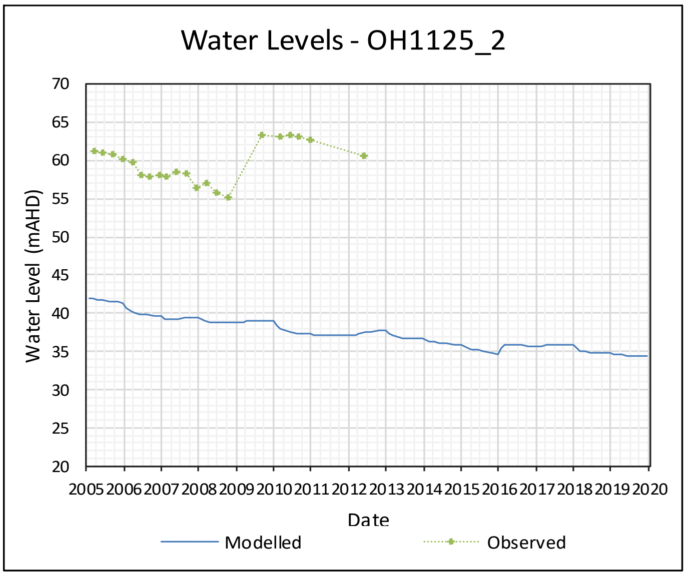

Water Levels - OH1123_3
Water Level (mAHD)
Date
Modelled
Observed

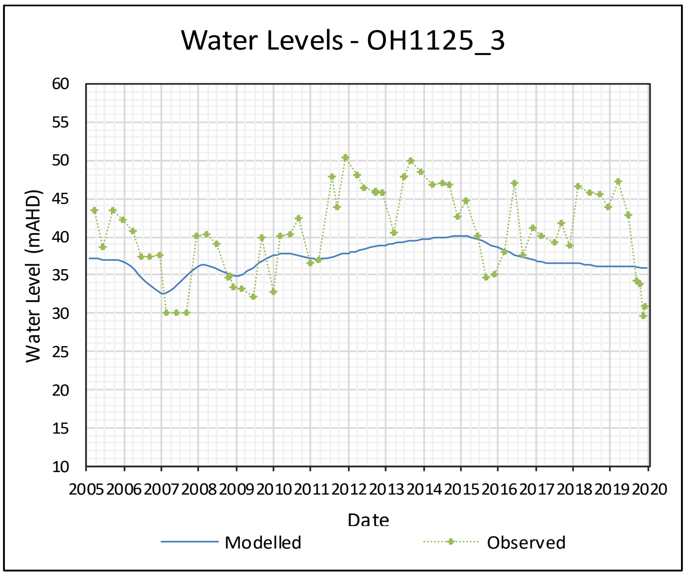

Water Levels - OH1124_1
Water Level (mAHD)
80
70
60
50
40
30
20
10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

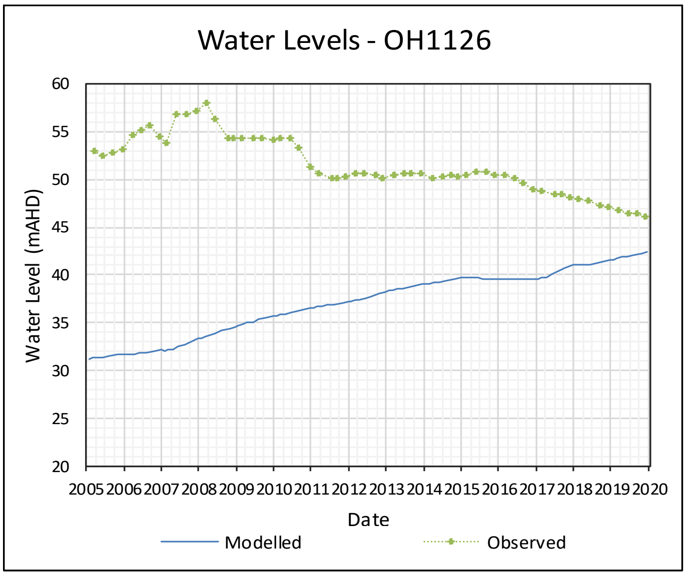

Water Levels - OH1124_2
Water Level (mAHD)
50
40
30
20
10
0
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

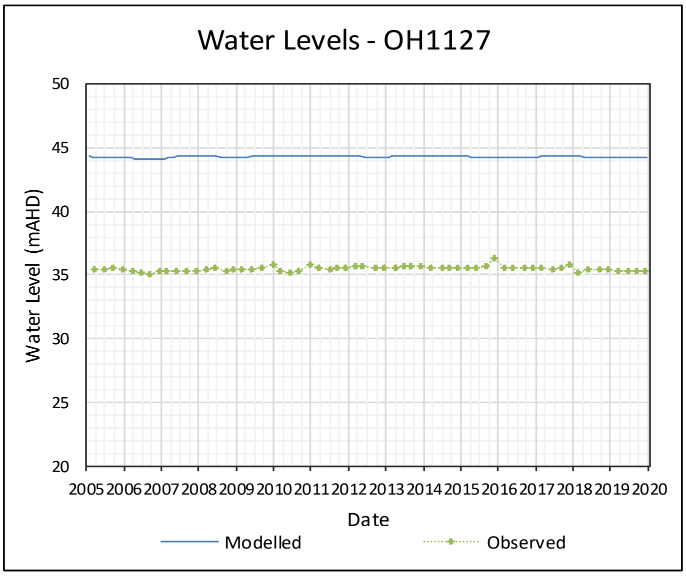

Water Levels - OH1124_3
Water Level (mAHD)
50
30
10
-10
-30
-50
-70
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

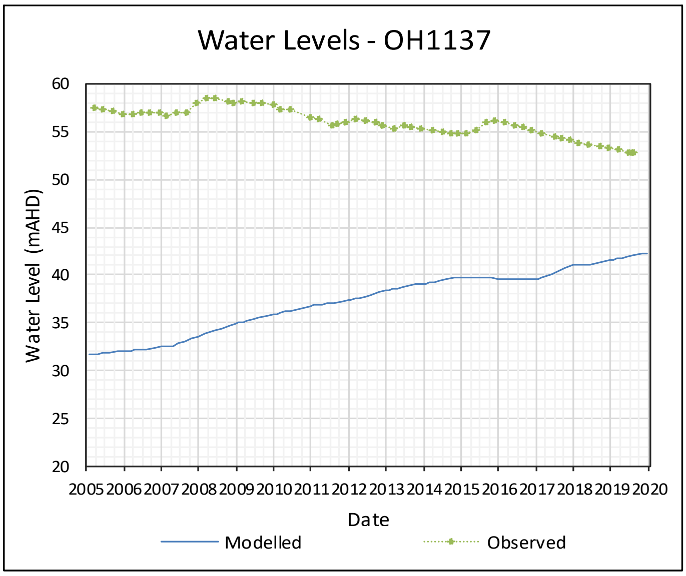

Water Levels - OH1125_1
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
25
20
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

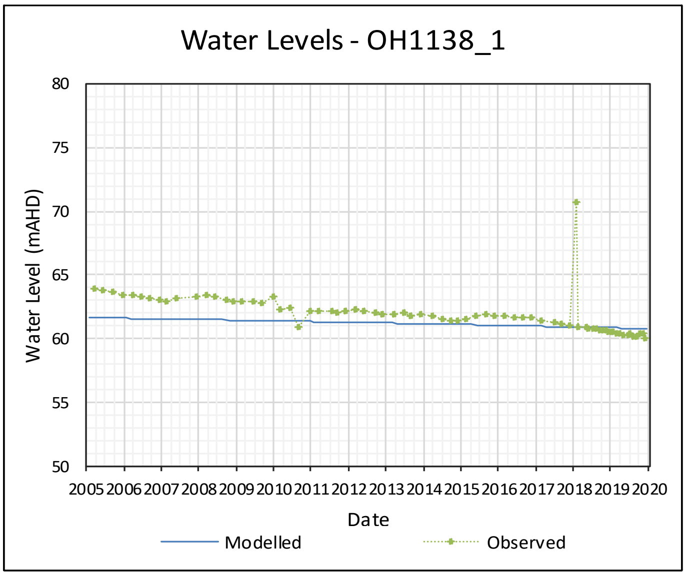

Water Levels - OH1125_2
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
25
20
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

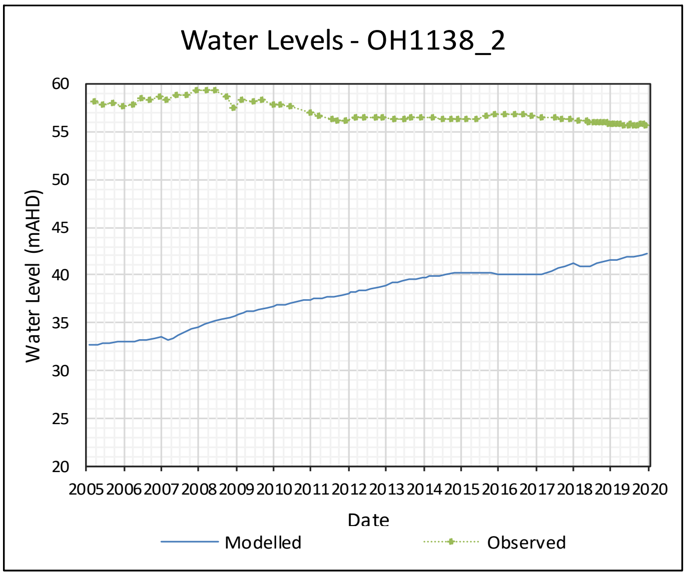

Water Levels - OH1125_3
Water Level (mAHD)
60
55
50
45
40
35
30
25
20
15
10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

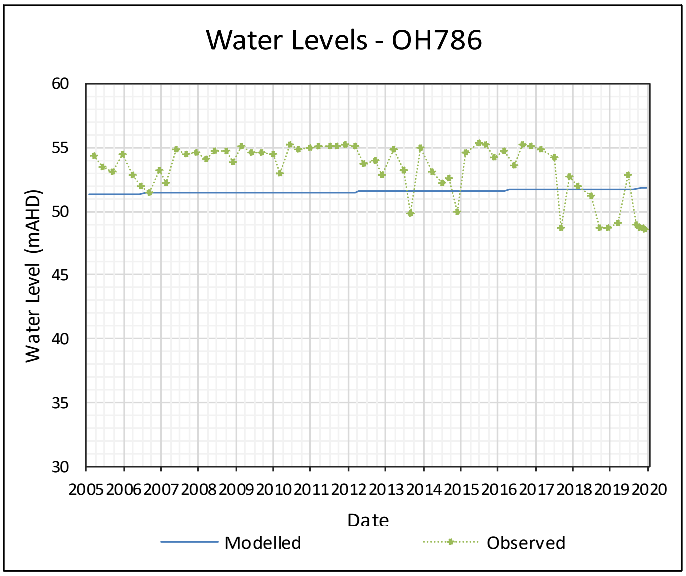

Water Levels - OH1126
Water Level (mAHD)
20 25 30 35 40 45 50 55 60
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

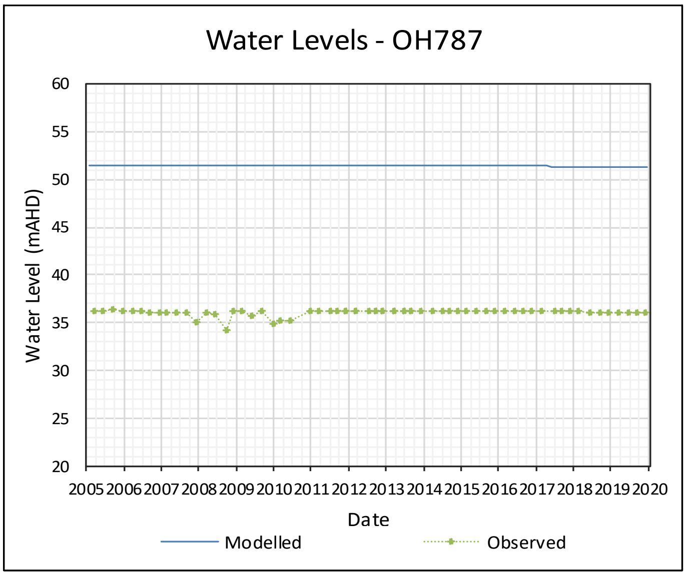

Water Levels - OH1127
Water Level (mAHD)
20 25 30 35 40 45 50
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

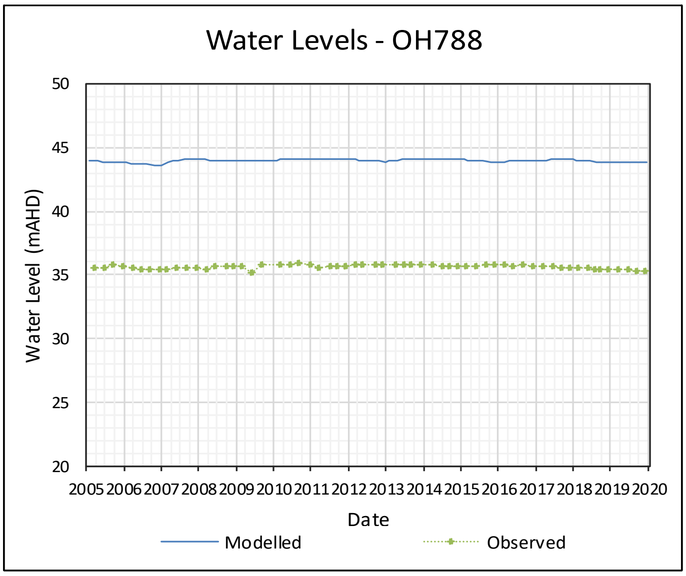

Water Levels - OH1137
Water Level (mAHD)
20 25 30 35 40 45 50 55 60
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

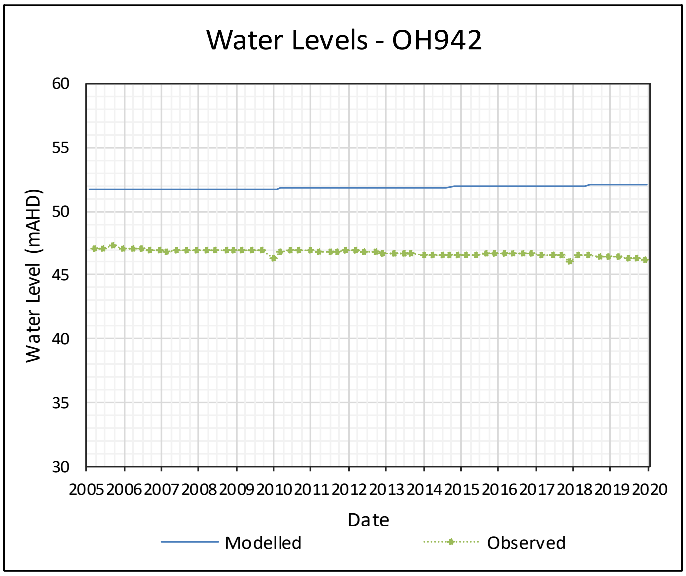

Water Levels - OH1138_1
Water Level (mAHD)
50 55 60 65 70 75 80
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

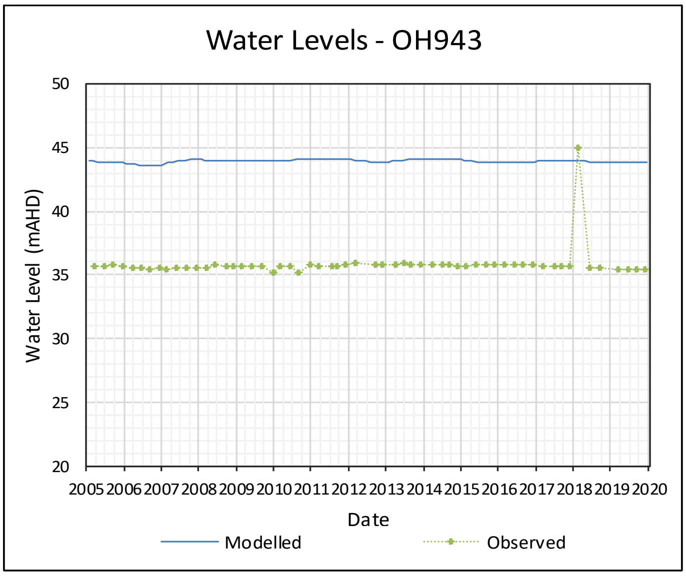

Water Levels - OH1138_2
Water Level (mAHD)
20 25 30 35 40 45 50 55 60
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

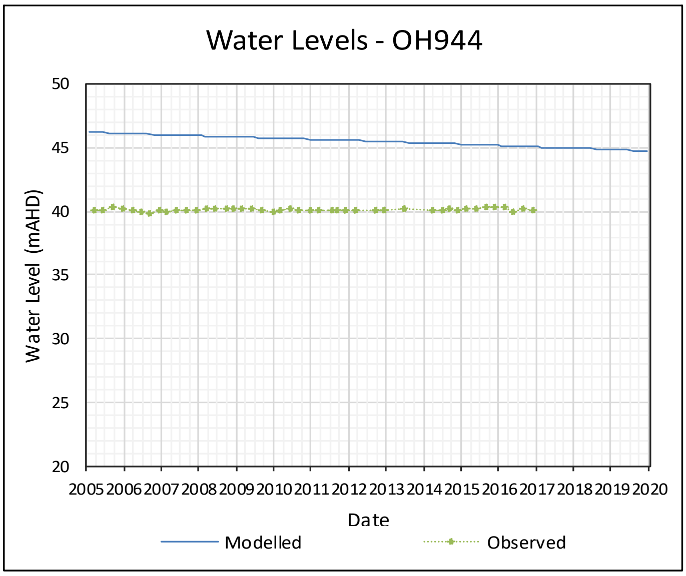

Water Levels - OH786
Water Level (mAHD)
30 35 40 45 50 55 60
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

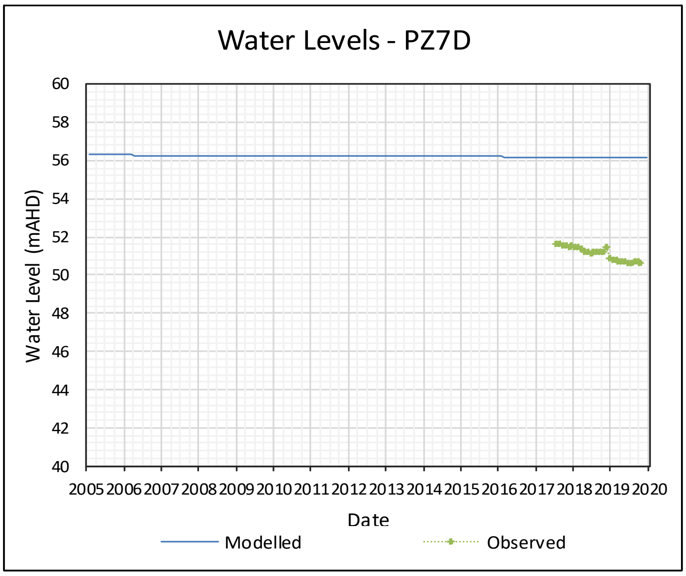

Water Levels - OH787
Water Level (mAHD)
Date
Modelled
Observed

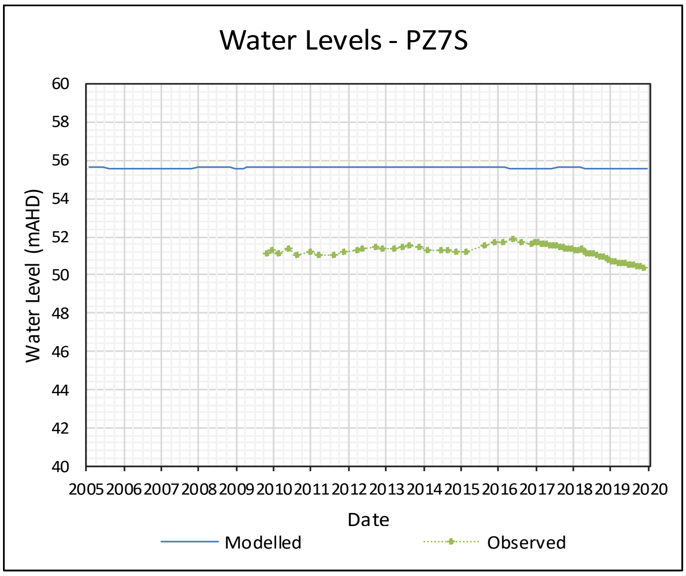

Water Levels - OH788
Water Level (mAHD)
Date
Modelled
Observed

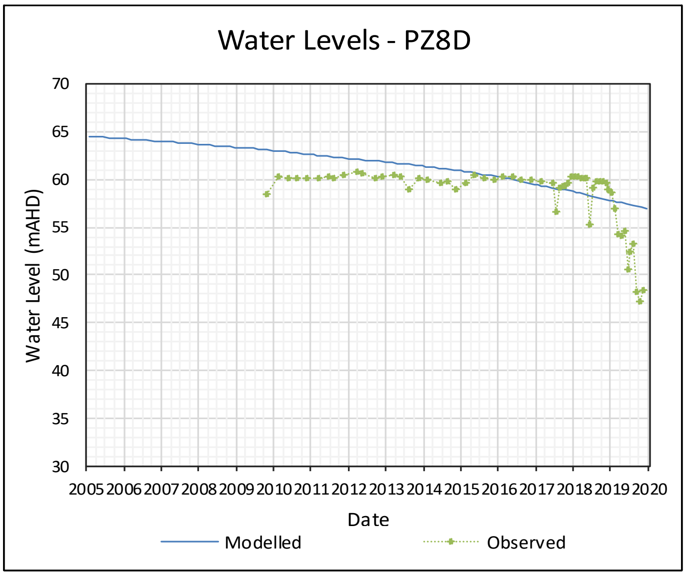

Water Levels - OH942
Water Level (mAHD)
Date
Modelled
Observed

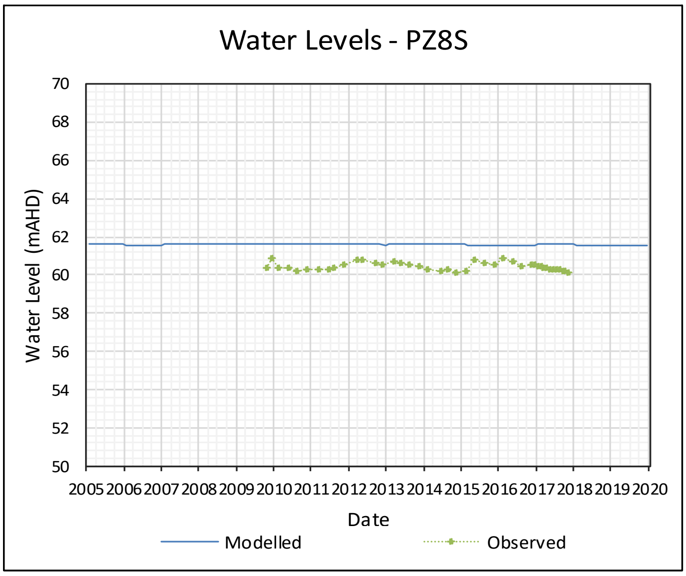

Water Levels - OH943
Water Level (mAHD)
Date
Modelled
Observed

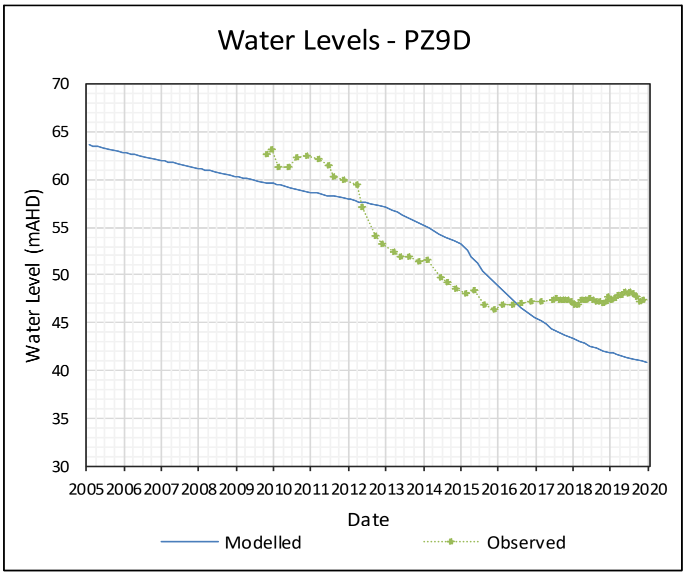

Water Levels - OH944
Water Level (mAHD)
Date
Modelled
Observed

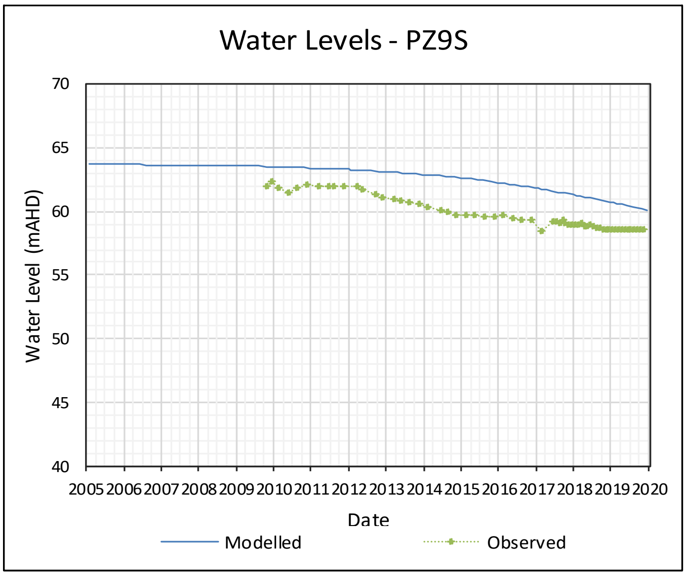

Water Levels - PZ7D
Water Level (mAHD)
Date
Modelled
Observed

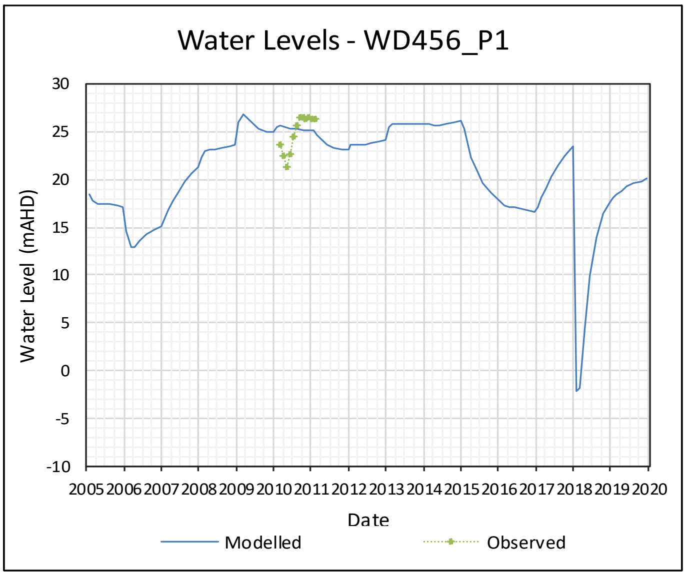

Water Levels - PZ7S
Water Level (mAHD)
60
58
56
54
52
50
48
46
44
42
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

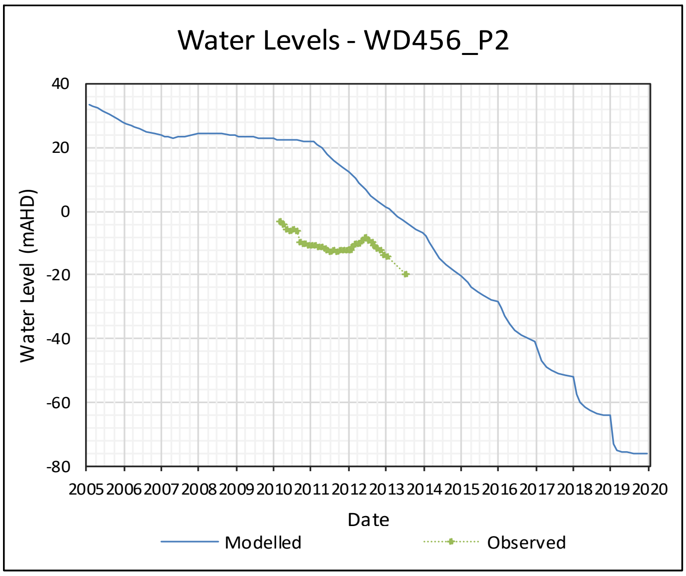

Water Levels - PZ8D
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

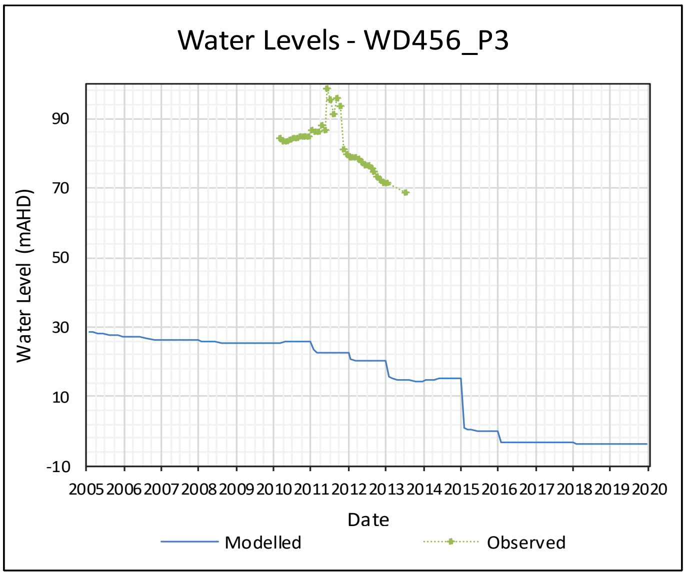

Water Levels - PZ8S
Water Level (mAHD)
70
68
66
64
62
60
58
56
54
52
50
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

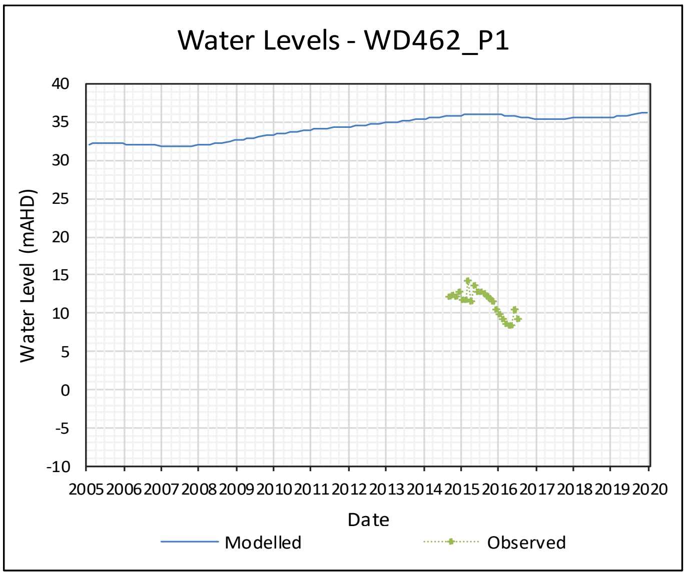

Water Levels - PZ9D
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

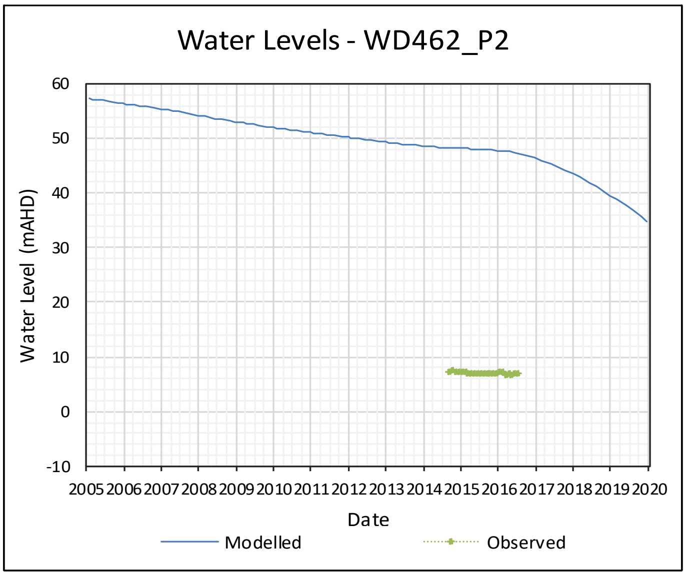

Water Levels - PZ9S
Water Level (mAHD)
70
65
60
55
50
45
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

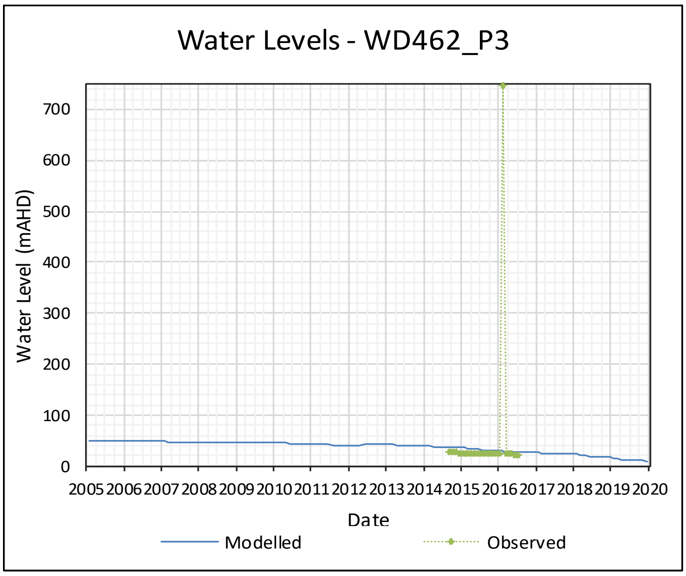

Water Levels - WD456_P1
Water Level (mAHD)
30
25
20
15
10
5
0
-5
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

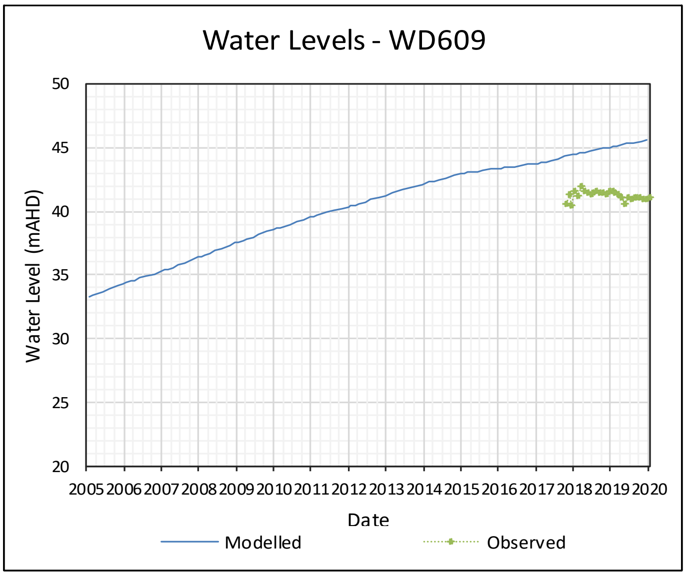

Water Levels - WD456_P2
Water Level (mAHD)
40
20
0
-20
-40
-60
-80
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed


Water Levels - WD456_P3
Water Level (mAHD)
90
70
50
30
10
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed


Water Levels - WD462_P1
Water Level (mAHD)
40
35
30
25
20
15
10
5
0
-5
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed


Water Levels - WD462_P2
Water Level (mAHD)
60
50
40
30
20
10
0
-10
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed


Water Levels - WD462_P3
Water Level (mAHD)
700
600
500
400
300
200
100
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed


Water Levels - WD609
Water Level (mAHD)
50
45
40
35
30
25
20
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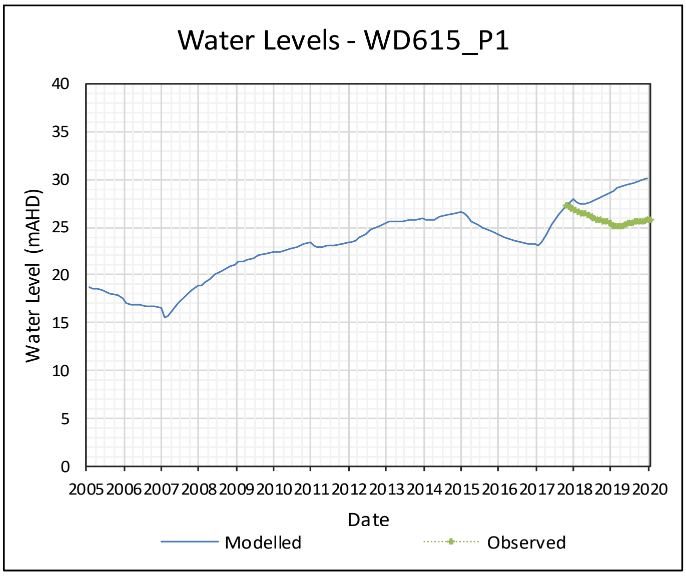
Date
Modelled
Observed



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5
10
15
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40
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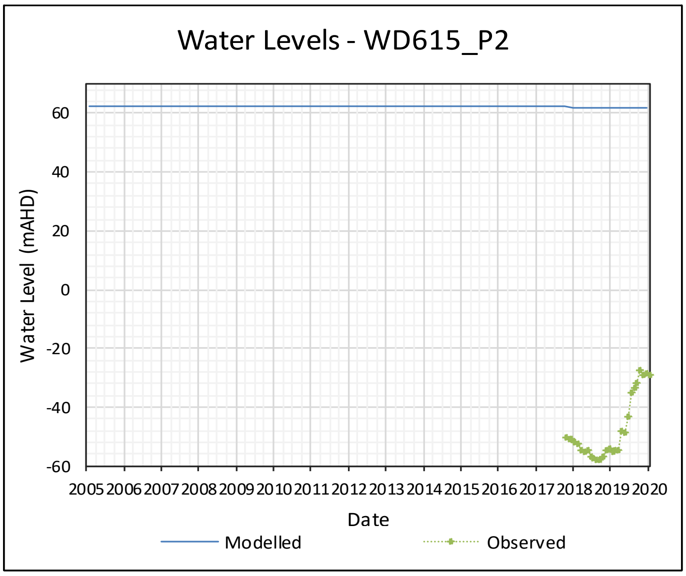
Date
Modelled
Observed



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Date
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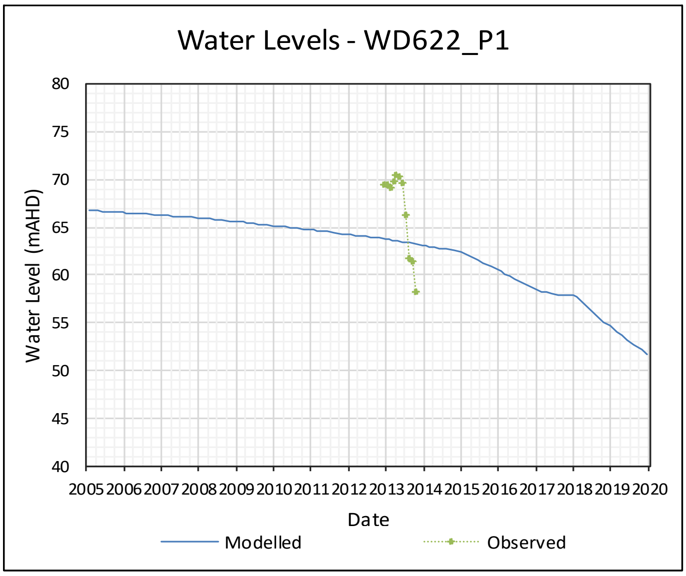
Observed



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Water Level (mAHD)
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80
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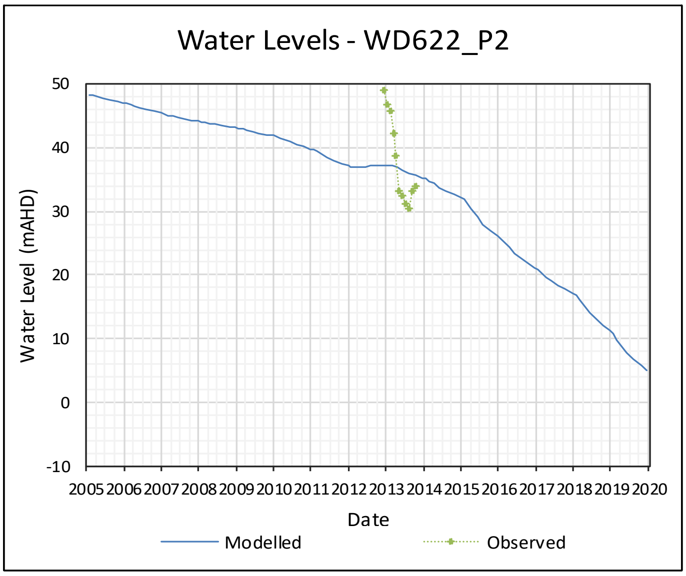
Date
Modelled
Observed



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20
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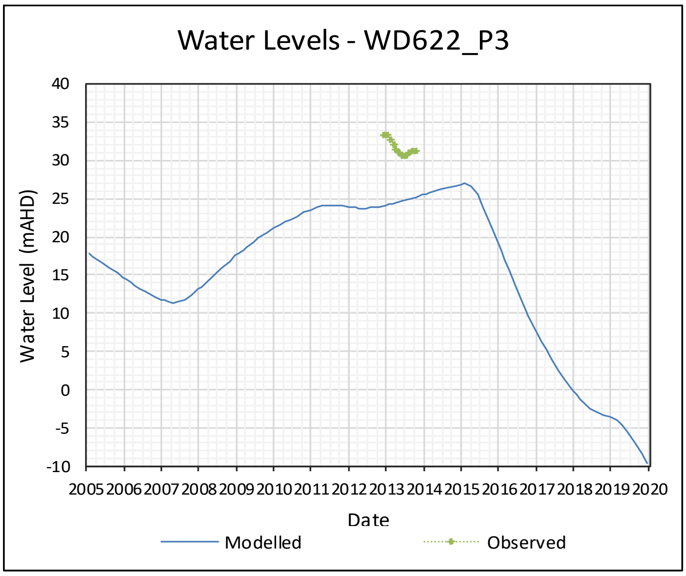
Date
Modelled
Observed



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Water Level (mAHD)
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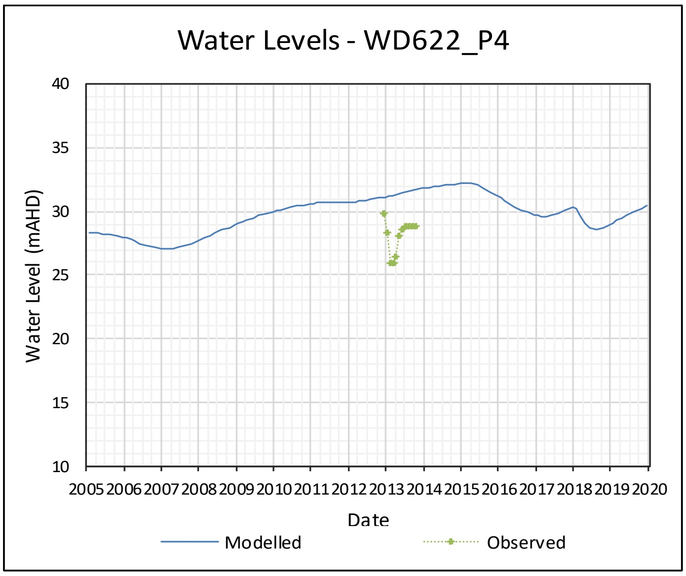
-5
0
5
10
15
20
25
30
35
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed



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Water Level (mAHD)
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25
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40
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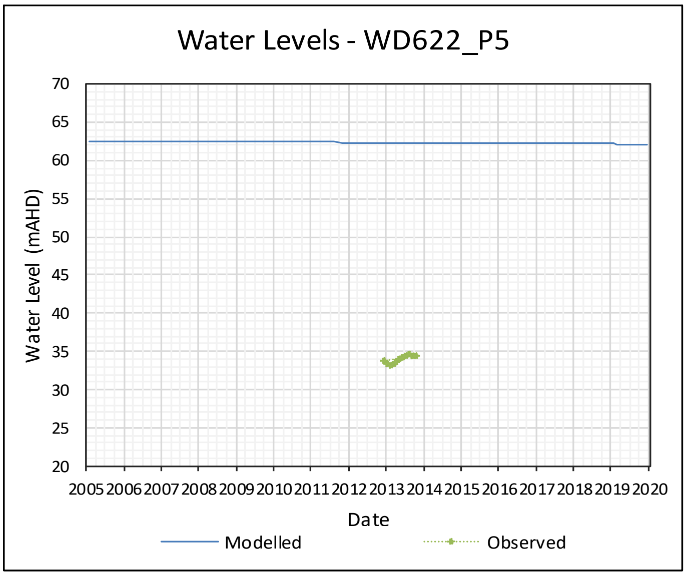
Date
Modelled
Observed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Water Level (mAHD)
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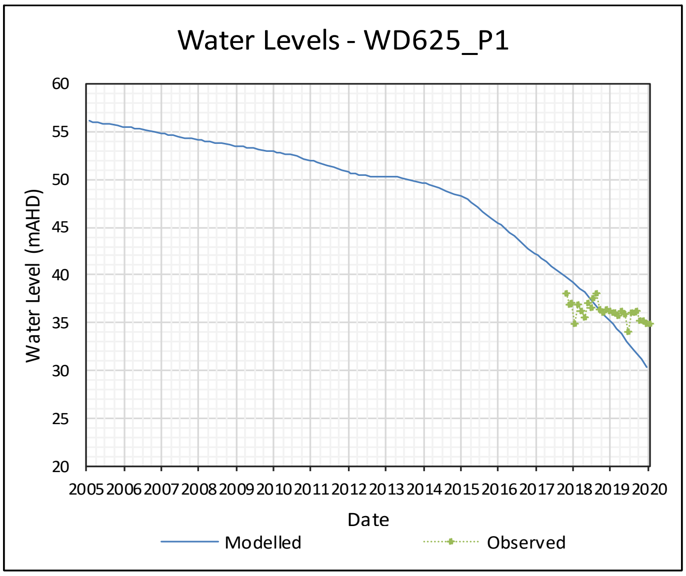
Date
Modelled
Observed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Water Level (mAHD)
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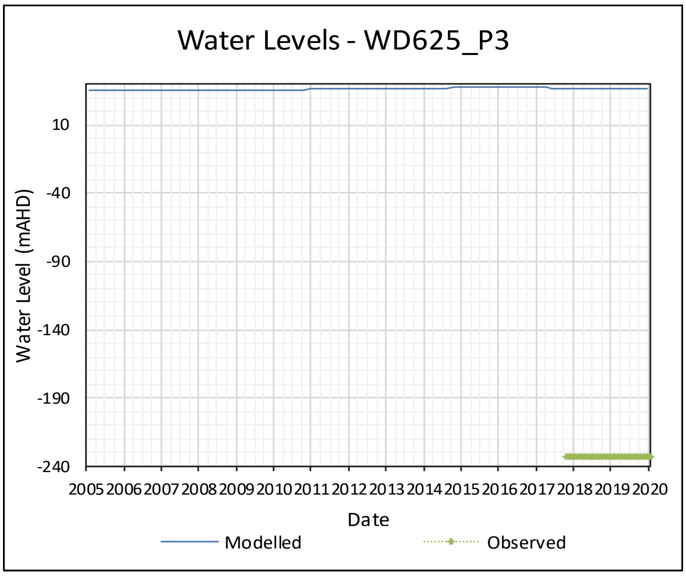
Date
Modelled
Observed


Water Levels - WD625_P3
Water Level (mAHD)
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-240
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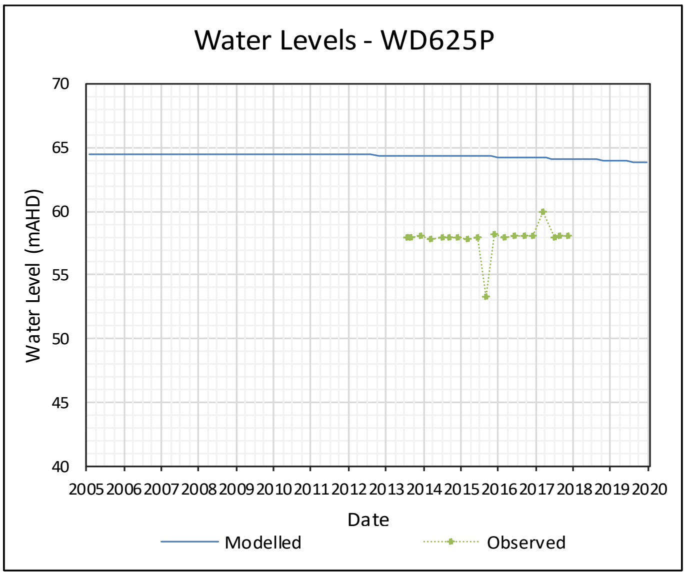
Date
Modelled
Observed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50
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40
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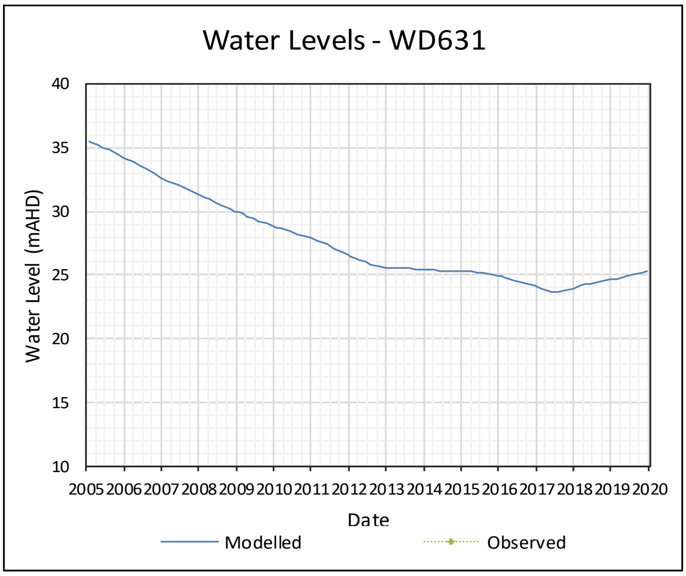
Observed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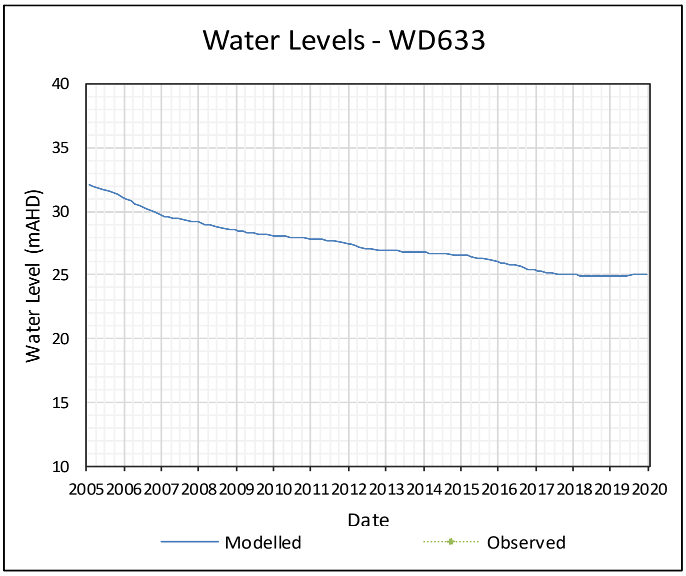
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Date
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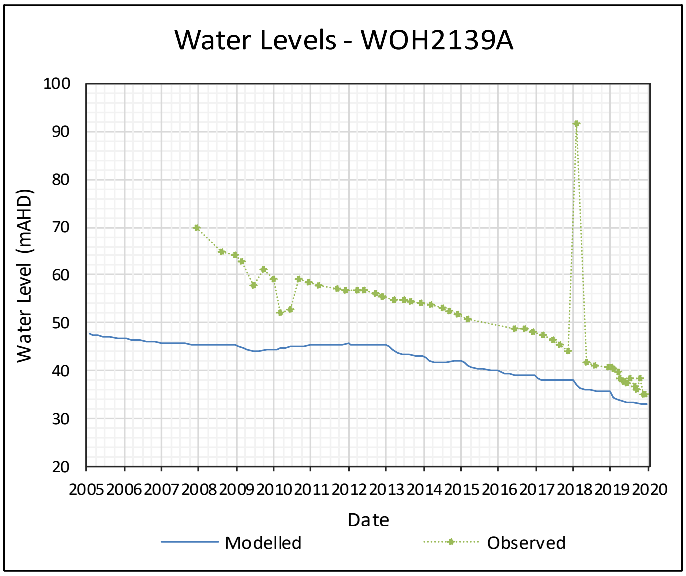
Water Levels - WOH2139A
Water Level (mAHD)
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40
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20
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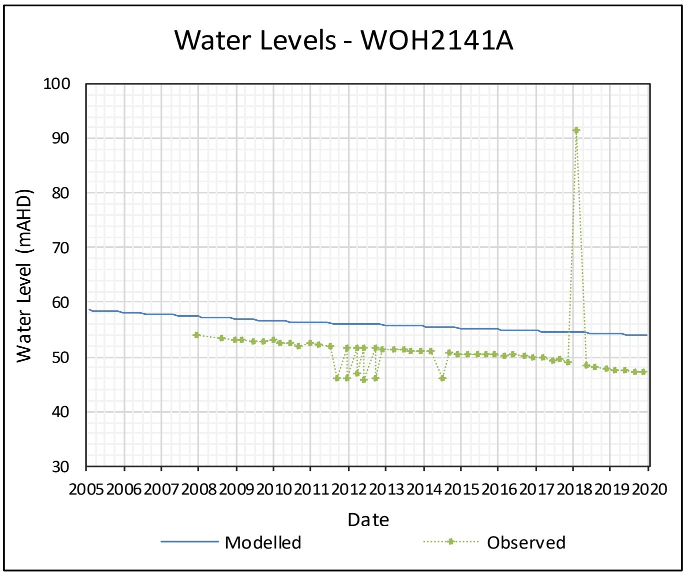
Date
Modelled
Observed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Water Level (mAHD)
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30
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Date
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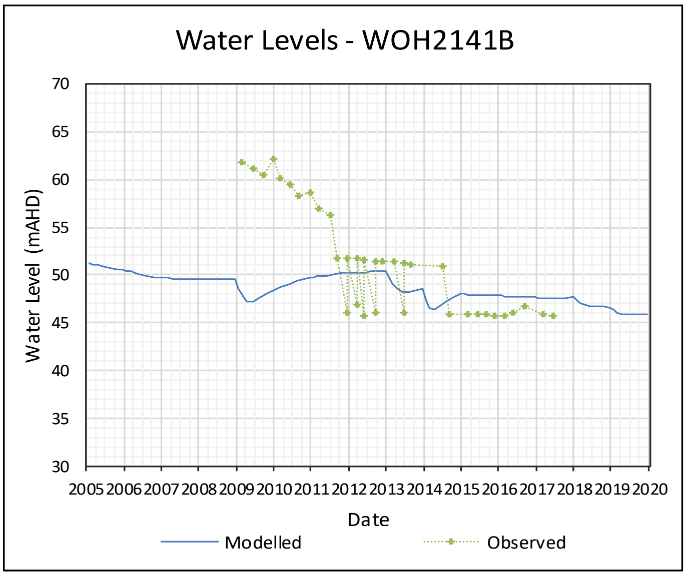
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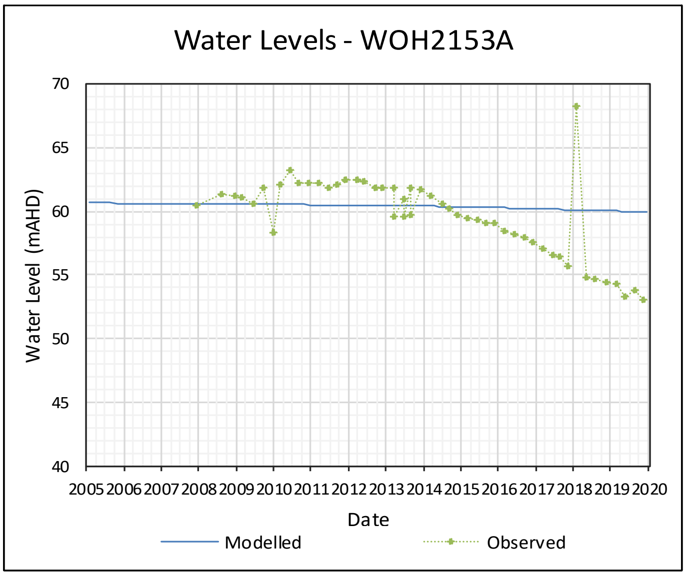
Observed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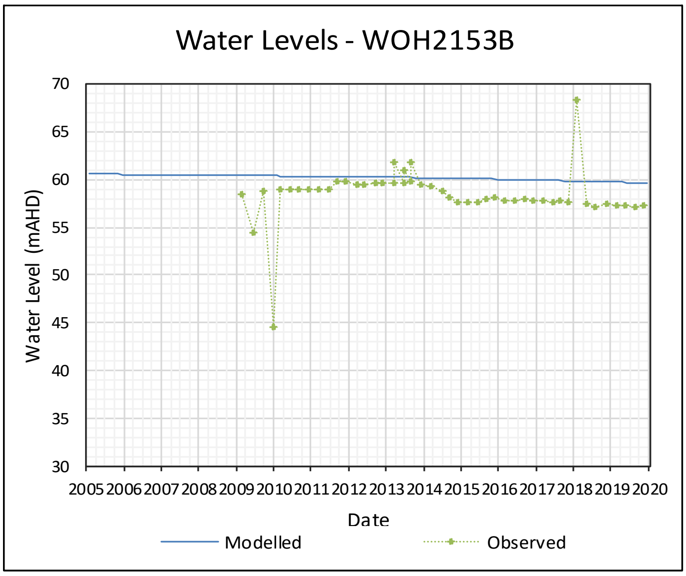
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Date
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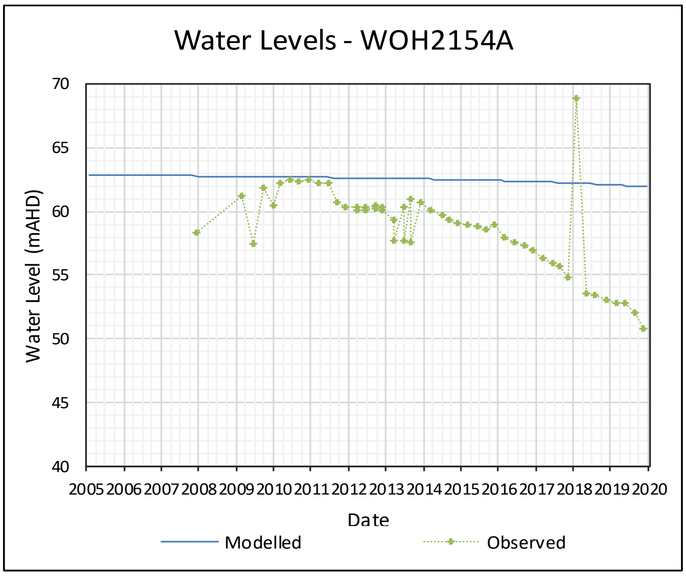
Observed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Water Level (mAHD)
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50
45
40
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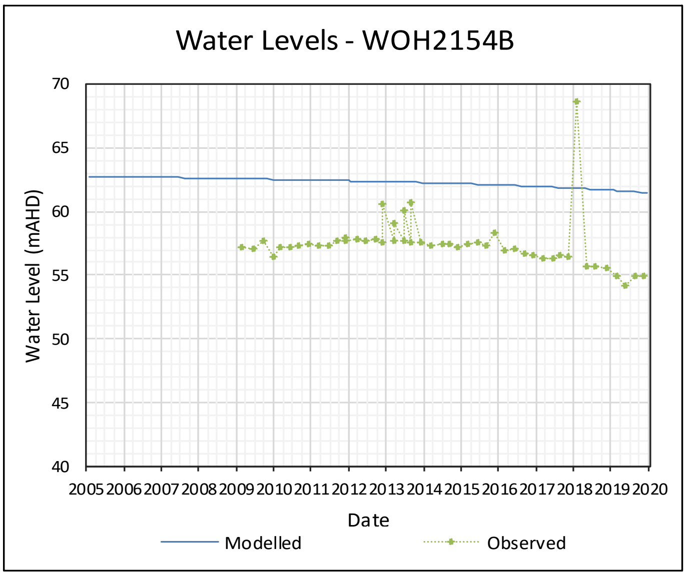
Observed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Water Level (mAHD)
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45
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
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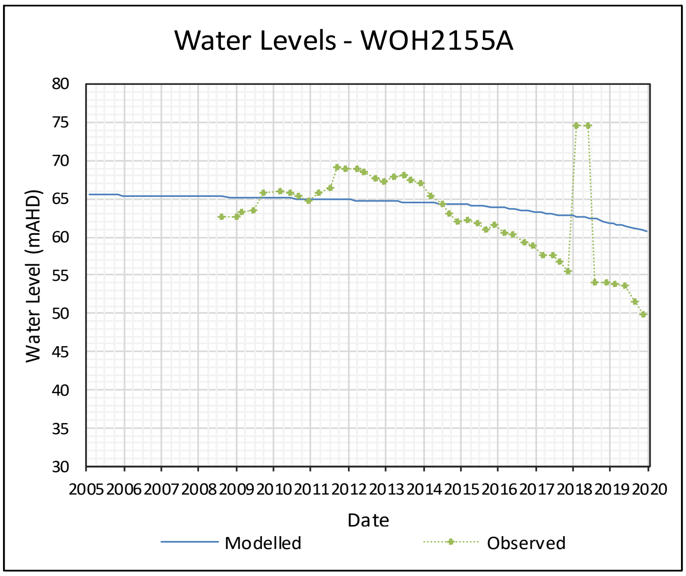
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Water Level (mAHD)
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30
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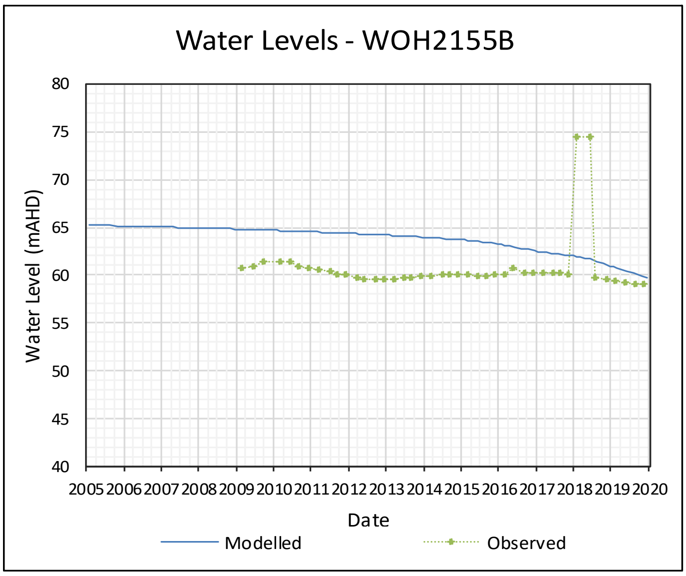
Modelled
Observed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Water Level (mAHD)
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40
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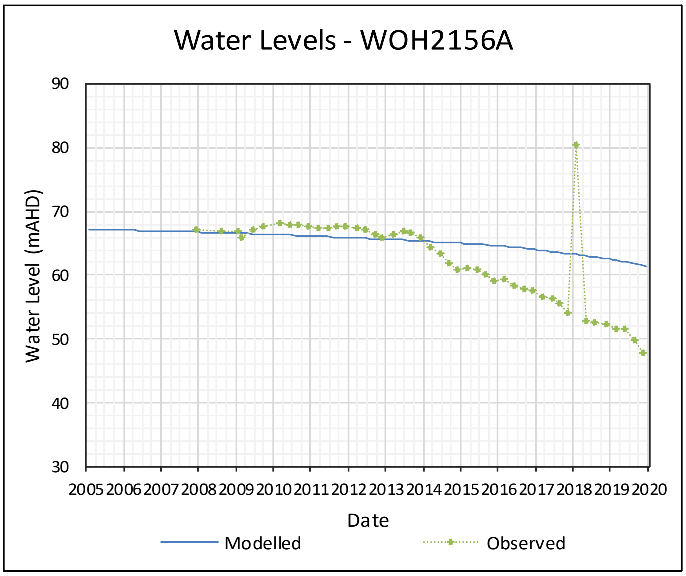
Date
Modelled
Observed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Water Level (mAHD)
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60
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40
30
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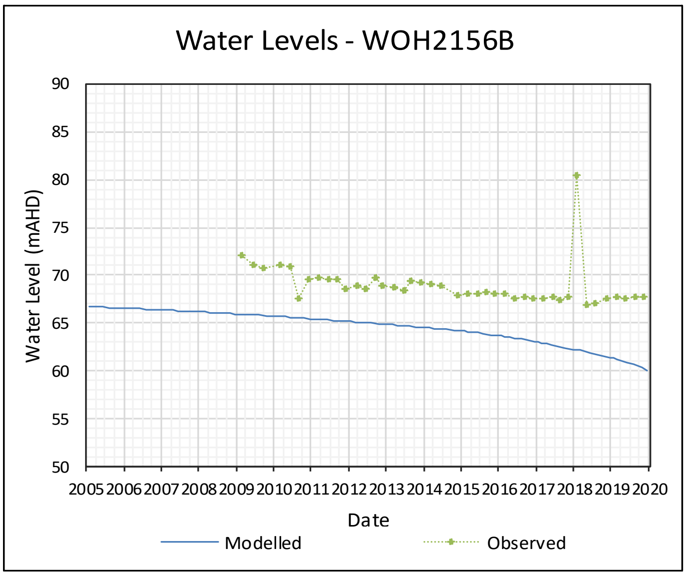
Date
Modelled
Observed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Water Level (mAHD)
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85
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75
70
65
60
55
50
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Date
Modelled
Observed

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Appendix 5:

Rehabilitation Monitoring Report

Mount Thorley Warkworth Rehabilitation Monitoring Report 2019

Prepared for Yancoal by Cumberland Plain Seeds

Document control		Cumberland Plain Seeds
Project Client	Yancoal Australia	Ecological restoration and consulting services
Document description	Report of findings of native vegetation monitoring conducted at Mount Thorley Warkworth and reference sites as part of the annual rehabilitation monitoring program	PO Box 201 Glenbrook 2773 NSW Email: tim@cpseeds.com.au
Project Manager	Tim Berryman	For further information or permissions relating to this report please contact John Moen via:
Authors	Brenden Field and John Moen	email: john@cpseeds.com.au
Internal review	Tim Berryman, Neridah Davies	Phone: 0447316933
Mapping	Supplied by Cambium Group	
Final draft released	14 October 2019	

Cover photograph: John Moen - Native vegetation establishing at Mount Thorley Operation rehabilitation site.

Contents

1 Introduction

Cumberland Plain Seeds (CPS) was engaged by Yancoal Australia Limited (Yancoal) to conduct monitoring of native vegetation on rehabilitated land at the Mount Thorley Warkworth Mine (MTW). The MTW mine is located in the Hunter Valley of NSW, approximately 10km South West of Singleton. CPS conducted the third round of vegetation monitoring in the MTW monitoring program. The first two rounds were undertaken by Niche Environment and Heritage Pty Ltd (Niche) in 2016 and 2017 for Coal and Allied as part of the combined MTW and Hunter Valley Operations rehabilitation monitoring program.

Due to an overlap with a project run through the Australian Coal Industry Research Program (ACARP Project C27038) the reference sites and selected rehabilitated sites were surveyed by Umwelt Australia. Further details of this project are included in the Appendices.

Umwelt personnel were:

- Travis Peake - Project Director
- Trish Robinson - Senior Ecologist
- Belinda Howe - Ecologist

Monitoring was repeated for sites surveyed in the 2016 and 2017 program and also includes several new sites. A total of 12 reference sites and 42 rehabilitation sites were surveyed and the results are presented in the following report.

The aim of the monitoring program is to record data which can be reported against a series of criteria specified in the Mining Operations Plan (MOP). Some extra measurements, not required by the MOP, were recorded to assist in management decisions.

The following tasks were completed at each of the monitoring sites:

- Establish permanent monitoring transects in new sites, sampled for the first time in 2019
- Complete Landscape Function Analysis (LFA) at all sites
- Floristic and vegetation quality monitoring based on Biobanking Assessment Methodology (BBAM).
- Visual monitoring at all monitoring sites.
- Photographic monitoring for all sites.
- Soil sampling for agricultural analysis at all sites.
- Soil sampling for microbial analysis at selected sites.
- Canopy development, stem density and overstorey regeneration assessments for all sites.

Following field data collection the rehabilitation site results were compared with those from reference sites or the relevant MOP criterion. The rehabilitation sites varied considerably in condition and some discussion of the significance of the monitoring results for each site has been included, along with implications for further management action.

2 Monitoring sites

2.1 Rehabilitation sites

Monitoring was conducted at 18 sites previously surveyed in the 2016 and 2017 monitoring rounds, except for MTWNPN201402, which was not sampled because the monitoring transect had been disturbed. Transects were established on an additional 24 sites. New transect locations were selected as randomly as possible. Transects were located away from the edges of the rehab site (minimum 20m) to avoid edge effects as far as possible. The transects were set up running downslope, as this is required by the LFA methodology, and this transect is also used for the BioBanking transect and quadrat. Site names and transect locations are provided in Appendix 8.3.

The MTW rehabilitation sites are spread across several areas within the mine and individual sites have been grouped together in this report accordingly. The rehabilitation areas are:

Rehabilitation area	Site name prefix
North Pit North	MTWNPN
CD Dump	MTWCDD
Tailings Dam 1	MTWTD1
South Pit North	MTWSPN
South Pit South	MTWSPS
Woodlands	MTWWDL
Mount Thorley Operations	MTWMTO

Table 1

For clarity the "MTW" has been removed from the site name prefix in graphs and tables below.

2.2 Reference (Analogue) sites

The MOP specifies that the target ecological community for rehabilitation sites at MTW to be Central Hunter Grey-Box Ironbark Woodland (Endangered Ecological Community). Reference sites were established in 2016 in two Biometric Vegetation Types (BVTs) which were chosen based on vegetation types cleared from the MTW site. These communities are:

- Central Hunter Grey Box - Ironbark Woodland
- Central Hunter Ironbark - Spotted Gum – Grey Box Forest

Niche 2018 lists these as Biometric Vegetation Types HU701 and HU632 respectively but the MOP lists Central Hunter Grey Box - Ironbark Woodland as HU817 and Central Hunter Ironbark - Spotted Gum – Grey Box Forest would appear to fit more closely to HU818. The OEH benchmark values for HU817 and HU818 are used for comparison with reference site benchmarks in this report.

The reference sites are located on four separate blocks of land through the central Hunter Valley, two managed by Yancoal, one managed by Wambo Coal Mine and one at Belford National Park, west of Branxton. Site names and transect locations are provided in the Appendix 8.2.

2.3 Reference site Benchmark and OEH Benchmark Values

Benchmark values were calculated from the reference site Biobanking data. The calculated benchmark values were also compared to the OEH published benchmarks to assess the relative quality of the reference site-derived benchmarks. These benchmarks are derived from surveys of high quality undisturbed (or nearly undisturbed) native vegetation communities. Although AECOM (2016) considered it inappropriate to refer to undisturbed vegetation when setting reference values for rehabilitation the Society for Ecological Restoration refer specifically to the use of combined data when setting reference values "*These sources may include multiple extant reference sites, field indicators, historical records (including human use) and predictive data*". (McDonald et. al. 2016).

Table 2 Biobanking reference site and benchmark values

	Reference site average values								Benchmark values			
	Central Hunter Ironbark-Spotted Gum - Grey Box Forest 2019		Central Hunter Grey Box Ironbark Woodland 2019		Combined values for reference sites 2019		Combined values for reference sites Niche 2018		Narrow-leaved Ironbark - Bull Oak - Grey Box shrub - grass open forest of the central and lower Hunter - HU817		Narrow-leaved Ironbark - Grey Box - Spotted Gum shrub - grass woodland of the central and lower Hunter - HU818	
BioBanking measure	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	upper	Lower	upper
Native plant species		44		44		44		27		41		41
Native overstorey cover	13.7	32.8	6.3	25	9.2	30.8	13.3	22.8	15	40	15	40
Native mid storey cover	0.3	10.9	1.8	6.6	0.6	7.9	0	10	5	20	5	20
Native ground cover grasses	16	23	6	32	8.6	23.8	18	33	30	50	30	50
Native ground cover shrubs	0	2	0	1	0	2	1	11	5	10	5	10
Native ground cover other	6	24	5	19	6	19.8	3	26	20	40	20	40
Exotic plant cover		<1		<1		<1	0	0	0	0	0	0
Number of trees with hollows	0	0	0	0	0	0	>1			3		3
Length of Fallen Logs		10		17		11	>21			5		5

The data for reference sites (2017 and 2019) and OEH benchmarks are comparable for most scores. The reference site ranges have been expanded in some categories although for most measures the reference sites do not meet the OEH benchmarks. This is not surprising because the reference sites are located in vegetation recovering from past disturbance. The notable exceptions are that the reference site average for species richness and fallen log length exceed that of the benchmarks.

3 Methods

3.1 Monitoring dates and team members

Monitoring Field work was undertaken between 3rd March and 5th May 2019. Field data was collected by Neridah Davies, Brenden Field and John Moen. Reference sites and selected rehabilitation sites were surveyed by Trish Robinson and Belinda Howe of Umwelt Australia.

3.2 Monitoring methodology design

The MTW rehabilitation program follows the AECOM 2012 *Monitoring Methodology – Post-mined Lands MTW and HVO North Mine Sites*. In brief the methodology derived by AECOM uses Landscape Function Analysis (LFA) and the BioBanking Assessment Method (BBAM), soil analysis and visual monitoring. LFA is used to measure the soil stability of a site and the levels of water infiltration and nutrient cycling. The BBAM is used to assess the biodiversity values of a given patch of vegetation.

Niche followed this methodology in 2016 and 2017 with some amendments including:

- Replacing the 1x1 m pasture/groundcover monitoring with a BioBanking plot (20x50m including a nested 20x20m plot).
- Addition of stem density counts to assist in vegetation management decisions (not a MOP criterion).
- Addition of tree tagging: canopy trees with a trunk diameter at breast height (DBH) of more than 5cm were tagged, numbered and DBH recorded.

  Note: for the purposes of stem density counts and canopy development assessment Niche counted the following species:

  - *Acacia implexa*
  - *Acacia salicina*
  - *Allocasuarina leuhmannii*
  - *Corymbia maculata*
  - All endemic *Eucalyptus* species

CPS continued the amended methodology used by Niche. Sampling techniques are described in further detail below.

3.2.1 Landscape Function Analysis (LFA)

LFA is a monitoring procedure developed by the CSIRO as a method for assessing rangelands and later extended for use on mine sites (Tongway and Hindley, 1997, revised 2004). It is designed to measure the soil surface properties of a slope within a landscape and thereby assess how well that landscape is working in a biophysical sense and whether a recovering landscape, such as a rehabilitated mine site, is improving or declining in function. In essence, a functioning landscape should trap and retain resources such as water, soil, seed and organic matter. A dysfunctional landscape will tend to lose these resources over time.

LFA provides a series of scores or indices which must be compared to each other over time and to values obtained from surveying reference sites. The LFA scores should not be used in isolation but as a complement to biodiversity assessment. The scores derived from an LFA survey are landscape organisation, soil stability, soil infiltration and nutrient cycling. Landscape organisation is derived by measuring *patches,* which trap resources within a landscape and *interpatches,* which lose resources. The landscape organisation index (LOI) is a measure of the proportion of patch size to the total transect length. The other three indices are derived by assessing eleven indicators in a soil surface assessment (SSA).

These indicators are listed in the following table (after Tongway and Hindley 2004):

Table 3 LFA Soil surface indicators and related processes

Soil surface indicator	Process
Soil cover	Rain splash erosion, crust formation
Basal cover of perennial plants	Below ground biological activity (root volume)
Litter cover, origin and degree of composition	Decomposition and nutrient cycling of surface organic matter
Soil biological crust cover (Cryptogams forming a protective crust)	Surface stability, resistance to erosion and nutrient availability
Crust brokenness	Wind ablation or water erosion
Erosion type and severity	Nature and severity of current soil erosion features
Deposited materials	Upslope soil stability (any deposited material has been eroded from upslope)
Surface roughness	Water infiltration, flow disruption, seed capture
Surface resistance to disturbance	Susceptibility to mechanical disturbance
Slake test	Soil stability/dispersiveness when wet
Soil texture	Infiltration rate and water storage potential

The values recorded for patch organisation and soil surface assessment are entered into a spreadsheet which calculates the four indices. The results from these assessments are presented as graphs in the results section.

Although the value of LFA as a tool for assessing mine site stability is questioned by some (Erskine et. Al. 2015), the criticisms are addressed by the number of transects used at MTW and the comparison of LFA data over time. The rehabilitation sites at MTW are usually relatively small (often less than 10 Ha) and quite uniform in slope, soil type and vegetation condition. It may be useful to include additional monitoring transects on sites larger than 10 Ha or where there are obvious changes in soil type or vegetation cover. This would improve the overall quality of the LFA data and allow for better identification of problems with landscape function.

3.2.1.1 LFA transect

The LFA transect is set up running perpendicularly down slope. At MTW 50m transects were used. The transect was broken up into patch zones and interpatch zones by observing patterns of vegetation and other obstructions and potential water flow paths. Once patches had been identified five soil surface assessments were conducted for each patch and interpatch type. In some cases it was not possible to conduct five replicates due to small or infrequent patch types. More details on LFA sampling techniques are available in the LFA Field Procedures (Tongway and Hindley, 2004).

3.2.1.2 Rill surveys

Where rills were observed at less than 30m spacings across the slope a rill survey was conducted as defined in the LFA methodology (Tongway and Hindley 2004). Rills were observed and surveyed at WDL201801 and NPN201602.

3.2.2 Biobanking and site value scores

The NSW BioBanking scheme was set up as a way of trading biodiversity credits in order to offset impacts on biodiversity from developments such as mining. The BioBanking Assessment Methodology is used to generate a site value score which can then be converted into an offset credit. The methodology measures several vegetation attributes: species richness and native plant cover in the canopy (over-storey), mid-storey and ground layer, the number of hollow-bearing trees, length of fallen timber and the quality of regeneration in the overstorey.

The values recorded for each of the site attributes are combined to calculate a site value score. This approach was suggested in AECOM (2021) but Niche considered it more useful to present each of the site attributes directly. CPS has continued this approach so as to more easily compare results with the MOP performance criteria.

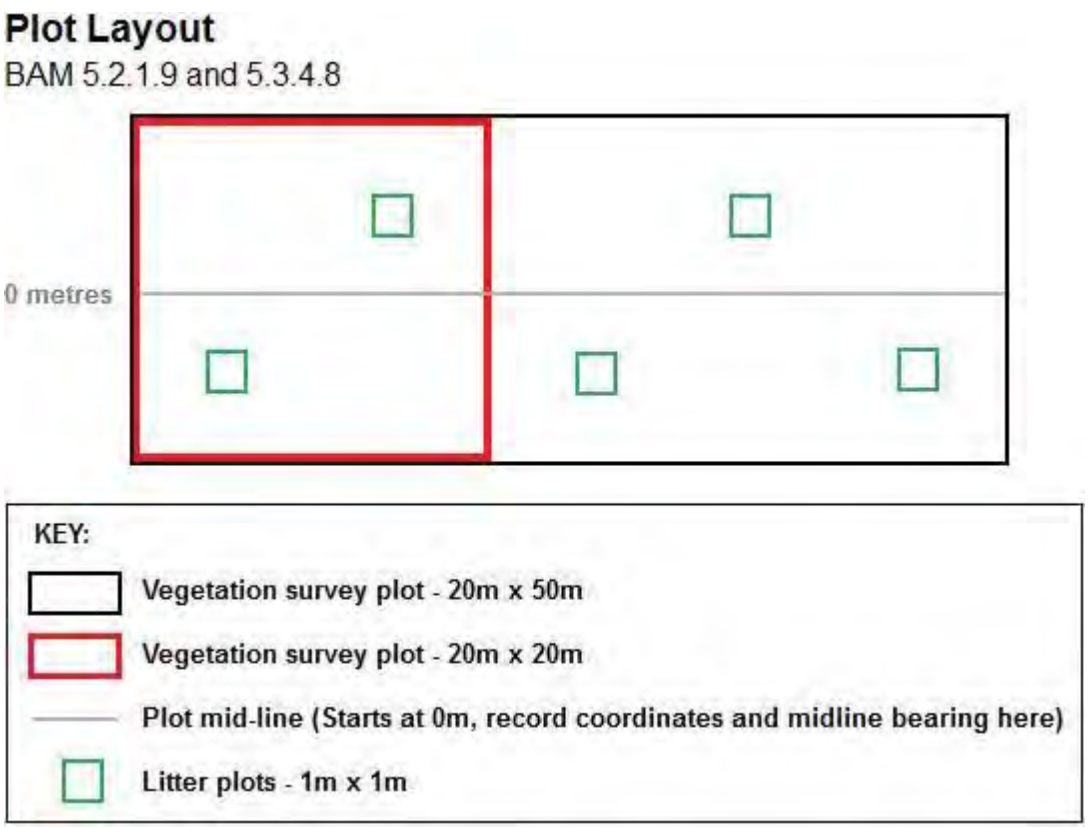


Figure 1 Biobanking survey transect and plot layout, OEH 2018. Note: 1x1m litter plots were not sampled

Table 4 Biobanking Attributes

Attribute	Abbreviation	Sampling method
Native plant species richness	NPS	Record number of species in each vegetation layer within a 20 x 20 m quadrat nested within the 50 x 20m quadrat.
Native overstorey % cover	NOS	Record % cover at 5m intervals along the 50m transect, then derive average for transect
Native mid-storey % cover	NMS	Record % cover at 5m intervals along the 50m transect, then derive average for transect
Native ground layer % cover (grasses)	NGCG	Record presence or absence at 1m intervals on along the 50m transect, then multiply total hits by 2 to calculate % cover
Native ground layer % cover (shrubs)	NGCS	Record presence or absence at 1m intervals on along the 50m transect, then multiply total hits by 2 to calculate % cover

Native ground layer % cover (other species)	NGCO	Record presence or absence at 1m intervals on along the 50m transect, then multiply total hits by 2 to calculate % cover
Exotic plant % cover	EPC	Record presence or absence at 1m intervals on along the 50m transect, then multiply total hits by 2 to calculate % cover
Overstorey regeneration	OR	Total number of tree species in the overstorey is divide by the number of species with a diameter at breast height (DBH) of >5cm. Maximum value for this score is 1. E.g. 2 species >5cm DBH / 5 species total = 0.4
Total length of fallen logs (m)	FL	Within the 20 x 50m quadrat any fallen timber >10cm diameter and >0.5m long was measured and the total length of all logs recorded.
Number of trees with hollows	NTH	Count the number of trees with hollows within the 20 x 50m quadrat.

Note: Native species growth form classes follows the list associated with the OEH Biodiversity Assessment Calculator (Office of Environment and Heritage, 2019). This list is included in Appendix 8.8.

3.2.3 Canopy Development and over-storey regeneration

The BioBanking methodology is not ideally suited to the mine rehabilitation context because it is designed to compare natural vegetation which are either mature or in an advanced state of recovery from past disturbance. To assist in better understanding the early stages of the mine site revegetation process and identify success or potential problems early two measurements were added to the monitoring program by Niche:

1. Stem density count for canopy species. Any individual of a canopy species was counted in a 2m to the left and 2m to the right of the central transect. The values were used to calculate a stem density per hectare. Where juvenile plants could not be identified to species level they were identified to genus.
2. Canopy development data were also collected from the 20 x 20m quadrat:
    a. Average trunk diameter, measured for tree species with a DBH >5cm. These trees were tagged with metal tree tags for future identification.
    b. Percentage of the canopy layer flowering or fruiting
    c. General condition of the tree population

Many of the sites surveyed in 2019 are in the early stages of revegetation and tree and shrub species were often too small to be recorded in the mid or over storey layers. In these cases some information about potential canopy establishment can be inferred from the stem density counts.

3.2.4 Visual Monitoring

3.2.4.1 Species composition and vegetation health

Dominant or sub-dominant plant species were recorded for each site. This observation is important to quickly understand the succession stage of the vegetation and quickly identify potential weed problems. Where observed, notes were made on species fruiting or flowering and whether there was evidence of second-generation recruitment of native plants.

3.2.4.2 Habitat and fauna monitoring

Observations were made on habitat features such as dams, habitat ponds, availability of large rocks and woody debris and stag trees.

3.2.4.3 Disturbance

Evidence of factors which can affect the success or quality of the rehabilitation were recorded:

- Evidence of disturbance from vehicles such as tracks or excavation
- Mine rubbish
- Maintenance activities – herbicide application, slashing, fencing
- Exotic weeds
- Feral animals
- Fire
- Erosion

3.2.5 Photographic monitoring

Photographs were taken at the beginning and end of each monitoring transect. Three photographs were taken at the start point and three at the end point facing into the quadrat: 45° left, centred on the transect and 45° right.

3.2.6 Soil Analysis

3.2.6.1 Agricultural/Chemical analysis and microbial analysis

A composite soil sample was collected from each monitoring quadrat. Samples were composed of a minimum of nine sub-samples collected from within a 20m radius of the 15m point on the central transect. Sub-samples were mixed in a bucket, then bagged, labelled and stored at 5° C until sent to Environmental Analysis Laboratory (EAL).

For selected sites a second sample was taken in the same way, though stored at -15° C until sent to Sydney Environmental and Soil Laboratory (SESL) for microbial analysis.

3.2.7 Weather

Weather records for the periods were obtained from the Bureau of Meteorology for the Singleton Army Base weather station and are presented in the appendix. The field data collection period took place just after significant autumn rain and so there was generally good plant growth at many sites. However the prevailing weather conditions of 2017-2019 have been drier than average, warmer than average and with often very windy conditions.

3.3 Limitations

The field data collection was carried out at a single point in the year. This means that some plant species were at a point in their life cycle where they were not observable. This was almost

certainly the case for many annual species. Other species were not identifiable to species because correct identification often relies on observing flowers or fruit which were absent at the time of survey.

As described in Niche 2018 the reference sites were located in remnants of Biometric Vegetation Types appropriate to the target vegetation of the MTW rehabilitation program. However, these sites are themselves in a state of recovery from past disturbances such as clearing, grazing and earthworks. As such the reference communities themselves lack some of the characteristics of old growth vegetation. For example, fallen timber and numbers of trees with hollows were much lower for reference sites than the OEH benchmark values for the target vegetation types. Canopy species stem counts were also very high when compared to stem densities in more mature vegetation (Kerle, 2005). This should be taken into consideration when comparing the rehabilitation monitoring results with reference site values and when making management decisions.

The BioBanking Assessment Methodology is designed for use in mature vegetation and as such is not ideally suited to monitoring vegetation in the early stages of establishment. In particular the methodology does not record individual species abundance or cover. This means that a particular site with high species richness may appear to be performing well in the early stages but species richness may decline over time if the abundance of a given species is too low. It would be useful to better understand the abundance of plant species on the mine sites so that potential problems could be identified before diversity declines.

3.4 Performance criteria

The Mining Operations Plan (MOP) 2019 provides performance criteria which are used to assess the success of rehabilitation efforts on the mine. Following the establishment of the final landform the revegetation is assessed at several stages: Growing Media Development, Ecosystem and Landuse Establishment and Ecosystem and Landuse Sustainability. Various criteria are to be measured in order for a given site to pass from one phase to the next. The performance criteria for each phase are given below, as specified in the MOP.

There are three target domain types for rehabilitated native vegetation at MTW: Grassland, Woodland – Endangered Ecological Community (EEC) and Woodland – Other. All rehabilitation sites were assessed against the MOP criteria for the Woodland – EEC domain. The Performance criteria for each rehabilitation stage are reproduced in the following tables.

3.5 Growth medium development

Table 5 Growth medium development performance criteria

Criterion	Performance measure	Measurement method
pH	>5.5 and <8.5	Soil analysis
Electrical Conductivity (EC)	<2dS/m	Soil analysis
Soil Phosphorous	Within analogue site values by year 5	Soil analysis
Organic Carbon %	Within analogue site values by year 5	Soil analysis
Cation Exchange Capacity (CEC)	Within analogue site values by year 2	Soil analysis
Exchangeable Sodium Percentage (ESP)	Within analogue site values by year 2	Soil analysis
Calcium : Magnesium ratio	Within analogue site values by year 2	Soil analysis

3.6 Ecosystem and Landuse Establishment – Woodland EEC

Table 6 Ecosystem and Landuse Establishment Performance criteria

Criterion	Performance measure	Measurement method
Tree species	1-4 species within a 20 x 20m quadrat	Flora survey
Shrub species	4-9 species within a 20 x 20m quadrat	Flora survey
Grass species	4-9 species within a 20 x 20m quadrat	Flora survey
Subshrub and understorey species other than grasses	10-20 species within a 20 x 20m quadrat	Flora survey
Native plant species richness	13-41 species within a 20 x 20m quadrat	Flora survey
Tree density	250-3,150 stems/Ha	Stem density survey
LFA Landscape Organisation	Trending towards or exceeding reference site values 0.84-1	LFA
LFA Stability Index	Trending towards or exceeding reference site values 53.9-81.8%	LFA
LFA Infiltration Index	Trending towards or exceeding reference site values 48.4-73.9%	LFA
LFA Nutrient Cycling index	Trending towards or exceeding reference site values 38.5-79.8%	LFA

3.7 Ecosystem and Landuse Sustainability – Woodland EEC

Table 7 Ecosystem and Landuse Sustainabiliy Performance Criteria

Criterion	Performance measure	Measurement method
Native over-storey	15-50% cover	BioBanking Assessment Methodology
Native mid-storey	5-60% cover	BioBanking Assessment Methodology
Native ground cover (grasses)	5-50 % cover	BioBanking Assessment Methodology
Native ground cover (shrubs)	5-10% cover	BioBanking Assessment Methodology
Native ground cover (other species)	5-40 % cover	BioBanking Assessment Methodology
Exotic Plant cover	5-33% or less than reference site range	BioBanking Assessment Methodology
Total groundcover	32-74%	BioBanking Assessment Methodology
Native understorey species richness / m^2 (across the site)	16-27 species in a 20m x 20m quadrat	Flora survey
Diversity of maturing trees	1-4 species in a 20m x 20m quadrat	Flora survey
Percentage of maturing trees and shrubs that are local endemic species	90-100%	Canopy development survey
Density of maturing trees (DBH>5cm)	50-725 stems/Ha	Canopy development survey
Average trunk diameter trending towards analogue sites	10.8-65cm	Canopy development survey
Percentage of tree population in a healthy condition, medium health and in advanced dieback	To be determined but comparable to analogue sites	Canopy development survey
Presence of reproductive structures	To be determined but comparable to analogue sites	Canopy development survey
Overstorey Species regeneration (OR)	0.5 to 1.0	Canopy development survey
Length of fallen logs	⩾ 3m in a 20m x 20m quadrat	BioBanking Assessment Methodology
Number of hollows/nesting sites	0.5 in a 20m x 20m quadrat	BioBanking Assessment Methodology

4 Results

4.1 Growth medium development

4.1.1 Soil Analysis

Complete soil analyses conducted by Southern Cross University's EAL laboratories are contained within the appendices, while values relevant to the MOP performance criteria are displayed in the following tables. Summary statistics between reference and rehabilitation site soil chemistry parameters are displayed in table 9. Attributes diverging most from reference sites values included: pH, Electrical Conductivity (EC), phosphorus and Exchangeable Sodium Percentage (ESP), with many site's phosphorus and EC values 10-fold that of reference site mean values. A trend of rehabilitation sites with higher pH values is exhibited, with all site pH values greater than those found for reference sites. The highest sites (CDD201501, MTO201703, MTO201803, NPN201702, TD1201501) were found to be between 2-3 pH units above the reference mean (5.68).

Table 9: Summary statistics for 2019 soil chemistry results.

	pH (units)	Electrical Conductivity (dS/m)	Phosphorous (Colwell - ppm)	Organic Carbon (% OM)	Cation Exchange Capacity (cmol+/kg)	Exchangble Sodium (%) (ESP)	Ca:Mg ratio
MTW 2019 Sites							
Mean	7.24	0.469	84.2	6.5	17.28	9.8	2.4
Max	8.62	1.863	422.8	18.6	29.86	39.4	11.1
Min	6.22	0.066	6.6	2.8	9.45	1.0	0.8
Reference Sites							
Mean	5.68	0.089	8.6	6.1	10.11	3.9	1.6
Max	6.20	0.152	15.1	8.7	17.43	7.6	3.2
Min	5.39	0.049	4.3	3.9	4.71	1.0	0.7

Reference sites

Reference site soil chemistry values are displayed in table 10. The pH values are consistent (mean 5.68) with only one site exceeding a pH of 6. High variability is evident between other parameters, even amongst site's results with a common soil texture. Of note is the high variability in phosphorus concentrations detected. Only parameters referred to by the MOP are displayed in the following tables to assist in interpretation of results.

Table 10: Reference site soil chemistry results (2019).

MTW (2019)	pH (units)	Electrical Conductivity (dS/m)	Phosphorous (Colwell - ppm)	Organic Carbon (% OM)	Cation Exchange Capacity (cmol+/kg)	Exchangable Sodium (%) (ESP)	Ca:Mg ratio
BEL01	5.39	0.082	6.2	8.7	8.94	5.0	0.7
BEL02	5.85	0.049	5.2	4.7	8.67	1.7	3.2
BEL03	5.59	0.089	4.9	7.5	10.08	5.2	1.1
WAMBOGB01	5.52	0.121	15.1	6.3	12.91	5.5	0.9
WAMBOGB02	5.98	0.152	13.0	5.3	16.13	4.2	1.2
WAMBOSPOT01	5.76	0.063	4.3	5.3	6.91	1.0	2.1
WAMBOSPOT02	6.20	0.083	10.2	7.5	17.43	1.8	2.3
WAMBOSPOT03	5.68	0.071	7.2	4.6	6.34	4.0	1.4
WARKGB01	5.66	0.087	8.2	7.9	12.27	2.8	2.3
WARKGB02	5.54	0.062	9.2	5.1	6.72	2.4	2.1
WARKGB03	5.57	0.065	4.9	3.9	4.71	5.5	1.3
WARKGB04	5.45	0.150	14.8	6.4	10.19	7.6	0.8
Mean	5.68	0.089	8.6	6.1	10.11	3.9	1.6
Maximum	6.20	0.152	15.1	8.7	17.43	7.6	3.2
Minimum	5.39	0.049	4.3	3.9	4.71	1.0	0.7
MOP Target Range	5.5 - 8.5	<2	1.2 - 13	1.6 - 8.7	7.4 - 20.4	0.2 - 8.7	0.7 - 2.1

Rehabilitation sites

Values obtained from this monitoring program are displayed in table 11, with reference to whether values fall within criteria set out in the current MOP. Performance criteria is also set out in table 11 for soil chemistry. Most criteria are determined by reference site values within a 2-5-year period.

Sites NPN200501, NPN200502 had soil sampling undertaken only, and these results are included in table 11.

Table 11: Rehabilitation site soil chemistry results (2019).

MTW (2019)	pH (units)	Electrical Conductivity (dS/m)	Phosphorous (Colwell - ppm)	Organic Carbon (% OM)	Cation Exchange Capacity (cmol+/kg)	Exchangeable Sodium (%) (ESP)	Ca/Mg ratio
CDD201101	6.34	0.112	6.6	5.3	11.90	7.3	0.8
CDD201301	7.48	0.326	82.7	6.5	17.53	7.9	2.8
CDD201401	7.14	0.103	69.5	6.5	14.84	1.8	1.8
CDD201501	8.09	0.091	42.6	4.9	11.46	2.7	1.6
CDD201701	6.52	0.855	11.5	2.8	12.10	13.5	1.4
CDD201702	6.86	0.384	70.2	4.4	12.46	7.4	2.2
CDD201801	6.55	0.829	76.1	6.3	18.23	14.0	2.2
MTO201601	7.72	1.183	88.2	5.0	21.77	17.8	2.1
MTO201701	7.80	1.037	264.0	16.2	27.58	24.8	9.5
MTO201702	7.55	0.395	181.1	9.9	21.62	10.6	4.4
MTO201703	8.29	0.366	39.4	4.7	16.76	10.6	1.9
MTO201704	6.86	0.486	50.5	3.5	14.54	10.5	1.9
MTO201801	6.34	0.222	15.7	3.8	11.96	6.6	1.5
MTO201802	7.54	1.251	80.7	9.7	25.57	7.6	3.5
MTO201803	8.11	0.512	422.8	18.6	27.53	19.6	11.1
NPN200501	6.30	0.159	15.1	5.5	12.17	3.3	1.0
NPN200502	6.22	0.125	7.2	5.4	11.86	2.6	0.8
NPN200901	6.31	0.104	10.8	5.1	14.28	2.8	1.2
NPN201101	7.25	0.099	7.5	4.5	14.62	1.0	1.4
NPN201301	6.54	0.379	28.5	3.6	11.31	7.3	2.4
NPN201401	6.69	0.066	30.8	3.9	12.02	2.3	1.6
NPN201601	7.36	1.863	74.5	5.7	24.74	19.0	1.4
NPN201602	6.76	0.704	42.6	4.8	22.85	16.8	0.8
NPN201701	6.98	0.338	94.8	5.7	17.84	6.1	1.7
NPN201702	8.08	0.692	16.4	2.9	17.00	23.9	1.1
NPN201703	7.37	0.941	102.3	5.1	23.64	13.3	1.5
NPN201801	7.42	0.245	147.9	6.2	15.53	6.4	4.5
NPN201802	6.78	0.272	45.3	3.9	9.45	6.8	2.5
NPN201803	7.64	1.234	275.5	15.7	29.86	17.0	3.6
SPN201401	7.64	0.111	56.7	5.5	14.59	4.7	2.0
SPN201501	7.43	0.245	237.1	10.6	21.13	1.7	4.3
SPN201601	6.79	0.234	85.3	7.0	18.39	3.8	3.0
SPN201602	6.89	0.177	75.1	5.1	15.11	8.7	1.9
SPN201701	7.16	0.321	119.0	4.8	15.51	11.1	2.2
SPS201601	7.46	0.188	44.3	8.4	18.40	4.2	1.7
SPS201602	7.15	0.450	46.6	4.7	20.36	5.8	2.0
SPS201701	7.37	0.236	65.9	4.3	15.03	6.3	2.8
SPS201703	7.97	0.817	42.0	5.2	17.65	22.1	1.3
SPS201801	7.62	0.760	144.3	10.2	23.48	11.6	2.7
TD1201501	8.62	0.909	18.4	10.0	20.19	39.4	0.9
WDL201401	7.13	0.126	31.5	6.5	14.88	8.6	0.9
WDL201402	7.78	0.128	23.6	5.5	13.68	6.4	1.1
WDL201801	7.57	0.576	312.9	11.8	28.90	7.3	3.7
Reference (Mean)	5.68	0.089	8.6	6.1	10.11	3.9	1.6
Reference (Max)	6.20	0.152	15.1	8.7	17.43	7.6	3.2
Reference (Min)	5.39	0.049	4.3	3.9	4.71	1.0	0.7
MTW Sites (Mean)	7.24	0.469	84.2	6.5	17.28	9.8	2.4
MTW Sites (Max)	8.62	1.863	422.8	18.6	29.86	39.4	11.1
MTW Sites (Min)	6.22	0.066	6.6	2.8	9.45	1.0	0.8
MOP Target Range	5.5 - 8.5	<2	1.2 - 13	1.6 - 8.7	7.4 - 20.4	0.2 - 8.7	0.7 - 2.1

Legend	
Outside MOP criterion	(brown)
Within MOP criterion	(green)

4.2 Soil microbial analysis

Both reference and rehabilitation sites presented as adequate in bacterial diversity, in terms of certain broader classification groups, including: *Pseudomonas, Actinomycetes* and gram-positive bacteria. Being the case, their abundance was not presented in the following tables for visual clarity. Although microbe composition appeared similar, rehabilitation site results surpassed many reference indices of microbial health (table 12). In should be noted that some of the reference sites such as the BEL sites are regenerating from previous thinning from forestry activity (NPWS, 2010). Specific associations appear to be congruent for reference and rehabilitation sites, with low diversity and greater abundance of bacteria groups versus fungi. The main exceptions in similarity are Protozoa and Vesicular-Arbuscular Mycorrhiza (VAM) levels.

Table 12: Summary statistics for microbial condition, including reference and rehabilitation sites (2019).

MTW 2019 Sites	Nutrient solubilisation rate	Nutrient cycling rate	Disease resistance	Drought resistance	Nutrient accessibility (VAM)	Residue breakdown rate	Overall microbial balance	Total Microbes	Microbial diversity	Protozoa	Mycorrhizal fungi	Gram negative
Mean	84.7	78.7	84.5	85.3	71.1	90.2	78.9	65.3	38.4	2.661	8.488	5.302
Max	100.0	90.5	100.0	100.0	100.0	100.0	89.5	98.7	48.3	5.794	18.611	6.831
Min	66.7	44	62	72.1	44.1	60	57.7	32.4	33.5	0.298	4.414	3.338
Reference Sites												
Mean	62.4	79.8	75.0	66.0	32.1	95.7	75.9	54.9	37.3	1.148	3.207	6.576
Max	77.2	92.9	84.8	77.2	54.4	100.0	84.2	80.8	45.9	3.950	5.441	9.015
Min	36.1	57	57.4	56.5	13	79.6	57.3	31	32.4	0.391	1.305	4.237

Reference site soil microbial results

Table 13 contains the results for microbial analysis of the reference site samples. Lack of diversity in some microbe populations of those sampled sites presents in the form of less than expected presence of protozoa, mycorrhizal fungi, gram-negative bacteria, and in considered aerated conditions, diminished methane oxidising bacteria. WamboSpot3 also deviates from the other site results, with alternative anaerobic bacteria presenting in numbers greater than expected, (True anaerobes). Microbial attributes for overall function for the reference sites mostly appear as expected for a typical natural state. Expected values for ideal conditions, including general microbial community health, were provided by Microbiology Labs Australia, and are referred to in table 13.Those results observed below 30% of these designated values or considered exceeding normal condition for anaerobic conditions are highlighted below.

Table 13: Reference site results for microbial soil condition. [1] Aggregated result. * Only values exceeding deemed common concentrations are displayed.

MTW (2019)	Nutrient solubilisation rate	Nutrient cycling rate	Disease resistance	Drought resistance	Nutrient accessibility (VAM)	Residue breakdown rate	Overall microbial balance	Total Microbes	Microbial diversity	Protozoa	Mycorrhizal fungi	Gram negative	Methane oxidisers*	Sulphur reducers*	True anaerobes*
BEL01	68.2	86.2	78.8	68.2	36.4	100	80.2	80.8	32.4	0.84	3.638	8.816	0	0	0.645
BEL02[1]	70.3	80.1	80.2	70.3	40.6	100	78.3	56.4	38.7	0.837	4.057	6.151	0	0	0.649
BEL03[1]	69	91.9	79.4	69	38.1	100	83.2	63	34.8	1.669	3.807	7.438	0	0	0.269
WAMBOGB01	54.6	72.2	69.8	62.3	24.7	100	72.2	50.8	41.2	0.449	2.465	5.979	0	0	0.650
WAMBOGB2	76.1	77.6	84	76.1	52.1	99.7	80	51.8	45.9	0.65	5.213	6.7001	0	0	0.725
WAMBOSPOT1	60.7	67	73.8	60.7	21.5	88.9	69.3	40.3	35.6	0.489	2.146	5.79	0	0	0.357
WAMBOSPOT2	77.2	87.7	84.8	77.2	54.4	100	84.2	70.4	41.8	0.897	5.441	9.015	0	0	0.785
WAMBOSPOT3	54.6	85.1	69.8	59.5	19	95.4	75.6	45.2	33.9	1.356	1.902	5.469	0	0	0.339
WARKGB01	69.5	92.9	79.7	69.5	39	100	84.2	71.7	38.1	3.95	3.896	7.873	0	0	0.705
WARKGB02	65.5	82.9	77	65.5	31	100	78.5	61.6	35.5	0.872	3.098	7.093	0	0	0.459
WARKGB03	47.1	77.4	64.8	57.6	15.1	85.1	68.1	35.2	33.1	1.372	1.515	4.354	0	0	0.287
WARKGB04	36.1	57	57.4	56.5	13	79.6	57.3	31	36.3	0.391	1.305	4.237	0	0	0.450
Below ideal values															

Rehabilitation site soil microbial results

Table 14 contains the results for microbial analysis of the rehabilitation site samples. Many attributes are shared with the reference sites, including lack of general diversity. The greater presence or absence of some anaerobic bacteria and methane oxidisers is also more prevalent in the rehabilitated site data then reference sites. Desired attributes for soil microbiome that align with reference values (50-100% of reference value) are displayed as green cells in table 14.

Table 14: Rehabilitated site results for microbial soil condition in. * Only values exceeding deemed common concentration are displayed.

MTW (2019)	Nutrient solubilisation rate	Nutrient cycling rate	Disease resistance	Drought resistance	Nutrient accessibility (VAM)	Residue breakdown rate	Overall microbial balance	Total microbes	Microbial diversity	Protozoa	Mycorrhizal fungi	Gram negative	Methane oxidisers*	Sulphur reducers*	True anaerobes*
MTWCDD201101	88.6	88.5	92.4	88.6	77.2	100	85.9	68	43.8	3.726	7.718	5.955	0.000	0.000	0.579
MTWCDD201501	83.3	60.8	69.4	81.3	66.6	69.9	66.2	41.4	33.5	0.949	6.663	3.338	0.000	0.081	0.268
MTWNPN200501	72.1	88.2	81.4	72.1	44.1	100	83.4	50.1	48.3	1.603	4.414	5.799	0.000	0.000	0.493
MTWNPN200901	73	87.7	82	73	45.9	100	80.5	84.7	35.8	2.634	4.591	5.596	0.000	0.000	0.472
MTWNPN201101	100	90.5	100	100	100	100	89.5	98.7	37.8	5.794	18.611	6.831	0.000	0.000	0.491
MTWNPN201301	80.7	76.3	82.9	80.7	61.4	93.5	74.8	43.6	38.1	1.063	6.137	3.983	0.000	0.000	0.277
MTWNPN201403	97.5	88.1	98.4	97.5	95.1	100	86.5	78.6	35.2	3.258	9.508	5.776	0.000	0.000	0.433
MTWSPN201401	100	84.6	92.2	100	100	88.3	85.5	89.9	35.2	4.628	13.827	6.789	0.000	0.000	0.647
MTWTD1201501	66.7	44	62	74.6	49.3	60	57.7	32.4	37.8	0.298	4.927	3.65	0.000	0.149	0.502
MTW 2019 Mean	84.7	78.7	84.5	85.3	71.1	90.2	78.9	65.3	38.4	2.661	8.488	5.302	0.000	0.026	0.462
MTW 2019 Max	100.0	90.5	100.0	100.0	100.0	100.0	89.5	98.7	48.3	5.8	18.6	6.8	0.0	0.149	0.6
MTW 2019 Min	66.7	44	62	72.1	44.1	60	57.7	32.4	33.5	0.298	4.414	3.338	0	0.000	0.268
Reference Mean	62.4	79.8	75.0	66.0	32.1	95.7	75.9	54.9	37.3	1.148	3.207	6.576	0.000	0.000	0.527
Reference Max	77.2	92.9	84.8	77.2	54.4	100	84.2	80.8	45.9	3.95	5.441	9.015	0.000	0.000	0.785
Reference Min	36.1	57	57.4	56.5	13	79.6	57.3	31	32.4	0.391	1.305	4.237	0.000	0.000	0.269

4.3 Ecosystem and land-use establishment

4.3.1 Landscape Function Analysis

Surface values assessed for the 2019 monitoring program are displayed in Table 16 for reference sites, along with Rehabilitation sites in table 17. Both summary statistics are presented below in table 15. Most parameters of the Landscape function analysis for rehabilitated sites are displayed as within reference site values, except for Level of Order Index (LOI) and nutrient cycling, which display numerous site values under 50% that of reference values. Many rehabilitation site values do not satisfy MOP LFA criteria as demonstrated in table 17.

Table 15: LFA Summary statistics for 2019.

Reference	LOI	Stability	Infiltration	Nutrient Cycling
Mean	1.0	66.1	49.0	43.5
Max	1.0	71.8	56.7	50.6
Min	0.9	62.0	43.1	38.0
MTW 2019	LOI	Stability	Infiltration	Nutrient Cycling
Mean	0.5	55.6	33.8	27.4
Max	1.0	75.9	47.4	48.8
Min	0.0	43.8	23.5	14.1

Temporal variation in landscape function for each site is displayed in the individual reports in the appendices, facilitating ease of interpretation regarding trajectory of each site's landscape function. Specific temporal variance of site surface function differences is illustrated in the following figures (1-4), with mean values from 2019 and 2016/2017 displayed to demonstrate wider change over MTW.

Table 16: Reference site LFA observations for 2019.

Site (Reference)	LOI	Stability	Infiltration	Nutrient Cycling
BEL01	1.00	69.4	50.6	46.8
BEL02	0.98	67.8	49.7	43.8
BEL03	1.00	68.1	56.7	50.6
WAMBOGB1	0.99	71.8	48.4	45.3
WAMBOGB2	0.86	62.5	47.0	40.6
WAMBOSPOT1	0.95	65.9	54.5	48.0
WAMBOSPOT2	0.96	64.4	46.6	40.7
WAMBOSPOT3	0.98	65.2	54.0	46.8
WARKGB1	0.94	62.0	44.4	38.0
WARKGB2	1.00	62.5	47.0	40.6
WARKGB3	0.94	67.3	45.9	39.4
WARKGB4	0.90	66.1	43.1	40.9
Mean	0.96	66.1	49.0	43.5

Table 17: Rehabilitation site surface assessment values for 2019.

MTW (2019)	LOI	Stability	Infiltration	Nutrient
CDD201101	1.00	65.8	38.1	35.1
CDD201301	0.02	50.7	31.4	27.9
CDD201401	1.00	61.1	40.9	36.8
CDD201501	1.00	58.0	34.9	27.4
CDD201701	0.47	48.1	26.6	21.4
CDD201702	0.81	61.4	33.9	33.3
CDD201801	0.30	51.3	27.9	20.2
MTO201601	0.02	52.0	23.7	21.8
MTO201701	0.15	53.2	27.4	16.7
MTO201702	0.55	50.4	28.0	18.1
MTO201703	0.29	43.8	24.5	17.8
MTO201704	0.53	49.1	27.1	21.1
MTO201801	0.09	43.9	23.5	14.1
MTO201802	0.05	46.6	32.1	22.5
MTO201803	0.03	45.4	30.3	22.0
NPN200901	0.64	61.6	47.1	40.8
NPN201101	0.24	57.1	35.7	36.2
NPN201301	1.00	75.9	46.3	48.8
NPN201401	0.33	55.2	36.0	31.7
NPN201601	0.00	55.9	36.6	30.3
NPN201602	0.68	46.8	24.6	24.6
NPN201701	0.83	60.1	33.7	24.4
NPN201702	0.80	53.8	32.5	29.4
NPN201703	0.12	50.3	30.3	15.5
NPN201801	0.27	55.0	39.7	24.9
NPN201802	0.17	50.5	33.5	18.3
NPN201803	0.04	58.2	40.2	32.5
SPN201401	0.93	67.6	43.6	40.3
SPN201501	0.40	65.6	46.1	37.7
SPN201601	0.96	57.9	34.6	27.6
SPN201602	0.92	61.1	47.4	38.0
SPN201701	0.78	48.0	27.0	18.9
SPS201601	0.66	57.4	28.9	25.0
SPS201602	0.59	49.1	31.2	22.5
SPS201701	1.00	57.3	33.1	24.5
SPS201703	0.01	46.3	24.3	20.9
SPS201801	0.90	64.4	37.2	33.2
TD1201501	0.67	52.0	29.0	22.7
WDL201401	0.89	65.9	42.2	34.6
WDL201402	1.00	66.8	37.2	32.4
WDL201801	0.96	58.2	37.8	32.8
MOP Ranges	0.84 - 1.00	53.9 - 81.8	48.4 - 73.9	38.5 - 79.8

Legend	
Within MOP range	
Performing above MOP range	
Below MOP Range	

Level of Order Index (LOI)

LOI temporally, is one of the most variable outcomes of the rehabilitation progression, indicating overall integrity of site – its ability to retain resources. Some fluctuation is observed for some sites, but an increase in Level of Order (Mean 0.54) is apparent in many sites with the previous year's data available, despite a lowering of the reference mean value (0.96).

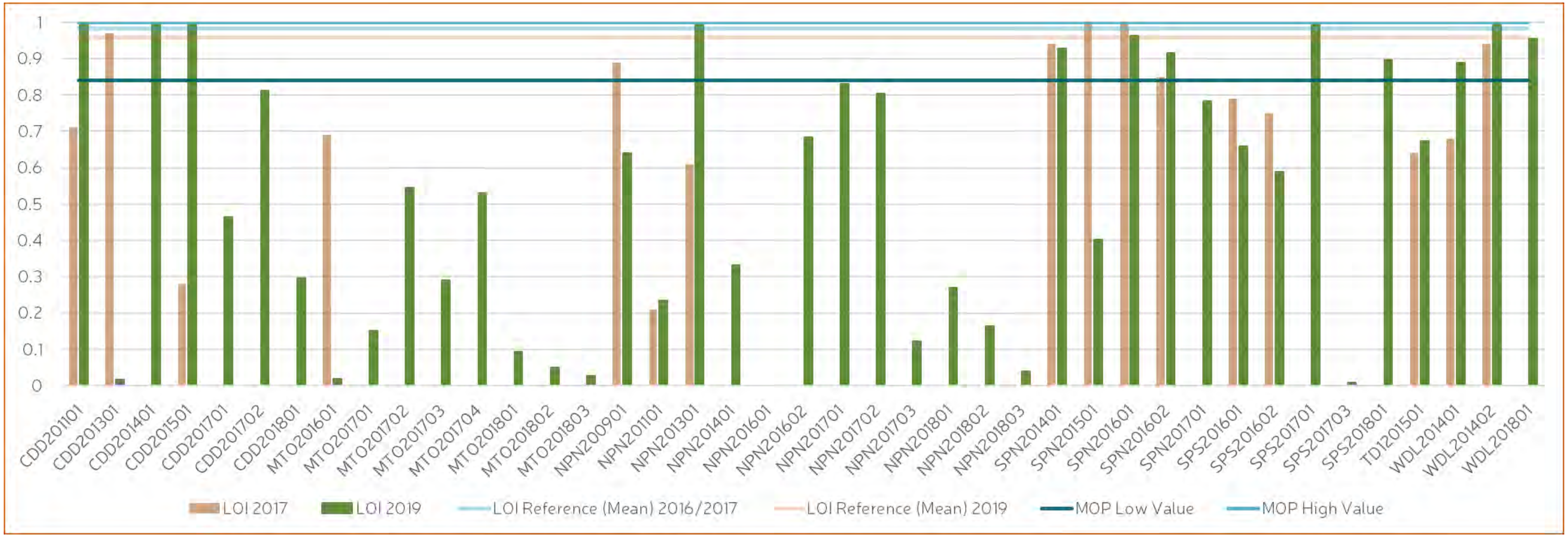


Figure 1: Surface assessment, Level of Order Index (LOI) 2017-2019.

Stability

Some sites follow the trend of raising in stability with the raise in mean stability for the reference sites. The mean rehabilitation value (55.6) and the below figure demonstrate how readily sites are tracking towards reference values for this surface assessment. CDD201501 has improved to near reference mean value within the period displayed.

Figure 2: Surface assessment, stability 2017-2019.

Infiltration

While values for the majority of sites has decreased, the mean reference value has also decreased by over 10 units, exhibiting a phenomenon impacting landscape function for the region. The overall site's mean value of 33.8 is still less than 10 units below that of the current reference mean.

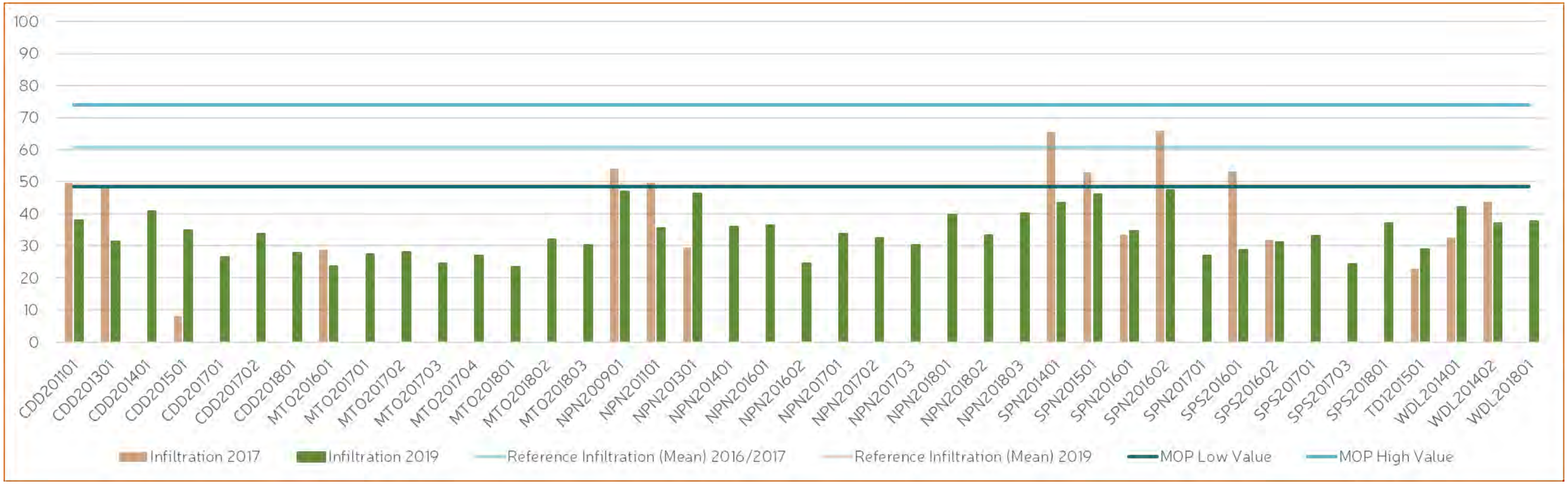


Figure 3: Surface assessment, infiltration 2017-2019.

Nutrient Cycling

A decrease in mean reference values is seen also in rehabilitation results for 2019, with the mean site value 63% that of the current reference mean value (43.5). CDD201501 and MTO201601 still have demonstrated a markable improvement in nutrient cycling for this period.

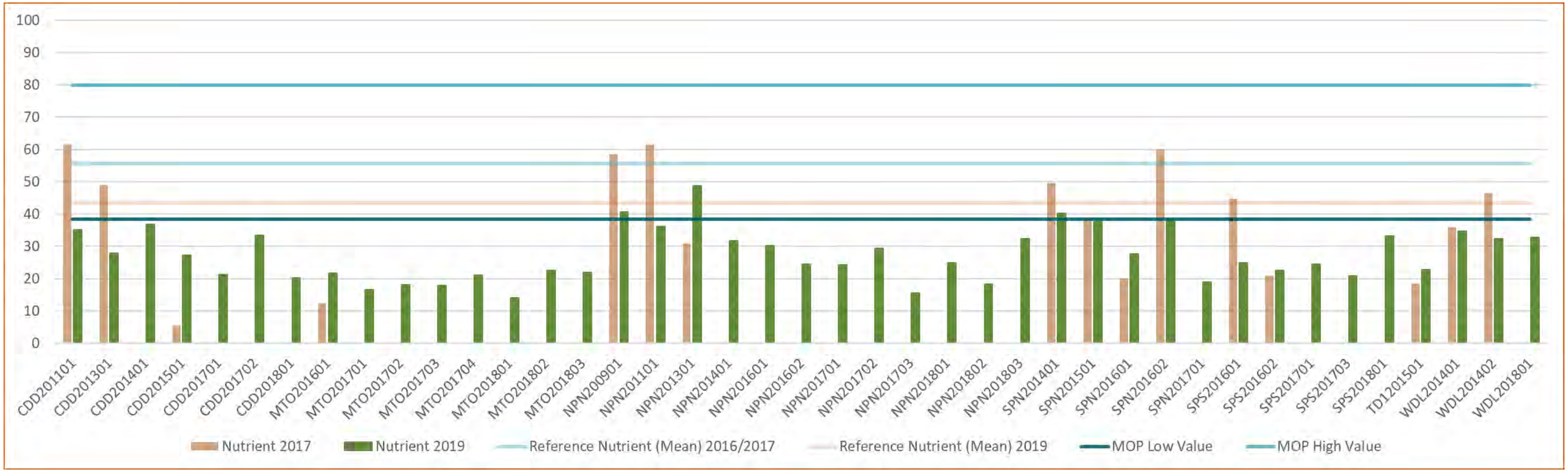


Figure 4: Surface assessment, nutrient cycling 2017-2019.

4.3.2 Species Richness

The diversity in species for each site is displayed for total observed and in those observed in different strata, in the following figures (figures 5-9). As depicted in figure 5, total species richness satisfies the MOP performance criteria for most sites as depicted by the mean value lying within the designated MOP values.

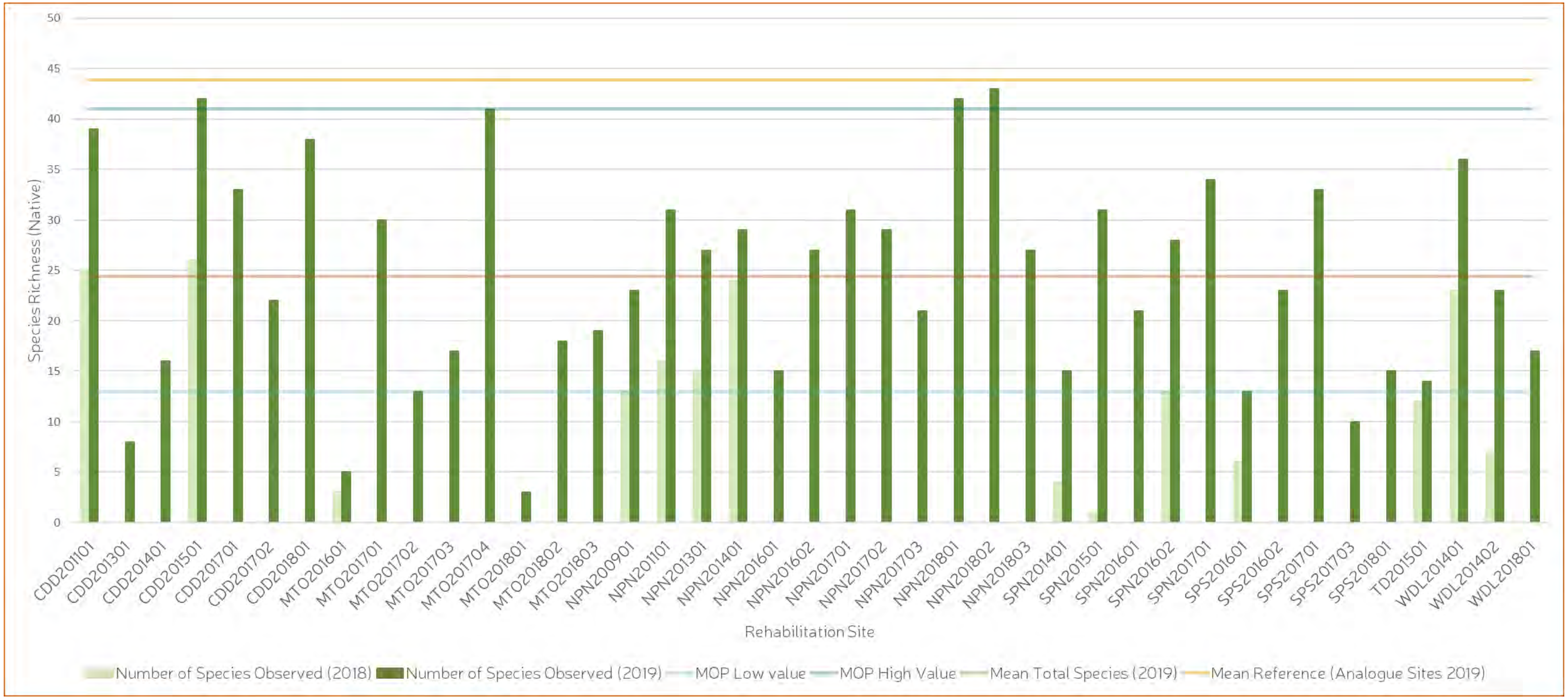


Figure 5: Total species richness observed at MTW in 2019.

Tree species richness

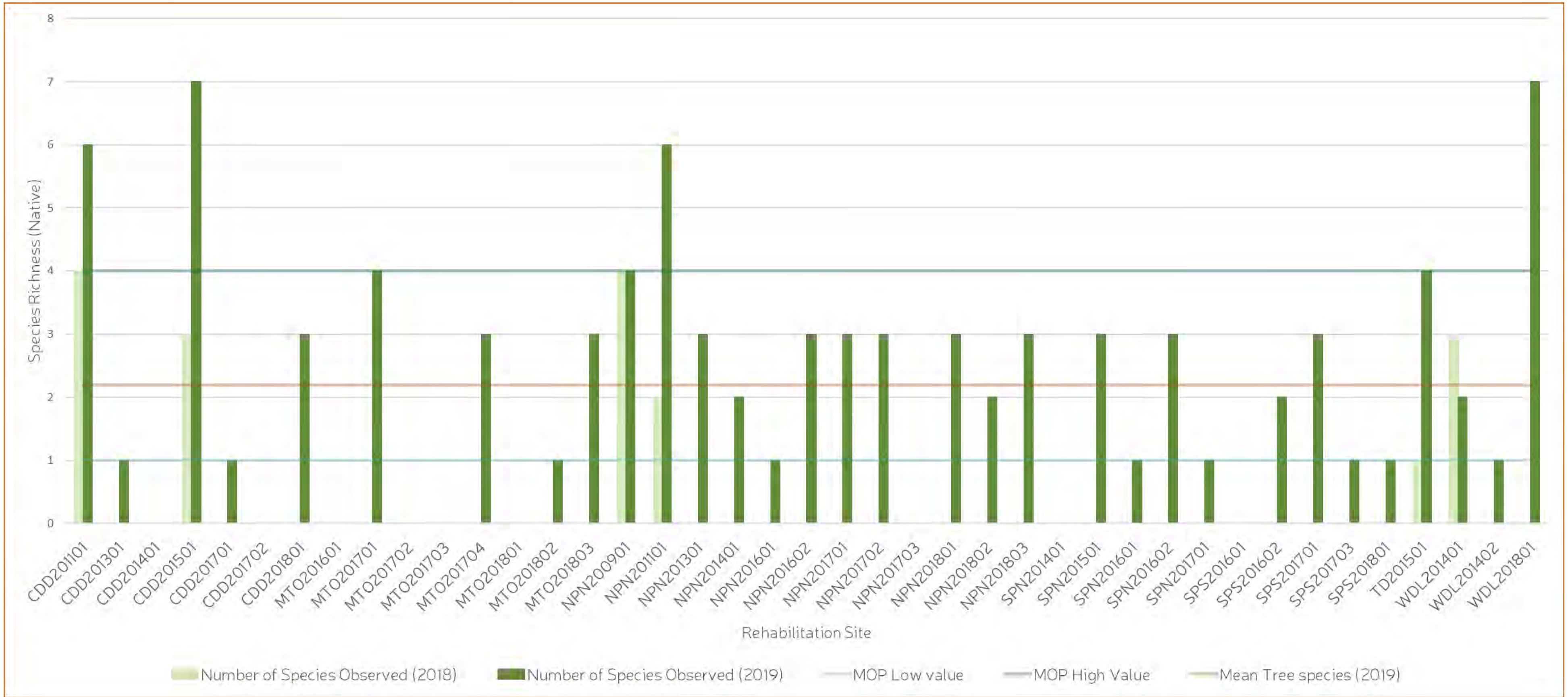


Figure 6: Tree species richness observed at MTW in 2019.

Shrub species richness

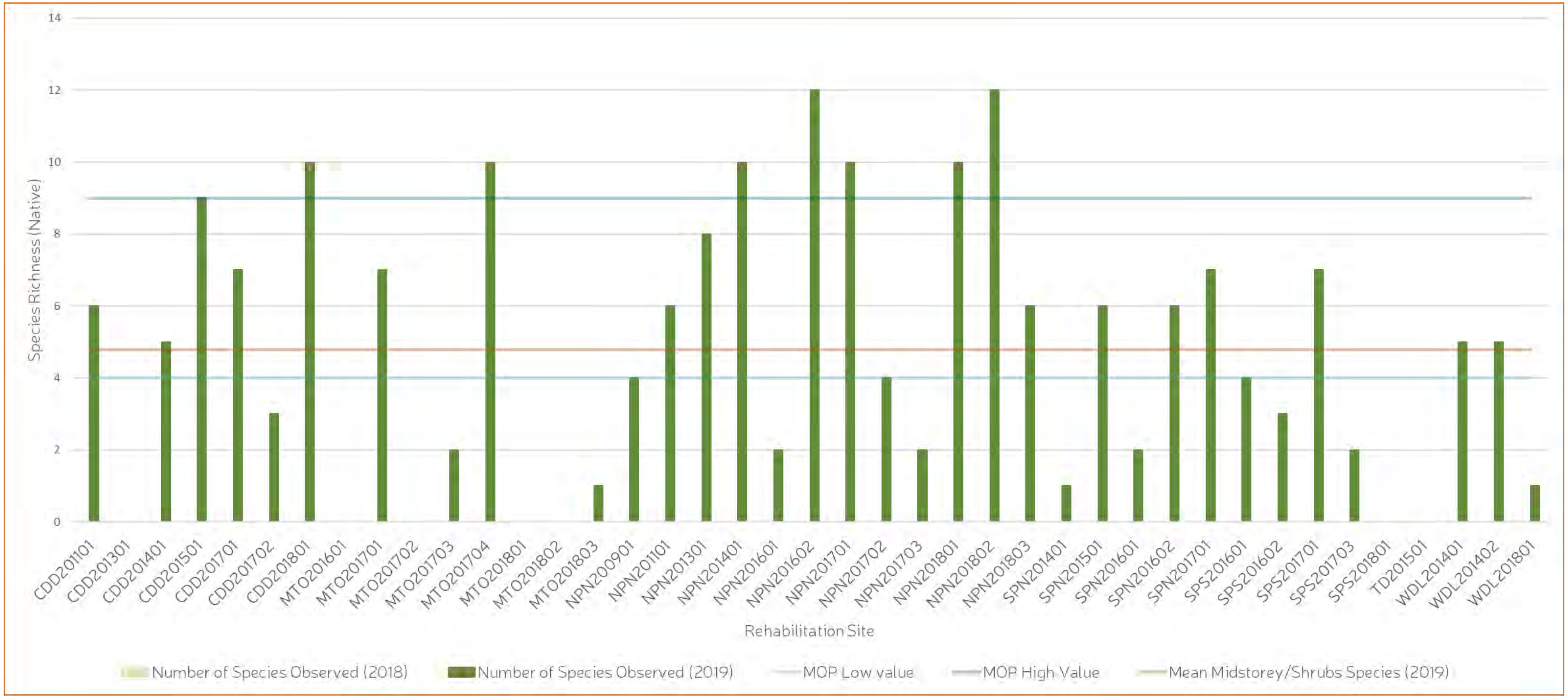


Figure 7: Shrub species richness observed at MTW in 2019.

Grass species richness

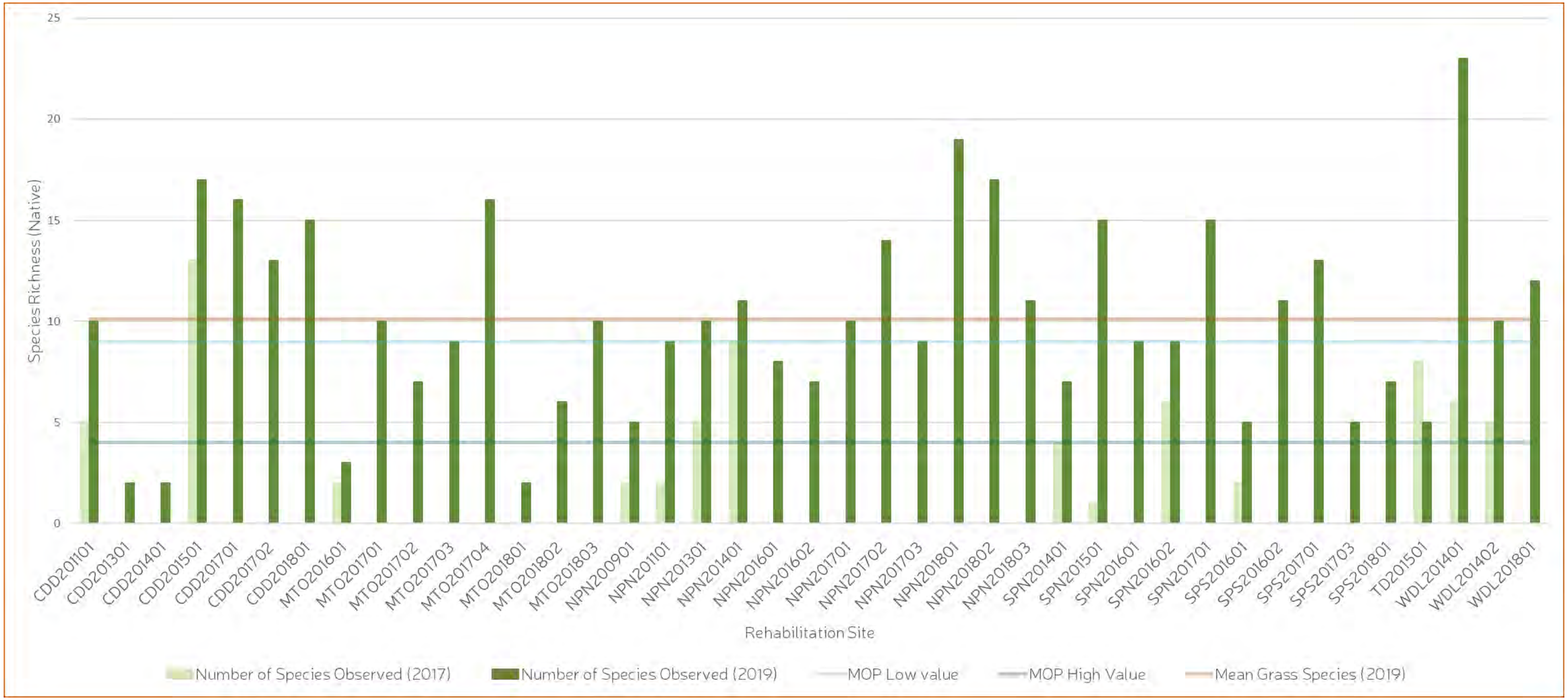


Figure 8: Grass species richness observed at MTW in 2019.

Other groundcover species richness

Figure 9: Other groundcover species richness observed at MTW in 2019.

4.3.3 Canopy Development

Specific observations made concerning canopy development have been placed in the individual site reports (appendices) due to the limited number of relevant sites (7 sites - CDD201101, CDD201501. NPN200901, NPN201101, NPN201301, NPN201401, WLD201401).

Stem density, MTW 2019 sites.

Established sites are reaching the desired stem density, but in the case of NPN200901 presented in figure 10, such sites are obtaining densities beyond reference values (reference mean 1658 stems ha^{-1}) – see figure 11. NPN200901 2019 Stem density of 30000 ha^{-1} not depicted in full.

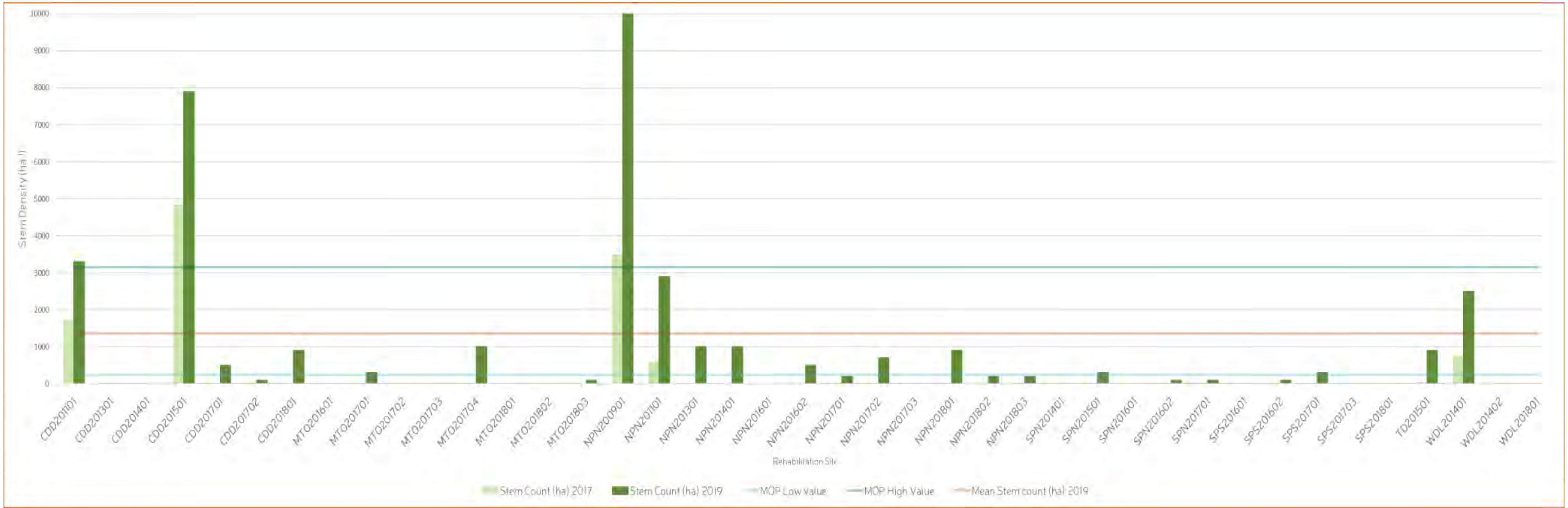


Figure 10: Stem density (ha^{-1}) observed at MTW in 2019.

Stem density, Reference sites.

The mean value for reference sites is 1658 stems ha^{-1}. The mean rehabilitation site value is depicted below in figure 11, with many of the reference sites intersected by the mean value. This rehabilitation mean value comprises of all stems, including those under 5 cm DBH, as most sites do not contain such mature specimens yet (1360 stems ha^{-1}).

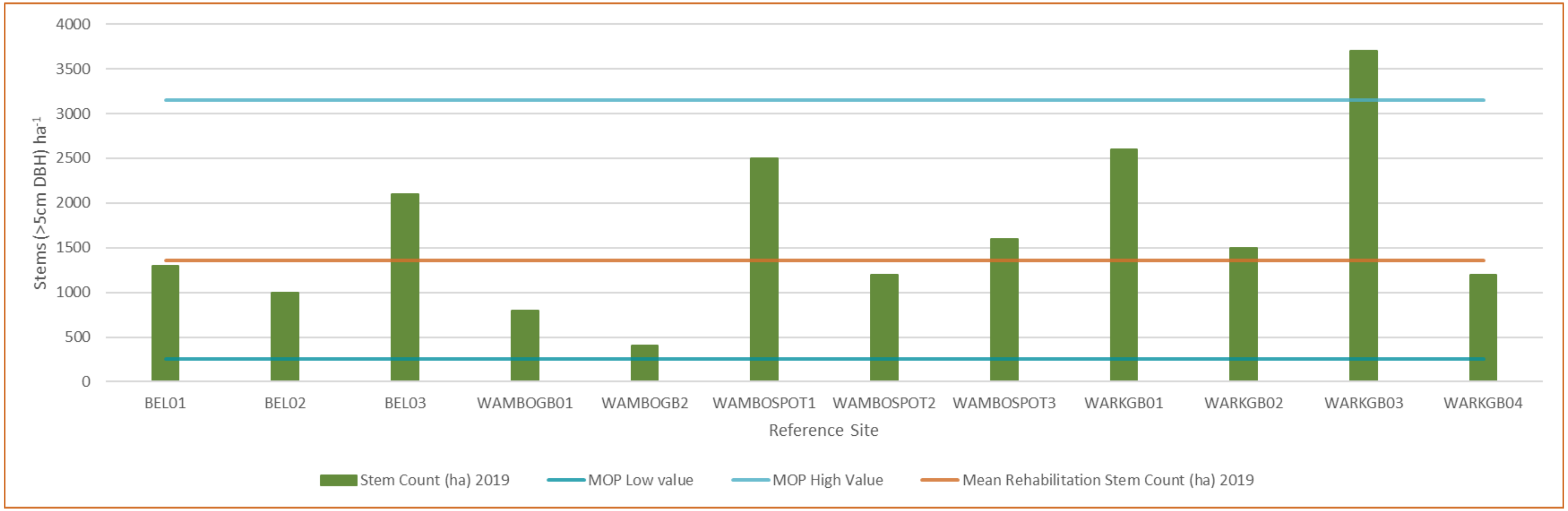


Figure 11: Stem density (ha^{-1}) observed at reference sites in 2019.

4.4 Ecosystem and Land Use Sustainability

4.4.1 Vegetation Structure and Species Richness

All cover values observed, along with habitat features are summarised in Table 18. Individual characteristics of sites are contained in the appendix 8.5, including relation of strata cover to stem density.

Table 18: Summary statistics for cover and habitat features. Foliage projective cover in percentages.

MTW-2019	Native species	Native Overstorey (%)	Native Midstorey (%)	Native grass cover (%)	Native cover - shrubs (%)	Native cover other (%)	Exotic plant cover (%)	Total groundcover (%)	Trees with hollows	Fallen logs (m)	Overstorey regen
Reference											
Mean	43.9	20.0	4.8	18.2	0.7	13.7	0.5	33	0	15	1.0
Max	60.0	34.5	13.7	46.0	2.0	30.0	4.0	64	0	39	1.0
Min	30	1.5	0	4	0	4	0	16	0	2	1
MTW 2019											
Mean	24.4	1.3	3.9	25.4	3.1	8.8	22.0	59	0	1	0.1
Max	43.0	33.0	35.0	66.0	40.0	30.0	72.0	100	0	20	1.0
Min	3	0	0	0	0	0	0	0	0	0	0
MOP Target Range	13 - 41	15 - 50	5 - 60	5 - 50	5 - 10	5 - 40	5 - 33	32 - 74	>0.5	>3	0.5 - 1

Reference site cover and habitat attributes are displayed in table 19. The younger age of vegetation at these sites is evident in that there are no records of trees with hollows. Exotic plant cover was also recorded for some of these sites, an instance not observed for four rehabilitated sites, as displayed in table 20.

Table 19: Cover and habitat features of reference sites. Foliage projective cover in percentages.

Reference	Native species	Native Overstorey (%)	Native Midstorey (%)	Native grass cover (%)	Native cover - shrubs (%)	Native cover other (%)	Exotic plant cover (%)	Total Groundcover (%)	Trees with hollows	Fallen logs (m)	Overstorey regen
BELL01	38.0	24.5	0.0	18.0	0.0	12.0	0.0	30	0.0	10.0	1.0
BELL02	37.0	21.5	0.5	22.0	2.0	30.0	2.0	56	0.0	10.0	1.0
BELL03	43.0	34.5	6.2	16.0	2.0	18.0	0.0	36	0.0	20.0	1.0
WAMBOGB1	36.0	28.5	7.0	14.0	0.0	18.0	0.0	32	0.0	4.0	1.0
WAMBOGB2	60.0	21.4	2.0	16.0	0.0	10.0	0.0	26	0.0	22.0	1.0
WAMBOSPOT03	46.0	18.4	5.0	16.0	2.0	16.0	0.0	34	0.0	4.0	1.0
WAMBOSPOT1	52.0	9.0	13.7	24.0	0.0	6.0	0.0	30	0.0	39.0	1.0
WAMBOSPOT2	45.0	31.0	8.0	16.0	0.0	6.0	0.0	22	0.0	7.0	1.0
WARKGB01	53.0	11.0	5.0	4.0	2.0	6.0	4.0	16	0.0	22.0	1.0
WARKGB02	39.0	19.0	2.0	46.0	0.0	18.0	0.0	64	0.0	27.0	1.0
WARKGB03	30.0	20.0	1.5	18.0	0.0	4.0	0.0	22	0.0	11.0	1.0
WARKGB04	48.0	1.5	6.2	8.0	0.0	20.0	0.0	28	0.0	2.0	1.0

Table 20 displays rehabilitation site data in relation to MOP performance criterion. Native grass and high native species diversity; lowered exotic plant cover, along with overall groundcover account for the majority of data values that align with MOP criterion. Low values of understorey cover (Shrub cover) are an apparent issue for the larger portion of sites. Although understorey species account for less cover than required, total understorey species (including grass species) for many sites fall within the respective MOP criteria as displayed in figure 12.

Table 20: 2019 Cover scores and habitat features in relation to MOP criterion.

MTW (2019)	Native species	Native Overstorey (%)	Native Midstorey (%)	Native grass cover (%)	Native cover - shrubs (%)	Native cover other (%)	Exotic plant cover (%)	Total groundcover (%)	Trees with hollows	Fallen logs (m)	Overstorey regen
CDD201101	39	4	9	8	0	6	12	26	0	0	1.00
CDD201301	8	0	0	22	0	0	16	38	0	0	0
CDD201401	16	0	0	52	2	2	36	92	0	0	0
CDD201501	42	1	3	38	14	6	8	66	0	0	1.00
CDD201701	33	0	2	20	0	6	38	64	0	0	0
CDD201702	22	0	0	56	4	10	34	100	0	0	0
CDD201801	38	0	2	20	8	14	12	54	0	0	0
MTO201601	5	0	0	6	0	0	32	38	0	0	0
MTO201701	30	0	0	20	0	2	8	30	0	0	0
MTO201702	13	0	0	4	0	30	30	64	0	0	0
MTO201703	17	0	0	28	0	12	0	40	0	0	0
MTO201704	41	0	1	54	2	8	8	72	0	20	0
MTO201801	3	0	0	2	0	0	2	4	0	0	0
MTO201802	18	0	0	10	0	10	26	46	0	0	0
MTO201803	19	0	0	18	0	4	2	24	0	0	0
NPN200901	23	33	0	2	0	2	0	4	0	2	0.50
NPN201101	31	9	11	10	0	0	10	20	0	0	0.30
NPN201301	27	2	12	50	0	12	26	88	0	0	0
NPN201401	29	6	21	30	0	0	14	44	0	0	0
NPN201601	15	0	0	2	0	2	68	72	0	0	0
NPN201602	27	0	5	16	14	22	22	74	0	0	0
NPN201701	31	0	2	66	2	4	16	88	0	14	0
NPN201702	29	0	1	44	6	14	10	74	0	0	0
NPN201703	21	0	0	14	0	2	10	26	0	0	0
NPN201801	42	0	1	50	0	2	12	64	0	0	0
NPN201802	43	0	2	30	0	16	20	66	0	1	0
NPN201803	27	0	35	2	40	10	0	52	0	0	0
SPN201401	15	0	0	46	0	0	34	80	0	0	0
SPN201501	31	0	0	23	1	2	19	45	0	0	0
SPN201601	21	0	0	20	0	10	48	78	0	0	0
SPN201602	28	0	22	24	12	30	26	92	0	0	0
SPN201701	34	0	3	30	4	20	34	88	0	0	0
SPS201601	13	0	0	20	0	10	48	78	0	0	0
SPS201602	23	0	9	14	2	22	46	84	0	0	0
SPS201701	33	0	1	38	0	16	36	90	0	0	0
SPS201703	10	0	0	8	0	0	10	18	0	0	0
SPS201801	15	0	0	22	2	2	72	98	0	0	0
TD1201501	14	0	0	24	4	18	34	80	0	0	0
WDL201401	36	1	20	44	10	30	8	92	0	0	0.85
WDL201402	23	0	0	0	0	0	0	0	0	0	0
WDL201801	17	0	0	54	2	4	16	76	0	0	0

Below MOP Criteria	
Satisfys MOP Criteria	
Performing beyond MOP Criteria	

40

Total understorey species richness

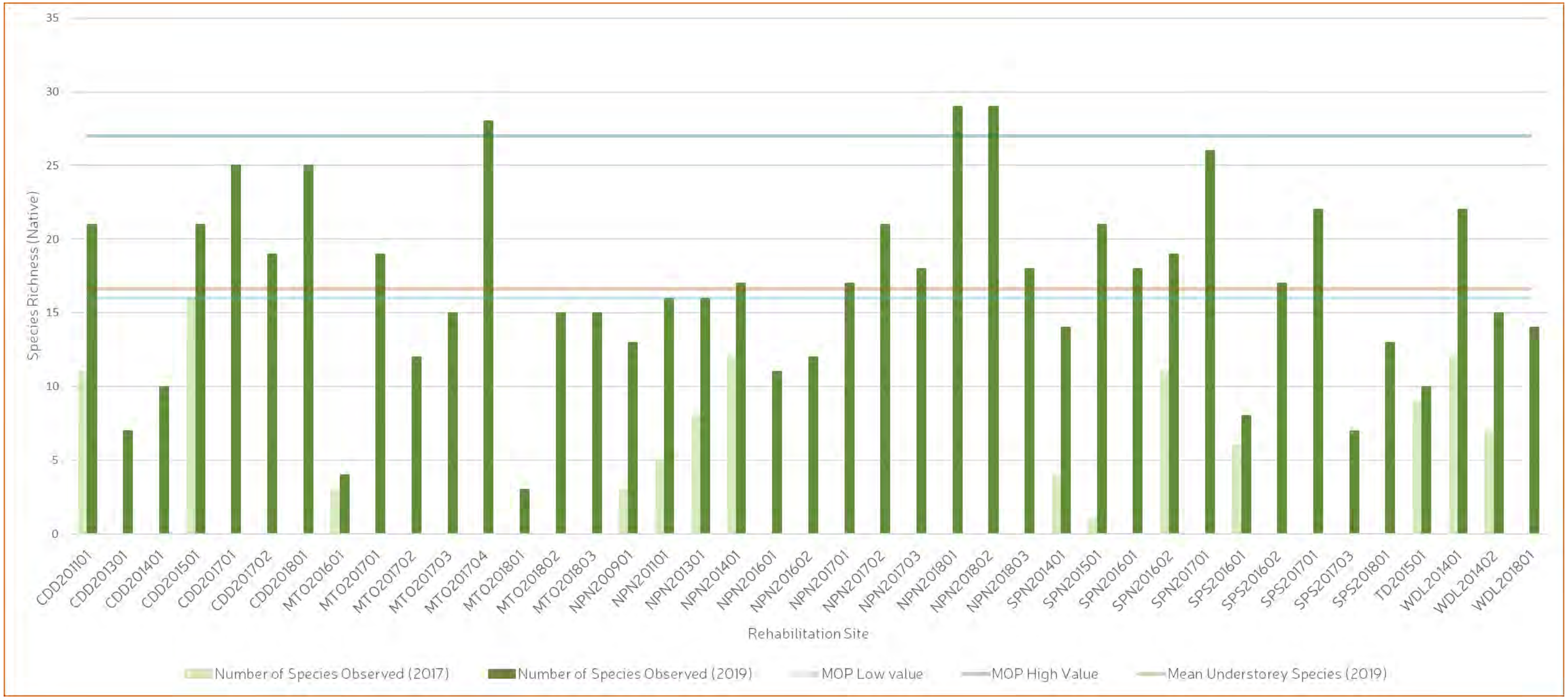


Figure 12: Total understorey species richness.

5. Discussion

Performance criteria are summarised in the introduction. Please refer to Tables 5, 6 and 7 as required.

5.1 Growth Medium Development

5.1.1 Soil analysis

Many sites sampled for this monitoring program satisfied benchmark MOP performance criteria for soil chemistry, with the only evident issues present in the form of high concentrations of available phosphorus, as well the undesirable sodium occupation of cation exchange capacity at some sites.

The organic carbon mean value for rehabilitation sites differed little from reference sites (Reference = 6.1, Rehabilitation = 6.6), although sites with higher organic carbon tended to have less exotic cover and, in some instances, greater species richness and native cover. For these cases, organic carbon appears to be a likely predictor of site performance in establishing native vegetation for the rehabilitation sites. While not all sites conform with this notion, results obtained from organic carbon assays can sometimes be confounded by coal contamination from coal tailings, dust etc., produced by mining operations (pers comm L McGrath, Landloch). If differentiated in a customised set of analyses, geogenic carbon has been demonstrated to constitute around 9%, and up to 20% of measured soil organic carbon from soil samples taken from remediated areas in Australian mines (Chan *et al.*, 2017). Therefore, some sites that are not performing well but exhibiting complying soil carbon values may well not be valid examples. Quantification of organic carbon should provide a measure of humus concentration in the soil, which if in a sufficient concentration, will facilitate a higher capacity of cation exchange sites and therefore, micronutrient retention, along with the other benefits of organic matter, including microbial nutrient provision and holding of moisture.

Exchangeable Sodium Percentage (ESP) above or near 15% values are present in this monitoring dataset for rehabilitation sites. Whilst these same sites comply with normal soil condition Electrical Conductivity measurements, as defined in the MOP, these soil characteristics indicate a lowered source of neutral salts and can therefore be considered somewhat Sodic (vanLoon & Duffy, 2011). This could explain some of the elevation in the pH measurement observed in TD1201501, as such a dominance of sodium tends to consist of

sodium carbonate, which after hydrolysis from soil pore water, produces hydroxide ions and raises pH (Brady, 1984). Such sodium concentrations also present as a potential factor in inhibiting the growth of native species, this considering reference site ranges of ESP and pH are well below that of rehabilitated sites. The observed levels of sodium concentration would also have an impact on soil condition, producing more dispersive soils, and thus, reduce the structure of these soils.

Phosphorus in different forms is exceedingly high for nearly all sites and may be impacting growth and recruitment of specific species, particularly available phosphorus as detailed by the Bray and Colwell analysis results. Mean reference site values are 10-fold less than that of rehabilitation sites. Nutrient imbalances involving phosphorus are thought to restrict the recruitment of healthy sclerophyll species in grassland communities (Specht and Specht, 1999).

Nitrogen supply appears to be adequate with carbon to nitrogen ratios for rehabilitated sites only slightly lower than that for reference sites (depicted in table 21), although carbon measures may be affected by coal contamination.

Table 21: Carbon to Nitrogen ratios across sites.

C:N	Reference sites	Rehabilitation sites	Expected (agronomy)
Mean	18.1	16.3	10 to 12
SD	1.7	3.5	NA

Calcium to magnesium ratios appear to compliant and if not, were elevated in calcium. These higher concentration sites are still within the desired agronomic range for calcium. Generally, calcium concentrations in the soil sampling results for this monitoring were higher in the rehabilitation sites than reference sites, most probably owing to initial gypsum applications. This may be of benefit in offsetting some of the effects of the sodium content of soils on some sites, particularly enhancing soil structure (Brady, 1984).

Potassium concentrations appear sufficient for all rehabilitation sites.

5.1.2 Microbial analysis

Analysis of soil samples was carried out by Microbiology Labs Australia (MLA). Their reports for each site are included in the Appendices. The microbial analysis results showed that many of the target values, as defined by the Microbiology Laboratories Australia, were not achieved by either the mine sites or the reference sites. Microbial diversity, for example, was much lower for all sites. This is probably due to the guide values being generated from more productive environments (e.g. higher rainfall forest sites). Many mine sites scored higher on some of the measures than the reference sites, for example nutrient solubilisation rate, drought resistance and Nutrient accessibility were over the guide levels for several mine sites but none of the reference sites.

Many of the mine sites compared favourably to the reference site scores on most measures, although some sites had elevated levels of Sulphur reducing or true anaerobic bacteria which indicate anaerobic soil conditions such as water logging or compaction.

5.2 Ecosystem and Landuse Establishment – Woodland EEC

5.2.1 Flora – Species richness

- Total species richness is quite good on many of the rehabilitation sites, with only six out of forty-two failing to meet the minimum MOP criterion. Several sites recorded species diversity of at least double the minimum and three sites met or exceeded the upper level required by the MOP.
- Overstorey diversity was generally good with few sites failing to meet the MOP minimum and several meeting or exceeding the MOP range. The sites with few or no native overstorey species recorded are usually younger sites which have either not yet been sown with native seed or where trees have not yet germinated. Some older sites, however, have generally poor native establishment in all categories.
- Midstorey diversity (shrubs >1m) was often good, though less consistently so with seventeen sites failing to meet the MOP minimum.
- Groundlayer shrub and herb diversity in the ground layer was often lower than the MOP minimum.
- Native grass diversity was generally good, with most sites achieving the MOP range and many exceeding it.

Total species richness	MOP range	Reference site range 2019	Rehabilitation sites within MOP range
Lower	13	31	
Upper	41	58	36
Overstorey species	**MOP range**	**Reference site range**	**Rehabilitation sites within MOP range**
Lower	1	2	
Upper	4	6	32
Midstorey species	**MOP range**	**Reference site range**	
Lower	4	0	
Upper	9	10	24
Ground cover shrubs and herbs	**MOP range**	**Reference site range**	
Lower	10	16	
Upper	20	36	8
Grasses	**MOP range**	**Reference site range**	
Lower	4	5	
Upper	9	12	37

5.2.2 Patterns of native vegetation establishment

It is difficult to make broad statements about native vegetation establishment due to the variability of conditions across the MTW rehabilitation sites. Soils can differ widely across the site and climatic conditions at the time of sowing have varied considerably in the ten years prior to this current monitoring season. Nevertheless it seems apparent that it is possible to establish diverse and functional native plant communities at MTW. Several sites have achieved most of the MOP performance criteria for Ecosystem and Landuse Establishment.

There may be several reasons for poor native establishment including soil quality, climatic factors following sowing and weed competition. Some sites have not yet been sown with native species and these of course are showing poor results e.g. MTO201801 and the eastern half of MTO201601 (where the monitoring transect is located).

At sites such as SPN201401 and SPS201601 this lack of native establishment seems to be due to weed competition because these sites are almost entirely dominated by exotic grasses.

At sites such as MTO201702 the relatively low native species diversity and cover may reflect soil conditions, or less favourable climatic conditions. However, this site is relatively young and so may prove successful over time.

5.2.3 Successful rehab species

The most successful species (recorded from at least 15 sites) are presented in the following table:

Family	Vegetation layer	Genus	Species	number of rehab sites sp. Present
Chenopodiaceae	Ground layer shrub	*Atriplex*	*semibaccata*	30
Chenopodiaceae	Ground layer shrub	*Enchylaena*	*tomentosa*	25
Fabaceae	GL shrub	*Hardenbergia*	*violaceaea*	15
Poaceae	Grass	*Bothriochloa*	*decipiens*	24
Poaceae	Grass	*Capillipedium*	*spicigerum*	23
Poaceae	Grass	*Chloris*	*truncata*	39
Poaceae	Grass	*Chloris*	*ventricosa*	21
Poaceae	Grass	*Cynodon*	*dactylon*	26
Poaceae	Grass	*Dichanthium*	*sericeum*	31
Poaceae	Grass	*Digitaria*	*divaricatissima*	22
Poaceae	Grass	*Eriochloa*	*pseudacrotricha*	32
Poaceae	Grass	*Panicum*	*queenslandicum*	19
Poaceae	Grass	*Sporobolus*	*creber*	29
Asteraceae	Herb	*Vittadinia*	*cuneata*	15
Chenopodiaceae	Herb	*Einadia*	*polygonoides*	18
Chenopodiaceae	Herb	*Einadia*	*trigonos*	27
Chenopodiaceae	Herb	*Einadia*	*nutans*	23
Fabaceae	Shrub	*Acacia*	*amblygona*	24
Fabaceae	Shrub	*Acacia*	*cultriformis*	20
Fabaceae	Shrub	*Acacia*	*decora*	23
Sapindaceae	Shrub	*Dodonaea*	*viscosa subsp. cuneata*	17
Solanaceae	Shrub	*Solanum*	*cinereum*	18
Fabaceae	Small tree	*Acacia*	*implexa*	15
Fabaceae	Small tree	*Acacia*	*salicina*	19
Myrtaceae	Tree	*Corymbia*	*maculata*	19

Many other species were recorded at more than one rehabilitation site and a total of 118 species was recorded for all sites. The plant families of Fabaceae, Chenopodiaceae and Poaceae are the best represented in this list. As may be expected primary and secondary colonisers have been the most successful the rehabilitation landscape. On the other hand, few long lived, shade tolerant species were recorded, even on older sites. This is most likely because ecological conditions on the rehabilitation sites are not yet suited to these species. While they may be included in seed mixes the monitoring results would suggest that they do not establish in early

stage rehabilitation. It may take many years before soil, light and biotic factors change enough to allow establishment of these species. While many local native plants have long-lived seed it is likely that the germinability of any seed sown as part of the rehabilitation program will decline quite quickly and that therefore these species will be lost from the seedbank.

This may explain why many sites do not achieve the performance criteria levels for understorey species other than grasses. If these species are required in the mine vegetation to meet MOP criteria then they will probably need to be re-sown once conditions have become more favourable or introduced by planting tube stock or by translocation.

Whilst many sites are approaching the species diversity levels required by the MOP the actual species composition of the sites does not always reflect that of the target Endangered Ecological Community (Central Hunter Grey Box-Ironbark Woodland). *Corymbia maculata,* for example was the most often recorded canopy species and whilst it may be found in CHGBIW remnants it is not usually a dominant species. A review of the seed mixes used at MTW and comparison of rehabilitation areas with nearby CHGBIW remnants may be useful in achieving the species composition of the target EEC. The location of reference sites may need to be reviewed to provide the most meaningful comparison between target EEC and rehabilitation vegetation types.

5.2.4 Canopy species stem density

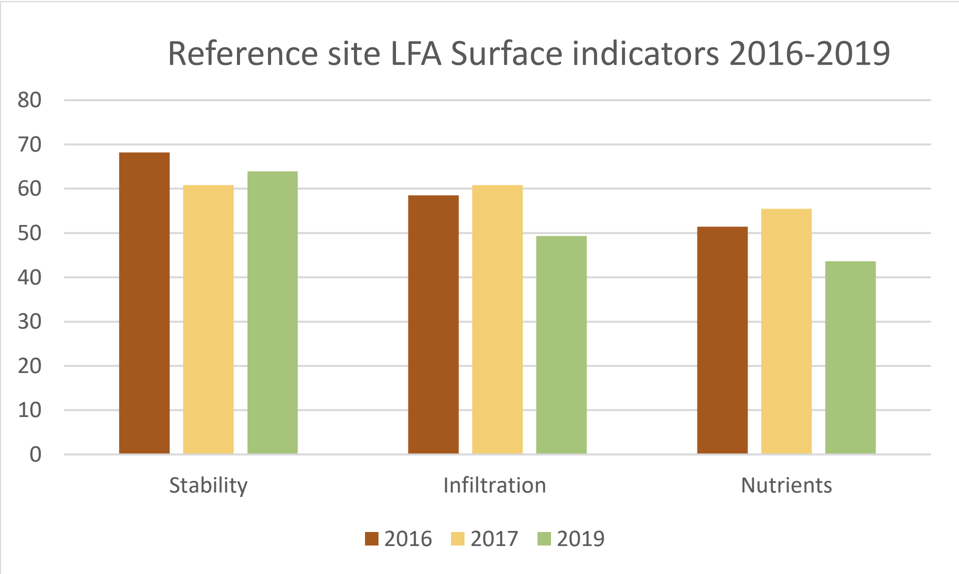
The MOP criterion for stem density is to have between 250 and 3150 stems per Hectare and 50-725 maturing trees with a DBH >5cm. Many sites are yet to reach the lower limit for stem density due to having been only recently sown. 14 sites are within the MOP criteria range and three sites exceed the range. The stem density maximum value is very high compared to the MOP range for maturing trees and also to published guidelines for Hunter Valley Woodland vegetation (Kerle, 2005). This means that several of the rehabilitation sites have stem densities too high for long-term stability and sustainability even though they are within the MOP range. High stem densities of canopy species leads to increased competition for moisture, light and other resources and can result in a decline in shrub and ground layer diversity and cover. This effect is demonstrated by the vegetation at sites such as NPN200901 which has very high stem density, low ground cover and lower ground layer diversity.

These sites would benefit from thinning of the dense canopy layer to reduce competition, particularly for water.

5.2.5 LFA

5.2.5.1 Comparison of reference site data

Survey year	LOI	Stability	Infiltration	Nutrient Cycling
2016	1	68.2	58.5	51.4
2017	1.0	60.8	60.8	55.5
2019	0.96	63.08	49.3	43.6



As can be seen in the table and graph above, there was a significant difference in the reference site LFA indices between 2017 and 2019. The differences in the reference site data between 2016 and 2017 are not enormous and may be within the standard error of the LFA calculations although raw data was unavailable to confirm this. However, the difference between 2017 and 2019 is significant, particularly for infiltration and nutrient cycling.

This difference may be because of different observers performing the LFA surveys (Niche in 2016/17 and Umwelt in 2019), although the LFA methodology is specifically designed to reduce the effect of observer difference when followed correctly. It may also be due to climatic factors which have reduced some of the soil surface indicator scores and thereby the overall indices (Tongway, Pers. Comm. 2019).

Infiltration is derived from perennial cover, litter cover, microtopography, slake test and soil texture. It is unlikely that slake test or soil texture would have changed significantly but perennial cover and litter cover may well have reduced as a result of prolonged drought.

Nutrient cycling is derived from perennial cover, litter cover, biological crust cover and microtopography. Some of these may have changed enough to affect the nutrient cycling index.

Reference site data was reviewed by CPS and Umwelt and it was felt that the decline in the reference site values is most likely a combination of observer differences and a reflection of the drought conditions prevailing since monitoring was begun.

5.2.6 LFA interpretation of site results

5.2.6.1 Landscape of MTW

The rehabilitated landscape at MTW is characterised by high dumps with flat tops and quite steep slopes. The slopes are constructed with contour banks to help control erosion and manage water runoff. The soil is composed of crushed overburden (spoil) which is often affected by alkalinity, salinity and sodicity, or a combination of these and other characteristics. Topsoils are usually thin and often naturally dispersive.

Soil is often covered only by living plants or litter from dried-off grasses and annuals. There is relatively little dead wood or rock cover in rehabilitation areas.

Vegetation growing in this landscape (at least on the sites surveyed during the 2019 monitoring period) is quite variable but it's character changes over the course of the year. Where trees and shrubs are present the canopy and mid-storey cover change little through the year. In grassland sites or sites where trees and shrubs are still in a juvenile state, the vegetation cover and therefore soil protection, is reliant on perennial grasses, sub-shrubs and herbs. Native perennial grasses often dry off during prolonged drought periods and reduce the amount of cover they provide. The herbs and sub shrubs which are successful in early stages of rehabilitation are usually chenopods such as *Atriplex*, *Einadia* and *Enchylaena*. *Einadia* species in particular defoliate and dry off at certain times of year. This means that ground cover on the rehabilitated land can change quite quickly with changes in climatic conditions and result in lower soil cover.

For LFA interpretation this means that sites which appear stable at one point in the year can be exposed to erosion or other negative influence at a different time of year. Because most sites lack coarse woody debris and large rocks a decline in vegetation cover can be particularly problematic.

An increase in mulch, woody debris and large rocks would help to stabilise rehabilitation slopes during times when vegetation cover was decreased and would help to increase and maintain LFA scores.

It is possible that older rehab sites may be declining in LFA measures because of too much competition from shrub and canopy species. This may also be linked to drought conditions which have prevailed in the last two seasons. These two factors, both by themselves and together, could be responsible for a decline in perennial ground cover and litter cover.

5.2.6.2 Assumptions for Landscape Organisation and Surface assessments

Some early stage rehab blocks had very few patches, or many small patches. In some cases where vegetation had not yet established (e.g. WDL201801) the only patches observed were formed by a large rock or piece of timber, or by the contour bank swale. In other cases the patches were often only single perennial plants. In this case larger patches (i.e. large plants or collections of small plants) were counted as patches, whereas single small perennial plants were counted as part of the interpatch.

Eriochloa pseudacrotricha, an annual native grass, was considered to form part of a patch for the purposes of Landscape Organisation. i.e. the plants help to stabilise an area which is overall gaining resources rather than losing them. Even though it is an annual plant it grows year-round and germinates readily on mine sites. However, when conducting surface assessments *E. pseudacrotricha* was counted as litter and not perennial cover.

Chenopods and Galenia form a large proportion of the ground cover on many sites. These plants usually have a central root stock and the stems sprawl or trail across the ground surface. While ground soil cover appears to be high, and one would expect higher LFA scores, these plants contribute less to patch quality than do perennial grasses because of their growth habit. The central root stock contributes less to soil stability than a grass tussock. The soil surface beneath a chenopod or Galenia plant is often crusted and has a lower organic matter content than amongst perennial grasses. This means that while these plants contribute to landscape patches, the patch quality is lower than for a grassy patch, resulting in lower LFA indices.

5.2.6.3 Comparing reference site and mine site scores.

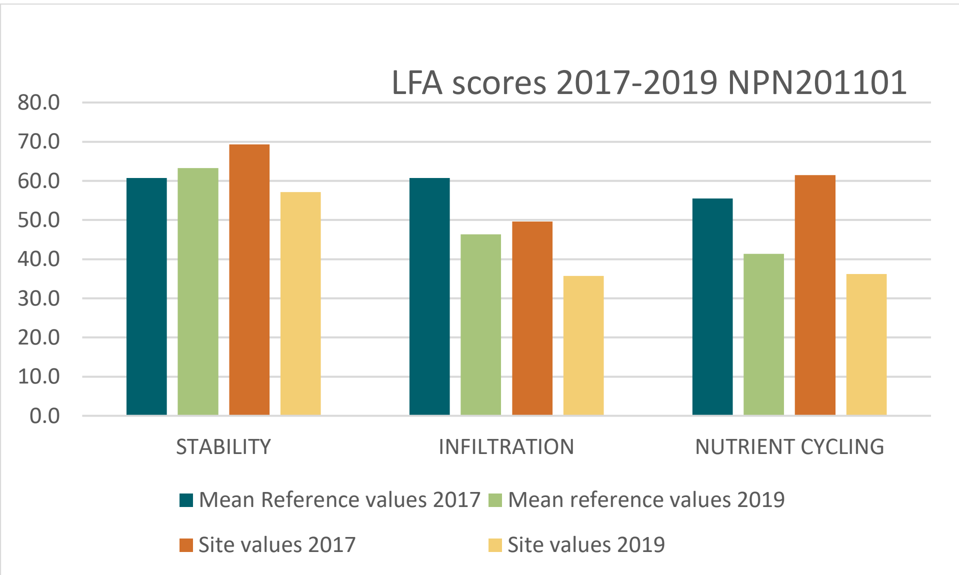
The reference sites are located in areas of remnant woodland and their topography is relatively flat. Water erosion in particular is partly a function of gradient and therefore erosive potential is higher on a steeper slope. Taking this into consideration a lower LFA index on a reference site or on a flat rehabilitation site may be less concerning than a low score on a sloping site.

The sites surveyed in 2019 ranged in age from 2009 to 2018. It would be expected that the older sites would have LFA indices closer to the reference site values. However, in some cases the older rehab sites have lower scores and some of the younger sites are performing much better.

Low LFA scores are not in themselves a problem, so long as they are comparable to reference site values. In the case of sloping sites, however, they may indicate the imminent decline of a site, because of the increased exposure to erosion.

An example of this is NPN201101. This site covers a large area – 43.3 Ha – and stretches from the flat top of the North Pit North Dump down the north west slope of the dump. The monitoring transect is located at the top of this slope and the vegetation here is characterised by well-established Eucalypts and Acacias with a low ground cover of 20% (10% Native Grass cover and 10% exotic grasses). The LFA indices are declining when compared to the 2017 values and because of the slope on this site there is an increased risk of instability.

Native sp. Richness	Native overstorey % cover	Native midstorey % cover	% Ground cover grasses	% Ground cover shrubs	% Ground cover other	% Exotic plant cover	Trees with hollows	Overstorey regeneration	Fallen logs (m)	Stem density (stem/Ha)
31	9	11	10	0	0	10	0	0.3	0	2900



In order to avert a decline at this site the causes of the decline in LFA indices should be addressed. Stability would be increased by the addition of coarse litter which would have

several effects: an increase in soil rain-splash protection (physical protection for the soil surface); provide organic matter for biological activity (increase biological crust protection) and increased soil stability (stability is increase by a higher organic matter content).

Infiltration and nutrient cycling can both be easily increased by the addition of litter, an increase in perennial grass cover and a roughening of the soil surface (microtopography).

At this site these increases could be achieved by mulching or otherwise thinning some of the standing vegetation. This would decrease stem density and reduce competition for perennial grasses and other ground covers. Mulching residue and fallen timber would increase soil litter cover and available organic matter. Soil surface roughness and infiltration could be further increased by ripping or aeration.

It is interesting to note the soil microbial results for this site in the context of the LFA indices.

Indicator/ microbial group	Target range (Recommended by lab)	reference average	MTWNPN 201101
Nutrient solubilisation rate	80.7	62.4	100.0
Nutrient Cycling rate	76.3	79.8	90.5
Disease resistance	82.9	75.0	100.0
Drought resistance	80.7	66.0	100.0
Nutrient accessibility (VAM)	61.7	32.1	100.0
Residue breakdown rate	93.5	95.7	100.0
Overall microbial balance	74.8	75.9	89.5
Total Microbes	50.0	54.9	98.7
Microbial diversity	80.0	37.3	37.8
Protozoa	1.3	1.1	5.8
Mycorrhizal fungi	10.0	3.2	18.6
Gram negative	11.0	6.6	6.8
Fungi:bacteria	2.3		4.4
Methane oxidisers	0.5		0.0
Sulphur reducers	<0.005		0.0
True anaerobes	<0.005		0.5

All the calculated microbial soil indicators are high (at the top of the guide ranges). Fungi are elevated compared to bacteria, which may indicate a lack of available simple organic matter, or an overabundance of resistant organic matter. True anaerobes are elevated which can indicate waterlogging or compaction. This aligns with the low LFA Infiltration index for this site.

Although the soil function indicators supplied by MLA appear to be positive the LFA results do not support this and the site is not performing well on floristic measures (native plant cover).

This brief comparison of LFA, floristic and microbial data suggests that further investigation of the data for this and other declining sites would be warranted.

5.3 Ecosystem and Landuse Sustainability

As can be seen from the table summarising the measurements for this MOP phase many sites are achieving some of the MOP criteria but no site sampled in 2019 achieves all of the criteria. This is not surprising given the age of the sites sampled in 2019. Most sites were less than 10 years old and many considerably younger. This is not enough time to build the vegetation diversity and structure necessary to fulfil the MOP criteria. The monitoring data does, however, give some clues as to which sites may achieve the MOP criteria for this phase with little intervention, and which sites are likely to fail to meet them without significant management.

Particular threats to the future success of the rehabilitation vegetation are:

- Exotic species, particularly perennial grasses
- High stem density of canopy species
- Poor establishment of native species in any layer defined by the MOP

Exotic plant cover was high for many sites sampled in 2019. However, the figures calculated from the field observations may be slightly misleading because of the observation methods used under the Biobanking methodology. The methodology differentiates between threatening and non-threatening exotic species, i.e. those which compete strongly with native plants and will therefore limit their establishment or reduce native cover over time. However, the sampling method does not differentiate between these two types of weeds. Therefore a site with a high Exotic Plant Cover (EPC) score may in fact be infested only with annual species which do not persist well in the rehab landscape and whose cover will decline quite rapidly over time. Conversely another site may have a low EPC score but be infested with exotic perennial species which are long lived, persist well in the rehabilitation environment and pose a serious threat to the establishment of native vegetation.

Further examination of the rehabilitation sites is therefore necessary to properly inform the management decisions for each site.

5.3.1 Habitat Features

Logs, frog ponds, rocks and other habitat features are to be found in some sites, providing valuable habitat complexity. Frog ponds and dams have been constructed across the rehabilitation landscape though these were often observed to be dry. Water was also observed ponding in other locations which may in time become ephemeral wetlands. Logs have been imported at some sites which has resulted in a fallen log score for some very young sites.

6 Conclusions

There has been some success in establishing diverse native vegetation on rehabilitation sites at MTW in spite of the challenges posed by the growth media, the climate and other factors such as weed invasion. However, these challenges are not yet fully overcome and while the landscape function, native plant diversity and cover are promising at some sites, other sites are failing to meet the MOP criteria on one or more measures.

Primary colonising plants have been most successful in establishing on the rehabilitation sites. Whilst diversity is often meeting MOP criteria in the canopy and mid-storey layers the species present are mostly Acacias, with other plant groups poorly represented by comparison. Diversity in the ground layer is good overall and often exceeds the MOP targets the diversity is low in species other than grasses.

Stem density is often too high on older sites, resulting in increased competition pressure for all plant groups in all vegetation layers.

Landscape function analysis may be giving inaccurate results for some sites due to the difference in slope between many rehabilitation sites and that at the reference sites. Further investigation of reference site suitability is warranted. There is also a need to examine the suitability of reference sites for floristic and habitat quality comparison to ensure a meaningful comparison with the target EEC vegetation.

Further investigation and interpretation of results presented in this report would give valuable insights into the future management and revegetation of rehabilitation sites at MTW.

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8 Appendices

8.1 ACARP Project C27038 details (provided by Bill Baxter, MTW)

Project title - Establishing Self-Sustaining Ecological Mine Rehabilitation that Achieves Recognised Ecological Communities.

The objectives of this project are to examine the performance of mine rehabilitation:
- Determine whether mine rehabilitation can support recognisable and self-sustaining ecological communities in temperate woodland Australian environments.
- Determine whether mine rehabilitation can support habitat for a range of threatened fauna species, including bats, birds and mammals.
- Develop a set of principles to inform the establishment of appropriate rehabilitation objectives, performance criteria and completion criteria for the establishment of recognisable and self-sustaining ecological communities (focusing on temperate woodlands).
- Provide guidance to industry to inform the establishment of benchmark successional stage criteria and a monitoring program to guide progressive ecological rehabilitation success or adaptive management.

8.2 Reference site monitoring transect locations

Central Hunter Grey Box-Ironbark Woodland site locations			
Label	**Position**	**Latitude**	**Longitude**
WamboGB01	Start	-32.58711339	150.9672765
WamboGB01	Finish	-32.58749743	150.9670441
WamboGB02	Start	-32.59344382	150.9705852
WamboGB02	Finish	-32.59304192	150.9708286
WARKGB01	Start	-32.58692534	151.0347976
WARKGB01	Finish	-32.58671198	151.0344187
WARKGB02	Start	-32.63008462	151.017324
WARKGB02	Finish	-32.63049866	151.0172723
WARKGB03	Start	-32.64038972	151.0268497
WARKGB03	Finish	-32.64035185	151.0273089
WARKGB04	Start	-32.64778948	151.0311537
WARKGB04	Finish	-32.6474165	151.0309487

Central Hunter Ironbark-Spotted Gum – Grey Box Forest			
Label	**Position**	**Latitude**	**Longitude**
BEL01	Start	-32.64713278	151.2949779
BEL01	Finish	-32.64713456	151.2944448
BEL02	Start	-32.65228506	151.2976595
BEL02	Finish	-32.65244961	151.2979687
BEL03	Start	-32.65465531	151.2990037
BEL03	Finish	-32.65428909	151.2992665
WamboSpot01	Start	-32.60801953	150.9567884
WamboSpot01	Finish	-32.6077463	150.9571782
WamboSpot02	Start	-32.60602176	150.9592737
WamboSpot02	Finish	-32.60563723	150.9594742
WamboSpot03	Start	-32.60913759	150.9567736
WamboSpot03	Finish	-32.60926623	150.9563658

8.3 Rehabilitation monitoring transect locations

Label	Position	Latitude	Long	Label	Position	Latitude	Long
CDC201101	Start	-32.61010468	151.0774038	SPS201601	Start	-32.6186	151.0912
CDC201101	Finish	-32.61002488	151.0769047	SPS201601	Finish	-32.6184	151.0916
CDD201301	Start	-32.61134434	151.0764929	SPS201602	Start	-32.6224	151.0903
CDD201301	Finish	-32.61092369	151.0767044	SPS201602	Finish	-32.6223	151.0908
CDD201401	Start	-32.6084847	151.0698623	SPS201701	Start	-32.6168	151.0886
CDD201401	Finish	-32.6085875	151.0704369	SPS201701	Finish	-32.6168	151.0892
CDD201501	Start	-32.61208847	151.0715007	SPS201703	Start	-32.6263	151.0945
CDD201501	Finish	-32.61245434	151.0718338	SPS201703	Finish	-32.6263	151.0951
CDD201701	Start	-32.60799339	151.0766701	SPS201801	Start	-32.6181	151.0872
CDD201701	Finish	-32.60840302	151.0765095	SPS201801	Finish	-32.618	151.0877
CDD201702	Start	-32.61320028	151.0802058	TDI201501	Start	-32.5932	151.0787
CDD201702	Finish	-32.61277028	151.0803348	TDI201501	Finish	-32.5927	151.0788
CDD201801	Start	-32.60703824	151.0697015	WDL201401	Start	-32.6263	151.0793
CDD201801	Finish	-32.60663066	151.069419	WDL201401	Finish	-32.6262	151.0797
NPN200901	Start	-32.5990188	151.0719939	WDL201402	Start	-32.6277	151.0774
NPN200901	Finish	-32.59891276	151.0715487	WDL201402	Finish	-32.6281	151.0773
NPN201101	Start	-32.59333509	151.0624955	WDL201801	Start	-32.6226	151.0769
NPN201101	Finish	-32.59293763	151.0627616	WDL201801	Finish	-32.6222	151.0773
NPN201301	Start	-32.59860779	151.0611141	MTO200001	Start	-32.6406	151.0869
NPN201301	Finish	-32.59888775	151.060554	MTO200001	Finish	-32.6402	151.0867
NPN201401	Start	-32.59372924	151.0570614	MTO200503	Start	-32.651	151.088
NPN201401	Finish	-32.5934127	151.0567135	MTO200503	Finish	-32.6513	151.0876
NPN201402	Start	-32.59500895	151.0568183	MTO201501	Start	-32.655	151.0955

Label	Position	Latitude	Long	Label	Position	Latitude	Long
NPN201402	Finish	-32.59463553	151.0571272	MTO201501	Finish	-32.6552	151.0959
NPN201601	Start	-32.60155668	151.0702536	NPN200501	Start	-32.6018	151.0799
NPN201601	Finish	-32.60190252	151.0706033	NPN200501	Finish	-32.6022	151.0802
NPN201602	Start	-32.60258237	151.0766643	NPN200502	Start	-32.5951	151.0785
NPN201602	Finish	-32.60240753	151.0771787	NPN200502	Finish	-32.595	151.079
NPN201701	Start	-32.58836595	151.0538148	NPN201403	Start	-32.6017	151.0619
NPN201701	Finish	-32.58796354	151.0537518	NPN201403	Finish	-32.6017	151.0614
NPN201702	Start	-32.60253761	151.0756326	MTO201601	Start	-32.6553	151.0878
NPN201702	Finish	-32.60290734	151.0753384	MTO201601	Finish	-32.6554	151.0884
NPN201703	Start	-32.58637462	151.0530814	MTO201701	Start	-32.6472	151.0741
NPN201703	Finish	-32.58597585	151.0529907	MTO201701	Start	-32.6471	151.0741
NPN201801	Start	-32.59115419	151.0523511	MTO201701	Finish	-32.6472	151.0747
NPN201801	Finish	-32.59075639	151.0524022	MTO201702	Start	-32.6488	151.0764
NPN201802	Start	-32.59886462	151.0573503	MTO201702	Finish	-32.6488	151.0769
NPN201802	Finish	-32.59864904	151.0577882	MTO201703	Start	-32.6507	151.0822
NPN201803	Start	-32.60230129	151.0672283	MTO201703	Finish	-32.6512	151.0822
NPN201803	Finish	-32.60208294	151.067677	MTO201704	Start	-32.6509	151.079
SPN201401	Start	-32.61148693	151.0834588	MTO201704	Finish	-32.6507	151.0795
SPN201401	Finish	-32.61116265	151.0836208	MTO201801	Start	-32.6354	151.0801
SPN201501	Start	-32.61028005	151.0812042	MTO201801	Finish	-32.6352	151.0807
SPN201501	Finish	-32.60991496	151.0815103	MTO201802	Start	-32.6474	151.0729
SPN201601	Start	-32.60762163	151.0831149	MTO201802	Finish	-32.6477	151.0727
SPN201601	Finish	-32.60725653	151.083421	MTO201803	Start	-32.648	151.0732
SPN201602	Start	-32.61506568	151.0863023	MTO201803	Finish	-32.6485	151.0733

Label	Position	Latitude	Long	Label	Position	Latitude	Long
SPN201602	Finish	-32.6150197	151.0868361				
SPN201701	Start	-32.60759903	151.0783467				
SPN201701	Finish	-32.60714393	151.0784705				

8.4 Floristic Data data

8.4.1 Native species recorded at reference sites

Central Hunter Ironbark-Spotted Gum - Grey Box Forest sites

Central Hunter Grey Box Ironbark Woodland sites

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Abutilon oxycarpum						x		x	x			
Acacia amblygona						x		x		x		
Acacia bulgaensis					x							
Acacia decora								x				
Acacia falcata	x	x	x					x				
Acacia implexa				x	x			x	x			
Acacia salicina							x					x
Acacia spp.	x	x	x									
Ajuga australis			x							x		
Allocasuarina luehmannii							x	x	x	x	x	x
Alphitonia excelsa					x							
Amyema spp.								x				
Ancistrachne uncinulata				x	x			x				
Aristida acuta		x										
Aristida ramosa			x			x	x	x	x	x	x	x
Aristida vagans	x	x	x	x	x	x				x	x	x

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Arthropodium sp. B	x	x										
Arthropodium spp.			x		x	x	x	x		x		
Austrostipa scabra						x	x	x	x	x		x
Austrostipa verticillata				x	x							
Boerhavia dominii									x			
Bothriochloa decipiens			x					x	x			
Bothriochloa spp.												x
Brachychiton populneus				x	x	x		x				
Breynia oblongifolia		x	x		x				x			
Brunoniella australis	x	x	x	x	x	x	x	x		x		x
Bursaria spinosa	x		x	x	x	x						
Calocephalus citreus								x				
Calotis cuneifolia	x	x	x					x	x	x	x	x
Calotis lappulacea									x	x		x
Carex inversa											x	
Cassinia quinquefaria									x			
Cassytha pubescens				x								
Cheilanthes distans		x	x	x	x	x	x	x	x	x		x
Cheilanthes sieberi	x	x	x	x	x	x	x	x	x	x	x	x
Chloris truncata								x				
Chloris ventricosa			x					x				x
Choretrum candollei				x	x							

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Chrysocephalum apiculatum								x	x	x		
Clematis glycinoides				x	x				x			
Commelina cyanea			x	x	x		x	x	x	x	x	x
Convolvulus erubescens									x			
Corymbia maculata	x	x	x	x	x	x						
Crassula sieberiana												x
Cymbopogon refractus	x	x	x	x	x	x	x	x	x	x	x	x
Cynodon dactylon											x	x
Cyperus gracilis				x	x		x	x	x	x		x
Cyperus spp.												x
Daviesia ulicifolia											x	
Denhamia silvestris				x								
Desmodium brachypodum	x		x	x	x	x	x	x	x	x		
Desmodium gunnii	x	x	x	x	x	x	x					
Desmodium rhytidophyllum	x											
Desmodium varians	x	x	x	x	x	x		x	x	x	x	x
Dianella caerulea		x										
Dianella longifolia	x		x			x	x			x	x	x
Dianella revoluta	x	x	x	x	x	x	x					
Dianella spp.								x				
Dichondra repens	x	x	x	x	x	x		x	x	x		x
Digitaria parviflora					x							

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Digitaria spp.						x						
Dodonaea boroniifolia						x						
Dodonaea viscosa				x	x	x						
Einadia hastata				x					x			x
Einadia nutans							x	x	x	x	x	x
Enchylaena tomentosa									x			x
Enteropogon acicularis							x	x				x
Entolasia marginata	x	x	x	x								
Entolasia stricta	x	x	x									
Eragrostis brownii											x	x
Eragrostis leptostachya		x		x			x	x	x			x
Eremophila debilis		x	x		x	x	x	x	x	x	x	x
Eriochloa pseudoacrotricha												x
Eucalyptus amplifolia											x	
Eucalyptus crebra				x	x		x		x	x	x	x
Eucalyptus fibrosa	x		x									
Eucalyptus moluccana		x	x			x	x	x				
Eucalyptus punctata				x	x							
Euphorbia drummondii									x		x	
Euphorbia spp												x
Evolvulus alsinoides									x	x		x
Fimbristylis dichotoma								x	x	x		x

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Gahnia aspera		x	x	x	x			x		x		
Galenia pubescens									x			x
Geijera salicifolia								x	x			
Geitonoplesium cymosum						x						
Glossocardia bidens	x		x				x	x	x	x		x
Glycine clandestina		x			x							
Glycine tabacina	x	x	x	x	x	x	x	x	x	x	x	x
Goodenia hederacea											x	
Goodenia rotundifolia	x	x			x					x		x
Grevillea montana						x						
Hardenbergia violacea	x					x						
Heliotropium amplexicaule												x
Hibbertia linearis		x		x	x							
Jacksonia scoparia					x							
Laxmannia gracilis										x	x	x
Lepidium spp								x	x			x
Lepidosperma laterale	x	x										
Linum marginale												x
Lissanthe strigosa	x	x	x									
Lomandra confertifolia				x								
Lomandra filiformis	x	x	x	x	x	x	x	x			x	x
Lomandra glauca				x								

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Lomandra multiflora subsp. multiflora	x	x	x	x	x	x	x	x	x	x	x	
Macrozamia spp.					x							
Maireana enchylaenoides						x	x	x	x			x
Maireana microphylla							x	x	x			
Marsdenia viridiflora	x					x						
Melaleuca decora											x	
Minuria leptophylla							x	x				
Notelaea microcarpa var. microcarpa					x	x		x	x			
Olearia elliptica	x			x	x	x		x				
Opercularia diphylla	x											
Oplismenus aemulus					x							
Oxalis exilis					x			x		x		
Oxalis perennans								x			x	x
Pandorea pandorana						x						
Panicum effusum										x		
Panicum simile				x					x			
Panicum spp.						x						
Paspalidium distans	x	x	x	x	x	x	x	x	x	x	x	
Persoonia linearis				x	x							
Phyllanthus gunnii				x								
Phyllanthus virgatus	x		x	x	x		x	x	x	x		x
Pimelea latifolia subsp. elliptifolia					x							

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Plantago debilis						x						
Plantago spp.								x				
Pomax umbellata	x	x	x									
Pratia purpurascens	x	x	x	x	x							
Psydrax odorata						x						
Pultenaea spinosa	x											
Pultenaea spp.			x									
Rostellularia adscendens								x				
Rytidosperma fulvum			x									
Rytidosperma spp.						x	x	x	x		x	
Rytidosperma tenuius		x										
Sarcostemma australe							x					
Scleria mackaviensis						x						
Sida corrugata				x	x	x	x	x	x	x		
Sida hackettiana					x		x	x	x			
Solanum brownii								x				
Solanum prinophyllum			x		x				x			
Solanum spp.								x				
Spartothamnella juncea		x							x			
Sporobolus creber			x					x	x			
Stackhousia viminea	x			x	x	x	x	x				x
Templetonia stenophylla						x					x	

Species name	BELL01	BELL02	BELL03	WAMBOSPOT03	WAMBOSPOT1	WAMBOSPOT2	WAMBOGB1	WAMBOGB2	WARKGB1	WARKGB2	WARKGB3	WARKGB4
Vernonia cinerea	x	x	x	x					x	x		
Veronica plebeia				x					x	x	x	
Vittadinia spp.					x			x				
Vittadinia sulcata									x			
Wahlenbergia communis								x				
Wahlenbergia gracilis												x
Wahlenbergia spp.					x							
Zornia dyctiocarpa										x		

8.4.2 Reference sites exotic Species presence/absence by site

Genus	Species	BELL1	BELL2	BELL3	WAMBOGB1	WAMBOGB2	WAMBOSPOT3	WAMBOSPOT1	WAMBOSPOT2	WARKGB1	WARKGB2	WARKGB3	WARKGB4	Number of reference sites sp. present
Bidens	*pilosa*										x		x	2
Bidens	*sp.*						x							1
Lantana	*camara*									x				1
Eragrostis	*curvula*												x	1
Gomphocarpus	*fruticosus*			x										1
Gomphrena	*celodioides*				x							x	x	3
Lycium	*ferocissimum*													0
Heliotropium	*amplexicaule*												x	1
Opuntia	*aurantiaca*									x	x	x	x	4
Opuntia	*humifusa*				x					x				2
Pavonia	*hastata*										x			1
Phytolacca	*octandra*													0
Plantago	*lanceolata*												x	1
Polygonum	*arenastrum*													0
Richardia	*stellaris*		x			x							x	3
Senecio	*madagascariensis*				x	x			x	x	x	x	x	7
Olea	*europaea subsp. Cuspidata*	x	x	x										3
Sida	*rhombifolia*												x	1

8.4.3 Exotic species observed on rehabilitation sites

Genus	Species	number of sites Present	CDD201101	CDD201301	CDD201401	CDD201501	CDD201701	CDD201702	CDD201801	MTO201601	MTO201701	MTO201702	MTO201703	MTO201704	MTO201801	MTO201802	MTO201803	WDL201401	WDL201402	WDL201801	TD201501	NPN200901	NPN201101	NPN201301	NPN201401	NPN201601
Galenia	*pubescens*	28		x	x		x	x	x		x		x	x	x	x	x				x			x	x	x
Chloris	*gayana*	31	x		x	x	x	x	x	x	x	x	x	x			x	x	x		x		x	x	x	
Chloris	*virgata*	20			x				x		x			x			x		x	x	x			x		x
Sida	*rhombifolia*	23	x				x	x	x					x				x	x	x		x	x			x
Brassica	*rapa*	20		x										x				x	x			x		x		x
Setaria	*parviflora*	21	x				x		x				x	x				x	x		x	x	x	x	x	
Panicum	*maximum var. trichoglume*	15		x	x		x						x						x	x	x			x		
Senecio	*madagascariensi s*	17	x	x	x	x					x		x			x			x	x	x				x	
Echinochloa	*crus-galli*	12		x						x						x			x							
Solanum	*nigrum*	12		x					x							x				x						x
Euphorbia	*sp.*	11			x											x			x	x						x
Sida	*spinosa*	11							x				x	x						x						x
Acacia	*saligna*	9								x	x	x	x			x			x				x			
Eragrostis	*parviflora*	8					x													x				x		
Lysimachia	*arvensis*	8		x					x						x	x									x	
Malva	*parviflora*	8						x		x			x						x							x
Modiola	*caroliniana*	10	x		x				x						x							x				x
Urochloa	*panicoides*	8			x			x						x												x
Bidens	*pilosa*	8			x			x				x			x			x								
Conyza	*bonariensis*	9				x					x		x					x			x					
Paspalum	*dilatatum*	8				x			x										x							
Eragrostis	*curvula*	8	x						x						x					x			x			
Phytolacca	*octandra*	6									x					x										
Aster	*subulatus*	5									x						x		x		x					
Chenopodium	*album*	6						x					x					x		x						
Medicago	*sp.*	5								x						x	x			x						
Melinus	*repens*	6				x								x									x			
Plantago	*lanceolata*	7	x			x						x				x							x			
Schkuhria	*pinnata*	6		x				x	x						x								x			

Genus	Species	number of sites Present	CDD201101	CDD201301	CDD201401	CDD201501	CDD201701	CDD201702	CDD201801	MTO201601	MTO201701	MTO201702	MTO201703	MTO201704	MTO201801	MTO201802	MTO201803	WDL201401	WDL201402	WDL201801	TD201501	NPN200901	NPN201101	NPN201301	NPN201401	NPN201601
Sonchus	*asper*	5		x													x		x							
Cenchrus	*clandestinus*	4											x													
Richardia	*brasiliensis*	4					x																			
Echinochloa	*esculenta (utilis)*	3												x	x		x									
Gomphocarpus	*fruticosus*	6	x							x			x									x	x			
Macroptilium	*atropurpureum*	3																								
Medicago	*sativa*	3			x				x																	
Bromus	*sp.*	2														x										
Opuntia	*humifusa*	2																						x		
Panicum	*antidotale*	1																		x						
Panicum	*capillare*	2												x												
Amaranthus	*sp.*	1																								
Cichorium	*intybus*	1																								
Cirsium	*vulgare*	1			x																					
Digitaria	*cilliaris*	1															x									
Eleusine	*tristachya*	1																								
Lycium	*ferocissimum*	1							x																	
Polygonum	*arenastrum*	1																								
Rumex	*sp.*	1																								x
Sisymbrium	*sp.*	1								x																
Trifolium	*repens*	1																								
Verbena	*bonariensis*	2																					x			

Genus	Species	number of sites sp. Present	NPN201602	NPN201701	NPN201702	NPN201703	NPN201801	NPN201802	NPN201803	SPN201401	SPN201501	SPN201601	SPN201602	SPN201701	SPS201601	SPS201602	SPS201701	SPS201703	SPS201801
Galenia	*pubescens*	28	x	x			x	x	x	x	x	x	x	x	x	x	x		
Chloris	*gayana*	31	x	x	x		x	x	x	x	x		x	x	x	x	x		
Chloris	*virgata*	20	x	x			x		x		x	x		x		x	x		x
Sida	*rhombifolia*	23		x		x		x		x	x	x	x	x		x	x	x	x
Brassica	*rapa*	20			x	x		x	x	x	x		x	x	x	x	x	x	x
Setaria	*parviflora*	21	x			x		x			x		x		x	x	x	x	
Panicum	*maximum var. trichoglume*	15					x			x	x	x				x	x		x
Senecio	*madagascariensis*	17	x		x					x			x			x		x	
Echinochloa	*crus-galli*	12		x		x	x	x	x					x		x			x
Solanum	*nigrum*	12	x	x		x	x	x			x					x			
Euphorbia	*sp.*	11		x							x				x	x	x		x
Sida	*spinosa*	11		x			x		x		x	x				x			
Acacia	*saligna*	9													x	x			
Eragrostis	*parviflora*	8			x									x		x		x	x
Lysimachia	*arvensis*	8						x		x						x			
Malva	*parviflora*	8		x												x			x
Modiola	*caroliniana*	10					x	x		x			x						
Urochloa	*panicoides*	8								x	x	x			x				
Bidens	*pilosa*	8	x									x				x			
Conyza	*bonariensis*	9			x					x	x					x			
Paspalum	*dilatatum*	8		x				x	x							x		x	
Eragrostis	*curvula*	8	x									x				x			
Phytolacca	*octandra*	6			x		x	x						x					
Aster	*subulatus*	5	x																
Chenopodium	*album*	6		x															x
Medicago	*sp.*	5																x	

Genus	Species	number of sites sp. Present	NPN201602	NPN201701	NPN201702	NPN201703	NPN201801	NPN201802	NPN201803	SPN201401	SPN201501	SPN201601	SPN201602	SPN201701	SPS201601	SPS201602	SPS201701	SPS201703	SPS201801
Melinus	*repens*	6			x		x									x			
Plantago	*lanceolata*	7			x	x													
Schkuhria	*pinnata*	6						x											
Sonchus	*asper*	5								x						x			
Cenchrus	*clandestinus*	4		x												x		x	
Richardia	*brasiliensis*	4					x						x	x					
Echinochloa	*esculenta (utilis)*	3																	
Gomphocarpus	*fruticosus*	6	x																
Macroptilium	*atropurpureum*	3									x				x			x	
Medicago	*sativa*	3																x	
Bromus	*sp.*	2																x	
Opuntia	*humifusa*	2					x												
Panicum	*antidotale*	1																	
Panicum	*capillare*	2										x							
Amaranthus	*sp.*	1				x													
Cichorium	*intybus*	1														x			
Cirsium	*vulgare*	1																	
Digitaria	*cilliaris*	1																	
Eleusine	*tristachya*	1						x											
Lycium	*ferocissimum*	1																	
Polygonum	*arenastrum*	1							x										
Rumex	*sp.*	1																	
Sisymbrium	*sp.*	1																	
Trifolium	*repens*	1				x													
Verbena	*bonariensis*	2																	x

8.4.4 Native species observed on rehabilitation sites

Vegetation layer	Genus	Species	number of rehab sites sp. Present	CDD201101	CDD201301	CDD201401	CDD201501	CDD201701	CDD201702	CDD201801	TD201501	WDL201402	WDL201801	WLD201401	MTO201601	MTO201701	MTO201702	MTO201703	MTO201704	MTO201801	MTO201802	MTO201803
Tree	*Acacia*	*implexa*	14	x			x			x				x		x						
Tree	*Acacia*	*salicina*	18	x	x		x	x			x	x		x							x	
Tree	*Corymbia*	*maculata*	19	x			x			x	x			x		x			x			x
Tree	*Eucalyptus*	*crebra*	10	x			x							x		x			x			x
Tree	*Eucalyptus*	*dawsonii?*	5							x				x		x						x
Tree	*Eucalyptus*	*fibrosa*	7	x			x				x	x										
Tree	*Eucalyptus*	*moluccana*	11	x			x				x		x	x								
Tree	*Eucalyptus*	*punctata*	1				x															
Tree	*Eucalyptus*	*spp.*	1											x								
Tree	*Eucalyptus*	*tereticornis?*	2																x			
Tree	*Eucalyptus*	*sp.*	3																			
Shrub	*Acacia*	*amblygona*	23	x			x	x	x	x		x	x	x					x			
Shrub	*Acacia*	*binervata*	1				x															
Shrub	*Acacia*	*cultriformis*	19	x		x	x	x	x	x		x		x		x			x			
Shrub	*Acacia*	*deanei*	2	x			x															
Shrub	*Acacia*	*decora*	22			x	x	x		x		x		x		x			x			
Shrub	*Acacia*	*decurrens*	1																			
Shrub	*Acacia*	*falcata*	13				x			x		x		x		x			x			
Shrub	*Acacia*	*filicifolia*	2							x												
Shrub	*Acacia*	*leiocalyx*	2																			
Shrub	*Acacia*	*linearifolia?*	6							x		x						x				
Shrub	*Acacia*	*longifolia*	3	x			x															
Shrub	*Acacia*	*paradoxa*	8													x		x	x			
Shrub	*Acacia*	*parvipinnula*	5																			
Shrub	*Acacia*	*sp.*	6																			
Shrub	*Acacia*	*spectabilis*	13	x			x	x	x	x									x			
Shrub	*Allocasuarina*	*sp.*	1				x															
Shrub	*Cassinia*	*uncata*	3																x			

Vegetation layer	Genus	Species	number of rehab sites sp. Present	CDD201101	CDD201301	CDD201401	CDD201501	CDD201701	CDD201702	CDD201801	TD201501	WDL201402	WDL201801	WLD201401	MTO201601	MTO201701	MTO201702	MTO201703	MTO201704	MTO201801	MTO201802	MTO201803
Shrub	*Daviesia*	*genistifolia*	1																			
Shrub	*Daviesia*	*ulicifolia*	2																			
Shrub	*Dodonaea*	*viscosa subsp. cuneata*	16			x		x		x									x			
Shrub	*Indigofera*	*australis*	10			x				x									x			
Shrub	*Myoporum*	*montanum*	5													x						
Shrub	*Olearia*	*elliptica*	1													x						
Shrub	*Salsola*	*australis*	9					x						x								
Shrub	*Sclerolaena*	*muricata var. muricata*	1																			
Shrub	*Senna*	*artemisioides subsp. zygophylla*	1																			
GL shrub	*Atriplex*	*semibaccata*	30	x		x	x	x	x	x	x	x	x	x		x	x	x			x	x
GL shrub	*Einadia*	*nutans*	23	x		x		x	x	x	x		x			x	x	x	x		x	x
GL shrub	*Einadia*	*nutans subsp. linifolia*	1											x								
GL shrub	*Einadia*	*nutans subsp. nutans*	1											x								
GL shrub	*Enchylaena*	*tomentosa*	25	x		x	x	x	x	x	x	x		x		x		x	x		x	x
GL shrub	*Hardenbergia*	*violaceaea*	14			x	x			x				x		x			x			
GL shrub	*Lotus*	*australis*	2																			
GL shrub	*Sida*	*hackettiana*	4																			
GL Shrub	*Solanum*	*cinereum*	18			x		x		x						x			x			x
GL Shrub	*Solanum*	*sp.*	1	x																		
Grass	*Aristida*	*ramosa*	7				x		x					x								
Grass	*Austrostipa*	*ramosissima*	12							x						x	x	x	x			x
Grass	*Austrostipa*	*scabra*	9				x												x			
Grass	*Austrostipa*	*sp.*	2																			
Grass	*Bothriochloa*	*biloba*	2																			
Grass	*Bothriochloa*	*decipiens*	23	x			x	x		x	x	x	x	x					x			x
Grass	*Capillipedium*	*spicigerum*	23	x			x	x	x	x		x	x			x		x	x			x
Grass	*Chloris*	*truncata*	39	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Grass	*Chloris*	*ventricosa*	21				x	x	x	x		x		x		x		x	x		x	x

Vegetation layer	Genus	Species	number of rehab sites sp. Present	CDD201101	CDD201301	CDD201401	CDD201501	CDD201701	CDD201702	CDD201801	TD201501	WDL201402	WDL201801	WLD201401	MTO201601	MTO201701	MTO201702	MTO201703	MTO201704	MTO201801	MTO201802	MTO201803
Grass	*Cymbopogon*	*refractus*	14				x	x	x	x			x	x			x		x			
Grass	*Cynodon*	*dactylon*	25				x	x	x			x	x	x	x			x	x	x	x	
Grass	*Dactyloctenium*	*radulans*	10		x				x			x	x						x			
Grass	*Dichanthium*	*sericeum*	31	x		x	x	x	x	x	x		x	x				x	x			x
Grass	*Digitaria*	*brownii*	8					x	x	x									x			
Grass	*Digitaria*	*diffusa*	2																			
Grass	*Digitaria*	*divaricatissima*	22				x			x		x		x		x	x	x	x			x
Grass	*Digitaria*	*spp.*	1																			
Grass	*Eragrostis*	*benthamii*	1																			
Grass	*Eragrostis*	*brownii*	6	x			x	x		x												
Grass	*Eragrostis*	*leptostachya*	13				x	x	x				x	x		x			x			
Grass	*Eragrostis*	*sp.*	3														x					
Grass	*Eriochloa*	*procera*	10								x	x	x									
Grass	*Eriochloa*	*pseudacrotricha*	31	x		x	x	x	x	x		x		x		x	x	x	x		x	x
Grass	*Heteropogon*	*contortus*	1																			
Grass	*Panicum*	*effusum*	12				x					x	x	x								
Grass	*Panicum*	*queenslandicum*	19					x	x	x		x				x	x		x		x	x
Grass	*Panicum*	*simile?*	1																			
Grass	*Paspalidium*	*breviflorum*	8					x		x												
Grass	*Paspalidium*	*distans*	2	x																		
Grass	*Perotis*	*rara*	1																			
Grass	*Rytidosperma*	*richardsonii*	4					x								x						
Grass	*Rytidosperma*	*tenuius*	2	x			x															
Grass	*Sporobolus*	*creber*	28	x			x	x	x	x	x			x	x	x		x	x		x	x
Grass	*Themeda*	*triandra*	9	x			x	x		x												
Forb	*Alternanthera*	*denticulata*	1																			
Forb	*Asteraceae*	*sp.*	1																			
Forb	*Brachyscome*	*sp.*	1											x								
Forb	*Calotis*	*cuneifolia*	4							x												

Vegetation layer	Genus	Species	number of rehab sites sp. Present	CDD201101	CDD201301	CDD201401	CDD201501	CDD201701	CDD201702	CDD201801	TD201501	WDL201402	WDL201801	WLD201401	MTO201601	MTO201701	MTO201702	MTO201703	MTO201704	MTO201801	MTO201802	MTO201803
Forb	*Calotis*	*lappulacea*	11			x		x						x					x			
Forb	*Cheilanthes*	*sieberi*	1																			
Forb	*Commelina*	*cyanaea*	1																			
Forb	*Convolvulus*	*erubescens*	0																			
Forb	*Convolvulus*	*gramenitinus*	4																x		x	
Forb	*Cyperus*	*aggregatus*	1	x																		
Forb	*Cyperus*	*gracilis*	1											x								
Forb	*Cyperus*	*sp.*	3																			
Forb	*Cyperus*	*sp. II*	1																			
Forb	*Desmodium*	*brachypodum*	2																x			
Forb	*Dichondra*	*repens*	6	x	x																	
Forb	*Dysphania*	*pumilio*	3		x																	x
Forb	*Einadia*	*hastata*	2				x			x												
Forb	*Einadia*	*polygonoides*	18					x	x	x			x			x	x	x	x		x	
Forb	*Einadia*	*trigonos*	27					x	x	x		x	x			x	x	x	x		x	x
Forb	*Eremophila*	*debilis*	3																			
Forb	*Erodium*	*crinitum*	10	x						x									x	x	x	
Forb	*Euphorbia*	*dallachyiana*	1	x																		
Forb	*Euphorbia*	*SPP.*	0																			
Forb	*Evolvulus*	*alcinoides*	3																			
Forb	*Geranium*	*sp.*	1		x																	
Forb	*Glycine*	*clandestina*	2																			
Forb	*Glycine*	*tabacina*	10	x															x			
Forb	*Lepidium*	*sp.*	16		x	x		x			x	x				x	x				x	
Forb	*Oxalis*	*perennans*	4	x		x																
Forb	*Phyllanthus*	*virgatus*	3	x																		
Forb	*Portulaca*	*oleracea*	12		x						x			x	x	x			x		x	
Forb	*Sida*	*corrugata*	5	x																		
Forb	*Sida*	*hackettiana*	1											x								

Vegetation layer	Genus	Species	number of rehab sites sp. Present	CDD201101	CDD201301	CDD201401	CDD201501	CDD201701	CDD201702	CDD201801	TD201501	WDL201402	WDL201801	WLD201401	MTO201601	MTO201701	MTO201702	MTO201703	MTO201704	MTO201801	MTO201802	MTO201803
Forb	*Vernonia*	*sp.*	2																			
Forb	*Vittadinia*	*cuneata*	15			x		x	x	x						x		x	x			
Forb	*Vittadinia*	*muelleri*	3					x														
Forb	*Vittadinia*	*sp.*	0																			
Forb	*Wahlenbergia*	*communis*	1																			

Vegetation layer	Genus	Species	NPN200901	NPN201101	NPN201301	NPN201401	NPN201601	NPN201602	NPN201701	NPN201702	NPN201703	NPN201801	NPN201802	NPN201803	SPN201401	SPN201501	SPN201601	SPN201602	SPN201701	SPS201601	SPS201602	SPS201701	SPS201703	SPS201801
Tree	*Acacia*	*implexa*		x	x	x		x	x			x		x				x				x		
Tree	*Acacia*	*salicina*		x	x	x	x		x			x	x				x				x	x		
Tree	*Corymbia*	*maculata*	x		x			x	x	x		x	x	x				x	x			x		
Tree	*Eucalyptus*	*crebra*	x	x				x								x								
Tree	*Eucalyptus*	*dawsonii?*														x								
Tree	*Eucalyptus*	*fibrosa*	x	x						x														
Tree	*Eucalyptus*	*moluccana*	x	x												x					x		x	x
Tree	*Eucalyptus*	*punctata*																						
Tree	*Eucalyptus*	*spp.*																						
Tree	*Eucalyptus*	*tereticornis?*																x						
Tree	*Eucalyptus*	*sp.*		x						x				x										
Shrub	*Acacia*	*amblygona*	x	x	x	x		x	x		x	x	x					x	x	x	x	x		
Shrub	*Acacia*	*binervata*																						
Shrub	*Acacia*	*cultriformis*		x	x	x		x	x			x	x	x		x								
Shrub	*Acacia*	*deanei*																						
Shrub	*Acacia*	*decora*	x	x	x	x		x	x			x	x	x	x	x		x		x	x			
Shrub	*Acacia*	*decurrens*	x																					
Shrub	*Acacia*	*falcata*			x			x	x			x	x						x			x		
Shrub	*Acacia*	*filicifolia*										x												
Shrub	*Acacia*	*leiocalyx*			x			x																
Shrub	*Acacia*	*linearifolia?*				x			x				x											
Shrub	*Acacia*	*longifolia*											x											
Shrub	*Acacia*	*paradoxa*			x	x		x									x		x					
Shrub	*Acacia*	*parvipinnula*			x	x		x					x	x										
Shrub	*Acacia*	*sp.*	x					x			x	x	x			x								
Shrub	*Acacia*	*spectabilis*							x	x		x	x					x			x	x		

Vegetation layer	Genus	Species	NPN200901	NPN201101	NPN201301	NPN201401	NPN201601	NPN201602	NPN201701	NPN201702	NPN201703	NPN201801	NPN201802	NPN201803	SPN201401	SPN201501	SPN201601	SPN201602	SPN201701	SPS201601	SPS201602	SPS201701	SPS201703	SPS201801
Shrub	*Allocasuarina*	*sp.*																						
Shrub	*Cassinia*	*uncata*				x											x							
Shrub	*Daviesia*	*genistifolia*										x												
Shrub	*Daviesia*	*ulicifolia*		x				x																
Shrub	*Dodonaea*	*viscosa subsp. cuneata*		x		x			x	x		x	x	x		x		x	x			x	x	
Shrub	*Indigofera*	*australis*			x	x		x	x				x			x						x		
Shrub	*Myoporum*	*montanum*							x									x	x			x		
Shrub	*Olearia*	*elliptica*																						
Shrub	*Salsola*	*australis*		x			x	x	x	x				x						x				
Shrub	*Sclerolaena*	*muricata var. muricata*																	x					
Shrub	*Senna*	*artemisioides subsp. zygophylla*				x																		
GL shrub	*Atriplex*	*semibaccata*			x			x	x	x	x		x	x	x	x	x	x	x		x	x		x
GL shrub	*Einadia*	*nutans*						x		x				x	x			x	x	x	x	x		x
GL shrub	*Einadia*	*nutans subsp. linifolia*																						
GL shrub	*Einadia*	*nutans subsp. nutans*																						
GL shrub	*Enchylaena*	*tomentosa*		x		x	x	x	x	x	x	x	x	x				x						
GL shrub	*Hardenbergia*	*violaceaea*			x	x		x				x	x	x					x				x	
GL shrub	*Lotus*	*australis*										x		x										
GL shrub	*Sida*	*hackettiana*			x						x						x		x					
GL Shrub	*Solanum*	*cinereum*					x	x		x		x	x	x		x		x	x	x		x	x	
GL Shrub	*Solanum*	*sp.*																						
Grass	*Aristida*	*ramosa*		x						x	x						x							
Grass	*Austrostipa*	*ramosissima*			x	x				x						x			x			x		
Grass	*Austrostipa*	*scabra*			x	x		x		x		x		x			x							

Vegetation layer	Genus	Species	NPN200901	NPN201101	NPN201301	NPN201401	NPN201601	NPN201602	NPN201701	NPN201702	NPN201703	NPN201801	NPN201802	NPN201803	SPN201401	SPN201501	SPN201601	SPN201602	SPN201701	SPS201601	SPS201602	SPS201701	SPS201703	SPS201801
Grass	*Austrostipa*	*sp.*			x												x							
Grass	*Bothriochloa*	*biloba*											x			x								
Grass	*Bothriochloa*	*decipiens*	x	x	x	x			x		x	x	x		x	x		x	x		x			
Grass	*Capillipedium*	*spicigerum*				x			x	x		x	x	x		x	x	x	x		x	x		
Grass	*Chloris*	*truncata*		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Grass	*Chloris*	*ventricosa*					x			x	x	x	x	x		x			x		x	x		
Grass	*Cymbopogon*	*refractus*	x							x		x	x	x							x			
Grass	*Cynodon*	*dactylon*		x	x	x	x		x	x	x		x		x			x		x		x	x	x
Grass	*Dactyloctenium*	*radulans*					x					xs							x		x	x		x
Grass	*Dichanthium*	*sericeum*		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Grass	*Digitaria*	*brownii*					x				x			x			x							
Grass	*Digitaria*	*diffusa*										x	x											
Grass	*Digitaria*	*divaricatissima*	x		x		x		x	x	x	x	x	x		x			x		x	x		
Grass	*Digitaria*	*spp.*	x																					
Grass	*Eragrostis*	*benthamii*										x												
Grass	*Eragrostis*	*brownii*											x						x					
Grass	*Eragrostis*	*leptostachya*								x			x			x			x			x	x	
Grass	*Eragrostis*	*sp.*										x	x											
Grass	*Eriochloa*	*procera*							x						x	x				x	x		x	x
Grass	*Eriochloa*	*pseudacrotricha*		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x		
Grass	*Heteropogon*	*contortus*				x																		
Grass	*Panicum*	*effusum*		x				x				x			x						x	x	x	x
Grass	*Panicum*	*queenslandicum*						x	x	x		x	x	x		x		x	x			x		

Vegetation layer	Genus	Species	NPN200901	NPN201101	NPN201301	NPN201401	NPN201601	NPN201602	NPN201701	NPN201702	NPN201703	NPN201801	NPN201802	NPN201803	SPN201401	SPN201501	SPN201601	SPN201602	SPN201701	SPS201601	SPS201602	SPS201701	SPS201703	SPS201801
Grass	*Panicum*	*simile?*										x												
Grass	*Paspalidium*	*breviflorum*						x				x	x			x		x	x					
Grass	*Paspalidium*	*distans*	x																					
Grass	*Perotis*	*rara*										x												
Grass	*Rytidosperma*	*richardsonii*				x													x					
Grass	*Rytidosperma*	*tenuius*																						
Grass	*Sporobolus*	*creber*		x	x			x	x	x	x	x	x			x	x	x	x		x	x		x
Grass	*Themeda*	*triandra*		x		x						x		x		x								
Forb	*Alternanthera*	*denticulata*								x														
Forb	*Asteraceae*	*sp.*																			x			
Forb	*Brachyscome*	*sp.*																						
Forb	*Calotis*	*cuneifolia*														x	x	x						
Forb	*Calotis*	*lappulacea*				x			x								x	x	x		x	x		
Forb	*Cheilanthes*	*sieberi*	x																					
Forb	*Commelina*	*cyanaea*										x												
Forb	*Convolvulus*	*erubescens*																						
Forb	*Convolvulus*	*gramenitinus*							x													x		
Forb	*Cyperus*	*aggregatus*																						
Forb	*Cyperus*	*gracilis*																						
Forb	*Cyperus*	*sp.*										x	x					x						
Forb	*Cyperus*	*sp. II*										x												
Forb	*Desmodium*	*brachypodum*		x																				
Forb	*Dichondra*	*repens*	x	x							x				x									

Vegetation layer	Genus	Species	NPN200901	NPN201101	NPN201301	NPN201401	NPN201601	NPN201602	NPN201701	NPN201702	NPN201703	NPN201801	NPN201802	NPN201803	SPN201401	SPN201501	SPN201601	SPN201602	SPN201701	SPS201601	SPS201602	SPS201701	SPS201703	SPS201801
Forb	*Dysphania*	*pumilio*										x												
Forb	*Einadia*	*hastata*																						
Forb	*Einadia*	*polygonoides*							x				x		x	x	x	x	x			x		x
Forb	*Einadia*	*trigonos*			x	x	x		x	x	x	x	x	x			x	x	x	x	x	x		x
Forb	*Eremophila*	*debilis*	x			x							x											
Forb	*Erodium*	*crinitum*	x		x						x					x	x							
Forb	*Euphorbia*	*dallachyiana*																						
Forb	*Euphorbia*	*SPP.*																						
Forb	*Evolvulus*	*alcinoides*											x		x			x						
Forb	*Geranium*	*sp.*																						
Forb	*Glycine*	*clandestina*										x	x											
Forb	*Glycine*	*tabacina*	x	x	x							x	x						x		x	x		
Forb	*Lepidium*	*sp.*				x					x		x	x	x	x						x	x	
Forb	*Oxalis*	*perennans*	x												x									
Forb	*Phyllanthus*	*virgatus*	x										x											
Forb	*Portulaca*	*oleracea*						x								x		x	x	x				
Forb	*Sida*	*corrugata*	x								x						x		x					
Forb	*Sida*	*hackettiana*																						
Forb	*Vernonia*	*sp.*		x													x							
Forb	*Vittadinia*	*cuneata*		x			x		x	x	x								x			x		x
Forb	*Vittadinia*	*muelleri*								x														x
Forb	*Vittadinia*	*sp.*																						
Forb	*Wahlenbergia*	*communis*		x																				

Central Hunter Ironbark-Spotted Gum-Grey Box forest reference sites

Rehabilitation Monitoring Report 2019

Figure 1

031123_F1_RehabMon_2019_190703_v01

Warkworth Mine

Central Hunter Grey Box-Ironbark Woodland reference sites

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Figure 2

031123_F2_RehabMon_2019_190703_v01

Central Hunter Ironbark-Spotted Gum-Grey Box forest reference sites

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Figure 3

031123_F3_RehabMon_2019_190703_v01

Central Hunter Grey Box-Ironbark Woodland reference sites

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Figure 4

031123_F4_RehabMon_2019_190703_v01

CD Dump, South Pit North and South monitoring sites

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Figure 5

031123_F5_RehabMon_2019_190704_v01

Mount Thorley Operation monitoring transect locations

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Figure 6

031123_F6_RehabMon_2019_190704_v01

North Pit North/ Tailings Dam 1 monitoring transect locations

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Figure 7

031123_F7_RehabMon_2019_190704_v01

Woodlands monitoring transect locations

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Figure 8

031123_F8_RehabMon_2019_190704_v01

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

			Sample 1	Sample 2	Sample 3	Sample 41	Sample 1A
		Sample ID:	BEL01	BEL02	BEL03	WAMBOGB01	Wambog602
		Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Area
		Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	Mount Thorley Warkworth
Parameter		**Method reference**	I2408/1	I2408/2	I2408/3	I2408/41	I3218/1
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	268	636	438	505	788
Soluble Magnesium (mg/kg)			363	172	334	433	494
Soluble Potassium (mg/kg)			155	113	156	138	189
Soluble Phosphorus (mg/kg)			2.2	2.4	1.8	3.6	2.2
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	2.1	1.2	1.4	6.5	4.1
		**Rayment & Lyons 2011 - 9B2 (Colwell)	6.2	5.2	4.9	15	13
		**Inhouse S3A (Bray 2)	3.6	2.3	2.3	15	6
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	2.3	3.6	5.0	11	24.1
Ammonium Nitrogen (mg/kg N)			9.7	5.4	7.6	5.7	5.2
Sulfur (mg/kg S)			16	12	15	30	16.0
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	5.39	5.85	5.59	5.52	5.98
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.082	0.049	0.089	0.121	0.152
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	8.7	4.7	7.5	6.3	5.3
Exchangeable Calcium	**(cmol$_+$/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	3.01	6.08	4.60	5.23	7.93
	(kg/ha)		1353	2731	2065	2347	3558
	(mg/kg)		604	1219	922	1048	1588
Exchangeable Magnesium	**(cmol$_+$/kg)**		4.47	1.89	4.08	6.09	6.51
	(kg/ha)		1216	516	1110	1657	1773
	(mg/kg)		543	230	495	740	792
Exchangeable Potassium	**(cmol$_+$/kg)**		0.71	0.45	0.75	0.79	0.99
	(kg/ha)		622	396	659	691	864
	(mg/kg)		278	177	294	309	386
Exchangeable Sodium	**(cmol$_+$/kg)**		0.45	0.15	0.53	0.71	0.67
	(kg/ha)		230	76	271	365	347
	(mg/kg)		103	34	121	163	155
Exchangeable Aluminium	**(cmol$_+$/kg)**	**Inhouse S37 (KCl)	0.18	0.10	0.11	0.01	<0.01
	(kg/ha)		36	20	22	2	1
	(mg/kg)		16	9	10	<1	<1
Exchangeable Hydrogen	**(cmol$_+$/kg)**	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	0.13	<0.01	0.01	0.08	0.02
	(kg/ha)		3	<1	<1	2	<1
	(mg/kg)		1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol$_+$/kg)	8.94	8.67	10.08	12.91	16.13
Calcium (%)		**Base Saturation Calculations - Cation cmol$_+$/kg / ECEC x 100	33.7	70.1	45.6	40.5	49.1
Magnesium (%)			49.9	21.8	40.5	47.2	40.4
Potassium (%)			7.9	5.2	7.5	6.1	6.1
Sodium - ESP (%)			5.0	1.7	5.2	5.5	4.2
Aluminium (%)			2.0	1.1	1.1	0.1	0.0
Hydrogen			1.4	0.0	0.1	0.6	0.1
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol$_+$/kg)	0.7	3.2	1.1	0.9	1.2

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50 Gipps Street CARRINGTON NSW 2294

		Sample 1	Sample 2	Sample 3	Sample 41	Sample 1A
	Sample ID:	BEL01	BEL02	BEL03	WAMBOGB01	Wambog602
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Area
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	Mount Thorley Warkworth
Parameter	**Method reference**	**I2408/1**	**I2408/2**	**I2408/3**	**I2408/41**	**I3218/1**
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	6.4	4.6	5.7	4.5	3.8
Manganese (mg/kg)		23	10.3	10.4	16	18
Iron (mg/kg)		369	126	327	99	67
Copper (mg/kg)		0.3	0.4	0.4	0.6	0.3
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.58	0.55	0.67	0.56	0.45
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	25	24	29	53	51
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	4.96	2.71	4.29	3.59	3.02
Total Nitrogen (%)		0.24	0.16	0.24	0.23	0.23
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	20.6	16.7	17.8	15.5	13.1
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	
Basic Colour		Brownish	Brownish	Brownish	Brownish	
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	53	31	57	78	97
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	1,146	1,975	1,267	1,811	2,158
Total Magnesium (mg/kg)		1,294	768	1,029	1,516	1,838
Total Potassium (mg/kg)		1,477	1,099	1,316	1,472	1,888
Total Sodium (mg/kg)		155	73	146	235	229
Total Sulfur (mg/kg)		228	163	203	213	205
Total Phosphorus (mg/kg)		176	119	166	244	202
Total Zinc (mg/kg)		38	38	27	37	40
Total Manganese (mg/kg)		131	177	110	260	334
Total Iron (mg/kg)		11,767	7,983	11,487	16,672	12,861
Total Copper (mg/kg)		4.9	10.8	4.4	7.9	7.4
Total Boron (mg/kg)		3.1	<2	<2	2.9	14
Total Silicon (mg/kg)		1,519	1,291	1,386	1,974	1,881
Total Aluminium (mg/kg)		6,048	4,874	6,056	7,826	8,215
Total Molybdenum (mg/kg)		0.4	0.2	0.4	0.8	0.8
Total Cobalt (mg/kg)		11.7	13.9	13.8	3.3	5
Total Selenium (mg/kg)		0.8	0.5	0.6	<0.5	0.5
Total Cadmium (mg/kg)		<0.5	<0.5	<0.5	<0.5	<0.5
Total Lead (mg/kg)		11	11	12	11	13
Total Arsenic (mg/kg)		5.0	2.8	5.4	8.8	7
Total Chromium (mg/kg)		11	8.3	10.2	7.4	7
Total Nickel (mg/kg)		10	8.4	8.7	5.5	5
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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50 Gipps Street CARRINGTON NSW 2294

		Sample 1	Sample 2	Sample 3	Sample 41	Sample 1A
	Sample ID:	**BEL01**	**BEL02**	**BEL03**	**WAMBOGB01**	**Wambog602**
	Crop:	**Rehab Natives**	**Rehab Natives**	**Rehab Natives**	**Rehab Natives**	**Rehab Area**
	Client:	**MTW Mine**	**MTW Mine**	**MTW Mine**	**MTW Mine**	**Mount Thorley Warkworth**
Parameter	**Method reference**	**I2408/1**	**I2408/2**	**I2408/3**	**I2408/41**	**I3218/1**

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_c/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
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50 Gipps Street CARRINGTON NSW 2294

Parameter		Method reference	Sample 42	Sample 43	Sample 44	Sample 45	Sample 46
Sample ID:			WAMBOSPOT01	WAMBOSPOT02	WAMBOSPOT03	WARKGB01	WARKGB02
Crop:			Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
Client:			MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
			I2408/42	I2408/43	I2408/44	I2408/45	I2408/46
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	428	1005	285	702	420
Soluble Magnesium (mg/kg)			177	339	176	256	167
Soluble Potassium (mg/kg)			107	234	130	165	118
Soluble Phosphorus (mg/kg)			2.5	3.9	2.1	2.9	2.5
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	2.0	2.9	3.3	2.7	3.7
		**Rayment & Lyons 2011 - 9B2 (Colwell)	4.3	10	7.2	8.2	9.2
		**Inhouse S3A (Bray 2)	3.1	4.6	4.3	4.7	3.7
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	16	10	6.6	8.6	14
Ammonium Nitrogen (mg/kg N)			6.0	4.7	3.8	3.6	5.1
Sulfur (mg/kg S)			13	8.5	12	28	10
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	5.76	6.20	5.68	5.66	5.54
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.063	0.083	0.071	0.087	0.062
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	5.3	7.5	4.6	7.9	5.1
Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	4.32	11.16	3.17	7.61	4.05
	(kg/ha)		1937	5011	1424	3416	1819
	(mg/kg)		865	2237	636	1525	812
Exchangeable Magnesium	(cmol+/kg)		2.06	4.85	2.24	3.36	1.92
	(kg/ha)		560	1320	608	913	522
	(mg/kg)		250	589	272	408	233
Exchangeable Potassium	(cmol+/kg)		0.43	0.98	0.59	0.87	0.48
	(kg/ha)		378	859	516	760	417
	(mg/kg)		169	384	230	339	186
Exchangeable Sodium	(cmol+/kg)		0.07	0.31	0.26	0.35	0.16
	(kg/ha)		35	158	132	178	82
	(mg/kg)		16	70	59	80	37
Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	<0.01	0.13	0.09	0.09	0.12
	(kg/ha)		<1	27	19	17	24
	(mg/kg)		<1	12	8	8	11
Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	0.04	<0.01	<0.01	<0.01	<0.01
	(kg/ha)		<1	<1	<1	<1	<1
	(mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	6.91	17.43	6.34	12.27	6.72
Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	62.5	64.0	50.0	62.0	60.3
Magnesium (%)			29.8	27.8	35.2	27.4	28.5
Potassium (%)			6.3	5.6	9.3	7.1	7.1
Sodium - ESP (%)			1.0	1.8	4.0	2.8	2.4
Aluminium (%)			0.0	0.8	1.5	0.7	1.8
Hydrogen			0.5	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	2.1	2.3	1.4	2.3	2.1

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Parameter	Method reference	Sample 42	Sample 43	Sample 44	Sample 45	Sample 46
	Sample ID:	WAMBOSPOT01	WAMBOSPOT02	WAMBOSPOT03	WARKGB01	WARKGB02
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
		I2408/42	I2408/43	I2408/44	I2408/45	I2408/46
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	1.4	2.9	1.1	5.3	3.4
Manganese (mg/kg)		39	18	21	19	21
Iron (mg/kg)		59	37	123	203	256
Copper (mg/kg)		0.2	0.4	0.2	0.5	0.3
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.40	0.47	0.43	0.64	0.51
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	21	23	31	49	32
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	3.03	4.31	2.65	4.54	2.92
Total Nitrogen (%)		0.15	0.23	0.14	0.27	0.19
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	20.9	18.8	19.3	17.0	15.7
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	40	53	45	55	40
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	1,450	3,406	991	2,175	1,160
Total Magnesium (mg/kg)		597	1,561	511	1,200	720
Total Potassium (mg/kg)		876	1,946	735	1,500	1,220
Total Sodium (mg/kg)		<50	159	95	174	120
Total Sulfur (mg/kg)		137	192	112	274	168
Total Phosphorus (mg/kg)		141	289	135	288	175
Total Zinc (mg/kg)		20	73	9	54	24
Total Manganese (mg/kg)		934	653	315	438	414
Total Iron (mg/kg)		13,304	38,255	15,353	22,907	10,065
Total Copper (mg/kg)		5.0	13.8	2.5	9.1	4.7
Total Boron (mg/kg)		2.2	3.5	<2	2.9	2.6
Total Silicon (mg/kg)		1,937	3,024	1,573	2,808	2,346
Total Aluminium (mg/kg)		4,014	7,486	4,222	7,378	5,376
Total Molybdenum (mg/kg)		<0.2	0.9	0.4	0.7	0.2
Total Cobalt (mg/kg)		9.7	16.3	6.5	6.3	6.1
Total Selenium (mg/kg)		<0.5	<0.5	<0.5	0.6	<0.5
Total Cadmium (mg/kg)		<0.5	<0.5	<0.5	<0.5	<0.5
Total Lead (mg/kg)		7.7	19	7.8	13	9.2
Total Arsenic (mg/kg)		<2	14.6	2.4	7.2	3.1
Total Chromium (mg/kg)		11	7.1	11	9.8	6.5
Total Nickel (mg/kg)		9.4	13	3.7	9.7	4.6
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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		Sample 42	Sample 43	Sample 44	Sample 45	Sample 46
	Sample ID:	WAMBOSPOT01	WAMBOSPOT02	WAMBOSPOT03	WARKGB01	WARKGB02
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	Method reference	I2408/42	I2408/43	I2408/44	I2408/45	I2408/46

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_+/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
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Parameter		Method reference	Sample 47	Sample 48	Heavy Soil	Medium Soil	Light Soil	Sandy Soil
		Sample ID:	WARKGB03	WARKGB04				
		Crop:	Rehab Natives	Rehab Natives				
		Client:	MTW Mine	MTW Mine	*Clay*	*Clay Loam*	*Loam*	*Loamy Sand*
Parameter		**Method reference**	**I2408/47**	**I2408/48**	**Indicative guidelines - refer to Notes 6 and 8**			
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	230	369	*1150*	*750*	*375*	*175*
Soluble Magnesium (mg/kg)		**Inhouse S10 - Morgan 1	151	378	*160*	*105*	*60*	*25*
Soluble Potassium (mg/kg)		**Inhouse S10 - Morgan 1	102	115	*113*	*75*	*60*	*50*
Soluble Phosphorus (mg/kg)		**Inhouse S10 - Morgan 1	1.9	2.9	*15*	*12*	*10*	*5.0*
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	1.8	7.7	*45 note 8*	*30 note 8*	*24 note 8*	*20 note 8*
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9B2 (Colwell)	4.9	15	*80*	*50*	*45*	*35*
Phosphorus (mg/kg P)		**Inhouse S3A (Bray 2)	2.1	9.2	*90 note 8*	*60 note 8*	*48 note 8*	*40 note 8*
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	3.9	12	*15*	*13*	*10*	*10*
Ammonium Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	7.9	5.3	*20*	*18*	*15*	*12*
Sulfur (mg/kg S)		**Inhouse S37 (KCl)	16	17	*10.0*	*8.0*	*8.0*	*7.0*
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	5.57	5.45	*6.5*	*6.5*	*6.3*	*6.3*
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.065	0.150	*0.200*	*0.150*	*0.120*	*0.100*
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	3.9	6.4	*> 5.5*	*>4 .5*	*> 3.5*	*> 2.5*
Exchangeable Calcium	**(cmol+/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	2.21	3.86	*15.6*	*10.8*	*5.0*	*1.9*
Exchangeable Calcium	**(kg/ha)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	994	1733	*7000*	*4816*	*2240*	*840*
Exchangeable Calcium	**(mg/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	444	774	*3125*	*2150*	*1000*	*375*
Exchangeable Magnesium	**(cmol+/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	1.74	4.91	*2.4*	*1.7*	*1.2*	*0.60*
Exchangeable Magnesium	**(kg/ha)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	475	1337	*650*	*448*	*325*	*168*
Exchangeable Magnesium	**(mg/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	212	597	*290*	*200*	*145*	*75*
Exchangeable Potassium	**(cmol+/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	0.39	0.54	*0.60*	*0.50*	*0.40*	*0.30*
Exchangeable Potassium	**(kg/ha)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	342	476	*526*	*426*	*336*	*224*
Exchangeable Potassium	**(mg/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	153	213	*235*	*190*	*150*	*100*
Exchangeable Sodium	**(cmol+/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	0.26	0.77	*0.3*	*0.26*	*0.22*	*0.11*
Exchangeable Sodium	**(kg/ha)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	134	399	*155*	*134*	*113*	*57*
Exchangeable Sodium	**(mg/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	60	178	*69*	*60*	*51*	*25*
Exchangeable Aluminium	**(cmol+/kg)**	**Inhouse S37 (KCl)	0.10	0.06	*0.6*	*0.5*	*0.4*	*0.2*
Exchangeable Aluminium	**(kg/ha)**	**Inhouse S37 (KCl)	20	12	*121*	*101*	*73*	*30*
Exchangeable Aluminium	**(mg/kg)**	**Inhouse S37 (KCl)	9	5	*54*	*45*	*32*	*14*
Exchangeable Hydrogen	**(cmol+/kg)**	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	0.04	*0.6*	*0.5*	*0.4*	*0.2*
Exchangeable Hydrogen	**(kg/ha)**	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<1	<1	*13*	*11*	*8*	*3*
Exchangeable Hydrogen	**(mg/kg)**	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<1	<1	*6*	*5*	*4*	*2*
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	4.71	10.19	*20.1*	*14.3*	*7.8*	*3.3*
Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	47.0	37.9	*77.6*	*75.7*	*65.6*	*57.4*
Magnesium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	37.0	48.2	*11.9*	*11.9*	*15.7*	*18.1*
Potassium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	8.3	5.3	*3.0*	*3.5*	*5.2*	*9.1*
Sodium - ESP (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	5.5	7.6	*1.5*	*1.8*	*2.9*	*3.3*
Aluminium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	2.1	0.6	*6.0*	*7.1*	*10.5*	*12.1*
Hydrogen		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	0.0	0.4				
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	1.3	0.8	*6.5*	*6.4*	*4.2*	*3.2*

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 47	Sample 48	*Heavy Soil*	*Medium Soil*	*Light Soil*	*Sandy Soil*
	Sample ID:	WARKGB03	WARKGB04				
	Crop:	Rehab Natives	Rehab Natives				
	Client:	MTW Mine	MTW Mine	*Clay*	*Clay Loam*	*Loam*	*Loamy Sand*
Parameter	**Method reference**	**I2408/47**	**I2408/48**	**Indicative guidelines - refer to Notes 6 and 8**			
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	1.3	3.6	*6.0*	*5.0*	*4.0*	*3.0*
Manganese (mg/kg)		13	17	*25*	*22*	*18*	*15*
Iron (mg/kg)		187	376	*25*	*22*	*18*	*15*
Copper (mg/kg)		0.2	0.3	*2.4*	*2.0*	*1.6*	*1.2*
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.49	0.67	*2.0*	*1.7*	*1.4*	*1.0*
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	24	34	*50*	*45*	*40*	*35*
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.20	3.66	*> 3.1*	*> 2.6*	*> 2.0*	*> 1.4*
Total Nitrogen (%)		0.12	0.21	*> 0.30*	*> 0.25*	*> 0.20*	*> 0.15*
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	19.0	17.3	*10–12*	*10–12*	*10–12*	*10–12*
Basic Texture	**Inhouse S65	Loam	Loam	..	..	..	..
Basic Colour		Brownish	Brownish	..	..	..	..
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	41	96	..	..	..	..
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	599	1,325	*1000–10 000 Ca*			
Total Magnesium (mg/kg)		446	1,064	*500–5000 Mg*			
Total Potassium (mg/kg)		642	746	*200–2000 K*			
Total Sodium (mg/kg)		124	230	*100–500 Na*			
Total Sulfur (mg/kg)		126	232	*100–1000 S*			
Total Phosphorus (mg/kg)		103	193	*400–1500 P*			
Total Zinc (mg/kg)		8	20	*20–50 Zn*			
Total Manganese (mg/kg)		122	197	*200–2000 Mn*			
Total Iron (mg/kg)		7,296	7,659	*1000–50 000 Fe*			
Total Copper (mg/kg)		2.4	5.4	*20–50 Cu*			
Total Boron (mg/kg)		<2	2.8	*2–50 B*			
Total Silicon (mg/kg)		1,682	1,682	*1000–3000 Si*			
Total Aluminium (mg/kg)		3,428	6,334	*2000–50 000 Al*			
Total Molybdenum (mg/kg)		0.5	0.3	*0.5–3.0 Mo*			
Total Cobalt (mg/kg)		2.5	4.0	*5–50 Co*			
Total Selenium (mg/kg)		<0.5	0.5	*0.1–2.0 Se*			
Total Cadmium (mg/kg)		<0.5	<0.5	*<1 Cd*			
Total Lead (mg/kg)		5.3	9.0	*2–200 Pb*			
Total Arsenic (mg/kg)		2.5	3.9	*1–50 As*			
Total Chromium (mg/kg)		4.5	6.7	*5–1000 Cr*			
Total Nickel (mg/kg)		2.6	3.8	*5–500 Ni*			
Total Mercury (mg/kg)		<0.1	<0.1	*< 0.2 Hg*			
Total Silver (mg/kg)		<1	<1	*.. Ag*			

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 47	Sample 48	*Heavy Soil*	*Medium Soil*	*Light Soil*	*Sandy Soil*
	Sample ID:	**WARKGB03**	**WARKGB04**				
	Crop:	**Rehab Natives**	**Rehab Natives**				
	Client:	**MTW Mine**	**MTW Mine**	*Clay*	*Clay Loam*	*Loam*	*Loamy Sand*
Parameter	**Method reference**	**I2408/47**	**I2408/48**	**Indicative guidelines - refer to Notes 6 and 8**			

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_c$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.e

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

			Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
		Sample ID:	MTWCDD201101	MTWCDD201301	MTWCDD201401	MTWCDD201501	MTWCDD201701
		Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
		Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter		**Method reference**	**I2408/4**	**I2408/5**	**I2408/6**	**I2408/7**	**I2408/8**
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	494	1450	988	1003	783
Soluble Magnesium (mg/kg)			421	356	404	351	385
Soluble Potassium (mg/kg)			132	311	274	104	92
Soluble Phosphorus (mg/kg)			1.3	24	11	8.9	2.3
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	<1	21	17	17	3.5
		**Rayment & Lyons 2011 - 9B2 (Colwell)	6.6	83	70	43	11
		**Inhouse S3A (Bray 2)	4.5	181	88	152	15
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	5.1	37	2.0	2.4	30
Ammonium Nitrogen (mg/kg N)			6.6	6.3	5.8	4.3	6.0
Sulfur (mg/kg S)			38	88	13	22	439
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	6.34	7.48	7.14	8.09	6.52
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.112	0.326	0.103	0.091	0.855
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	5.3	6.5	6.5	4.9	2.8
Exchangeable Calcium	**(cmol$_{+}$/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	4.59	10.81	8.49	6.66	5.88
	(kg/ha)		2059	4853	3809	2988	2638
	(mg/kg)		919	2167	1701	1334	1178
Exchangeable Magnesium	**(cmol$_{+}$/kg)**		5.67	3.89	4.83	4.04	4.11
	(kg/ha)		1544	1058	1315	1099	1120
	(mg/kg)		689	472	587	491	500
Exchangeable Potassium	**(cmol$_{+}$/kg)**		0.72	1.40	1.22	0.39	0.39
	(kg/ha)		631	1225	1069	344	340
	(mg/kg)		282	547	477	154	152
Exchangeable Sodium	**(cmol$_{+}$/kg)**		0.87	1.39	0.27	0.31	1.63
	(kg/ha)		450	717	138	161	839
	(mg/kg)		201	320	61	72	374
Exchangeable Aluminium	**(cmol$_{+}$/kg)**	**Inhouse S37 (KCl)	0.05	0.04	0.04	0.07	0.09
	(kg/ha)		10	9	8	13	18
	(mg/kg)		5	4	3	6	8
Exchangeable Hydrogen	**(cmol$_{+}$/kg)**	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	(kg/ha)		<1	<1	<1	<1	<1
	(mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol$_{+}$/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol$_{+}$/kg)	11.90	17.53	14.84	11.46	12.10
Calcium (%)		**Base Saturation Calculations - Cation cmol$_{+}$/kg / ECEC x 100	38.5	61.7	57.2	58.1	48.6
Magnesium (%)			47.6	22.2	32.5	35.2	34.0
Potassium (%)			6.0	8.0	8.2	3.4	3.2
Sodium - ESP (%)			7.3	7.9	1.8	2.7	13.5
Aluminium (%)			0.4	0.2	0.3	0.6	0.7
Hydrogen			0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol$_{+}$/kg)	0.8	2.8	1.8	1.6	1.4

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408
Analysis requested by John Moen. Your Job: MTW Mine
50 Gipps Street CARRINGTON NSW 2294

		Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
	Sample ID:	MTWCDD201101	MTWCDD201301	MTWCDD201401	MTWCDD201501	MTWCDD201701
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/4**	**I2408/5**	**I2408/6**	**I2408/7**	**I2408/8**
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	2.6	17	12	12	2.2
Manganese (mg/kg)		7.2	9.1	4.5	0.8	13
Iron (mg/kg)		80	26	26	17	53
Copper (mg/kg)		0.8	1.9	1.6	2.1	0.4
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.54	0.55	0.46	0.29	0.48
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	47	31	28	13	31
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	3.00	3.69	3.71	2.78	1.58
Total Nitrogen (%)		0.15	0.26	0.24	0.15	0.10
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	20.3	14.3	15.7	19.0	16.3
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	71	209	66	58	547
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	1,401	4,633	3,170	7,802	1,930
Total Magnesium (mg/kg)		1,296	1,457	1,531	3,375	1,291
Total Potassium (mg/kg)		1,158	1,591	1,547	1,182	931
Total Sodium (mg/kg)		260	426	157	197	526
Total Sulfur (mg/kg)		184	457	240	167	520
Total Phosphorus (mg/kg)		125	530	363	439	100
Total Zinc (mg/kg)		38	84	67	81	27
Total Manganese (mg/kg)		184	181	178	220	113
Total Iron (mg/kg)		17,112	15,867	16,520	13,458	7,339
Total Copper (mg/kg)		8.7	24.8	18.7	19.6	5.3
Total Boron (mg/kg)		3.5	4.5	<2	<2	<2
Total Silicon (mg/kg)		1,017	901	850	832	1,030
Total Aluminium (mg/kg)		7,445	6,171	6,014	3,607	5,225
Total Molybdenum (mg/kg)		0.7	1.0	0.6	0.5	0.3
Total Cobalt (mg/kg)		7.4	6.1	7.3	8.8	3.9
Total Selenium (mg/kg)		0.7	<0.5	0.6	<0.5	<0.5
Total Cadmium (mg/kg)		<0.5	<0.5	<0.5	<0.5	<0.5
Total Lead (mg/kg)		13	25	19	17	8.0
Total Arsenic (mg/kg)		5.2	5.2	5.8	4.8	2.5
Total Chromium (mg/kg)		8.6	8.8	7.3	5.1	3.7
Total Nickel (mg/kg)		7.4	8.4	7.9	11.7	4.0
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
	Sample ID:	MTWCDD20110 1	MTWCDD20130 1	MTWCDD20140 1	MTWCDD20150 1	MTWCDD20170 1
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/4**	**I2408/5**	**I2408/6**	**I2408/7**	**I2408/8**

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_c/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

			Sample 9	Sample 10	Sample 11	Sample 12	Sample 13
		Sample ID:	MTWCDD201702	MTWCDD201801	MTWMTO021803	MTWMTO201601	MTWMTO201701
		Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
		Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter		**Method reference**	**I2408/9**	**I2408/10**	**I2408/11**	**I2408/12**	**I2408/13**
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	1097	1336	4578	1796	3077
Soluble Magnesium (mg/kg)			317	440	213	544	197
Soluble Potassium (mg/kg)			204	245	270	284	215
Soluble Phosphorus (mg/kg)			9.2	13	65	21	41
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	35	33	125	55	118
		**Rayment & Lyons 2011 - 9B2 (Colwell)	70	76	423	88	264
		**Inhouse S3A (Bray 2)	94	104	678	181	541
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	14	29	38	188	74
Ammonium Nitrogen (mg/kg N)			5.7	20	12	3.5	9.0
Sulfur (mg/kg S)			145	359	97	487	423
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	6.86	6.55	8.11	7.72	7.80
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.384	0.829	0.512	1.183	1.037
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	4.4	6.3	18.6	5.0	16.2
Exchangeable Calcium	(cmol$_+$/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	7.34	9.94	18.90	11.18	17.80
	(kg/ha)		3294	4460	8483	5017	7991
	(mg/kg)		1470	1991	3787	2240	3567
Exchangeable Magnesium	(cmol$_+$/kg)		3.36	4.58	1.71	5.42	1.87
	(kg/ha)		915	1248	465	1474	510
	(mg/kg)		408	557	207	658	228
Exchangeable Potassium	(cmol$_+$/kg)		0.82	1.12	1.45	1.20	1.04
	(kg/ha)		719	982	1269	1052	913
	(mg/kg)		321	438	566	470	408
Exchangeable Sodium	(cmol$_+$/kg)		0.92	2.54	5.40	3.88	6.84
	(kg/ha)		474	1310	2782	2000	3524
	(mg/kg)		212	585	1242	893	1573
Exchangeable Aluminium	(cmol$_+$/kg)	**Inhouse S37 (KCl)	0.03	0.04	0.08	0.09	0.02
	(kg/ha)		5	9	16	18	4
	(mg/kg)		2	4	7	8	2
Exchangeable Hydrogen	(cmol$_+$/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	(kg/ha)		<1	<1	<1	<1	<1
	(mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol$_+$/kg)	12.46	18.23	27.53	21.77	27.58
Calcium (%)		**Base Saturation Calculations - Cation cmol$_+$/kg / ECEC x 100	58.9	54.5	68.6	51.3	64.5
Magnesium (%)			27.0	25.1	6.2	24.9	6.8
Potassium (%)			6.6	6.2	5.3	5.5	3.8
Sodium - ESP (%)			7.4	14.0	19.6	17.8	24.8
Aluminium (%)			0.2	0.2	0.3	0.4	0.1
Hydrogen			0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol$_+$/kg)	2.2	2.2	11.1	2.1	9.5

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Environmental Analysis Laboratory

AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

Parameter	Method reference	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13
Sample ID:		MTWCDD201702	MTWCDD201801	MTWMTO021803	MTWMTO201601	MTWMTO201701
Crop:		Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
Client:		MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
		I2408/9	I2408/10	I2408/11	I2408/12	I2408/13
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	12	32	127	12	54
Manganese (mg/kg)		5.2	19	16	2.1	8.1
Iron (mg/kg)		44	59	47	18	63
Copper (mg/kg)		1.4	4.3	18.2	1.2	7.4
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.58	0.70	0.81	0.42	0.65
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	24	31	24	13	19
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.49	3.62	10.60	2.87	9.27
Total Nitrogen (%)		0.18	0.25	0.65	0.25	0.61
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	14.0	14.7	16.3	11.6	15.3
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	245	530	328	757	663
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	2,925	4,148	13,029	5,107	15,311
Total Magnesium (mg/kg)		1,164	1,221	2,421	1,810	4,544
Total Potassium (mg/kg)		1,137	1,197	1,630	1,313	1,670
Total Sodium (mg/kg)		293	705	2,117	1,249	4,104
Total Sulfur (mg/kg)		379	650	593	737	1,007
Total Phosphorus (mg/kg)		280	436	1,431	411	1,650
Total Zinc (mg/kg)		46	137	324	69	216
Total Manganese (mg/kg)		99	184	274	147	332
Total Iron (mg/kg)		7,618	12,333	11,739	9,569	18,590
Total Copper (mg/kg)		14.3	49.9	101.4	21.0	3,038.8
Total Boron (mg/kg)		5.4	<2	4.3	<2	3.9
Total Silicon (mg/kg)		641	423	1,036	957	1,317
Total Aluminium (mg/kg)		4,877	5,701	4,586	4,750	6,235
Total Molybdenum (mg/kg)		0.5	0.6	1.0	0.4	0.8
Total Cobalt (mg/kg)		3.9	5.7	8.0	4.4	13.0
Total Selenium (mg/kg)		0.6	0.6	<0.5	<0.5	<0.5
Total Cadmium (mg/kg)		<0.5	0.9	2.6	<0.5	0.9
Total Lead (mg/kg)		14	31	98	17	41
Total Arsenic (mg/kg)		2.8	5.6	4.4	4.4	5.4
Total Chromium (mg/kg)		4.7	9.5	14	6.1	15
Total Nickel (mg/kg)		5.2	8.8	17	6.8	22
Total Mercury (mg/kg)		<0.1	<0.1	0.2	<0.1	0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 9	Sample 10	Sample 11	Sample 12	Sample 13
	Sample ID:	MTWCDD201702	MTWCDD201801	MTWMTO021803	MTWMTO201601	MTWMTO201701
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	I2408/9	I2408/10	I2408/11	I2408/12	I2408/13

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_c/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.e

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

	Sample 14	Sample 15	Sample 16	Sample 17	Sample 18
Sample ID:	MTWMTO201702	MTWMTO201703	MTWMTO201704	MTWMTO201801	MTWMTO201802
Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine

Parameter		Method reference	I2408/14	I2408/15	I2408/16	I2408/17	I2408/18
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	2283	1480	1016	698	3548
Soluble Magnesium (mg/kg)			329	468	375	335	566
Soluble Potassium (mg/kg)			251	177	173	138	226
Soluble Phosphorus (mg/kg)			52	5.4	7.7	2.2	12
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	107	24	26	6.3	37
		**Rayment & Lyons 2011 - 9B2 (Colwell)	181	39	51	16	81
		**Inhouse S3A (Bray 2)	408	60	71	6.8	139
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	14	27	39	55	144
Ammonium Nitrogen (mg/kg N)			6.6	3.2	3.7	5.7	7.1
Sulfur (mg/kg S)			191	151	184	58	688
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	7.55	8.29	6.86	6.34	7.54
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.395	0.366	0.486	0.222	1.251
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	9.9	4.7	3.5	3.8	9.7
Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	14.70	9.23	7.94	6.26	17.39
	(kg/ha)		6601	4143	3563	2809	7807
	(mg/kg)		2947	1850	1591	1254	3485
Exchangeable Magnesium	(cmol+/kg)		3.36	4.93	4.23	4.18	5.03
	(kg/ha)		915	1341	1152	1137	1371
	(mg/kg)		408	599	514	508	612
Exchangeable Potassium	(cmol+/kg)		1.16	0.77	0.78	0.70	1.12
	(kg/ha)		1019	678	682	616	985
	(mg/kg)		455	303	304	275	440
Exchangeable Sodium	(cmol+/kg)		2.29	1.77	1.53	0.79	1.96
	(kg/ha)		1181	913	788	406	1007
	(mg/kg)		527	407	352	181	450
Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	0.10	0.05	0.07	0.04	0.06
	(kg/ha)		20	11	13	8	12
	(mg/kg)		9	5	6	3	5
Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	(kg/ha)		<1	<1	<1	<1	<1
	(mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	21.62	16.76	14.54	11.96	25.57
Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	68.0	55.1	54.6	52.3	68.0
Magnesium (%)			15.5	29.4	29.1	34.9	19.7
Potassium (%)			5.4	4.6	5.4	5.9	4.4
Sodium - ESP (%)			10.6	10.6	10.5	6.6	7.6
Aluminium (%)			0.5	0.3	0.5	0.3	0.2
Hydrogen			0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	4.4	1.9	1.9	1.5	3.5

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Environmental Analysis Laboratory

AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 14	Sample 15	Sample 16	Sample 17	Sample 18
	Sample ID:	MTWMTO201702	MTWMTO201703	MTWMTO201704	MTWMTO201801	MTWMTO201802
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/14**	**I2408/15**	**I2408/16**	**I2408/17**	**I2408/18**
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	26	7.0	10	3.0	31
Manganese (mg/kg)		6.1	2.1	6.6	14	6.3
Iron (mg/kg)		42	18	58	57	15
Copper (mg/kg)		2.6	1.4	1.3	0.6	6.0
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.72	0.37	0.52	0.35	0.60
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	26	9	24	39	18
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	5.64	2.70	1.98	2.15	5.55
Total Nitrogen (%)		0.49	0.15	0.15	0.16	0.33
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	11.5	18.1	13.0	13.9	16.8
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	253	234	311	142	800
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	8,262	4,737	3,498	6,637	10,639
Total Magnesium (mg/kg)		1,450	2,224	1,372	1,356	2,582
Total Potassium (mg/kg)		1,330	1,197	992	1,292	1,621
Total Sodium (mg/kg)		733	677	404	247	607
Total Sulfur (mg/kg)		739	293	328	194	901
Total Phosphorus (mg/kg)		1,041	204	465	169	734
Total Zinc (mg/kg)		109	58	48	32	138
Total Manganese (mg/kg)		187	556	161	273	264
Total Iron (mg/kg)		19,270	18,149	11,727	13,030	17,953
Total Copper (mg/kg)		37.0	14.3	11.9	6.2	70.0
Total Boron (mg/kg)		2.5	<2	3.0	<2	2.7
Total Silicon (mg/kg)		874	904	675	820	797
Total Aluminium (mg/kg)		5,774	4,948	5,711	7,973	7,062
Total Molybdenum (mg/kg)		0.9	0.7	0.5	0.4	1.5
Total Cobalt (mg/kg)		5.7	6.7	4.2	6.9	8.6
Total Selenium (mg/kg)		0.6	<0.5	<0.5	<0.5	0.7
Total Cadmium (mg/kg)		<0.5	<0.5	<0.5	<0.5	1.1
Total Lead (mg/kg)		26	16	15	10	27
Total Arsenic (mg/kg)		7.0	6.5	4.3	4.6	5.6
Total Chromium (mg/kg)		9.0	6.0	6.6	7.5	74
Total Nickel (mg/kg)		9.4	7.5	5.2	6.3	52
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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AGRICULTURAL SOIL ANALYSIS REPORT

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Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 14	Sample 15	Sample 16	Sample 17	Sample 18
	Sample ID:	MTWMTO201702	MTWMTO201703	MTWMTO201704	MTWMTO201801	MTWMTO201802
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/14**	**I2408/15**	**I2408/16**	**I2408/17**	**I2408/18**

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_c/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408
Analysis requested by John Moen. Your Job: MTW Mine
50 Gipps Street CARRINGTON NSW 2294

Parameter		Method reference	Sample 53	Sample 19	Sample 20	Sample 21	Sample 22
		Sample ID:	MTWNPN200901	MTWNPN201101	MTWNPN201301	MTWNPN201401	MTWNPN201602
		Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
		Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter		Method reference	I2408/53	I2408/19	I2408/20	I2408/21	I2408/22
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	707	915	917	702	831
Soluble Magnesium (mg/kg)			432	451	260	325	712
Soluble Potassium (mg/kg)			162	165	180	165	142
Soluble Phosphorus (mg/kg)			2.3	2.4	5.1	3.3	3.9
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	1.3	2.9	17	14	22
		**Rayment & Lyons 2011 - 9B2 (Colwell)	11	7.5	29	31	43
		**Inhouse S3A (Bray 2)	5.8	21	36	41	73
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	13	12	6.7	3.2	34
Ammonium Nitrogen (mg/kg N)			5.8	5.5	4.2	4.0	8.4
Sulfur (mg/kg S)			45	46	184	15	383
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	6.31	7.25	6.54	6.69	6.76
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.104	0.099	0.379	0.066	0.704
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	5.1	4.5	3.6	3.9	4.8
Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	7.04	7.87	6.87	6.70	8.41
	(kg/ha)		3161	3534	3083	3008	3774
	(mg/kg)		1411	1577	1377	1343	1685
Exchangeable Magnesium	(cmol+/kg)		5.90	5.70	2.84	4.26	9.95
	(kg/ha)		1606	1553	772	1160	2708
	(mg/kg)		717	693	345	518	1209
Exchangeable Potassium	(cmol+/kg)		0.87	0.82	0.71	0.78	0.61
	(kg/ha)		765	714	626	687	536
	(mg/kg)		342	319	279	307	239
Exchangeable Sodium	(cmol+/kg)		0.40	0.15	0.83	0.28	3.83
	(kg/ha)		206	78	426	143	1972
	(mg/kg)		92	35	190	64	880
Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	0.07	0.08	0.06	<0.01	0.06
	(kg/ha)		13	15	12	<1	12
	(mg/kg)		6	7	5	<1	5
Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	(kg/ha)		<1	<1	<1	<1	<1
	(mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	14.28	14.62	11.31	12.02	22.85
Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	49.3	53.9	60.7	55.7	36.8
Magnesium (%)			41.3	39.0	25.1	35.4	43.5
Potassium (%)			6.1	5.6	6.3	6.5	2.7
Sodium - ESP (%)			2.8	1.0	7.3	2.3	16.8
Aluminium (%)			0.5	0.5	0.5	0.0	0.3
Hydrogen			0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	1.2	1.4	2.4	1.6	0.8

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 53	Sample 19	Sample 20	Sample 21	Sample 22
	Sample ID:	MTWNPN20090 1	MTWNPN20110 1	MTWNPN20130 1	MTWNPN20140 1	MTWNPN20160 2
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/53**	**I2408/19**	**I2408/20**	**I2408/21**	**I2408/22**
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	3.2	4.3	7.8	9.8	15
Manganese (mg/kg)		5.8	5.3	4.9	5.9	9.0
Iron (mg/kg)		71	18	39	55	29
Copper (mg/kg)		0.8	0.9	1.1	1.6	2.4
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.46	0.31	0.36	0.53	0.55
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	51	31	34	35	28
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.91	2.57	2.05	2.20	2.77
Total Nitrogen (%)		0.16	0.14	0.14	0.14	0.15
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	18.0	18.2	14.7	15.3	19.1
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	67	63	243	42	450
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	2,131	3,172	2,050	1,920	2,760
Total Magnesium (mg/kg)		1,678	1,926	785	978	2,049
Total Potassium (mg/kg)		1,546	1,355	898	1,005	1,035
Total Sodium (mg/kg)		155	105	223	108	916
Total Sulfur (mg/kg)		214	177	363	186	526
Total Phosphorus (mg/kg)		174	274	202	218	249
Total Zinc (mg/kg)		56	42	38	44	74
Total Manganese (mg/kg)		235	209	87	141	77
Total Iron (mg/kg)		22,384	14,925	6,978	11,075	13,126
Total Copper (mg/kg)		11.2	9.2	10.7	13.8	24.6
Total Boron (mg/kg)		<2	<2	<2	<2	<2
Total Silicon (mg/kg)		1,956	653	701	629	497
Total Aluminium (mg/kg)		9,290	7,600	4,339	6,030	5,159
Total Molybdenum (mg/kg)		0.9	0.7	0.6	0.5	0.6
Total Cobalt (mg/kg)		8.0	7.9	3.1	4.6	4.3
Total Selenium (mg/kg)		0.9	0.7	<0.5	0.6	<0.5
Total Cadmium (mg/kg)		<0.5	<0.5	<0.5	<0.5	<0.5
Total Lead (mg/kg)		14	8.8	19	14	23
Total Arsenic (mg/kg)		5.3	4.7	2.8	4.0	4.0
Total Chromium (mg/kg)		8.5	7.0	4.3	6.1	6.2
Total Nickel (mg/kg)		8.4	8.3	4.7	5.9	8.1
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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AGRICULTURAL SOIL ANALYSIS REPORT

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Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 53	Sample 19	Sample 20	Sample 21	Sample 22
	Sample ID:	MTWNPN20090 1	MTWNPN20110 1	MTWNPN20130 1	MTWNPN20140 1	MTWNPN20160 2
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	Method reference	I2408/53	I2408/19	I2408/20	I2408/21	I2408/22

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 cmol$_c$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.e

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55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

			Sample 23	Sample 24	Sample 25	Sample 26	Sample 27
		Sample ID:	MTWNPN201701	MTWNPN201702	MTWNPN201703	MTWNPN201801	MTWNPN201802
		Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
		Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter		**Method reference**	**I2408/23**	**I2408/24**	**I2408/25**	**I2408/26**	**I2408/27**
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	1113	749	1482	1535	794
Soluble Magnesium (mg/kg)			453	431	648	221	213
Soluble Potassium (mg/kg)			211	143	250	264	146
Soluble Phosphorus (mg/kg)			8.9	3.2	15	31	10
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	32	11	43	77	30
		**Rayment & Lyons 2011 - 9B2 (Colwell)	95	16	102	148	45
		**Inhouse S3A (Bray 2)	103	78	150	246	97
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	15	20	104	6.7	17
Ammonium Nitrogen (mg/kg N)			4.8	6.8	3.1	4.5	2.9
Sulfur (mg/kg S)			139	204	354	57	100
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	6.98	8.08	7.37	7.42	6.78
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.338	0.692	0.941	0.245	0.272
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	5.7	2.9	5.1	6.2	3.9
Exchangeable Calcium	**(cmol$_+$/kg)**	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	9.79	6.34	11.47	10.91	5.80
	(kg/ha)		4395	2847	5151	4896	2602
	(mg/kg)		1962	1271	2299	2186	1161
Exchangeable Magnesium	**(cmol$_+$/kg)**		5.82	5.82	7.62	2.43	2.35
	(kg/ha)		1583	1584	2074	661	640
	(mg/kg)		707	707	926	295	286
Exchangeable Potassium	**(cmol$_+$/kg)**		1.11	0.72	1.32	1.11	0.61
	(kg/ha)		970	631	1154	970	537
	(mg/kg)		433	282	515	433	240
Exchangeable Sodium	**(cmol$_+$/kg)**		1.08	4.07	3.15	1.00	0.64
	(kg/ha)		558	2096	1623	513	329
	(mg/kg)		249	936	724	229	147
Exchangeable Aluminium	**(cmol$_+$/kg)**	**Inhouse S37 (KCl)	0.04	0.05	0.08	0.09	0.05
	(kg/ha)		7	9	15	18	11
	(mg/kg)		3	4	7	8	5
Exchangeable Hydrogen	**(cmol$_+$/kg)**	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	(kg/ha)		<1	<1	<1	<1	<1
	(mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol$_+$/kg)	17.84	17.00	23.64	15.53	9.45
Calcium (%)		**Base Saturation Calculations - Cation cmol$_+$/kg / ECEC x 100	54.9	37.3	48.5	70.2	61.3
Magnesium (%)			32.6	34.2	32.2	15.6	24.9
Potassium (%)			6.2	4.2	5.6	7.1	6.5
Sodium - ESP (%)			6.1	23.9	13.3	6.4	6.8
Aluminium (%)			0.2	0.3	0.3	0.6	0.6
Hydrogen			0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol$_+$/kg)	1.7	1.1	1.5	4.5	2.5

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Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 23	Sample 24	Sample 25	Sample 26	Sample 27
	Sample ID:	MTWNPN201701	MTWNPN201702	MTWNPN201703	MTWNPN201801	MTWNPN201802
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/23**	**I2408/24**	**I2408/25**	**I2408/26**	**I2408/27**
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	14	4.3	17	49	16
Manganese (mg/kg)		8.8	2.9	10.3	7.8	4.2
Iron (mg/kg)		69	10	53	69	46
Copper (mg/kg)		1.8	1.9	1.9	5.8	2.3
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.67	0.40	0.84	0.95	0.62
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	20	24	20	30	29
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	3.23	1.64	2.91	3.55	2.21
Total Nitrogen (%)		0.23	0.08	0.24	0.26	0.14
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	14.0	20.8	12.2	13.4	15.5
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	216	443	602	157	174
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	3,971	2,590	3,765	5,008	2,172
Total Magnesium (mg/kg)		1,693	1,758	1,757	660	1,015
Total Potassium (mg/kg)		1,406	1,362	1,473	829	914
Total Sodium (mg/kg)		319	1,008	751	251	203
Total Sulfur (mg/kg)		388	251	583	353	263
Total Phosphorus (mg/kg)		490	313	467	553	219
Total Zinc (mg/kg)		72	68	79	123	52
Total Manganese (mg/kg)		273	340	219	130	105
Total Iron (mg/kg)		19,702	17,148	24,438	4,549	6,224
Total Copper (mg/kg)		22.9	23.9	23.4	49.4	15.8
Total Boron (mg/kg)		2.5	2.1	2.5	3.6	<2
Total Silicon (mg/kg)		769	564	459	743	944
Total Aluminium (mg/kg)		7,516	4,760	7,872	3,103	3,896
Total Molybdenum (mg/kg)		0.7	0.7	1.1	0.4	0.4
Total Cobalt (mg/kg)		6.4	9.8	6.2	2.4	3.1
Total Selenium (mg/kg)		0.7	<0.5	<0.5	<0.5	<0.5
Total Cadmium (mg/kg)		<0.5	<0.5	0.6	1.0	<0.5
Total Lead (mg/kg)		20	15	22	34	14
Total Arsenic (mg/kg)		4.6	6.3	6.6	2.3	2.0
Total Chromium (mg/kg)		8.1	5.9	10.2	4.7	3.8
Total Nickel (mg/kg)		9.6	13	8.9	5.8	5.1
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 23	Sample 24	Sample 25	Sample 26	Sample 27
	Sample ID:	MTWNPN20170 1	MTWNPN20170 2	MTWNPN20170 3	MTWNPN20180 1	MTWNPN20180 2
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	I2408/23	I2408/24	I2408/25	I2408/26	I2408/27

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 cmol$_c$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
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Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 28	Sample 29	Sample 30	Sample 49	Sample 31
	Sample ID:	MTWNPN201803	MTWSPN201401	MTWSPN201501	MTWSPN201501	MTWSPN201601
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/28**	**I2408/29**	**I2408/30**	**I2408/49**	**I2408/31**
Soluble Calcium (mg/kg)	**Inhouse S10 - Morgan 1	3552	1108	2673	684	1316
Soluble Magnesium (mg/kg)		516	382	365	462	314
Soluble Potassium (mg/kg)		371	191	330	182	369
Soluble Phosphorus (mg/kg)		33	7.3	24	5.1	11
Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9E2 (Bray 1)	83	28	102	13	33
	**Rayment & Lyons 2011 - 9B2 (Colwell)	276	57	237	18	85
	**Inhouse S3A (Bray 2)	455	83	432	83	132
Nitrate Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	13	3.5	23	5.4	7.3
Ammonium Nitrogen (mg/kg N)		7.4	3.6	5.6	3.1	4.2
Sulfur (mg/kg S)		740	39	40	330	107
pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	7.64	7.64	7.43	8.62	6.79
Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	1.234	0.111	0.245	0.909	0.234
Estimated Organic Matter (% OM)	**Calculation: Total Carbon x 1.75	15.7	5.5	10.6	10.0	7.0
Exchangeable Calcium (cmol₊/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	18.17	8.66	15.75	5.46	11.78
Exchangeable Calcium (kg/ha)		8157	3888	7071	2450	5288
Exchangeable Calcium (mg/kg)		3642	1736	3156	1094	2361
Exchangeable Magnesium (cmol₊/kg)		5.06	4.29	3.64	5.84	3.96
Exchangeable Magnesium (kg/ha)		1378	1168	992	1589	1079
Exchangeable Magnesium (mg/kg)		615	521	443	709	482
Exchangeable Potassium (cmol₊/kg)		1.49	0.89	1.35	0.86	1.93
Exchangeable Potassium (kg/ha)		1309	782	1186	753	1690
Exchangeable Potassium (mg/kg)		584	349	530	336	754
Exchangeable Sodium (cmol₊/kg)		5.07	0.68	0.35	7.96	0.70
Exchangeable Sodium (kg/ha)		2612	352	180	4101	361
Exchangeable Sodium (mg/kg)		1166	157	80	1831	161
Exchangeable Aluminium (cmol₊/kg)	**Inhouse S37 (KCl)	0.06	0.07	0.03	0.07	0.02
Exchangeable Aluminium (kg/ha)		12	14	7	14	3
Exchangeable Aluminium (mg/kg)		5	6	3	6	1
Exchangeable Hydrogen (cmol₊/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
Exchangeable Hydrogen (kg/ha)		<1	<1	<1	<1	<1
Exchangeable Hydrogen (mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol₊/kg)	**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol₊/kg)	29.86	14.59	21.13	20.19	18.39
Calcium (%)	**Base Saturation Calculations - Cation cmol₊/kg / ECEC x 100	60.9	59.3	74.5	27.0	64.1
Magnesium (%)		17.0	29.4	17.2	28.9	21.6
Potassium (%)		5.0	6.1	6.4	4.3	10.5
Sodium - ESP (%)		17.0	4.7	1.7	39.4	3.8
Aluminium (%)		0.2	0.5	0.2	0.3	0.1
Hydrogen		0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio	**Calculation: Calcium / Magnesium (cmol₊/kg)	3.6	2.0	4.3	0.9	3.0

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Analysis requested by John Moen. Your Job: MTW Mine

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Parameter	Method reference	Sample 28	Sample 29	Sample 30	Sample 49	Sample 31
	Sample ID:	MTWNPN201803	MTWSPN201401	MTWSPN201501	MTWSPN201501	MTWSPN201601
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
		I2408/28	I2408/29	I2408/30	I2408/49	I2408/31
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	76	17	45	9.5	14
Manganese (mg/kg)		5.8	2.8	3.1	0.9	6.6
Iron (mg/kg)		39	30	47	23	41
Copper (mg/kg)		18	2.5	5.1	2.9	1.6
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	1.12	0.66	0.63	0.37	0.74
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	14	24	26	13	44
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	8.95	3.13	6.04	5.73	3.99
Total Nitrogen (%)		0.53	0.20	0.46	0.18	0.30
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	16.8	15.9	13.2	32.0	13.3
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	790	71	157	582	150
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	14,572	3,235	8,994	4,780	5,518
Total Magnesium (mg/kg)		3,344	1,462	2,285	3,893	1,486
Total Potassium (mg/kg)		1,793	1,166	1,333	1,653	2,107
Total Sodium (mg/kg)		1,455	213	164	1,957	230
Total Sulfur (mg/kg)		1,549	247	618	570	349
Total Phosphorus (mg/kg)		1,997	353	1,197	324	488
Total Zinc (mg/kg)		350	71	175	81	77
Total Manganese (mg/kg)		296	139	188	222	318
Total Iron (mg/kg)		13,736	11,229	11,891	14,492	14,705
Total Copper (mg/kg)		300.2	22.7	56.5	24.9	20.7
Total Boron (mg/kg)		5.4	<2	<2	2.9	<2
Total Silicon (mg/kg)		723	839	743	1,039	851
Total Aluminium (mg/kg)		4,427	5,024	5,092	3,626	8,006
Total Molybdenum (mg/kg)		1.1	0.7	0.8	0.5	0.6
Total Cobalt (mg/kg)		11.1	5.6	5.0	9.0	7.7
Total Selenium (mg/kg)		0.6	<0.5	<0.5	0.7	0.6
Total Cadmium (mg/kg)		2.5	<0.5	0.7	<0.5	<0.5
Total Lead (mg/kg)		74	22	48	14	18
Total Arsenic (mg/kg)		7.3	3.6	4.8	5.4	5.1
Total Chromium (mg/kg)		12	11	9.2	4.7	8.7
Total Nickel (mg/kg)		24	10	12	12.3	10
Total Mercury (mg/kg)		0.2	<0.1	0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

			Sample 28	Sample 29	Sample 30	Sample 49	Sample 31
		Sample ID:	MTWNPN201803	MTWSPN201401	MTWSPN201501	MTWSPN201501	MTWSPN201601
		Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
		Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
	Parameter	Method reference	I2408/28	I2408/29	I2408/30	I2408/49	I2408/31

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_c/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.e

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

			Sample 50	Sample 32	Sample 33	Sample 34	Sample 35
		Sample ID:	MTWSPN20160 1 -Orica	MTWSPN20160 2	MTWSPS20160 1	MTWSPS20160 2	MTWSPS20170 1
		Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
		Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter		**Method reference**	**I2408/50**	**I2408/32**	**I2408/33**	**I2408/34**	**I2408/35**
Soluble Calcium (mg/kg)		**Inhouse S10 - Morgan 1	1111	939	1176	1508	1579
Soluble Magnesium (mg/kg)			335	335	498	529	305
Soluble Potassium (mg/kg)			195	200	210	169	171
Soluble Phosphorus (mg/kg)			24	12	5.7	4.7	6.5
Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9E2 (Bray 1)	64	40	18	18	28
		**Rayment & Lyons 2011 - 9B2 (Colwell)	119	75	44	47	66
		**Inhouse S3A (Bray 2)	189	141	80	63	86
Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	15	3.1	3.1	30	9.1
Ammonium Nitrogen (mg/kg N)			6.2	6.3	3.8	5.3	3.6
Sulfur (mg/kg S)			261	55	63	222	90
pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	7.16	6.89	7.46	7.15	7.37
Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.321	0.177	0.188	0.450	0.236
Estimated Organic Matter (% OM)		**Calculation: Total Carbon x 1.75	4.8	5.1	8.4	4.7	4.3
Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	8.82	8.36	10.32	12.18	9.78
	(kg/ha)		3961	3752	4634	5468	4392
	(mg/kg)		1768	1675	2069	2441	1961
Exchangeable Magnesium	(cmol+/kg)		3.96	4.41	6.25	6.05	3.44
	(kg/ha)		1079	1201	1702	1648	936
	(mg/kg)		481	536	760	736	418
Exchangeable Potassium	(cmol+/kg)		0.91	0.96	0.98	0.85	0.81
	(kg/ha)		794	839	854	743	712
	(mg/kg)		354	375	381	332	318
Exchangeable Sodium	(cmol+/kg)		1.73	1.32	0.77	1.19	0.94
	(kg/ha)		889	680	395	611	485
	(mg/kg)		397	304	176	273	217
Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	0.09	0.06	0.09	0.09	0.05
	(kg/ha)		18	13	17	18	10
	(mg/kg)		8	6	8	8	4
Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	(kg/ha)		<1	<1	<1	<1	<1
	(mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	15.51	15.11	18.40	20.36	15.03
Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	56.9	55.3	56.1	59.8	65.1
Magnesium (%)			25.5	29.2	34.0	29.7	22.9
Potassium (%)			5.8	6.3	5.3	4.2	5.4
Sodium - ESP (%)			11.1	8.7	4.2	5.8	6.3
Aluminium (%)			0.6	0.4	0.5	0.4	0.3
Hydrogen			0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	2.2	1.9	1.7	2.0	2.8

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408
Analysis requested by John Moen. Your Job: MTW Mine
50 Gipps Street CARRINGTON NSW 2294

		Sample 50	Sample 32	Sample 33	Sample 34	Sample 35
	Sample ID:	MTWSPN20160 1 -Orica	MTWSPN20160 2	MTWSPS20160 1	MTWSPS20160 2	MTWSPS20170 1
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/50**	**I2408/32**	**I2408/33**	**I2408/34**	**I2408/35**
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	13	12	11	11	9.9
Manganese (mg/kg)		5.2	4.0	2.4	5.4	2.9
Iron (mg/kg)		44	61	20	32	51
Copper (mg/kg)		1.3	1.0	2.2	1.6	0.9
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.61	0.60	0.55	0.48	0.52
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	29	39	18	21	22
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.76	2.92	4.80	2.69	2.46
Total Nitrogen (%)		0.23	0.22	0.22	0.18	0.17
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	11.8	13.5	21.5	14.8	14.9
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	206	113	121	288	151
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	3,970	2,506	4,858	4,464	4,537
Total Magnesium (mg/kg)		1,441	1,145	2,722	1,809	1,058
Total Potassium (mg/kg)		1,310	1,200	1,528	1,356	1,096
Total Sodium (mg/kg)		478	334	258	336	293
Total Sulfur (mg/kg)		389	258	341	788	289
Total Phosphorus (mg/kg)		491	391	324	366	379
Total Zinc (mg/kg)		68	48	83	70	49
Total Manganese (mg/kg)		112	116	280	182	133
Total Iron (mg/kg)		8,439	6,787	16,245	17,289	8,296
Total Copper (mg/kg)		18.0	14.0	26.5	25.2	16.6
Total Boron (mg/kg)		2.7	<2	<2	2.0	3.0
Total Silicon (mg/kg)		1,349	745	664	1,339	1,598
Total Aluminium (mg/kg)		7,034	4,911	5,229	7,854	5,228
Total Molybdenum (mg/kg)		0.5	0.4	0.6	0.7	0.6
Total Cobalt (mg/kg)		3.8	3.8	8.8	5.7	4.0
Total Selenium (mg/kg)		<0.5	<0.5	0.7	0.7	<0.5
Total Cadmium (mg/kg)		<0.5	<0.5	<0.5	<0.5	<0.5
Total Lead (mg/kg)		14	14	21	21	15
Total Arsenic (mg/kg)		3.4	2.9	4.9	5.3	3.6
Total Chromium (mg/kg)		6.8	4.7	6.3	7.6	5.5
Total Nickel (mg/kg)		5.5	5.0	12	8.9	5.6
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	<0.1
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 50	Sample 32	Sample 33	Sample 34	Sample 35
	Sample ID:	MTWSPN20160 1 -Orica	MTWSPN20160 2	MTWSPS20160 1	MTWSPS20160 2	MTWSPS20170 1
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	I2408/50	I2408/32	I2408/33	I2408/34	I2408/35

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.

2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.

3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).

4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.

5. Guidelines for phosphorus have been reduced for Australian soils.

6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.

7. Total Acid Extractable Nutrients indicate a store of nutrients.

8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.

9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.

10. Conversions for 1 $cmol_c/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium

11. Conversions to kg/ha = mg/kg x 2.24

12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate

13. ** NATA accreditation does not cover the performance of this service.

14. Analysis conducted between sample arrival date and reporting date.

15. This report is not to be reproduced except in full. Results only relate to the item tested.

16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.e

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 36	Sample 37	Sample 38	Sample 39	Sample 40
	Sample ID:	MTWSPS201703	MTWSPS201801	MTWWDL201401	MTWWDL201402	MTWWDL201801
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	**Method reference**	**I2408/36**	**I2408/37**	**I2408/38**	**I2408/39**	**I2408/40**
Soluble Calcium (mg/kg)	**Inhouse S10 - Morgan 1	1071	2413	642	817	3763
Soluble Magnesium (mg/kg)		514	527	492	501	538
Soluble Potassium (mg/kg)		143	241	219	209	309
Soluble Phosphorus (mg/kg)		9.0	34	4.8	6.4	103
Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9E2 (Bray 1)	24	61	14	14	101
	**Rayment & Lyons 2011 - 9B2 (Colwell)	42	144	31	24	313
	**Inhouse S3A (Bray 2)	75	234	72	64	440
Nitrate Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	55	20	14	5.6	13
Ammonium Nitrogen (mg/kg N)		2.5	4.1	4.1	5.0	4.3
Sulfur (mg/kg S)		268	390	35	23	284
pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	7.97	7.62	7.13	7.78	7.57
Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.817	0.760	0.126	0.128	0.576
Estimated Organic Matter (% OM)	**Calculation: Total Carbon x 1.75	5.2	10.2	6.5	5.5	11.8
Exchangeable Calcium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	7.36	14.28	6.03	6.09	19.78
Exchangeable Calcium (kg/ha)		3304	6411	2705	2732	8877
Exchangeable Calcium (mg/kg)		1475	2862	1208	1220	3963
Exchangeable Magnesium (cmol+/kg)		5.67	5.36	6.43	5.72	5.32
Exchangeable Magnesium (kg/ha)		1544	1459	1749	1556	1450
Exchangeable Magnesium (mg/kg)		689	651	781	695	647
Exchangeable Potassium (cmol+/kg)		0.64	1.04	1.05	0.97	1.66
Exchangeable Potassium (kg/ha)		563	913	917	848	1452
Exchangeable Potassium (mg/kg)		251	407	410	378	648
Exchangeable Sodium (cmol+/kg)		3.90	2.71	1.28	0.88	2.10
Exchangeable Sodium (kg/ha)		2008	1398	660	454	1081
Exchangeable Sodium (mg/kg)		896	624	295	203	482
Exchangeable Aluminium (cmol+/kg)	**Inhouse S37 (KCl)	0.07	0.09	0.10	0.03	0.04
Exchangeable Aluminium (kg/ha)		15	17	19	6	8
Exchangeable Aluminium (mg/kg)		6	8	9	3	4
Exchangeable Hydrogen (cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
Exchangeable Hydrogen (kg/ha)		<1	<1	<1	<1	<1
Exchangeable Hydrogen (mg/kg)		<1	<1	<1	<1	<1
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)	**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	17.65	23.48	14.88	13.68	28.90
Calcium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	41.7	60.8	40.5	44.5	68.4
Magnesium (%)		32.1	22.8	43.2	41.8	18.4
Potassium (%)		3.6	4.4	7.0	7.1	5.7
Sodium - ESP (%)		22.1	11.6	8.6	6.4	7.3
Aluminium (%)		0.4	0.4	0.6	0.2	0.1
Hydrogen		0.0	0.0	0.0	0.0	0.0
Calcium/Magnesium Ratio	**Calculation: Calcium / Magnesium (cmol+/kg)	1.3	2.7	0.9	1.1	3.7

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

Parameter	Method reference	Sample 36	Sample 37	Sample 38	Sample 39	Sample 40
	Sample ID:	MTWSPS201703	MTWSPS201801	MTWWDL201401	MTWWDL201402	MTWWDL201801
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	Method reference	I2408/36	I2408/37	I2408/38	I2408/39	I2408/40
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	9.8	29	9.0	6.8	82
Manganese (mg/kg)		2.0	4.2	2.4	2.4	8.3
Iron (mg/kg)		19	20	58	21	24
Copper (mg/kg)		1.5	4.8	1.1	1.1	16
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.37	0.76	0.38	0.56	1.38
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	13	22	33	24	37
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.95	5.81	3.69	3.13	6.77
Total Nitrogen (%)		0.15	0.29	0.23	0.17	0.48
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	19.2	20.1	16.0	18.1	14.0
Basic Texture	**Inhouse S65	Loam	Loam	Loam	Loam	Loam
Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	523	486	81	82	369
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	5,354	9,243	2,264	3,686	14,002
Total Magnesium (mg/kg)		3,050	3,835	1,856	2,622	2,442
Total Potassium (mg/kg)		1,196	1,663	1,481	1,497	1,683
Total Sodium (mg/kg)		985	821	394	328	691
Total Sulfur (mg/kg)		441	1,077	275	268	780
Total Phosphorus (mg/kg)		291	829	315	294	1,955
Total Zinc (mg/kg)		71	159	50	59	279
Total Manganese (mg/kg)		173	321	163	208	357
Total Iron (mg/kg)		12,103	22,531	9,969	15,143	14,723
Total Copper (mg/kg)		18.9	45.8	20.0	15.3	99.3
Total Boron (mg/kg)		2.4	4.4	2.3	2.8	6.0
Total Silicon (mg/kg)		1,227	1,612	1,926	1,410	1,181
Total Aluminium (mg/kg)		4,084	5,192	5,590	6,525	6,580
Total Molybdenum (mg/kg)		0.5	0.9	0.6	0.5	1.3
Total Cobalt (mg/kg)		6.2	11.9	5.0	6.6	7.4
Total Selenium (mg/kg)		<0.5	0.7	<0.5	<0.5	<0.5
Total Cadmium (mg/kg)		<0.5	0.6	<0.5	<0.5	1.6
Total Lead (mg/kg)		16	34	11	14	88
Total Arsenic (mg/kg)		4.1	6.5	3.8	4.2	5.5
Total Chromium (mg/kg)		4.9	11	4.5	6.2	17
Total Nickel (mg/kg)		8.3	18	6.7	7.9	20
Total Mercury (mg/kg)		<0.1	<0.1	<0.1	<0.1	0.2
Total Silver (mg/kg)		<1	<1	<1	<1	<1

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55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 36	Sample 37	Sample 38	Sample 39	Sample 40
	Sample ID:	MTWSPS201703	MTWSPS201801	MTWWDL201401	MTWWDL201402	MTWWDL201801
	Crop:	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives	Rehab Natives
	Client:	MTW Mine	MTW Mine	MTW Mine	MTW Mine	MTW Mine
Parameter	Method reference	I2408/36	I2408/37	I2408/38	I2408/39	I2408/40

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 cmol+/kg = 230 mg/kg Sodium, 390 mg/kg Potassium,
122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.e

Quality Checked: Kris Saville
Agricultural Co-Ordinator

KS

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Environmental Analysis Laboratory

AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 51	Heavy Soil	Medium Soil	Light Soil	Sandy Soil
	Sample ID:	NPN201101				
	Crop:	Rehab Natives				
	Client:	MTW Mine	Clay	Clay Loam	Loam	Loamy Sand
Parameter	**Method reference**	**I2408/51**	**Indicative guidelines - refer to Notes 6 and 8**			
Soluble Calcium (mg/kg)	**Inhouse S10 - Morgan 1	948	1150	750	375	175
Soluble Magnesium (mg/kg)	**Inhouse S10 - Morgan 1	336	160	105	60	25
Soluble Potassium (mg/kg)	**Inhouse S10 - Morgan 1	135	113	75	60	50
Soluble Phosphorus (mg/kg)	**Inhouse S10 - Morgan 1	4.5	15	12	10	5.0
Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9E2 (Bray 1)	5.4	45 note 8	30 note 8	24 note 8	20 note 8
Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9B2 (Colwell)	10	80	50	45	35
Phosphorus (mg/kg P)	**Inhouse S3A (Bray 2)	33	90 note 8	60 note 8	48 note 8	40 note 8
Nitrate Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	1.7	15	13	10	10
Ammonium Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	4.6	20	18	15	12
Sulfur (mg/kg S)	**Inhouse S37 (KCl)	154	10.0	8.0	8.0	7.0
pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	7.42	6.5	6.5	6.3	6.3
Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.108	0.200	0.150	0.120	0.100
Estimated Organic Matter (% OM)	**Calculation: Total Carbon x 1.75	4.5	> 5.5	>4 .5	> 3.5	> 2.5
Exchangeable Calcium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	8.65	15.6	10.8	5.0	1.9
Exchangeable Calcium (kg/ha)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	3882	7000	4816	2240	840
Exchangeable Calcium (mg/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	1733	3125	2150	1000	375
Exchangeable Magnesium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	4.15	2.4	1.7	1.2	0.60
Exchangeable Magnesium (kg/ha)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	1129	650	448	325	168
Exchangeable Magnesium (mg/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	504	290	200	145	75
Exchangeable Potassium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	0.66	0.60	0.50	0.40	0.30
Exchangeable Potassium (kg/ha)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	582	526	426	336	224
Exchangeable Potassium (mg/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	260	235	190	150	100
Exchangeable Sodium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	0.11	0.3	0.26	0.22	0.11
Exchangeable Sodium (kg/ha)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	55	155	134	113	57
Exchangeable Sodium (mg/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	25	69	60	51	25
Exchangeable Aluminium (cmol+/kg)	**Inhouse S37 (KCl)	0.04	0.6	0.5	0.4	0.2
Exchangeable Aluminium (kg/ha)	**Inhouse S37 (KCl)	8	121	101	73	30
Exchangeable Aluminium (mg/kg)	**Inhouse S37 (KCl)	4	54	45	32	14
Exchangeable Hydrogen (cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	0.6	0.5	0.4	0.2
Exchangeable Hydrogen (kg/ha)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<1	13	11	8	3
Exchangeable Hydrogen (mg/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<1	6	5	4	2
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)	**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	13.61	20.1	14.3	7.8	3.3
Calcium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	63.6	77.6	75.7	65.6	57.4
Magnesium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	30.5	11.9	11.9	15.7	18.1
Potassium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	4.9	3.0	3.5	5.2	9.1
Sodium - ESP (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	0.8	1.5	1.8	2.9	3.3
Aluminium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	0.3	6.0	7.1	10.5	12.1
Hydrogen	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	0.0				
Calcium/Magnesium Ratio	**Calculation: Calcium / Magnesium (cmol+/kg)	2.1	6.5	6.4	4.2	3.2

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AGRICULTURAL SOIL ANALYSIS REPORT

55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

		Sample 51	Heavy Soil	Medium Soil	Light Soil	Sandy Soil
	Sample ID:	NPN201101				
	Crop:	Rehab Natives				
	Client:	MTW Mine	Clay	Clay Loam	Loam	Loamy Sand
Parameter	**Method reference**	**I2408/51**	**Indicative guidelines - refer to Notes 6 and 8**			
Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	3.3	*6.0*	*5.0*	*4.0*	*3.0*
Manganese (mg/kg)		5.3	*25*	*22*	*18*	*15*
Iron (mg/kg)		14	*25*	*22*	*18*	*15*
Copper (mg/kg)		0.5	*2.4*	*2.0*	*1.6*	*1.2*
Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.32	*2.0*	*1.7*	*1.4*	*1.0*
Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	33	*50*	*45*	*40*	*35*
Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.56	*> 3.1*	*> 2.6*	*> 2.0*	*> 1.4*
Total Nitrogen (%)		0.14	*> 0.30*	*> 0.25*	*> 0.20*	*> 0.15*
Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	18.3	*10–12*	*10–12*	*10–12*	*10–12*
Basic Texture	**Inhouse S65	Loam	..	..	..	..
Basic Colour		Brownish	..	..	..	..
Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	69	..	..	..	..
Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	2,947	*1000–10 000 Ca*			
Total Magnesium (mg/kg)		1,648	*500–5000 Mg*			
Total Potassium (mg/kg)		1,296	*200–2000 K*			
Total Sodium (mg/kg)		93	*100–500 Na*			
Total Sulfur (mg/kg)		211	*100–1000 S*			
Total Phosphorus (mg/kg)		258	*400–1500 P*			
Total Zinc (mg/kg)		47	*20–50 Zn*			
Total Manganese (mg/kg)		310	*200–2000 Mn*			
Total Iron (mg/kg)		16,368	*1000–50 000 Fe*			
Total Copper (mg/kg)		11.0	*20–50 Cu*			
Total Boron (mg/kg)		2.7	*2–50 B*			
Total Silicon (mg/kg)		1,307	*1000–3000 Si*			
Total Aluminium (mg/kg)		6,089	*2000–50 000 Al*			
Total Molybdenum (mg/kg)		0.6	*0.5–3.0 Mo*			
Total Cobalt (mg/kg)		8.2	*5–50 Co*			
Total Selenium (mg/kg)		<0.5	*0.1–2.0 Se*			
Total Cadmium (mg/kg)		<0.5	*<1 Cd*			
Total Lead (mg/kg)		10	*2–200 Pb*			
Total Arsenic (mg/kg)		5.7	*1–50 As*			
Total Chromium (mg/kg)		5.9	*5–1000 Cr*			
Total Nickel (mg/kg)		9.0	*5–500 Ni*			
Total Mercury (mg/kg)		<0.1	*< 0.2 Hg*			
Total Silver (mg/kg)		<1	*.. Ag*			

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55 samples supplied by Cumberland Plain Seeds Pty Ltd on 4th June, 2019. Lab Job No.i2408

Analysis requested by John Moen. Your Job: MTW Mine

50 Gipps Street CARRINGTON NSW 2294

			Sample 51	Heavy Soil	Medium Soil	Light Soil	Sandy Soil
		Sample ID:	NPN201101				
		Crop:	Rehab Natives				
		Client:	MTW Mine	*Clay*	*Clay Loam*	*Loam*	*Loamy Sand*
	Parameter	**Method reference**	**I2408/51**	**Indicative guidelines - refer to Notes 6 and 8**			
Notes:							

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
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Quality Checked: Kris Saville
Agricultural Co-Ordinator

KS

CRICOS Provider: 01241G

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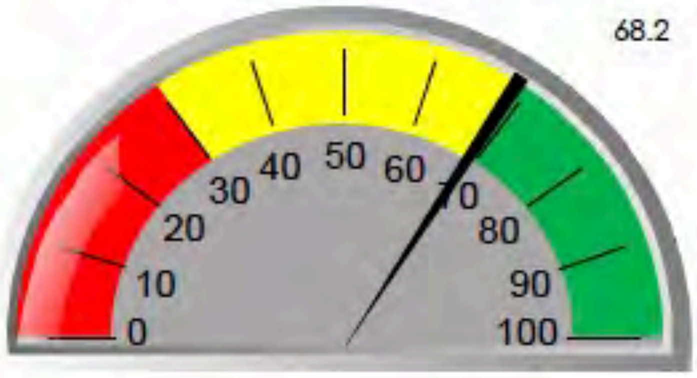
MICROBE WISE
FOR SOIL

Name: **SESL Australia** Sample: **Bell 01-52885:1** Analysis no.: **2230-1-MWSS** Date: **4/06/2019**

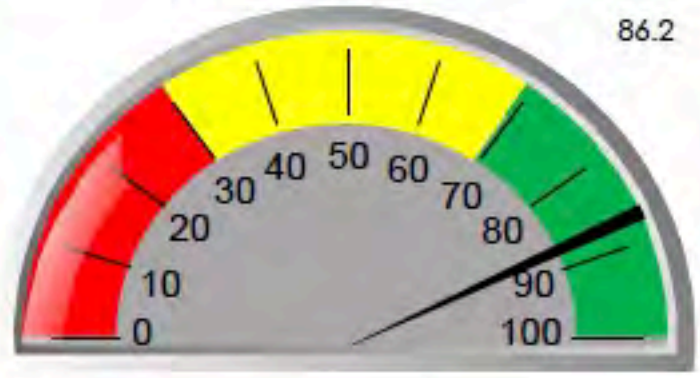
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	Bell 01-52885:1	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-1-MWSS

Microbial Soil Indicators

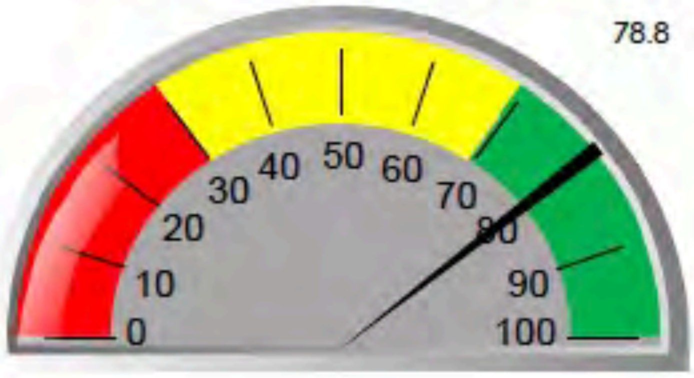
Nutrient solubilisation rate



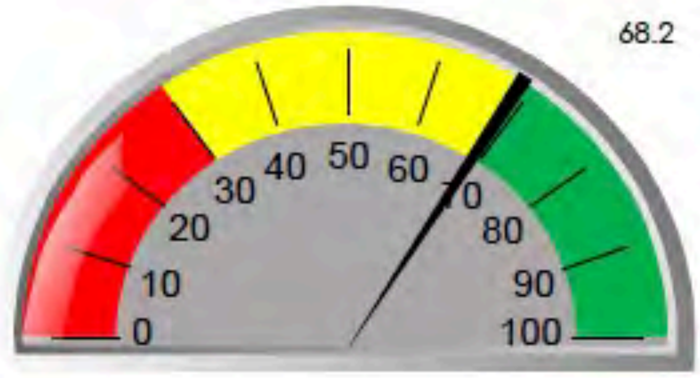
Nutrient cycling rate



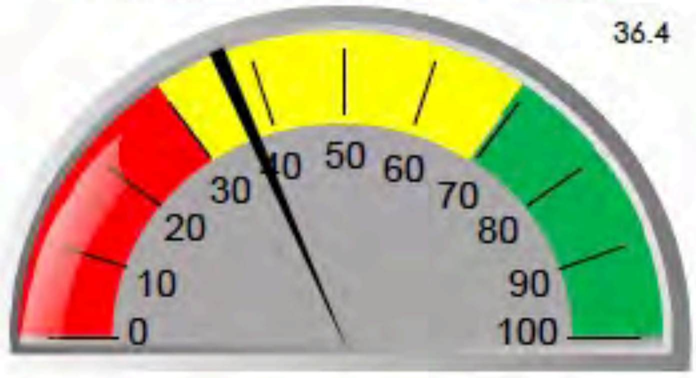
Disease resistance



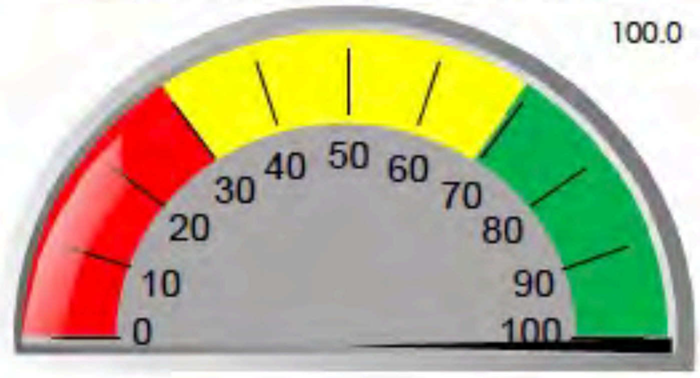
Drought resistance



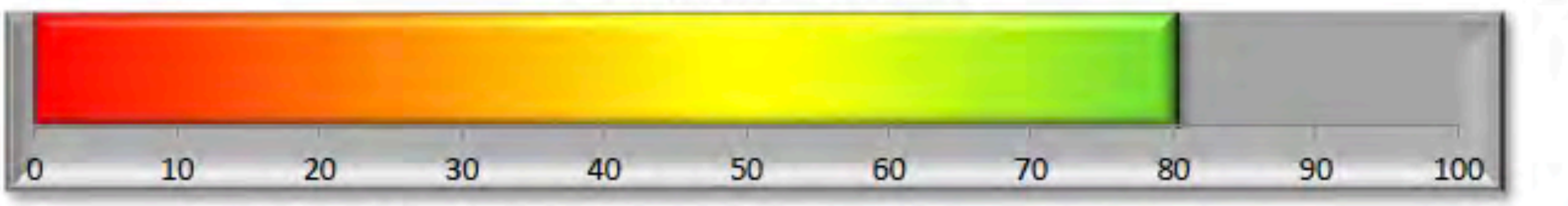
Nutrient accessibility (VAM)



Residue breakdown rate



Overall microbial balance



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **Bell 01-52885:1** Analysis no.: **2230-1-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	80.8	50.0
Total bacteria	22.1	15.0
Total fungi	57.8	33.8

Microbial indicators	Yours	Guide
Microbial diversity	32.4	80.0
Fungi : Bacteria	2.6	2.3
Bacterial stress	1.2	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	1.368	1.000
Actinomycetes	3.839	1.000
Gram positive	13.334	4.000
Gram negative	8.816	11.000
Methane oxidisers	0.000	0.500
Sulphur reducers	0.000	< 0.005
True anaerobes	0.645	< 0.005
Eukaryotes		
Protozoa	0.840	1.300
Mycorrhizal fungi (including VAM)	3.638	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor Fair Good

Comments

The soil indicators ranged from fair, to good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups ranged from fair to poor for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were fair to good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit www.microbelabs.com.au for more information.

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MICROBE WISE FOR SOIL

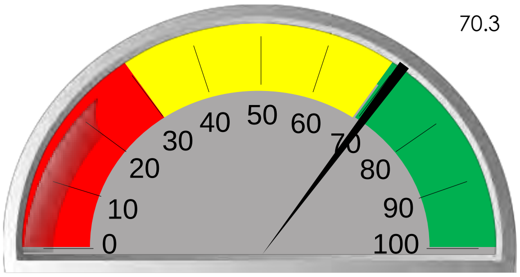
Name: **SESL Australia** Sample: **Bell 02 - 52885:2** Analysis no.: **2230-2-MWSS** Date: **4/06/2019**

Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	Bell 02 - 52885:2	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-2-MWSS

Microbial Soil Indicators

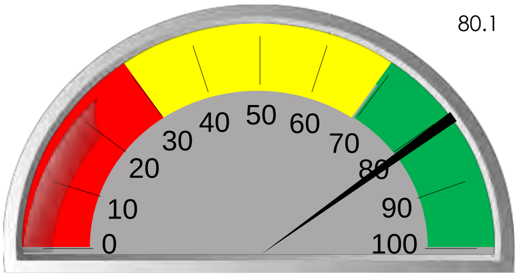
Nutrient solubilisation rate

70.3



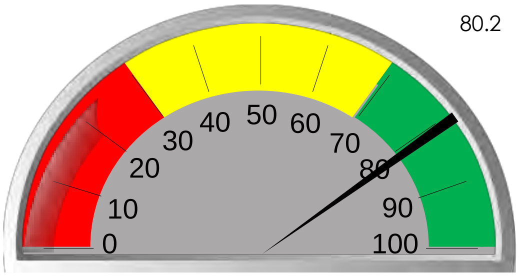
Nutrient cycling rate

80.1



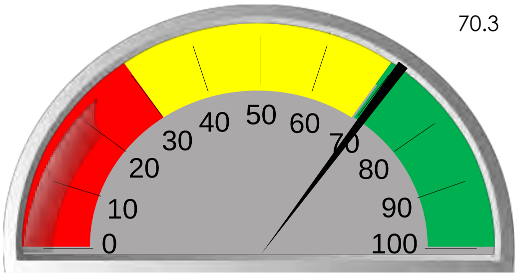
Disease resistance

80.2



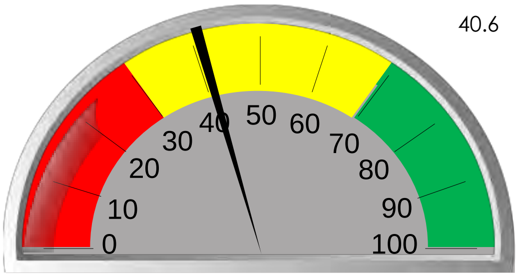
Drought resistance

70.3



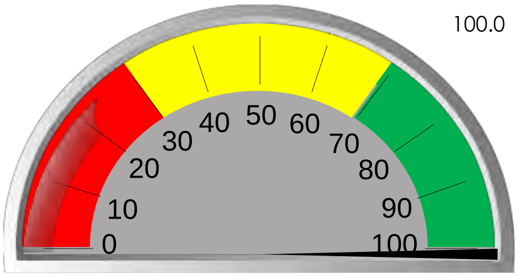
Nutrient accessibility (VAM)

40.6



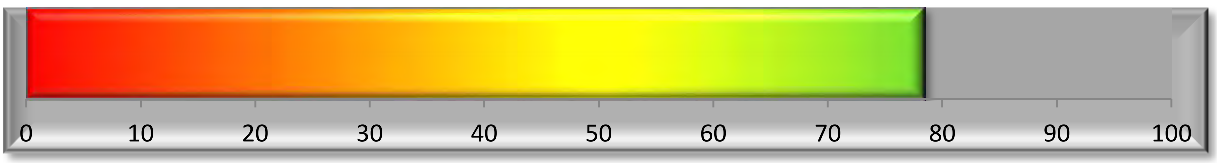
Residue breakdown rate

100.0



Overall microbial balance

78.3



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **Bell 02 - 52885:2** Analysis no.: **2230-2-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**56.4**	50.0
Total bacteria	**14.3**	15.0
Total fungi	**41.2**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**38.7**	80.0
Fungi : Bacteria	**2.9**	2.3
Bacterial stress	**0.9**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.188**	1.000
Actinomycetes	**2.259**	1.000
Gram positive	**8.199**	4.000
Gram negative	**6.151**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.269**	< 0.005
Eukaryotes		
Protozoa	**0.837**	1.300
Mycorrhizal fungi (including VAM)	**4.057**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor Fair Good

Comments

The soil indicators ranged from fair, to good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups ranged from fair for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were fair to good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi and Gram negative bacteria. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

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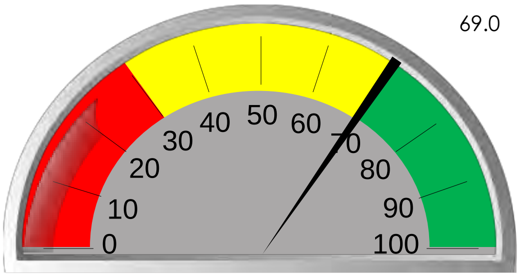
MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **Bell 02 - 52885:3** Analysis no.: **2230-3-MWSS** Date: **4/06/2019**

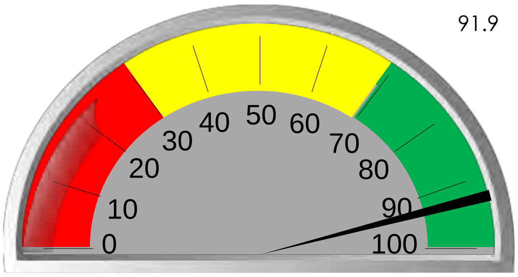
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	Bell 02 - 52885:3	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-3-MWSS

Microbial Soil Indicators

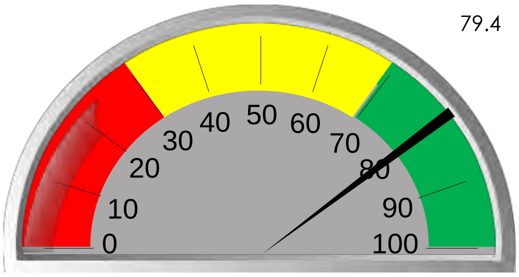
Nutrient solubilisation rate



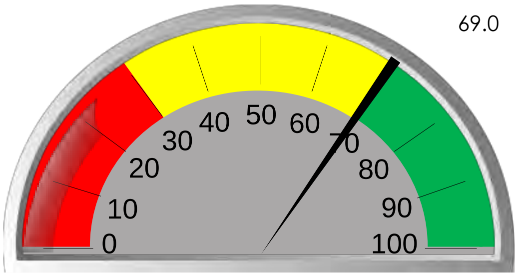
Nutrient cycling rate



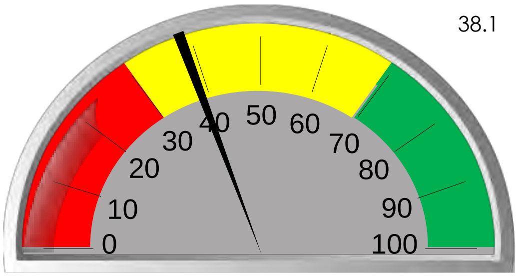
Disease resistance



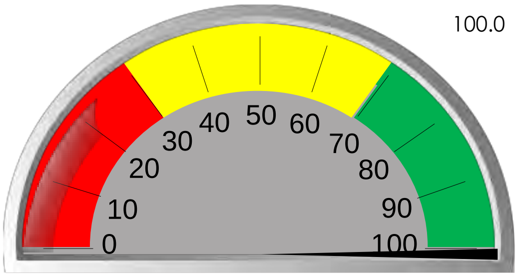
Drought resistance



Nutrient accessibility (VAM)

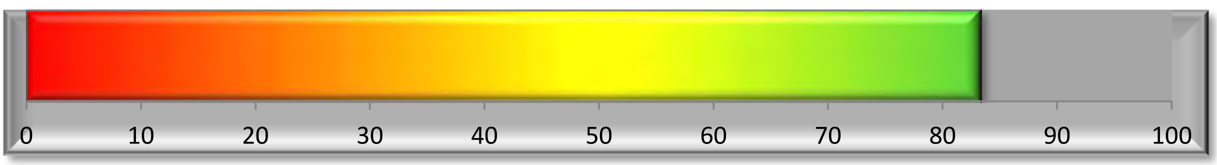


Residue breakdown rate



Overall microbial balance

83.2



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **Bell 02 - 52885:3** Analysis no.: **2230-3-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Guide
Total microorganisms	**63.0**	50.0
Total bacteria	**18.1**	15.0
Total fungi	**43.3**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**34.8**	80.0
Fungi : Bacteria	**2.4**	2.3
Bacterial stress	**1.1**	< 0.5

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor Fair Good

Group	Biomass (mg/kg) Yours	Guide
Bacteria		
Pseudomonas	**1.191**	1.000
Actinomycetes	**3.115**	1.000
Gram positive	**10.615**	4.000
Gram negative	**7.438**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.649**	< 0.005
Eukaryotes		
Protozoa	**1.669**	1.300
Mycorrhizal fungi (including VAM)	**3.807**	10.000

Comments

The soil indicators ranged from fair, to good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups ranged from fair to poor for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi and Gram negative bacteria. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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MICROBE WISE FOR SOIL

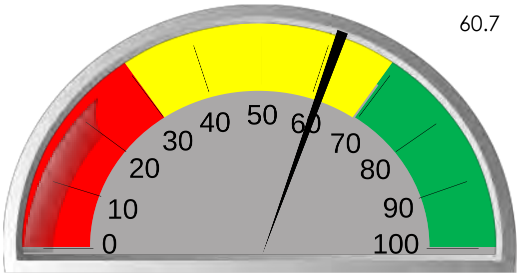
Name: **SESL Australia** Sample: **WanboSpot 1 - 52885:8** Analysis no.: **2230-8-MWSS** Date: **4/06/2019**

Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	WanboSpot 1 - 52885:8	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-8-MWSS

Microbial Soil Indicators

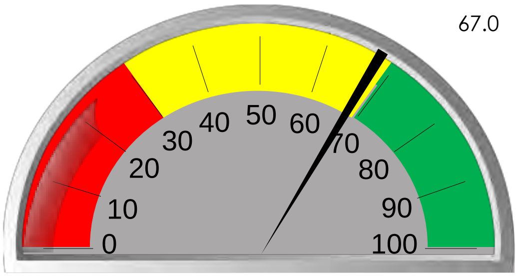
Nutrient solubilisation rate

60.7



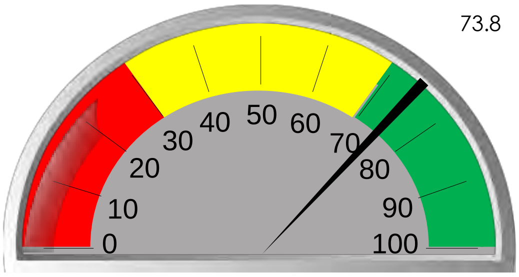
Nutrient cycling rate

67.0



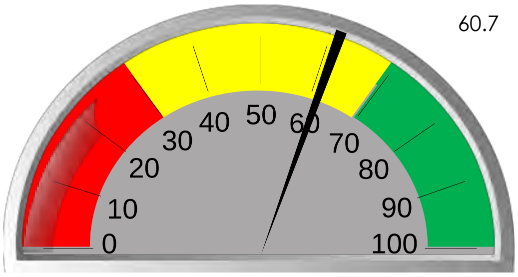
Disease resistance

73.8



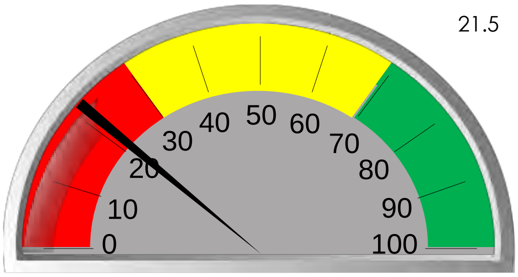
Drought resistance

60.7



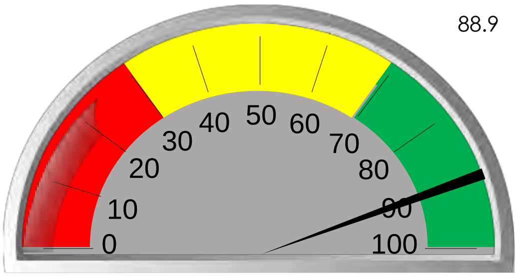
Nutrient accessibility (VAM)

21.5



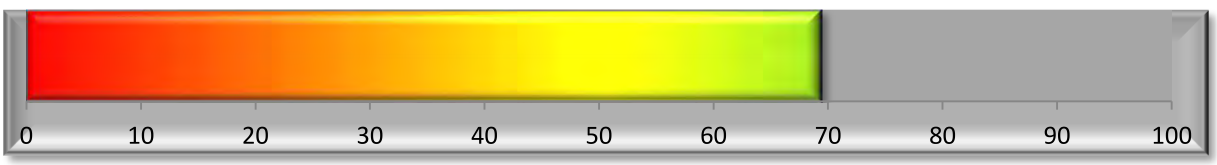
Residue breakdown rate

88.9



Overall microbial balance

69.3



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Name: **SESL Australia** Sample: **WanboSpot 1 - 52885:8** Analysis no.: **2230-8-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**40.3**	50.0
Total bacteria	**13.5**	15.0
Total fungi	**26.3**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**35.6**	80.0
Fungi : Bacteria	**1.9**	2.3
Bacterial stress	**0.9**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.075**	1.000
Actinomycetes	**1.927**	1.000
Gram positive	**7.735**	4.000
Gram negative	**5.790**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.357**	< 0.005
Eukaryotes		
Protozoa	**0.489**	1.300
Mycorrhizal fungi (including VAM)	**2.146**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators ranged from poor, to good. The total mass of microbes in your sample was fair to good. Biomasses of other key desirable microbe groups ranged from poor for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were fair to poor here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was sligtly lower than the guide but it may not be of concern here. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi and Protozoa. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

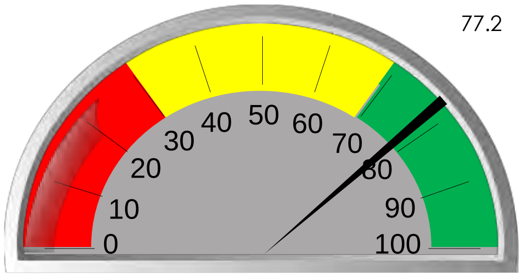
Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

Name: **SESL Australia** Sample: **WanboSpot 2 - 52885:9** Analysis no.: **2230-9-MWSS** Date: **4/06/2019**

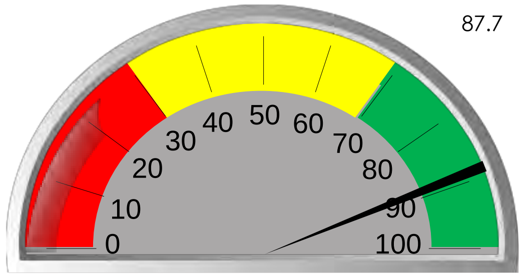
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	WanboSpot 2 - 52885:9	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-9-MWSS

Microbial Soil Indicators

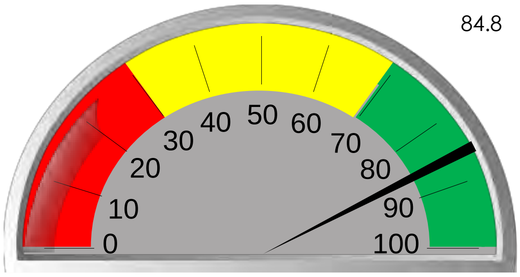
Nutrient solubilisation rate



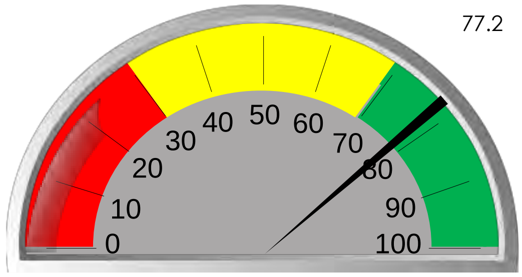
Nutrient cycling rate



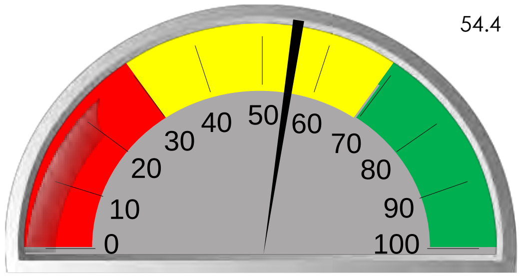
Disease resistance



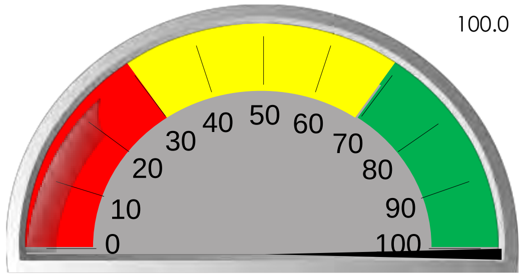
Drought resistance



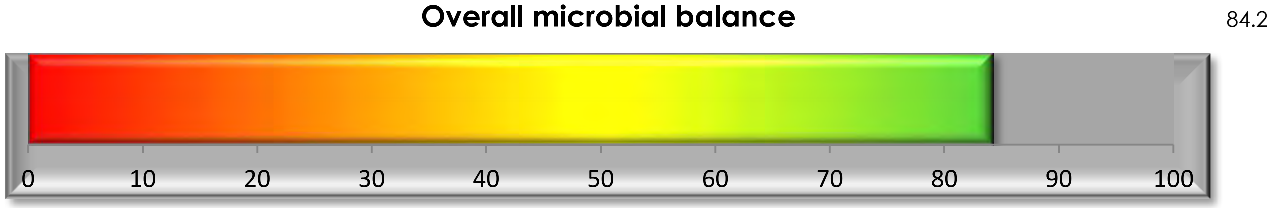
Nutrient accessibility (VAM)



Residue breakdown rate



Overall microbial balance



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **WanboSpot 2 - 52885:9** Analysis no.: **2230-9-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**70.4**	50.0
Total bacteria	**20.8**	15.0
Total fungi	**48.7**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**41.8**	80.0
Fungi : Bacteria	**2.3**	2.3
Bacterial stress	**0.6**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.761**	1.000
Actinomycetes	**3.244**	1.000
Gram positive	**11.797**	4.000
Gram negative	**9.015**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.785**	< 0.005
Eukaryotes		
Protozoa	**0.897**	1.300
Mycorrhizal fungi (including VAM)	**5.441**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators were all good. Except for Nutrient Accessibility, which was fair. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups ranged from fair for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were fair to good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

Disclaimer

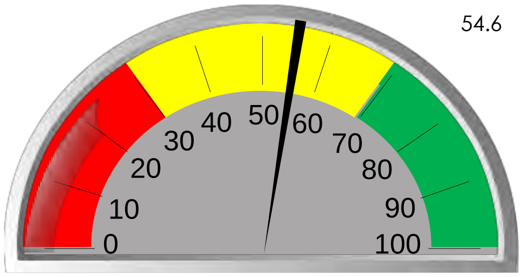
Name: **SESL Australia** Sample: **WanboSpot 3 - 52885:10** Analysis no.: **2230-10-MWSS** Date: **4/06/2019**

Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	WanboSpot 3 - 52885:10	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-10-MWSS

Microbial Soil Indicators

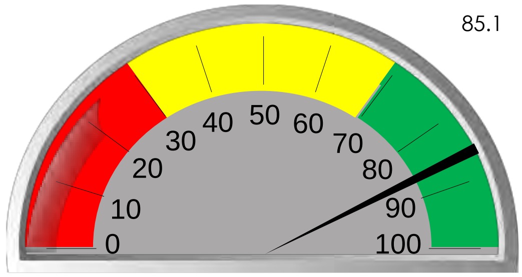
Nutrient solubilisation rate

54.6



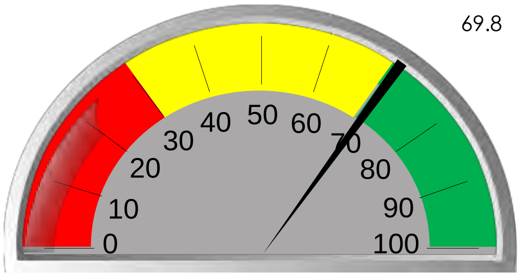
Nutrient cycling rate

85.1



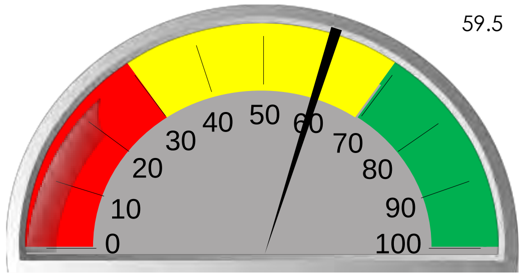
Disease resistance

69.8



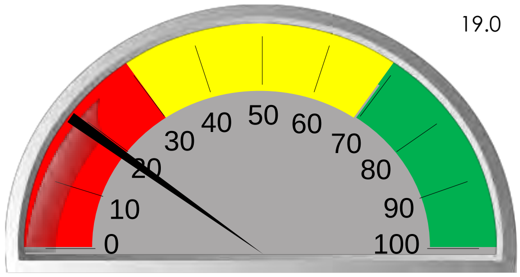
Drought resistance

59.5



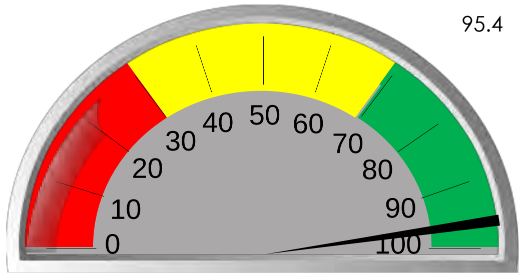
Nutrient accessibility (VAM)

19.0



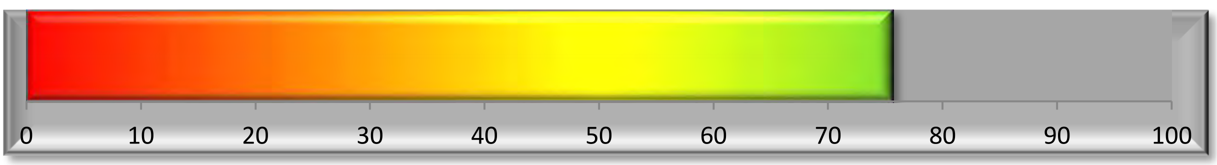
Residue breakdown rate

95.4



Overall microbial balance

75.6



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **WanboSpot 3 - 52885:10** Analysis no.: **2230-10-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**45.2**	50.0
Total bacteria	**13.2**	15.0
Total fungi	**30.7**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**33.9**	80.0
Fungi : Bacteria	**2.3**	2.3
Bacterial stress	**1.0**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**0.903**	1.000
Actinomycetes	**2.132**	1.000
Gram positive	**7.741**	4.000
Gram negative	**5.469**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.339**	< 0.005
Eukaryotes		
Protozoa	**1.356**	1.300
Mycorrhizal fungi (including VAM)	**1.902**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators ranged from poor, to good. The total mass of microbes in your sample was good. Biomasses of other key desirable microbe groups ranged from poor for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. However, as the levels of Mycorrhizal fungi were poor, this may indicate a possible pathogen problem. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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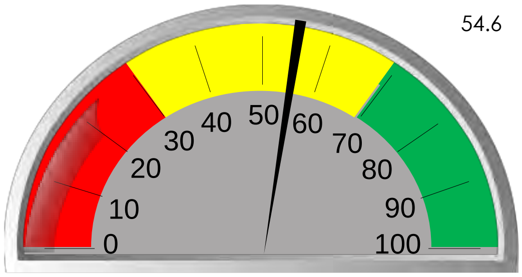
MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **Wantobg1 - 52885:11** Analysis no.: **2230-11-MWSS** Date: **4/06/2019**

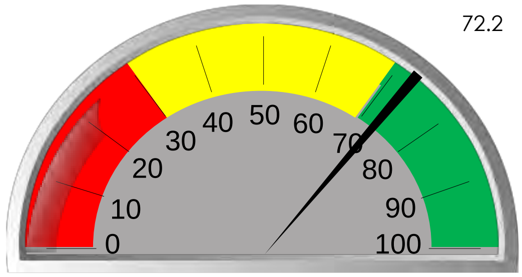
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	Wantobg1 - 52885:11	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-11-MWSS

Microbial Soil Indicators

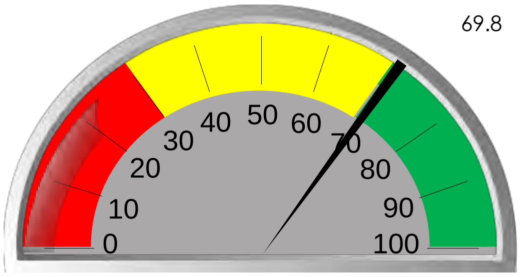
Nutrient solubilisation rate



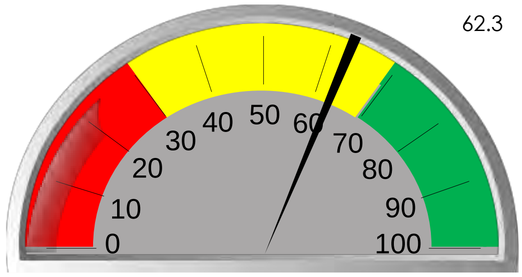
Nutrient cycling rate



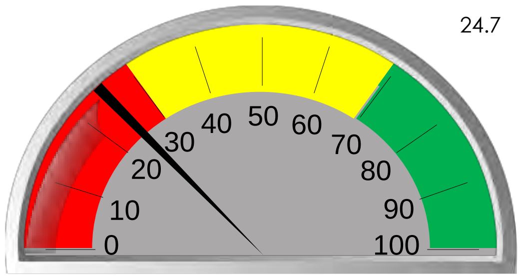
Disease resistance



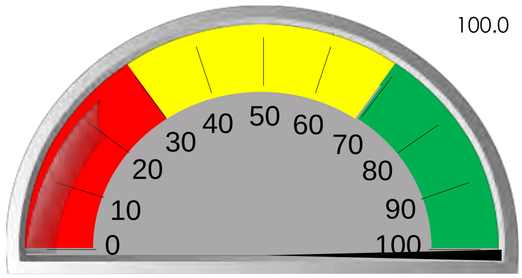
Drought resistance



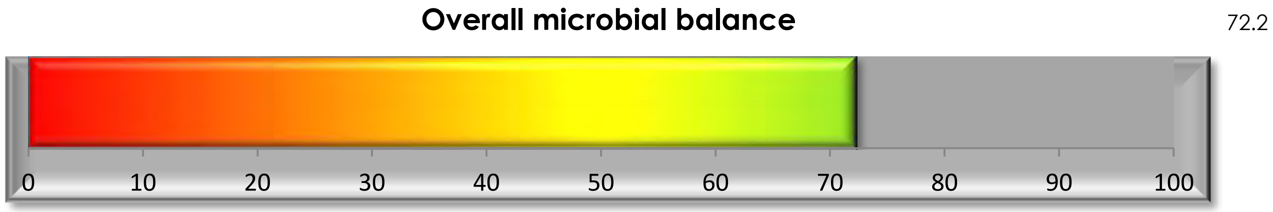
Nutrient accessibility (VAM)



Residue breakdown rate



Overall microbial balance



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **Wantobg1 - 52885:11** Analysis no.: **2230-11-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**50.8**	50.0
Total bacteria	**15.9**	15.0
Total fungi	**34.5**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**41.2**	80.0
Fungi : Bacteria	**2.2**	2.3
Bacterial stress	**1.0**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**0.846**	1.000
Actinomycetes	**2.893**	1.000
Gram positive	**9.915**	4.000
Gram negative	**5.979**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.650**	< 0.005
Eukaryotes		
Protozoa	**0.449**	1.300
Mycorrhizal fungi (including VAM)	**2.465**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor — Fair — Good

Comments

The soil indicators ranged from poor, to good. The total mass of microbes in your sample was good. Biomasses of other key desirable microbe groups ranged from poor for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were poor here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. However, as the levels of Mycorrhizal fungi were poor, this may indicate a possible pathogen problem. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

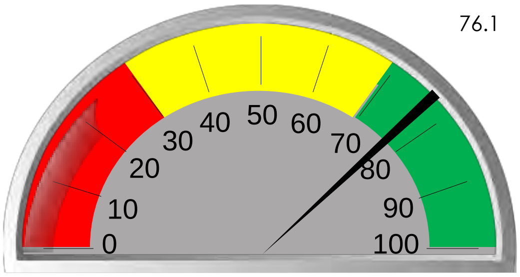
Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

Name: **SESL Australia** Sample: **Wantobg2 - 52885:12** Analysis no.: **2230-12-MWSS** Date: **4/06/2019**

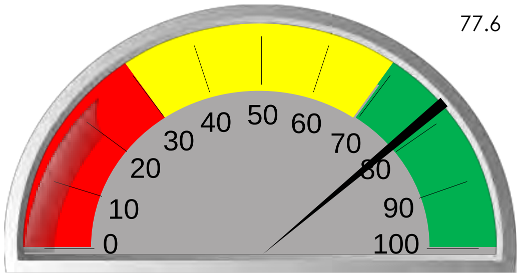
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	Wantobg2 - 52885:12	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-12-MWSS

Microbial Soil Indicators

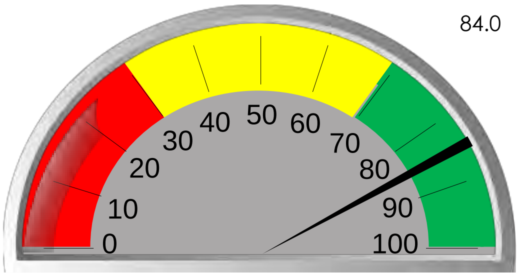
Nutrient solubilisation rate



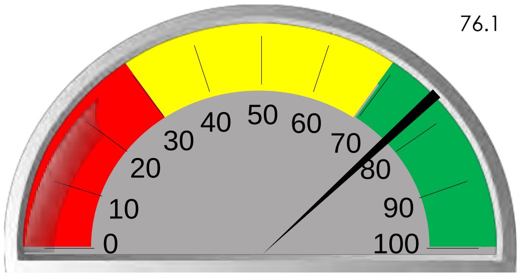
Nutrient cycling rate



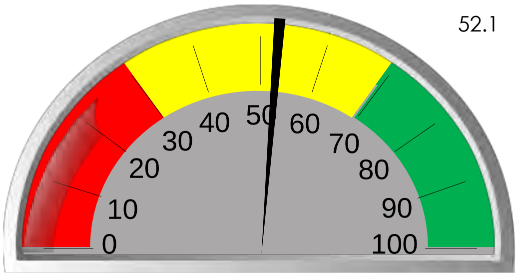
Disease resistance



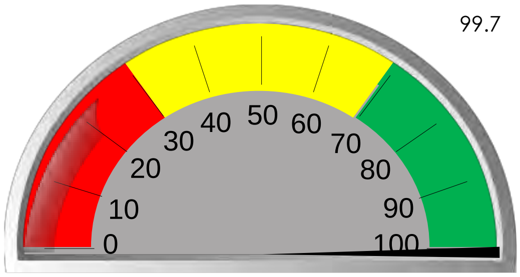
Drought resistance



Nutrient accessibility (VAM)

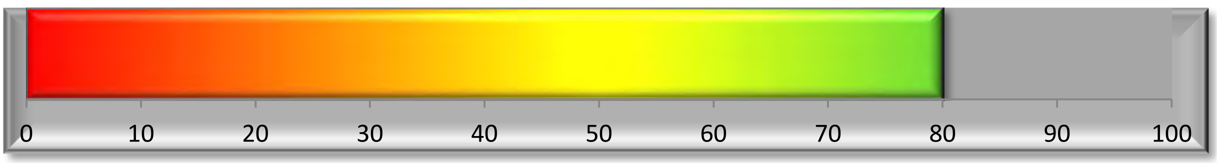


Residue breakdown rate



Overall microbial balance

80.0



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **Wantobg2 - 52885:12** Analysis no.: **2230-12-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Guide
Total microorganisms	**51.8**	50.0
Total bacteria	**17.5**	15.0
Total fungi	**33.6**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**45.9**	80.0
Fungi : Bacteria	**1.9**	2.3
Bacterial stress	**0.8**	< 0.5

Group	Biomass (mg/kg) Yours	Guide
Bacteria		
Pseudomonas	**1.183**	1.000
Actinomycetes	**3.369**	1.000
Gram positive	**10.830**	4.000
Gram negative	**6.701**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.725**	< 0.005
Eukaryotes		
Protozoa	**0.650**	1.300
Mycorrhizal fungi (including VAM)	**5.213**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor Fair Good

Comments

The soil indicators were all good. Except for Nutrient Accessibility, which was fair. The total mass of microbes in your sample was good. Biomasses of other key desirable microbe groups ranged from fair for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were fair here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was lower than the guide but it may not be of concern here. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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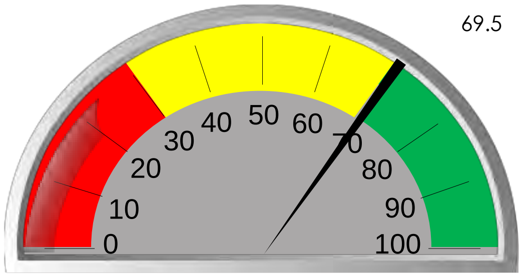
MICROBE WISE FOR SOIL

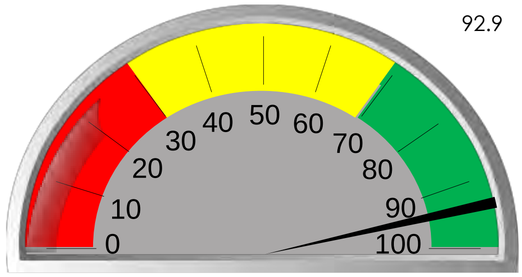
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	WarkGB01 - 52885:4	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-4-MWSS

Microbial Soil Indicators

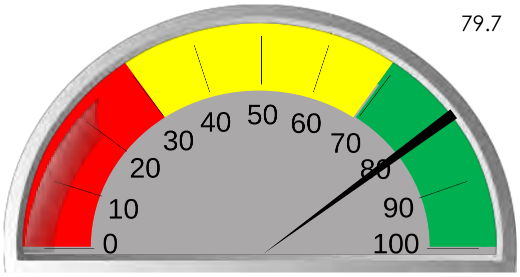
Nutrient solubilisation rate



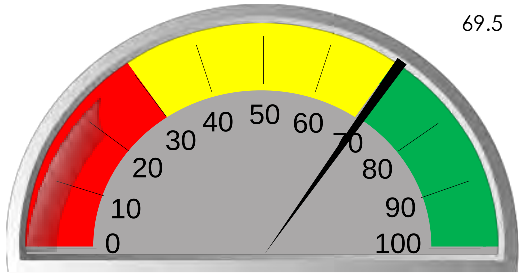
Nutrient cycling rate



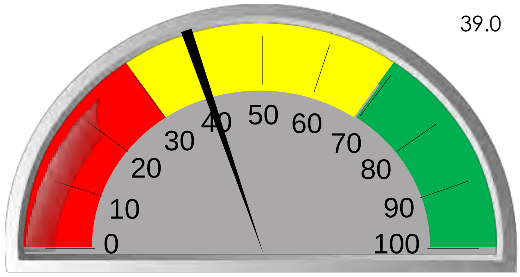
Disease resistance



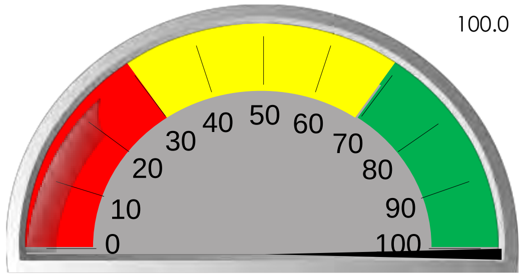
Drought resistance



Nutrient accessibility (VAM)

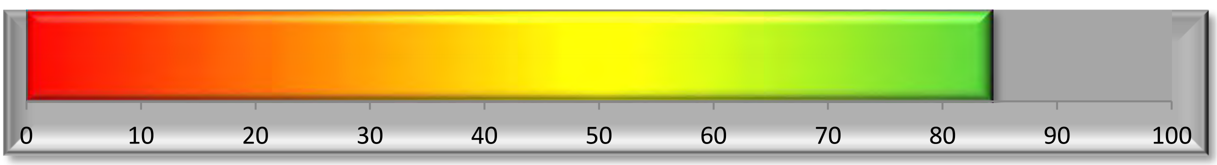


Residue breakdown rate



Overall microbial balance

84.2



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **WarkGB01 - 52885:4** Analysis no.: **2230-4-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**71.7**	50.0
Total bacteria	**17.4**	15.0
Total fungi	**50.4**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**38.1**	80.0
Fungi : Bacteria	**2.9**	2.3
Bacterial stress	**0.8**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.353**	1.000
Actinomycetes	**1.681**	1.000
Gram positive	**9.555**	4.000
Gram negative	**7.873**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.705**	< 0.005
Eukaryotes		
Protozoa	**3.950**	1.300
Mycorrhizal fungi (including VAM)	**3.896**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators ranged from fair, to good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups ranged from fair for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were fair to good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

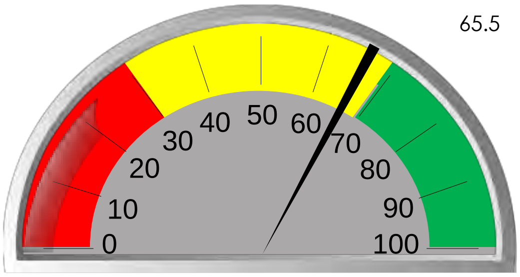
Name: **SESL Australia** Sample: **WarkGB02 - 52885:5** Analysis no.: **2230-5-MWSS** Date: **4/06/2019**

Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	WarkGB02 - 52885:5	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-5-MWSS

Microbial Soil Indicators

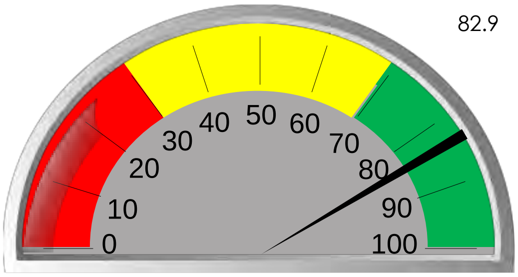
Nutrient solubilisation rate

65.5



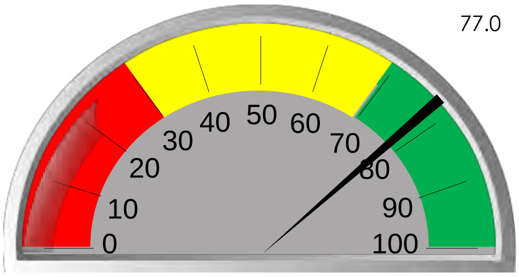
Nutrient cycling rate

82.9



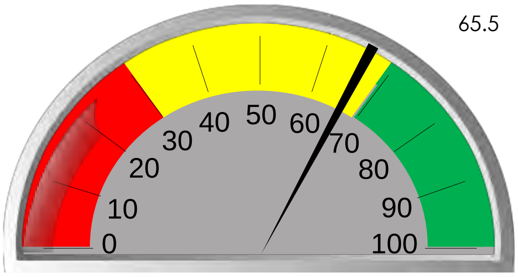
Disease resistance

77.0



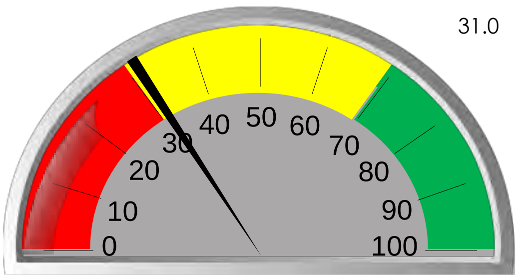
Drought resistance

65.5



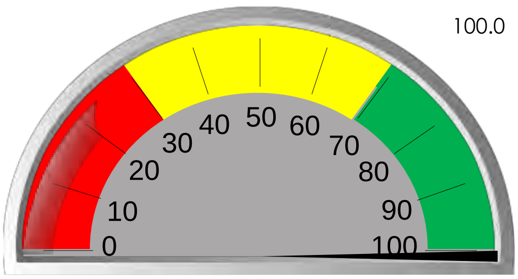
Nutrient accessibility (VAM)

31.0



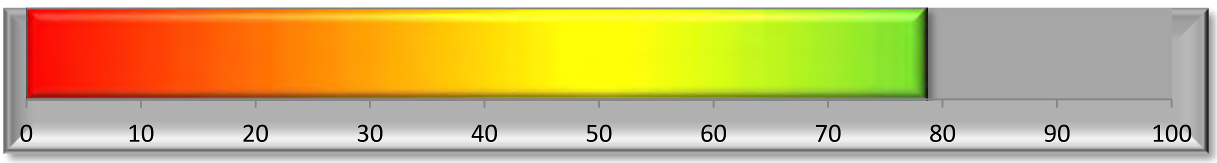
Residue breakdown rate

100.0



Overall microbial balance

78.5



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **WarkGB02 - 52885:5** Analysis no.: **2230-5-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**61.6**	50.0
Total bacteria	**17.8**	15.0
Total fungi	**43.0**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**35.5**	80.0
Fungi : Bacteria	**2.4**	2.3
Bacterial stress	**0.9**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.273**	1.000
Actinomycetes	**3.011**	1.000
Gram positive	**10.659**	4.000
Gram negative	**7.093**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.459**	< 0.005
Eukaryotes		
Protozoa	**0.872**	1.300
Mycorrhizal fungi (including VAM)	**3.098**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators ranged from fair to poor, to good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups ranged from fair to poor for Mycorrhizal fungi, to good for Pseudomonas, Actinomycetes, etc. Protozoa, which were fair to fair to good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

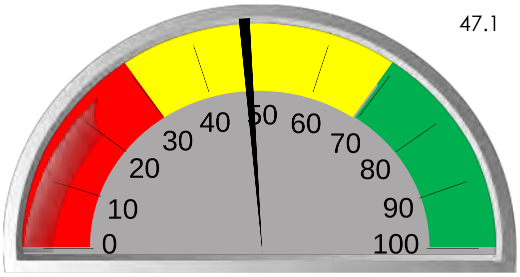
Name: **SESL Australia** Sample: **WarkGB03 - 52885:6** Analysis no.: **2230-6-MWSS** Date: **4/06/2019**

Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	WarkGB03 - 52885:6	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-6-MWSS

Microbial Soil Indicators

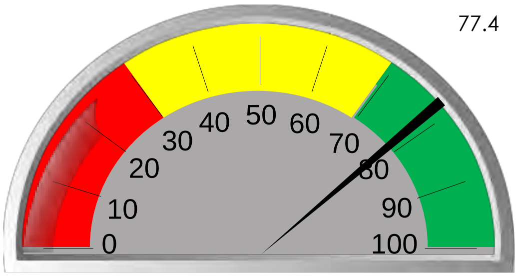
Nutrient solubilisation rate

47.1



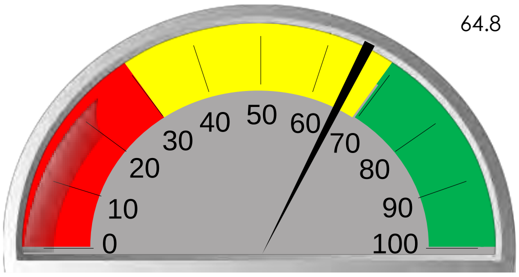
Nutrient cycling rate

77.4



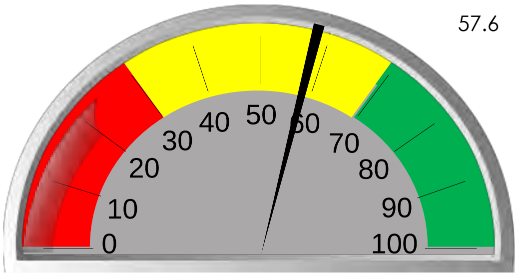
Disease resistance

64.8



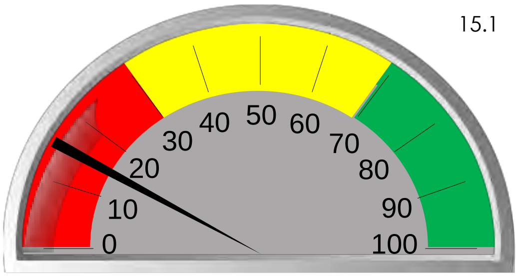
Drought resistance

57.6



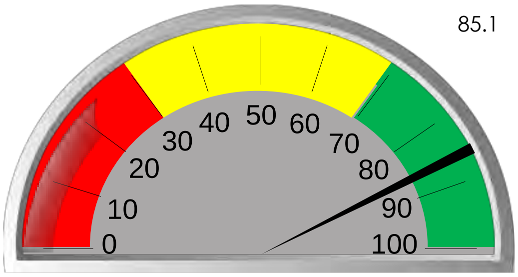
Nutrient accessibility (VAM)

15.1



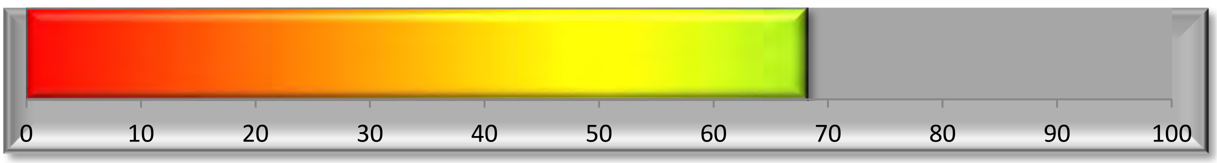
Residue breakdown rate

85.1



Overall microbial balance

68.1



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **WarkGB03 - 52885:6** Analysis no.: **2230-6-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Guide
Total microorganisms	**35.2**	50.0
Total bacteria	**10.1**	15.0
Total fungi	**23.7**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**33.1**	80.0
Fungi : Bacteria	**2.3**	2.3
Bacterial stress	**0.9**	< 0.5

Group	Biomass (mg/kg) Yours	Guide
Bacteria		
Pseudomonas	**0.791**	1.000
Actinomycetes	**1.615**	1.000
Gram positive	**5.768**	4.000
Gram negative	**4.354**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.287**	< 0.005
Eukaryotes		
Protozoa	**1.372**	1.300
Mycorrhizal fungi (including VAM)	**1.515**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor Fair Good

Comments

The soil indicators ranged from poor, to good. The total mass of microbes in your sample was fair to good. Biomasses of other key desirable microbe groups ranged from poor for Mycorrhizal fungi, to good for Actinomycetes, etc. Protozoa, which were good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good, however the levels of Mycorrhizal fungi were poor indicating a possible problem with pathogens. These results suggest that management practices should initially focus on building general microbial biomass but mainly Mycorrhizal fungi and Gram negative bacteria. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

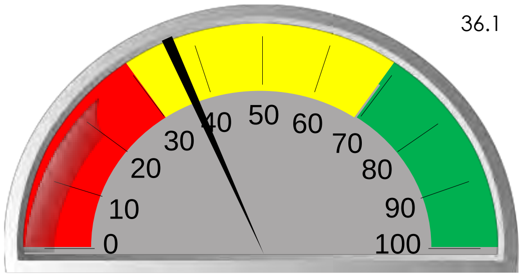
Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

Name: **SESL Australia** Sample: **WarkGB04 - 52885:7** Analysis no.: **2230-7-MWSS** Date: **4/06/2019**

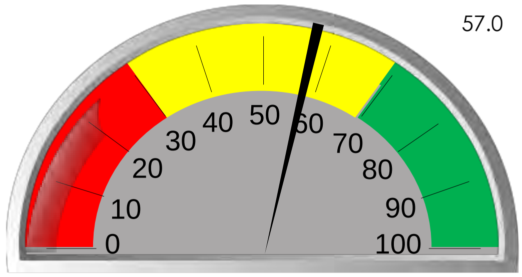
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	WarkGB04 - 52885:7	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-7-MWSS

Microbial Soil Indicators

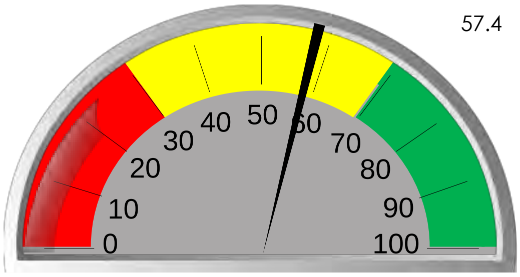
Nutrient solubilisation rate



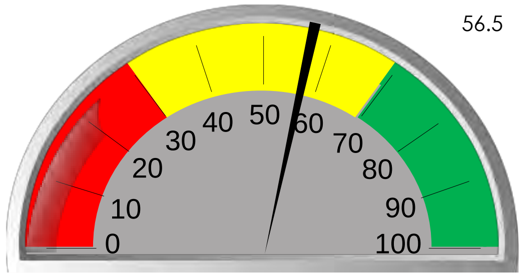
Nutrient cycling rate



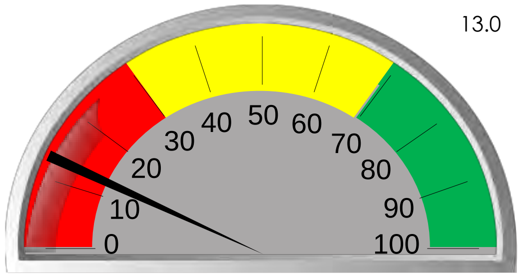
Disease resistance



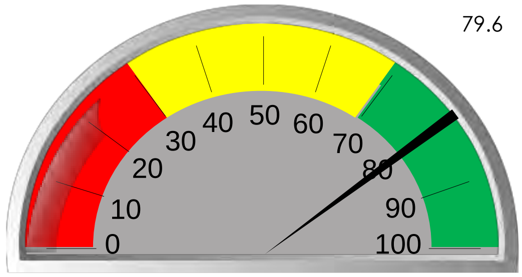
Drought resistance



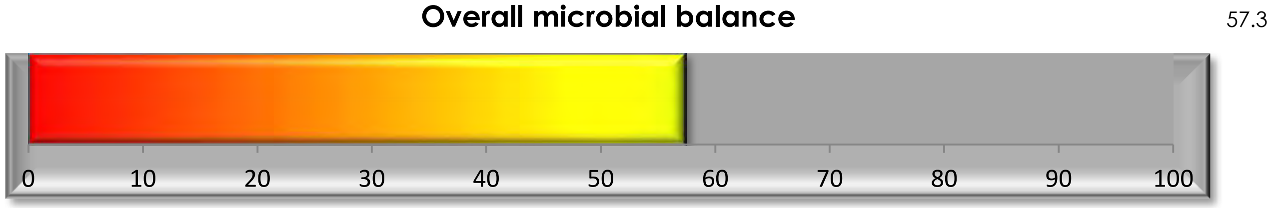
Nutrient accessibility (VAM)



Residue breakdown rate



Overall microbial balance



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Name: **SESL Australia** Sample: **WarkGB04 - 52885:7** Analysis no.: **2230-7-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Guide
Total microorganisms	**31.0**	50.0
Total bacteria	**10.5**	15.0
Total fungi	**20.0**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**36.3**	80.0
Fungi : Bacteria	**1.9**	2.3
Bacterial stress	**1.0**	< 0.5

Group	Biomass (mg/kg) Yours	Guide
Bacteria		
Pseudomonas	**0.591**	1.000
Actinomycetes	**1.849**	1.000
Gram positive	**6.306**	4.000
Gram negative	**4.237**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.450**	< 0.005
Eukaryotes		
Protozoa	**0.391**	1.300
Mycorrhizal fungi (including VAM)	**1.305**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor — Fair — Good

Comments

The soil indicators ranged from poor, to good. The total mass of microbes in your sample was fair to good. Biomasses of other key desirable microbe groups ranged from poor for Mycorrhizal fungi, to good for Actinomycetes, etc. Protozoa, which were poor here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was slightly lower than the guide but it may not be of concern here. These results suggest that management practices should initially focus on building general microbial biomass. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

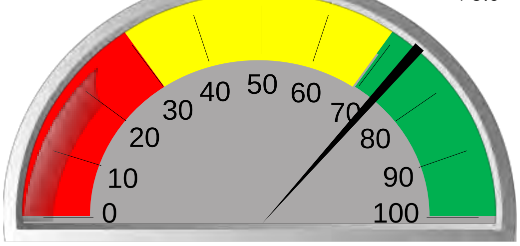
Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

Name: **SESL Australia** Sample: **MTWNPN200901 - 52885:13** Analysis no.: **2230-13-MWSS** Date: **4/06/2019**

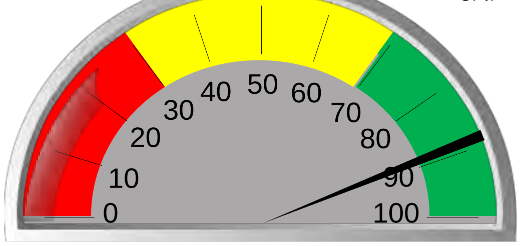
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	MTWNPN200901 - 52885:13	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-13-MWSS

Microbial Soil Indicators

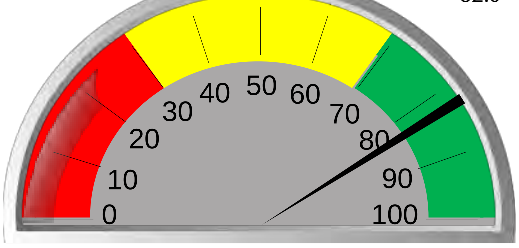
Nutrient solubilisation rate



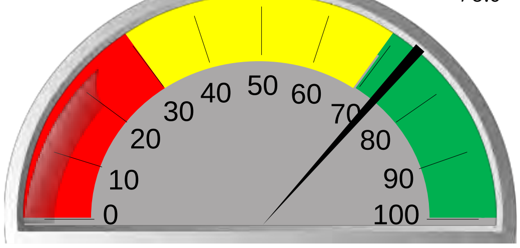
Nutrient cycling rate



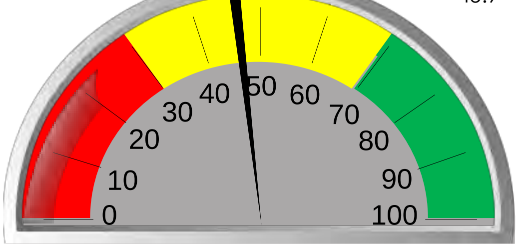
Disease resistance



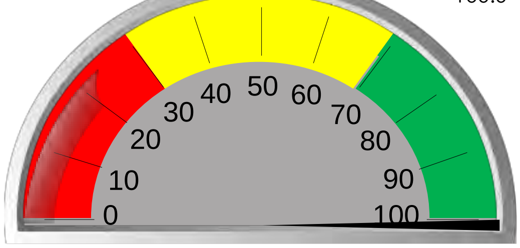
Drought resistance



Nutrient accessibility (VAM)

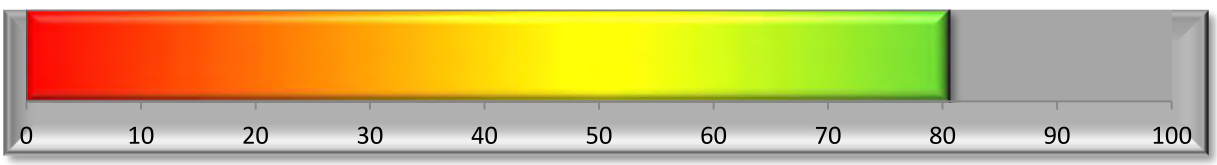


Residue breakdown rate



Overall microbial balance

80.5



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTWNPN200901 - 52885:13** Analysis no.: **2230-13-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**84.7**	50.0
Total bacteria	**12.5**	15.0
Total fungi	**69.6**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**35.8**	80.0
Fungi : Bacteria	**5.6**	2.3
Bacterial stress	**0.5**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.077**	1.000
Actinomycetes	**1.832**	1.000
Gram positive	**6.894**	4.000
Gram negative	**5.596**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.472**	< 0.005
Eukaryotes		
Protozoa	**2.634**	1.300
Mycorrhizal fungi (including VAM)	**4.591**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators were all good. Except for Nutrient Accessibility, which was fair due to intermediate levels of Mycorrhizal fungi. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups ranged from fair, to good. Protozoa, which were good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was highly elevated, and needs to be balanced as Mycorrhizal fungi were fair. These results suggest that management practices should initially focus on building bacteria and Mycorrhizal fungi biomasses. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

Disclaimer

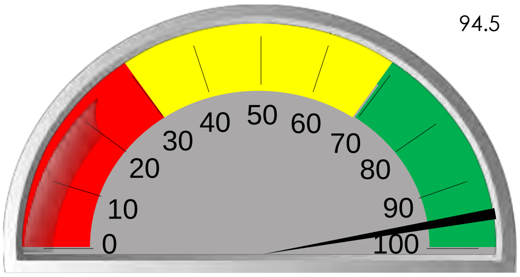
Name: **SESL Australia** Sample: **MTWNPN201101 - 52885:14** Analysis no.: **2230-14-MWSS** Date: **4/06/2019**

Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	MTWNPN201101 - 52885:14	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-14-MWSS

Microbial Soil Indicators

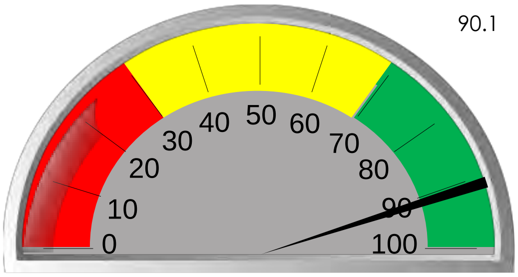
Nutrient solubilisation rate

94.5



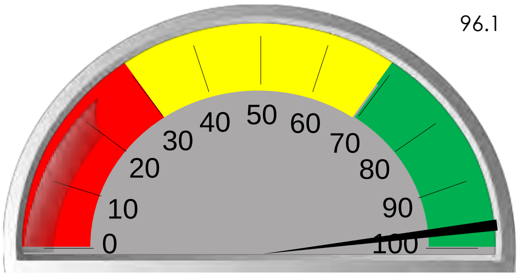
Nutrient cycling rate

90.1



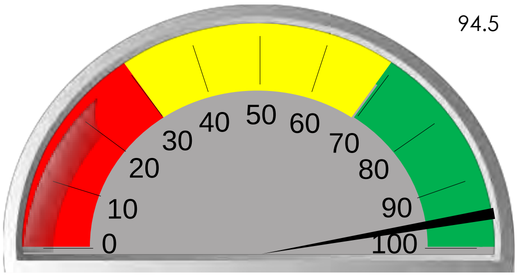
Disease resistance

96.1



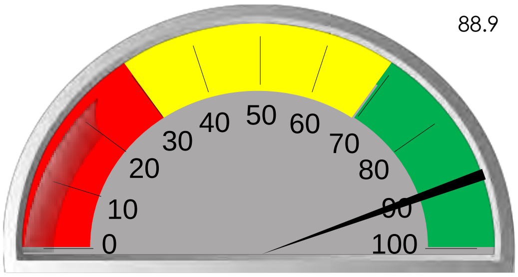
Drought resistance

94.5



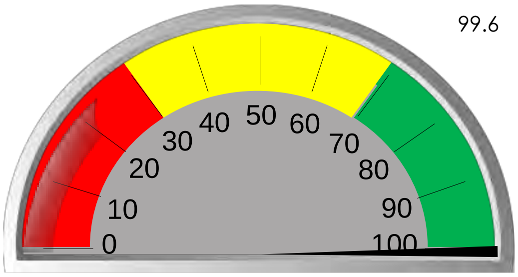
Nutrient accessibility (VAM)

88.9



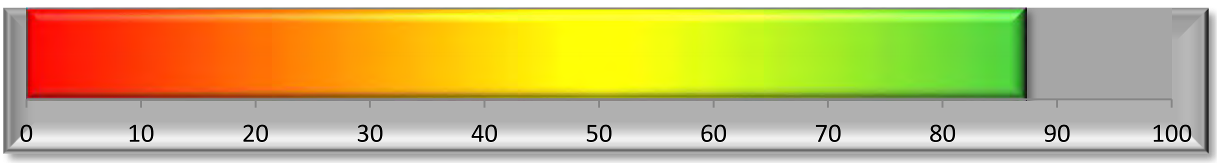
Residue breakdown rate

99.6



Overall microbial balance

87.2



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTWNPN201101 - 52885:14** Analysis no.: **2230-14-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Guide
Total microorganisms	**72.8**	50.0
Total bacteria	**13.0**	15.0
Total fungi	**56.8**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**39.2**	80.0
Fungi : Bacteria	**4.4**	2.3
Bacterial stress	**0.2**	< 0.5

Group	Biomass (mg/kg) Yours	Guide
Bacteria		
Pseudomonas	**1.671**	1.000
Actinomycetes	**0.992**	1.000
Gram positive	**6.276**	4.000
Gram negative	**6.706**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.604**	< 0.005
Eukaryotes		
Protozoa	**3.046**	1.300
Mycorrhizal fungi (including VAM)	**8.892**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators were all good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups were also good. Except for Gram negative bacteria. Protozoa, which were good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was highly elevated due to much higher levels of fungi compared to bacteria and needs to be balanced. These results suggest that management practices should initially focus on building Gram positive bacteria biomass. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

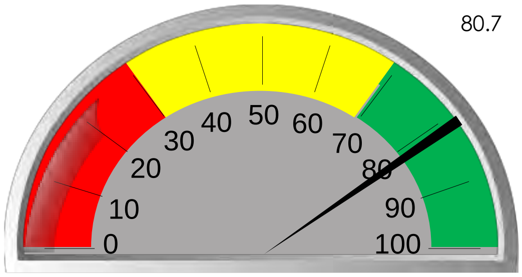
Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

Name: **SESL Australia**	Sample: **NPN 201301 - 52885:26**	Analysis no.: **2230-26-MWSS**	Date: **4/06/2019**

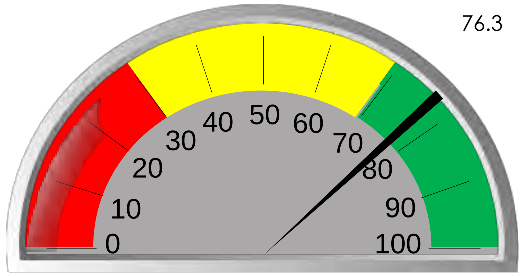
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	NPN 201301 - 52885:26	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-26-MWSS

Microbial Soil Indicators

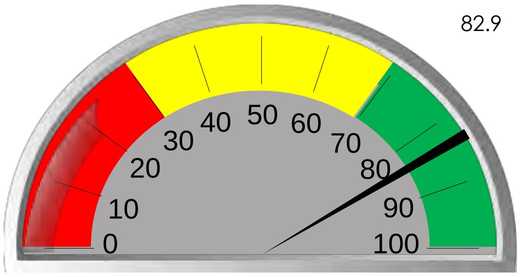
Nutrient solubilisation rate



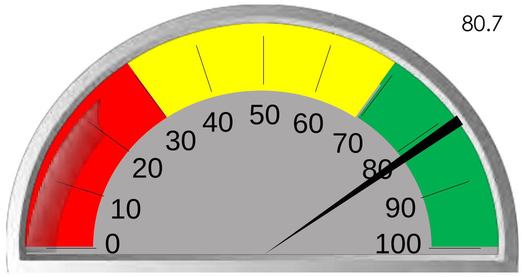
Nutrient cycling rate



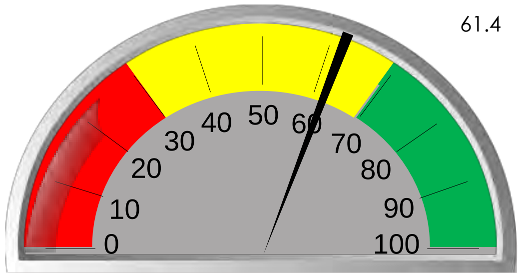
Disease resistance



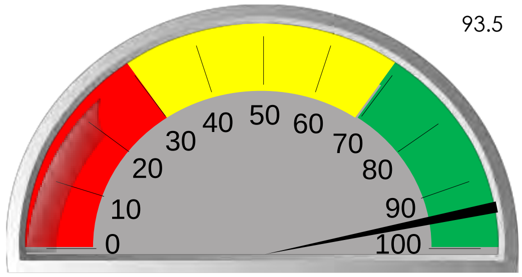
Drought resistance



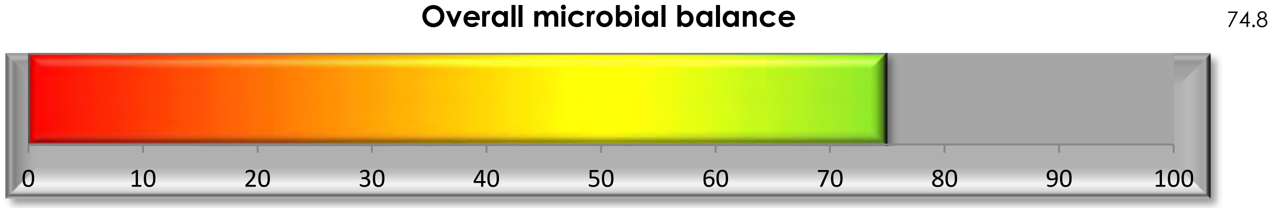
Nutrient accessibility (VAM)



Residue breakdown rate



Overall microbial balance



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **NPN 201301 - 52885:26** Analysis no.: **2230-26-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Guide
Total microorganisms	**43.6**	50.0
Total bacteria	**8.9**	15.0
Total fungi	**33.7**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**38.1**	80.0
Fungi : Bacteria	**3.8**	2.3
Bacterial stress	**0.3**	< 0.5

Group	Biomass (mg/kg) Yours	Guide
Bacteria		
Pseudomonas	**1.140**	1.000
Actinomycetes	**0.873**	1.000
Gram positive	**4.892**	4.000
Gram negative	**3.983**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.277**	< 0.005
Eukaryotes		
Protozoa	**1.063**	1.300
Mycorrhizal fungi (including VAM)	**6.137**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor — Fair — Good

Comments

The soil indicators ranged from fair, to good. The total mass of microbes in your sample was fair to good. Biomasses of other key desirable microbe groups ranged from poor for Gram negative bacteria, to Good for Pseudomonas, Actinomycetes, etc. Protozoa, which were good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was highly elevated due to much higher levels of fungi compared to bacteria and needs to be belanced. These results suggest that management practices should initially focus on building bacteria biomass. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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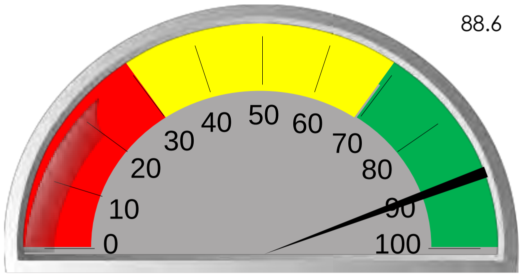
MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTWCDD201101 - 52885:16** Analysis no.: **2230-16-MWSS** Date: **4/06/2019**

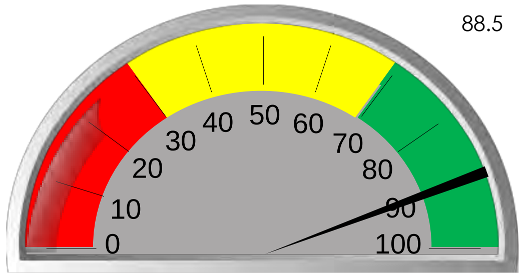
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	MTWCDD201101 - 52885:16	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-16-MWSS

Microbial Soil Indicators

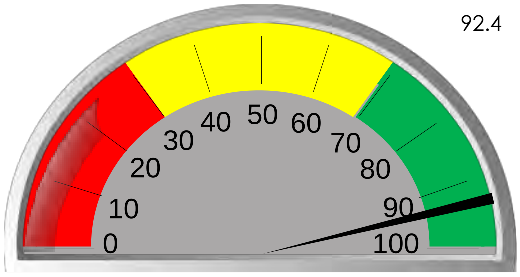
Nutrient solubilisation rate



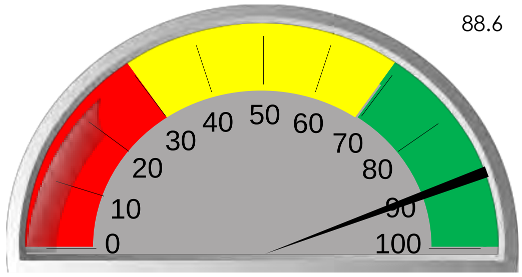
Nutrient cycling rate



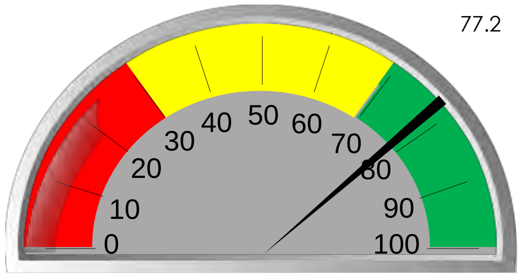
Disease resistance



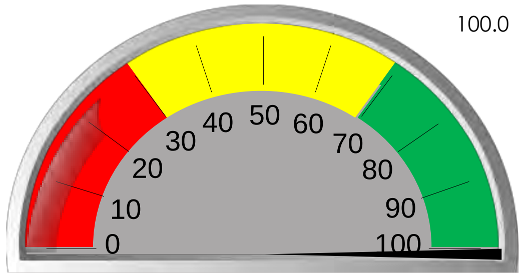
Drought resistance



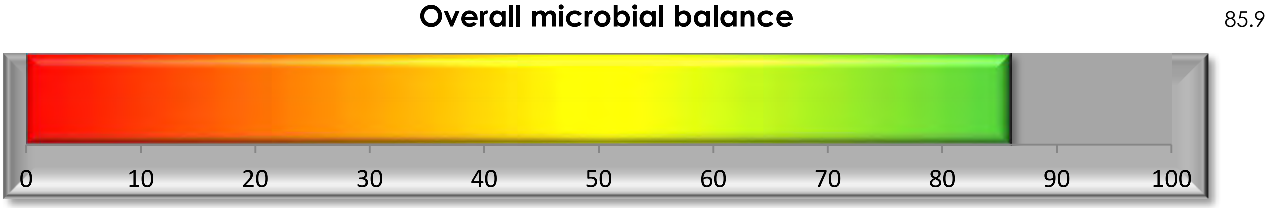
Nutrient accessibility (VAM)



Residue breakdown rate



Overall microbial balance



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTWCDD201101 - 52885:16** Analysis no.: **2230-16-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**68.0**	50.0
Total bacteria	**13.1**	15.0
Total fungi	**51.2**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**43.8**	80.0
Fungi : Bacteria	**3.9**	2.3
Bacterial stress	**0.4**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.237**	1.000
Actinomycetes	**2.198**	1.000
Gram positive	**7.133**	4.000
Gram negative	**5.955**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.579**	< 0.005
Eukaryotes		
Protozoa	**3.726**	1.300
Mycorrhizal fungi (including VAM)	**7.718**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators were all good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups were also good. Except for Gram negative bacteria, which were fair. However, with these microbial levels, Nitrogen needs to be monitored as high amounts of this nutrient may be kept by the microbes thus competing with the plant. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was highly elevated due to higher levels of fungi compared to bacteria and needs to be balanced. These results suggest that management practices should initially focus on building Gram negative bacteria biomass and microbial diversity. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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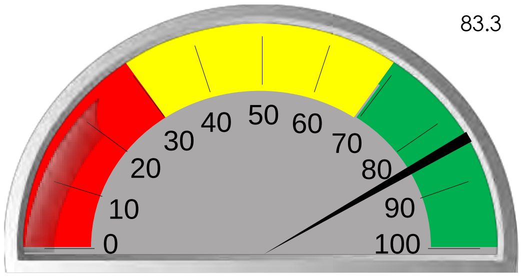
MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTWCDD201501 - 52885:17** Analysis no.: **2230-17-MWSS** Date: **4/06/2019**

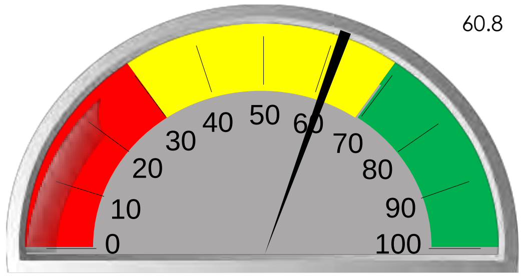
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	MTWCDD201501 - 52885:17	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-17-MWSS

Microbial Soil Indicators

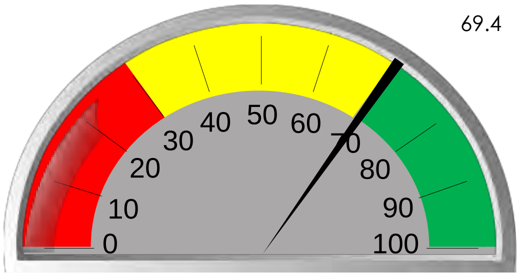
Nutrient solubilisation rate



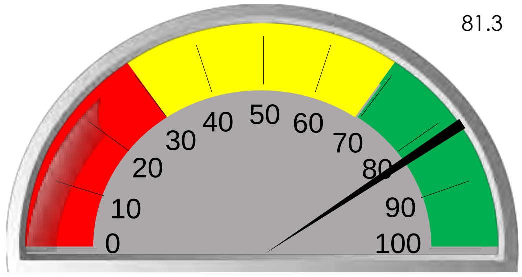
Nutrient cycling rate



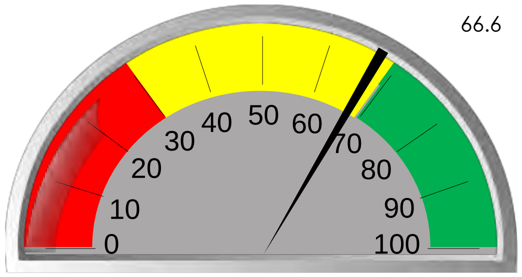
Disease resistance



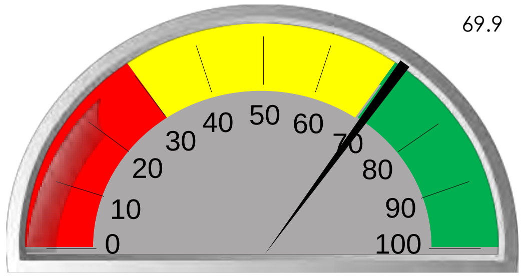
Drought resistance



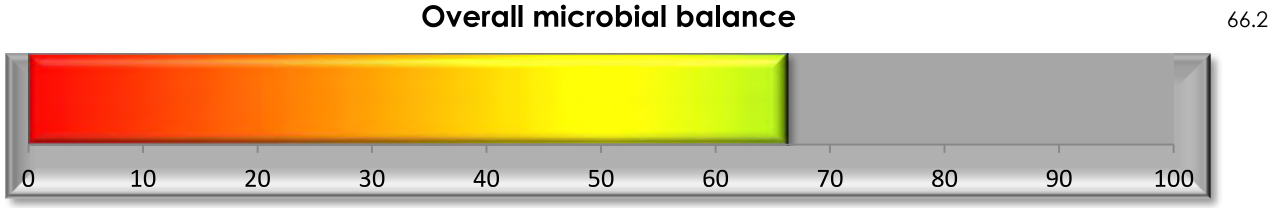
Nutrient accessibility (VAM)



Residue breakdown rate



Overall microbial balance



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTWCDD201501 - 52885:17** Analysis no.: **2230-17-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**41.4**	50.0
Total bacteria	**7.2**	15.0
Total fungi	**33.3**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**33.5**	80.0
Fungi : Bacteria	**4.6**	2.3
Bacterial stress	**0.3**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**1.014**	1.000
Actinomycetes	**0.415**	1.000
Gram positive	**3.840**	4.000
Gram negative	**3.338**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.081**	< 0.005
True anaerobes	**0.268**	< 0.005
Eukaryotes		
Protozoa	**0.949**	1.300
Mycorrhizal fungi (including VAM)	**6.663**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor Fair Good

Comments

The soil indicators ranged from fair to good. The total mass of microbes in your sample was fair to good. Biomasses of other key desirable microbe groups ranged from fair to poor for Gram negative bacteria, to good for Pseudomonas, etc. Protozoa, which were fair to fair to good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was highly elevated due to much higher levels of fungi compared to bacteria and needs to be balanced. These results suggest that management practices should initially focus on building general microbial biomass but mainly bacteria. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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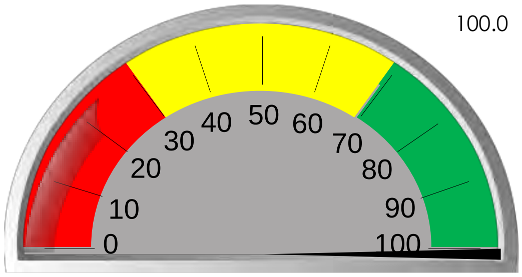
MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTW SPN201401 11/04/19 - 52885:21** Analysis no.: **2230-21-MWSS** Date: **4/06/2019**

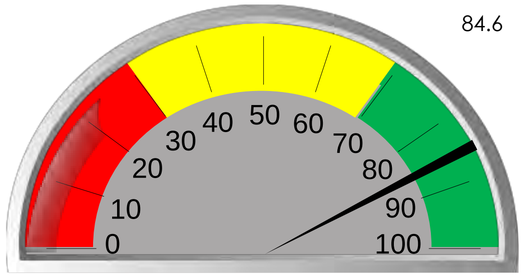
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	MTW SPN201401 11/04/19 - 52885:21	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-21-MWSS

Microbial Soil Indicators

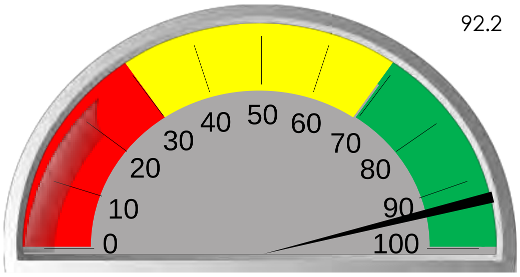
Nutrient solubilisation rate



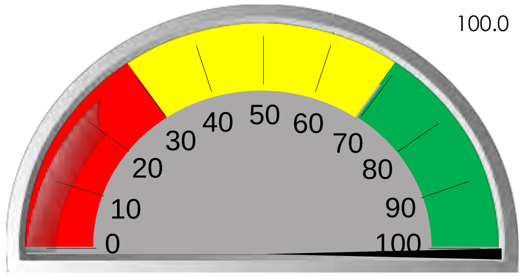
Nutrient cycling rate



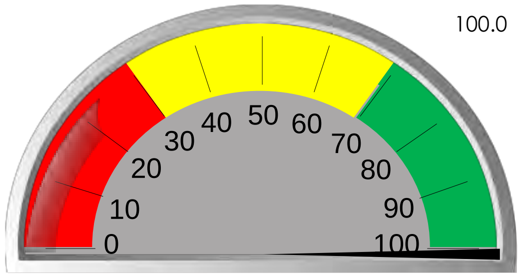
Disease resistance



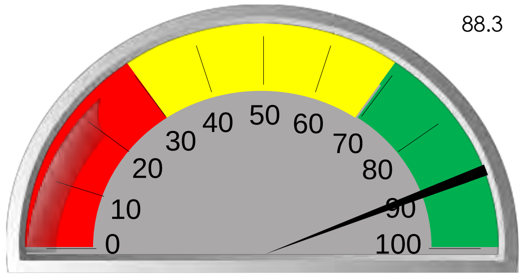
Drought resistance



Nutrient accessibility (VAM)

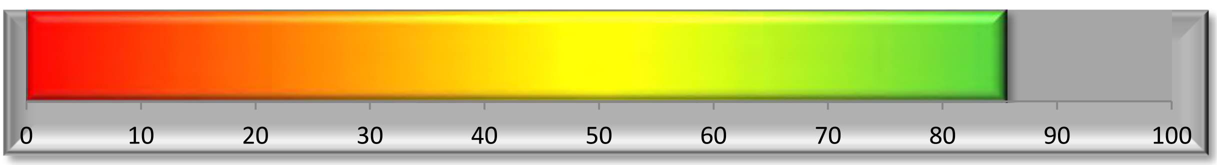


Residue breakdown rate



Overall microbial balance

85.5



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTW SPN201401 11/04/19 - 52885:21** Analysis no.: **2230-21-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Guide
Total microorganisms	**89.9**	50.0
Total bacteria	**13.1**	15.0
Total fungi	**72.2**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**35.2**	80.0
Fungi : Bacteria	**5.5**	2.3
Bacterial stress	**0.3**	< 0.5

Group	Biomass (mg/kg) Yours	Guide
Bacteria		
Pseudomonas	**2.007**	1.000
Actinomycetes	**0.766**	1.000
Gram positive	**6.279**	4.000
Gram negative	**6.789**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.000**	< 0.005
True anaerobes	**0.647**	< 0.005
Eukaryotes		
Protozoa	**4.628**	1.300
Mycorrhizal fungi (including VAM)	**13.827**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor **Fair** **Good**

Comments

The soil indicators were all good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups were also good. Except for Gram negative bacteria, which was fair to good. However, with these microbial levels Nitrogen needs to be monitored as high amounts of this nutrient may be kept by the microbes thus competing with the plant. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair and needs to be improved. The fungi to bacteria ratio was highly elevated, and needs to be balanced. These results suggest that management practices should initially focus on building bacteria biomass to balance the fungi to bacteria ratio. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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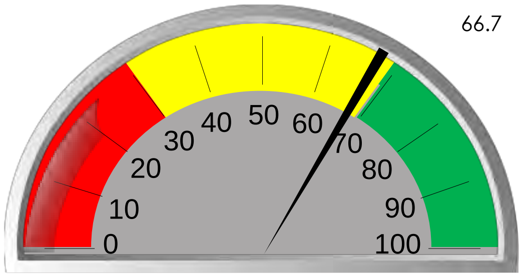
MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTW TDI201501 - 52885:24** Analysis no.: **2230-24-MWSS** Date: **4/06/2019**

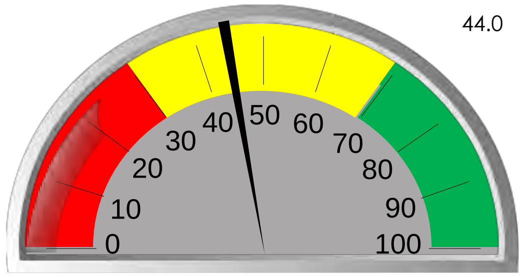
Customer name	SESL Australia	**Date received**	4/06/2019
Client name	Harrison Leake	**Agent**	SESL Australia
Sample name	MTW TDI201501 - 52885:24	**Advisor**	Harrison Leake
Crop		**Authorised by**	Dr Maria Manjarrez
Date sampled	31/05/2019	**Analysis no.**	2230-24-MWSS

Microbial Soil Indicators

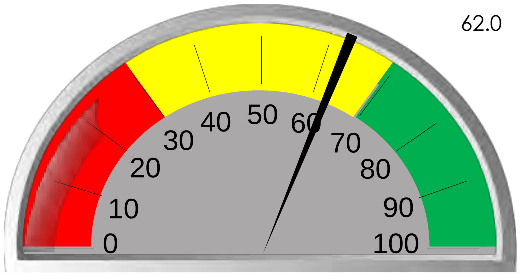
Nutrient solubilisation rate



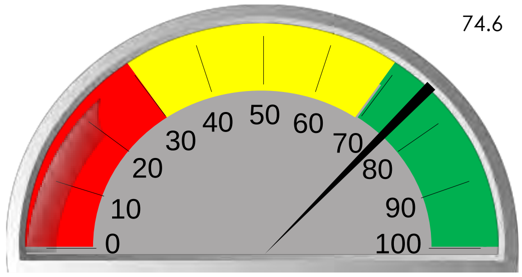
Nutrient cycling rate



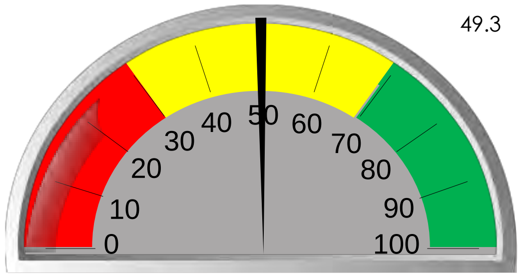
Disease resistance



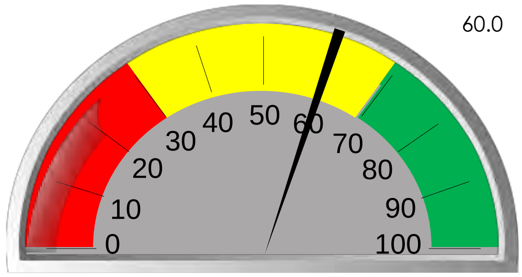
Drought resistance



Nutrient accessibility (VAM)

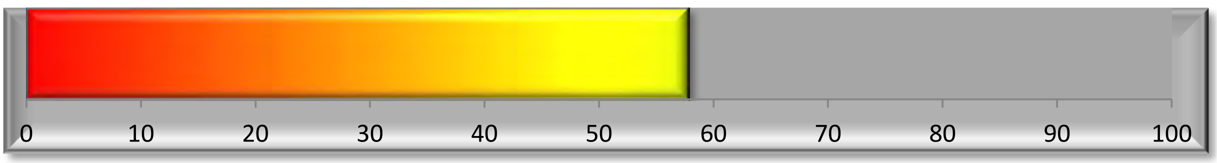


Residue breakdown rate



Overall microbial balance

57.7



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MICROBE WISE FOR SOIL

Name: **SESL Australia** Sample: **MTW TDI201501 - 52885:24** Analysis no.: **2230-24-MWSS** Date: **4/06/2019**

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	**32.4**	50.0
Total bacteria	**9.4**	15.0
Total fungi	**22.7**	33.8

Microbial indicators	Yours	Guide
Microbial diversity	**37.8**	80.0
Fungi : Bacteria	**2.4**	2.3
Bacterial stress	**0.4**	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	**0.841**	1.000
Actinomycetes	**0.528**	1.000
Gram positive	**5.796**	4.000
Gram negative	**3.650**	11.000
Methane oxidisers	**0.000**	0.500
Sulphur reducers	**0.149**	< 0.005
True anaerobes	**0.502**	< 0.005
Eukaryotes		
Protozoa	**0.298**	1.300
Mycorrhizal fungi (including VAM)	**4.927**	10.000

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor Fair Good

Comments

The soil indicators ranged from fair, to good. The total mass of microbes in your sample was fair to good. Biomasses of other key desirable microbe groups ranged from poor for Gram negative bacteria, to Good for Pseudomonas. Protozoa, which were poor here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was good indicating a balance between both groups. These results suggest that management practices should initially focus on building general microbial biomass. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit **www.microbelabs.com.au** for more information.

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How to Interpret Microbe Wise Reports

Does this look like you after your receive your Microbe Wise report?! Read on and we'll explain everything.

Background information

- **Plant roots** exude different amounts of photosynthetically fixed carbon (from 5% to 20%) to the rhizosphere; by doing so, plants are regulating soil microbial communities.
- **Plant root** exudates and all other carbon sources in the soil are the main drivers for soil microbial communities.
- **Extracted fatty acids** (FAMEs, the method used in Microbe Wise) from microbial communities differ among different soil characteristics and agronomic practices: e.g., rhizosphere soil vs non-rhizosphere soil, crop types, soil pH, carbon amendments, crop rotations and cultivation practices.
- **Soil indicators** in Microbe Wise reports are unitless as they are based on the relative abundance of different microbial groups (Table 1).
- **Microbial diversity** is a calculation that describes the variability and relative abundance of microbe groups. The Microbial Diversity Indicator is calculated using the ecological statistic 'True Diversity', which is the exponential of Shannon's Diversity Index.
- **Fungi to bacteria ratio** is based on the relative abundance of each group when compared to total microbial biomass. It may indicate how available soil organic matter is to microbes.
- **Use Table 1** to get an easy understanding of what your results mean in the field.
- **Use Table 2** to learn what the microbial groups in your soil do, and how you can manage them to improve the bio-fertility of your soil.

Interpreting Soil Indicators (page 1 of the report)

Table 1. Microbial groups used in the calculation of Soil Indicators.

Soil Indicator	Microbe groups involved
Nutrient solubilisation	Pseudomonas VAM (Mycorrhizal fungi)
Nutrient Cycling	Total fungi Actinomycetes Gram negative bacteria Protozoa
Disease resistance	Pseudomonas Actinomycetes VAM (Mycorrhizal fungi)
Drought resistance	Gram Positive bacteria VAM
Nutrient accessibility	VAM
Residue breakdown	Total fungi Actinomycetes
Overall microbial balance	All microbial groups Microbial diversity

Interpreting Results and Comments (page 2 of the report)

Table 2. Roles and management options for microbial groups and indicators in Microbe Wise.

Microbe group or Indicator	Role and how to manage
Total Microorganisms	Indicates the overall living microbial biomass. If low: Check for any particular microbe groups that are low (see separate entries for each group). If the biomasses of all microbe groups are generally low: Supply a diverse range of carbon compounds to build Total Bacteria, Total Fungi and Protozoa (see separate entries for these groups).
Total bacteria	Indicates the overall living bacterial biomass. If low: Supply simple and semi-complex carbon compounds, such as sugars, starches, proteins (fish and blood meal), compost tea and legume residues.
Total fungi	Indicates the overall living fungal biomass. If low: Increase carbon in a resistant form, such as organic residues that contain cellulose and lignin (e.g., broadacre crop residues, woody residues, matured compost, compost juice, humic acids).
Pseudomonas	Pseudomonas are Gram negative (see separate entry, below). If low (under aerobic conditions): Supply simple carbohydrates, such as sugars.
Actinomycetes	Actinomycetes are Gram positive (see separate entry, below). If low: Increase semi-complex carbohydrates and compounds, such as starches, proteins (fish and blood meal), composted animal manure, and other organic residues.
Gram positive bacteria	This group includes numerous well-known plant growth-promoting rhizobacteria (PGPR), such as *Bacillus subtilis*. If low: Supply semi-complex carbohydrates and compounds, such as starches, proteins (fish and blood meal) and composted animal manure.
Gram negative bacteria	This group includes some well-known plant growth promoting Rhizobacteria (PGPR), such as *Pseudomonas fluorescens*, free-living nitrogen fixing bacteria (FLNFB), such as *Azotobacter vinelandii*, and nitrifying bacteria, such as *Nitrosomonas* spp. If low: Supply simple carbohydrates, such as sugars, or apply compost tea.
True anaerobes	These multiply when there is a lack of oxygen in the soil and are undesirable. If high: Identify the cause (e.g., waterlogging or compaction) and implement physical solutions where practicable, such as better irrigation management, drainage works or deep ripping.
Sulphur reducers	Sulphur reducers are Anaerobic and Gram negative, and are undesirable. If high: Implement physical solutions where practicable, such as better irrigation management, drainage works or deep ripping.

Microbe group or Indicator	Role and how to manage
Protozoa	Protozoa are neither bacteria nor fungi, but rather like 'micro animals. If low: Increase Total bacteria biomass (see separate entry) if that is low; minimise agrochemical inputs, particularly herbicides; apply a straw tea (search the internet using the terms "straw brew protozoa" for more information).
Mycorrhizal fungi (including VAM)	Mycorrhizal fungi (including VAM) are a key indicator of soil microbial health. If low: Use crop rotations with mycorrhizal host crops such as legumes, supply matured compost, inoculate with a multi-species mycorrhizal fungi inoculum, avoid high P and N fertilizer applications.
Microbial diversity	Indicates the number and abundance of different types of microbes present in the soil. If low: Determine if any particular desirable microbial groups are low, and if so increase them. Otherwise supply a mixture of carbon compounds; simple carbohydrates (e.g., sugars); semi-complex carbon compounds (e.g., molasses, starches, fish and blood meal); complex carbon compounds (e.g. matured compost) and resistant carbon compounds (e.g. crop residues).
Fungi to Bacteria ratio	The Fungi to Bacteria ratio should be considered in conjunction with the biomasses of Total fungi and Total bacteria. If the Fungi to Bacteria ratio is HIGH, and: + Total bacteria biomass is very good: The ratio is probably indicative of the type of agricultural system + Total bacteria biomass is less than very good: Increase bacterial biomass (see separate entry for Total Bacteria) If the Fungi to bacteria ratio is LOW, and: + Total fungi biomass is very good: The ratio is probably indicative of the type of agricultural system or recent soil management practices, such as fertiliser application. + Total fungi biomass is less than very good: Increase fungal biomass (see separate entry for Total Fungi)
Bacterial stress	Under conditions of stress, bacteria change some components of their cell membranes, which can be measured using Microbe Wise. If high: Determine the cause of the stress and take actions to reduce it.

[end of document]

Appendix 6:

Annual Rehabilitation Report Summary Table

Annual Rehabilitation Report Form, Rehabilitation Maps and Rehabilitation Summary

Annual Rehabilitation Report Form – Mines
Year Ending: 2019
Mine: Mt Thorley Warkworth
Company: Yancoal Australia
Plans Attached:
Mt Thorley Warkworth – AER 2019
Approved Mining Operations Plan:
MTW MOP Amendment B (2015 – 2021) – Approval Date 11/06/2019
Total Area Covered by Mining Operations Plan:
MTW MOP – 6,185ha
Total Area Covered by Mining Lease for This Mine: 6,185ha

Table 1: Rehabilitation Progress 2019

Rehabilitation Activity Type	Domain Identifier	Primary Domain	Secondary Domain	Total Area Last Reported (ha)	Total Area to date (ha)
1.1 Active mining and infrastructure area, facilities, including roads and tracks	1A	Final Void	Final Void	312.8	373.0
	2C	Water Management Areas	Rehabilitation Area - Grassland	42.0	42.1
	2E	Water Management Areas	Rehabilitation Area - Woodland EEC	22.8	22.8
	3C	Infrastructure Area	Rehabilitation Area - Grassland	100.7	100.6
	3E	Infrastructure Area	Rehabilitation Area - Woodland EEC	68.6	68.5
	4C	Tailings Storage Facility	Rehabilitation Area - Grassland	75.7	76.4
	4D	Tailings Storage Facility	Rehabilitation Area - Woodland	11.7	11.7
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland EEC	88.3	88.3
	5C	Overburden Emplacement Area	Rehabilitation Area - Grassland	364.4	363.2
	5D	Overburden Emplacement Area	Rehabilitation Area - Woodland	256.1	242.1

Rehabilitation Activity Type	Domain Identifier	Primary Domain	Secondary Domain	Total Area Last Reported (ha)	Total Area to date (ha)
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland EEC	1248.1	1191.1
	Total Active			2591.2	2579.8
1.2 Decommissioning	Total - Decommissioning			0.0	0.0
1.3 Landform Establishment	4C	Tailings Storage Facility	Rehabilitation Area - Grassland		0.1
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland EEC		0.2
	5C	Overburden Emplacement Area	Rehabilitation Area - Grassland		3.2
	5D	Overburden Emplacement Area	Rehabilitation Area - Woodland		2.7
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland EEC		18.0
	Total - Landform Establishment			93.1 (included in 1.1)	24.2
1.4 Growth Medium Development	2C	Water Management Areas	Rehabilitation Area - Grassland		1.2
	2E	Water Management Areas	Rehabilitation Area - Woodland EEC		2.9
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland EEC		4.0
	5C	Overburden Emplacement Area	Rehabilitation Area - Grassland		18.9
	5D	Overburden Emplacement Area	Rehabilitation Area - Woodland		26.1
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland EEC		81.8
	Total - Growth Medium Development			4.3 (included in 1.1)	134.9
1.5 Ecosystem and Land Use Establishment	1A	Final Void	Final Void		1.5
	2C	Water Management Areas	Rehabilitation Area - Grassland	1.2	1.6
	2E	Water Management Areas	Rehabilitation Area - Woodland EEC	2.9	3.3
	3C	Infrastructure Area	Rehabilitation Area - Grassland		5.4
	3E	Infrastructure Area	Rehabilitation Area - Woodland EEC		0.5
	4C	Tailings Storage Facility	Rehabilitation Area - Grassland		26.4
	4D	Tailings Storage Facility	Rehabilitation Area - Woodland		1.4

Rehabilitation Activity Type	Domain Identifier	Primary Domain	Secondary Domain	Total Area Last Reported (ha)	Total Area to date (ha)
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland EEC	4.0	35.2
	5C	Overburden Emplacement Area	Rehabilitation Area - Grassland	35.9	567.5
	5D	Overburden Emplacement Area	Rehabilitation Area - Woodland	28.4	52.8
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland EEC	95.5	446.7
	Total - Ecosystem and Land Use Establishment			167.9	1142.3
1.6 Ecosystem and Land Use Development	1A	Final Void	Final Void	1.8	0.0
	2C	Water Management Areas	Rehabilitation Area - Grassland	1.8	0.0
	2E	Water Management Areas	Rehabilitation Area - Woodland EEC	3.3	0.0
	3C	Infrastructure Area	Rehabilitation Area - Grassland	5.4	0.0
	3D	Infrastructure Area	Rehabilitation Area - Woodland	1.5	0.0
	3E	Infrastructure Area	Rehabilitation Area - Woodland EEC	0.5	0.0
	4C	Tailings Storage Facility	Rehabilitation Area - Grassland	27.3	0.0
	4D	Tailings Storage Facility	Rehabilitation Area - Woodland	1.4	0.0
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland EEC	35.5	0.0
	5C	Overburden Emplacement Area	Rehabilitation Area - Grassland	550.4	0.0
	5D	Overburden Emplacement Area	Rehabilitation Area - Woodland	43.7	0.0
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland EEC	395.3	0.0
	Total - Ecosystem and Land Use Development			961.1	0.0
1.7 Rehabilitation Complete	Total - Rehabilitation Complete			0.0	0.0
1.8 Total Area Disturbed (items 1.1 to 1.7)	1A	Final Void	Final Void	314.6	374.5
	2C	Water Management Areas	Rehabilitation Area - Grassland	45.0	44.9
	2E	Water Management Areas	Rehabilitation Area - Woodland EEC	29.0	29.0
	3C	Infrastructure Area	Rehabilitation Area - Grassland	106.1	106.0
	3D	Infrastructure Area	Rehabilitation Area - Woodland	1.5	0.0

Rehabilitation Activity Type	Domain Identifier	Primary Domain	Secondary Domain	Total Area Last Reported (ha)	Total Area to date (ha)
	3E	Infrastructure Area	Rehabilitation Area - Woodland EEC	69.1	69.0
	4C	Tailings Storage Facility	Rehabilitation Area - Grassland	103.0	102.9
	4D	Tailings Storage Facility	Rehabilitation Area - Woodland	13.1	13.1
	4E	Tailings Storage Facility	Rehabilitation Area - Woodland EEC	127.8	127.7
	5C	Overburden Emplacement Area	Rehabilitation Area - Grassland	950.7	952.8
	5D	Overburden Emplacement Area	Rehabilitation Area - Woodland	328.2	323.7
	5E	Overburden Emplacement Area	Rehabilitation Area - Woodland EEC	1738.9	1737.6
	Total Footprint			3827.0	3881.2

Table 2: Soil Management and Erosion, 2019

Soil Stockpiling/ Use	Soil Used This Period (m3)	Soil Pre-stripped This Period (m3)	Stockpile Inventory to Date (m3)	Soil Stockpiled Last Report (m3)
	68,500	40,030	660,357	688,826
2.2 Erosion Treatment	Total Area to Date (ha)	Total Area Last Report (ha)	Total Area This Report (ha)	Area Retreated This Period (ha)
Approx. area of sheet or gully erosion requiring reshaping topdressing and/or resowing	Not Available	21.7	6.0	3.5

Table 3: Weed Control

	Area (ha)
3.1 Approx. area adversely affected by weeds as of the date of this report	Not Available
3.2 Area treated for weed control during the period covered by the report	336.0
3.3 Give summary of control strategies used and verification by approval agency(s)	
Species targeted in rehabilitation areas during 2019 included: *Galenia pubescens*, Rhodes grass, green panic, *Acacia saligna*, mustard weed (Brassica), farmers friend (*Bidens pilosa*) and paddys lucerne (*Sida rhombifolia*). 164.5ha treated for weed control using boom spray or wick wiper treatment; 171.5ha treated for weed control using Quikspray units or backpack sprays.	

Table 4: Management of Rehabilitation Areas

4.1 Area treated with maintenance fertiliser	0ha
4.2 Area treated by rotational grazing, cropping or slashing	90ha
Give Summary	90ha Warkworth rehabilitation area licence agreement in place for grazing.

Table: 5 Variations to Rehabilitation Program

Has rehabilitation work proceeded generally in accordance with the conditions of an accepted Mining Operations Plan?	Yes
If not please cite any approval granted for variations, or briefly describe the seasonal conditions or other reasons for any changes and the nature of any changes which have been made.	NA

Table 6: Planned Operations During the Next Report Period

6.1 Area estimated to be disturbed	60ha
6.2 Area estimated to be rehabilitated	64ha

Appendix 7:

Rehabilitation and Disturbance Summary

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MTW
Rehabilitation Areas 2019

MTW

File:MTW Rehab Areas 2019.wor
MTW Rehab Areas 2019.PDF

Date:	06/03/2020
Produced By:	BB
Map Size:	A4 Portrait
Coordinate System:	MGA94 Zone 56
Revision	01
Data Source	Various

MTW Annual Review Appendix 2 – Rehabilitation Summary

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
CD RL160 Stockpile Area	Woodland	318,885.56 E 6,390,194.33 N	0.7	▪ The landform was constructed from a waste emplacement. ▪ The landform is flat in this area, no aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised minor shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Area was an old topsoil stockpile so there was remaining Clay loam/sandy clay loam topsoil from the floor of the stockpile at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation and aerating as required ▪ The area was sown in December with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
CD RL180 Geofluv Topsoil A	Woodland	318,926.55 E 6,389,856.67 N	8.0	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. Typical slope of the landform is 10 to 14 degrees with limited areas at 16 to 18 degrees. The slope has a primarily easterly aspect. ▪ Drainage is via rock-lined drainage lines, directing run-off to sediment control structures to the east. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ The area was sown in September with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement. ▪ Selective weed control of mainly *Galenia pubescens* was undertaken after desirable native species and weed species had started to germinate.
CD RL180 Geofluv Topsoil B	Woodland	319,068.55 E 6,389,506.31 N	0.7	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. Typical slope of the landform is 10 to 14 degrees with limited areas at 16 to 18 degrees. The slope has a primarily easterly aspect. ▪ Drainage is via rock-lined drainage lines, directing run-off to sediment control structures to the east. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in September with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement. ▪ Selective weed control of mainly *Galenia pubescens* was undertaken after desirable native species and weed species had started to germinate.
CD RL180 Topsoil A	Woodland	319,280.83 E 6,389,697.26	4.1	▪ The landform was constructed from a waste emplacement. ▪ Typical slope of the landform is 10 degrees with a primarily northerly aspect. ▪ Drainage is via westerly draining contours reporting to an engineered rock-lined chute. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in September with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement. ▪ Selective weed control of mainly *Galenia pubescens* was undertaken after desirable native species and weed species had started to germinate.
CD RL180 Topsoil B	Woodland	319,221.33 E 6,389,562.33 N	1.3	▪ The landform was constructed from a waste emplacement. ▪ Typical slope of the landform is 10 degrees with a primarily northerly aspect. ▪ Drainage is via westerly draining contours reporting to an engineered rock-lined chute. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in September with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement. ▪ Selective weed control of mainly *Galenia pubescens* was undertaken after desirable native species and weed species had started to germinate.
CD RL185	Woodland	320,207.39 E 6,389,707.77 N	8.8	▪ The landform was constructed from a waste emplacement. ▪ Typical slope of the landform is 10 degrees with a primarily southerly aspect. ▪ Drainage is via easterly draining contours reporting to adjacent existing contour drainage and then to an engineered rock-lined chute.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in December with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
CD RL190 Spoil/Compost	Woodland	319,632.10 E 6,389,688.05 N	5.2	▪ The landform is flat in this area, no aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ No topsoil was added, spoil has been used as the growth medium. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in December with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
CD RL190 Topsoil A	Woodland	319,443.37 E 6,389,707.77 N	5.2	▪ The landform was constructed from a waste emplacement. ▪ Typical slope of the landform is 10 degrees with a primarily northerly aspect. ▪ Drainage is via easterly draining contours reporting to an engineered rock-lined chute. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in December with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO Geofluv RL130 Topsoil A	Woodland	319,784.64 E 6,387,557.34 N	0.1	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. This small section of landform has a typical slope of 22 degrees. The slope has a primarily northerly aspect. ▪ Drainage is via rock-lined drainage lines, directing run-off to sediment control structures to the east. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Sandy topsoil with a high amount of woody mulch was spread directly from stripping areas at a nominal thickness of 100mm. ▪ Soil ameliorants were not applied due to the slope being too steep for access by spreaders. ▪ The area was sown by hand in December with Diverse Native Woodland at 15.7kg/ha.
MTO Geofluv RL130 Topsoil B	Woodland	319,802.28 E 6,387,509.92 N	4.9	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. Typical slope of the landform is 10 to 14 degrees. The slope has a primarily north-easterly aspect. ▪ Drainage is via rock-lined drainage lines, directing run-off to sediment control structures to the north. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in October with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Geofluv Topsoil A	Woodland	319,845.67 E 6,386,872.08 N	1.6	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. This section of the landform is flat and therefore without any aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in October with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Geofluv Topsoil B	Woodland	320,012.22 E 6,387,049.56 N	12.2	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. Typical slope of the landform is 10 to 14 degrees. The slope section has a primarily northerly aspect. There is also a flat section of landform above the slope. ▪ Drainage is via rock-lined drainage lines, directing run-off to sediment control structures to the north. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in October with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Geofluv Topsoil C	Woodland	320,093.04 E 6,387,041.13 N	1.9	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. This section of the landform is flat and therefore without any aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from stripping areas in West Pit South was spread directly at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in October with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Spoil/Compost	Woodland	320,311.38 E 6,385,990.70 N	5.1	▪ The landform was constructed from a waste emplacement. ▪ Typical slope of the landform is 10 degrees with a primarily southerly aspect. ▪ Drainage is via westerly draining contours reporting to an engineered rock-lined chute. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ No topsoil was added, spoil has been used as the growth medium. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in November with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Topsoil A	Woodland	319,611.14 E 6,386,649.08 N	2.3	▪ The landform was constructed from a waste emplacement. ▪ The landform is flat in this area, no aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised minor shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from stripping areas in West Pit South was spread directly at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation and aerating as required ▪ The area was sown in October with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Topsoil B	Woodland	319,538.68 E 6,386,642.15 N	2.1	▪ The landform was constructed from a waste emplacement. ▪ The landform is flat in this area, no aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised minor shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles (sourced from rehabilitation disturbance) was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation and aerating as required

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ The area was sown in October with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Topsoil C	Woodland	319,613.39 E 6,386,416.30 N	0.8	▪ The landform was constructed from a waste emplacement. ▪ The landform is flat in this area, no aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised minor shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from stripping areas in West Pit South was spread directly at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation and aerating as required ▪ The area was sown in November with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Topsoil D	Woodland	319,747.84 E 6,386,141.08 N	1.4	▪ The landform was constructed from a waste emplacement. ▪ The landform is flat in this area, no aspect. ▪ Area is flat and hence not requiring drainage controls. ▪ Landform surface preparation comprised minor shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles (sourced from rehabilitation disturbance) was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation and aerating as required ▪ The area was sown in November with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
MTO RL154 Topsoil E	Woodland	319,821.58 E 6,386,085.74 N	6.5	▪ The landform was constructed from a waste emplacement. ▪ Typical slope of the landform is 10 degrees with a primarily southerly aspect. ▪ Drainage is via westerly draining contours reporting to an engineered rock-lined chute. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam topsoil from stripping areas in West Pit South was spread directly at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in November with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
NPN RL175 Geofluv	Woodland	317,038.19 E 6,392,473.36 N	3.4	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. Typical slope of the landform is 10 to 14 degrees with limited areas at 16 to 22 degrees. The slope has a primarily northerly aspect. ▪ Drainage is via rock-lined drainage lines, directing run-off to sediment control structures to the north west. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Sandy topsoil with a high amount of woody mulch was spread directly from stripping areas at a nominal thickness of 100mm. High amount of mulch was used for erosion protection on slopes. ▪ Soil ameliorant comprising recycled gypsum compost was applied at a rate of 5t/ha. No compost was used due to high organic component in topsoil. ▪ Growth medium preparation included ameliorant incorporation, and aerating as required

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ The area was sown in September with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement. A small area was hand sown due to the steep slope.
Tailings Dam 2	Woodland	319,043.07 E 6,392,347.22	2.2	▪ The landform was constructed from spoil placed as an inert cap over a tailings dam. This section of the tailings dam had a layer of Redbank ash deposited on top of the tailings surface. ▪ Typical slope of the landform is 10 degrees with a primarily northerly aspect. ▪ Drainage from the slope reports to an engineered rock-lined chute. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ No topsoil was added, capping spoil has been used as the growth medium. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively. ▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in September with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.
Woodlands RL155	Woodland	319,634.08 E 6,388,797.99 N	4.1	▪ The landform was constructed from a waste emplacement. ▪ The landform has been designed using a geomorphological landform approach based on alluvial analogues. Typical slope of the landform is 6 to 14 degrees. The slope has a primarily north-easterly aspect. ▪ Drainage is via rock-lined drainage lines, directing run-off to sediment control structures to the north east. ▪ Landform surface preparation comprised bulk shaping, deep ripping, rock raking, and removal of oversize rock material. ▪ Clay loam/sandy clay loam topsoil from existing topsoil stockpiles was spread at a nominal thickness of 100mm. ▪ Soil ameliorants comprising recycled gypsum and Bettergrow Biomulch compost were applied at rates of 5t/ha and 50t/ha respectively.

Rehabilitation Site Name	Type	Coordinates (GDA94)	Area (ha)	*Rehabilitation Summary*
				▪ Growth medium preparation included ameliorant incorporation, rock windrowing, rock picking, and aerating as required ▪ The area was sown in October with Diverse Native Woodland at 15.7kg/ha. Non-flowable (grass) seed was spread onto the surface using a direct drill and then the flowable components of the seed mix were spread via an air-seeder mounted on the aerator implement.

Appendix 8:

IEA Action Status Table

Audit Action Plan Status from MTW IEA 2017 (Rev C)

Reference	Non Compliance / MTW Response	Action Status Update	Target Date for Completion
SSD6464 Sch. 3, C24(a) WMP 7.4.3.1	On the 6th January 2016, a sediment dam overtopped resulting in an uncontrolled discharge. **Response/Action Description** An internal investigation was undertaken in response to this incident. The investigation and subsequent action plan has been completed to rectify the issues at this dam and to prevent reoccurrence not only at this dam but other dams being constructed or modified. No further action is required in response to this finding.	Complete.	N/A
SSD 6464 Sch.3 C.27(b)(ii) SSD 6465 Sch.3 C.25(b)(ii)	The Surface Water Management Plan does not include detailed performance indicators of management objectives for Final Voids **Response/Action Description** MTW to update the WMP to include further detail on the performance objectives and management objectives for Final Voids, as indicated in the development consents and the EIS commitments.	Complete. The MTW Mining Operations Plan includes detailed plans and rehabilitation objectives for the site, including for final voids. To address this item, a link to the Mining Operations Plan was included in an update to the Water Management Plan approved by DP&E on 20 September 2018	N/A

Reference	Non Compliance / MTW Response	Action Status Update	Target Date for Completion
MT EIS 2.4.4 (iii)	No ongoing characterisation of overburden materials was conducted. **Response/Action Description** Extensive geochemical testing of overburden has been carried out across MTW with results showing very low risk of Acid Rock Drainage (ARD) in the overburden material being mined at MTW. The results of sampling conducted to date will be presented to DP&E to justify why ongoing characterisation of overburden materials across MTW is not required.	Complete. Presentation made to DP&E Compliance Team on 09/10/2018 to present results of overburden and interburden ARD assessments and testing conducted at MTW to illustrate why ongoing characterisation of overburden materials across MTW is not required. No further action required.	N/A
AHMP 9	There was no written or electronic record of which personnel had completed site specific environmental training for Cultural Heritage. **Response/Action Description** MTW to ensure that the AHMP and the MTW induction will cover all specific Cultural Heritage awareness requirements and that suitable training records are maintained	Complete. MTW induction has been updated and now covers all specific Cultural Heritage awareness requirements as prescribed by the AHMP. Training records are maintained by H&S Department.	N/A
BMP 5.2.3	On the 8-06-16 a blast was not monitored by the Bulga Village blast monitor due to a software malfunction. **Response/Action Description** An internal investigation identified the cause of the data loss to be isolated to a GPS fault on a single blast monitoring unit. This fault has since been corrected and no further action is required in response to this finding.	Complete.	N/A

Reference	Non Compliance / MTW Response	Action Status Update	Target Date for Completion
BMP 5.2.2	Blasting Controls Training was not documented **Response/Action Description** MTW to review process for documenting training records for training required by BMP to ensure that suitable training records are maintained.	In Progress. Action item is included on MTW's action tracking system.	30/04/2020
NMP 6.2	There was no substantive evidence of car-pooling encouragement programs at the time of the audit. **Response/Action Description** Car-pooling occurs however MTW do not run programs to specifically encourage car-pooling nor is it deemed to be necessary to do so. The Noise Management Plan will be revised to reflect this.	Complete.	N/A

Reference	Non Compliance / MTW Response	Action Status Update	Target Date for Completion
20BL170012 C.9 20BL170011 C.9 20BL171930 C.8 20BL171932 C.8	Water flow devices used to measure the volume of water extracted were not approved by NOW (DPI – Water). Three bore licences were found to be non-compliant with this condition; however two were decommissioned and are not in use and one related to the bore licence associated with groundwater inflow to the Warkworth Pit. **Response/Action Description** Following commencement of the North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan on 1/7/2016, Licences 20BL170011 and 20BL170012 have been converted to Water Access Licences (WALs 40464 and 40465 respectively). Revised licence conditions issued by DPI Water are to be reviewed; to reflect that groundwater inflows to a pit excavation cannot be measured using a flow meter. Licences 20BL171930 and 20BL171932 are related to a historical methane extraction project; the bores are not in use. An investigation will be undertaken to determine if the bores should be formally abandoned and the licences relinquished, or if used for monitoring, an application sought to modify the licence purpose and conditions to reflect no water is to be abstracted.	Complete. At this point in time there are no mandatory or discretionary conditions on the works approval 20MW065009 for licenses WAL 40464 or WAL 40465 as advised by the Natural Resource Access Regulator (NRAR) during phone conversation 23/9/2018. NRAR has advised the only WAL with license conditions at this time is WAL 18233.	N/A

Reference	Non Compliance / MTW Response	Action Status Update	Target Date for Completion
20BL170011 C.8 and C.10 20BL170012 C.8 and C.10	Water flow devices used to measure the volume of water extracted were not calibrated. This related to the aforementioned bore licences that did not have flow devices attached and as such are not able to be calibrated. **Response/Action Description** Following commencement of the North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan on 1/7/2016, Licences 20BL170011 and 20BL170012 have been converted to Water Access Licences (WALs 40464 and 40465 respectively). Revised licence conditions issued by DPI Water are to be reviewed; to reflect that groundwater inflows to a pit excavation cannot be measured using a flow meter.	Complete. At this point in time there are no mandatory or discretionary conditions on the works approval 20MW065009 for licenses WAL 40464 or WAL 40465 as advised by the Natural Resource Access Regulator (NRAR) during phone conversation 23/9/2018. NRAR has advised the only WAL with license conditions at this time is WAL 18233.	N/A
Recommendations			
1.	Complete the Salvage report for salvage work conducted in 2016. **Response/Action Description** A final report will be compiled to bring together the results and completed compliance actions relating to the MTW 2016 ACH salvage	Complete. 2016 Compliance and Salvage Report (19 CH sites within the Stage 1 AHMP area) updated and finalised on 21/8/18.	N/A

Reference	Non Compliance / MTW Response	Action Status Update	Target Date for Completion
2.	MTW will determine the Wollombi Brook Probable Maximum Flood (PMF) RL at the Charlton levee and ensure there is 500mm of freeboard (from PMF to levee top RL). **Response/Action Description** Determine the Wollombi Brook Probable Maximum Flood (PMF) RL at the Charlton levee and ensure there is 500mm of freeboard (from PMF to levee top RL).	Complete. A review of the 2016 flood mapping by WBM BMT for Singleton Council indicates that the PMF flood level around the salt pan creek (tributary of Wollombi Brook) is approx 70.0m AHD. A review of MTW survey data indicates that the Charlton levee crest is maintained above RL 70.5 or higher throughout the levee length as at 17/10/2018.	N/A
3.	All training required by the SSD 6464 and 6465 approvals or as required by the Management Plans required by the approvals should be documented. **Response/Action Description** Review process for documenting training records for training required by approvals, Implement process for documenting these training records as required.	In Progress. Action item is included on MTW's action tracking system.	30/04/2020