SOUTH32 Illawarra Metallurgical Coal

WC21 AND DONALDS CASTLE CREEK REHABILITATION PLAN

Contents

Tables

Figures

Attachments

Attachment 1- TARP

Attachment 2- Tracer Testing

Review History

Revision	Description of Changes	Date
A	New Document for submission to DPE	December 2015
B	Update following extraction of Longwall 11	July 2016
2.0	Updated to include Donalds Castle Creek	September 2017
2.1	Updated to include trial remediation sites	May 2021
3	Updated to incorporate feedback received	July 2021
4	Updated to include remediation trial results	January 2023

Persons involved in the development of this document include:

Name	Title	Company
Josh Carlon	Environmental Coordinator	Illawarra Metallurgical Coal
Cody Brady	Principal Approvals	Illawarra Metallurgical Coal
Nicola Curtis	Principal Approvals	Illawarra Metallurgical Coal
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1 INTRODUCTION

South32 Illawarra Metallurgical Coal (IMC) operates the Dendrobium Mine in the Southern Coalfield of New South Wales (NSW). Longwalls from the Wongawilli Seam are currently being extracted from Dendrobium Area 3A (DA3A).

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007 IMC proposed to modify its mining operations using *s75W* of the *Environmental Planning and Assessment Act 1979* (*EP&A Act*) and the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from cracking and diversion of water as a result of the proposed mining. These impacts include diversion of flow, lowering of aquifers, changes to habitat for threatened species as well as other impacts and environmental consequences.

On 8 December 2008, the Minister for Planning approved a modification to *DA_60-03-2001* for the Dendrobium Underground Coal Mine and associated surface facilities and infrastructure.

On 4 October 2012, IMC submitted a Subsidence Management Plan (SMP) for approval by the Directors General (now Secretaries) of the Department of Planning and Infrastructure (now the Department of Planning and Environment, DPE) and Trade and Investment (T&I) (now the Resources Regulator (RR)). The SMP incorporates the Watercourse Impact, Monitoring, Management and Contingency Plan (WIMMCP). The SMP was approved by the Secretary T&I 5 February 2013 and the Secretary DPE 6 February 2013.

Mining of Longwalls 9, 10, 11, 12 and 13 were undertaken in accordance with the approved SMP and WIMMCP. Impacts associated with Longwalls 9, 10, 11, 12 and 13 have been identified at Donalds Castle Creek (DCC) and WC21, a tributary to Wongawilli Creek.

Reporting of impacts has been carried out as required under the SMP and WIMMCP. Inspections and measurements have identified iron staining and rock fracturing to pools and rockbars along the streams. A decline in pool water levels below baseline and extended periods of no flow and dry pools has been recorded.

1.1 SCOPE

The WIMMCP has been prepared to comply with the Dendrobium Consent and the SMP Approval for Area 3B. The WIMMCP outlines the requirements for and proposed approach to rehabilitation in Area 3B.

The WIMMCP is subject to *Schedule 3, Condition 4* of the Consent as provided below.

> *4. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant must prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:*
>
> *(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;*
>
> *(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and Resources Regulator of the subsidence effects and impacts (individual and cumulative) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;*
>
> *(c) include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function;*
>
> *(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses, which includes a tabular contingency plan (based on the Trigger Action Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;*
>
> *(e) address third and higher order streams individually but address first and second order streams collectively;*

(f) be prepared in consultation with BCS, Water NSW and Resources Regulator;

(g) incorporate means of updating the plan based on experience gained as mining progresses;

(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and

(i) *be implemented to the satisfaction of the Secretary.*

The WIMMCP addresses:

- impact assessment and how the subsidence impact limits, specified in the approval, will be met;
- monitoring and reporting;
- trigger levels that initiate the implementation of management or remedial measures (including contingency measures);
- implementation of remedial measures should mining induced degradation to the watercourses be observed or measured (including contingency measures); and
- access to watercourses and rehabilitation of access routes to watercourses.

The WC21 and DCC Rehabilitation Plan (this Plan) addresses the proposed remediation activities for the observed subsidence impacts to DCC and WC21 as a result of the extraction of Longwalls 9, 10, 11, 12 and 13.

1.1.1 OBJECTIVES

As outlined in the SMP and WIMMCP the approach to reducing impacts within Area 3B includes avoidance, minimising, mitigation and remediation measures.

If the performance measures in Table 1 of the SMP Approval are not met, then following consultation with Biodiversity Conservation and Science Directorate (formerly Office of Environment and Heritage (OEH)), WaterNSW and T&I (Resources Regulator), the Secretary of DPE may issue a direction in writing to undertake actions or measures to mitigate or remediate subsidence impacts and/or associated environmental consequences. The direction must be implemented in accordance with its terms and requirements, in consultation with the Secretary and affected agencies.

The Secretary wrote to IMC on 28 August 2015 to request, under *Schedule 3, Condition 4*, that IMC prepare a remediation program for the impacts to WC21. This Plan is to comply with the Area 3B SMP Approval Conditions including *Condition 9* Performance Measures for Area 3B.

On 16 December 2016 the Secretary of DPE approved the SMP for Longwalls 14 and 15. *Condition 13* of the Approval requires the Applicant undertake remediation programs for WC21 and DCC, to the satisfaction of the Secretary.

The success of the WC21 and DCC Rehabilitation Plan will be assessed against the objectives and success criteria provided in **Table 1-1**.

Table 1-1 Plan Objectives and Success Measurements

Objective	Success Measurements
Characterising the impacts to inform an assessment of the potential efficacy of any remediation	• Drill holes at trial grout-injection sites with an appropriate number of holes angled to identify sub-vertical fracturing • Holes logged using core, acoustic scanners, down-hole cameras, geophysical tools and packer tests • The depth and interconnectivity of the surface fracture zone characterised • Nested piezometers installed • Drilling to identify the water table

Objective	Success Measurements
	• Down-hole camera and geophysical tools identify zones of major cracking and/or inflow • Packer testing and/or rising and falling head tests • "Full path" and/or "intermediate-distance" tracer test as advised by experts
Avoiding additional impacts during remediation where possible	• Impacts resulting from the remediation are in line with the Plan • No environmental incidents during remediation activities
Implementing the WIMMCP TARPs and responding to impacts to watercourses	• Continue monitoring program and submit Impact Reports • Report in the End of Panel (EoP) Report and Annual Review • Review monitoring frequency • Seek advice and implement agreed Corrective Management Actions (CMAs) • Site visits and additional monitoring • Review relevant TARP and Management Plan
Achieving the Performance Measures outlined in the Area 3B SMP Approval, to the satisfaction of the Secretary	• Structural integrity of the bedrock base of any significant pool or controlling rockbar restored i.e. pool water level within the pool after CMAs above baseline period • Iron staining and associated increases in dissolved iron resulting from the mining is not observed in downstream monitoring sites (FR6)
Restoring flows	• Change in modelled periods of recessional, baseflow and small storm unit hydrograph periods <6%
Protecting and restoring water quality	• Iron staining and associated increases in dissolved iron resulting from the mining is not observed in water at downstream monitoring site (FR6)
Restoring key habitats and ecosystems	• Pool water level, interconnectivity between pools and connectivity at aquatic ecology sites • Noticeable improvement of habitat
Monitoring and reporting effectiveness of this Plan	• Results from the Plan are included in EoP Reports and Annual Review • Results are reviewed monthly by the IMC Subsidence Management Committee

The CMAs described in this Plan have been developed in consultation with key stakeholders to manage the observed impacts in accordance with relevant approvals. This Plan provides for the implementation of mitigation and remediation of mining impacts to WC21 and DCC.

This Plan addresses:

- aims and objectives for corrective actions;
- consideration of relevant aspects from the SMP and WIMMCP;
- description, analysis and assessment of the impacts compared to prediction;
- assessment of the need for management options and contingent measures;
- specific actions required to mitigate/manage and timeframes for implementation;
- roles and responsibilities;

- gaining appropriate approvals from landholders and government agencies; and
- reporting, consultation and communication.

1.1.2 CONSULTATION

The SMP and WIMMCP were developed with extensive consultation, as documented in the current Area 3B LW18 SMP and WIMMCP (2019).

The Secretary wrote to IMC on 28 August 2015 to request, under Schedule 3, Condition 4, that IMC prepare a remediation program for the impacts to WC21. The WC21 Rehabilitation Plan was submitted to DPE in December 2016 and distributed for comment to key agencies including WaterNSW and DRE. Feedback received was used to update the document. A revised WC21 Rehabilitation Plan was submitted to DPE in July 2016 and distributed for comment to key agencies including WaterNSW. Feedback received was used to update the document.

IMC met with DPE, OEH and WaterNSW 30 May 2017 where it was agreed to update the Plan to address remediation of impacts within WC21 and DCC, as required by *Condition 13* of the Longwalls 14 and 15 SMP Approval. In September 2017 the revised WC21 and DCC Rehabilitation Plan was submitted to DPE and distributed for comment to key agencies. Feedback received has been used to update the document.

IMC met with DPE, OEH and WaterNSW 26 October 2018 where it was agreed to undertake a trial at select remediation sites to inform the WC21 and DCC Rehabilitation Plan. Details of the proposed rehabilitation trial method and objectives were provided to WaterNSW in March 2021 for their review and feedback, prior to being incorporated into this Plan.

1.1.3 APPROVALS

Table 1-2 lists the Conditions of Consent relevant to this Plan and where the conditions are addressed.

Table 1-2 Dendrobium *DA-60-03-2001* Approval Conditions

Project Approval Condition	Relevant Section
Condition 4 – Schedule 3	
Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant must prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;	Sections 3, 4, 5 and Attachment 1
(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and Resources Regulator of the subsidence effects and impacts (individual and cumulative) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;	Section 3 and Attachment 1
(c) include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function;	Section 3 and Attachment 1
(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses; include a tabular contingency plan (based on the Trigger Action Response Plan structure) which focuses on measures for remediating both predicted and unpredicted impacts on watercourses;	Section 4, 5 and Attachment 1
(e) address third and higher order streams individually but address first and second order streams collectively;	Sections 4
(f) be prepared in consultation with BCS, Water NSW and Resources Regulator;	Section 1.3
(g) incorporate means of updating the plan based on experience gained as mining progresses;	Section 5
(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and	Section 2
(i) be implemented to the satisfaction of the Secretary.	

The following licences and permits may be applicable to this Plan:

- Dendrobium Mining Lease as shown in **Table 1-3**;
- *Environmental Protection Licence (EPL) 3241,* which applies to the Dendrobium Mine. A copy of the licence can be accessed at the EPA website via the following link Environment & Heritage | PRPOEO (nsw.gov.au)
- Dendrobium Rehabilitation Management Plan;
- Relevant Occupational, Health, Safety and Environmental approvals; and
- Any additional leases, licences or approvals resulting from the Dendrobium Approval.

Table 1-3 Dendrobium Leases

Mining Lease - Document Number	Issue Date	Expiry Date/ Anniversary Date
CCL 768	7 May 1998	7 October 2029

As indicated in *Schedule 2*, *Conditions 1 and 14* of the Development Consent (Minister for Planning 2008) and *Conditions 12 and 13* of the Area 3B SMP Approval (Secretary DPE 2016), the mitigation and remediation described in this Plan are required for the development, and an integral component of the proposed mining activity. To the extent these activities are required for the development approved under the Dendrobium Mine Development Consent no other licence under the Biodiversity Conservation Act is required in respect of those activities.

At the time of grant of the Dendrobium Development Consent there was no requirement for concurrence in respect of threatened species or ecological communities. The requirement for concurrence was, at that time, governed by section *79B* of the *EP&A Act*. At the time of grant of the Dendrobium Consent there was a requirement for consultation with the Minister administering the Threatened Species Conservation Act and this consultation was undertaken.

2 STUDY AREA

Detailed exploration has been completed for Dendrobium Mine and these assessments are ongoing. The exploration and associated monitoring provides extensive understanding of the geology of the mining areas. Dendrobium Mine lies in the southern part of the Permo-Triassic Sydney Basin. The geology mainly comprises sedimentary sandstones, shales and claystones, which have been intruded by igneous sills.

The sandstone units vary in thickness from a few metres to as much as 120 m. The major sandstone units are interbedded with other rocks and, though shales and claystones are extensive in places, the sandstone predominates.

The major sedimentary units at Dendrobium are, from the top down:

- The Hawkesbury Sandstone.
- The Narrabeen Group (including the Bulgo Sandstone).
- The Eckersley Formation.

The Strahler stream classification system is commonly used to define the class of a watercourse and was used in the Southern Coalfield Inquiry (*Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review, 2008*). Streams are classified based on the number of contributing tributaries, with headwater streams classed as first and second order streams and third and higher order streams given the classification of 'streams of significance'. The impacted portions of DCC and WC21 are first or second order streams.

Extensive geomorphological mapping has been completed for DCC and WC21 as well as other streams within Dendrobium Area 3. WC21 flows to Wongawilli Creek which is located between Areas 3A and 3B. DCC flows to Cordeaux River, below Cordeaux Dam.

The geomorphology of the DCC and WC21 catchments is characterised by upland plateau and a series of 'benches' comprised of catenary hill-slopes and swamps enclosed in roughly crescent-shaped cliff lines.

2.1 MONITORING HISTORY AND REPORTING

Monitoring in WC21, DCC and Wongawilli Creek commenced in 2001 (**Figure 2-1**).

Table 2-1: Monitoring in Wongawilli Creek and WC21

Watercourse	Catchment	Monitoring
Wongawilli	Cordeaux	Water quality, Observations, Photo points, Water level, Flow, Groundwater level, Subsidence movements, Aquatic ecology
WC21	Cordeaux	Water quality, Observations, Photo points, Water level, Flow, Groundwater level, Subsidence movements, Aquatic ecology
Donalds Castle Creek	Cordeaux	Water quality, Observations, Photo points, Water level, Flow, Groundwater level, Subsidence movements, Aquatic ecology

The IMC Environmental Field Team undertakes monitoring and assessments in Area 3B, including DCC, Wongawilli Creek and WC21. These include:

- Water: location, volume, quality and flow characteristics.
- Significant features: rockbars, pools and flow channels.
- Vegetation: location, species, and observed health/appearance.
- Sediment: composition, depth and moisture.

This data is used to compare differences in site conditions before and after mining. Sites that will not be mined beneath are also monitored to provide a comparison of sites mined beneath and sites away from mining, during different climatic conditions.

Pool water levels are measured in DCC, WC21 and Wongawilli Creek using installed benchmarks (**Figure 2-1**). Water level/flow gauges and data loggers are installed at key stream flow monitoring sites (**Figure 2-2**).

Pool water levels are measured monthly before and after mining, on a weekly basis during active subsidence and in response to any identified impacts.

Flow monitoring sites are installed downstream of the mining area to assess any changes in surface flow from a catchment resulting from the mining.

These sites are not installed directly over the longwalls as mining induced surface fracture networks typically result in receding flows being entirely diverted below the surface, which is the case for DCC and WC21. The downstream monitoring sites are specifically designed to answer the question: to what extent do diverted flows within the surface fracture network return to the surface downstream of the mining area.

Water quality monitoring has been undertaken since 2003 and includes pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and laboratory tested analytes (DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si).

Pools within streams are measured monthly before and following mining, weekly during active subsidence and in response to any observed impacts.

Standardised transects in potential breeding habitat for the threatened frog species Littlejohn's Tree Frog and Giant Burrowing Frog have been established in Area 3B, including DCC and WC21 which commenced in 2012 (**Figure 2-3**).

Along each transect the monitoring includes counts of frogs, an assessment of pools used for breeding as well as counts of tadpoles and egg masses.

Aquatic ecology monitoring includes direct measures of aquatic flora and fauna as well as biophysical measures. Aquatic ecology monitoring sites for Area 3B are shown in **Figure 2-4**. These sites are located in watercourses that contain “significant” or “moderate” aquatic habitat and are suitable for AUSRIVAS assessment (i.e. are at least 100 m long).

Two methods are used to sample aquatic macroinvertebrates: the AUSRIVAS protocol for NSW streams (Turak et al. 2004) and artificial aquatic macroinvertebrate collectors, a quantitative monitoring method for freshwater environmental impact assessment.

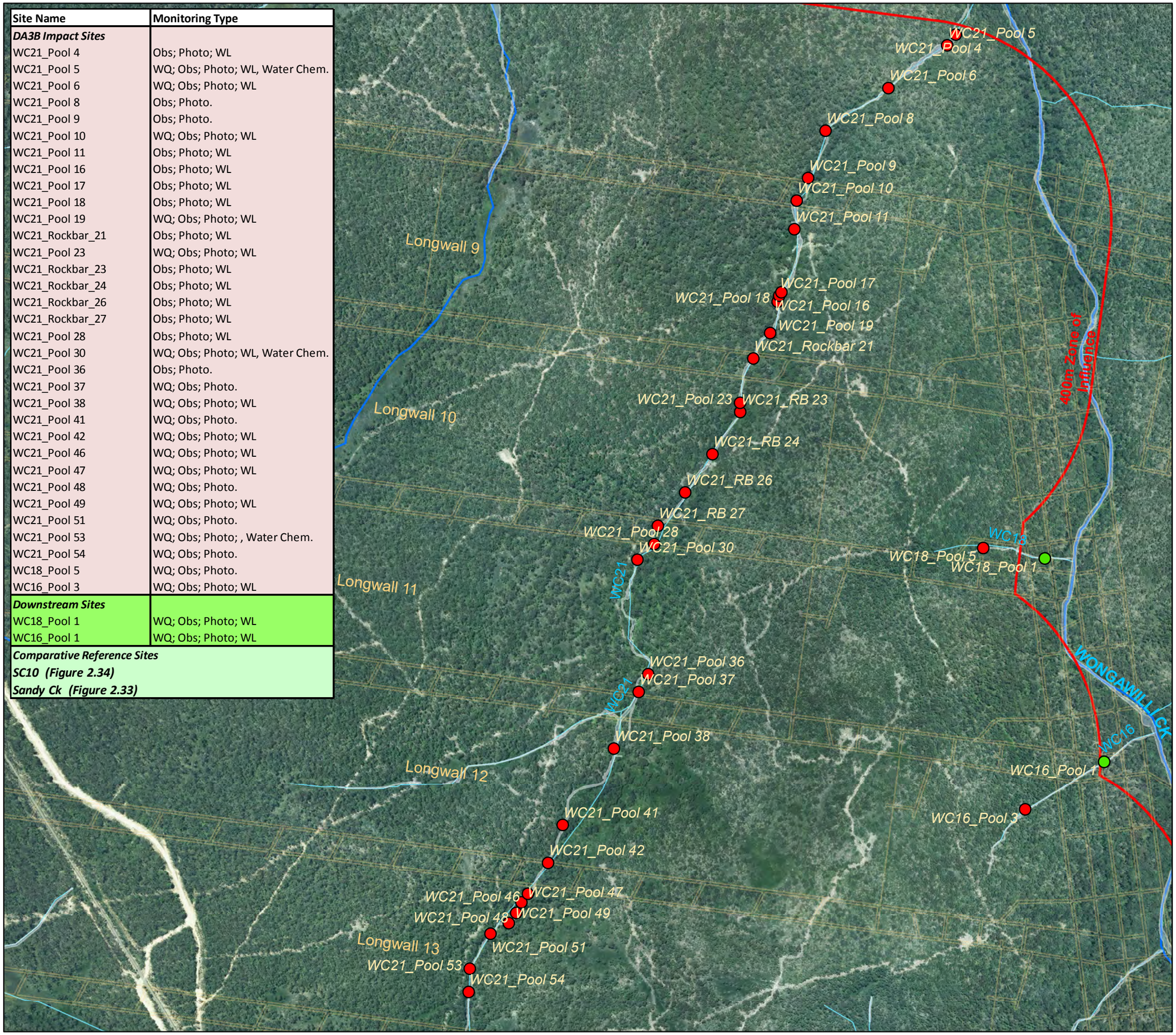
Fish are sampled using a back-pack electrofisher (model LR-24 Smith-Root) and baited traps.

Aquatic ecology monitoring Sites 1, 2, 3, 4, 5, X4, X5 and X6, are situated in Wongawilli Creek, Sites X2, X3 and 6 are located in WC21 and Sites X1 and 14 are in DCC.

End of Panel Reports are prepared in accordance with *Schedule 3, Condition 9* of the Dendrobium Area 3 Modification Approval. Results from the monitoring program are included in the EoP Report and in the Annual Review. These reports detail the outcomes of monitoring undertaken, provide results of inspections and determine whether performance indicators have been exceeded.

Monitoring results are reviewed monthly by the IMC Subsidence Management Committee.

Site Name	Monitoring Type
DA3B Impact Sites	
WC21_Pool 4	Obs; Photo; WL
WC21_Pool 5	WQ; Obs; Photo; WL, Water Chem.
WC21_Pool 6	WQ; Obs; Photo; WL
WC21_Pool 8	Obs; Photo.
WC21_Pool 9	Obs; Photo.
WC21_Pool 10	WQ; Obs; Photo; WL
WC21_Pool 11	Obs; Photo; WL
WC21_Pool 16	Obs; Photo; WL
WC21_Pool 17	Obs; Photo; WL
WC21_Pool 18	Obs; Photo; WL
WC21_Pool 19	WQ; Obs; Photo; WL
WC21_Rockbar_21	Obs; Photo; WL
WC21_Pool 23	WQ; Obs; Photo; WL
WC21_Rockbar_23	Obs; Photo; WL
WC21_Rockbar_24	Obs; Photo; WL
WC21_Rockbar_26	Obs; Photo; WL
WC21_Rockbar_27	Obs; Photo; WL
WC21_Pool 28	Obs; Photo; WL
WC21_Pool 30	WQ; Obs; Photo; WL, Water Chem.
WC21_Pool 36	Obs; Photo.
WC21_Pool 37	WQ; Obs; Photo.
WC21_Pool 38	WQ; Obs; Photo; WL
WC21_Pool 41	WQ; Obs; Photo.
WC21_Pool 42	WQ; Obs; Photo; WL
WC21_Pool 46	WQ; Obs; Photo; WL
WC21_Pool 47	WQ; Obs; Photo.
WC21_Pool 48	WQ; Obs; Photo; WL
WC21_Pool 49	WQ; Obs; Photo; WL
WC21_Pool 51	WQ; Obs; Photo.
WC21_Pool 53	WQ; Obs; Photo; , Water Chem.
WC21_Pool 54	WQ; Obs; Photo.
WC18_Pool 5	WQ; Obs; Photo; WL
WC16_Pool 3	WQ; Obs; Photo; WL
Downstream Sites	
WC18_Pool 1	WQ; Obs; Photo; WL
WC16_Pool 1	WQ; Obs; Photo; WL
Comparative Reference Sites	
SC10 (Figure 2.34)	
Sandy Ck (Figure 2.33)	



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Dendrobium Area 3B
Watercourse Monitoring Sites
WC21, WC18 and WC16

Figure 2-1

Legend

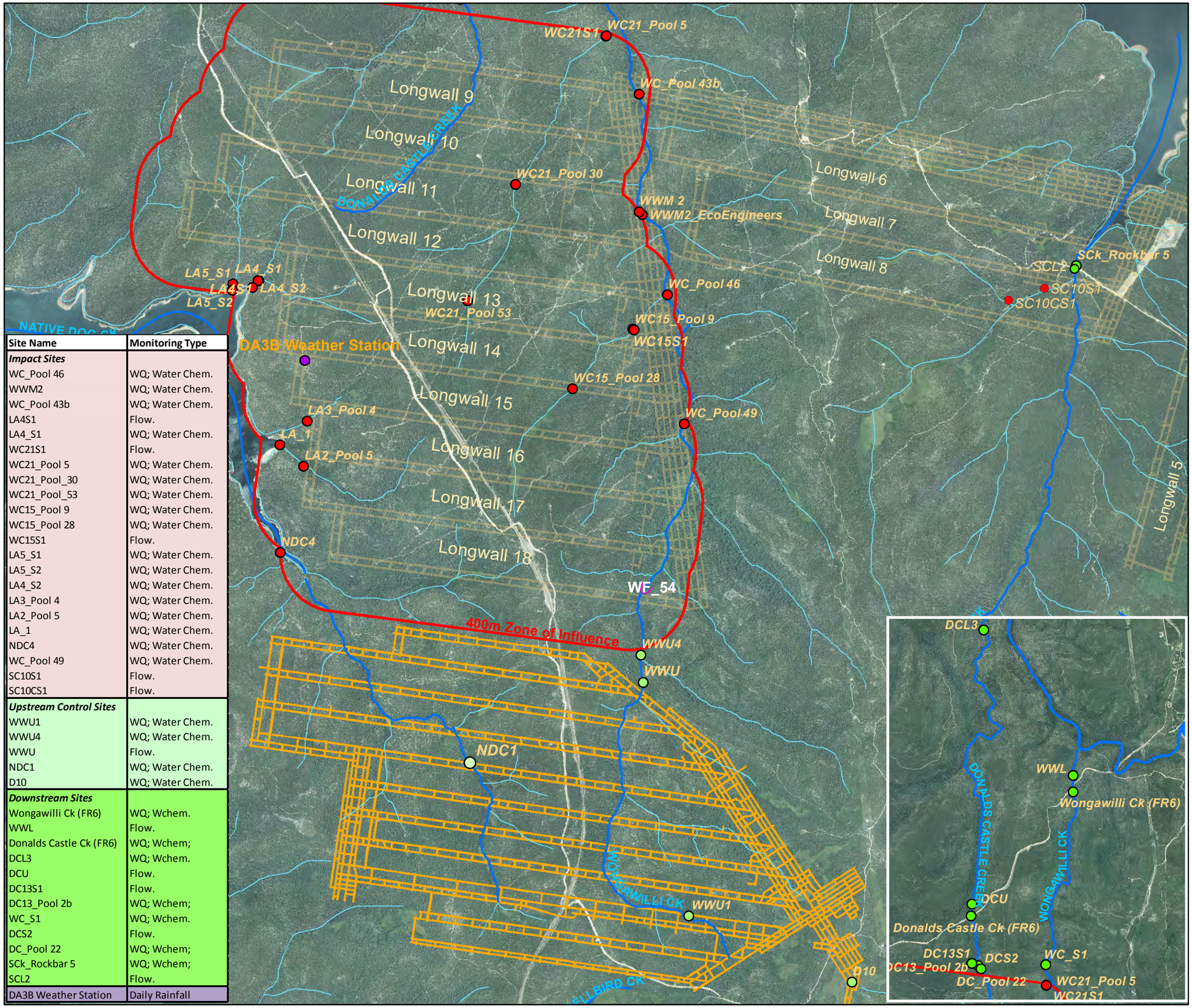
- Impact Monitoring Site
- Dendrobium Layout
- 400m Zone of Influence (DA3B)
- Stream Mapping
- Creeks
- Tributaries

Date: December, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

0 50 100 200 300 400
Metres



Site Name	Monitoring Type
Impact Sites	
WC_Pool 46	WQ; Water Chem.
WWM2	WQ; Water Chem.
WC_Pool 43b	WQ; Water Chem.
LA4S1	Flow.
LA4_S1	WQ; Water Chem.
WC21S1	Flow.
WC21_Pool 5	WQ; Water Chem.
WC21_Pool_30	WQ; Water Chem.
WC21_Pool_53	WQ; Water Chem.
WC15_Pool 9	WQ; Water Chem.
WC15_Pool 28	WQ; Water Chem.
WC15S1	Flow.
LA5_S1	WQ; Water Chem.
LA5_S2	WQ; Water Chem.
LA4_S2	WQ; Water Chem.
LA3_Pool 4	WQ; Water Chem.
LA2_Pool 5	WQ; Water Chem.
LA_1	WQ; Water Chem.
NDC4	WQ; Water Chem.
WC_Pool 49	WQ; Water Chem.
SC10S1	Flow.
SC10CS1	Flow.
Upstream Control Sites	
WWU1	WQ; Water Chem.
WWU4	WQ; Water Chem.
WWU	Flow.
NDC1	WQ; Water Chem.
D10	WQ; Water Chem.
Downstream Sites	
Wongawilli Ck (FR6)	WQ; Wchem.
WWL	Flow.
Donalds Castle Ck (FR6)	WQ; Wchem;
DCL3	WQ; Wchem.
DCU	Flow.
DC13S1	Flow.
DC13_Pool 2b	WQ; Wchem;
WC_S1	WQ; Wchem.
DCS2	Flow.
DC_Pool 22	WQ; Wchem;
SCk_Rockbar 5	WQ; Wchem;
SCL2	Flow.
DA3B Weather Station	Daily Rainfall

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Dendrobium Area 3B Water Quality and Flow Monitoring

Figure 2-2

Legend

- Upstream Control Site
- Downstream Reference Site
- Impact Site
- DA3B Weather Station
- Wongawilli Creek Waterfall (WF_54)
- 400m Zone of Influence (DA3B)
- Creeks
- Tributaries
- Dendrobium Layout
- Elouera Workings

Date: December, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

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W E
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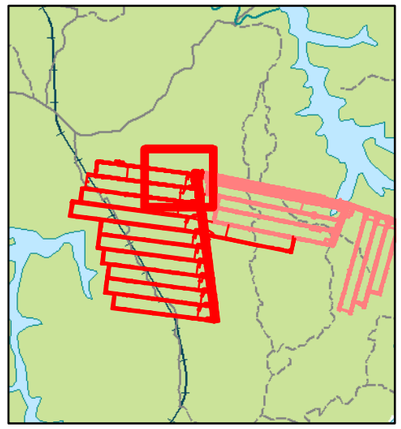
0 500 1,000
Metres

DC_Pool_23
DC_Pool_29
DC_Pool_30
DC(1) Transect
DC_Pool_32
DC_Pool_33
DC_Pool_34
DC(1)-T-E
DONALDS CASTLE CREEK
WC22
WC21-T-S
WC21_Pool_4
WC21_Pool_5
WC21_Pool_6
WC21_Pool_8
WC21
WC21_Pool_10
WC21_Pool_11
WC21 Transect
WC21_Pool_17
WC21_Pool_16
WC21_Pool_18
WC21_Rockbar_21
WC21_Pool_23
WC21_Rockbar_23
WC21_Rockbar_24
WC21_Rockbar_26
WC21_Rockbar_27
WC21_Pool_30
WC21-T-E
WC Pool 41
WC Pool 42b
WC20
WONGAWILLI CK
WC Pool 43a
WC19
WC18
WONGAWILLI CREEK



Legend

- Pool Level Monitoring Sites

Threatened Frog Monitoring

- Impact - Transect Start
- Impact - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.44: WC21 Transect

Fig 2-3 Threatened Frog Monitoring

0 50 100 150 200 250

Metres
Scale: 1:5,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

N

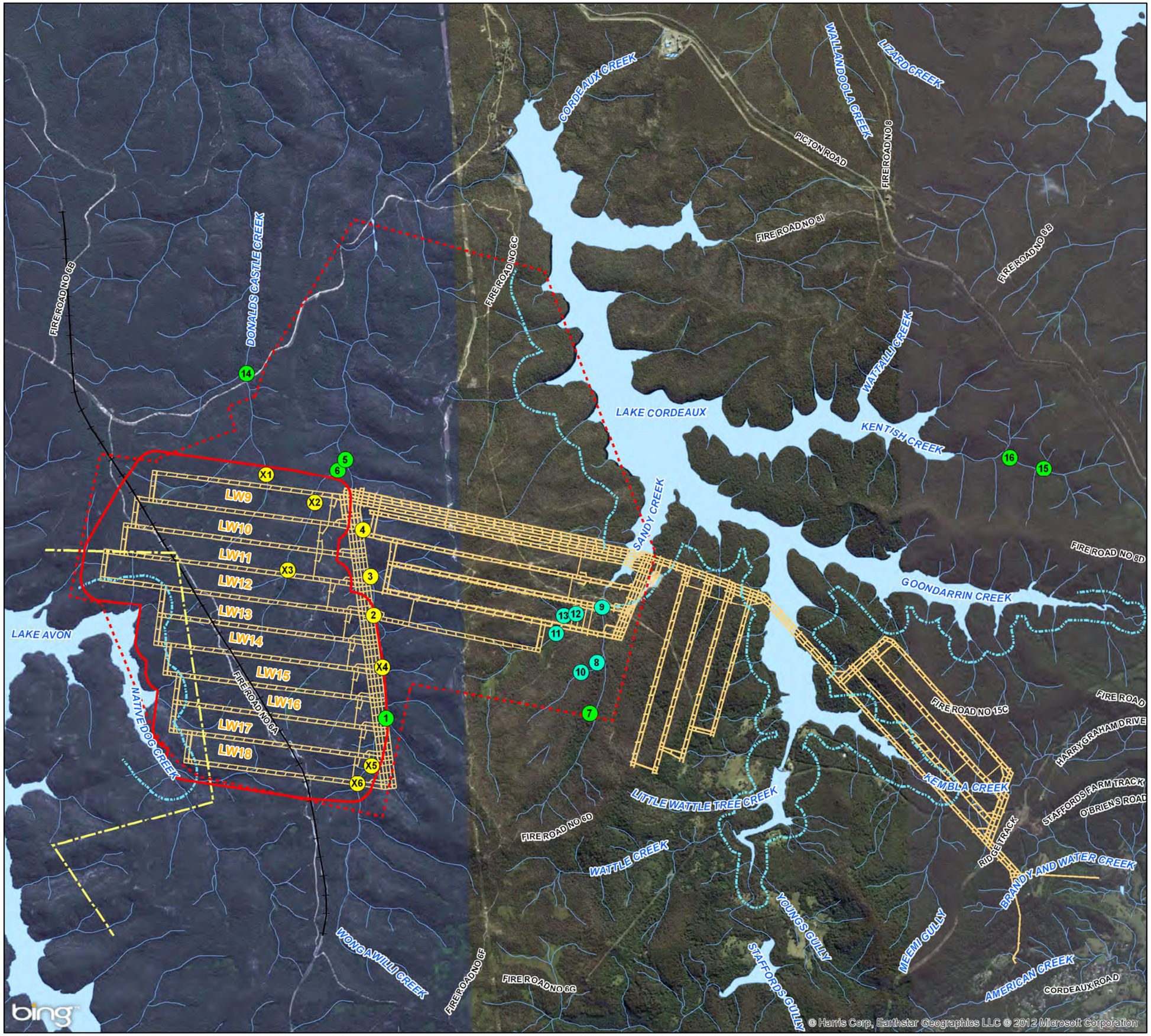
biosis

Biosis Pty Ltd

Ballarat, Brisbane, Canberra, Melbourne, Sydney, Wangaratta & Wollongong

Matter: 17994
Date: 19 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B TF Transects

Acknowledgements: Topo (c) NSW Land and Planning Information (2011);Overivew (c) State of NSW (c.2003)Imagery (c) Nearmap 2012



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Aquatic Ecology Monitoring Locations

DENDROBIUM AREA 3B SMP

Legend

Monitoring Sites (Cardno Ecology Lab)

- Area 3A Monitoring Sites
- Control Sites
- Potential Impacts Sites
- Watercourses (LPI)
- SMP Area (1,199 ha)
- Maximum Footprint Area 3
- Restricted Zone
- DSC Notification Zone
- Maldon to Dombarton Rail
- Longwall Layout (BHPBIC, 2012)
- Waterbodies (LPI)

N
W E
S

FIGURE 2-4

1:45,000 Scale at A3

Metres
0 500 1,000 1,500 2,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-21
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1038_AquaticMonitoringSiteTypes.mxd 01

Data supplied by MSEC (2012) unless otherwise stated
Aerial imagery supplied by Bing Maps and associated third party suppliers

2.2 SUBSIDENCE IMPACT MANAGEMENT

The potential impacts of mine subsidence to watercourses and associated features in Area 3B, including DCC and WC21 is described in the WIMMCP. The impact minimisation, mitigation and remediation measures are described below. Contingency measures, offsets and research are also addressed.

2.2.1 IMPACTS

In accordance with the findings of the Southern Coalfield Inquiry:

- **Subsidence effects** are defined as the deformation of ground mass such as horizontal and vertical movement, curvature and strains.
- **Subsidence impacts** are the physical changes to the ground that are caused by subsidence effects, such as tensile and sheer cracking and buckling of strata.
- **Environmental consequences** are then identified, for example, as a loss of surface water flows and standing pools.

Subsidence is an unavoidable consequence of longwall mining and includes vertical and horizontal movement of the land surface. Subsidence effects include surface and sub-surface cracking, buckling, dilation and tilting. These effects have occurred in DCC and WC21, resulting in changes to the hydrology of the streams.

DCC and WC21 are directly over the goaf and therefore, underwent temporary extensional “face line” cracking (perpendicular to the long axis of the panel) as the panels retreated, followed by re-compression as the maximum subsidence occurs at any one location. In addition, it underwent both longer term extensional “rib line” cracking (parallel to the long axis of the panel) along the outer edge and compression within the central portion of the subsidence trough. DCC and WC21 are located within valleys and were therefore, subject to downslope and valley closure movements.

Impact predictions were completed for the Study Area, including predictions for DCC and WC21 in order to record potential and likely impacts from mining. The predictions are based on mathematical and empirical models and utilised the best available information for the Southern Coalfield at that time and in particular Dendrobium Mine conditions. This comprehensive impact assessment is provided in the Area 3B SMP (Cardno 2012).

The impacts that have occurred to DCC and WC21 from mining in Area 3B are detailed in Appendix A. The broad mechanisms of subsidence which have impacted DCC and WC21 include:

- The bedrock of the streams has fractured as a consequence of strain.
- Surface flow and pool water has drained into the fracture network.
- The size and depth of the fractures are such that the impacts will persist in the medium to long-term.
- It is not expected that the fractures extend to the mine workings.
- It is likely that bedding shear pathways have developed to the surface lower in the catchment.
- Surface water diverted through freshly fractured sandstone and groundwater that returns to the surface through the fracture network has increased levels of iron and other minerals.

Changes to watercourse hydrology and water quality have resulted in environmental consequences. The environmental consequences in DCC and WC21 relate to changes in hydrology and water quality and include loss of aquatic ecology and habitat resulting from a reduction of surface water quality, flows and standing pools.

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2012 and 2015) the bedrock of DCC and WC21 was likely to fracture as a consequence of subsidence induced strains.

A Condition of Approval for Dendrobium Mine Longwalls 14-15 was set by DPE in 2017, as follows:

The Applicant must undertake a comprehensive program of groundwater monitoring and assessment, including:

(a) undertaking detailed geotechnical and hydrological investigations of the height of connective cracking in Longwalls 6 to 12, prior to the extraction of Longwall 14;

This program of work undertaken by Professor Bruce Hebblewhite adds to previous work for DPE by Mackie (2017). It is clear from the results, that mining-induced impacts are occurring above all panels throughout the overburden sequence, through to, or very close to the surface in all cases. This includes increased defect/fracture impacts; significant increases in permeability; and reduction to near-zero pressure head throughout the strata (Hebblewhite 2020).

There is some evidence of very localised retained groundwater in perched aquifers at some locations, and at different vertical horizons, but these are not extensive. On the basis of this evidence, it is reasonable to conclude that the height of depressurisation is close to, or equal to the total depth of overburden above the working coal seam, i.e. extending to the surface in each instance.

Subsidence, upsidence and closure along DCC and WC21 were predicted. A summary of the maximum predicted values of total subsidence, upsidence and closure after the extraction of the proposed longwalls is provided in **Table 2-2**.

Table 2-2 Maximum Predicted Total Subsidence, Valley Related Upsidence and Closure at DCC and WC21.

Stream	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
WC21	3500	700	700
DCC	2700	370	280

2.2.2 TRIGGER ACTION RESPONSE PLAN

The WIMMCP TARPs relate to identifying, assessing and responding to impacts to watercourses (including impacts greater than predicted). The TARPs for Area 3B watercourses are included in **Attachment 1**.

TARPs include actions to be taken upon reaching a defined trigger level. This Plan includes CMAs to manage observed impacts to DCC and WC21.

The following Watercourse TARP Triggers have been observed in DCC and WC21:

- Level 1
  - Fracturing, uplift and dilation of existing joints
  - Iron staining within the mining area
- Level 2
  - Fracturing with associated flow diversion
  - Iron staining continues outside the mining area
  - Reduction in downstream sub-catchment flow
  - Reduction in Littlejohn's tree frog habitat
  - Reduction in aquatic habitat
- Level 3
  - Reduction in downstream sub-catchment flow

Along WC21, 77% of mapped stream features within the mining area are affected by water loss. Along DCC, 67% of mapped stream features are affected by water loss.

Mining-related fracturing of bedrock, flow diversions and associated reductions in pool water levels and flow were first observed in WC21 in December 2013. By 2015, there was a complete loss of surface water base-flow at aquatic ecology monitoring site X2 (approximately 100 m long) and surface water was restricted to a few small, disconnected pools. By March 2016 the length of WC21 that had been affected by reduction in surface flow and pool water levels was 1,050 m and by April 2017 it was approximately 1,600 m. During the aquatic ecology monitoring survey in April 2017, the only aquatic habitat at X2 in WC21 consisted of a few small and disconnected pools, likely derived from rainfall. This reduction in aquatic habitat availability and connectivity in WC21 represents a significant impact to aquatic ecology with respect to this tributary.

2.3 MITIGATION AND REMEDIATION

Where the bedrock base of any significant permanent pool or controlling rockbar within Wongawilli Creek or DCC are impacted from subsidence and where there is limited ability for these fractures to seal naturally, they will be sealed with an appropriate and approved grout (WIMMCP).

2.3.1 REMEDIATION TECHNIQUES

Sealing of Rock Fractures

Grouting will focus on fractures resulting in diversion of flow from pools or through the controlling rockbar. Significant success has been achieved in the remediation of the Georges River where four West Cliff longwalls mined directly under the river and pool water level loss was observed.

A number of grouts are available for use including cement with various additives. Grouts can be used with or without fillers such as clean sand, depending on the grout design. Grouts are mixed on-site and injected into the fracture network or placed by hand.

Such operations do have the potential to result in additional environmental impacts and will be carefully planned and executed to avoid contamination. Mixing areas will be restricted to cleared seismic lines or other open areas wherever possible. Bunds will contain any local spillage at mixing points. The selection of grouting materials will be determined in consultation with WaterNSW and be based on demonstrated effectiveness and avoiding significant impact to water quality or ecology.

The placement of grout to seal rock fractures can normally be completed within a day for each pool. Setting times for grout vary depending on the grout design but typically the grout will set overnight and allow for testing of the pool the following day. A number of grouting and testing sequences may be required.

Injection Grouting

Injection grouting involves the delivery of grout through holes drilled into the bedrock targeted for rehabilitation. A variety of grouts and filler materials can be injected to fill the voids in the fractured strata intercepted by the drill holes. The intention of this grouting is to achieve a low permeability ‘layer’ below any affected pool as well as the full depth of any significant rockbar. Where alluvial materials overlie sandstone, grouts are injected through grout rods to seal voids in or under the soil profile.

Grouting holes are drilled in a pattern, usually commencing at a grid spacing of 2 m x 2 m. The holes are installed using small drill rigs or handheld drills. The drills are powered by compressed air distributed to the work area from a compressor. The equipment will be sited on cleared seismic lines or other clear areas wherever possible with hoses run out to target areas. Where no cleared areas exist, small areas will be cleared for access and grouting operations.

Grout is delivered from a small tank into the ground via mechanical packers installed at the surface Wherever possible the set up and mixing areas are restricted to cleared seismic lines and other open areas. Bunds are used to contain any local spillage at mixing points. Equipment is transported in vehicles capable of travelling on tracks, seismic lines and cleared access sites. The grout is mixed and pumped according to a grout design. A high viscosity or short set-time grout is used if vertical fracturing is present. A long set-time or low viscosity grout is used if cross-linking is noted during grouting. Once the grout is installed the packers are removed and the area cleaned.

Grouting typically commences at the upstream sections of the impacted area to allow for catchment water to flow into the rehabilitated area for pool integrity testing. Where there is no upstream flow, water is imported to the site for testing pool integrity. To allow sufficient time for the product to set, any flow from upstream is temporarily blocked and/or diverted around the grouting area. Once a pool is tested the area may be in-filled with additional grouting holes that target areas of significant grout take from the previous grouting or areas where flow diversion is observed.

Grouting volumes and locations are recorded, and high-volume areas identified. The rate at which the water drains is measured and compared to pre-grouting results. The grouting process is iterative; relying on monitoring of grout injection quantities, grout backpressures and measurements of water holding capacity. In the Georges River the majority of pools were sealed with two to three grout passes. Depending on the size of the pool the drilling, grouting, cleaning and testing of a pool will require one to two weeks to complete.

Where flow diversion is observed through a large rockbar it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via traditional or directional drilling (track or wheel mounted). These techniques are used where there is limited success using hand-held equipment. As a deeper grout curtain requires the access and installation of powered drill equipment these operations can require two to four weeks to complete. Grouting is implemented at the completion of subsidence movements in the area to reduce the risk of the area being re-impacted.

Figure 2-5: Rockbar Grouting in the Georges River

(clockwise from top-left): (a) Drilling into the bedrock; (b) Grout pump station setup; (c) Injecting grout into bedrock via a specially designed packer system

Alternative Remediation Approaches

IMC has successfully implemented a subsidence rehabilitation program in the Georges River where there were impacts associated with mining directly under streams. This rehabilitation focused on grouting of mining induced fractures and strata dilation to reinstate the structural integrity and water holding capacity of the bedrock. Metropolitan Colliery is currently undertaking work aimed at rehabilitating areas impacted by subsidence using Poly-urethane Resin (PUR) and other grouting materials. IMC is consulting with Metropolitan Colliery in relation to these technologies. The best grout option available for the rehabilitation work will be identified and agreed with WaterNSW.

Cracking due to subsidence will tend to seal as the natural processes of erosion and deposition act on them. The characteristics of the surface materials and the prevailing erosion and depositional processes of a specific area will determine the rate of infill of cracks and sealing of any fracture network.

2.3.2 REMEDIATION WORK PLAN

Prior to remediation work commencing, a work plan will be developed for the features being targeted. The work plan will include the proposed construction and operation methodology proposed, including details such as:

- environmental controls;
- the access routes and staging areas selected;
- an appropriate risk assessment;
- identification of relevant success measurements; and
- a Trigger Action Response Plan in the event success measurements are not achieved or not on trajectory.

2.3.3 REMEDIATION SUCCESS

Baseline studies have been completed to record the biophysical characteristics of the streams in Area 3B. Monitoring of DCC and WC21 has been conducted before, during and after mining.

The monitoring program will remain in place during and after the implementation of the rehabilitation measures. The monitoring locations will be reviewed during the rehabilitation as required and can be modified (with agreement) accordingly.

Analyses of monitoring data (principally pool water level recession curves) from pre-mining, control, impact and mitigation sites is used to determine the success of the rehabilitation. Observations undertaken as part of the monitoring program will provide contextual information to the above assessment approach. Monitoring data and observations are documented and reported.

Objective performance criteria will be developed following the rehabilitation works and monitoring at the WC21 trial remediation sites (**Section 2.5**).

2.4 INVESTIGATIONS TO SUPPORT REHABILITATION

Prior to remediation works within DCC and WC21 the depth and characteristics of the fracturing will be assessed by drilling, coring, geophysical logging, establishment of piezometers, down-hole cameras and calliper measurements. The hydraulic conductance of these fracture networks will also be assessed. Tracer tests will be used to determine likely flow paths for the diverted water.

IMC and WaterNSW held a joint inspection of WC21 (9 February 2016) to consider the investigations required to understand rehabilitation requirements.

WaterNSW believes that the remedial approach of fracture characterisation followed by grout injection may be of little value in restoring flows, where perched and regional water tables have been lowered.

WaterNSW considers the objectives of investigations are to:

- Characterise the near-surface fracture zone in terms of fracture distribution and spatial extent.
- Characterise the post-mining hydrogeological regime (perched and regional groundwater) within the valley.
- Identify areas of stream flow diversions and quantify or estimate the proportion of the diverted streamflow that is currently returning to the channel.
- Inform the design of grout-injection and other remediation options.

Based on field observations and local experience, first and second order streamflow would naturally be fed by a combination of surface flow and seeping discharges from hillside aquifers perched on sub-horizontal claystone bedding planes or ironstone bands. It is likely that at least the lower parts of the

streams are also naturally "gaining" seepage from the regional aquifer, but the complexity of the steeply stepped terrain makes it difficult to estimate where the gaining and losing portions of the stream are. Both types of aquifer are likely to be affected by subsidence effects.

Water tables which support stream base flow have fallen below the base of the streams and therefore remediation which re-seals the surface rocks will only restore run-off water. Surface water contributions from groundwater are only likely to contribute to flows within first and second order streams that have been mined beneath where the groundwater is temporarily charged from large rainfall events. It is therefore important to have an understanding of the post-mining hydrogeological regime in order to understand the extent to which grout-injection or other types of rehabilitation will restore pool water levels and flows.

To investigate the post-mining hydrogeological regime IMC installed piezometers along the impacted length of WC21, targeting the behaviour of significant perched and regional aquifers and their interaction with surface waters over time, e.g. behaviour after rainfall events and during drier periods (HGEO, 2017).

Characterising the nature and distribution of the fracturing network was undertaken via core-drilling and testing of open holes at the proposed remediation trial sites (SCT, 2016).

A key objective of the investigations is to estimate what proportion of streamflow diverted from the WC21 valley is returning to Wongawilli Creek. Tracer studies will be implemented by specialist hydrogeologists, including release-and-capture scenarios.

A pre-mining monitoring site over Longwall 12 and a post-mining site over Longwall 11 was installed. These sites are monitoring water levels to depths of approximately 30 m and provide access for fracture characterisation and packer-testing. Shallow holes were completed as open-hole piezometers for ongoing monitoring of the upper HBSS aquifer in the WC21 valley. The main purpose of these holes is to provide an understanding of shallow aquifer behaviour changes imposed by mining.

The key design elements for the investigation components are provided in **Table 2-3**.

Table 2-3: Recommended Investigations

Aspect	Investigation
Fracture characterisation	• Drill holes at trial grout-injection sites. • Appropriate number of holes to be drilled at an angle to identify sub-vertical fracturing. • Holes logged (using core, acoustic scanners and/or down-hole cameras as appropriate), and suitable geophysical tools and packer tests may be used to further characterise the fracture networks. • Drilling to be continued until the depth and interconnectivity of the surface fracture zone are adequately characterised.
Hydrogeological regime characterisation	• Nested piezometers installed at suitable locations within the trial area. • Drilling to identify the water table (5m saturated zone to confirm continuity saturation). • Down-hole camera and geophysical tools to identify zones of major cracking and/or inflow. • Undertake packer testing and/or rising and falling head tests if this is considered viable.
Diverted flow estimation	• "Full path" and/or "intermediate-distance" tracer test as advised by experts (Further details in Attachment 2).

Aspect	Investigation
Pool and valley bedrock base investigation	• A handheld auger will be used to map the sediment depth to bedrock adjacent to the pool. This investigation will partially inform targeted grouting around the pool.

Locations were selected on the basis of proximity to the trial sites and areas with appropriate access. The number and location of the investigations will be subject to ongoing expert review during the studies, in consultation with WaterNSW. The investigations have commenced, and preliminary results are reported in SCT 2016 and HGEO 2017 and summarised below.

The investigations are designed to answer the following questions:

- What are the most appropriate strategies for remediation, in terms of restoring pre-mining flows and ecological functions and values?
- What proportion of upstream flow is re-emerging below the impacted parts of the stream?
- To what extent does connective fracturing extend below the base of the stream?
- What are the most appropriate measures of success to guide remedial efforts and ongoing assessment of the hydrological and ecological functionality of the stream?

Investigations to date involved the drilling and installation of four monitoring boreholes at two sites within the WC21 valley; one site located above the already mined Longwall 10, and the other site located above Longwall 12 which had not been mined under at the time of installation.

The two sites therefore provide valuable information on groundwater characteristics before and after the passage of longwalls beneath the watercourse. The four piezometers installed at the two sites are named S2335/S2336 and S2337/S2338. The sections below review the results to date, with a focus on responses to mining and the large rainfall events in March 2017.

The monitoring data at both sites indicates groundwater forms a series of perched systems within the shallow Hawkesbury Sandstone beneath the streambed. Available data from the pre-mining sites indicate groundwater level was several metres below the streambed and therefore was a perched (disconnected) and loosing system with respect to the regional groundwater system. Although these sites had not been directly mined beneath, they are within the Area 3B mining domain, and therefore a groundwater influence from mining cannot be ruled-out.

Groundwater levels have declined as a result of direct mining beneath both locations. Two large rainfall events in March 2017 fell on an already saturated catchment, resulting in significant surface runoff and groundwater recharge. Hydrographs at both sites indicate recharge to the perched aquifers in response to the flooding, but apparently no response to the moderate rainfall and runoff events prior to the March events (HGEO, 2017).

These results support the above position that the "*water tables which support stream base flow have fallen below the base of the streams and therefore rehabilitation which re-seals the surface rocks will only restore run-off water. Surface water contributions from groundwater are only likely to contribute to flows within first and second order streams that have been mined beneath where the groundwater is temporarily charged from large rainfall events*".

2.4.1 TRACER TESTING

The role of tracer testing is to "estimate the diversion of flow from WC21 over a 'full-path' or 'intermediate distance' as advised by experts". Specific objectives for the tracer testing are:

- To observe the location(s) of flow diversion along the wetting front down-stream of the tracer injection point.
- To determine if and where the flow tracer re-emerges, either:
    - on WC21, downstream of the tracer injection point, and/or;
    - on Wongawilli Creek adjacent to, and downgradient of the tracer injection point, and/or;
    - in underground workings of Area 3B over which WC21 flows.

- To use field measurements of tracer concentration to determine the proportion of flow that has returned to down-gradient stream reaches or underground workings.

A tracer test was carried out in October 2021 (prior to the commencement of the rehabilitation trial detailed in Section 2.5), as follows:

- Baseline monitoring commenced in the week prior to the planned test. The monitoring will include continuous flow, EC, pH, water fluorescence, and deployment of activated carbon bags at nominated sites.
- The tracer was deployed at Rockbar 24 on 7 October 2021, prior to the rehabilitation trial commencing and when weather and stream flow conditions were favourable. Approximately 6880 Litres was injected over 2 hours into an open joint.
- Monitoring was carried out at designated downstream monitoring points using automated loggers, manual observations and activated carbon sampler bags. Key observation points were at existing sites (WC21S1, WCS1, Wongawilli Creek (FR6)), and underground (Area 3B).

Further detail on the tracer testing included in **Attachment 2**. Future tracer testing will be undertaken as advised by experts.

2.5 REMEDIATION TRIAL

Sections 2.5.1 to 2.5.7 detail the agreed methodology of two remediation trial sites, which were requested during discussions with the DPE and WaterNSW on 26 October 2018.

Section 2.5.8 describes the trial as executed, and the results will be described in Section 2.5.9 following a 6-month monitoring period.

2.5.1 LOCATION

The remediation trial targeted two sites: Pool 24 and Pool 25 on WC21 (the Trial Site), as shown on Figure 2-6. The Trial Site is close to an existing vehicle access track, which lies adjacent to WC21. Staging Area 1 is proposed for storage and preparation of grouts and tracers.

2.5.2 OBJECTIVES

The principal objective of the trial is to hold water in the two targeted pools following remediation activities. Monitoring of water level, water quality and abundance of macro-invertebrates was conducted at the trial sites in order to develop suitable success criteria for the post trial implementation of the WC21 and DCC Remediation Plan. The scope of the trial included:

- Review the ground characterisation report to develop grout injection plan and constructability assessment for the trial.
- Procurement of materials, equipment setup and commissioning and mobilisation of plant and equipment to site.
- Grouting trial works that may involve techniques such as shallow pattern grouting and or a combination of a directional/angled grout curtain. Information obtained of ground conditions encountered during the trial shall be recorded in order to refine the ground characterisation investigation.
- Post remediation borehole drilling, logging and testing to compare ground condition to pre-trial ground characterisation investigations; and
- Aesthetic remediation of the Trial Site at the completion of the trial.

2.5.3 PRE-TRIAL INVESTIGATIONS

A water level logger has been installed at each site (Pool 24 and Pool 25). Datalogging commenced as of January 2019.

To investigate the depth of soil above bedrock at the Trial Site, intrusive methods such as manual hand auger, drill rig solid flight auger or equivalent were employed. A tracked drill rig and support vehicles were mobilised to the Trial Site and ground characterisation boreholes are proposed to be drilled at:

- Rockbar 24 – one 10 m vertical borehole;
- Pool 24 – one 35 m inclined borehole; and
- Pool 24 – one 25-30 m vertical borehole.

Refer to Figure 2-7.

The water level data records prior to the remediation trial will be used by IMC to calculate the baseline post mining pool water level recession rates.

Tracer testing was proposed at the rehabilitation trial sites, the details of which, are included in **Attachment 2** and Section 2.4.1.

2.5.4 TRIAL METHODS

The general methods that were considered for the trial included:

- Hand grouting - The sealing of surface cracks using hand tools, woven natural fibre material (i.e. hessian), wedges and grout (PUR/cement mortar).
- Shallow pattern grouting - Drilling of shallow boreholes using handheld equipment or mini drill rigs at pre-determined, targeted locations (nominal grid spacing of 2 m) using a hitone-miss-one split spaced method. Shallow pattern drilling and grouting is the primary method proposed for Pool 25, Rockbar 25 and Pool 24.
- Directional/angled grout curtain (a grout curtain to construct a low permeable “curtain like” flow barrier below the surface by placing grout under pressure) was not used for the trial.

Coffer dams and diversion piping were used to divert any surface flow during works as required. It is likely that water will need to be pumped into the sites in order to assess the water holding potential of the pools following remediation. Overlying sediment was managed during the drilling and grouting process.

2.5.5 POST GROUT INJECTION TRIAL VERIFICATION

A post grout injection trial verification borehole was positioned at a suitable safe location within Pool 24 in close proximity (~2 m) to the previously drilled investigation borehole. The purpose of this borehole is to evaluate and validate the grout remediation trial. An additional post trial verification hole was positioned in close proximity to the Rock bar 24 investigation borehole.

IMC will continue to monitor pool water levels during the remediation trial and for a period of time (up to 6 months) after works conclude. The data from this period will be used to calculate post remediation pool water level recession rates.

Validation of the trial works in achieving the project objective to hold water in the two targeted pools following remediation activities will be assessed using the pool water level recession rates and visual observations over time. The rainfall data and recession rates for the period post mining and post remediation will be compared to observe any improvement in the rate by which the pool water levels change over time and length of time pool water capacity is maintained.

2.5.6 AESTHETIC REMEDIATION

Following completion of the investigation and remediation trial works surface remedial concreting and sparging works of borehole collars occurred. The aim of these works was to reduce the visual impact of the works undertaken at the Site rather than eliminate all remnants of the activities.

2.5.7 TRIAL SEQUENCING AND PROGRAM

The following outlines the proposed program for the trial:

- Receive approval of the Plan from DPE (2 months).
- Receive approval from the landholder (WaterNSW) to enter the land to undertake the activity (1 month).
- Tendering and procurement of the investigation equipment and team (1 month).
- Establishment of access to the investigation sites (1 month).
- Site investigations to support rehabilitation works and reparation of ground characterisation report (1 month).
- Preparation of grout injection plan (2 weeks).
- Revision of the Trial Plan, if required, in consultation with key stakeholders (1 month).
- Establishment of site and equipment setup (1 month).
- Remediation Trial (2 months).
- Testing to confirm success of trial works including water pressure/packer testing and borehole backfilling (1 month).
- Aesthetic remediation of trial sites and completion works (1 month).
- Completion report preparation (2 weeks).
- IMC monitoring and testing period (3 - 6 months).

2.5.8 TRIAL EXECUTION

The trial commenced in October 2021. The pre-grouting characterisation field program was undertaken in October and November 2021 and involved the following:

- Twenty-seven hand auger holes to investigate the shallow soil profile above bedrock in systematic cross sections across Pools 24 and 25, as shown on Figure 2-7.
- The drilling of three NQ sized ground characterization boreholes using a small track mounted drill rig. Geotechnical logging and geophysical logging was undertaken on all pre-grouting investigation holes for fracture characterization.
- Water pressure (packer) testing was undertaken for each borehole using a terminal single packer assembly set up with a constant rate injection method to provide an indication of hydraulic conductivity.
- Pool recession tests were undertaken by artificially filling the pools and measuring the recession using the existing data loggers.

On the basis of the investigations, a shallow pattern grouting methodology was recommended. The grouting product selected was a single component, inert, potable water compatible Polyurethane Resin (PUR) used for consolidation, stabilisation and sealing of the strata. A maximum PUR injection volume of 100L was adopted for the grout boreholes within a grid alignment.

The grouting trial works commenced in November 2021 and were paused in December 2021 due to restricted access to WaterNSW Special Area during wet weather. Ongoing La Nina conditions restricted access to the Special Areas until September 2021 and lead to track damage requiring repair. Following track repairs the grouting trial resumed and was completed in November and December 2022.

The grouting trial included shallow pattern grouting and drilling using handheld equipment at pre-determined targeted locations to a target depth of 3.5 metres below the surface of bedrock. The purpose of the shallow pattern grouting was to reduce the permeability of the rock mass of the shallow strata to create a ‘bathtub’ effect.

The post remediation verification works were undertaken in December 2022 and January 2023 and involved drilling of two post verification holes using a small track mounted drill rig, as shown on Figure 2-7. Geotechnical logging, geophysical logging and packer testing was undertaken on the post grouting verification holes.

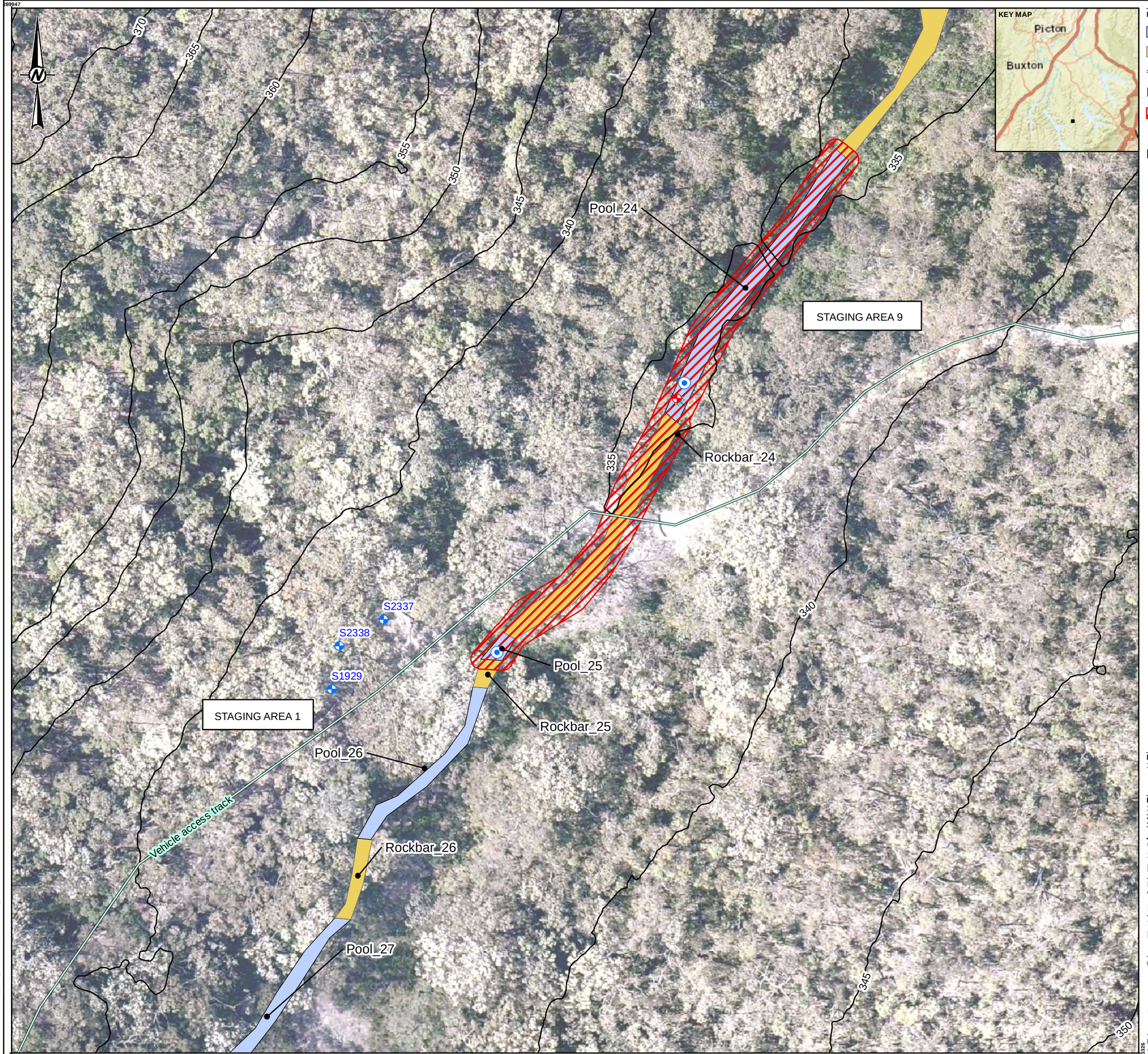
Aesthetic remediation involving capping and infilling the open boreholes with a cementitious grout, coloured to match the surface of the rock. Some aesthetic hand grouting was undertaken for surface cracks adjacent to the shallow pattern grout holes.

2.5.9 TRIAL RESULTS

The initial post remediation investigations indicate that PUR has penetrated open features up to 3.5m deep into the bedrock.

In accordance with this Plan, IMC will continue to monitor the pools for 6 months prior to undertaking an assessment of the outcome of the trial. The assessment will include consideration of the post remediation verification hole logging, piezometer data (S2337/S2338) and pool water level data collected during the monitoring period.

This section and Section 4 (pool water observation tables) will be updated following the monitoring period. Results from the trial will be included in EoP Reports and Annual Review.



LEGEND

- Pool
- Rockbar
- Vehicle access

Proposed remediation

- Trial remediation zone
- Post trial verification borehole

Existing investigations

- Existing borehole
- Watercourse monitoring site

0 30 60

1:750 METRES

NOTE(S)

1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 56

REFERENCE(S)

1. AERIAL PHOTO (C) NEARMAP
2. STREAM MAPPING PROVIDED BY SOUTH32 ILLAWARRA COAL.
3. DEM PROVIDED BY DEPARTMENT OF FINANCE, SERVICE AND INNOVATION

CLIENT
SOUTH32 ILLAWARRA METALURGICAL COAL

PROJECT
WC21 REHABILITATION REMEDIATION TRIAL

TITLE
REMEDIATION TRIAL LOCATION PLAN

CONSULTANT
GOLDER

DD-MM-YYYY	29-05-2020
DESIGNED	EAA
PREPARED	EAA
REVIEWED	BJA
APPROVED	GJF

PROJECT NO.	CONTROL	REV.	FIGURE
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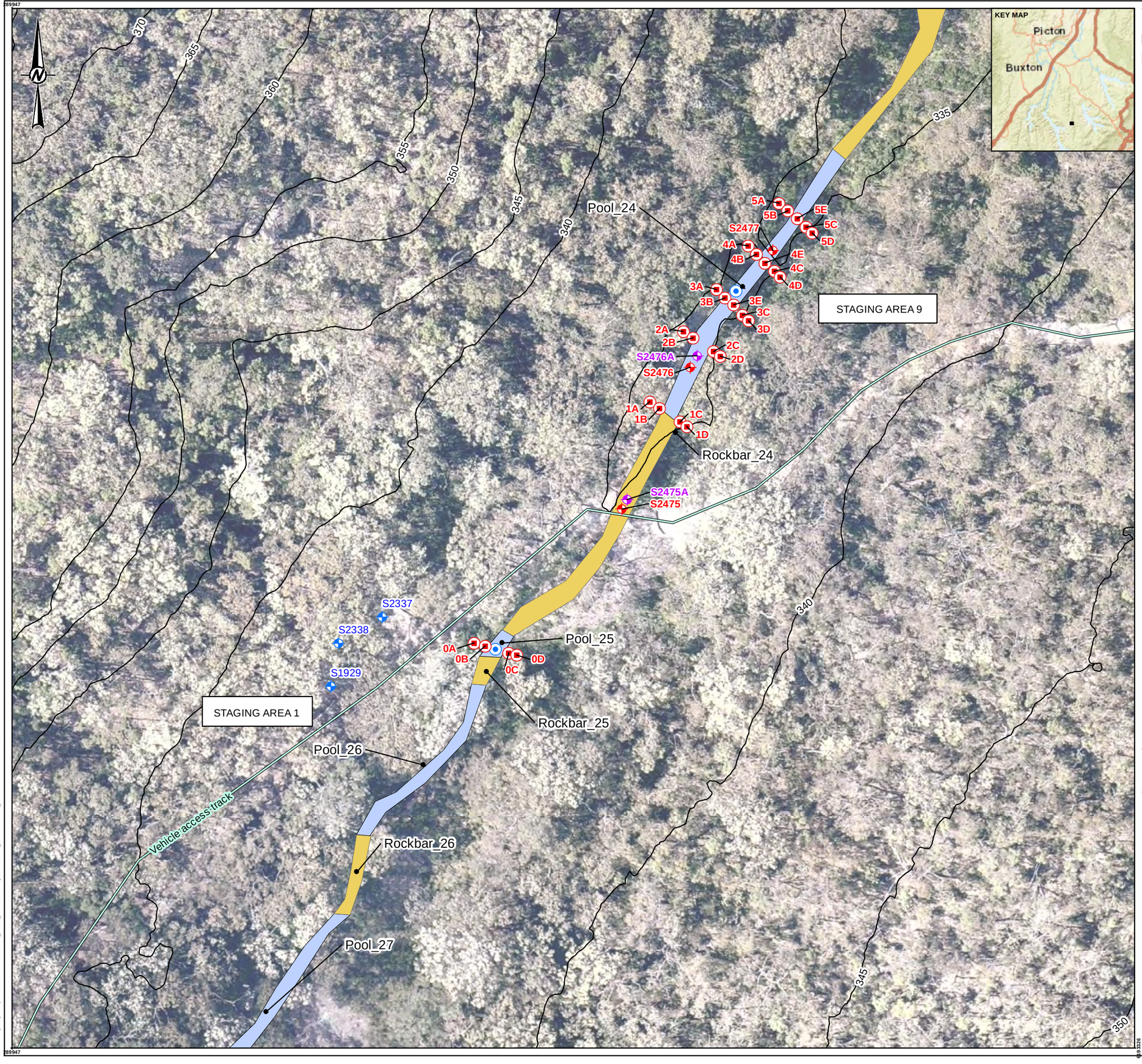

LEGEND

- Pool
- Rockbar
- Vehicle access

Proposed investigations (Indicative Locations)

- Ground characterisation borehole
- Post-trial verification borehole
- Hand auger locations

Existing investigations

- Existing borehole
- Watercourse monitoring site

0 30 60

1:750 METRES

NOTE(S)
1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 56

REFERENCE(S)
1. AERIAL PHOTO (C) NEARMAP
2. STREAM MAPPING PROVIDED BY SOUTH32 ILLAWARRA COAL.
3. DEM PROVIDED BY DEPARTMENT OF FINANCE, SERVICE AND INNOVATION

CLIENT
SOUTH32 ILLAWARRA METALURGICAL COAL

PROJECT
WC21 REHABILITATION REMEDIATION TRIAL

TITLE
INVESTIGATION LOCATION PLAN

CONSULTANT
wsp

DD-MM-YYYY	25-01-2023
DESIGNED	-
PREPARED	DN
REVIEWED	BN
APPROVED	ML

PROJECT NO.	CONTROL	REV.	FIGURE
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3 REHABILITATION CONSIDERATIONS

Implementation and timing of the Plan is contingent on:

- Undertaking the rehabilitation trial and monitoring period (as per Section 2.5.7).
- Revision of the Plan and/or approach, if required following the Trial, in consultation with key stakeholders (1 month).
- Receiving approval of the Plan from DPE (2 months).
- Development of the work plan for the targeted sites (as per Section 2.3.2) (2 weeks).
- Receiving approval from the landholder (WaterNSW) to enter the land to undertake the activity (1 month).
- Tendering and procurement of the investigation equipment and team (1 month).
- Establishment of access to the investigation sites (1 month).
- Implementation and analysis of site investigations (2 months).
- Revision of the Plan and/or approach, if required, in consultation with key stakeholders (1 month).
- Tendering and procurement of the rehabilitation equipment and team (2 months).
- Establishment of access to the rehabilitation sites (1 month).
- Ground characterisation and rehabilitation timing per site (3 - 4 weeks).
- Monitoring of rehabilitation at each pool (recommended minimum period of 12 months of monitoring to consider seasonal impacts).
- Analysis and reporting (3 - 6 months).

Access to the Catchment Area is restricted during wet weather and total fire bans and this has caused and may continue to cause significant delays to activities in the area. Grouting activities are an iterative process with periods of grouting followed by periods of testing. Significant flows within streams would reduce the ability to safety and effectively carry out the grouting activities. Significant dry periods without flow in the streams will reduce the potential to test integrity of grouting. In these circumstances testing will be via water brought to site, resulting in delays and reduced effectiveness of the testing.

3.1 ENVIRONMENTAL CONTROLS

Safety of the Rehabilitation Team, the community and personnel using the area is the primary consideration in all aspects of the rehabilitation. The rehabilitation is within the WaterNSW Catchment Area and all access is subject to strict access controls implemented by WaterNSW. All persons accessing the site are inducted, including all requirements for the safety of people and the site.

Rehabilitation activities ensure that the areas are stable without risk of increased erosion. Disturbance is minimised, and where disturbance is unavoidable, stabilisation works are implemented.

The aesthetics of the area is a consideration in the rehabilitation activities. The intended results of the remediation activities are to leave the area as natural as possible, and limit activities that will have permanent unnatural visual impacts in the landscape.

During rehabilitation activities, impacts on native flora and fauna is minimised wherever feasible. Revegetation of the disturbed area occurs naturally from adjacent native vegetation. Selection of access tracks, investigation sites and rehabilitation areas will limit, to the greatest possible extent, the need for primary vegetation clearing. Alternative options for access and investigation sites are discussed and agreed with WaterNSW.

Potential impacts on water quality as a result of the works include sedimentation and the release of materials brought onto site. These could include fuel, lubricants, grout and domestic waste. Safeguards are implemented to control these potential impacts.

Temporary sediment controls (e.g. sand bags, filter fabric) are installed where appropriate to intercept sediment movement that may occur during the works and for a period after completion. Erosion and sediment control works are installed generally in accordance with applicable erosion and sediment control principles and guidelines (e.g. the requirements of the NSW Blue Book "Managing Urban Stormwater – Soils and Construction").

These controls are maintained as required by removing any excessive build-up of sediment and repairing any failure of the structures e.g. due to storm activity. Sediment fencing and/or sandbags and coir logs are used for sediment controls.

Fuels and lubricants are kept in self-contained vessels or appropriately bunded. Volumes of material on site are limited to that used for day-to-day operations. Emergency spill response equipment is located appropriately at the work sites.

Consumables and wastes are removed from work sites daily. Fully maintained chemical toilets are available for work crews.

The rehabilitation area is remote from sensitive receivers and noise is not expected to be an issue. Operations are conducted during daylight hours.

The rehabilitation techniques proposed do not generate dust. Dust generated on access tracks and Fire Roads are controlled using standard road maintenance techniques and via reduced speed limits.

Specific monitoring strategies to reduce potential for release of grout material include:

- Implement an 'inject and confirm' approach. Once grouting is complete in one section, a small section is tested to confirm its effectiveness, before moving off- site. Each section is allowed to fill with water to see if the treatment has been effective. In this way a feedback loop is established;
- Water monitoring is undertaken to ensure quality is maintained; and
- Measure the injection pressure and volumes at the hole so that the potential for hydraulic fracturing (and therefore wastage of grout product) is minimised.

Once remediation activities are completed, all equipment and materials are removed. Routine monitoring would continue as described in the WIMMCP.

3.2 ENVIRONMENTAL OFFSETS

Subject to *Schedule 3, Condition 14* of the Development Consent:

> The Applicant must provide suitable offsets for loss of water quality or loss of water flows to WaterNSW storages, clearing and other ground disturbance caused by its mining operations and/or surface activities within the mining area, unless otherwise addressed by the conditions of this consent, to the satisfaction of the Secretary. These offsets must:
>
> (a) be submitted to the Secretary for approval by 30 April 2009;
>
> (b) be prepared in consultation with WaterNSW;
>
> (c) provide measures that result in a beneficial effect on water quality, water quantity, aquatic ecosystems and/or ecological integrity of WaterNSW's Special Areas or water catchments.

IMC transferred 33 ha of land adjacent to the Cataract River to WaterNSW to meet the above condition.

A biodiversity offset strategy has been developed in consultation with OEH and WaterNSW, which was approved by the Secretary of DPE 16 December 2016. The strategy proposes a process whereby suitable residual environmental offset can be provided where the actual impacts on watercourses exceed those predicted in the SMP.

3.3 RESEARCH

To assist in further understanding the impacts of subsidence and rehabilitation IMC is undertaking research. The research is improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences. The knowledge and techniques developed through implementing rehabilitation at DCC and WC21 will assist with this research.

3.4 PLAN ADMINISTRATION

The Plan will be administered in accordance with the requirements of the Dendrobium WIMMCP, Environmental Management System (EMS) and the Area 3B Approval Conditions.

3.4.1 INCIDENTS AND NON-CONFORMANCES

IMC will notify DPE and other relevant agencies of any incident associated with the rehabilitation as soon as practicable after IMC becomes aware of the incident. IMC will provide DPE and relevant agencies with a report on the incident within seven days of confirmation of any event.

IMC will:

- Provide a readily accessible contact point through a 24-hour toll-free Community Call Line (1800 102 210). The number is displayed at work sites.
- Respond to complaints in accordance with the IMC Community Complaints and Enquiry Procedure.
- Maintain good communication lines between the community and IMC. The rehabilitation activities are discussed with the Dendrobium Community Consultative Committee (DCCC).
- Keep a register of any complaints.

The requirement to comply with all approvals, plans and procedures is the responsibility of all personnel (staff and contractors) employed on or in association with Area3B operations, including the Plan.

Non-conformances, corrective actions and preventative actions are managed in accordance with the Reporting and Investigation Standard (IMCSTD0069) and Environmental Compliance/Conformance Assessment and Reporting Procedure (IMCP0186). This procedure details how IMC identifies non-conformances, nominates and manages corrective and preventive actions to ensure their effectiveness.

3.4.2 ROLES AND RESPONSIBILITIES

The overall responsibility for the implementation of the Plan resides with the Manager Approvals. Specific responsibilities include:

Vice President Operations and General Manager Mining Services

- Verify that the requisite personnel and equipment are provided to enable this Plan to be implemented effectively.

Manager Approvals

- Authorise the Plan and any amendments and to document any approved changes.
- Provide regular updates to IMC and other stakeholders.
- Prepare any report and maintain records.
- Organise and participate in review meetings.
- Respond to any queries or complaints.
- Address any identified non-conformances, assess improvement ideas and implement if considered appropriate.
- Arrange implementation of any agreed actions, responses or remedial measures.
- Ensure monitoring and analysis is conducted.

Project Manager

- Implement the Plan as described in this document.
- Instruct suitable person(s) in the required standards and be satisfied that these standards are maintained.
- Investigate any additional impacts that may result from the rehabilitation.
- Identify and report any non-conformances.
- Participate in assessment and review meetings.

Coordinator Environment

- Implement the monitoring, assessment and reporting requirements of the WIMMCP.
- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Identify and report any non-conformances.
- Participate in assessment and review meetings.

Survey Coordinator

- Collate survey data and present in an acceptable form for review at assessment meetings.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Manager Approvals and formally provide expert opinion as requested.

Person(s) Performing Rehabilitation and Inspections

- Conduct rehabilitation and inspections in an effective and safe manner.

3.4.3 RESOURCES REQUIRED

The Vice President Operations and General Manager Mining Services provides resources sufficient to implement the Plan.

Equipment is needed for the implementation of the Plan. Where this equipment is of a specialised nature, it is provided by the supplier of the relevant service. All equipment is appropriately maintained, calibrated and serviced as required in operations manuals.

The Project Manager shall ensure personnel and equipment are provided as required to allow the Plan to be implemented.

3.4.4 TRAINING

All staff and contractors working on IMC sites, including the Plan, are required to complete the IMC training program which includes:

- An initial site induction (including all relevant aspects of environment, health, safety and community).
- Safe Work Method Statements and Job Safety Analyses, Toolbox Talks and pre-shift communications.
- On-going job specific training and re-training (where required).

All training records are to be maintained such that they can be accessed by IMC staff.

It is the responsibility of the Project Manager to verify that all persons and organisations having responsibilities under this Plan are trained and understand their responsibilities.

The persons implementing the Plan will be under the supervision of the Project Manager and will be trained in the requirements of this Plan. The Project Manager shall be satisfied that the persons performing the works are capable of meeting and maintaining the standards required by this Plan.

The person(s) performing regular inspections shall be under the supervision of the Coordinator Environment and be trained in observation, measurement and reporting. The Coordinator Environment shall be satisfied that the person(s) performing the inspections are capable of meeting and maintaining this standard.

3.4.5 RECORD KEEPING AND CONTROL

Environmental Records are maintained in accordance with the IMC procedure *Records Management (IMCP0108)*. The IC *Document Control Procedure (IMCP0103)* outlines the method for control of defined 'business critical' documentation for all IMC operations, including the Plan.

Plan operations and implementation are reviewed on a monthly basis by the IMC Subsidence Review Committee. The Plan is reviewed against the overall success of the aims and objectives of the Plan on an annual basis. The Plan is updated to take account of the changing nature of impacts as well as any additional impacts from future mining.

If deficiencies in the Plan are identified it is modified, with agreement of relevant Government Agencies.

3.5 REFERENCES

BHP Billiton Illawarra Coal, 2006. Georges River Report: Assessment of Georges River Remediation Longwalls 5A1-4. November 2006.

Golder Associates Pty Ltd, 2020. WC21 Rehabilitation Investigations and Remediation Trial. Report to South32 IMC, May 2020.

Hebblewhite, 2020. Dendrobium Mine – Longwalls 14-18 Independent Review – Height of Depressurisation (Stage 3).

Hgeo, June 2017. Dendrobium Mine: Review of groundwater monitoring at WC21 piezometers S2335 and S2337. Report D17266.

Mackie, 2017. Height of fracturing at Dendrobium Mine – Peer review of PSM Report for DPE, Feb

2017.

Niche Environment and Heritage, 2021. WC21 Investigation and Trial Remediation Plan REF. Prepared for South32 Illawarra Metallurgical Coal. 20 April 2021

SCT, 2016. Factual Report on Observations Made in WC21 Boreholes in Area 3B at Dendrobium Mine. DEN4575. 22 November 2016.

4 APPENDIX A – SITES

Longwall 9, 10, 11, 12, 13 and 14 passed directly beneath DCC and WC21. As predicted, surface impacts including iron staining, rock fracturing; flow diversion and small rockfalls have been identified within the streams.

4.1 WC21

4.1.1 WC21_POOL 54

Baseline Description

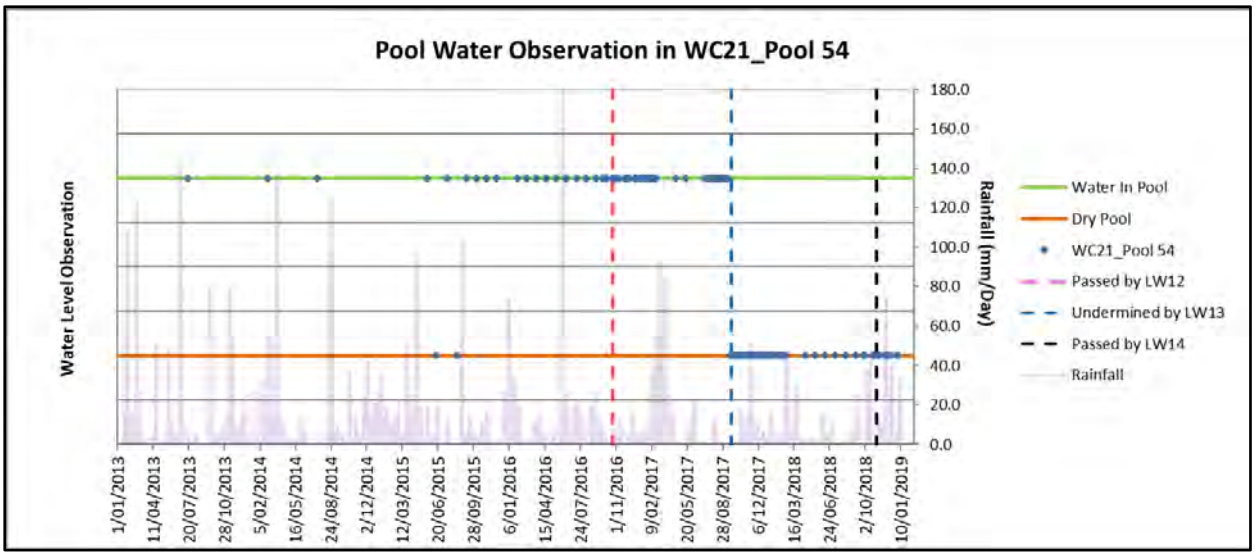
The base of Pool 24 is predominantly sediment-based, though the rock base is exposed towards the downstream extent of the feature. The pool is approximately 13 m long and 1.5 m wide.

Monitoring and Impacts to Feature

WC21_Pool 54 was passed by Longwall 12 on 22 October 2016 at an approximate distance of 297 m and was mined beneath by Longwall 13 on 22 September 2017. A reduction in pool water level was first observed on 20 September 2017. Rock fracturing (*DA3B_LW13_009*) at the downstream extent of Pool 54 was observed on 23 October 2017, although the fractures did not appear to extend to the base of the pool (**Graph 4-1**, **Photo 1, Photo 2**).

Recommendation

The pool is not recommended for remediation due to its relatively small size and largely sediment-covered base.



Graph 4-1: Pool water observations (presence/absence) for WC21_Pool 54.

Photo 1: WC21_Pool 54 looking upstream, taken 8 November 2016.

Photo 2: WC21_Pool 54 looking upstream, 20 November 2017.

4.1.2 WC21_POOL 53

Baseline Description

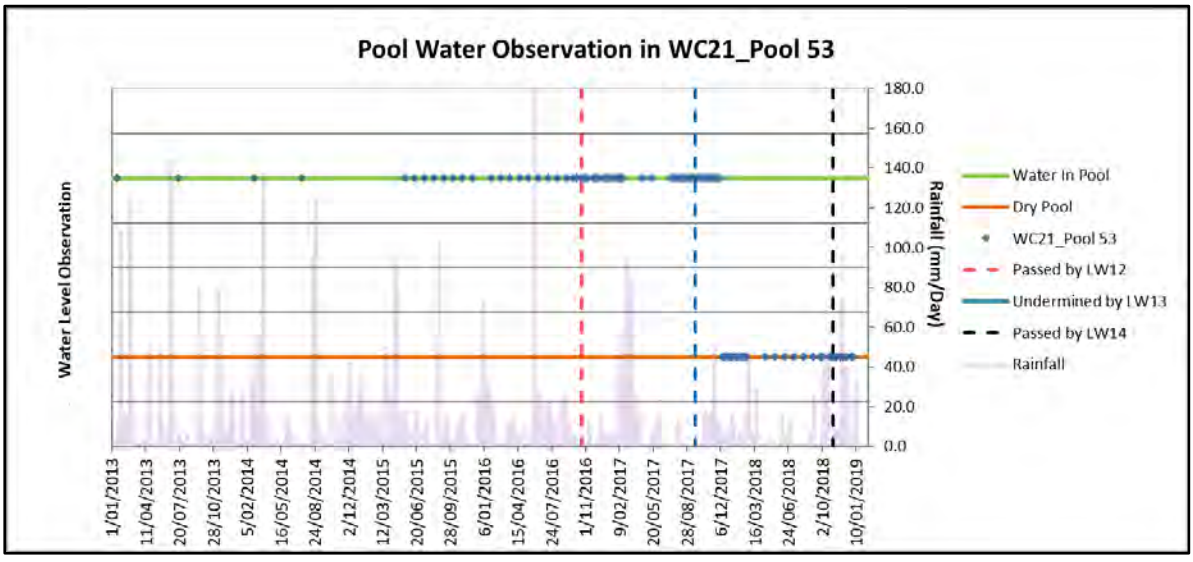
Rock-based pool with high sediment content, approximately 9 m long, 7 m wide and 1.2 m deep. The pool is located at the base of an approximately 3 m high step.

Monitoring and Impacts to Feature

Longwall 12 passed Pool 53 on 22 October 2017 at an approximate distance of 232 m; Longwall 13 mined beneath Pool 53 on 21 September 2017. Rock fracturing to the step at the upstream extent of Pool 53 was observed on 23 October 2017 (*DA3B_LW13_010*). Although there is no benchmark installed to measure water level, a visible decline in water level was observed at the site (**Graph 4-2**, **Photo 3 and Photo 4**). Water has not been observed in the pool since 18 November 2017.

Recommendation

Due to the potential for aquatic habitat in Pool 53, it is recommended that the site is targeted for remediation. Because there are no observable surface cracks in the base of the pool, it is recommended that the site be remediated by means of pattern grouting and potentially a grout curtain. Safety factors need to be considered due to the fractured steps on either side of the pool. This may affect what remediation options can be safety implemented at the site. Staging Area 7 would be used for works at the site.



Graph 4-2: Pool water observations (presence/absence) for WC21_Pool 53.

Photo 3: WC21_Pool 53 looking upstream, taken 8 November 2016.

Photo 4: WC21_Pool 53 looking upstream, taken 20 November 2017.

4.1.3 WC21_POOL 51

Baseline Description

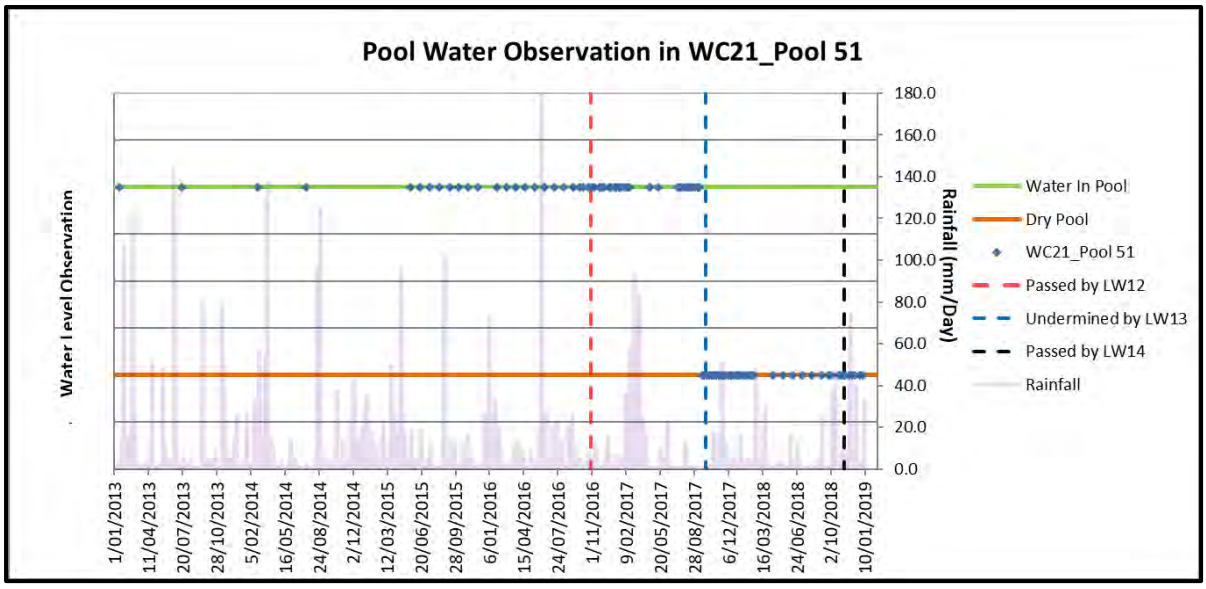
Sediment and rock-based pool, approximately 10 m long and 2 m wide.

Monitoring and Impacts to Feature

Longwall 12 passed Pool 51, at an approximate distance of 154 m, on 29 October 2016. Longwall 13 mined beneath Pool 51 on 24 September 2017. No surface impacts have been observed at the site; however, water has not been observed in the pool since 20 September 2017, which has been attributed to subsidence impacts from Longwall 13 (**Graph 4-3, Photo 5 and Photo 6**).

Recommendation

Given that no surface impacts have been observed at the site, remediation is not recommended.



Graph 4-3: Pool water observations (presence/absence) for WC21_Pool 51.

Photo 5: WC21_Pool 51 looking upstream, taken 8 November 2016.

Photo 6: WC21_Pool 51 looking upstream, taken 20 November 2017.

4.1.4 WC21_POOL 49

Baseline Description

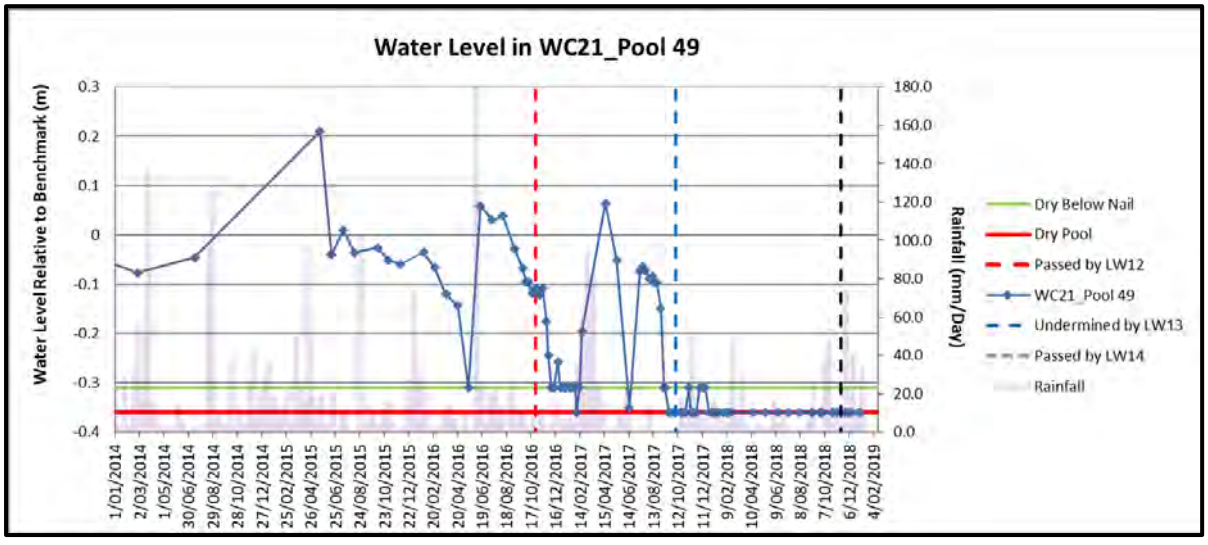
Rockbar-based pool, approximately 8 m long and 2 m wide.

Monitoring and Impacts to Feature

Longwall 12 passed Pool 49 at an approximate distance of 130 m, on 29 October 2016. No surface impacts have been observed at Pool 49. Observations show a downward trend in water level at Pool 49, which is coincident with the passing of Longwall 12. Pool 49 was mined beneath by Longwall 14 on 7 October 2017 and has since exhibited consistently dry pool levels (**Graph 4-4**, **Photo 7** and **Photo 8**).

Recommendation

Given that no surface impacts have been observed at the site, remediation is not recommended.



Graph 4-4: Water level measurements relative to installed benchmark at WC21_Pool 49.

Photo 7: WC21_Pool 49, looking downstream. Taken on 6 December 2016.

Photo 8: WC21_Pool 49, looking downstream. Taken on 15 June 2017.

4.1.5 WC21_POOL 48

Baseline Description

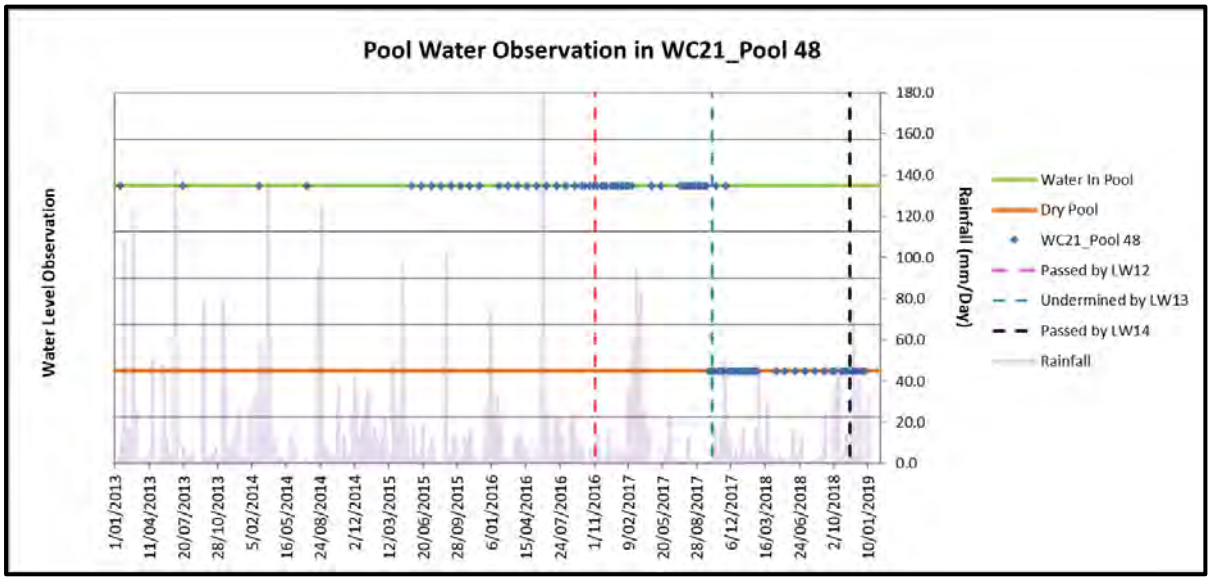
Rockbar-based pool, approximately 10 m long and 3.5 m wide.

Monitoring and Impacts to Feature

Longwall 12 passed Pool 48 at an approximate distance of 100 m, on 5 November 2016. Fracturing and associated uplift to the step upstream of Pool 48 was identified on 9 November 2016 (*DA3B_LW12_019*); no signs of flow diversion were identified (**Photo 9** and **Photo 10)**. Routine monitoring has been established for Pool 48, but there is no suitable feature to install a benchmark to monitor surface water level; instead, categorical observations of whether water is present, or not present on the feature. Pool 48 was mined beneath by Longwall 13 on 11 October 2017 and has since exhibited consistently dry conditions (**Graph 4-5**).

Recommendation

Rehabilitation to the impacted step is not recommended at this stage; however, Pool 48 is recommended for rehabilitation given the relatively high water-holding capacity of the pool and potential for aquatic habitat (**Photo 11** and **Photo 12)**. Staging Area 8 would be used for works at the site.



Graph 4-5: Categorical observation of surface water in WC21_Pool 48.

Photo 9: Impact DA3B_LW12_019, upstream of Pool 48, looking upstream. Taken 22 December 2016.

Photo 10: Impact DA3B_LW12_019, upstream of Pool 48, looking upstream. Taken 22 December 2016.

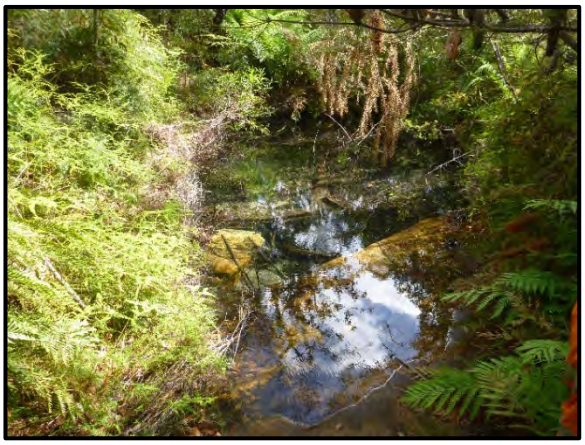


Photo 11: WC21_Pool 48, looking downstream. Taken on 29 November 2016.

Photo 12: WC21_Pool 48, looking downstream. Taken on 18 April 2017.

4.1.6 WC21_POOL 47

Baseline Description

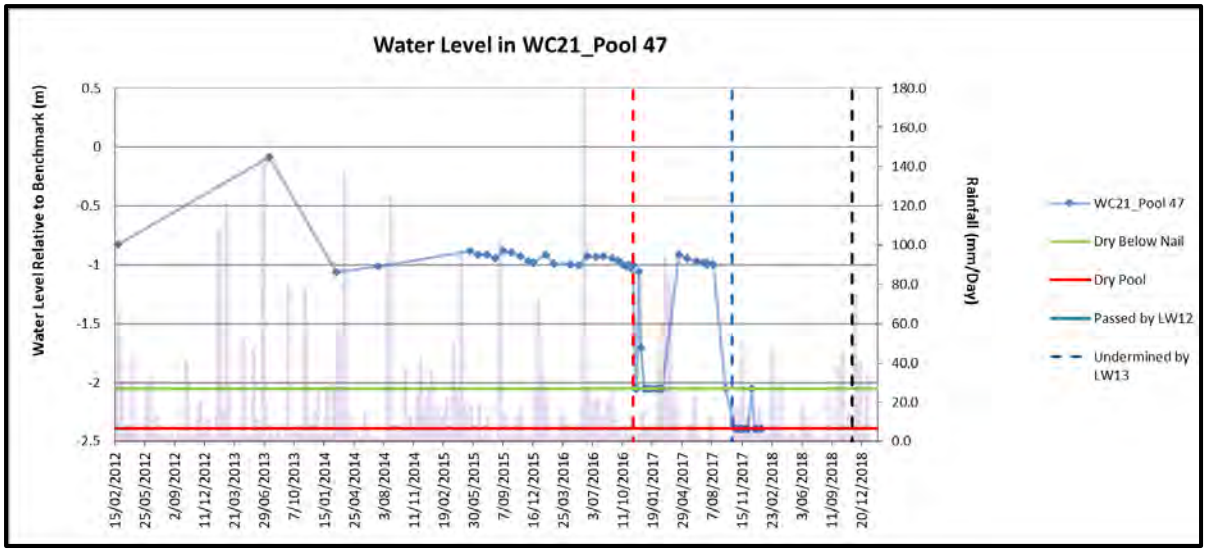
Rockbar-based pool, approximately 8 m long and 2.5 m wide.

Monitoring and Impacts to Feature

Longwall 12 passed Pool 47 at an approximate distance of 80 m, on 5 November 2016. A visible drop in water level was observed following the passing of Longwall 12. However, whilst the water level was dry beneath the benchmark, a considerable amount of water remained within the pool. This was due to the low sensitivity of the installed benchmark past a certain water level; i.e. changes in water level below a certain level may produce a 'dry below benchmark' measurement, despite a relatively high water level in the pool. Pool 47 was mined beneath by Longwall 13 on 12 October 2017 and has since exhibited consistently dry pool conditions (**Graph 4-6**). Rock fracturing to the base of the pool was observed on 23 October 2017 (*DA3B_LW13_011*).

Recommendation

Pool 47 is recommended for rehabilitation given the relatively high water-holding capacity of the pool and potential for aquatic habitat. Staging Area 6 would be used for works at the site.



Graph 4-6: Water level measurements relative to installed benchmark at WC21_Pool 47.

Photo 13: WC21_Pool 47, looking downstream. Taken on 12 December 2016.

Photo 14: WC21_Pool 47, looking downstream. Taken on 15 June 2017.

4.1.7 WC21_POOL 46

Baseline Description

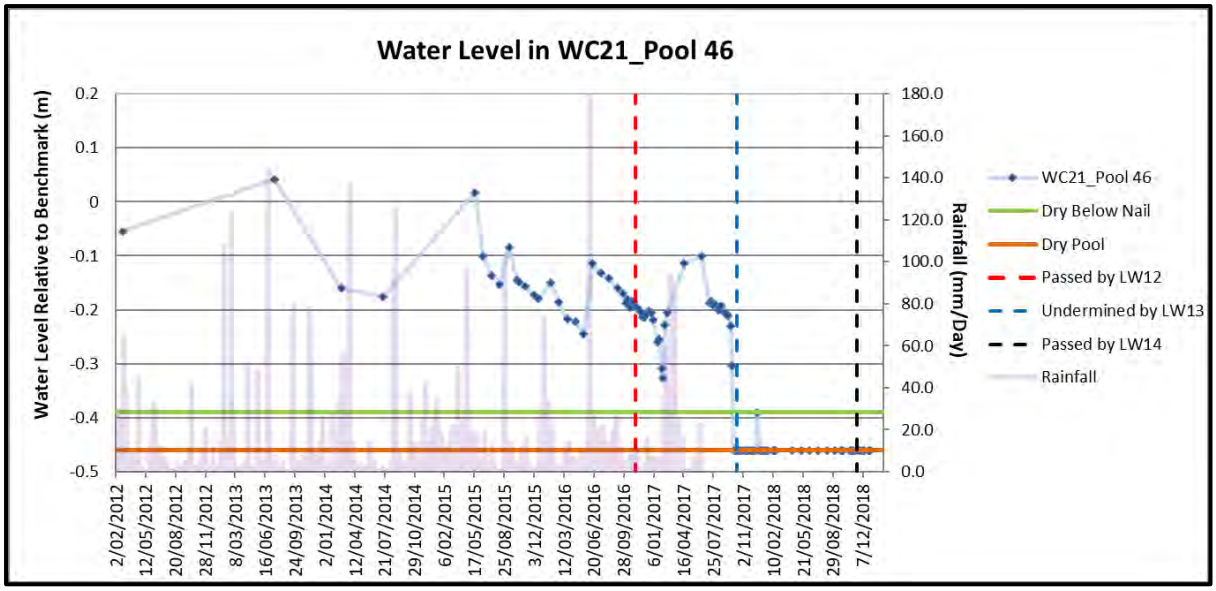
Rockbar-based pool with cobble and boulder deposits, approximately 15 m long and 2 m wide.

Monitoring and Impacts to Feature

Longwall 12 passed Pool 46 at an approximate distance of 70 m, on 5 November 2016. Pool 46 was mined beneath by Longwall 13 on 13 October 2017 and has since exhibited consistently dry pool conditions (**Graph 4-7**).

Recommendation

Pool 46 is recommended for rehabilitation given the relatively high water-holding capacity of the pool and potential for aquatic habitat (**Photo 16**). Staging Area 6 would be used for works at the site.



Graph 4-7: Water level measurements relative to installed benchmark at WC21_Pool 46.

Photo 15: WC21_Pool 46, looking downstream. Taken on 18 May 2016.

Photo 16: WC21_Pool 46, looking downstream. Taken on 15 June 2017

4.1.8 WC21_POOL 45 TO WC21_POOL 43

Baseline Description

A section of shallow, narrow, rockbar-based pools and exposed rockbars with surface flow. The banks are generally well-vegetated.

Monitoring and Impacts to Features

This section of the tributary overlies the chain pillar between Longwalls 12 and 13; Longwall 12 passed this area on 11 November 2016. The area was mined beneath by Longwall 13 on 15 October 2017. One surface impact was observed (*DA3B_LW13_017*), which consisted of fracturing to the base of Pool 45 and associated flow diversion. In general, this section of the tributary has exhibited a reduction in water.

Recommendation

Pool 45 is recommended for rehabilitation at this stage. Staging Area 6 would be used for works at the site.

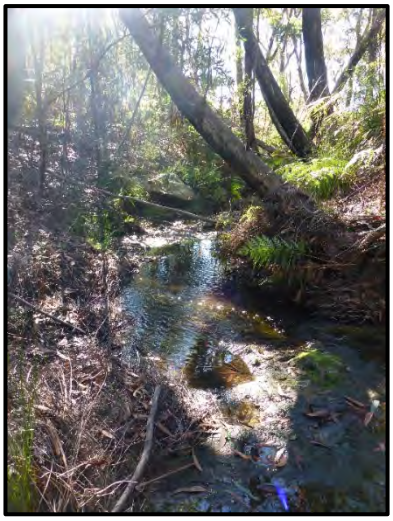


Photo 17: WC21_Rockbar 43, looking downstream. Taken on 11 July 2017.

Photo 18: WC21_Pool 43, looking downstream. Taken 1 July 2017

Photo 19: WC21_Pool 45, looking upstream. Taken on 11 July 2017.

Photo 20: WC21_Pool 45, looking downstream. Taken 11 July 2017.

4.1.9 WC21_POOL 42

Baseline Description

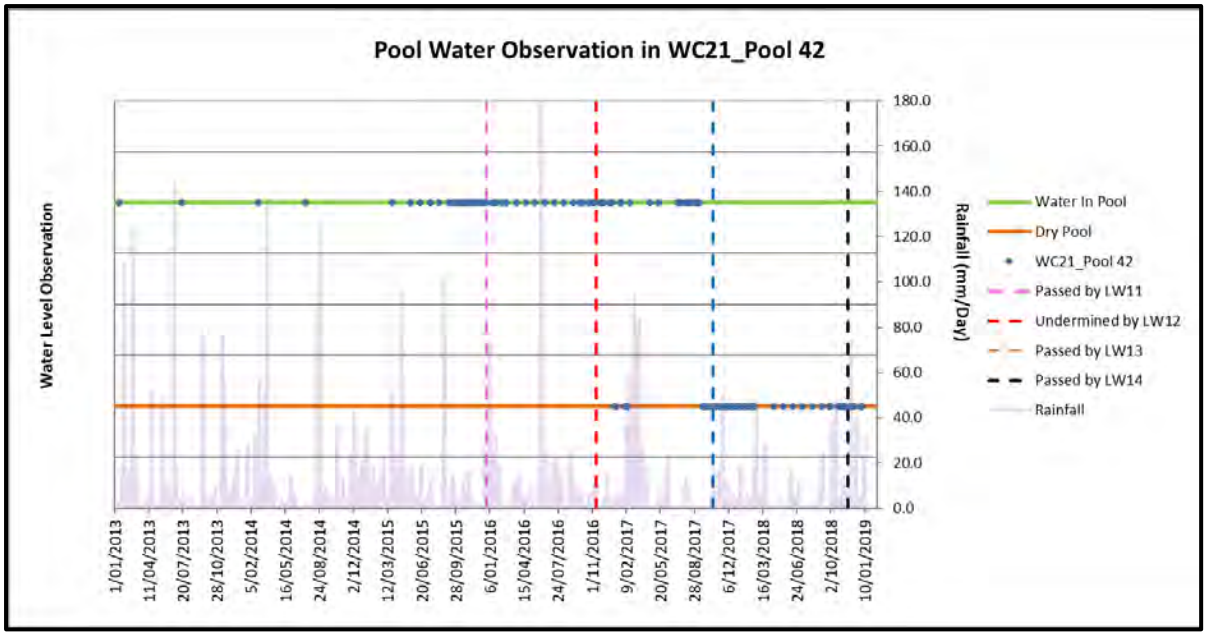
Sediment-based pool, approximately 20 m long and 3 m wide.

Monitoring and Impacts to Features

Pool 42 was undermined by Longwall 12 on 12 November 2016. Pool 42 is monitored regularly but due to a lack of suitable features, a benchmark was not installed to measure water level. No surface impacts have been observed at the site; however, since being undermined, a considerable drop in water level has been observed (**Graph 4-8**). Additionally, since Longwall 13 mined beneath the upper reaches of WC21, there has been an observable decrease in water at Pool 42 (**Graph 4-1**).

Recommendation

Given the morphology of Pool 42, it is not recommended that this feature be considered a priority target for remediation.



Graph 4-8: Categorical observation of surface water in WC21_Pool 42.

Photo 21: WC21_Pool 42 looking downstream. Taken on 22 December 2016.

Photo 22: WC21_Pool 42 looking downstream. Taken on 15 June 2017.

4.1.10 WC21_POOL 41

Baseline Description

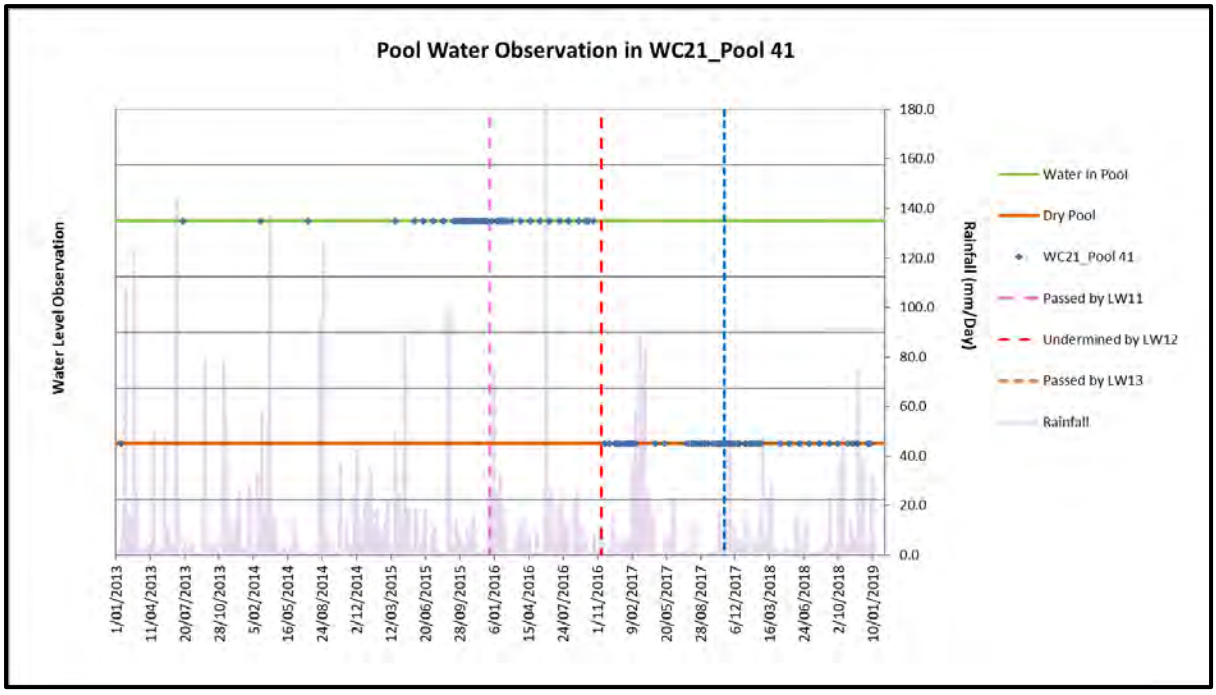
Sediment based pool, approximately 20 m long and 3 m wide.

Monitoring and Impacts to Features

Routine monitoring has been established for Pool 41, but there is no suitable feature to install a benchmark to monitor surface water level; instead, categorical observations of whether water is present, or not present on the feature. Pool 41 was undermined by Longwall 12 on 12 November 2016. No surface impacts have been observed at Pool 41; however, a considerable reduction in pool water level has been observed (**Graph 4-9**, **Photo 23 and Photo 24**).

Recommendations

Given the morphology of Pool 41, remediation is not recommended at the site.



Graph 4-9: Categorical observation of surface water in WC21_Pool 41.

Photo 23: WC21_Pool 41, looking downstream. Taken on 20 April 2016.

Photo 24: WC21_Pool 41, looking downstream. Taken on 12 December 2016.

4.1.11 WC21_POOL 40 TO WC21_ROCKBAR 38

Baseline Description

This section of the tributary is characterised mainly by narrow sediment-based channels and pools.

Monitoring and Impacts to Features

No routine monitoring of this section of the tributary has been established. The area was undermined by Longwall 12 on 19 November 2016. No surface impacts have been identified on this section of the tributary. However, a considerable decrease in surface flow has been observed since undermining by Longwall 12; these conditions have persisted and were recorded during recent inspections (**Photo 25** and **Photo 26)**.

Recommendation

Given the morphology of these features, it is not recommended that they are targeted for remediation.

Photo 25: WC21_Pool 40, looking downstream. Taken on 11 July 2017.

Photo 26: WC21_Pool 39, looking downstream. Taken on 11 July 2017.

4.1.12 WC21_POOL 38

Baseline description

Pool 38 is 6 m long, 3 m wide and up to 0.3 m deep.

Monitoring and Impacts to feature

WC21_Pool 38 was passed by Longwall 11 on 2 January 2016 and undermined by Longwall 12 on 19 November 2016. No surface impacts have been observed at WC21_Pool 38. However, there has been an appreciable decrease in water level since the pool was undermined by Longwall 12 (**Graph 4-10, Photo 27** and **Photo 28**).

Recommendation

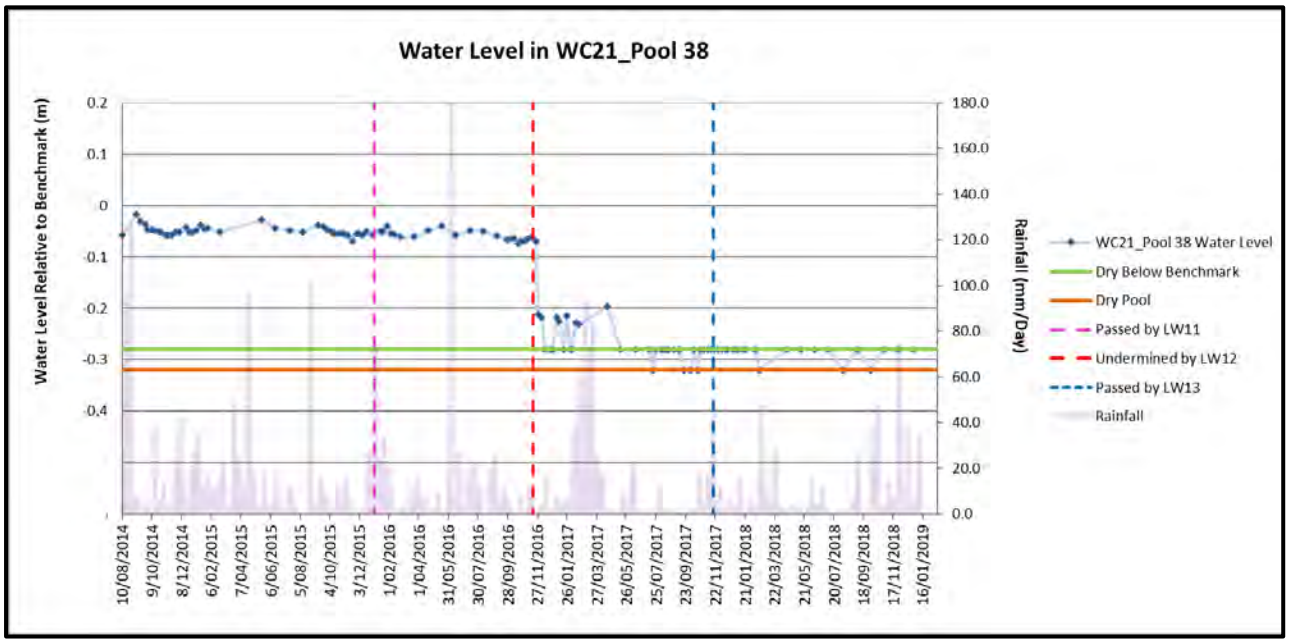
No remediation works are recommended at the site due to the morphology of the pool.

Photo 27: WC21_Pool 38, looking upstream. Taken on 23 March 2016.

Photo 28: WC21_Pool 38, looking downstream. Taken on 23 March 2016.

Photo 29: WC21_Pool 38, looking upstream. Taken on 5 January 2017.

Photo 30: WC21_Pool 38, looking downstream. Taken on 5 January 2017.



Graph 4-10: Water level measurements relative to installed benchmark at WC21_Pool 38.

4.1.13 WC21_POOL 37

Baseline description

Pool is 8 m long, 4 m wide and 1 m deep.

Monitoring and Impacts to feature

WC21_Pool 37 was undermined by the southern edge of Longwall 11 on 5 January 2016. No surface impacts have been observed at the pool. Whilst no quantitative water level monitoring could be established at the site, a categorical 'Water Level Observation' has been recorded during monitoring (**Graph 4-11**). These observations show a period (10 January 2017 – 13 February 2017) where the pool has no observable surface water (**Graph 4-11**), which follows when the pool was undermined by Longwall 11.

Recommendation

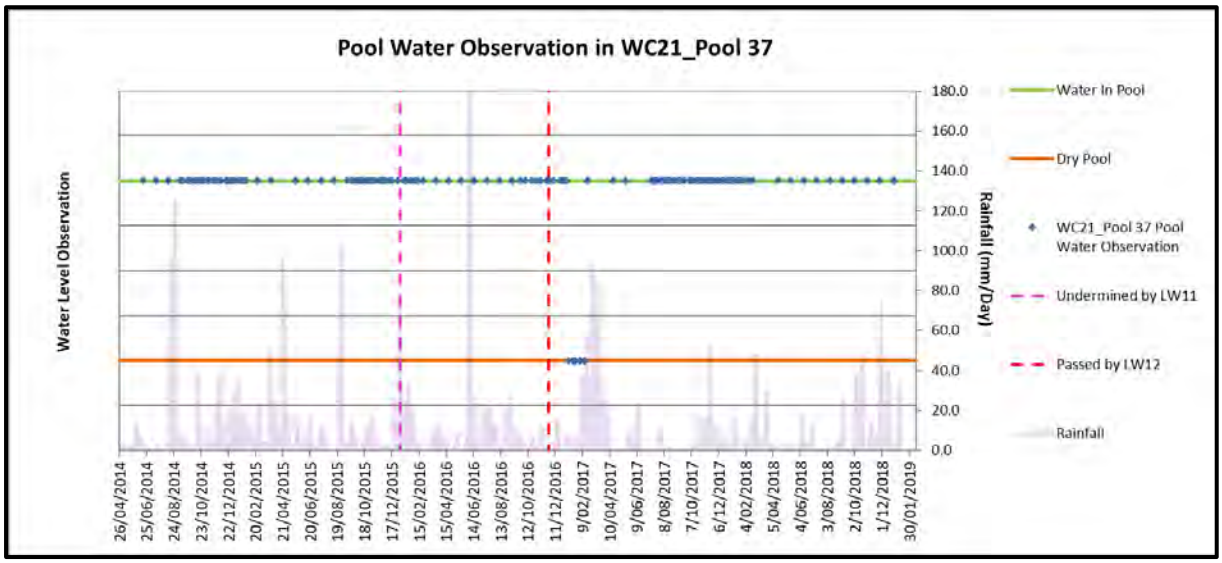
The sediment base and lack of visible fracturing at Pool 37 makes targeted remediation difficult at this site; no remediation is proposed at this stage.

Photo 31: WC21_Pool 37, looking upstream. Taken on 23 March 2016.

Photo 32: WC21_Pool 37, looking downstream. Taken on 23 March 2016.

Photo 33: WC21_Pool 37, looking upstream. Taken on 10 January 2017.

Photo 34: WC21_Pool 37, looking upstream. Taken on 15 June 2017.



Graph 4-11: Water level observations at WC21_Pool 37. These observations are categorical: either 'water in pool' or 'dry pool'.

4.1.14 WC21_POOL 36

Baseline description

Pool is 40 m long, up to 5 m wide and 1.5 m deep with a considerable amount of sand deposition.

Monitoring and Impacts to feature

No surface impacts have been observed at Pool 36; however, an absence in surface flow has been identified since the site was undermined, on 6 January 2016, by Longwall 11 (**Graph 4-12**). Whilst no quantitative water level monitoring could be established at the site, a categorical 'Water Level Observation' has been recorded during monitoring. The nature of flow transitions from surface to subsurface just upstream from Pool 36 (**Graph 4-12**).

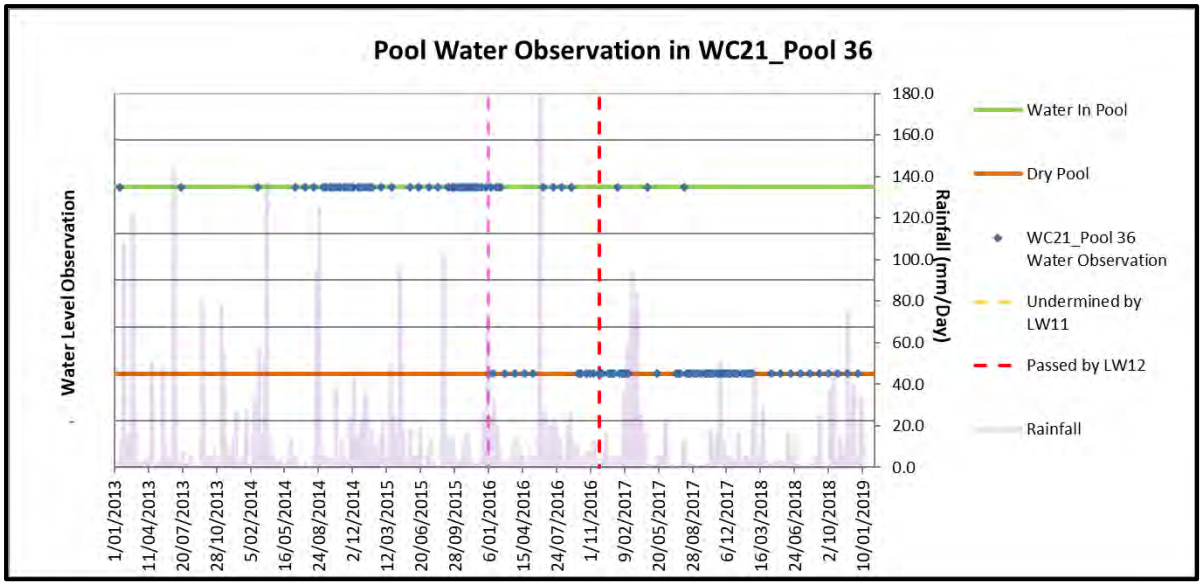
Recommendation

The sediment base and lack of visible fracturing at Pool 36 makes targeted remediation difficult at this site; no remediation is proposed at this stage.

Photo 35: WC21_Pool 36, looking upstream. Taken on 23 March 2016.

Photo 36: WC21_Pool 36, looking downstream. Taken on 23 March 2016.

Photo 37: Flow becomes subsurface, upstream from WC21_Pool 36 looking across stream. Taken on 20 April 2016.



Graph 4-12: Water level observations at WC21_Pool 36. These observations are categorical: either 'water in pool' or 'dry pool'.

4.1.15 WC21_POOL 35 TO POOL 31

Baseline description

This section of the tributary consists of predominantly sediment-based channels intersected by shallow pools. Thick leaf litter and organic debris overlies sediment in places. Banks are heavily vegetated, obscuring access and observation in sections.

Monitoring and Impacts to feature

This section of the tributary was undermined by Longwall 11 on 2 January 2016. While no routine monitoring sites have been established in this section of the tributary, a reduction in surface flow is evident, continuing from Pool 36. Recent inspections of WC21 show that this section of the tributary remains predominately dry, with surface water only observed at the rockbar based, Pool 31.

Recommendation

No fracturing or active flow diversion is evident in this section of the tributary, making any targeted remediation difficult. No remediation to this section of tributary is proposed at this stage.

Photo 38: WC21_Pool 35, looking downstream. Taken on 11 July 2017.

Photo 39: WC21_Pool 34, looking upstream. Taken on 11 July 2017.

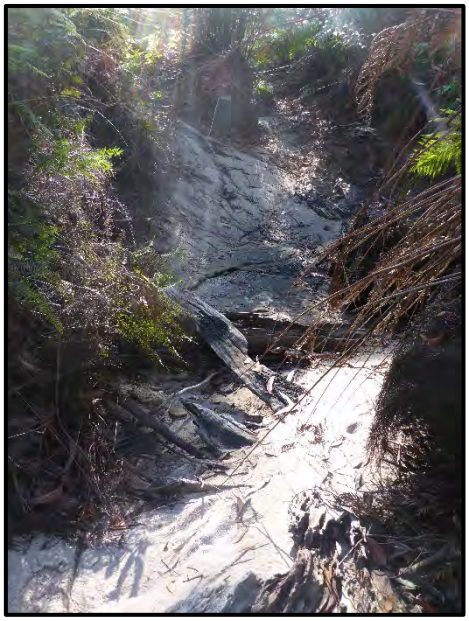


Photo 40: WC21_Pool 33, looking upstream. Taken on 11 July 2017.

Photo 41: WC21_Pool 32, looking downstream. Taken on 11 July 2017.

Photo 42: WC21_Pool 31, looking downstream. Taken on 11 July 2017.

4.1.16 WC21_POOL 30

Baseline description

Pool is 8 m long, 3 m wide and 0.3 m deep.

Monitoring and Impacts to feature

WC21_Pool 30 was undermined by Longwall 11 on 28 December 2015; a zone of fracturing (*Impact LW11_008*) was observed upstream from the site (**Photo 43**, **Photo 44** and **Photo 45**). Since being undermined, an absence of surface water at WC21_Pool 30 has been observed (**Graph 4-13**).

Recommendation

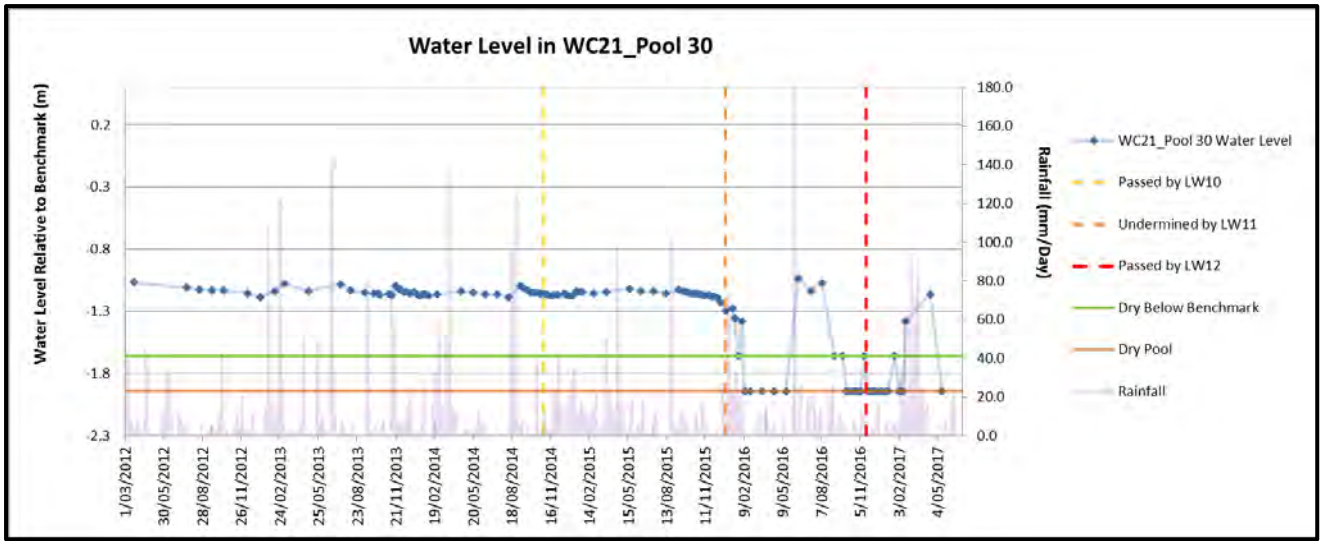
Pattern grouting is proposed at this site, in conjunction with works at downstream Pool 29. Staging Area 5 will be used for works at the site.

Photo 43: Impact LW11_008- Rock fracturing to upstream from WC21_Pool 30, looking upstream. Taken on 14 January 2016.

Photo 44: Impact LW11_008- Rock fracturing to upstream from WC21_Pool 30. Taken on 14 January 2016.

Photo 45: WC21_Pool 30, looking downstream. Taken on 13 February 2017.

Photo 46: WC21_Pool 30, looking upstream. Taken on 13 February 2017.



Graph 4-13: Water level measurements relative to installed benchmark at WC21_Pool 30.

4.1.17 WC21_POOL 29

Baseline description

Feature is 15 m long, 3 m wide with pooling of up to 0.4 m deep.

Monitoring and Impacts to features

WC21_Pool 29 was undermined by the northern edge of Longwall 11 on 2 January 2016. No routine water level monitoring is installed at this pool. No surface impacts have been identified at the site, however, there is an absence of surface flow from upstream (**Photo 47**).

Recommendation

Pattern grouting is proposed at this site, in conjunction with works at Pool 30, directly upstream. Coffer dams and diversion piping will be used to divert any surface flow during works if required. Staging Area 5 will be used for works at the site.

Photo 47: WC21_Pool 29, looking downstream. Taken on 17 May 2016.

4.1.18 WC21_POOL 28

Baseline description

Pool is 30 m long, 6m wide and 1 m deep. Subsurface flow was identified at the site during baseline mapping.

Monitoring and Impacts to features

WC21_Pool 28 overlies the chain pillar between Longwall 10 and Longwall 11. No surface impacts have been identified at the site to date. A reduction in pool water level has been observed, progressively, following the passing of Longwalls 10, 11 and 12 (**Graph 4-14, Photo 48, Photo 49, Photo 50 and Photo 51**).

Recommendation

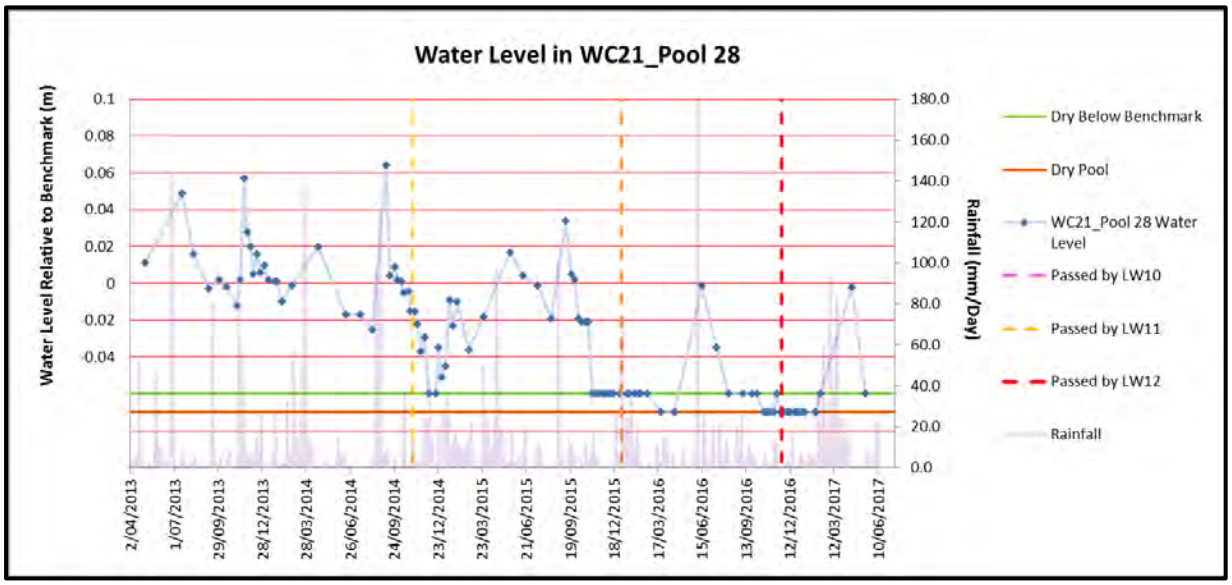
The sediment banks and pool base, and pre-mining subsurface flow conditions make any targeted remediation difficult at the site. The downstream end of the pool continues to hold water. No works are proposed at this site.

Photo 48: WC21_Pool 28, looking upstream. Taken on 23 March 2016.

Photo 49: WC21_Pool 28, looking downstream. Taken on 23 March 2016.

Photo 50: WC21_Pool 28, looking downstream. Taken 25 January 2017.

Photo 51: WC21_Pool 28, looking downstream. Taken 15 June 2017.



Graph 4-14: Water level measurements relative to installed benchmark at WC21_Pool 28.

4.1.19 WC21_ROCKBAR 27

Baseline description

Feature is 40 m long, 3 m wide with pooling of up to 0.3 m deep.

Monitoring and Impacts to features

Rockbar 27 overlies the chain pillar between Longwall 10 and Longwall 11. Rock fracturing was identified on Rockbar 27 (*Impact LW11_010*) (**Photo 52** and **Photo 53**). A reduction in water level, below baseline, was observed following the passing of Longwall 11 on 1 November 2014 (**Graph 4-14**).

Recommendation

Pattern grouting is proposed at this site, with focus on incised jointing on the western side of pool. Access to the site will be from Staging Area 5.

Photo 52: Impact LW11_010- Fracturing to Rockbar 27. Taken on 11 February 2016.

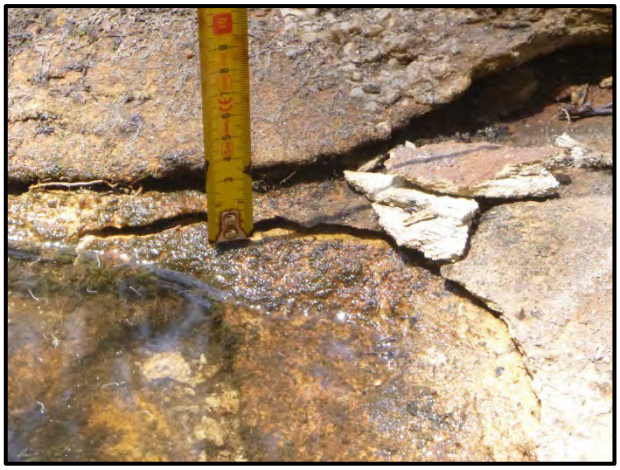


Photo 53: Impact LW11_010- Fracturing to Rockbar 27. Taken on 11 February 2016.

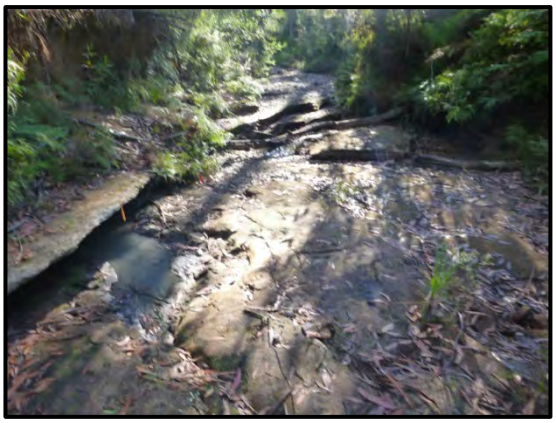
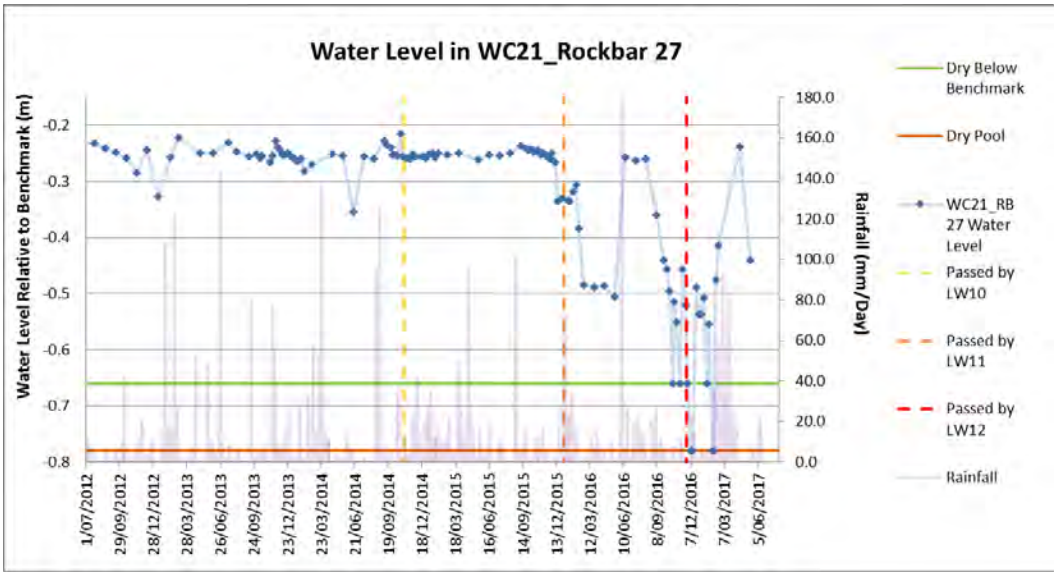


Photo 54: WC21_Rockbar 27, looking downstream. Taken on 23 March 2016.

Photo 55: WC21_Rockbar 27, looking upstream.Taken on 15 June 2017.



Graph 4-15: Water level measurements relative to installed benchmark at WC21_Rockbar 27.

4.1.20 WC21_POOL 27

Baseline description

Pool is 40 m long, 1 m wide and 0.5 m deep.

Monitoring and Impacts to features

WC21_Pool 27 overlies the southern edge of Longwall 10. No routine water level monitoring is installed at this pool. No surface impacts have been identified at the site. However, a reduction in surface flow has been observed following mining (**Photo 56** and **Photo 57**).

Recommendation

No remediation is proposed at the site at this stage.

Photo 56: WC21_Pool 27, looking upstream. Taken on 17 May 2016.

Photo 57: WC21_Pool 27, looking upstream. Taken on 17 May 2016.

4.1.21 WC21_ROCKBAR 26

Baseline description

Rockbar is 20 m long and 2 m wide with pooling along the rockbar.

Monitoring and Impacts to features

Rockbar 26 was undermined by Longwall 10 on 6 November 2014. Fracturing was identified to the downstream end of Rockbar 26 (*Impact LW10_007*); some localised flow diversion was observed during low flow conditions. A reduction in pool water level has been recorded following undermining by Longwall 10, and the upstream passing of Longwall 11 (**Photo 58**, **Photo 59**, **Photo 60, Photo 61** and **Graph 4-16**).

Recommendation

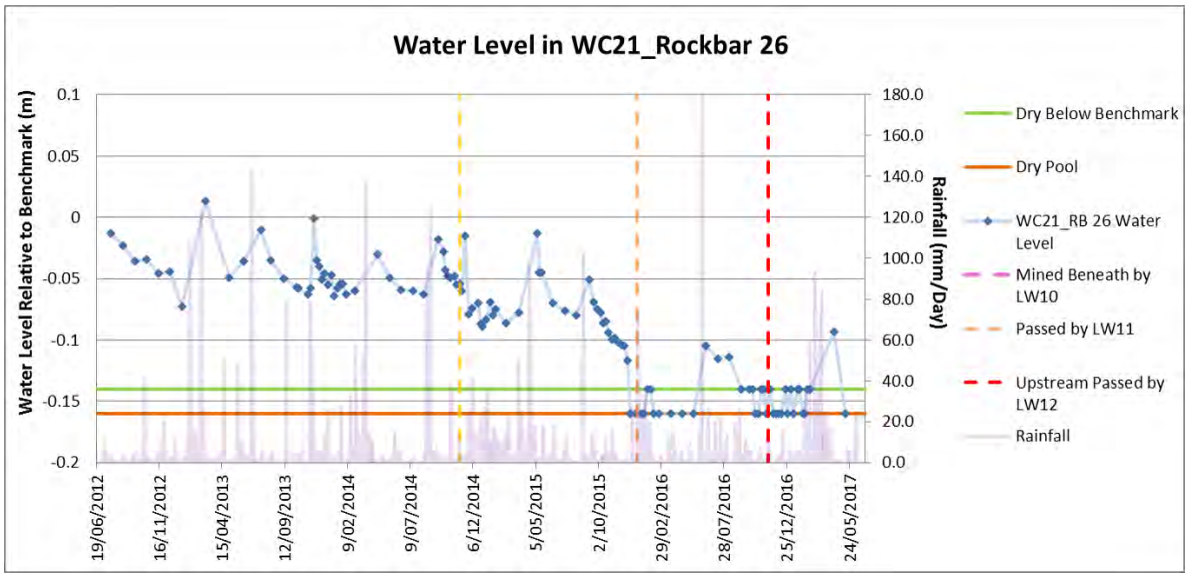
The morphology of the feature makes targeted remediation difficult at this site. No remediation is proposed at this stage.

Photo 58: WC21_Rockbar 26, looking upstream. Taken on 23 March 2016.

Photo 59: WC21_Rockbar 26, looking downstream. Taken on 23 March 2016.

Photo 60: Impact LW10_007- Fracturing to downstream end of Rockbar 26. Taken on 18 November 2014.

Photo 61: WC21_Rockbar 26, looking downstream. Taken on 15 May 2017



Graph 4-16: Water level measurements relative to installed benchmark at WC21_Rockbar 26.

4.1.22 WC21_POOL 26

Baseline description

Pool is 20 m long, 2 m wide and 0.3 m deep.

Monitoring and Impacts to features

Pool 26 was undermined by Longwall 10 on 8 November 2014 No routine water level monitoring is installed at this pool. Dilation of a joint on the base of Pool 26 (*Impact LW10_010*) was identified (**Photo 62**); no active flow diversion has been observed to date. A visible decrease in surface water at the pool has been observed since being undermined by Longwall 10 (**Photo 63** and **Photo 64**).

Recommendation

At this stage no remediation is proposed at the site.

Photo 62: Impact LW10_010- dilation of joint on base of pool, looking downstream. Taken on 25 November 2014.

Photo 63: WC21_Pool 26, looking upstream. Taken on 17 May 2016.

Photo 64: WC21_Pool 26, looking downstream. Taken on 17 May 2016.

4.1.23 WC21_RB 24 AND WC21_POOL 25

Baseline description

The rockbar is approximately 60m long with a total vertical drop of approximately 2 m. Pool 25, which is at the upstream extent of Rockbar 24, is approximately 6 m long, 4m wide with pooling up to 0.3 m deep.

Monitoring and Impacts to feature

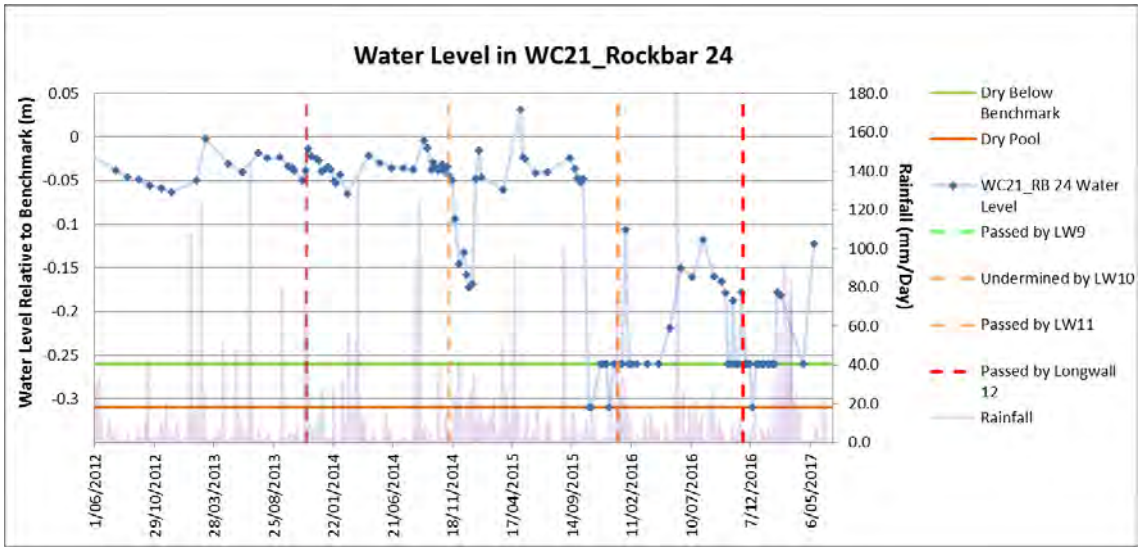
Rockbar 24 was undermined by Longwall 10 on 8 November. Multiple fractures and uplift have been observed at Rockbar 24 (*Impact LW10_011*); flow diversion is evident with a general decline in surface water over both the rockbar and pool (**Graph 4-17**). Additionally, rock fractures to the downstream section of Rockbar 24 were observed (*Impact LW10_020*).

Recommendation

Flow diversion has been observed through fracturing and an existing joint which runs perpendicular to the rockbar. The site is proposed as a remediation trial site. Pending results of the investigation at the

site, injection grouting is recommended to target fracturing in the joint. Staging Area 1 will be used for works at the site.

Staging Area 1 is proposed as the site for the investigation hole. This location is already cleared and would require minimal secondary clearing.



Graph 4-17: Water level measurements relative to installed benchmark at WC21_Rockbar 24.

4.1.24 WC21_POOL 24

Baseline description

The pool is 50 m long, up to 5 m wide and 1 m deep. The upstream section contains the widest and deepest section of the pool. Sediment covers much of the base in this upstream section. The downstream section of the pool is narrow and channel-like in appearance before merging into downstream Rockbar 23.

Monitoring and Impacts to feature

Pool 24 was undermined by Longwall 10 on 10 November 2014. No routine pool water level monitoring is installed at this site. Rock fracturing and uplift was identified in the base of Pool 24 towards the downstream section of the pool (*Impact LW10_008*) (**Photo 70**). There is an absence of surface water during most inspections. Subsurface inflow to the sediment base of the upstream section of the pool is evident. The pool continues to hold water for periods following rainfall (**Photo 72**).

Recommendation

Pool 24 is proposed as a rehabilitation trial site. The site is close to an existing vehicle access track; Staging Area 1 is proposed for storage and mixing of grouts. Overlying sediment needs to be managed during the drilling and grouting process.

Photo 65: Impact LW10_011- fracturing with dislodged fragment on Rockbar 24, looking downstream. Taken 25 November 2014.

Photo 66: Impact LW10_011- fracturing in joint and decline in surface flow, looking upstream. Taken on 25 November 2014.

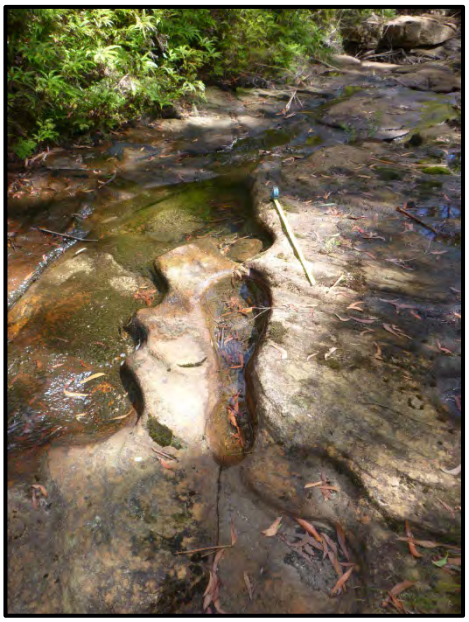


Photo 67: Impact LW10_020- fracturing to downstream end of Rockbar 24, looking downstream. Taken on 30 January 2015.

Photo 68: WC21_Rockbar 24, looking upstream. Taken on 17 June 2017.

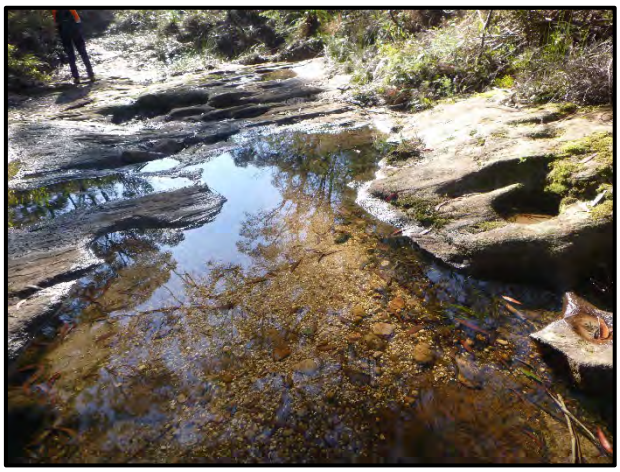


Photo 69: WC21_Rockbar 24, looking upstream. Taken on 17June 2017.

Photo 70: Impact LW10_008- fracturing and decline in surface flow, looking upstream. Taken on 25 November 2014.

Photo 71: Upstream end of WC21_Pool 24, without water in pool, looking downstream. Taken on 15 October 2015.

Photo 72: Upstream end of WC21_Pool 24, with water in pool, looking downstream. Note: this is often dry. Taken on 10 September 2015.

Photo 73: Downstream section of WC21_Pool 24, looking upstream. Taken on 10 September 2015.

Photo 74: Downstream section of WC21_Pool 24, looking downstream. Taken on 10 September 2015.

4.1.25 WC21_ROCKBAR 23

Baseline description

The rockbar has shallow pooling and multiple flow paths and is approximately 50 m long and 9 m at its widest point.

Monitoring and Impacts to feature

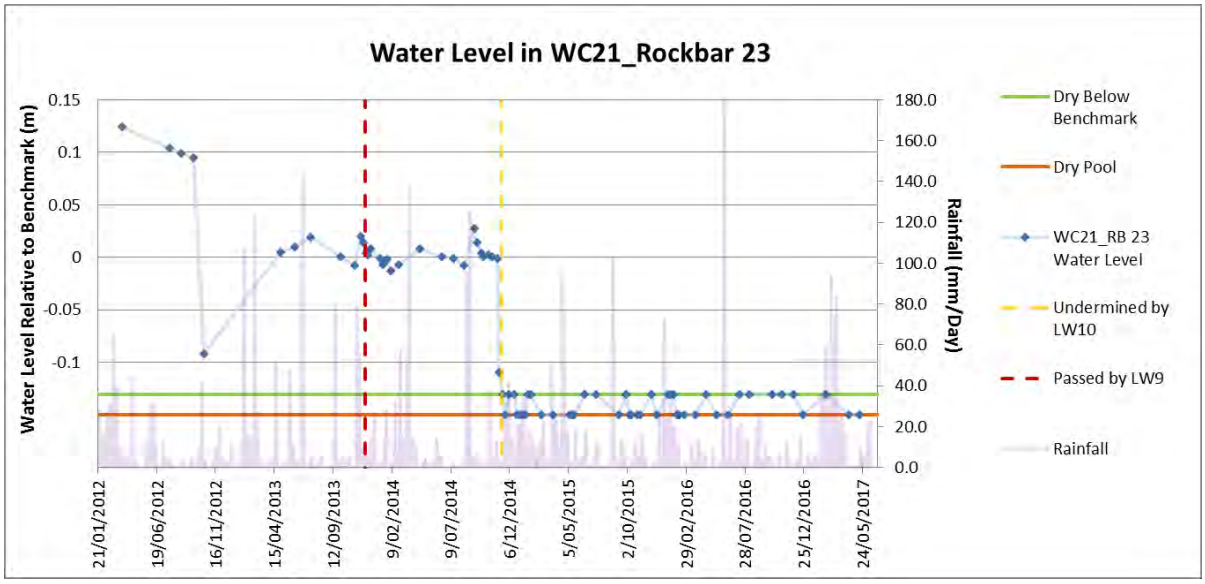
Rockbar 23 was undermined by Longwall 10 on 15 November 2014. Multiple impacts were observed at this site:

- *Impact LW10_018* - Rock fracture upstream from Rockbar 23. Surface flow absent (**Photo 75**).
- *Impact LW10_019* - Multiple fractures to Rockbar 23. Surface flow absent (**Photo 76**).
- *Impact LW10_009* - Multiple fractures to the downstream end of Rockbar 23. Surface flow absent (**Photo 77**).
- *Impact LW10_013* - Rock fracturing to base of Pool 23 on western margin (**Photo 78**).
- *Impact LW10_026* - Multiple rock fractures to the downstream section of Rockbar 23. Surface flow absent (**Photo 79**).

A reduction in water level, below baseline, was observed following after Rockbar 23 was undermined by Longwall 10. These reduced water levels have persisted throughout periods of considerable rainfall (**Graph 4-18**).

Recommendations

Reassessment of surface flow conditions on the rockbar are proposed following return of surface flow to upstream features. Grouting of any flow diversion is recommended. It is recommended that remediation initially target Pool 23.



Graph 4-18: Water level measurements relative to installed benchmark at WC21_Rockbar 23.

Photo 75: Impact DA3B_LW10_018. Taken on 18 December 2014

Photo 76: Impact DA3B_LW10_019. Taken on 18 December 2014

Photo 77: Impact DA3B_LW10_009. Taken on 18 November 2014

Photo 78: Impact DA3B_LW10_013. Taken on 4 December 2014

Photo 79: Impact DA3B_LW10_026. Taken on 3 March 2015.

Photo 80: WC21_Rockbar 23, looking upstream. Taken on 15 July 2017.

Photo 81: WC21_Rockbar 23, looking downstream. Taken on 15 July 2017.

4.1.26 WC21_POOL 23

Baseline description

Pool is 18 m long, 5 m wide and 1 m deep.

Monitoring and Impacts to feature

Pool 23 was undermined by Longwall 10 on 15 November 2014. Fracturing to the base of WC21_Pool 23, with an absence of surface flow, was identified (*Impact LW10_014*) (**Photo 82** and **Photo 83**). Additionally, hairline fracturing, with an absence of surface flow, was identified downstream from Pool 23 (*Impact LW10_015*) (**Photo 84** and **Photo 85**). Regular observation show that Pool 23 has consistently been dry (or dry below the benchmark) since it was undermined by Longwall 10 (**Graph 4-19**).

Recommendation

Remediation is proposed at Pool 23. Staging Area 2 will be used for works at the site.

Photo 82: Impact DA3B_LW10_014- Fracture to base of WC21_Pool 23, looking across stream. Photo taken on 4 December 2014.

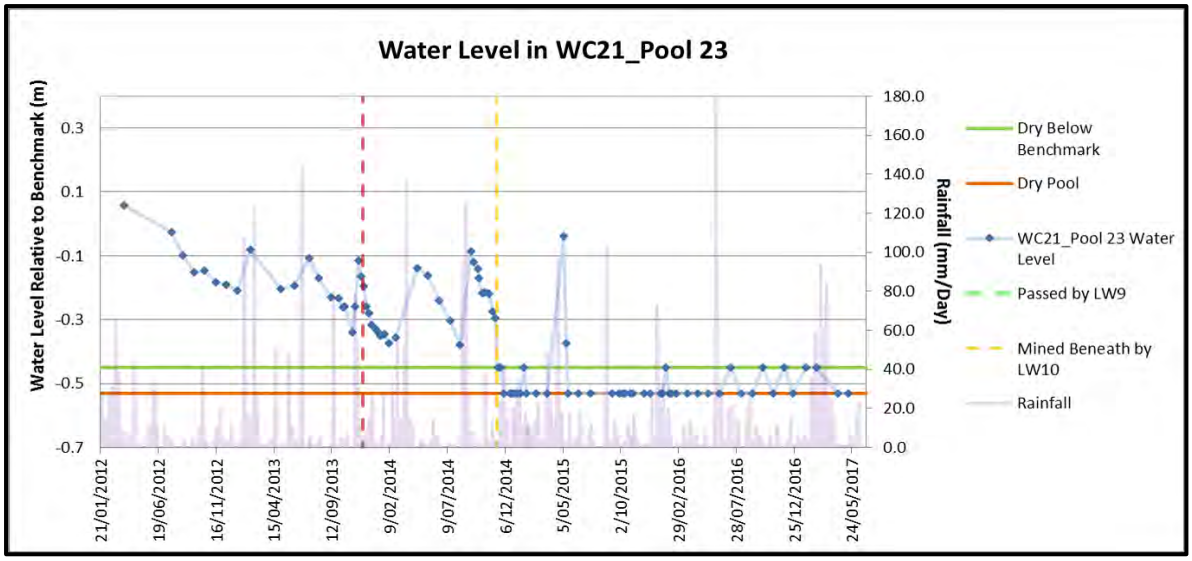
Photo 83: Impact DA3B_LW10_014- Fracture to base of WC21_Pool 23. Photo taken on 4 December 2014.

Photo 84: Impact DA3B_LW10_015- Fracturing downstream from WC21_Pool 23, looking upstream. Photo taken on 4 December 2014.

Photo 85: Impact DA3B_LW10_015- Fracturing downstream from WC21_Pool 23. Photo taken on 4 December 2014.

Photo 86: WC21_Pool 23, looking upstream. Taken on 17/06/2017.

Photo 87: WC21_Pool 23, looking downstream. Taken on 17/06/2017.



Graph 4-19: Water level measurements relative to installed benchmark at WC21_Pool 23.

4.1.27 WC21_POOL 22

Baseline description

The pool is 20 m long, 1 m wide and 0.5 m deep.

Monitoring and Impacts to feature

Pool 22 was undermined by Longwall 10 on 15 November 2014. No routine pool water level monitoring is installed at this site.

No surface impacts have been observed; however, a reduction in surface water is evident following mining.

Recommendation

Targeted remediation is not currently proposed at this site.

Photo 88: WC21_Pool 22, looking upstream. Taken on 10 September 2015.

Photo 89: WC21_Pool 22, looking downstream. Taken on 10 September 2015.

4.1.28 WC21_ROCKBAR 21

Baseline description

The rockbar is 50 m long, 4 m wide with pooling up to 0.4 m deep.

Monitoring and Impacts to feature

The majority of Rockbar 21 overlies the chain pillar between Longwalls 9 and 10; a small downstream section of the rockbar was undermined by the southern edge of Longwall 9 on 2 December 2013, and the upstream end was passed by Longwall 10 on 15 November 2014.

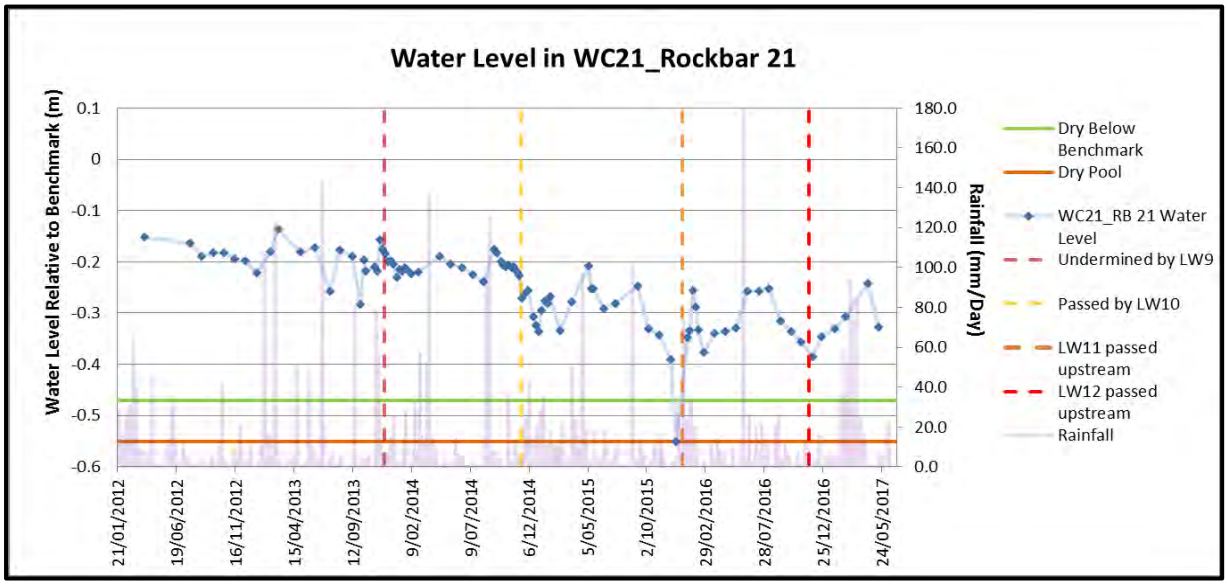
No surface impacts have been observed, however, an appreciable reduction in surface water level was observed, especially after the site was passed by Longwall 10. The reduction in surface water at the site may be due to the diversion of surface water upstream, as a result of mining; hence the sequential decrease of surface water following the passing of Longwalls 10, 11 and 12 (**Graph 4-20**). The site, however, continues to retain water and responds to rainfall.

Recommendation

The rockbar continues to hold areas of surface water for periods after rainfall. Targeted remediation is not currently proposed at this site.

Photo 90: WC21_Rockbar 21, looking upstream. Taken on 10 September 2015.

Photo 91: WC21_Rockbar 21, looking downstream. Taken on 10 September 2015.



Graph 4-20: Water level measurements relative **to installed benchmark at WC21_Pool 21.**

4.1.29 WC21_POOL 21

Baseline description

The pool is 12 m long, 3.5 m wide and 0.6 m deep.

Monitoring and Impacts to feature

Pool 21 was undermined by Longwall 9 on 7 December 2013. No routine pool water level monitoring is installed at this site. No surface impacts have been observed, however, a reduction in surface water is evident following mining (**Photo 92** and **Photo 93**).

Recommendations

The pool continues to hold areas of surface water. No targeted remediation is proposed at the site.

Photo 92: WC21_Pool 21, looking upstream. Taken on 10/09/2015.

Photo 93: WC21_Pool 21, looking downstream. Taken on 10/09/2015.

4.1.30 WC21_ROCKBAR 20

Baseline description

Rockbar is 15 m long, 4 m wide with pooling up to 0.2 m deep.

Monitoring and Impacts to feature

Rockbar 20 was undermined by Longwall 9 on 7 December 2013. No routine pool water level monitoring is installed at this site. Rock fracturing and dilation of an existing joint on Rockbar 20 was identified at the site (*Impact LW10_016*), with an absence of surface flow (**Photo 96**). Flow diversion has not been observed through the fracture; however there has been a reduction in surface flow at the site.

Recommendations

The rockbar continues to hold areas of surface water for periods after rainfall. No targeted remediation is proposed at the site. Remediation is proposed at the downstream Pool 20.

Photo 94: WC21_Rockbar 20, looking upstream. Taken on 10 September 2015.

Photo 95: WC21_ Rockbar 20, looking downstream. Taken on 10 September 2015.

Photo 96: Impact LW10_016- Rock fracture extending across rockbar and through joint, looking across stream. Taken on 4 December 2014.

4.1.31 WC21_POOL 20 (MONITORING SITE 'WC21_POOL 19')

Baseline description

Pool is 12 m long, 5 m wide and 0.6 m deep.

Monitoring and Impacts to feature

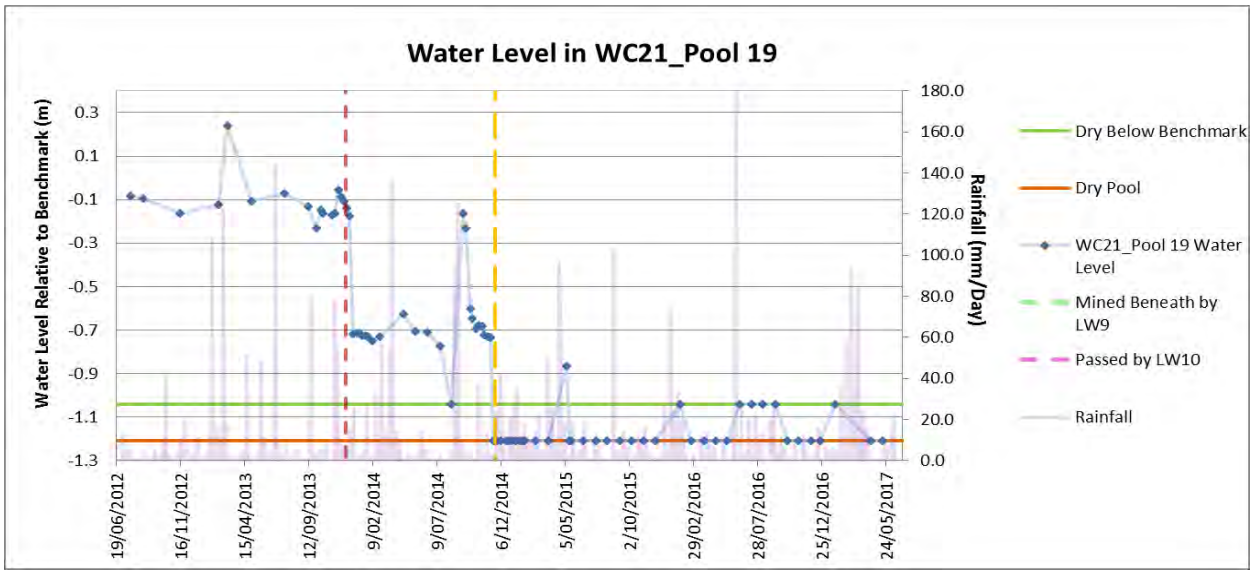
Pool 19 was undermined by Longwall 9 on 7 December 2013. No surface impacts have been observed; however, a reduction in pool water level has been recorded following Longwall 9 and Longwall 10. The pool has been dry on most inspections following Longwall 10 (**Graph 4-21**).

Recommendations

Targeted remediation is proposed at the site. Staging Area 3 will be used for works at the site.

Photo 97: WC21_Pool 19, looking upstream. Taken on 10 September 2015.

Photo 98: WC21_Pool 19, looking downstream. Taken on 10 September 2015.



Graph 4-21: Water level measurements relative to installed benchmark at WC21_Pool 19. Note: feature retains the mapping name of 'Pool 20'.

4.1.32 WC21_ROCKBAR 18

Baseline description

The rockbar is 30 m long, 6 m wide with small areas of pooling up to 0.4 m deep. Incision of cross-bedded strata is evident.

Monitoring and Impacts to feature

Rockbar 18 was undermined by Longwall 9 on 7 December 2013. Multiple impacts were identified at the site:

- *Impact LW9_021* - Multiple rock fractures to the upstream end of Rockbar 18 and an absence of surface flow has been observed (**Photo 99**).
- Impact LW9_022 - Fracturing and dilation of a joint on the downstream section of Rockbar 18 and an absence of surface flow has been observed (**Photo 100**).

Recommendation

Targeted remediation is proposed for the upstream end of Rockbar 18. Staging Area 3 will be used for works at the site.

Photo 99: Impact LW9_021- Rock fracturing to Rockbar 18. Taken on 2 January 2014.

Photo 100: Impact LW9_022- Rock fracturing to Rockbar 18. Taken on 2 January 2014.

Photo 101: WC21_Rockbar 18, looking upstream. Taken on 10 September 2015.

Photo 102: WC21_ Rockbar 18, looking downstream. Taken on 10 September 2015.

4.1.33 WC21_POOL 18

Baseline description

The pool is 7 m long, 4 m wide and up to 0.5 m deep.

Monitoring and Impacts to feature

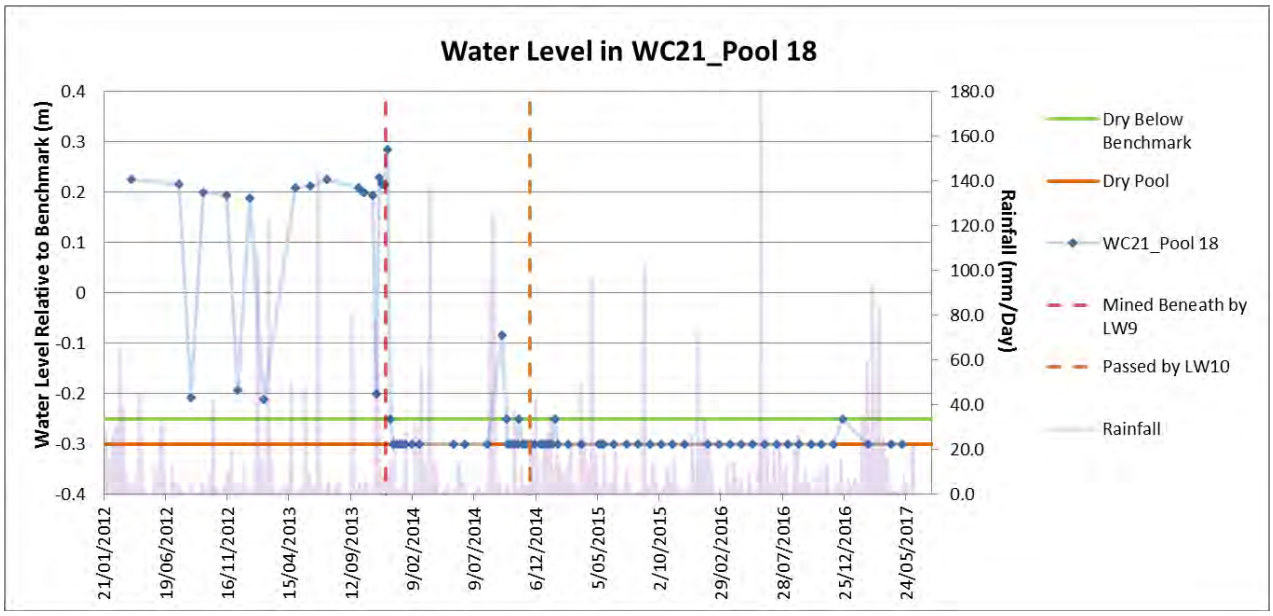
Pool 18 was undermined by Longwall 9 on 7 December 2013. No surface impacts have been observed however a reduction in pool water level has been recorded following Longwall 9. The pool has been dry on most inspections following Longwall 9 (**Graph 4-22**).

Recommendation

Targeted remediation is not currently proposed at the site.

Photo 103: WC21_Pool 18, looking upstream. Taken on 10 September 2015.

Photo 104: WC21_Pool 18, looking downstream. Taken on 10 September 2015.



Graph 4-22: Water level measurements relative to installed benchmark at WC21_Pool 18.

4.1.34 WC21_ROCKBAR 17

Baseline description

The pool is 6 m long, 5 m wide with flow over the rockbar.

Monitoring and Impacts to feature

Rockbar 17 was mined beneath by Longwall 9 on 7 December 2013. Dilation of joints and fracturing to Rockbar 17 and an absence of surface flow were identified at the site (*Impact LW9_016*) (**Photo 105**).

Recommendation

Remediation is not currently proposed at this location due to the shallowness of the pool and the localised nature of flow diversion at the site.

Photo 105: Impact LW9_016, dilation of joint looking across stream. Taken on 17 December 2013.

Photo 106: Rockbar 17, looking upstream at fracturing. Taken on 10 September 2015.

4.1.35 WC21_POOL 17

Baseline description

Pool is 8 m long, 3 m wide and up to 0.8 m deep.

Monitoring and Impacts to feature

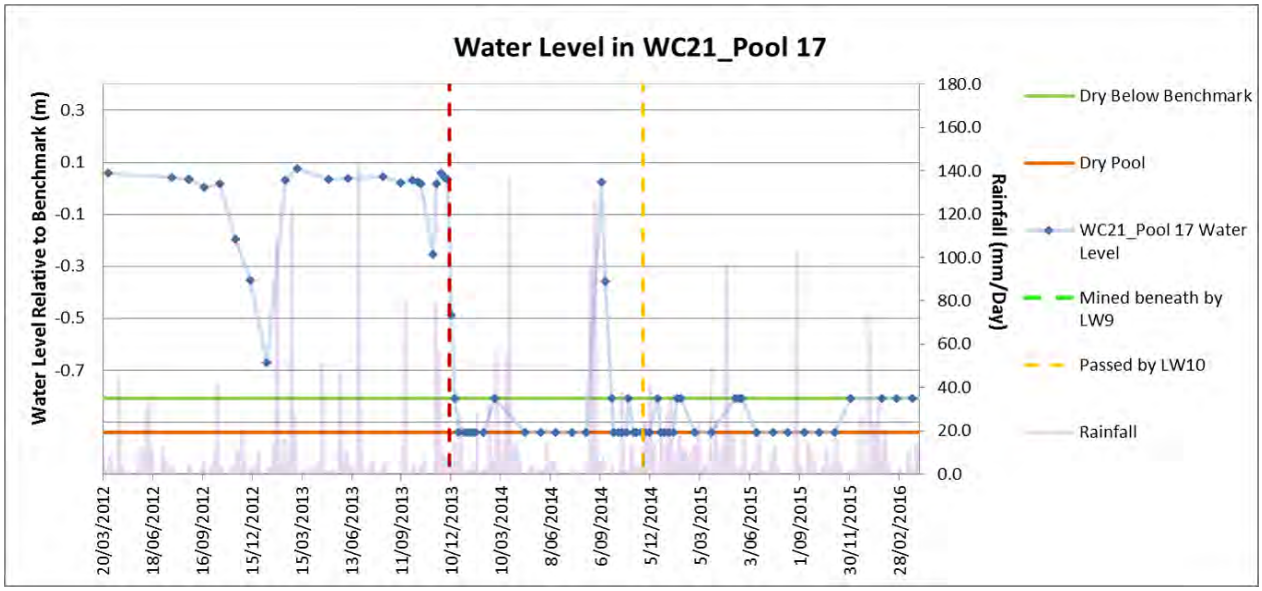
Pool 17 was mined beneath by Longwall 9 on 7 December 2013. No surface impacts have been observed in the pool; however, a reduction in pool water level has been recorded following Longwall 9 (**Graph 4-23**, **Photo 107** and **Photo 108**). The pool has been dry on multiple inspections following Longwall 9.

Recommendation

No remediation is currently proposed at the site.

Photo 107: WC21_Pool 17, looking upstream. Taken on 10 September 2015.

Photo 108: WC21_Pool 17, looking downstream. Taken on 10 September 2015.



Graph 4-23: Water level measurements relative to installed benchmark at WC21_Pool 17.

4.1.36 WC21_POOL 16

Baseline description

The pool is 6 m long, 5 m wide and up to 0.8 m deep.

Monitoring and Impacts to feature

Pool 16 was undermined by Longwall 9 on 7 December 2013. Multiple surface impacts were observed at the site:

- *Impact LW9_014* - Fracturing to the rock shelf adjacent Pool 16 (**Photo 111**) which does not intersect the pool.
- *Impact LW9_015* - Fracturing, uplift and dilation of jointing on the base of Pool 16 with an absence of surface flow observed (**Photo 112**) shows the location of surface impacts. The pool retains water for short periods following rainfall (**Graph 4-24**).

Recommendation

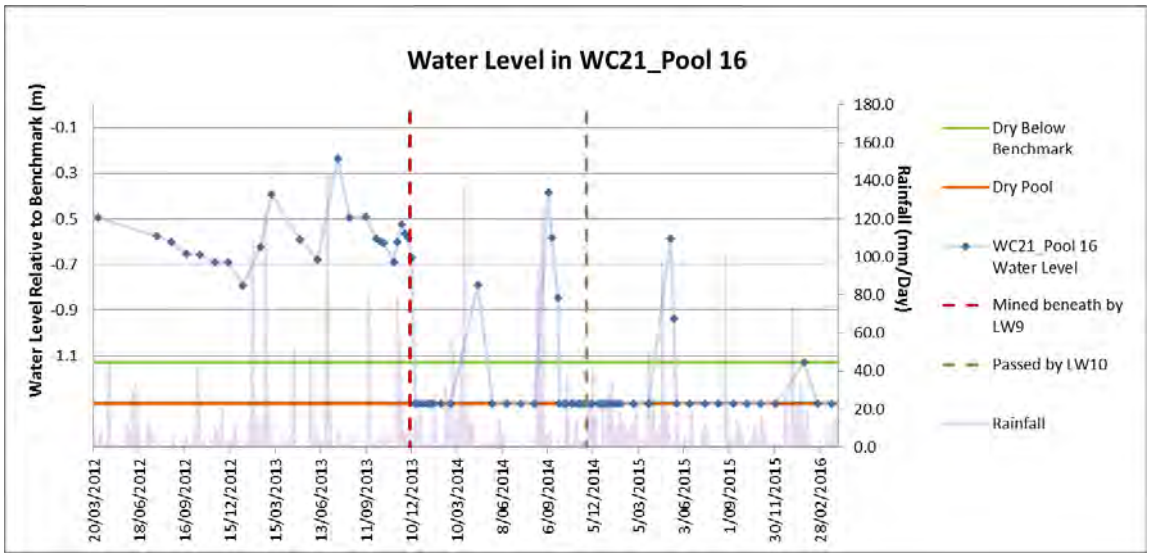
Targeted remediation is proposed at Pool 16. Staging Area 4 will be used for works at the site.

Photo 109: WC21_Pool 16, looking downstream. Taken on 10 September 2015.

Photo 110: WC21_Pool 16, looking upstream. Taken on 10 September 2015.

Photo 111: Impact DA3B_LW9_014- fracturing to rock shelf adjacent to WC21_Pool 16. Taken on 10 December 2013.

Photo 112: Impact DA3B_LW9_015- fracturing to base of WC21_Pool 16, looking downstream. Taken on 15 October 2015.



Graph 4-24: Water level measurements relative to installed benchmark at WC21_Pool 16.

4.1.37 WC21_POOL 15

Baseline description

Pools is up to 6 m long, 2 m wide and 0.5 m deep. Pool consists of cross-bedded strata, which is incised and overlain with fluvial material.

Monitoring and Impacts to features

Pool 15 was undermined by Longwall 9 on 7 December 2013. No surface impacts have been observed at this site; however, there is a consistent absence of surface water during inspections at the site (**Photo 113** and **Photo 114**).

Recommendation

The absence of any visible fracturing and observed flow diversion makes any initial remediation difficult at this pool. Reassessment of the site is proposed following return of flow upstream. Any flow diversion identified will be targeted with grouting.

Photo 113: WC21_Pool 15, looking upstream. Taken on 11 July 2017.

Photo 114: WC21_Pool 15, looking downstream. Taken on 11 July 2017.

4.1.38 WC21_POOL 14 TO WC21_POOL 11

Baseline description

This section of the tributary consists of rockbar sections intersected with small pools.

Monitoring and Impacts to features

Pools 14 to 11 were undermined by Longwall 9 on 7 December 2013. Hairline fracturing and dilation of jointing on Rockbar 12 and an absence of surface flow identified during inspections (*Impact LW9_018*) (**Photo 115**). No other surface impacts have been observed throughout this section of the tributary. There is an absence of surface flow across the majority of this section of WC21. It continues to hold surface water in sections following rainfall (**Photo 122** to **Graph 4-25**). **Photo 123** shows WC21_Pool 11, which has been dry on various occasions following the extraction of Longwall 9.

Recommendation

Visible fracturing is negligible in this area and any initial remediation would be difficult. No remediation of this pool is proposed due to the small size of Pool 11 and re-emergence of flow directly downstream. An investigation site is proposed adjacent to Rockbar 12.

Photo 115: Impact LW9_018, looking across stream. Taken on 24 December 2013.

Photo 116: WC21_Pool 14, looking upstream. Taken on 10 September 2015.

Photo 117: WC21_Pool 14, looking downstream. Taken on 11 July 2017.

Photo 118: WC21_Pool 13, looking upstream. Taken on 11 July 2017.

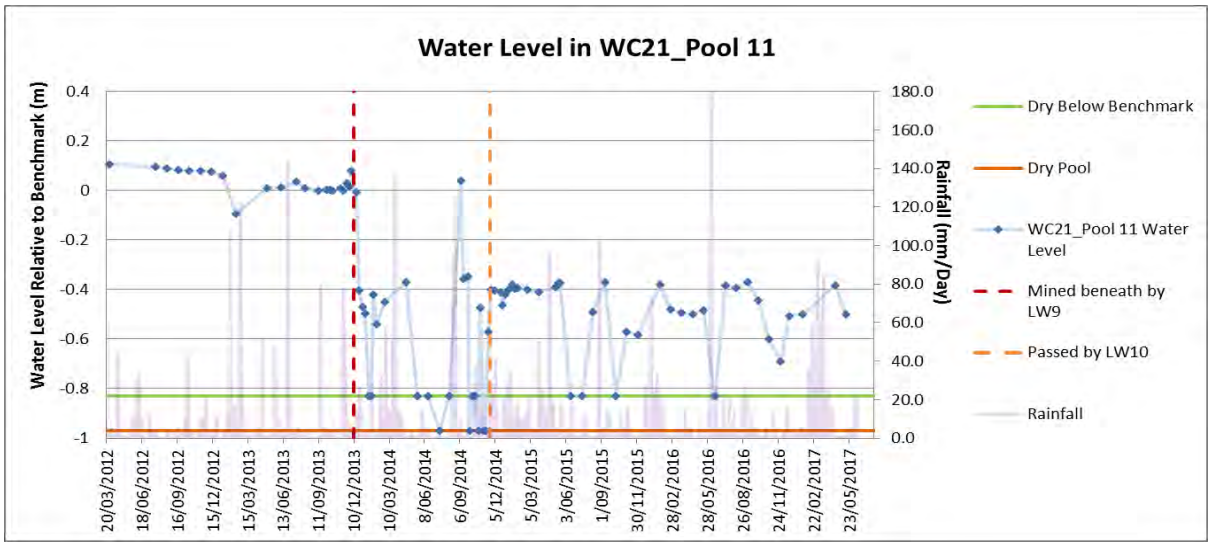
Photo 119: WC21_Pool 13, looking downstream. Taken on 11 July 2017.

Photo 120: WC21_Pool 12, looking upstream. Taken on 10 September 2015.

Photo 121: WC21_Pool 12, looking downstream. Taken on 10 September 2015.

Photo 122: WC21_Pool 11, looking upstream. Taken on 10 September 2015.

Photo 123: WC21_Pool 11, looking upstream. Taken on 10 September 2015.



Graph 4-25: Water level measurements relative to installed benchmark at WC21_Pool 11.

4.1.39 WC21_POOL 10

Baseline description

Pool is 35 m long, 10 m wide and up to 1.5 m deep. Pool is often intersected by accumulation of sand during different flow conditions.

Monitoring and Impacts to features

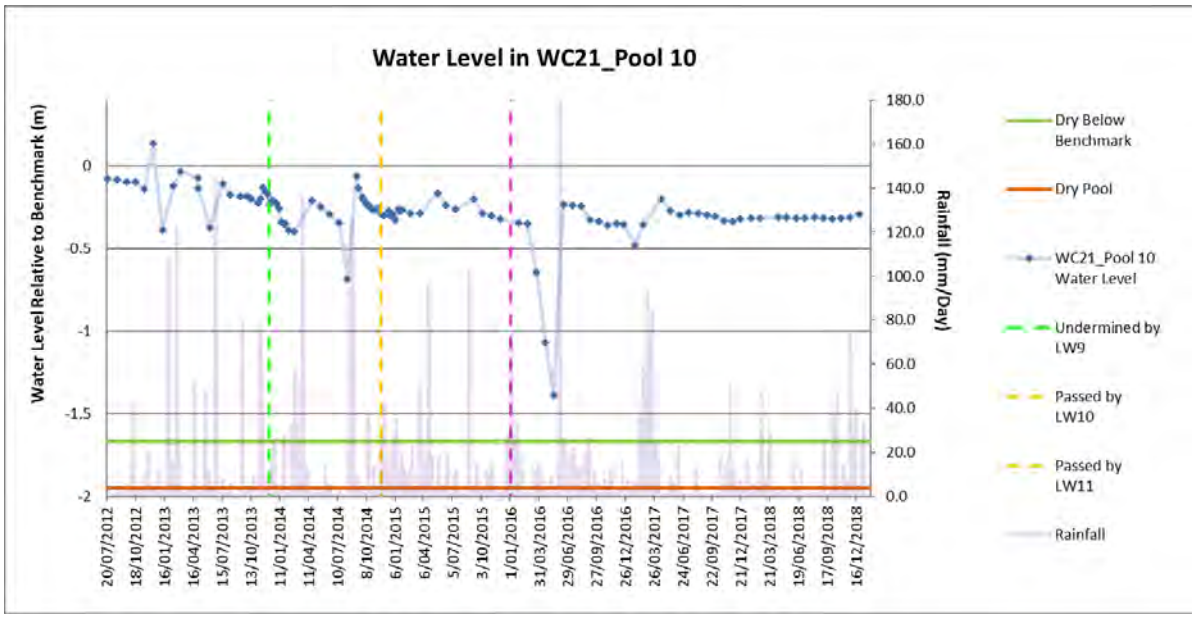
Pool 10 was passed by the northern edge of Longwall 9 on 7 December 2013. Multiple surface impacts have been identified at the site:

- *Impact LW9_027*- small rockfall to overhang directly to the west of Pool 10 (**Photo 126**);
- *Impact LW9_028* - small rockfall to overhang directly to the east of Pool 10 (**Photo 127**);
- *Impact LW9_019* - iron staining originating from subsurface outflow upstream from Pool 10 (**Photo 124**).

Surface water levels at Pool 10 do not appear to be directly impacted by mining (**Graph 4-26**). However, post-mining surface water levels at Pool 10 have been observed below baseline levels during periods of low rainfall. It is likely that the reduced surface flow into Pool 10 can be attributed to both low rainfall, and reduced inflows, as a result of mining impacts to WC21 previously mentioned (upstream of Pool 10).

Recommendation

No remediation is proposed at this site. It is recommended that the site be monitored during the implementation of upstream remediation and an assessment be made of any changes at this pool. Pools 5 and 10 is proposed as a tracer section site to be used in association with upstream investigation sites (**Figure 2-6**).



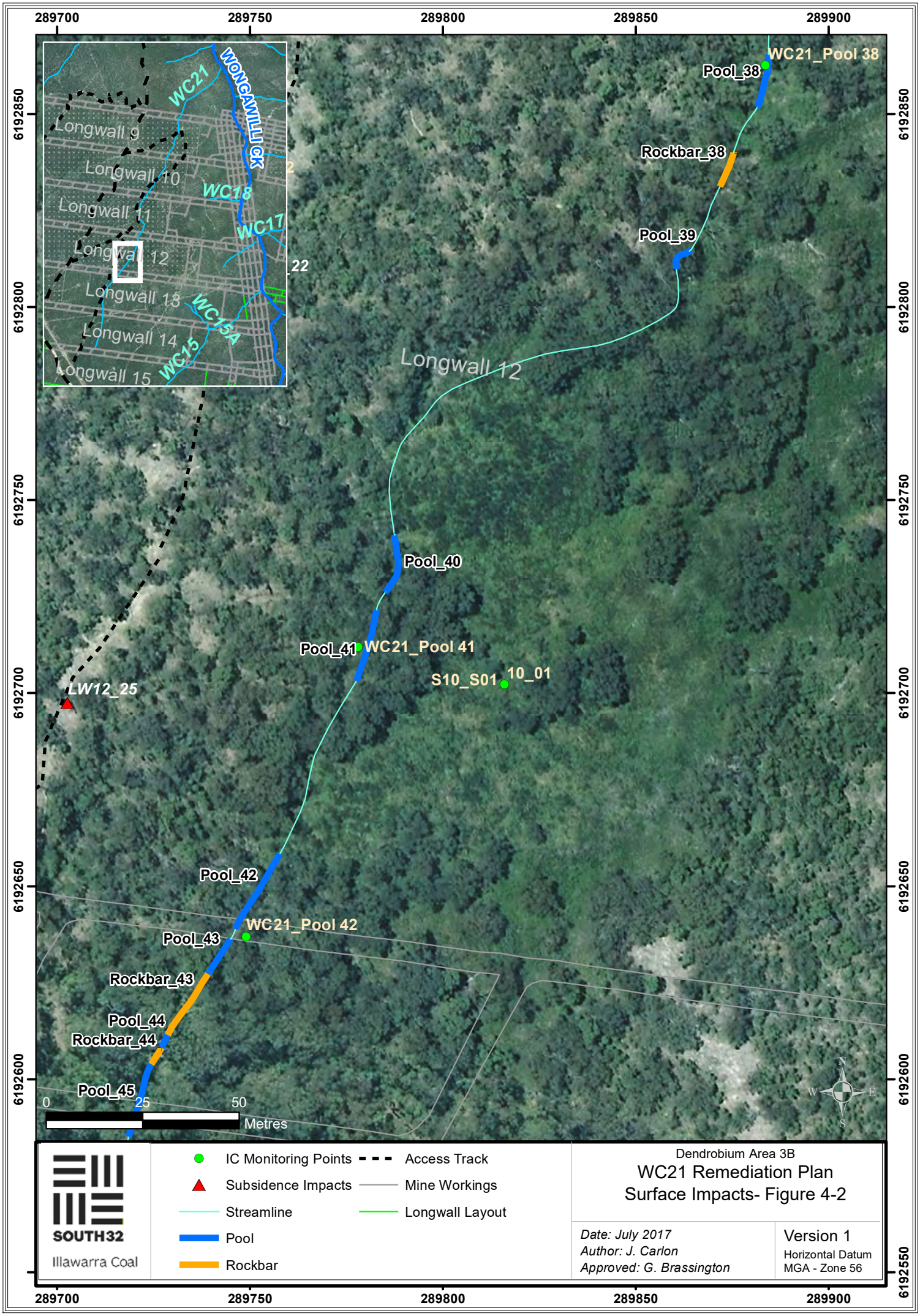
Graph 4-26: Water level measurements relative to installed benchmark at WC21_Pool 10.

Photo 124: WC21_Pool 10, looking upstream. Taken on 10 September 2015.

Photo 125: WC21_Pool 10, looking across stream. Taken on 10 September 2015.

Photo 126: Impact LW9_027, small rockfall adjacent to Pool 10. Taken on 28 January 2014.

Photo 127: Impact LW9_028, small rockfall to overhang adjacent to Pool 10. Taken on 17 March 2014.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WC21_Pool 38
Pool_38
Rockbar_38
Pool_39
Pool_40
Pool_41
WC21_Pool 41
S10_S01_10_01
LW12_25
Pool_42
WC21_Pool 42
Pool_43
Rockbar_43
Pool_44
Rockbar_44
Pool_45
Longwall 12
WONGAWILLI CK
WC21
WC18
WC17
WC15A
WC15
Longwall 9
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Longwall 11
Longwall 13
Longwall 14
Longwall 15
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IC Monitoring Points
Subsidence Impacts
Streamline
Pool
Rockbar
Access Track
Mine Workings
Longwall Layout
SOUTH32
Illawarra Coal
Dendrobium Area 3B
WC21 Remediation Plan
Surface Impacts- Figure 4-2
Date: July 2017
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56


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WC21
WC18
WC17
WC15A
WC15
Longwall 9
Longwall 10
Longwall 11
Longwall 12
Longwall 13
Longwall 14
Longwall 15
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Rockbar_30
Rockbar_30
WC21_Pool 30
LW11_008
Pool_31
S08_S01
08_01
Pool_32
Longwall 11
Pool_33
Pool_34
Pool_35
Pool_36
WC21_Pool 36
LW11_009
Surface flow becomes subsurface at this point
WC21_Pool 37
Pool_37
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Metres
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SOUTH32
Illawarra Coal
IC Monitoring Points
Access Track
Subsidence Impacts
Mine Workings
Streamline
Longwall Layout
Pool
Rockbar
Dendrobium Area 3B
WC21 Remediation Plan
Surface Impacts- Figure 4-3
Date: July 2017
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
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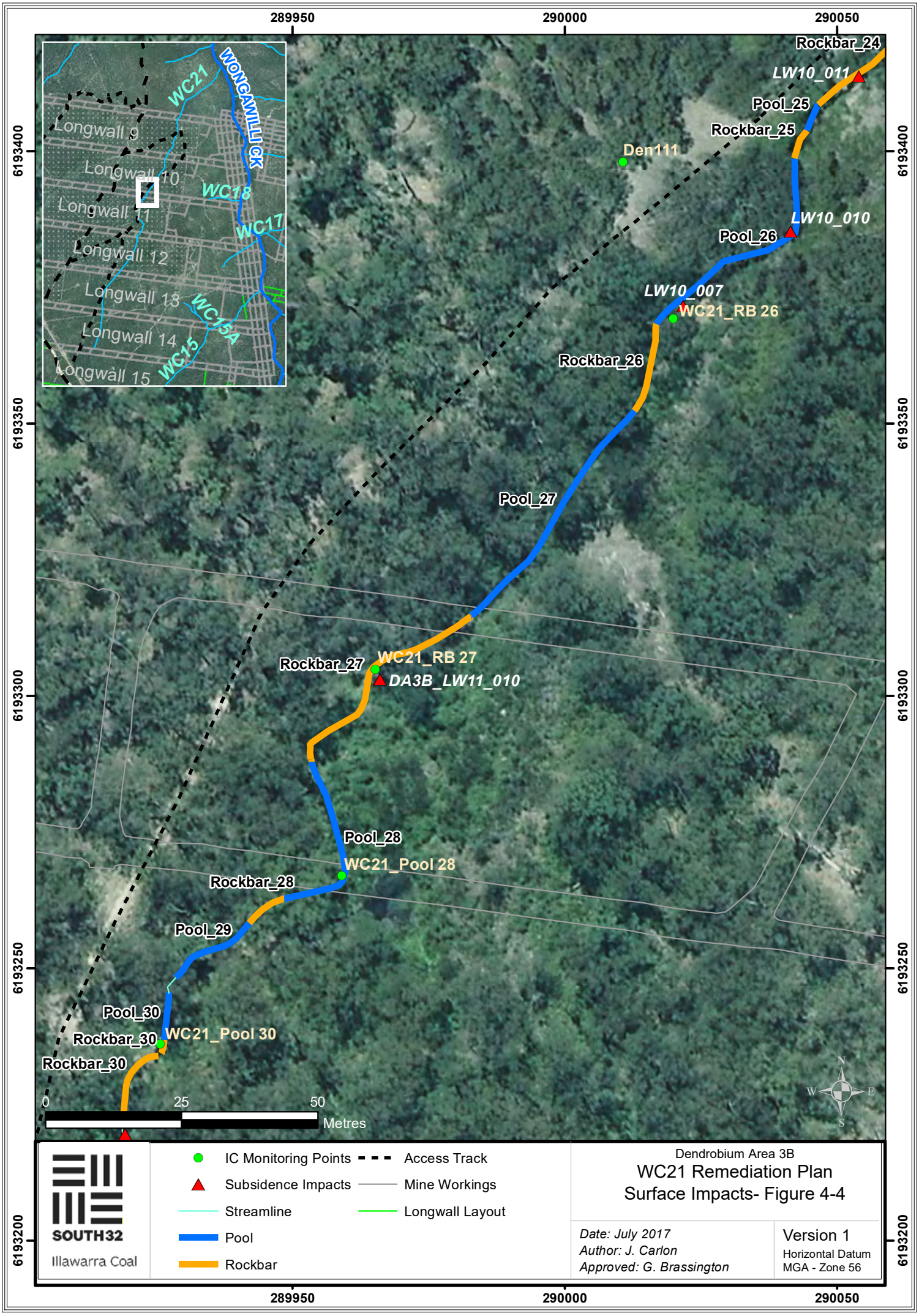
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Pool_27
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Subsidence Impacts
Mine Workings
Streamline
Longwall Layout
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SOUTH32
Illawarra Coal
Dendrobium Area 3B
WC21 Remediation Plan
Surface Impacts- Figure 4-4
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Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56


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LW10_018
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LW10_020
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IC Monitoring Points
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Streamline
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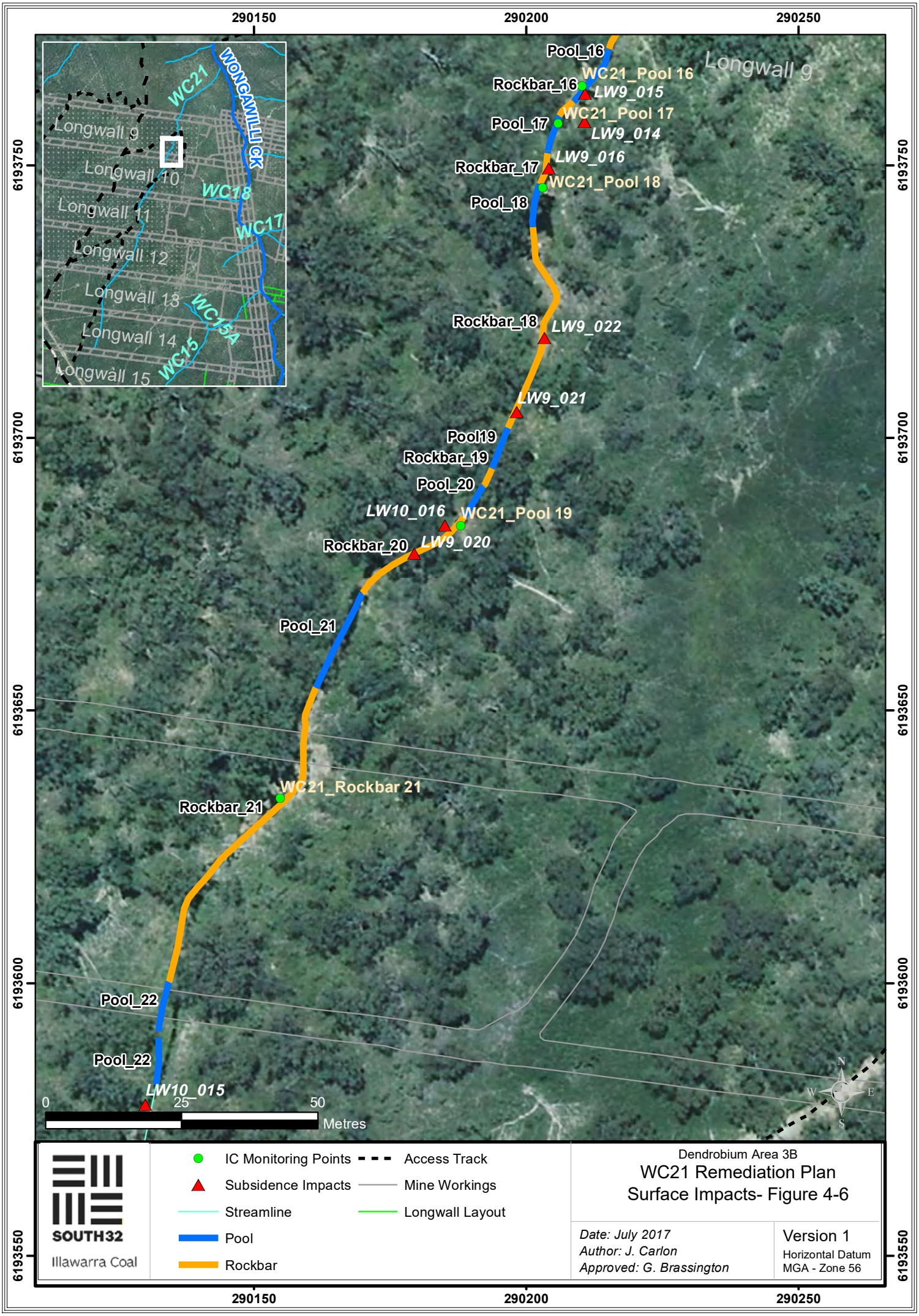
Access Track
Mine Workings
Longwall Layout
Dendrobium Area 3B
WC21 Remediation Plan
Surface Impacts- Figure 4-5
Date: July 2017
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56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WC18
WC17
WC15A
WC15
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Subsidence Impacts
Streamline
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Access Track
Mine Workings
Longwall Layout
SOUTH32
Illawarra Coal
Dendrobium Area 3B
WC21 Remediation Plan
Surface Impacts- Figure 4-6
Date: July 2017
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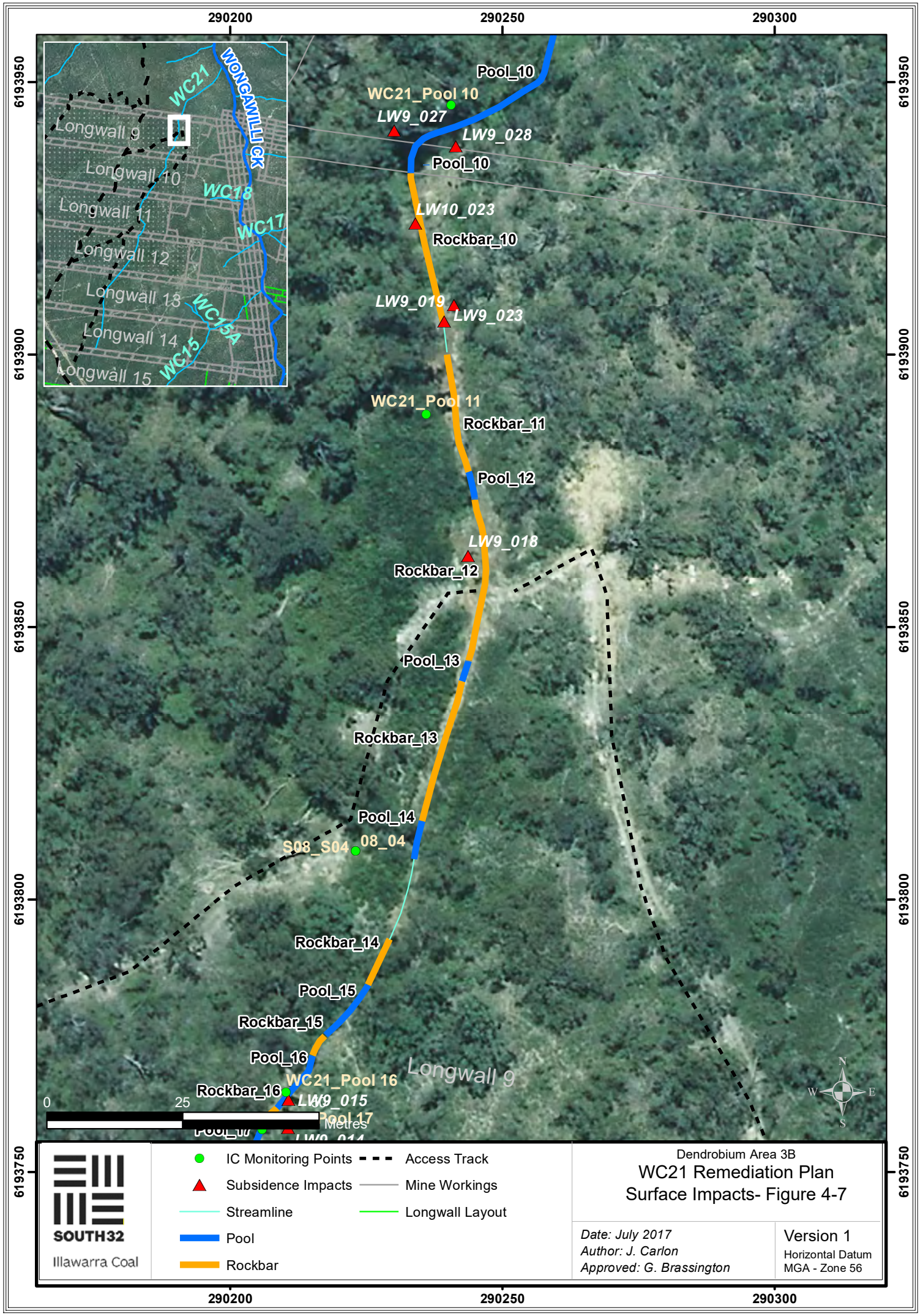
Version 1
Horizontal Datum
MGA - Zone 56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Longwall 15
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Pool_14
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08_04
Rockbar_14
Pool_15
Rockbar_15
Pool_16
WC21_Pool 16
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LW9_015
Pool_17
LW9_014
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IC Monitoring Points
Subsidence Impacts
Streamline
Pool
Rockbar
Access Track
Mine Workings
Longwall Layout
SOUTH32
Illawarra Coal
Dendrobium Area 3B
WC21 Remediation Plan
Surface Impacts- Figure 4-7
Date: July 2017
Author: J. Carlon
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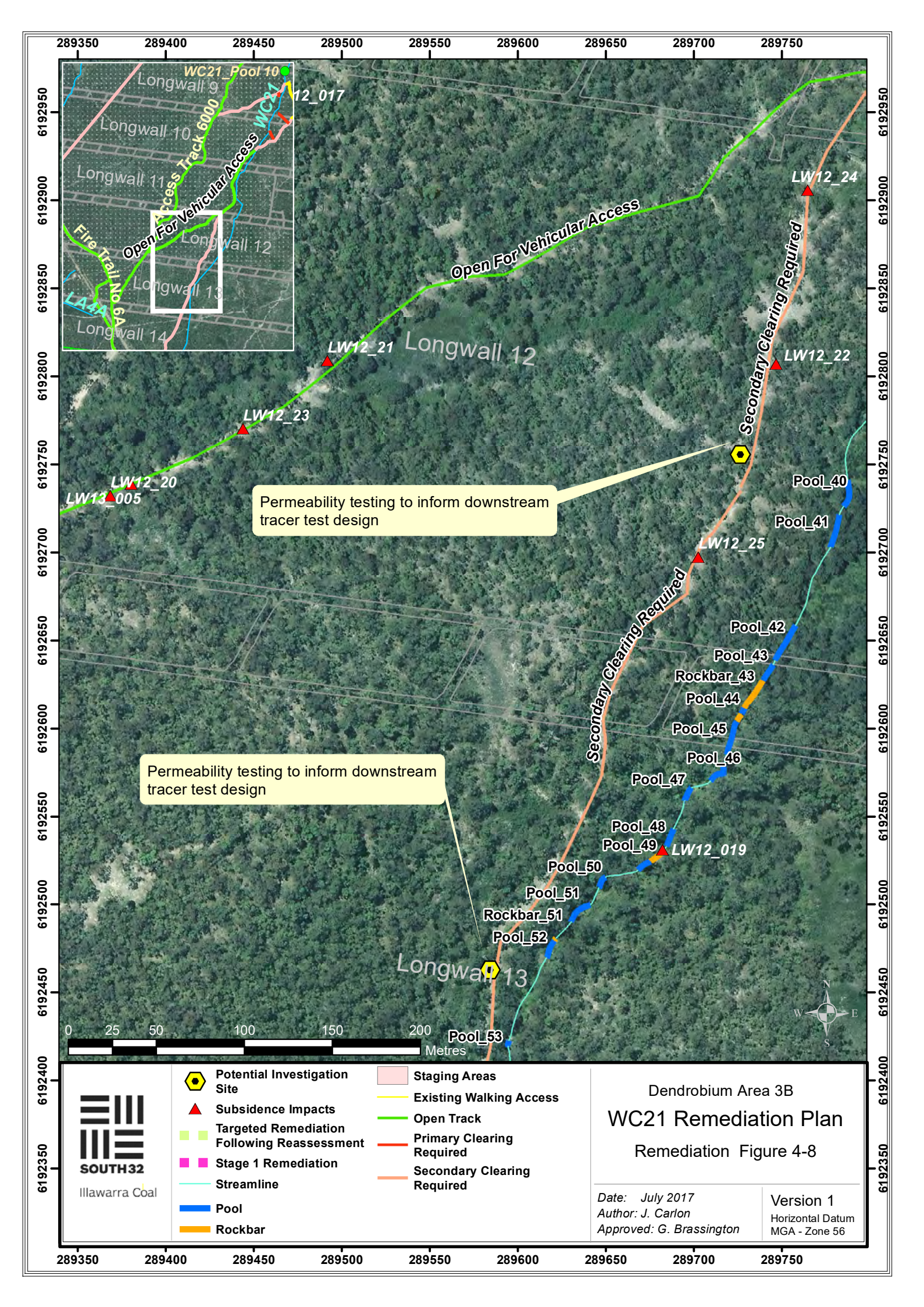
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Open For Vehicular Access
Fire Trail No.6A
LA4A
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LW12_21
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LW12_23
LW12_20
LW13_005
Secondary Clearing Required
Permeability testing to inform downstream tracer test design
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Pool_41
LW12_25
Pool_42
Pool_43
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Pool_46
Pool_47
Pool_48
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Rockbar_51
Pool_52
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0
25
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200
Metres
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SOUTH32
Illawarra Coal
Potential Investigation Site
Subsidence Impacts
Targeted Remediation Following Reassessment
Stage 1 Remediation
Streamline
Pool
Rockbar
Staging Areas
Existing Walking Access
Open Track
Primary Clearing Required
Secondary Clearing Required
Dendrobium Area 3B
WC21 Remediation Plan
Remediation Figure 4-8
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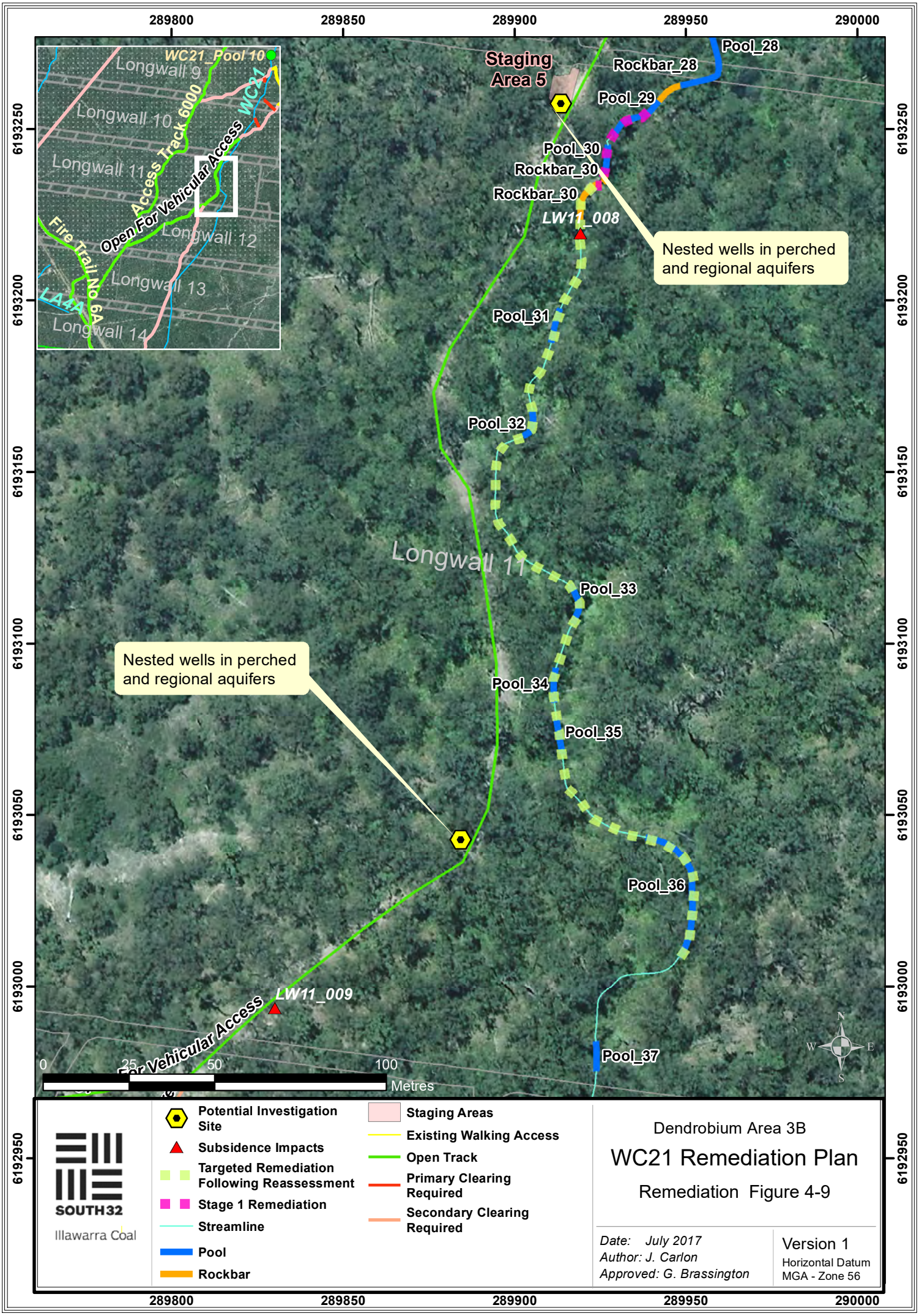
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56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Fire Trail No 6A
LA4A
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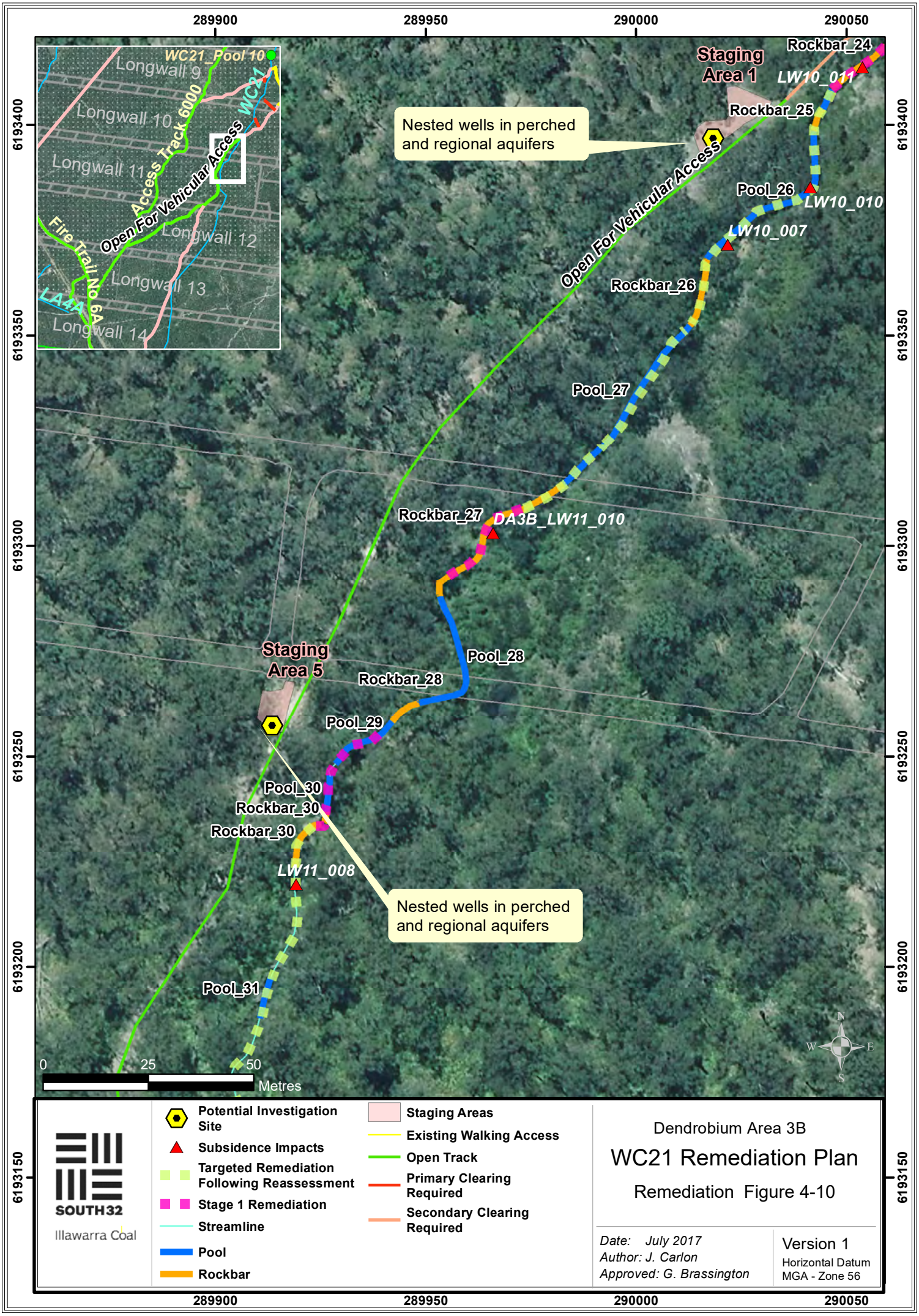
Potential Investigation Site
Subsidence Impacts
Targeted Remediation Following Reassessment
Stage 1 Remediation
Streamline
Pool
Rockbar
Staging Areas
Existing Walking Access
Open Track
Primary Clearing Required
Secondary Clearing Required
SOUTH32
Illawarra Coal
Dendrobium Area 3B
WC21 Remediation Plan
Remediation Figure 4-9
Date: July 2017
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56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Open For Vehicular Access
Fire Trail No 6A
LA4A
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Pool_30
Rockbar_30
Rockbar_30
LW11_008
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Metres
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Potential Investigation Site
Subsidence Impacts
Targeted Remediation Following Reassessment
Stage 1 Remediation
Streamline
Pool
Rockbar
Staging Areas
Existing Walking Access
Open Track
Primary Clearing Required
Secondary Clearing Required
SOUTH32
Illawarra Coal
Dendrobium Area 3B
WC21 Remediation Plan
Remediation Figure 4-10
Date: July 2017
Author: J. Carlon
Approved: G. Brassington
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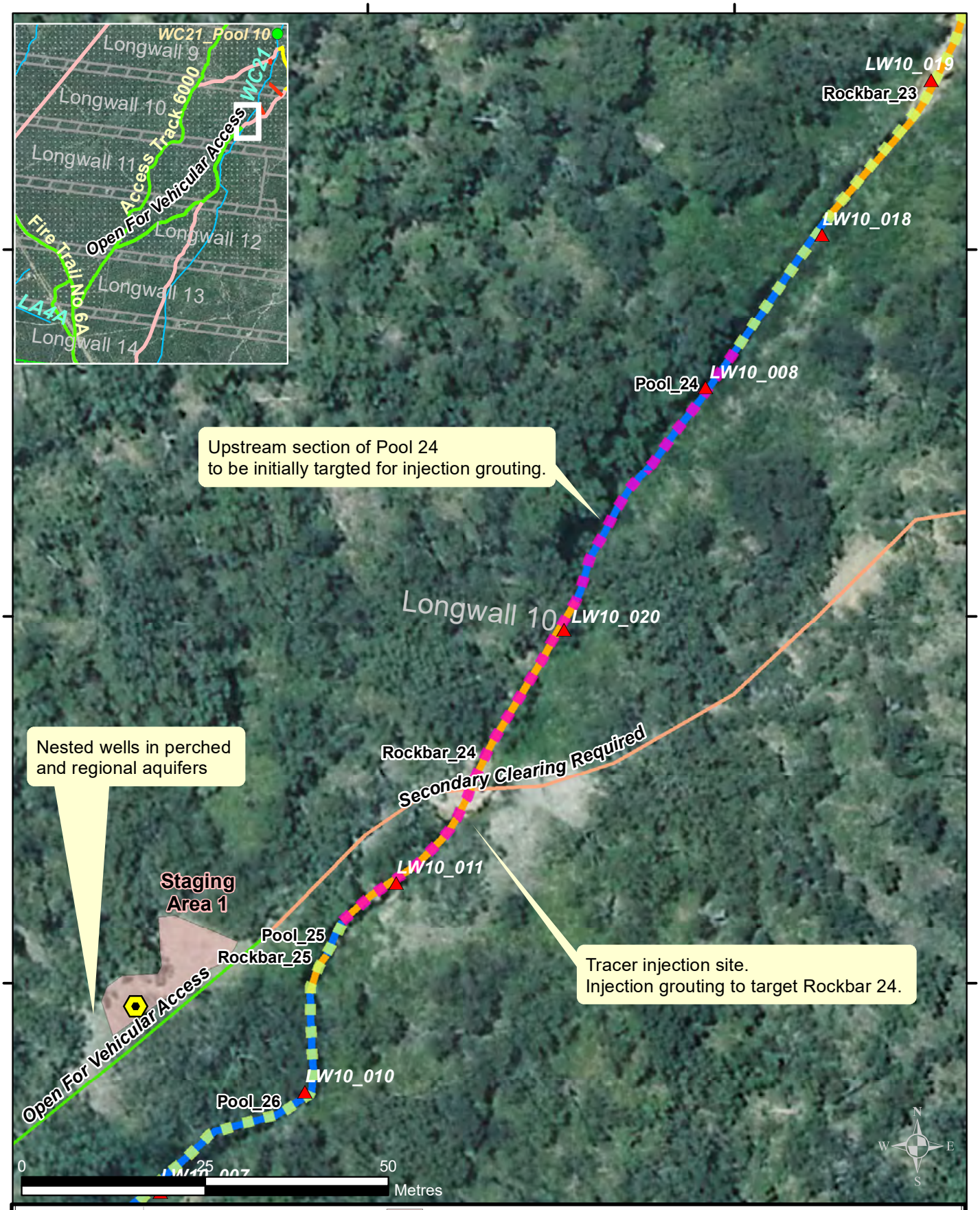
Horizontal Datum
MGA - Zone 56



SOUTH32
Illawarra Coal

- Potential Investigation Site
- Subsidence Impacts
- Targeted Remediation Following Reassessment
- Stage 1 Remediation
- Streamline
- Pool
- Rockbar
- Staging Areas
- Existing Walking Access
- Open Track
- Primary Clearing Required
- Secondary Clearing Required

Dendrobium Area 3B

WC21 Remediation Plan

Remediation - Figure 4-11

Date: July 2017
Author: J. Carlon
Approved: G. Brassington

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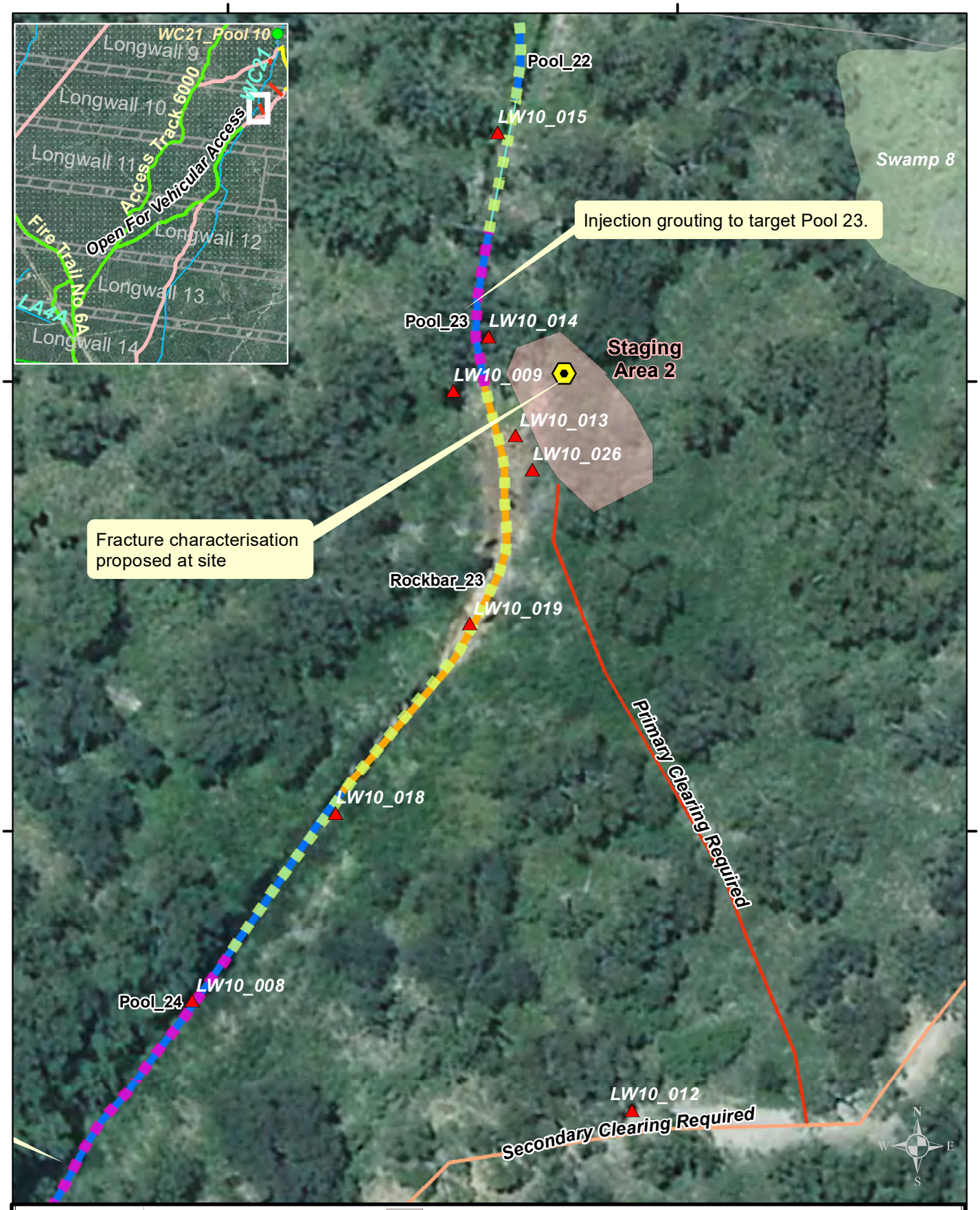
Horizontal Datum
MGA - Zone 56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WC21
Open For Vehicular Access
Fire Trail No 6A
LA4A
Pool_22
LW10_015
Swamp 8
Injection grouting to target Pool 23.
Pool_23
LW10_014
Staging Area 2
LW10_009
LW10_013
LW10_026
Fracture characterisation proposed at site
Rockbar_23
LW10_019
Primary Clearing Required
LW10_018
LW10_008
Pool_24
LW10_012
Secondary Clearing Required
N
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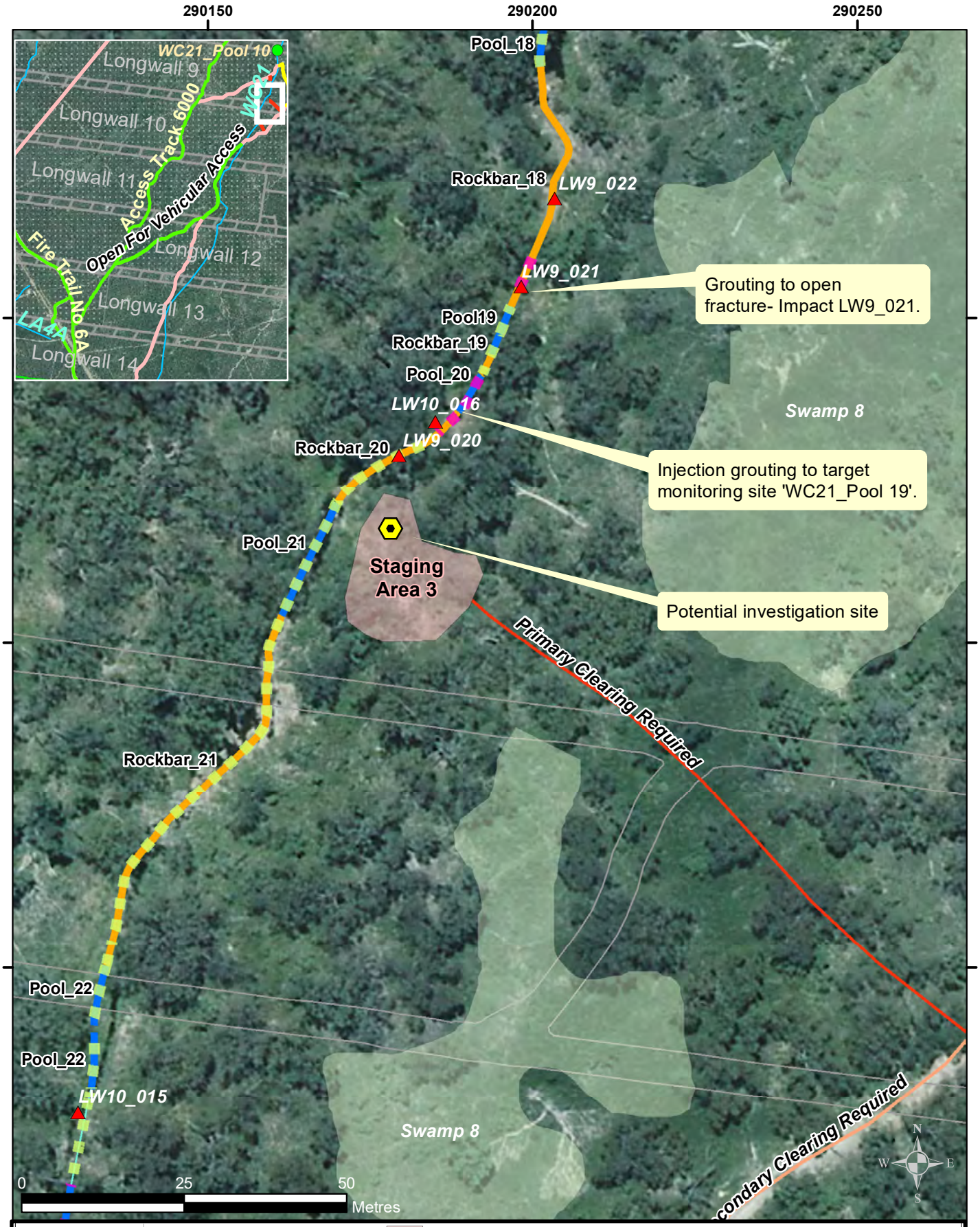
Potential Investigation Site
Subsidence Impacts
Targeted Remediation Following Reassessment
Stage 1 Remediation
Streamline
Pool
Rockbar
Staging Areas
Existing Walking Access
Open Track
Primary Clearing Required
Secondary Clearing Required
SOUTH32
Illawarra Coal
Dendrobium Area 3B
WC21 Remediation Plan
Remediation - Figure 4-12
Date: July 2017
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56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Longwall 14
Access Track 6000
Open For Vehicular Access
Fire Trail No.6A
LA4A
WC21
Pool_18
Rockbar_18
LW9_022
LW9_021
Grouting to open fracture- Impact LW9_021.
Pool19
Rockbar_19
Pool_20
LW10_016
LW9_020
Rockbar_20
Swamp 8
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Pool_21
Staging Area 3
Potential investigation site
Primary Clearing Required
Rockbar_21
Pool_22
Pool_22
LW10_015
Swamp 8
Secondary Clearing Required
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SOUTH32
Illawarra Coal
Potential Investigation Site
Subsidence Impacts
Targeted Remediation Following Reassessment
Stage 1 Remediation
Streamline
Pool
Rockbar
Staging Areas
Existing Walking Access
Open Track
Primary Clearing Required
Secondary Clearing Required
Dendrobium Area 3B
WC21 Remediation Plan
Remediation - Figure 4-13
Date: July 2017
Author: J. Carlon
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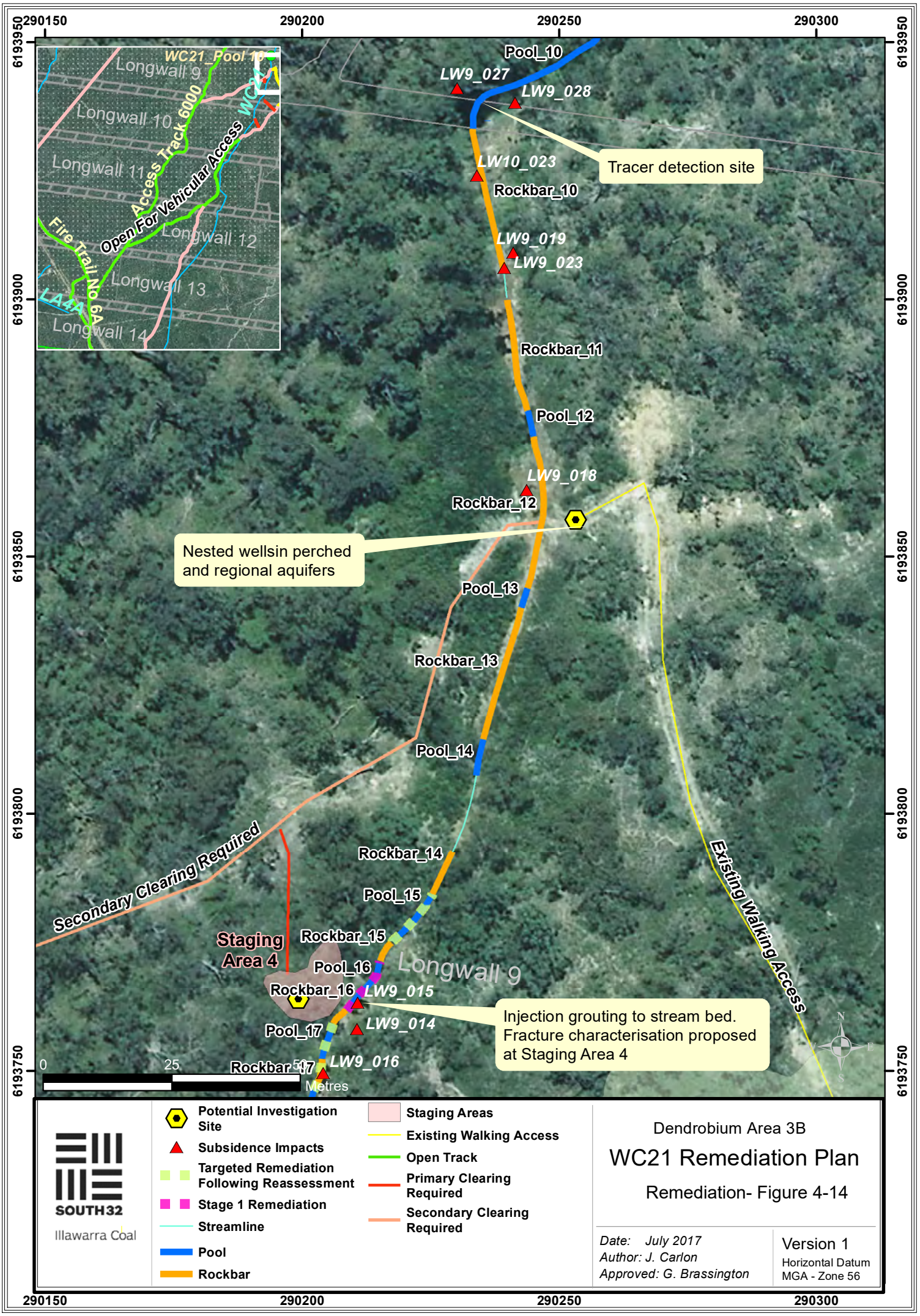
Version 1
Horizontal Datum
MGA - Zone 56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Fire Trail No 6A
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LW9_023
Rockbar_11
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LW9_018
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Pool_13
Rockbar_13
Pool_14
Rockbar_14
Pool_15
Rockbar_15
Staging Area 4
Pool_16
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LW9_015
Pool_17
LW9_014
Rockbar_17
LW9_016
Secondary Clearing Required
Existing Walking Access
Injection grouting to stream bed. Fracture characterisation proposed at Staging Area 4
Longwall 9
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SOUTH32
Illawarra Coal
Potential Investigation Site
Subsidence Impacts
Targeted Remediation Following Reassessment
Stage 1 Remediation
Streamline
Pool
Rockbar
Staging Areas
Existing Walking Access
Open Track
Primary Clearing Required
Secondary Clearing Required
Dendrobium Area 3B
WC21 Remediation Plan
Remediation- Figure 4-14
Date: July 2017
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56


289650
289700
289750
6194150
6194100
6194050
6194000
Pool_31
Pool_32
DC_Pool_32
Pool_33
DC_Pool_33
LW9_007
LW9_006
Rockbar_33
Pool_34
DC_Pool_34
Pool_35
Rockbar_35
Den05
Den01a
Longwall 9
Longwall 10
Longwall 11
Longwall 12
Longwall 13
Den10
WC21
S CASTLE CREEK
0
25
50
Metres
N
E
S
W
IC Monitoring Points
Subsidence Impacts
Streamline
Pool
Rockbar
Access Track
Mine Workings
SOUTH32
Illawarra Coal
Dendrobium Area 3B
Donalds Castle Creek
Remediation Plan Surface
Impacts- Figure 4-15
Date: July, 2017
Author: J. Carlon
Approved: G. Brassington
Version 1
Horizontal Datum
MGA - Zone 56

4.2 DONALDS CASTLE CREEK

4.2.1 DC_POOL 34

Baseline Description

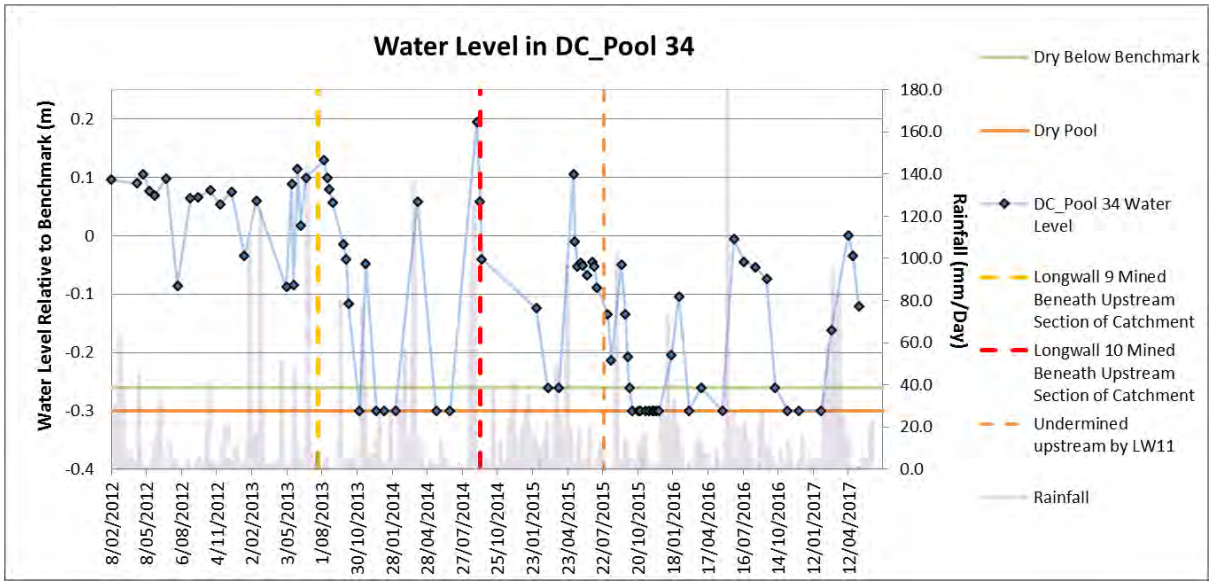
Shallow, rock-based pool, approximately 6 m long and 2 m wide (**Photo 128** and **Photo 129**).

Monitoring and Impacts to Feature

Longwall 9 passed Pool 34 at an approximate distance of 85 m on 22 July 2015. Whilst no surface impacts have been detected at Pool 34, a reduction in surface flow at the site has been observed since the passing of Longwalls 9, 10 and 11 (**Photo 130** and **Photo 131; Graph 4-27**). Pool 34 often holds water following rainfall events, however, it receives minimal water from the catchment upstream, i.e. Swamp 5.

Recommendations

No remediation is recommended at Pool 34. While there is a lack of surface flow upstream from this site, there is an absence of exposed bedrock or visible surface impacts.



Graph 4-27: Water level measurements relative to installed benchmark at DC_Pool 34.

Photo 128: DC_Pool 34, looking downstream. Taken on 13 November 2012.

Photo 129: DC_Pool 34, looking across stream. Taken on 13 November 2012.

Photo 130: DC_Pool 34, looking downstream. Taken on 28 February 2017.

Photo 131: DC_Pool 34, looking across stream. Taken on 28 February 2017.

4.2.2 DC_POOL 33 AND DC_ROCKBAR 33

Baseline Description

This section of the creek consists of a rockbar (Rockbar 33), approximately 18 m long and 3m wide; a 1.5 m high step (Step 33); and a downstream pool (Pool 33), approximately 9 m long and 3 m wide. Baseline observations note that Pool 33 is often dry during periods of low-rainfall, particularly away from the immediate base of the step.

Monitoring and Impacts to Feature

Longwall 9 passed this section of the creek at an approximate distance of 108 m, on the 27th of July 2013. Multiple fractures, with some associated flow diversion, were identified on Rockbar 33, continuing downstream to the step (*DA3B_LW9_006*). Pool 33 is routinely monitored but due to the shallow nature of the pool, it is unsuitable for quantitative water level monitoring. Observations show a reduction in surface flow over these features after the extraction of Longwalls 9, 10 and 11(**Photo 134** and **Photo 135**).

Recommendations

Targeted remediation is proposed for Rockbar 33 and Pool 33. This would include injection grouting of the rockbar and base of the pool, as well as surface grouting of any visible fracturing within the stream bed.

Staging Area DC1 is proposed adjacent to DC_Rockbar 33, on an existing access track. The track would require secondary clearing to reopen it for vehicular access. Grout would be pumped from the staging area to Pool 33 and Rockbar 33.

A monitoring and investigation site is also proposed at this staging area to better inform the final remediation approach.

Photo 132: DC_Pool 33, looking upstream. Taken on 10 January 2012.

Photo 133: DC_Pool 33, looking upstream. Taken on 26 July 2012.

Photo 134: DC_Pool 33, looking upstream. Taken on 28 February 2017.

Photo 135: DC_Pool 33, looking upstream. Taken on 24 April 2017

4.2.3 DC_POOL 32

Baseline Description

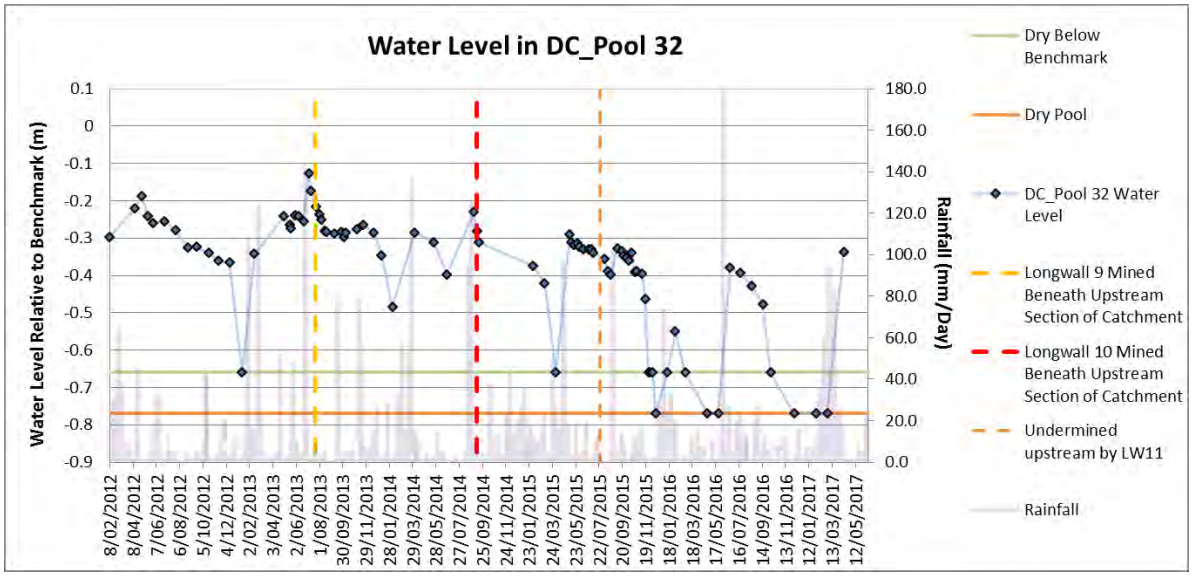
Pool 32 is a sediment-based pool, approximately 14 m long and 3 m wide, with a steep concave bank.

Monitoring and Impacts to Feature

Longwall 9 passed Pool 32 at an approximate distance of 155 m, on 27 July 2013. No surface impacts have been observed at Pool 32, however, an increase in the frequency of 'dry below benchmark' and 'dry pool' readings, relative to baseline monitoring, is indicative of a decrease in surface flow to the site (**Photo 138** and **Photo 139**).

Recommendations

No surface impacts have been observed to DC_Pool 32. Additionally, the pool continues to hold water for extended periods (**Graph 4-28**). As a result, no targeted remediation is proposed at the site. Results of upstream remediation on Pool 32 water levels will be assessed.



Graph 4-28: Water level measurements relative to installed benchmark at DC_Pool 32.

Photo 136: DC_Pool 32, looking upstream. Taken on 28 August 2012.

Photo 137: DC_Pool 32, looking downstream. Taken on 28 August 2012

Photo 138: DC_Pool 32, looking upstream. Taken on 28 February 2017.

Photo 139: DC_Pool 32, looking downstream. Taken on 28 February 2017.

Photo 140: DC_Pool 32, looking upstream. Taken on 24 April 2017.

Photo 141: DC_Pool 32, looking downstream. Taken on 24 April 2017.

4.2.4 DC_POOL 30

Baseline Description

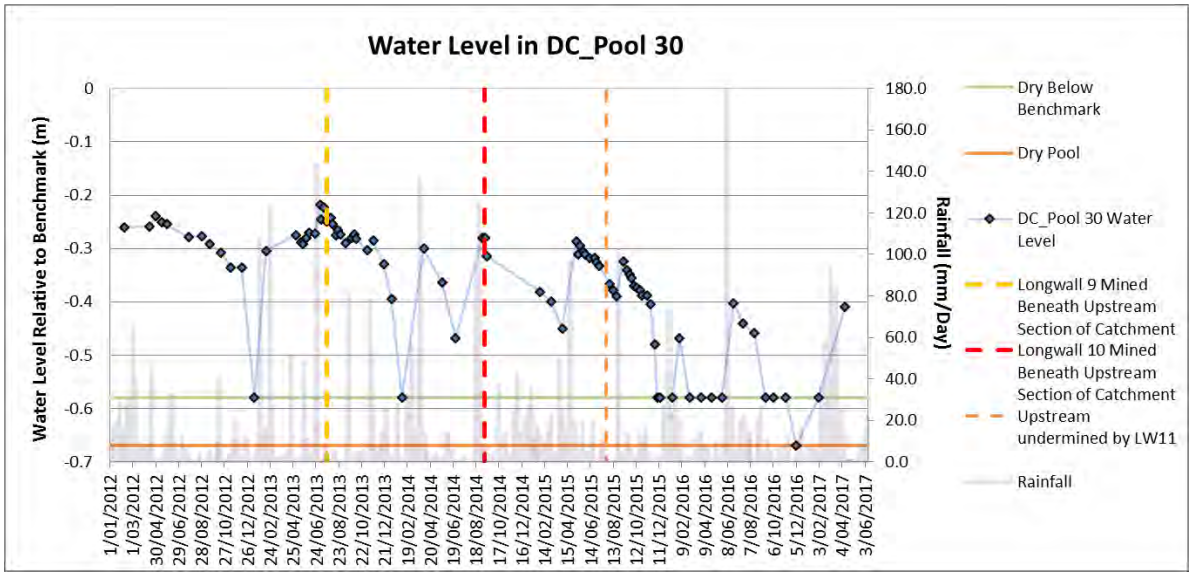
Sediment-based pool with densely vegetated banks, approximately 28 m long and 4 m wide (**Photo 142**).

Monitoring and Impacts to Feature

Longwall 9 passed Pool 30 at an approximate distance of 26 m, on 27 July 2017. No surface impacts have been identified at Pool 30. However, observations show a decrease in surface water level at the site, particularly an increase in the frequency of 'dry below benchmark' measurements, relative to baseline monitoring (**Photo 143**; **Graph 4-29**).

Recommendations

No remediation is recommended for this feature.



Graph 4-29: Water level measurements relative to the installed benchmark at DC_Pool 30.

Photo 142: DC_Pool 30, looking downstream. Taken on 13 April 2012.

Photo 143: DC_Pool 30, looking downstream. Taken on 09 May 2017

4.2.5 DC_POOL 29 AND DC_ROCKBAR 29

Baseline Description

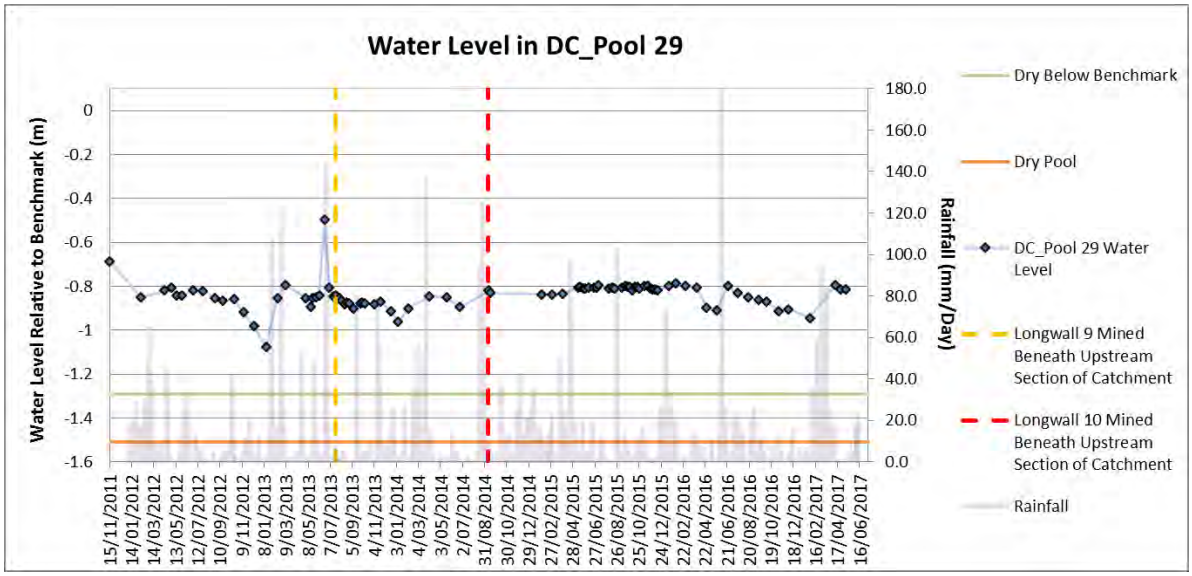
This section of the creek consists of a 9 m long and 2.5 m wide rockbar-based pool. A small step, approximately 1 m high, at the downstream extent of the 4 m long rockbar leads into the pool.

Monitoring and Impacts to Feature

No surface impacts have been observed at these features. No reduction in surface water level has been observed at Pool 29, in relation to the extraction of Longwalls 9 and 10 (**Photo 144** and **Photo 145**; **Graph 4-30**).

Recommendations

No remediation is recommended for these features.



Graph 4-30: Water level measurements relative to installed benchmark at DC_Pool 29.

Photo 144: DC_Pool 29, looking upstream. Taken on 14 February 2013.

Photo 145: DC_Pool 29, looking upstream. Taken on 16 May 2017.

4.2.6 DC_POOL 23

Baseline Description

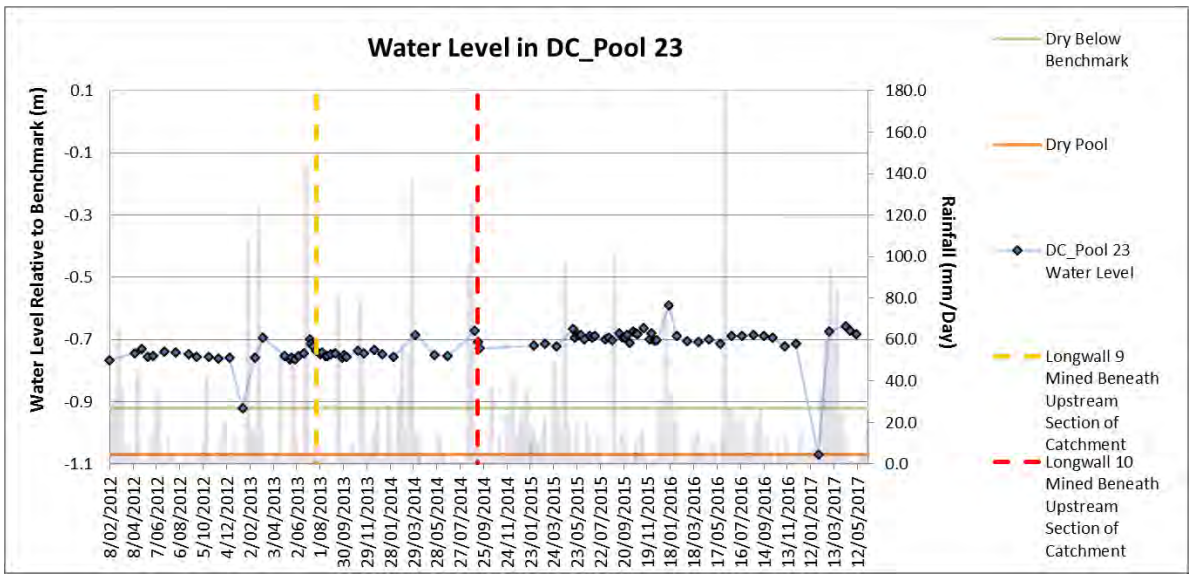
Pool 23 is a sediment-based pool, approximately 18 m long and 2.5 m wide.

Monitoring and Impacts to Feature

No surface impacts have been observed at Pool 23 (**Photo 146** and **Photo 147**). No reductions in surface water level resulting from the extraction of Longwalls 9 and 10 have been observed at Pool 23 (**Graph 4-31**).

Recommendations

No remediation is recommended for Pool 23.



Graph 4-31: Water level measurements relative to installed benchmark at DC_Pool 23.

Photo 146: DC_Pool 23, looking downstream. Taken on 14 February 2013.

Photo 147: DC_Pool 23, looking downstream. Taken on 26 May 2017.

4.2.7 DC_POOL 19

Baseline Description

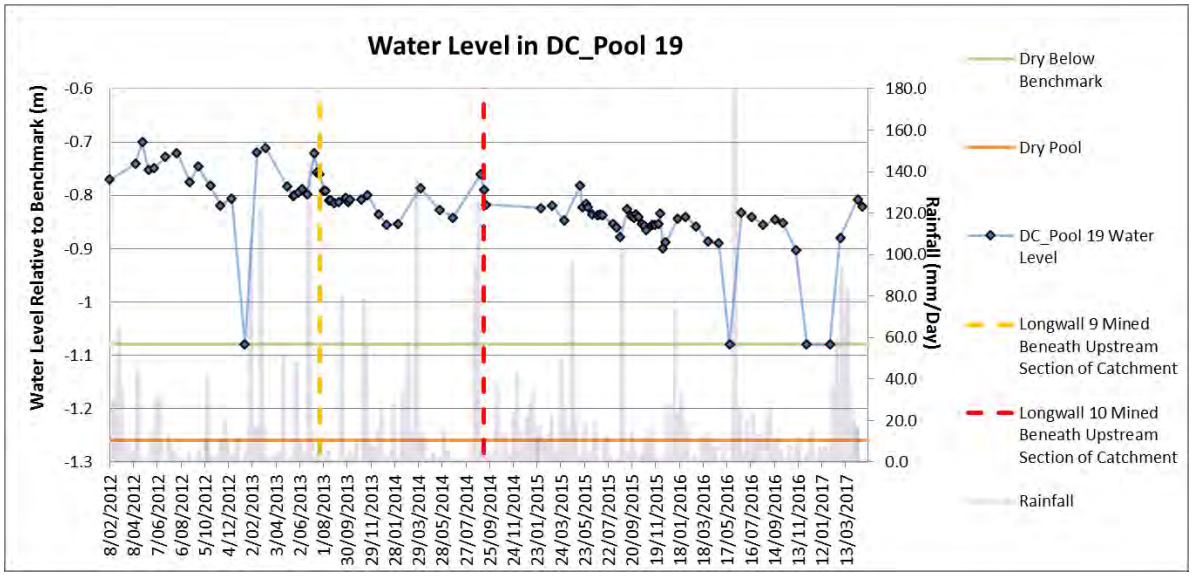
Pool 19 is a rockbar-based pool, approximately 18 m long and 5 m wide. The feature has multiple sections of pooling, the deepest at the base of the upstream rockbar.

Monitoring and Impacts to Feature

No surface impacts have been observed at Pool 19 (**Photo 148** and **Photo 149**). No reductions in Pool 19 water level has been observed as a result of the extraction of Longwalls 9 and 10 (**Graph 4-32**).

Recommendations

No remediation is recommended at this site.



Graph 4-32: Water level measurements relative to installed benchmark at DC_Pool 19.

Photo 148: DC_Pool 19, looking upstream. Taken on 6 May 2013

Photo 149: DC_Pool 19, looking upstream. Taken on 24 April 2017.


289650
289700
289750
6194150
6194100
6194050
6194000
Pool_31
Pool_32
DC_Pool_32
Pool_33
DC_Pool_33
LW9_007
LW9_006
Rockbar_33
Pool_34
DC_Pool_34
Pool_35
Rockbar_35
Den05
Den01a
Longwall 9
Longwall 10
Longwall 11
Longwall 12
Longwall 13
Den10
WC21
S CASTLE CREEK
0
25
50
Metres
N
E
S
W
IC Monitoring Points
Subsidence Impacts
Streamline
Pool
Rockbar
Access Track
Mine Workings
SOUTH32
Illawarra Coal
Dendrobium Area 3B
Donalds Castle Creek
Remediation Plan Surface
Impacts- Figure 4-15
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Author: J. Carlon
Approved: G. Brassington
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289550
289600
289650
6194450
6194400
6194350
6194300
Pool_25
Rockbar_25
Pool_26
Pool_27
Pool_28
DC_Pool_28
Pool_29
DC_Pool_29
Rockbar_29
Pool_30
Den01a
Den05
Longwall 9
Longwall 10
Longwall 11
Longwall 12
Longwall 13
Den10
WC21
S CASTLE CREEK
0
25
50
Metres
N
W
E
S
IC Monitoring Points
Subsidence Impacts
Streamline
Pool
Rockbar
Access Track
Mine Workings
SOUTH32
Illawarra Coal
Dendrobium Area 3B
Donalds Castle Creek
Remediation Plan Surface
Impacts- Figure 4-16
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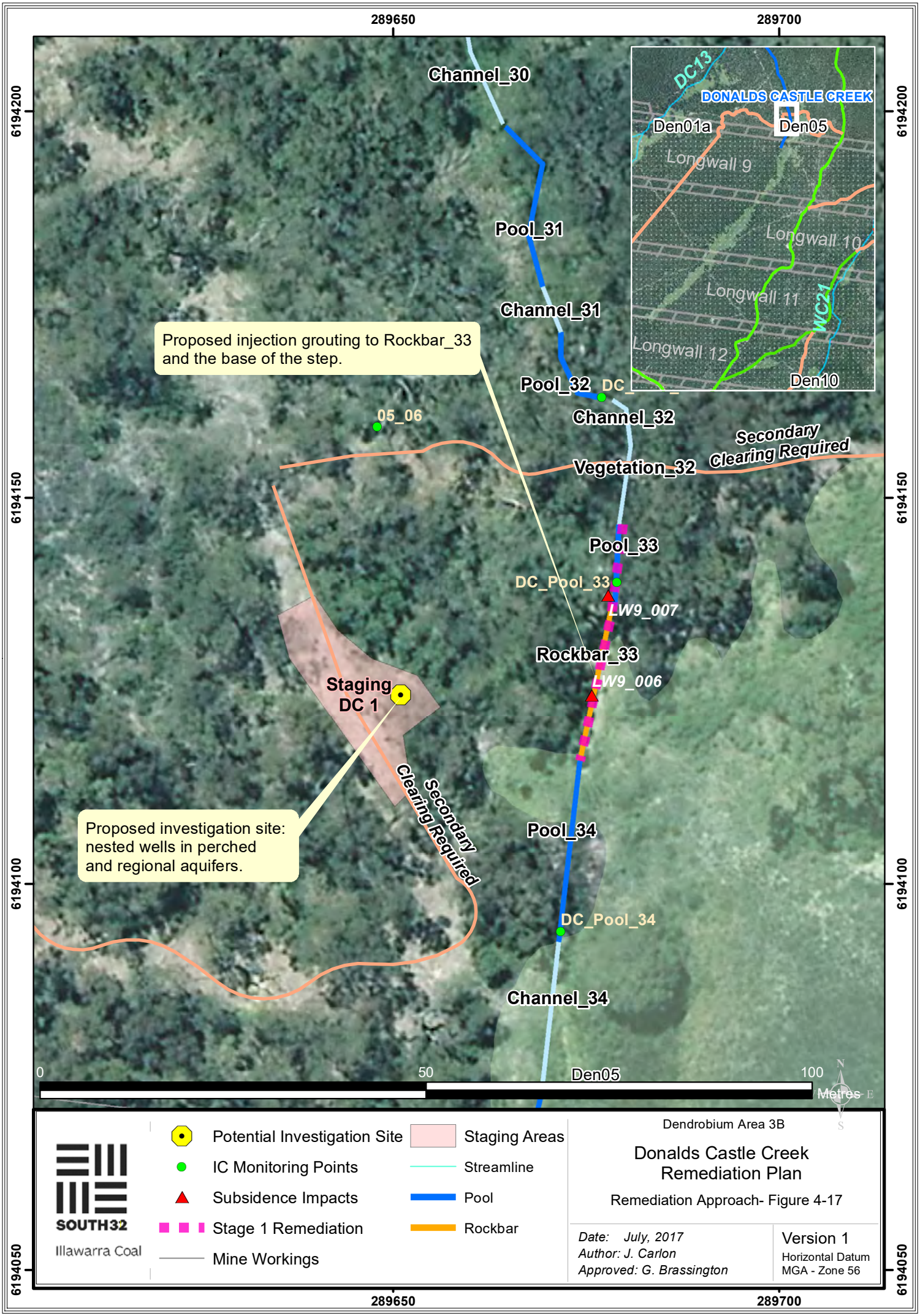
289650
289700
6194200
6194150
6194100
6194050
Channel_30
Pool_31
Channel_31
Pool_32
DC_
Channel_32
05_06
Vegetation_32
Secondary Clearing Required
Pool_33
DC_Pool_33
LW9_007
Rockbar_33
LW9_006
Staging DC 1
Secondary Clearing Required
Pool_34
DC_Pool_34
Channel_34
Proposed injection grouting to Rockbar_33 and the base of the step.
Proposed investigation site: nested wells in perched and regional aquifers.
DC13
DONALDS CASTLE CREEK
Den01a
Den05
Longwall 9
Longwall 10
Longwall 11
Longwall 12
WC21
Den10
0
50
Den05
100
Metres
N
S
E
SOUTH32
Illawarra Coal
Potential Investigation Site
IC Monitoring Points
Subsidence Impacts
Stage 1 Remediation
Mine Workings
Staging Areas
Streamline
Pool
Rockbar
Dendrobium Area 3B
Donalds Castle Creek Remediation Plan
Remediation Approach- Figure 4-17
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MGA - Zone 56

5 APPENDIX B – CONSULTATION LOG

Agency Comments	IMC Response
Resources Regulator – Response received 22/6/2021	
"The Rehabilitation Plan should be reviewed and updated on an annual basis including clear identification of changes in content, identification of new impacts requiring remediation and progress updates compared to the previous version(s)". **Status** - There is no commitment to update the Report on an annual basis. The next review in the document footer is scheduled for 12 May 2024 (a 3 year review period) **Recommendation** – a commitment to review and update the Report on a regular basis would be appropriate, whether time bound or subject to other triggers. I believe the review period should be less than 3 years.	The three-year review period is consistent with other Dendrobium Mine management plans. The Plan will be reviewed following the Rehabilitation Trial, ahead of the main rehabilitation scope (Section 3).
Specific Work Plans should be prepared and submitted for individual activities. This would include further detail about the works to be undertaken, including timing, completion criteria to be achieved, justification of access route, environmental controls and a cost/benefit analysis of the proposed works. **Status** - There is no indication that detailed site plans will be developed. **Recommendation** – site specific work plans should be developed, addressing key items such as ▪ details of the specific rehabilitation works to be undertaken ▪ environmental controls to be implemented ▪ the access route, including justification of the route selected ▪ an appropriate risk assessment, including assessment of financial and environmental risks. ▪ identification of completion criteria ▪ A Trigger Action Response Plan in the event that completion criteria are not achieved or not on trajectory. These would be done on a site by site basis prior to commencement of remediation works.	Section 3 and Section 2.3.2 updated to confirm that work plans will be developed ahead of rehabilitation works in each area. The work plan developed for the Rehabilitation Trial has been provided.
It is noted that the report does not reference the 'Height of Fracturing-Dendrobium Area 3B, March 2017" Report commissioned by DPE. As such, sections of the report still indicate the understanding that there will be no connection between surface and the mine workings. Ideally, the Height of Fracturing report should be referenced and relevant sections (such as Section 4.1 [of the Sept 2017 Report – *Section 2.2.1 of the May 2021 Revision*]) related to assumptions and actual/potential impacts updated accordingly.	Section 2.2.1 updated to reflect Mackie 2017 and Hebblewhite 2020.

Status - No significant update to the Report to address this comment has been identified other than removal of the following paragraph *"It was predicted that surface flows would be captured by the fracture network and re-emerge further downstream. This prediction is based on an assessment of the depth of fracturing resulting from valley closure movements and measurements of water balances during the modelled periods of recessional, baseflow and small storm unit hydrograph periods downstream of mining areas."* **Recommendation –** An update to Section 2.2.1 to provide additional context regarding the Height of Fracturing Report should be included.	
It is noted that LW14 has also undermined WC21 and DCC but the Report does not cover remediation of any impacts associated with LW14. **Recommendation** - The Report should clarify whether the exclusion of LW14 related impacts is due to there being no impacts requiring remediation or some other reason. If applicable, the Report should be expanded to cover LW14 as well.	On ground mapping has confirmed there is no watercourse over LW14 at WC21 or DCC.
Biodiversity & Conservation Division - Response received 30/06/2021	
2.2.2 Trigger Action response Plan The overwhelming majority of the bedrock bases of significant permanent pools and controlling rockbars will not seal naturally (see PAC 2010) and so if the objective is to rehabilitate the creek, extensive rehabilitation/remediation work is required in WC21 and Donald's Castle Creek. EES's Biodiversity Conservation and Science (BCS) group supports this trial remediation as it is hopeful that this will restore some of the pool water holding capacity and, if successful (or substantially so), could assist in reconnecting pools with flow from upstream. Close attention needs to be focussed on quantitative (not subjective) assessments of 'success'. This will require a sound scientific assessment of pool levels before and after rehabilitation and it is recommended that South32 consult BCS in such assessments.	Noted.
2.3.1. Remediation Techniques In regard to a previous subsidence rehabilitation program in the Georges River where there were impacts associated with mining directly under streams, BCS note that an independent review of pool water levels in these areas (Krogh 2017) identified that ongoing impacts remain but are being masked by a near continuous release of waste mine water from Brennan's Creek Dam. When these releases cease (as has occurred on several occasions over the last 5-10 years) many of these pools either drain or experience large drawdowns in pool levels (including Marhnyes Hole). The Bulli Seam PAC (PAC 2010) also expressed doubts as	Noted.

to whether this area had been successfully repaired. BCS scientists do not consider these areas to have been fully remediated and have concerns that a similar subjective assessment of remediation 'success' will be applied to WC21 and Donald's Castle Creek.	
Appendix A – Sites selection The remediation plan specifically identifies 41 pools in WC21 in the APPENDIX A – SITES Section. Of these, 19 (46.3% will have no remediation) and 8 (19.5%) will not have remediation 'at this stage'. This means that around 66% of pools in WC21 are not currently identified to be remediated. It is additionally noted that there appears to be no mention/description of WC21 pools 52 or 19. The remediation plan specifically identifies 7 pools in Donald's Castle Creek in the APPENDIX A – SITES Section (34, 33, 32, 30, 29, 23, 19). Of these, only pool 33 is proposed to have 'targeted remediation'. The other 6 (86%) are stated not to be remediated. It is additionally noted that there appears to be no mention/description of pools 31, 28-24, 22, 21 or 20.	The Plan targets those stream features with visible surface impacts, where there is limited ability for these fractures to seal naturally, and where there is access to a rock base. The results from initial rehabilitation sites will inform any approach taken at other tributary features where impacts have not been observed. This iterative approach focuses resources on sites of known impact. Some pools noted as not being in the Plan are downstream of the mining area or very small pools not targeted for observation in the SMP.
Assessment A – Sites selection BCS Science question the proposal for reassessment of surface flow conditions on the rockbar following return of surface flow to upstream features. BCS Science considers it highly unlikely that a return of connectivity and surface flow is possible with 66% of pools in WC21 receiving no remediation and only one pool in Donald's Castle Creek receiving remediation. Under such circumstance, BCS Science considers the current rehabilitation plan is unlikely to address the underlying issues (loss of pool water and lack of flow) for the majority of areas in WC21 and Donald's Castle Creek. Impacts to unremediated areas are likely to remain in perpetuity and highly unlikely to provide the aquatic habitat and flow that once existed in these areas. This has long-term implications for the persistence of threatened and endangered species (such as Littlejohn's tree frog, Giant Burrowing frog) in these areas.	As above, additional stream features will be considered following remediation at targeted sites. Following remediation, it will be possible to assess the suitability of applying the methods on the remaining sites.

Attachment 1- TARP

Appendix A – Watercourse Monitoring and Trigger Action Response Plan

Watercourse monitoring within Dendrobium Area 3 will be installed ahead of mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring will be conducted throughout the mining period and for at least 2 years following active subsidence or until the consequences of mining have stabilised. A review of post mining monitoring will be carried out in consultation with DPIE, WaterNSW and other relevant agencies where required. Where impacts are observed, the monitoring period will be extended and this will be reported in Impact Assessment Reports and End of Panel Reports. For Level 2 and 3 Triggers and for impacts exceeding prediction this review will be conducted in consultation with key agencies. The location of monitoring sites is indicated on the figures of the relevant areas WIMMCP.

Table 1.1 – Dendrobium Area 3 Watercourse Monitoring

	Monitoring Site	Site Type	Monitoring Frequency	Parameters
OBSERVATIONAL MONITORING				
AREA 3A	Sandy Creek and tributaries (including SC7 and SC10) Wongawilli Creek and tributaries *Refer to Figure 3-1 of 3A WIMMCP*	Observation and photo point monitoring: • Sites based on an assessment of risk • Streams and swamps • Pools and rockbars • Previously observed impacts that warrant follow-up inspection	• Monthly 2 years pre- and post-mining, weekly when longwall is within 400 m of monitoring site • Reference sites 6 monthly	Visual signs of impacts to creeks and drainage lines (i.e. cracking, vegetation changes, increased erosion, changes in water colour, soil moisture etc.) determined by comparing baseline photos with photos during the mining period Manual Field Testing: Key water quality parameters in pools analysed to identify any changes resulting from mining including pH, Temp, EC, DO and ORP Pool water levels to identify any changes resulting from mining. At suitable sites, pool water levels will be measured with a pressure transducer and continuous logger. A benchmark for manual readings will be installed at sites that are not suitable for a logger
AREA 3B	**Impact Sites** Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC18, WC16, WC15, WC12, WC9, WC7, LA5, LA4, LA3, LA2, LA1, ND1, ND2 and DC13 Swamps 5, 10, 11, 13, 14, 23, 35a, 35b, 1a, 1b, 8, 3 and 4 *Refer to Figures 2-2 to 2-11 and 2-25 to 2-32 of 3B WIMMCP* **Reference Sites** Wongawilli Creek, Sandy Creek, Gallaghers Creek, LC5[(1)], WC11, DC10, SC9A, CR36 and D10 Swamps 2[(1)], 7[(1)], 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88 *Refer to Figures 2-12 to 2-25, 2-28 to 2-30 and 2-33 to 2-35*			
AREA 3C	**Impact Sites** [(2, 3)] Wongawilli Creek, , WC20, WC21, WC22, WC23, WC24, , LC5[(1)] Swamps), ,), 9, , , 144 and 145 **Reference Sites** CR36 (Cordeaux River tributary)			
WATER CHEMISTRY				
AREA 3A	**Wongawilli Creek** WWU1, WWU4, WC_Pool 46, WWM2, WC_Pool 43b and Wongawilli Creek (FR6) WC17_S1 (Wongawilli Creek tributary) WC14_S1 (Wongawilli Creek tributary) WC13_S1 (Wongawilli Creek tributary) **Sandy Creek** SCk_Rockbar 5 (Sandy Creek adjacent to LW7) SC10_Rockbar 3 (Sandy Creek tributary) SC10C_Pool 1 (SC10 tributary) SC7_S1 (Sandy Creek tributary)	• Collect sample • Field water quality	• Monthly monitoring pre, during and post mining for two years	Lab. Analytes: • (incl. lab checks of pH, lab. check of EC, DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si)

	Lake Cordeaux Sandy Creek Arm (lake site) *Refer to Figure 3-2 of 3A WIMMCP*			
AREA 3B	**Wongawilli Creek** WWU1 (Wongawilli Creek headwaters) WWU4 (Wongawilli Creek upstream) WC_Rockbar 39 (Wongawilli Creek adjacent to LW17) WC Pool 49 (Wongawilli Creek adjacent to LW15) WC_Pool 46 (Wongawilli Creek adjacent to LW12) WWM2 (Wongawilli Creek adjacent to LW11) WC_Pool 43b (Wongawilli Creek downstream of LW9) Wongawilli Creek (FR6) (Wongawilli Creek downstream) WC21_Pool 5 (Wongawilli Creek tributary downstream of mining) WC21 Pools 30 and 53 (Wongawilli Creek tributaries over mining) WC15_Pool 28 (Wongawilli Creek tributary downstream of mining) WC15_Pool 9 (Wongawilli Creek tributary downstream of mining) WC15_Pool 2 (Wongawilli Creek tributary downstream of mining) WC7_Pool 1(Wongawilli Creek tributary downstream of mining) WC12_Pool 1 (Wongawilli Creek tributary downstream of mining) **Lake Avon** LA4_S1, LA4_S2, LA5_S1, LA5_S2, LA3 Pool 4, LA2 Pool 5, LA1 and LA_1 (Lake Avon tributaries downstream of mining) NDC_Pool 1 (Native Dog Creek downstream of mining) NDC_Pool 3 (Native Dog Creek downstream of mining) ND1_Pool 2 (tributary to Native Dog Creek downstream of mining) **Donalds Castle Creek** Donalds Castle Creek (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek Upstream approx. 1km from Cordeaux River) DC_Pool 22 (Donalds Castle Creek downstream of mining) DC13_Pool 2b (Donalds Castle Creek tributary downstream of mining) **Lake Cordeaux** *LC5_S1 (Reference Site)* *Refer to Figure 2-35* **Cordeaux River** CR36_S1 (Cordeaux River tributary Reference Site)			

AREA 3C	**Wongawilli Creek** WWU1 (headwaters; upstream of Area 3C) WWU4 (upstream of Area 3C) WC_S3 (adjacent to Longwall 20) Wongawilli Creek (FR6) (Wongawilli Creek downstream) WC_Pool 43b (adjacent to Longwall 20) WC_S1 (downstream of Longwall 21) WC20_S1 (downstream of Longwall 20) (4) WC24_S1 (downstream of Longwall 20) (4) WC26_S1 (downstream of Longwall 20) (4) WC21_Pool 5 (Wongawilli Creek tributary within the study area) **Donalds Castle Creek** Donalds Castle Creek (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek upstream of Cordeaux River confluence) **Lake Cordeaux** LC5_S1[1] (downstream of Longwall 20) **Cordeaux River** CR36_S1 (Reference site northeast of Area 3C)			
WATER FLOW				
Ref Sites	**O'Hares Creek** [NSW govt site] 213200 (O'Hares Creek @ Wedderburn) **Wongawilli Creek** WWU (Wongawilli Creek upstream)	• Some data (for reference sites) is provided by Water NSW		Other reference sites may be used depending on data availability and quality (e.g. Woronora River 2132101 and Bomaderry Creek 215016)
AREA 3A	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WC14S1 (Wongawilli Creek tributary) **Sandy Creek** SCL2(Sandy Creek at downstream) SC10S1 and SC10CS1 (Sandy Creek tributary) *Refer to Figures 3-5 of 3A WIMMCP*	• Pressure transducer with data logger • Flow gauging site (volumetric or flow meter). Low-profile weir or suitable natural rockbar control	• Continuous 1-hour logging intervals	Automatic pool water level measurements which are converted to flows by calculation of rating curves using measured creek cross sections/measured flows at the monitoring point. Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from similar reference sites (that are not impacted by mining).
AREA 3B	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WC21S1 (Wongawilli Creek tributary downstream of mining) WC15S1 (Wongawilli Creek tributary downstream of mining) WC12S1 (Wongawilli Creek tributary downstream of mining) **Donalds Castle Creek** DCU (Donalds Castle Creek @ FR6) DC13S1 (Donalds Castle Creek tributary downstream of mining) DCS2 (Donalds Castle Creek downstream of mining)			

	Lake Avon LA4S1 (Lake Avon tributary downstream of mining) LA3S1 (Lake Avon tributary downstream of mining) LA2S1 (Native Dog Creek tributary downstream of mining) NDCS1 (Lake Avon tributary downstream of mining) NDTS1 (Native Dog Tributary downstream of mining) **Lake Cordeaux** LC5S1 (Reference Site) **Cordeaux River** CR36S1 (Cordeaux River tributary Reference Site) *Refer to Figure 2-36 of 3B WIMMCP*			
AREA 3C	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WWL (Wongawilli Creek downstream) WCS1 (Wongawilli Creek downstream) WC20S1 (Wongawilli Creek tributary downstream of mining) WC24S1 (Wongawilli Creek tributary downstream of mining) WC26S1 (Wongawilli Creek tributary within the study area) WC21S1 (Wongawilli Creek tributary within the study area) **Donalds Castle Creek** DCU (Donalds Castle Creek downstream of mining) DCS2 (Donalds Castle Creek within study area) **Lake Cordeaux** LC5S1[1] (Downstream of LW20) **Cordeaux River** CR36S1 (Cordeaux River tributary Reference Site)			
AQUATIC ECOLOGY				
AREAS 3A, 3B and 3C	**Impact Sites:** Sites 2, 3, 4, X4, X5 and X6 (Wongawilli Creek) Sites X2 and X3 (WC21) Site X1 (Donalds Castle Creek) Sites 8, 9, 11, 12 and 13 (Sandy Creek Catchment) *Refer to Figure 2-57 of 3B WIMMCP* **Reference Sites:** Site 1 (Wongawilli Creek – until LW15) Site 5 (Wongawilli Creek) Site 14 (Donalds Castle Creek) Site 6 (WC21) Site 7 (Sandy Creek)	• Quantitative and observational monitoring	• Two baseline monitoring campaigns prior to mining during autumn and spring • Biennial monitoring during mining in autumn and spring • Biennial monitoring post mining for two years or as otherwise required • Biennial monitoring targets sites as mining progresses through the domain	Macroinvertebrate sampling and assessment using the AUSRIVAS protocol and quantitative sampling using artificial collectors In consideration of Adams Emerald Dragonfly, Giant Dragonfly and Sydney Hawk Dragonfly, individuals of the genus Austrocorduliidae and Gomphomacromiidae, Petalura are identified to species level if possible

	Sites 15 and 16 (Kentish Creek) *Refer to Figure 2-57 of 3B WIMMCP*			Fish are sampled by visual observations and dip netting in Area 3A, and sampled using baited traps in Area 3B
TERRESTRIAL ECOLOGY				
AREAS 3A, 3B and 3C	**Impact Sites:** DC13 (Donalds Castle Creek tributary) DC(1) (Donalds Castle Creek) WC15 and 21 (Wongawilli Creek tributaries) LA4A (Lake Avon tributary) ND1 (Native Dog Creek tributary) **Reference Sites:** WC10 and 11 (Wongawilli Creek tributaries) SC6, SC7-1, SC7-2, SC7A and SC8 (Sandy Creek tributaries) DC8 (Donalds Castle Creek tributary) NDC (Native Dog Creek)	• Standardised transects in potential breeding habitat for two threatened frog species, Littlejohn's Tree Frog and Giant Burrowing Frog	• Surveys are undertaken in optimal periods over the season (i.e. when frogs are calling and/or active at known sites)	Frog surveys are conducted along creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn's Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals at each site from one year to the next. Tadpole counts will also be undertaken as part of the breeding habitat monitoring transects. These transects are surveyed by walking down the creekline and counting all amphibians seen or heard on either side of the line

(1) *Reference site for Area 3B; impact site when mining commences in Area 3C.*

(2) *The proposed sites are designed to monitor each mapped pool/rockbar complex within the Study Area reach of Wongawilli Creek. Based on site inspections (August 2019), continuous monitoring will be implemented at suitable sites. A benchmark for manual readings will be installed at sites that are not suitable for continuous monitoring.*

(3) *Proposed sites within the Wongawilli Creek tributaries are subject to change based on further field inspections. The sites will target pool/rockbar complexes and steps.*

(4) *The proposed water chemistry monitoring sites are designed to detect changes to water quality, due to mining in Area 3C, within Wongawilli Creek. The proposed tributary sites (WC26, WC24 and WC20) aim to detect surface water inputs into Wongawilli Creek. Based on field observations, the Wongawilli Creek tributaries WC28, WC27, WC25, WC23 and WC22 were deemed as unsuitable for water chemistry sites due to a lack of site flows and the morphology of the tributaries.*

Table 1.2 – Dendrobium Area 3B Watercourse Impacts, Triggers and Response

OBSERVATIONAL-MONITORING		
Wongawilli Creek, Donalds Castle Creek and WC-WF54 **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences • Waterfall WC-WF54 – negligible environmental consequences General observation of streams in active mining areas when longwall is within 400m	***Level 1*** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area • Observation that a pool on a subject Creek is dry • Observation that the subject Creek has ceased to flow	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Observation that a single pool on a subject Creek is dry in consecutive monitoring events • Observation that two or more pools on a subject Creek are dry in a single monitoring event • Observation that the subject Creek has ceased to flow in consecutive monitoring event	• *Actions as stated for Level 1* • Carry out Water Flow Assessment Method D • Review monitoring frequency • Submit letter report to DPIE, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	• Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced

	• Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
	Exceeding Prediction • Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • Gas release results in vegetation dieback that does not revegetate • Gas release results in mortality of threatened species or ongoing loss of aquatic habitat • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Creek (FR6) • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Creek (FR6) • Rock fall at WC-WF54 or its overhang • Impacts on the structural integrity of WC-WF54, its overhang or its pool	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Native Dog Creek, ND1, ND2, WC15, WC12, WC7, LA1 and LA2 General observation of streams in active mining areas when longwall is within 400m	***Level 1*** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR

	Level 2 • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
WATER QUALITY		
Wongawilli Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences Wongawilli Creek (FR6) Baseline means: • pH 5.98 • EC 98.8 uS/cm • DO 89.5%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)

	Level 3 • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Donalds Castle Creek **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences Donalds Castle Creek (FR6) Baseline means: • pH 5.41 • EC 116.0 uS/cm • DO 85.6%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required

	• Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Lake Avon **Relevant Performance Measure(s):** • Lake Avon - negligible reduction in the quality of surface water inflows to Lake Avon Lake Avon tributary (LA4_S1) Baseline means: • pH 5.38 • EC 90.8 uS/cm • DO 89.9%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required

	• Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
POOL WATER LEVEL		
Wongawilli Creek and Donalds Castle Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences	***Level 1*** • Single pool on a subject Creek is observed as dry	• Continue monitoring program • Carry out Water Flow Assessment Method D. • Submit letter report to DPIE, MEG and Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Single pool on a subject Creek is observed as dry in consecutive monitoring events • Two or more pools on a subject Creek are observed as dry in a single monitoring event	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)

	Level 3 • Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BD, DPIE, MEG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Waterfall WC-WF54 **Relevant Performance Measure(s):** • Waterfall WC-WF54 – negligible environmental consequences	***Exceeding Prediction*** • Fracturing in Wongawilli Creek within 30m of the waterfall which results in observable flow diversion • Fracturing in Wongawilli Creek which results in observable flow diversion from the lip of the waterfall	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Monitoring	Trigger	Action
SURFACE WATER FLOW		
Wongawilli Creek and Donalds Castle Creek **Lake Avon and Cordeaux River** **Relevant Performance Measure(s):**	***Level 1*** • A) Lower flow than expected (additional 10-15% of days where Q% lower than Reference Q%) • B) 5-10% increase in cease-to-flow frequency beyond natural) • C) Reduction in Q50 (10-15% beyond natural)	• Continue monitoring program. • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.

• Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences • Lake Avon - negligible reduction in the quantity of surface water inflows to Lake Avon[1] • Cordeaux River - negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek[2] **Surface water flow Reference sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek at Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016) NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019). Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from the reference sites. *Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.*	***Level 2*** • A) Lower flow than expected (additional 15-20% of days where Q% lower than Reference Q%). • B) 10-20% increase in cease-to-flow frequency (beyond natural) • C) 15-20% reduction in Q50 (beyond natural) • D) Observation that the subject Creek has ceased to flow at spatially consecutive monitoring sites.	• *Actions as stated for Level 1* • Review monitoring frequency. • D) → carry out Water Flow Assessment Method D. • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3 • A) Lower flow than expected (additional >20% of days where Q% lower than Reference Q%) • B) >20% increase in cease-to-flow frequency (beyond natural) • C) >20% reduction in Q50 (beyond natural)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW. • Implement additional monitoring or increase frequency if required. • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success. • Review relevant TARP and Management Plan in consultation with key agencies.
	Exceeding Prediction Measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".	• *Actions as stated for Level 3* • Investigate reasons for the exceedance. • Update future predictions based on the outcomes of the investigation. • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent.

[1] Surface water inflows calculation = [Impacts at gauged catchments (LA1 + LA2 + LA3 + LA4 + LA6+ NDT1 + ND2) + estimated impacts at ungauged but undermined catchments (e.g. LA5)] / [total inflow to LA].
[2] Flow reduction as determined from measured at flow gauging station WWL_A.

Tributaries of Wongawilli Creek and Donalds Castle Creek and other affected watercourses not subject to performance measures **Surface water flow Reference sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek and Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016) NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019). Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from the reference sites. *Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.*	***Level 1*** • A) Lower flow than expected (additional 10-20% of days where Q% lower than Reference Q%) • B) 5-10% increase in cease-to-flow frequency (beyond natural) • C) 10-20% reduction in Q50 (beyond natural)	• Continue monitoring program. • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.
	Level 2 • A) Lower flow than expected (additional 20-30% of days where Q% lower than Reference Q%) • B) 10-20% increase in cease-to-flow frequency (beyond natural) • C) 20-30% reduction in Q50 (beyond natural)	• *Actions as stated for Level 1* • Review monitoring frequency. • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3 • A) Lower flow than expected (additional >30% of days where Q% lower than Reference Q%) • B) >20% increase in cease-to-flow frequency (beyond natural) • C) >30% reduction in Q50 (beyond natural)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW. • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success. • Review relevant TARP and Management Plan in consultation with key agencies.
AQUATIC ECOLOGY		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 8 sites • Donalds Castle Creek catchment – 1 site	***Level 1*** • Reduction in aquatic habitat for 1 year	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2	• *Actions as stated for Level 1*

Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences	• Reduction in aquatic habitat for 2 years following the active subsidence period	• Review monitoring frequency • Submit letter report to DPIE, BCD, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Reduction in aquatic habitat for >2 years following the active subsidence period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
TERRESTRIAL FAUNA – THREATENED FROG SPECIES		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 2 sites • Donalds Castle Creek catchment – 2 sites • Lake Avon tributary – 1 site • Native Dog tributary – 1 site **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences	***Level 1*** • Reduction in habitat for 1 year	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Reduction in habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, BCD, MEG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Reduction in habitat for > 2 years following the active subsidence period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and Water NSW (i.e. may be after mining induced

		movements and impacts are complete), including monitoring and reporting on success

Department of Planning, Industry and Environment (DPIE)

Biodiversity and Conservation Division (BCD)

Department of Mining, Exploration and Geosciences (MEG)

WaterNSW

Attachment 2- Tracer Testing

HGEO Pty Ltd ■ ABN 64 614 389 178
PO Box 312, Lindfield NSW 2070 ■ Phone: 0427 004 2338
www.hgeo.com.au ■ stuart.brown@hgeo.com.au

DATE:	13 February 2019	
TO:	Josh Carlon	cc:
	South32 Illawarra Coal	
FROM:	Stuart Brown	
RE:	**WC21 Rehabilitation Project: Tracer test preliminary specification**	
OUR REF:	D19320	

1. Introduction

Dendrobium Mine is located approximately 65 km southwest of Sydney in the Southern Coalfield. Longwall mining has occurred in the Wongawilli Seam at the mine since 2005. Extraction of Longwalls 9 to 13 in Area 3B has been completed, with Longwall 14 currently in progress. The eastern extents of Longwalls 9 to 12 have mined under the WC21 tributary to Wongawilli Creek, leading to changes in surface water flow characteristics attributed to mine subsidence.

In 2016, Illawarra Coal commenced groundwater investigations into the interactions between mining activities and the WC21 watercourse. The scope of investigations is outlined on the WC21 and Donalds Castle Creek Rehabilitation Plan (South32 2017). A key part of the investigation is to characterise the near-surface fracturing beneath WC21 and determine its effects on the hydrological regime. The scope includes drilling and testing of boreholes, installation of multi-level piezometers, and tracer testing. The results of drilling investigations and subsequent monitoring at locations above Longwalls 10 and 12 have been reported previously (SCT 2016; HGEO 2018). This memo provides background and preliminary specifications for the proposed stream tracer testing.

1.1 Tracers

In hydrology, tracers are substances that are contained in water that can be measured and used to infer hydrological processes such as flow-paths and contributions from various water sources (Leibundgut & Seibert 2011; Cook 2015). Hydrological tracers are divided into two broad categories:

1. ***Environmental tracers***: Naturally occurring chemical and isotopic markers that can be used to understand hydrological processes on broad range of scales and timeframes: e.g. stable and radiogenic isotopes, dissolved gasses and dissolved ions).
2. ***Artificial tracers***: Compounds intentionally added to hydrological systems in planned experiments. Their application is generally more limited in terms of spatial extent and timeframe (typically sub-catchment and < 1 year). On the other hand, artificial tracers can provide specific information about systems because the tracer source and conditions of release are precisely known. Commonly used artificial tracers include fluorescent dyes, dissolved salts, isotopes, dissolved gasses and particulate matter.

Natural and artificial tracers have been used successfully to assess surface water and groundwater systems on the Illawarra Plateau. For example, fluorescent dye and salt tracers were used to assess hydrological changes in Waratah Rivulet due to longwall subsidence at Metropolitan Mine (Parsons Brinckerhoff 2010). Bore-hole tracer tests were carried out above Longwall 9 at Dendrobium Area 3B both prior to and following extraction of the longwall top asses changes in groundwater flow conditions

and the height of connected fracturing (Parsons Brinckerhoff 2015). These studies were carried out under conditions analogous to those at WC21 and therefore the observations and field techniques used in those studies are directly relevant to this investigation. A wealth of practical advice and supporting data for performing tracer tests is provided by Aley (2002).

1.2 Context and constraints

The scope and scale of the test is largely constrained by ease of access to the watercourse and the current flow conditions. At the time of writing it is understood that creek flow has been diverted and flow has ceased upstream of Pool 10, except for brief periods of flow after heavy rain. Pool 10 is located just to the north of Longwall 9. Pool 24 is located above the mid-line of Longwall 10 within the flow-diverted (losing) section of WC21. The pool is known to hold water for short periods following rainfall events and has recently been equipped with a datalogger that measures water level at 30-minute intervals. There is good vehicular access to the creek via a track that crosses between Pool 24 and Pool 25.

The fate of diverted flow is not yet known but is assumed to flow through fracture networks to emerge further down-stream (on WC21 and/or Wongawilli Creek), and/or be drawn into underground workings. Distinguishing between these possible fates is critical to understanding the effect of mining on the catchment water balance and is the aim of this tracer investigation.

1.3 Objectives

With reference to the WC21 Remediation Plan, the role of tracer testing is to "estimate the diversion of flow from WC21 over a 'full-path' or 'intermediate distance' as advised by experts": In light of the conditions outlined in Section 1.2 (above), specific objectives for the tracer testing, defined here, are:

- to observe the location(s) of flow diversion along the wetting front down-stream of the tracer injection point;
- to determine if and where the flow tracer re-emerges, either:
    - on WC21, downstream of the tracer injection point, and/or;
    - on Wongawilli Creek adjacent to, and downgradient of the tracer injection point, and/or;
    - in underground workings of Area 3B over which WC21 flows.
- to use field measurements of tracer concentration to determine the proportion of flow that has returned to down-gradient stream reaches or underground workings.

2. Proposed tracer test

2.1 Overview

The tracer test will be carried out as follows:

1. Baseline monitoring will commence in the week prior to the planned test. The monitoring will include continuous flow (at existing flow monitoring sites), EC, pH, water fluorescence, and deployment of activated carbon bags at nominated sites.
2. The tracer will be deployed at one or more of the small fracture-hosted pools on Rock bar 24 when weather and stream flow conditions are favourable.
3. Monitoring will be carried out at designated downstream monitoring points using automated loggers, manual observations and activated carbon sampler bags. Key observation points will be at existing flow gauge sites (WC21S1, WCS1, Wongawilli Creek FR6), and underground

(Area 3B). Supplementary sites will be established at most permanent and currently monitored pool sites.

Further detail is provided below.

2.2 Tracer

A wide variety of artificial tracers have been used in hydrological studies. An ideal tracer should be:

- easy to transport, mix and deploy
- non-toxic
- detectable over a wide range of concentrations
- conservative in the aquatic environment (non-reactive and non-sorptive)
- stable under prevailing light and pH conditions
- and preferably visible to the naked eye

For this investigation it is recommended that the tracer comprise **a combination of Fluorescein and sodium chloride salt solution**.

Illawarra Coal owns two Cyclops 7 logging fluorometers with interchangeable sensors for Fluorescein and Rhodamine WT. Fluorescein is a preferred dye for tracer studies, given its wide detection range and favourable sorption characteristics (Aley 2002). However, it was noted during the Longwall 9 borehole tracer tests, that intermittent false detections of fluorescein in goaf water were likely due to the use of the dye as an additive to hydraulic fluids underground (since none of the other tracers used in the experiment were detected). Provided there is adequate baseline monitoring at Area 3B a significant tracer breakthrough should be detectible above the low-level and intermittent interferences from hydraulics fluids. Alternatively, a second test could be carried out using Rhodamine WT.

Breakthrough of fluorescein tracer will be observed directly as a vivid fluorescent green colouration, provided that the concentration is above the visible threshold (7 - 140 parts per billion; ppb). Fluorescein is detectible using a laboratory fluorimeter or field sensor down to very low levels (0.0005 ppb), far below the visible threshold, and over many orders of magnitude of concentration (and significant dilution). Fluorescein is sensitive to degradation by sunlight (compared with Rhodamine WT), but is more resistant to loss by adsorption to clay minerals than Rhodamine WT (Aley 2002). Given that much of the initial (post-diversion) travel path will be underground and large portions of the streams are shaded by trees, photo-degradation is not expected to be significant.

Figure 1. Fluorescein tracer solution used in the Longwall 9 investigation (2013)

The addition of a salt tracer allows breakthrough to be observed and concentrations measured using more than one method. Relative salt concentrations can be monitored using an Electrical Conductivity (EC) probe when the concentration is above the stream background. When combined with adequate flow gauging, concentration time-series curves can be used to determine the percentage of tracer recovered at the monitoring point. The same calculation is theoretically possible using dye measurements. However, its is common for a portion of the dye to be lost along the flow path to adsorption and photo-degradation.

An important consideration is the relative density of the salt solution. The concentration of salt should be as high as possible to allow detection over a large dilution range, but not so high as to cause significant density stratification in stream pools or fracture systems. Density stratification is unlikely to be a significant issue at salt concentrations of less than 3000 mg/L; a solution of 3000 mg/L NaCl would be <0.2% more dense than fresh stream water – a magnitude similar to the change in density with temperature over the range 10°C – 25°C.

2.3 Tracer deployment

The combined salt / dye tracer should be deployed at one or more of the small fracture-hosted pools on Rock bar 24. Multiple fractures and uplift have been observed at Rockbar 24 (Impact LW10_011) and flow diversion is evident with a general decline in surface water over the rockbar. Due to the nature of the observed impacts and excellent track access, the rockbar has been selected for rehabilitation trials (South32 2017).

The tracer will be prepared on-site at Staging Area 1. A 10 kL tank will be used to mix the tracer prior to the test which should be carried out under favourable conditions. Ideally the tracer would be deployed 2 to 3 days after a moderate rainfall event as pool levels are receding (and no major rainfall is forecast for the next few days). Field staff should ensure that the crystalline salt has completely dissolved prior to use.

Specifications of the tracer will be confirmed closer to the tracer test. However nominally it would consist of:

- 2000 mg/L salt (NaCl), equating to 20 kg in 10 kL.
- 120 mg/L Fluorescein, equating to 1.2 kg of Fluorescein powder in 10 kL.

The tracer will be pumped from the 10 kL tank to the target site (Rockbar 24) using a suitable transfer pump and lay-flat hose. If possible, the rate of pumping should be monitored using a suitable in-line flow meter or a V-notch weir.

It is important to test the tracer solution prior to the tracer test as follows:

- record field parameters using a hand-held water quality meter (EC, pH, DO, Temperature)
- collect a grab sample of the tracer in a large brown bottle and keep the bottle in a fridge for future reference.
- submit a laboratory sample for the standard analytical suite (or at a minimum: EC, pH, TDS, Major ions)
- make a set of standards from the tracer solution sample (above) by preparing known dilutions (e.g. 1, 0.1, 0.01, 0.001 using the same makeup water). The theoretical salt and dye concentrations can be calculated.
- for each standard solution record:
    - field EC & pH
    - fluorescence using a field spectrophotometer and data-logging fluorometers
- an activated carbon bag should be submerged in a subsample of each standard for 1 hour, then carefully bagged and sent to Ozarc Laboratories for analysis.

In addition, samples should be collected of:

- the stream or river water used to make the tracer;
- standing water in Pool 24 (if different to the above)

Both samples should be analysed as per the standard solutions above, and sent for laboratory analysis (EC, TDS and major ions).

2.4 Monitoring

Monitoring locations and methods are summarised in Table 1. The primary monitoring method will be activated carbon samplers, since they will record any dye tracer that has passed at any time during the monitoring period. The sampling bags will be deployed at all monitoring locations and changed periodically.

The bags should be secured so that they sit within a deep flowing part of the stream and preferably suspended above the creek bed so they are less likely to be covered by debris and sediment. Two bags should be deployed at each location in case one is lost or damaged. The bags should be deployed in such a way as to be protected from direct sunlight and damage from abrasion. Previous tests at Dendrobium used 50 mm PVC pipe with holes drilled in it to protect the bags from damage.

Continuous measurements of dye concentration will be made using the two Cyclops 7 logging fluorometers at selected locations, preferably those with flow gauges. The loggers should be set to log as frequently as possible over the estimated test length. Continuous measurements of water EC will be made using EC loggers at selected pools, including those equipped with flow gauges to allow quantitative assessment of tracer recovery.

If possible, field staff should be located at key pools to observe (and photograph) tracer breakthrough when and if it occurs. The time and duration of the tracer passing should be noted. It may be possible to follow the tracer upstream to one or more discharge points along the stream bed.

Utmost care should be taken not to cross-contaminate sampling bags or monitoring equipment with traces of dye power of liquid.

Table 1. Proposed monitoring locations for WC21 tracer testing

Monitoring location	Observation and manual sampling	Activated carbon sampler	EC / Level logger	Cyclops 7 Logging Fluorometer	Flow gauge
WC21					
WC21_Pool 24	Y				
WC21_Pool 10	Y	Y	Y		
WC21_Pool 9		Y			
WC21S1 / Pool 5		Y	Y	Y	Y
Wongawilli Creek					
WC_Pool 43a		Y			
WC_Pool 43b		Y			
WC_Pool 42a		Y			
WC_Pool 42b		Y			
WC_Pool 41		Y			
WC_S1		Y	Y	Y?	
Wongawilli Ck (FR6)	Y	Y	Y		Y
Underground					
DWS203 (TG9 Pump Stn)	Y	Y			Water Balance

2.4.1 Baseline monitoring

At least one round of sampling using the carbon bags should be carried out prior to the tracer release. This is so that any baseline fluorescence associated with dissolved organic material in the creeks can be identified and quantified.

The Cyclops 7 loggers should be calibrated and set up to log over the baseline period also. Depending on the available memory and battery life onboard the logger, they could be left to log continuously over the baseline period and the tracer test. If memory and/or battery life is insufficient, then they should be downloaded and re-set immediately prior to the tracer release. In the case of the EC loggers, they should be set to log from the baseline period continuously through the tracer test (again if they have sufficient memory).

At each of the gauging sites, field parameters should be measured, and water samples should be collected and submitted for standard chemical analysis.

2.4.2 Monitoring after tracer release

All activated carbon bags should be replaced prior to the tracer preparation and release. Activated carbon bags should be replaced according to the following schedule:

- Baseline: 1 week prior to tracer
- Replace prior to tracer release
- First round: 1 day after tracer release
- Second round: 3 days after tracer release
- Third and subsequent: At weekly intervals

Automated dataloggers should be set to log continuously for at least two weeks after tracer release at the highest possible frequency. The Cyclops 7 loggers may need to be downloaded and re-set and battery checked at regular intervals.

2.4.3 Option of a two-stage test

The above methodology could be further refined by carrying out a trial (Stage 1) tracer test using fluorescent dye only to observe (visually) if and where tracer breakthrough occurs. If the breakthrough locations and times are approximately known, then the monitoring locations and intervals could be optimised to recover quantitative information from the Stage 2 (dye + salt) tracer test. Different dyes could be used for the Stage 1 and Stage 2 tests to avoid interference between the two tests.

2.5 Preliminary tasks

- Contact Ozark Underground Laboratories and arrange for delivery of tracer dyes and activated carbon samplers. It is also worthwhile discussing the planned tracer test with the lab as they may be able to provide advice (as they have in the past).
- Assemble and test the Cyclops 7 loggers
- Calibrate the Cyclops 7 loggers using standard dye solutions (these will need to be prepared)
- Assemble and test EC/level loggers
- Obtain water tank(s), pumps, lay flat hose etc
- Obtain sample bottles

3. References

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Department of Planning and Environment

Our ref: DA60-03-2001-PA-186

Nicola Curtis
Principal Minine Approvals
Illawarra Metallurgical Coal

Via: NSW Major Project Portal (ref: DA60-03-2001-PA-186)

24/05/2023

Subject: Dendrobium Mine (DA60-03-2001) - WC21 and Donalds Castle Creek Rehabilitation Plan (Version 4)

Dear Nicola

I refer to the above plan which has been revised to report on the progress of rehabilitation trials undertaken at Pool 24 and Pool 25 during December 2022 and January 2023.

The Department notes that in accordance with the approved WC21 and Donalds Castle Creek Rehabilitation Plan (Version 3), Illawarra Metallurgical Coal is currently monitoring the pools for a period of 6 months prior to assessing the outcome of the trial. An update to the plan will be required to report on the results of the trial.

The Department also notes the enclosed advice received from the Biodiversity and Conservation Division (BCD) regarding the broader rehabilitation plan. The Department considers that the matters raised by BCD should be considered and responded to as part of the next revision of the WC21 and Donalds Castle Creek Rehabilitation Plan.

Accordingly, as nominee of the Planning Secretary, I approve the WC21 and Donalds Castle Creek Rehabilitation Plan (Version 4 dated 31 January 2023) on the condition that a further revision of the plan is submitted to the Department following the six-month monitoring period, and no later than 31 August 2023. The revised plan is to include consideration of the enclosed advice from BCD.

If you wish to discuss the matter further, please contact Gabrielle Allan on 9585 6078.

Yours sincerely

JEvans

Jessie Evans
Director, Resource Assessments
Resource Assessments

As nominee of the Planning Secretary