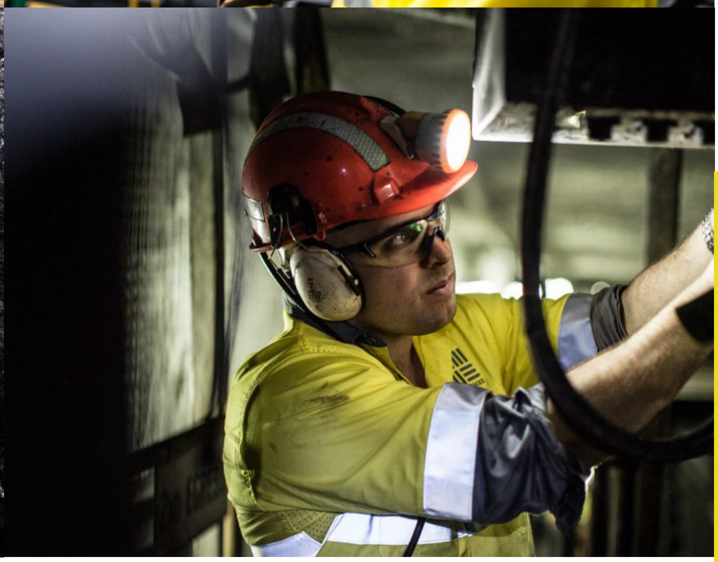
SOUTH32

DENDROBIUM
AREA 3B

AUGUST 2020



AREA 3B

SWAMP IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

Table of Contents

Tables

Figures

Appendices

Review History

Revision	Description of Changes	Date	Approved
A	New Document-DRAFT	August 2012	GB
B	Updated with comments from agencies – post submission	October 2012	GB
C	Updated with comments from agencies – post submission	November 2012	GB

1	Updated to address SMP Conditions of Approval 6 February 2013	May 2013	GB
1.1	Updated to address Agency Feedback May 2013	October 2013	GB
1.2	Updated to address Agency Feedback December 2013 – March 2014	June 2014	GB
1.3	Updated to address DPE Feedback October 2014	December 2014	GB
1.4	Updated to address DPE Feedback June 2015	June 2015	GB
1.5	Updated to address Longwalls 14 – 18 requirements	October 2015	GB
1.6	Updated to address Longwall 14 – 15 Conditions	October 2017	GB
1.7	Updated to address Longwall 16 Conditions and IEP (2018)	March 2019	GB
1.8	Update to address Longwall 17 SMP Approval Conditions and IEP (2019a and b)	February 2020	GB
1.9	Updated to address Longwall 18 SMP Application	August 2020	GB

Persons involved in the development of this document include:

Name	Title	Company
Cody Brady	Principal Approvals	Illawarra Metallurgical Coal
Gary Brassington	Approvals Manager	Illawarra Metallurgical Coal
Josh Carlon	Coordinator Environment	Illawarra Metallurgical Coal

1 INTRODUCTION

1.1 Project Background

Illawarra Metallurgical Coal (IMC) operates underground coal mining operations at Dendrobium Mine, located in the Southern Coalfield of New South Wales. Longwalls from the Wongawilli Seam are currently being extracted from Area 3B.

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 underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of s75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and required the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from cracking and diversion of surface water as a result of the proposed mining. These impacts included 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 Dendrobium Underground Coal Mine and associated surface facilities and infrastructure under Section 75W of the EP&A Act.

On 4 October 2012 IMC submitted a Subsidence Management Plan (SMP) for approval from the Director Generals (now Secretaries) of the Department of Planning and Infrastructure (which became the Department of Planning and Environment, [DPE]) and Trade and Investment (T&I). 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.

On 4 March 2016, IMC submitted a SMP, for Longwalls 14 – 19, for approval from the Secretary of the DPE. Conditional approval, for Longwalls 14 and 15, was granted by the DPE on 16 December 2016. Schedule 3, Condition 7 of the approval, stated the requirement for additional approval of the Secretary for Longwalls 16 to 18.

On 25 October 2017, the DPE requested a standalone application for Longwall 16 for approval consideration. IMC submitted the Longwall 16 SMP application to the DPE on 14 November 2017. The DPE established the Independent Expert Panel (IEP), on 26 February 2018, to provide informed expert advice on the impact of mining activities in the Greater Sydney Water Catchment Special Areas, with a particular focus on risks to the quantity of water in the Catchment. The Longwall 16 SMP was approved by the Secretary of the DPE on 30 May 2018.

Schedule 3 Condition 7 of the Longwall 16 SMP Approval states the requirement of approval by the Secretary of DPE prior to gateroad development for, or the extraction of, Longwalls 17 to 18.

On 25 March 2019, IMC submitted a SMP application to Department of Planning, Industry and Environment (DPIE) for Longwall 17, for approval from the Secretary. The Longwall 17 SMP was approved by the Secretary of DPIE on 11 July 2019.

1.2 Scope

The SIMMCP has been prepared to comply with the Dendrobium Development Consent and the SMP Approval in respect to swamp management within Dendrobium Area 3B.

The Dendrobium Development Consent requires a SIMMCP subject to Schedule 3, Condition 6 as provided below.

> 6. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:
>
> (a) demonstrate how the subsidence impact limits in condition 5 are to be met;
>
> (b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) of each Area 3A Longwall on Swamp 15a;
>
> (c) include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function;

(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on swamps, 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 headwater and valley infill swamps separately and address each swamp individually;

(f) be prepared in consultation with DECC, SCA and DPI;

(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 swamps in the relevant Area; and

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

The SMP Area for the SIMMCP is defined in accordance with Mine Subsidence Engineering Consultants (MSEC] 2020), as the surface area that is likely to be affected by the mining of Longwall 18 in Dendrobium Area 3B. The extent of the Longwall 18 SMP Area has been calculated by combining the areas bounded by the following limits:

- A 35 degree angle of draw from the extents of Longwall 18;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of Longwall 18;
- The natural features within 600 m of the extent of the longwall mining area, in accordance with Condition 8(d) of the Dendrobium Development Consent; and
- Features which are expected to experience either far-field horizontal movements, or valley related movements, and which could be sensitive to these movements.

The swamps located outside the extent of longwall mining which could experience far-field or valley related movements, and could be sensitive to these movements, have been identified and included in the assessments provided in this report. The SIMMCP also provides updated monitoring, management and contingency for the Area 3B mining domain.

Swamp 15a, as defined in the Dendrobium Development Consent, is not within the defined area of study relative to the proposed extents of Longwall 18.

A number of smaller swamps or swamp-like vegetation are scattered throughout the Study Area. These small patches of swamp like vegetation are often too small to map as discrete swamps and occur in small areas of impeded drainage that contain a mix of plant species common to the upland swamps and fringing eucalypt woodlands of the region. These patches of vegetation have not been identified in the existing swamp mapping of the Study Area (**Figure 1-1**) and field observations indicate that these patches of vegetation occur randomly in the landscape and are not typically restrained by sandstone rock bars. Further, these vegetation patches do not occur in valley floors and therefore are not likely to be subject to valley closure movements resulting from longwall extraction (Niche 2020).

A plan of the swamps as provided in the Area 3B SMP Application is shown as **Figure 1-1**. This swamp mapping was undertaken by IMC using air photo interpretation and includes Fringing Eucalypt Woodland, Banksia Thicket, Sedgeland-heath complex and/or Tea Tree Thicket and other areas consistent with the geomorphology of upland swamps. **Figure 1-1** is provided for consistency with the SMP Application. **Figure 3-43** shows detailed mapping of Banksia Thicket, Sedgeland-heath complex and Tea Tree Thicket, being listed as the Costal Upland Swamp Endangered Ecological Community (EEC). Niche (2020) undertook further detailed mapping which included ground-truthing and verification as part of the terrestrial ecology assessment for Longwall 18 SMP application. Additional areas of swamp vegetation identified during these surveys are presented in **Figure 3-89**.

This SIMMCP 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 to swamps should mining induced degradation to the swamp be observed or measured (including contingency measures); and

- Access to swamps and rehabilitation of access routes to swamps.

The SIMMCP does not provide detailed reporting of monitoring data. These requirements are fulfilled by the EA (Cardno 2007), Area 3B SMP (2012), End of Panel (EoP) Reports, Annual Environmental Management Reports (AEMRs) and other reports.

1.3 Objectives

The objectives of this SIMMCP are to identify at risk swamp features and characteristics within the Dendrobium 3B Longwall 18 Study Area (**Figure 1-1**) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on swamps. The SIMMCP is to comply with the Area 3B SMP Approval Conditions including Schedule 3, Condition 13 Performance Measures for Area 3B. The SIMMCP also provides updated monitoring, management and contingency for the Area 3B mining domain.

1.4 Consultation

The SIMMCP has been developed by IMC, in consultation with:

- DPIE; the Biodiversity Conservation Division within the Department (BCD), MEG; and WaterNSW (previously SCA).

The SIMMCP and other relevant documentation are available on the IMC website (Condition 11 Schedule 8*:* DA 60-03-2001).

1.4.1 SMP and SIMMCP Consultation

A number of submissions were made in relation to the Area 3B SMP and the SIMMCP, including detailed submissions from OEH (26 October, *an undated submission* and 13 December 2012) and WaterNSW (December 2012 *undated*). IMC provided a detailed response to submissions 20 December 2012.

1.4.2 2013 SMP Condition 12 SIMMCP Revision

The Secretary of the DPE approved the Dendrobium Area 3B SMP (including the SIMMCP) 6 February 2013. Condition 12 of this approval requires the SIMMCP be reviewed to the satisfaction of the Secretary by 31 May 2013. The SIMMCP was redrafted to take into account feedback during the SMP consultation period as well as the conditions and performance measures included in the Area 3B SMP Approval. The revised SIMMCP was provided to DPE, OEH, NoW, WaterNSW and T&I 10 May 2013. The SIMMCP (Rev 1.4) was approved by the Secretary 10 August 2015.

1.4.3 Agency Workshop – May 2013

The Wollongong Office of T&I hosted a joint Agency workshop with IMC to discuss the SIMMCP. The workshop was held 27 May 2013 with the following agencies attending DPE, OEH, WaterNSW and T&I. Following the workshop, the agencies provided submissions:

- Minutes of the workshop 5 June 2013;
- DPE 4 June 2013; WaterNSW 13 June 2013; and OEH 14 June 2013.

The SIMMCP was revised on the basis of the agreed outcomes from this workshop and taking the above submissions into account.

1.4.4 Agency Workshop – December 2013

The Wollongong Office of T&I hosted a second joint Agency workshop with IMC to discuss the SIMMCP. The workshop was held 16 December 2013 with the following agencies attending DPE, OEH, WaterNSW and T&I. Following the workshop, the agencies provided submissions:

- T&I 10 January 2014;
- OEH 17 January 2014;
- WaterNSW 7 February 2014; and
- DPE 10 October 2014.

The SIMMCP has been revised on the basis of the agreed outcomes from the workshop and taking the above submissions into account.

1.4.5 2016 SMP Condition 15 SIMMCP Revision

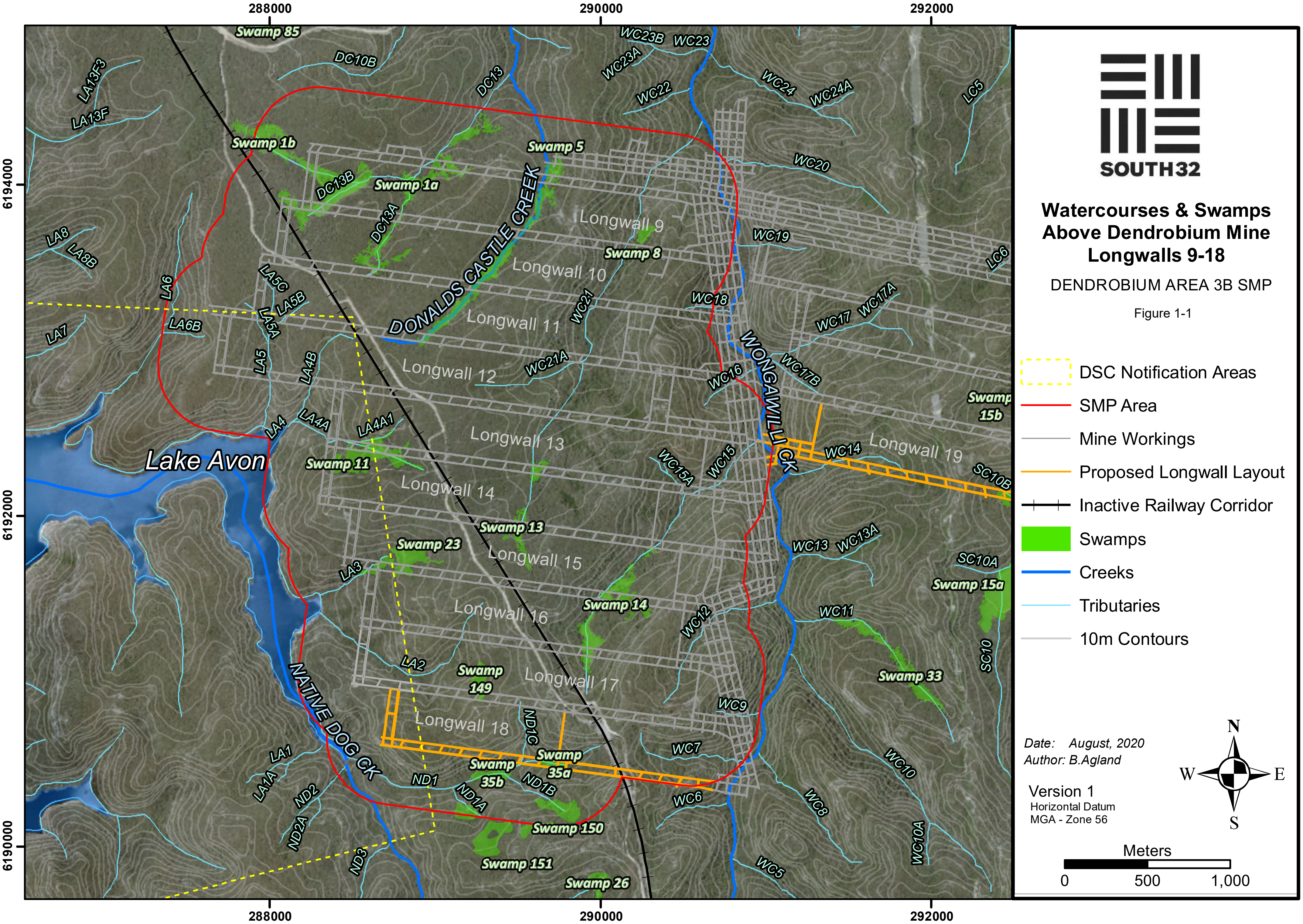
The Secretary of DPE approved the Dendrobium Area 3B SMP for Longwalls 14 – 15 on 16 December 2016. Condition 15 of this approval requires the SIMMCP be reviewed to the satisfaction of the Secretary prior to the extraction of Longwall 14.

1.4.6 2018 Longwall 16 SMP Approval - Condition 12

The Secretary of DPE approved the Dendrobium Area 3B SMP for Longwall 16 on 30 May 2018. Condition 12 of this approval requires the SIMMCP be reviewed to the satisfaction of the Secretary prior to the extraction of Longwall 15.

1.4.7 2019 SMP Schedule 4, Condition 6 SIMMCP Revision

The Secretary of DPIE approved the Dendrobium Area 3B SMP for Longwall 17 on 11 July 2019. Schedule 4, Condition 6 of this approval requires the SIMMCP to be reviewed in consultation with WaterNSW to the satisfaction of the Secretary, prior to the extraction of Longwall 16. The revised plan must include suitable revisions to the Trigger Action Response Plan, which take into consideration the revised groundwater model predictions and advice from the Independent Expert Panel.



SOUTH32

Watercourses & Swamps Above Dendrobium Mine Longwalls 9-18

DENDROBIUM AREA 3B SMP

Figure 1-1

Date: August, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

2 PLAN REQUIREMENTS

Extraction of coal from Longwall 18 will be in accordance with the conditions set out in the Dendrobium Development Consent and the requirements of the Area 3B SMP Approval as well as conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence from the Area 3B extraction. The baseline studies have identified monitoring sites in these areas based on the Before After Control Impact (BACI) design criteria.

A comprehensive monitoring program for swamps is outlined in this Plan that includes Swamps 14, 35a and 35b as well as other swamps in the Area 3B mining domain. These swamps may be subjected to mine subsidence within Dendrobium Area 3B and **Appendix A** details the monitoring to be undertaken.

Monitoring commenced at Dendrobium in 2003, providing a comprehensive understanding of baseline conditions. The extensive period of monitoring provides a detailed understanding of local conditions and the impacts of longwall mining on this area. Baseline monitoring for Dendrobium Area 3B includes:

- Observational monitoring, fixed photo points, soil surface moisture and vegetation health monitoring within swamps commenced 2003;
- Flora diversity and abundance quantitative transects in swamps commenced 2003;
- Fauna presence and abundance monitoring in swamps commenced 2003;
- Shallow groundwater level monitoring within swamps commenced 2003;
- Relative soil moisture measurements to 1.1 m depth commenced 2011;
- Field and laboratory analysis of water quality downstream of swamps commenced 2001;
- Flow monitoring downstream of swamps commenced 2001;
- Regional weather monitoring commenced 2002; and
- Area 3B automated weather station installed 2007.

A summary of swamp monitoring within Dendrobium Area 3B is provided in the following sections. In the event that monitoring reveals impacts greater than what is authorised by the approval, modifications to the project and mitigation measures would be considered to minimise impacts.

The monitoring locations for swamps within Dendrobium Area 3B will be reviewed as required and can be modified (with agreement) accordingly.

2.1 Dendrobium Development Consent

The Dendrobium Underground Coal Mine (DA 60-03-2001) modification was approved under Section 75W of the EP&A Act on 8 December 2008. **Table 2-1** lists the Conditions of Consent relevant to the SIMMCP and where the conditions are addressed.

Table 2-1 Dendrobium Development Consent

Dendrobium Development Consent Condition	Relevant SIMMCP Section
Condition 5 – Schedule 3 The Applicant shall ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a and that the structural integrity of its controlling rock-bar is maintained or restored, to the satisfaction of the Secretary.	Not Applicable to Area 3B
Condition 6 – 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 shall prepare a	

Dendrobium Development Consent Condition	Relevant SIMMCP Section
Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in condition 5 are to be met;	Not Applicable to Area 3B
(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) of each Area 3A Longwall on Swamp 15a;	Not Applicable to Area 3B
(c) include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function;	Section 3 and Appendix A
(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on swamps, which includes a tabular contingency plan (based on the Trigger Action Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;	Section 6 and Appendix A
(e) address headwater and valley infill swamps separately and address each swamp individually;	Section 5
(f) be prepared in consultation with DECC, SCA and DPI;	Section 1.4
(g) incorporate means of updating the plan based on experience gained as mining progresses;	Section 8
(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on swamps in the relevant Area; and	Section 1.4
(i) be implemented to the satisfaction of the Secretary.	

2.2 Dendrobium Area 3B SMP

The Dendrobium Mine Area 3B SMP (July 2019) Schedule 4 Condition 6 requires the SIMMCP to be revised as provided below. This Plan was submitted to the Department on 7 February in accordance with this condition.

Swamp Impact Monitoring, Management and Contingency Plan
6. Prior to the extraction of Longwall 16, the Applicant must review the Swamp Impact Monitoring, Management and Contingency Plan for Area 3B prepared under condition 6 of Schedule 3 of the development consent (DA 60-03-2001) to provide for achievement of the performance measures listed in Table 1 in consultation with WaterNSW, to the satisfaction of the Secretary. The revised plan must include suitable revisions to the Trigger Action Response Plan, which take into consideration the revised groundwater model predictions and advice from the Independent Expert Panel.

The Dendrobium Mine Area 3B SMP performance measures for swamps are outlined below.

Performance Measures for Area 3B
13. The Applicant must ensure that the development does not cause any exceedance of the performance measures in Table 1, to the satisfaction of the Secretary.
Swamps 1a, 1b, 5, 8, 11, 14 and 23
• Minor environmental consequences including: o negligible erosion of the surface of the swamps; o minor changes in the size of the swamps; o minor changes in the ecosystem functionality of the swamp;

- no significant change to the composition or distribution of species within the swamp; and
- maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.

Swamps 3, 4, 10, 13, 35a and 35b

- No significant environmental consequences beyond predictions in the Subsidence Management Plan (2012).

2.3 Leases and Licences

The following licences and permits may be applicable to IMC's operations in Dendrobium Area 3B:

- Dendrobium Mining Lease as shown in **Table 2-2**;
- Environmental Protection Licence 3241 which applies to the Dendrobium Mine. A copy of the licence can be accessed at the EPA website via the following link http://www.environment.nsw.gov.au/poeo;
- Dendrobium Mining Operations Plan FY 2016 to FY 2022;
- Relevant Occupational Health and Safety approvals; and
- Any additional leases, licences or approvals resulting from the Dendrobium Development Consent.

Table 2-2 Dendrobium Leases

Mining Lease - Document Number	Issue Date	Expiry Date/ Anniversary Date
CCL 768	7 May 1998	7 September 2026

3 MONITORING

3.1 Subsidence Monitoring

Survey monitoring techniques will be employed at Upland Swamps and watercourses throughout the Study Area to measure subsidence movements. Additionally, regional 3D Global Navigation Satellite System (GNSS) marks will be placed at strategic positions throughout the Study Area to monitor absolute surface movements.

Pending site access and approval, survey monitoring lines will be established across watercourses and Upland Swamps within the 20 mm predicted subsidence contour. The monitoring lines will target controlling rockbars and steps. Additionally, survey monitoring lines have been installed across the Wongawilli Creek valley to measure closure (or opening) of the valley.

Watercourse and Upland Swamp monitoring lines will employ a series of marks along a transect at nominally 20 m intervals. If practical, Upland Swamp transects will be related to a GNSS control network to provide absolute 3D movements in addition to level, tilt and strain changes.

Nominal accuracy will be +/- 5 mm relative between marks and +/- 20 mm for horizontal and vertical accuracy if the swamp is related to a GNSS control network. Survey closure lines across the Wongawilli Creek valley will be measured for closure only; nominal accuracy will be +/- 5 mm.

Survey monitoring sites will be chosen for suitability and detailed in the Dendrobium Survey Monitoring Program, separate to the SMP. Baseline monitoring will be conducted prior to active subsidence.

3.2 Area 3B Swamps

Upland swamps are commonly known as vegetated freshwater wetlands occurring in shallow basins located in low hills or mountains. They occur in either low sloped headwater tributary valleys (headwater swamps) that are characteristically derived from colluvial sand eroded from the ridgelines or along the riparian zone of the creeks (valley infill swamps) within the headwater valleys.

There is one headwater swamps and four valley infill swamps identified within the Longwall 18 Study Area (**Table 3-1**). It should be noted, however, that large swamps can display attributes of the two swamp types and often grade from one to the other rather than having a distinct change from one type to the other.

Table 3-1 Summary of Swamps within the Study Area

Swamp	Headwater Swamp	Valley Infill Swamp	Description	Location	Drainage line
14		X	MU43-Tea Tree Thicket; MU44a-Sedgeland; MU44c-Cyperoid.	Directly above LW15 to LW17	Upper reaches of WC15
35a		X	MU43-Tea Tree Thicket.	Above the maingate of LW18	Upper reaches of ND1
35b		X	MU42-Banksia Thicket.	85 m south of the maingate of LW18	Middle reaches of ND1
149	X		MU42-Banksia Thicket.	Directly above LW17 and partially above LW18	Valley side of LA2
150	X		MU43-Tea Tree Thicket; MU42-Banksia Thicket.	225 m south of the maingate of LW18	Upper reaches of ND1B
151	X		MU42-Banksia Thicket.	325 m south of the maingate of LW18	Upper and lower reaches of ND1A

The swamps have bedrock bases and are associated with shallow groundwater aquifers. A number of the swamps in Area 3B terminate in rocky outcrops, exposed rock platforms or small waterfalls.

Swamp material builds up behind these obstructions (e.g. prominent rock outcrop) and in-fills the depression upslope of the obstruction to form a beach like feature which also traps organic material. The Hawkesbury Sandstone is the predominant source of sediment for the swamps.

Area 3B was extensively burnt by wildfires in December 2001. Fire severity in the majority of the area was assessed as being high to extreme (Chafer *et al.*, 2004).

Swamp vegetation has been mapped by Biosis (2013) using field mapping to supplement NPWS (2003), Tozer *et al.*, (2006) and Niche (2012). The upland swamp areas identified in Area 3B comprise Fringing Eucalypt Woodland, Banksia Thicket, Sedgeland-heath complex and/or Tea Tree Thicket, with the later three communities being listed as the EEC (**Figure 3-43**).

The EECs which make up the upland swamps in the Study Area, specifically, the Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex, as defined by the NSW Scientific Committee's 2012 determination, have been mapped and are presented in the SIMMCP.

Niche (2020) undertook further detailed mapping which included ground-truthing and verification as part of the terrestrial ecology assessment for the Longwall 18 SMP application. Swamps 149, 150 and 151 were identified during this process. Due to the timing of these supplementary surveys, the minimum two years baseline monitoring cannot be achieved for these swamps.

3.3 Observational Monitoring

IMC has conducted ongoing monitoring of upland swamps in the Dendrobium area since 2003. This monitoring builds upon the understanding of processes within the swamps, along with identifying and assessing any episodic or temporal changes. This monitoring (along with other monitoring programs described in the SIMMCP) is consistent with (in part) Condition 6 – Schedule 3 of the Dendrobium Development Consent "*include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function*".

The IMC Environmental Field Team is continuing to undertake structured monitoring assessments including identifying:

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

Monitoring sites and frequencies are provided in **Table 1.1 (Appendix A)**. Additional monitoring within Dendrobium Area 3B will be installed ahead of longwall mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring).

Sites are monitored before and after mining and sites that will not be mined under are also monitored for the same parameters to provide a comparison of sites mined under and sites not mined under during different climatic conditions **(Appendix A)**.

The following Area 3B impact (**Figure 3-1 to Figure 3-10**) and reference (**Figure 3-11 to Figure 3-23**) swamp sites are included in the observational and photo point monitoring program (as described in this section):

- Impact sites;
  - Swamps 5, 10, 11, 13, 14, 23, 35a, and 35b (commenced March 2005);
  - Swamps 1a and 1b (commenced May 2012);
  - Swamp 8 (commenced February 2013); and
  - Swamp 4 (commenced December 2013); and
  - Swamp 3 (commenced January 2014); and
  - Swamp 149, 150 and 151 (proposed to commence September 2020).
- Reference sites:
  - Swamps 2, 7, 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88.

3.4 Pool Water Level and Surface Water Flow

Pool water levels in swamps and associated streams are measured using installed benchmarks in impact sites (**Figure 3-24 to Figure 3-32**) and reference sites (**Figure 3-33 to Figure 3-35**). Not all swamps have pool features within their boundary. Pool water levels are measured within or adjacent to the following swamps:

- Swamp 14: WC15_Pool 28 and 34 (**Figure 3-25**).
- Swamp 8: WC21_Pool 16 to 19 (**Figure 3-26**).
- Swamp 10: WC21_Pool 41 and 42 (**Figure 3-26**).
- Swamp 5: DC_Pool 33 and 34 (**Figure 3-27** and **Figure 3-28**).
- Swamp 1A and 1B: DC13_Pool 6 to 10, 12, 14 to 17, 20 and 21 (**Figure 3-29**).
- Swamp 23: LA3_Pool4 (**Figure 3-31**).
- Swamp 11: LA4_Ch3 (**Figure 3-32**).
- Swamp 15B: SC10C_Pool 14, 15, 17, 21 to 24, 26 to 32 (**Figure 3-34**).
- Swamp 22: S22_Pool 10 (**Figure 3-15**).
- Swamp 33: WC11_Pool 20 (**Figure 3-18**).
- Swamp 84: S84_Pool 10 (**Figure 3-19**).
- Swamp 86: S86_Pool 10 (**Figure 3-21**).
- Swamp 88: S88_Pool 10 (**Figure 3-23**).

Water level/flow gauges and data loggers are installed at key stream flow monitoring sites (**Figure 3-35** and **Figure 3-37**). Data has been collected since 2003 and has been compiled within monitoring and field inspection reports (BHPBIC 2011), EoP Reports and regular impact update reports. Pool water level and flow monitoring sites have been established in Dendrobium Area 3B for monitoring before, during and after mining.

Pool water levels will be measured monthly before and after mining and on a weekly basis during active subsidence. Water level measurements will be undertaken relative to benchmarks installed on rocks or other stable features on the edge of the pools.

This data is used to compare differences in pool water level within swamps and associated streams before and after mining. Sites that will not be mined under are also monitored to provide a comparison of mined and not mined under sites during different climatic conditions.

This monitoring provides the key data to assess the Performance Measure: Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar. Performance against this measure will be based on comparing pool water levels before mining with after mining. Pool water level data would also be used to determine the success of any pool/rockbar mitigation or rehabilitation.

Surface water flow data for the Dendrobium area is available from a series of flow gauges operated by IMC. These gauging stations provide estimates of stream flow via:

- A structure behind which water pools and flows over. Structures can be:
  - natural, e.g. a rock bar, or
  - man-made, e.g. a half-pipe flume.
- A sensor and logger that measure and record the water level (“stage”) in the pool at 15-minute intervals.
- A “rating curve” which is a chart or graph of discharge (flow) versus stage for each gauging station. The rating curve is developed via periodic measurements of flow in the channel at a known water level.
- Estimates of mean daily flow are then provided.

IMC and an independent hydrologist are currently working to systematically identify and quantify the accuracy or error involved in each part of the process. The aim of the assessment is to document accuracy across the range of flows at a sample of representative sites.

The flow monitoring sites are installed downstream of the mining area to assess any changes in surface flow from a catchment resulting from the mining. Sites have previously been installed using natural flow control features such as rockbars. However, in line with the recommendations of the IEP (2019a) and approval from WaterNSW, the installation of low-flow weirs has commenced, in order to gain high quality low-flow data. Flow monitoring 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. The downstream monitoring sites are installed to measure catchment flow reductions downstream of the mining area.

Flow gauges have been installed on Sandy Creek (Area 3A); Wongawilli Creek (Area 3B and 3A) and its tributaries WC21, WC15 and WC12 (DA3B); Donalds Castle Creek and its tributary DC13 (DA3B) and Lake Avon tributary LA2, LA3, LA4 and NDT1 (Area 3B). The historical flow record has been plotted alongside the record from a nearby 'control' gauge i.e. a gauge that was not mined under, either at all or not during the period of interest (**Figure 3-37**).

A review of the Trigger Action Response Plan (TARP) regarding surface water flows was undertaken in consultation with WaterNSW, DPIE and BCD in 2020 (Appendix A of the WIMMCP). This review determined that two key flow reference sites were required:

- WWU on upper Wongawilli Creek. This sites is close to Dendrobium and has the same catchment geology, land use and vegetation cover.
- O'Hares Creek at Wedderburn (#213200). This station has a long record, extending back to the late 1970s. The catchment is large (73 sq.km) compared to the area of mining, but is considered to be appropriate as a control site. This gauging station is approximately 28 km north of Area 3B.

Surface water flow sites in the mining area will be assessed against the key flow reference sites during assessments for the EoP Report. The assessment comprises three checks of pre- versus post-mining behaviour for each assessment site. Further details are available in the WIMMCP.

A more detailed discussion of these assessments, developed and refined in consultation with agencies, is provided in Watershed Hydrogeo (2019).

IMC commissioned the development of a regional-scale numerical groundwater flow model in support of mining at Dendrobium Colliery (Coffey Geotechnics 2012). IMC commissioned HydroSimulations (2014) to review and enhance the Model and this model has been updated and revised at regular intervals since then.

The Dendrobium Regional Groundwater Model (2020) has been updated as required by Condition 7, Schedule 4 of the Area 3B SMP Approval (2019).

3.5 Groundwater and Soil Moisture

The surface area above Dendrobium Area 3B is characterised by a series of drainage basins separated by steep ridges. The drainage basins drain to Wongawilli Creek, Donalds Castle Creek and directly into Lake Avon (Ecoengineers 2012).

Monitoring of shallow groundwater levels allows for the indirect measurement of water storage and transmission parameters within the saturated part of hill-slope/upland swamp complexes. Shallow groundwater piezometers have been installed in several swamps within and around Area 3 (**Figure 3-1** to **Figure 3-23**) including the hill-slope aquifers on the eastern side of Sandy Creek; within Swamp 15b and Swamp 12. Within Area 3B long-term piezometer records are available for Swamp 11 as well as additional sites installed since 2011 (**Figure 3-1** to **Figure 3-10**).

Swamps 2, 7, 15a, 24, 22, 24, 25, 33, 84, 85, 86, 87 and 88 have been selected as reference monitoring sites (**Figure 3-11** to **Figure 3-23**). Shallow groundwater monitoring has been installed in reference swamps. This data is used to compare differences in shallow groundwater levels within swamps and hill-slope aquifers before and after mining. Sites that will not be mined under are monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The timing of groundwater monitoring installation (and other monitoring) is provided in **Table 3-2**.

Table 3-2 Shallow Piezometer Monitoring Records

Swamp	Site	Records Date From
Swamp 1a	01a_01	28/06/2012
Swamp 1a	01a_02	1/08/2012

Swamp	Site	Records Date From
Swamp 1a	01a_03	7/05/2012
Swamp 1a	01a_04	28/06/2012
Swamp 1a	01a_04i	6/03/2013
Swamp 1a	01a_04ii	22/02/2013
Swamp 1a	01a_04iii	22/02/2013
Swamp 1a	01a_04iv	22/02/2013
Swamp 1a	01a_04v	6/03/2013
Swamp 1b	01b_01	28/06/2012
Swamp 1b	01b_02	27/07/2012
Swamp 1b	01b_02i	20/02/2013
Swamp 1b	01b_02ii	20/02/2013
Swamp 1b	01b_02iii	20/02/2013
Swamp 1b	01b_02iv	20/02/2013
Swamp 1b	01b_03	24/05/2012
Swamp 2	02_01	29/06/2012
Swamp 5	03_01	15/06/2012
Swamp 5	05_01	26/07/2012
Swamp 5	05_02	26/06/2012
Swamp 5	05_03	26/07/2012
Swamp 5	05_03i	2/04/2013
Swamp 5	05_03ii	6/03/2013
Swamp 5	05_03iii	6/03/2013
Swamp 5	05_04	26/06/2012
Swamp 5	05_05	8/08/2014
Swamp 5	05_06	14/05/2012
Swamp 8	08_01	27/07/2012
Swamp 8	08_02	27/07/2012
Swamp 8	08_03	18/05/2012
Swamp 8	08_04	27/07/2012

Swamp	Site	Records Date From
Swamp 8	08_05	18/05/2012
Swamp 8	08_06	31/05/2012
Swamp 10	10_01	27/07/2012
Swamp 13	13_01	30/07/2012
Swamp 15a	15a_02	3/02/2009
Swamp 15a	15a_03	30/07/2009
Swamp 15a	15a_04	3/02/2009
Swamp 15a	15a_05	27/01/2009
Swamp 15a	15a_06	5/02/2009
Swamp 15a	15a_07	5/02/2009
Swamp 15a	15a_08	10/02/2009
Swamp 15a	15a_09	10/02/2009
Swamp 15a	15a_11	29/01/2009
Swamp 15a	15a_12	13/02/2009
Swamp 15a	15a_13	27/01/2009
Swamp 15a	15a_14	27/01/2009
Swamp 15a	15a_15	5/02/2009
Swamp 15a	15a_16	29/01/2009
Swamp 15a	15a_17	6/08/2009
Swamp 15a	15a_18	29/01/2009
Swamp 15b	15b_20	8/01/2009
Swamp 15b	15b_21	7/07/2009
Swamp 15b	15b_22	8/01/2009
Swamp 15b	15b_23	13/01/2009
Swamp 15b	15b_24	13/01/2009
Swamp 15b	15b_25	13/01/2009
Swamp 15b	15b_26	23/12/2008
Swamp 15b	15b_27	7/07/2009
Swamp 15b	15b_28	30/12/2008

Swamp	Site	Records Date From
Swamp 15b	15b_29	8/01/2009
Swamp 15b	15b_30	30/12/2008
Swamp 15b	15b_31	8/01/2009
Swamp 15b	15b_32	7/07/2009
Swamp 15b	15b_33	23/12/2008
Swamp 15b	15b_34	13/01/2009
Swamp 15b	15b_35	20/01/2009
Swamp 15b	15b_36	20/01/2009
Swamp 15b	15b_37	20/01/2009
Swamp 15b	15b_38	22/01/2009
Swamp 15b	15b_39	22/01/2009
Swamp 25	25_01	15/01/2009
Swamp 11	S11-H1	7/10/2003
Swamp 11	S11-H2	11/09/2003
Swamp 11	S11-H3	7/10/2003
Swamp 15	S15b-H1	8/08/2003
Swamp 15	S15b-H2	8/08/2003
Swamp 15	S15b-H3	8/08/2003
Swamp 14	14_01	June 2015
Swamp 14	14_02	June 2015
Swamp 23	23_01	June 2015
Swamp 23	23_02	June 2015
Swamp 35a	35a_01	June 2015
Swamp 35b	35b_01	June 2015
Swamp 7	07_05	June 2015
Swamp 7	07_06	June 2015
Swamp 22	22_01	June 2015
Swamp 22	22_02	June 2015
Swamp 24	24_01	June 2015

Swamp	Site	Records Date From
Swamp 25	25_01	June 2015
Swamp 33	33_01	June 2015
Swamp 33	33_03	June 2015
Swamp 84	84_02	June 2015
Swamp 85	85_01	June 2015
Swamp 85	85_02	June 2015
Swamp 86	86_01	June 2015
Swamp 86	86_02	June 2015
Swamp 87	87_01	June 2015
Swamp 87	87_02	June 2015
Swamp 88	88_01	June 2015
Swamp 88	88_02	June 2015

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles up to a maximum depth of 1.2 m. Key monitoring sites will be installed with loggers to provide a continuous soil moisture record (**Figure 3-4** to **Figure 3-23**).

The shallow groundwater piezometers and soil moisture probe data is compared with the Cumulative Monthly Rainfall Residuals (a key parameter for interpreting temporal soil and shallow groundwater data).

Comparisons of the Cumulative Monthly Rainfall Residuals against mean monthly water heads in shallow groundwater piezometers and soil moisture profiles will take into account the known distribution of rainfall isohyets (contours of equal annual precipitation) in the local region (these being denser and less smooth closer to the Illawarra Escarpment and much wider proceeding northwest).

Several climate stations are available for analysis and modelling in Dendrobium Area 3B with the most appropriate data taking into account proximity, length of record and data quality.

Dendrobium Mine has installed a comprehensive array of multi-level piezometers on the centreline of panels at Dendrobium Mine in order to monitor pore pressure changes associated with subsidence. These monitoring holes include at least five transducers per borehole with installation at least 2 years prior to undermining, in line with the recommendations of the IEP (2019a). Where these monitoring sites are damaged as a result of undermining they are reinstalled after subsidence movements cease. Daily monitoring of local rainfall and mine water ingress from overlying and surrounding strata, and separation of rainfall correlated inflows for base flow volumetric analyses is also undertaken (IEP 2019a).

3.6 Water Quality

Monitoring undertaken by IMC since 2003 (**Figure 3-35**) includes water quality monitoring of parameters such as 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).

The key field parameters of DO, pH, EC and ORP for monitoring sites within Dendrobium Area 3B (**Figure 3-24** to **Figure 3-32**) will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from the Area 3B mining (**Figure 3-33 to Figure 3-35**) are monitored to allow for a comparison to sites not influenced by mining.

Pools will be measured at weekly intervals during active subsidence and monthly before and following mining.

The monitoring of water chemistry provides a sensitive means of detecting and providing quantitative assessment of effects in the early stages of streambed fracturing or induction of ferruginous springs. Assessment of water quality data will be supported by geochemical modelling using PHREEQC, where applicable (Parkhurst and Appelo 1999).

3.7 Slopes and Gradients

Slopes within Area 3B have been mapped according to their gradients and are identified on Drawing 8 in MSEC (2020). Valley infill swamps such as Swamps 1a, 5, 8, 10, 14, 23, 35a and 35b, are located along the valley floors of streams and are characterised by steeper gradients than headwater swamps which occur on low sloped areas of weathered Hawkesbury Sandstone where hillslope aquifers exist. Monitoring of landscape features such as slopes and swamps is undertaken in Area 3B (**Figure 3-38**).

Monitoring of steep slopes allows for the measurement of any changes to the surface including soil cracking, erosion and/or sedimentation impacts resulting from subsidence.

The inspections and monitoring includes the following monitoring sites:

- Monitoring sites based on an assessment of risk of impact where pre-mining measurements have been undertaken and reported;
- Areas of steep slopes that are en route or near monitoring sites;
- Rock outcrops that are en route or near monitoring sites;
- Any other sites where impacts have been previously observed that warrant follow-up inspection (i.e. rockfalls and soil cracking); and
- The general areas above the current mining location at the time of inspection.

The monitoring sites include comprehensive investigation as described below, and the wider area around the monitoring site is subject to inspection during monitoring events.

Observations on landform and land surface at the monitoring sites are recorded to account for the Australian Soil and Land Survey, Field Handbook, 2nd Edition (McDonald, Isbell, Speight, Walker and Hopkins 1990) as modified for subsidence monitoring.

Observations have been made of the landform elements in accordance with the Landform section of the Field Handbook. The landform element has generally been described in terms of the following attributes:

- Slope;
- Morphological type;
- Dimensions;
- Mode of geomorphological activity; and
- Geomorphological agent.

In addition, observation has been made of the land surface in accordance with the Land Surface section of the Field Handbook. The land surface has generally been described in terms of the following attributes:

- Aspect, elevation and drainage height;
- Disturbance at the site, including erosion and aggradations;
- Micro relief;
- Inundation;
- Coarse fragments and rock outcrop;
- Depth to free water; and
- Runoff.

A watercourse reach of between ten and twenty times the channel width is monitored to cover local geomorphological units (e.g. pool/riffle).

For each watercourse monitoring site (including those associated with swamps), a range of measurements and observations of the watercourse characteristics are recorded along with established photo points.

Measurements and observations incorporate the relevant parts of the Field Handbook, and relevant parts of the Riparian-Channel-Environmental Assessment (RCE) methodology (Petersen 1992).

While in most cases, impacts on steep slopes are likely to be restricted to surface cracks, there remains a low probability of large scale downslope movements. Steep slopes, including those occurring within the proximity of swamps, are therefore monitored throughout the mining period and until any necessary rehabilitation is complete. Slopes and gradients are monitored prior to mining as well as monthly during active subsidence during mining. The monitoring is undertaken at six-monthly intervals for two years following completion of mining.

3.8 Erodibility

Most of the surface of Area 3B has been identified as highly weathered Hawkesbury Sandstone outcrops and Sandstone derived-soils. This soil landscape has been identified to have high to extreme erosion susceptibilities to concentrated flows. This results in potential flow on effects to slope stability and erosion from any cracking resulting from subsidence (Ecoengineers 2012).

Studies undertaken by Earth Tech (2005) identified that if shear stress thresholds are not exceeded then swamps are most likely to remain intact. Swamps at risk of erosion include those that have vegetation of poor condition or those that lie on higher order streams. Tomkins and Humphrey (2006) concluded that the occurrence of wildfires can also lead to erosion of swamps. Landscape monitoring of slopes and swamps is undertaken in Area 3B to identify any erosion of the surface (**Figure 3-38**).

The types of erosion which could manifest within swamps are sheet, rill, gully, tunnel and stream channel. These types of erosion will be monitored in swamps in the mining area as well as in reference swamps not in the mining area. The types and magnitude of any erosion identified in swamps in the mining area will be compared to any erosion away from the mining area. In the event of a bushfire any comparison between mining area and reference swamps will take into account the increased potential for erosion following a fire.

An extensive survey network has been implemented with some emphasis given to swamps and Wongawilli and Donalds Castle Creeks.

Swamps 1a, 1b, 4, 5, 10, 11, 13 and 23 are monitored for relative and absolute horizontal and vertical movements. Additional swamps will be incorporated into the monitoring program prior to subsidence movements impacting the sites.

Due to terrain, vegetation and access restrictions, the primary method of identifying any gully erosion over Area 3B will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwalls and mining domains and will also provide identification of any gully erosion developing within the swamps. The maximum length, area and depth of gully erosion will be measured by standard survey methods and compared to the areas and lengths of the swamps (**Figure 3-43**).

Base surveys over Area 3B using ALS were completed in December 2005, with a verification base survey performed in 2013, immediately prior to the commencement of Longwall 9 extraction. Subsidence landscape models using the same methodology after the completion of subsidence at each longwall will provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to identify new or increases in existing erosion. Erosion will be quantified by comparison of the immediate post subsidence landscape model with the long-term monitoring model. Targeted ALS scans will be completed where erosion is observed via the observational and landscape monitoring programs or after significant events such as bushfire and flooding. The length and area of any erosion identified by the ALS scans will be measured by traditional survey methods.

The pre-mining landscape model from the ALS scan of Swamp 1A is provided as **Figure 3-39**. This landscape model identifies active pre-mining erosion of 179 m in DC13, adjacent to Swamp 1A, and 8m within the swamp. The erosion is not visible in orthophotos (**Figure 3-40**) prior to the area being burnt in 2001-2002. The erosion was identified in 2003 (**Figure 3-41**) and has persisted during and following extraction of Longwall 9 in 2013 (**Figure 3-42**).

The nominal accuracy of ALS derived subsidence contours is in the order of +/- 0.10m and effective algorithms have been developed to allow the use of ground strike data only within the assessment. This effectively allows the analysis to see through vegetation to the ground surface.

General observational inspections of swamps will be undertaken at regular intervals, during active subsidence of the swamp. In addition to erosion, these observations aim to identify any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, and slope and gradient changes.

The observational monitoring program will also include specific attention to the condition of controlling rockbars and will incorporate both impacts sites (**Figure 3-1** to **Figure 3-10**) and reference Swamps 2, 7,15a, 22, 24, 25, 33, 85, 86, 87 and 88 (**Figure 3-11** to **Figure 3-23**).

3.9 Flora, Fauna and Ecosystem Function

Terrestrial flora and vegetation communities in the Study Area are described in the SMP Terrestrial Ecology Assessment (Niche 2020). Aquatic flora and fauna in the Study Area are described in the SMP Aquatic Ecology Assessment (Cardno 2020).

A monitoring program designed to detect potential impacts to ecology and ecosystem function from subsidence has been implemented for Area 3B. As recommended by the IEP (2019a), the monitoring program is based on a BACI design with sampling undertaken at impact and control locations prior to the commencement of extraction, during extraction and after extraction.

Over two years of baseline data is available for Area 3B and this data indicates that the habitat in this area is relatively undisturbed. There is sufficient baseline data to enable the detection of changes to ecology associated with mining related impacts.

The study focuses on flora, fauna and ecosystem function of swamps and watercourses and is measured via the following attributes:

- The size of the swamps and the groundwater dependent communities contributing to the swamps;
- The composition and distribution of species within the swamps;
- RCE including a photographic record of each stream assessment site;
- Water quality, including pH, DO, ORP, temperature, turbidity and EC;
- Aquatic macrophytes, including presence, species composition and total area of coverage;
- Aquatic macroinvertebrates using the Australian River Assessment System (AUSRIVAS) sampling protocol and artificial aquatic macroinvertebrate collectors;
- Fish presence and numbers using backpack electro fisher and/or baited traps; and
- Presence of threatened species (including Macquarie perch, Littlejohn's tree frog, Giant burrowing frog, Adams emerald dragonfly, Giant dragonfly and Sydney hawk dragonfly).

3.9.1 Ecosystem Function

The upland swamps in the Study Area fit the description of Coastal Upland Swamps in the Sydney Basin Bioregion, which has been listed as an EEC under the BC Act (Niche 2012 and Niche 2020). Specifically, the Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex are considered part of the Coastal Upland Swamp EEC as defined by the NSW Scientific Committee's 2012 determination.

At the Agency Consultation Workshop 27 May 2013 there was discussion about the definition of 'ecosystem functionality' in relation to subsidence impact performance measures for swamps. The term 'ecosystem functionality' is included in Table 1 of Condition 13 of the SMP Approval. The term is not included in the definitions of the Approval.

At the workshop it was stated that BCD disagrees with the definition of ecosystem function included in the Plans as they consider it is too simplistic and does not cover shallow groundwater levels. DPIE advised the intent of the performance measure relating to ecosystem functionality for swamps was more general in intent; basically, the swamp will remain a swamp.

The outcome of the workshop was that IMC is to propose a definition in the next version of the Plan. It is proposed that the ecosystem function of swamps is measured via the following attribute: the size of the groundwater dependent communities contributing to the swamps. Specifically, any changes in the proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex within the monitored swamps.

Any change in area of a groundwater dependent community within a swamp will be compared to its pre-mining area and any change in area of that groundwater dependent community within reference swamps (**Figure 3-43**).

The first baseline assessment of the EEC areas was undertaken using detailed on-ground mapping in 2013. For this report the NPWS Woronora Plateau mapping was used for Swamps 10, 35A and 35B. Detailed swamp mapping will be updated as mining approaches each swamp. The following results were obtained from the study:

- Swamp 1a
    - Sedgeland-heath complex (Restioid Heath) 4.05ha
    - Sedgeland-heath complex (Cyperoid Heath) 0.50ha
    - Banksia Thicket 2.37ha
    - Tea-tree Thicket 0.55ha
- Swamp 1b
    - Sedgeland-heath complex (Restioid Heath) 9.30ha
    - Sedgeland-heath complex (Cyperoid Heath) 2.05ha
    - Tea-tree Thicket 0.08ha
- Swamp 5
    - Sedgeland-heath complex (Restioid Heath) 2.22ha
    - Sedgeland-heath complex (Cyperoid Heath) 0.56ha
    - Sedgeland-heath complex (Sedgeland) 0.48ha
    - Banksia Thicket 2.92ha
    - Tea-tree Thicket 1.33ha
- Swamp 8
    - Banksia Thicket 0.95ha
- Swamp 10
    - Sedgeland-heath complex 1.10ha
- Swamp 11
    - Sedgeland-heath complex (Restioid Heath) 0.94ha
    - Sedgeland-heath complex (Cyperoid Heath) 0.59ha
    - Sedgeland-heath complex (Sedgeland) 0.70ha
    - Banksia Thicket 3.62ha
    - Tea-tree Thicket 0.23ha
- Swamp 13a
    - Sedgeland-heath complex (Restioid Heath) 0.89ha
    - Sedgeland-heath complex (Cyperoid Heath) 0.30ha
    - Banksia Thicket 0.65ha
- Swamp 13b
    - Sedgeland-heath complex (Restioid Heath) 0.06ha
    - Sedgeland-heath complex (Cyperoid Heath) 0.12ha
    - Banksia Thicket 0.49ha
    - Tea-tree Thicket 0.10ha
- Swamp 14
    - Sedgeland-heath complex (Cyperoid Heath) 1.15ha
    - Sedgeland-heath complex (Sedgeland) 0.02ha

  - Banksia Thicket 2.37ha
  - Tea-tree Thicket 2.18ha
- Swamp 15a(1)
  - Sedgeland-heath complex (Restioid Heath) 2.47ha
  - Sedgeland-heath complex (Cyperoid Heath) 3.48ha
  - Banksia Thicket 5.11ha
  - Tea-tree Thicket 2.40ha
- Swamp 23
  - Sedgeland-heath complex (Cyperoid Heath) 0.18ha
  - Banksia Thicket 3.08ha
  - Tea-tree Thicket 0.62ha
- Swamp 33
  - Sedgeland-heath complex (Cyperoid Heath) 0.43ha
  - Banksia Thicket 2.35ha
  - Tea-tree Thicket 1.58ha
- Swamp 85 (Swamp DC10)
  - Sedgeland-heath complex (Restioid Heath) 1.36ha
  - Sedgeland-heath complex (Sedgeland) 0.67ha
  - Banksia Thicket 0.26ha

Mapping will be replicated prior to mining (where needed), following mining and on an ongoing basis for the life of the mine or as agreed by the Secretary. This will allow direct comparison of changes in the size of the EECs within upland swamps. It is envisaged that this monitoring will be ongoing for up to ten years.

3.9.2 Swamp Size

Detailed mapping of the boundaries of the swamps and vegetation sub-communities has been undertaken for Swamps 1a, 1b, 5, 8, 11, 13, 14, 23, 149, 150 and 151 (**Figure 3-44** to **Figure 3-51** and **Figure 3-89**). Three reference swamps were selected for mapping, including Swamp DC10 (Swamp 85), Swamp 15a(1) and 33 (**Figure 3-52** to **Figure 3-54**). These swamps were selected based on size, similar vegetation sub-communities, geographic proximity and a lack of previous mining near them.

The detailed mapping included the use of LiDAR data to indicate the location and extent of upland swamp boundaries followed by ground-truthing of these boundaries and the vegetation sub-communities.

This mapping will allow for detailed comparison of the size of upland swamps following mining, as well as detailed comparison of the extent of sub-communities within upland swamps over time. Mapping will be replicated following mining and on an ongoing basis for the life of the mine or as agreed by the Secretary. This will allow direct comparison of changes in the size of upland swamps as well as the distribution of vegetation sub-communities within upland swamps.

Any change in the total area of a swamp will be compared to its pre-mining area and any change in area of reference swamps.

3.9.3 Composition and Distribution of Species

Quantitative flora monitoring is undertaken within Area 3B Swamps 1a (**Figure 3-55**), 1b (**Figure 3-56**) and 5 (**Figure 3-57**) along with continued monitoring of Swamp 11 (**Figure 3-58**), which has a long-term monitoring record. Control sites have been established at Gallahers Creek Swamp (Swamp 88) (**Figure 3-59**), Fire Trail 15e Swamp (Swamp 87) (**Figure 3-60**), Fire Trail 6x Swamp (Swamp 86) (**Figure 3-61**), Swamp 15A(1) (**Figure 3-62**), Swamp 22 (**Figure 3-63**) and Swamp 33 (**Figure 3-64**). An initial round of monitoring was completed in summer 2012. The second round of monitoring was undertaken in autumn 2013.

Three 15 m transects consisting of thirty 0.5 m by 0.5 m quadrats have been (and will be for future longwalls) established in upland swamps. The monitoring will record:

- Presence of all species within each quadrat;
- Percentage foliage cover and vegetation height;
- Observations of dieback or changes in community structure; and
- Photo point monitoring at each transect.

Data from other monitoring programs (such as groundwater and observational data) in both mining sites and reference sites will be used to assist in the determination and reporting of any impacts identified by the quantitative vegetation monitoring.

The selection of monitoring sites has been determined by specialists in the ecology of upland swamps based on a multi-criteria analysis. Criteria used to determine locations include:

- The location of the swamp in relation to longwall layout;
- Predicted subsidence, including vertical movements, tilts and strains;
- Location of vegetation sub-communities within the upland swamp, particularly those hypothesised to be most susceptible to changes in groundwater;
- Ensuring a representative sample of vegetation sub-communities in the monitoring program;
- Availability of reference sites; and
- Access requirements and workplace health and safety.

Twelve transects have been installed within the 400m zone of influence of the longwalls. Ten of these are directly over the proposed goaf where the subsidence movements are predicted to be greatest, with five of these close to the centre of the longwall. One transect is over a chain pillar and one transect is off the goaf area within the 400m zone of influence of the longwall.

A particular focus has been placed on those vegetation sub-communities expected to undergo the greatest change. Tea-tree Thickets and Cyperoid Heath are considered to be more susceptible to change given their dependency on groundwater, followed by Sedgeland, Restioid Heath and finally Banksia Thicket.

Data will be analysed according to the BACI design. Statistical analyses of species richness and species diversity between control and impact sites is used to determine whether there are statistically significant differences between these sites. This analysis will be compared with baseline data collected prior to mining to assist in determining if these differences could be a result of mining or natural variation in vegetation communities.

Where differences are detected in species richness or diversity between control and impact sites then additional analyses, such as Analysis of Similarities (ANNOSIM), will be undertaken to determine where these differences lie and provide a more definitive conclusion on the impacts of mining in Dendrobium Area 3B.

Observation data will also be collected as part of the monitoring program. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

Change to the composition or distribution of species within the swamps will be measured via statistically significant changes in species richness or diversity during a period compared to species richness/diversity in a reference swamp.

3.9.4 Fauna

Seven-Part tests undertaken by Niche (2012) concluded that the proposed activities are unlikely to cause a significant impact to any threatened plant species, however significant impact on local populations of Littlejohn’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet and Giant Dragonfly. Impacts to these species is detailed further in the Terrestrial Ecology Assessment (Niche 2020).

In consideration of the possible presence of threatened macroinvertebrate species within the SMP Area, all dragonfly larvae collected in invertebrate sampling will be identified to the taxonomic level of family. Any individuals of the genus Petalura, Austrocorduliidae and Gomphomacromiidae will be further identified to species level if possible, and if there is uncertainty, specimens will be referred to a specialist taxonomist.

The confirmed presence of a threatened species will trigger further investigation into the species and its habitats in relation to potential subsidence impacts.

Standardised transects in potential breeding habitat for the threatened frog species Littlejohn's tree frog and Giant burrowing frog have been established in Dendrobium Area 3B. These repeatable surveys enable direct comparison of the numbers of individuals recorded at each site from one year to the next. The sites have been established within creeks associated with and/or downstream of swamps.

Creeks DC13 (**Figure 3-65**), DC(1) (**Figure 3-66**), WC21 (**Figure 3-67**), LA4A (**Figure 3-68**), ND1 (**Figure 3-69**) and WC15 (**Figure 3-70**) are monitored as a part of the Dendrobium Area 3B monitoring program, with additional monitoring commencing in other streams two years prior to mining.

Monitoring is also undertaken away from mining to act as control sites for the mining versus non-mining comparative assessment (**Figure 3-71** to **Figure 3-79**). Although there has been mining upstream of Sites SC6, SC8 and NDC, data to date indicates there are strong numbers of frogs in these areas for monitoring purposes.

Baseline surveys commenced in winter 2013 and included counts of frogs along each transect, an assessment of pools being used for breeding and counts of tadpoles and egg masses in each pool. This will enable a quantitative as well as qualitative assessment of breeding habitat for these species prior to, during and after mining.

Observations of the sites, photo points and pool water level data will also be collected as part of the frog and observational monitoring programs (**Figure 3-65** to **Figure 3-70**). Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

3.10 Pools and Controlling Rockbars

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 quite 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.

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of pools and rockbars (**Figure 3-80**).

The eastern area is broadly sited on a plateau dissected by a number of relatively shallow sub-catchments draining either into Cordeaux River via Wongawilli Creek or Donalds Castle Creek or five un-named 1st and 2nd order streams draining directly to the southern end of Lake Avon.

The largest watercourse within Area 3B is Wongawilli Creek (**Figure 3-24**) which is located between Areas 3A and 3B. The headwaters of Wongawilli Creek are located along a drainage divide separating surface runoff and shallow groundwater outflow runoff from Native Dog Creek and Lake Avon to the west. Wongawilli Creek is located 1 km to the east of the finishing end of Longwall 18

Donalds Castle Creek and its tributaries (**Figure 3-27**, **Figure 3-28** and **Figure 3-29**) also drain the north-western part of Area 3B through a weakly incised plateau. Donalds Castle Creek catchment on this plateau is characterised by low topography, upland swamps and numerous unconfined shallow hillslope aquifers. Much of the soil is derived from weathering of shale-rich Mittagong Formation and is more clayey and of lower permeability than residual soils developed purely on Hawkesbury Sandstone outcrop.

The south western area drains directly to Lake Avon via five 1st and 2nd order streams designated as Native Dog Creek, ND1 (**Figure 3-30**) and LA2, LA3, LA4 and LA5 (**Figure 3-31** and **Figure 3-32**).

The geomorphology of tributary sub-catchments in Area 3B is typically characterized by upland plateau and a series of ‘benches’ comprised of catenary hill-slopes and swamps enclosed in roughly crescent-shaped cliff lines.

The upstream southern end of the catchment consists of a ridge containing a thin sandy soil profile accumulated on a generally dome shaped outcrop. This outcrop exhibits pronounced removal of the sandstone's kaolinite clay cement and is typically white and friable (Hazelton and Tille 1990).

Drainage is to the north east and south west down slopes with little evidence of surface drainage channels. This is consistent with headwater hill-slope aquifer zones and overland sheet flow during extreme storm events.

Wongawilli and Donalds Castle Creeks are typically perennial flowing streams with small base flows and increased flows for short periods of time after each significant rain event.

Beds of the creeks are typically formed within Bulgo Sandstone, which overlies the Stanwell Park Claystone; however, there are small sections of the headwaters of these creeks which are formed within the Hawkesbury Sandstone.

Three distinct channel types may be recognised in the main channel uplands, and in the tributaries of Wongawilli and Donalds Castle Creek:

1. Narrow indistinct channels associated with low sedge/heath type vegetation cover and a relatively thick sandy riparian soil profile. The streambed consists of weathered bedrock and/or sandy materials. This is the situation in which valley infill swamps may be found.

2. Rock platforms of variable width which are usually smooth except for minor depressions on joint planes and occasional potholes. These platforms normally grade to a thinly vegetated sandy soil on both sides and usually exhibit the effects of chemical deposition of hydrated iron oxides. This deposition ranges from a slight colouration of the surface strata to intense replacement of the rock fabric.

3. Channels that are erosive into cross-bedded sandstone and exhibit a rough riffle like surface usually with accumulations of boulders and other sediments. These channels are usually bounded by solid rock outcrop.

A number of semi-permanent pools may be found within the channels of these drainage lines and creeks. The mechanisms of pool stability are variable and uniquely depend on local stratigraphy, structure and gradient. Pools range from:

- Water accumulations in a depression in an impermeable bedrock shelf (analogous to a bathtub) that is fed by direct precipitation, seepage or flood events; to
- Pools within eroded sections of sandy sediment and a free water surface that is dependent on surface flows and the local groundwater regime for stability.

A number of distinct pool types can be recognised:

1. Shallow, usually linear, small pools located in depressions formed by joint systems or cross-bedding and sometimes associated with potholes. Accumulated water is usually less saline than that in surrounding pools and probably has little interaction with the local groundwater system.
2. Linear pools associated with narrow erosion channels in sandy soil profiles. The soil profile is usually vegetated with heath/sedge like species. The downstream end is usually associated with a low rockbar or outcrop.
3. Larger pools constrained by a rockbar on the downstream end. These rockbars are usually undercut by erosion and exhibit signs of chemical weathering.
4. Larger pools constrained mainly by sediments on the downstream end. The sediments may extend for a considerable distance downstream and are associated with valley infill channels described above.

Pools within unconsolidated (sandy) sediments are in a state of equilibrium between water in (from a higher part of the phreatic groundwater surface either upstream or laterally) and water out (flowing down the phreatic surface). These pools are usually embedded in a valley infill swamp.

Most bedrock pools and riffle complexes rely on equilibrium between excess water in compared to water out. If the water inflow is less than the outflow, then the pool level declines. The nature of this equilibrium is ultimately dependent on the position of the pool on the overall stream gradient. Many pools in the streams naturally develop at rockbars and at the sediment and debris accumulations.

Controlling basal rockbars and pools greater than 6 m long and 4 m wide in or adjacent to swamps have been mapped for Area 3B (**Figure 3-81** to **Figure 3-87**).

The key dimensions and a photograph of each of the mapped features are provided in **Figure 3-88**. Due to its size (12 m long by 9 m wide) and the prominence of the feature adjacent to Swamp 14, Pool 34 on WC15 is considered a significant permanent pool within a swamp (**Figure 3-86**).

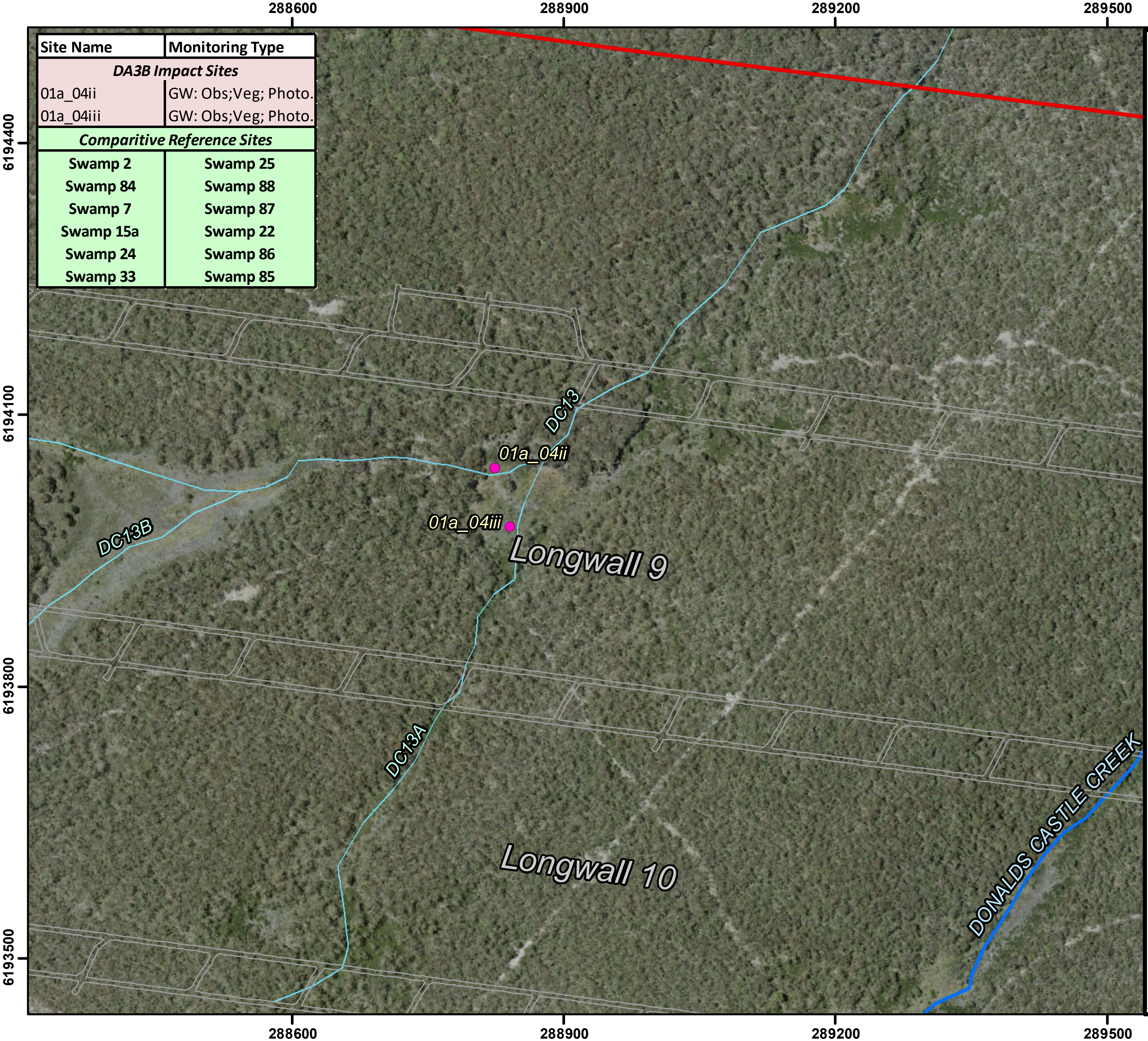
3.11 Reporting

EoP Reports are prepared in accordance with Condition 9, Schedule 3 of the Dendrobium Development Consent. Results from the monitoring program are included in the EoP Report and in the AEMR. These reports detail the outcomes of monitoring undertaken; provide results of visual inspections, and determine whether performance indicators have been exceeded.

Monitoring results will be reviewed monthly by the IMC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Principal Approvals will initiate the requirements of the TARPs shown as **Appendix A**.

Monitoring results are included in the Annual Reporting requirement under Condition 5 Schedule 8 in accordance with the Dendrobium Development Consent and are made publicly available in accordance with Condition 11, Schedule 8.

Figure 3-1 Swamp 1a Monitoring Sites



Site Name	Monitoring Type
DA3B Impact Sites	
01a_04ii	GW: Obs;Veg; Photo.
01a_04iii	GW: Obs;Veg; Photo.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**

SOUTH32

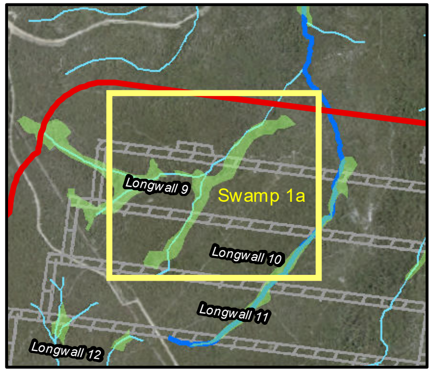
Dendrobium Area 3B

Swamp 1a Monitoring Sites

Figure 3-1

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Tributaries
- Creeks
- Swamps



Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

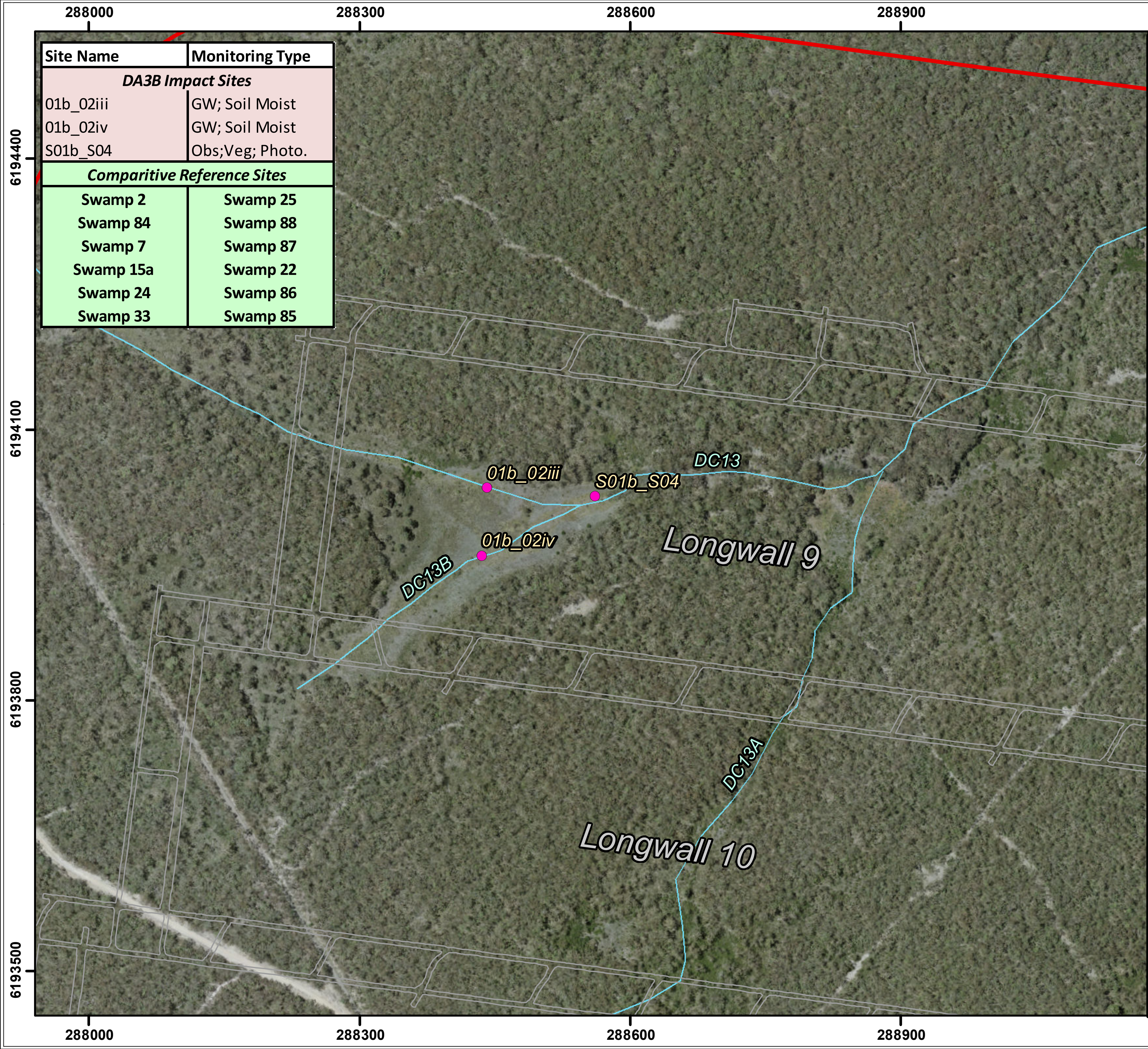
Meters
0 125 250

Dendrobium Area 3B

Swamp 1b Monitoring Sites

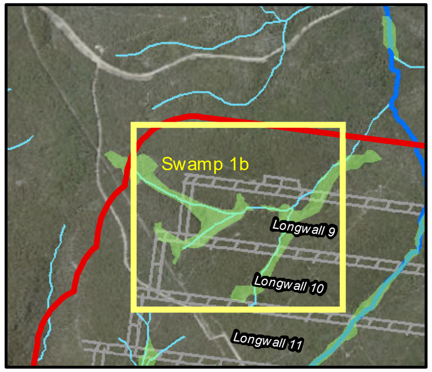
Figure 3-2

Site Name	Monitoring Type
DA3B Impact Sites	
01b_02iii	GW; Soil Moist
01b_02iv	GW; Soil Moist
S01b_S04	Obs;Veg; Photo.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**



Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Tributaries
- Creeks
- Swamps



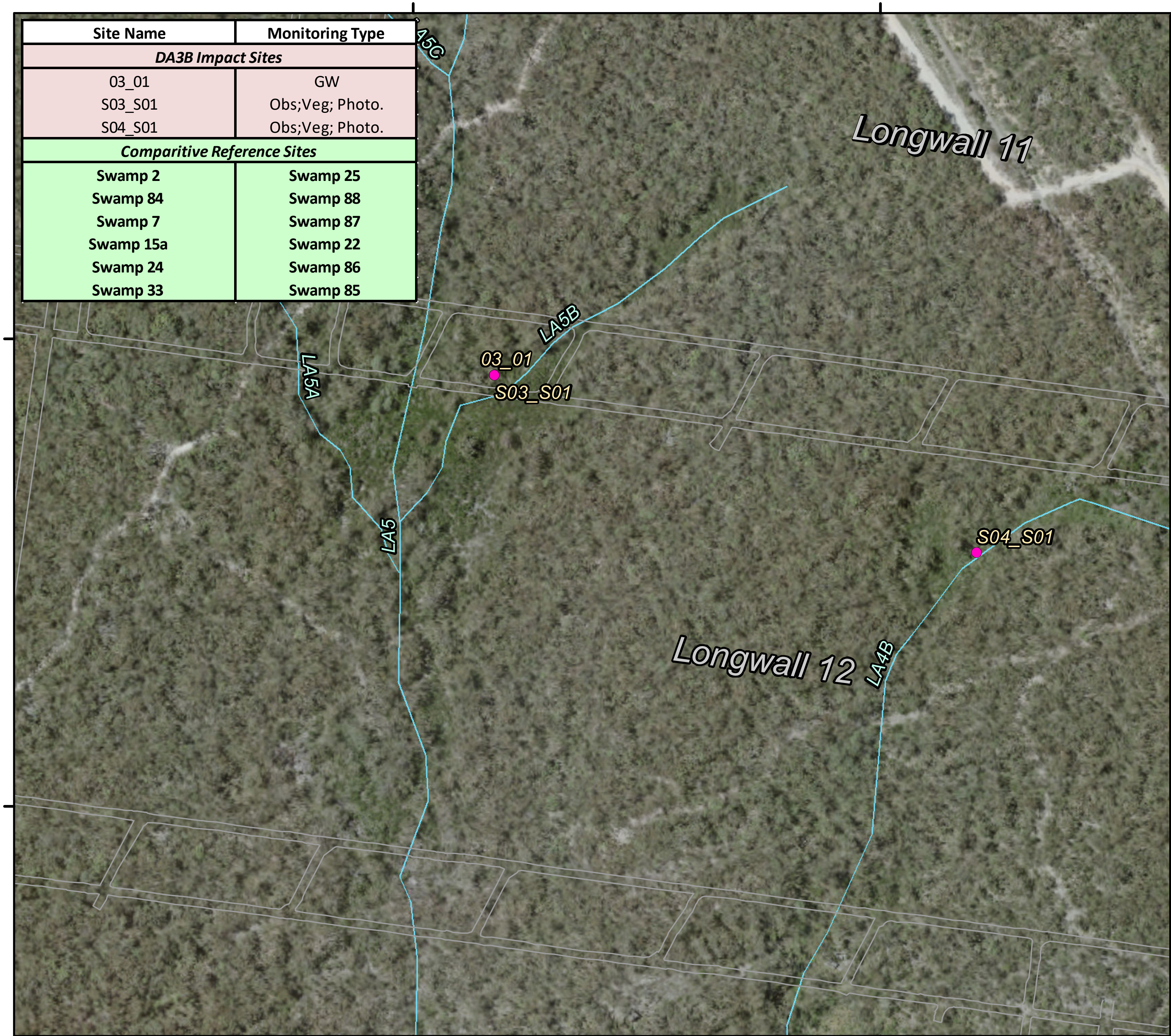
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 125 250

Site Name	Monitoring Type
DA3B Impact Sites	
03_01	GW
S03_S01	Obs;Veg; Photo.
S04_S01	Obs;Veg; Photo.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**



SOUTH32

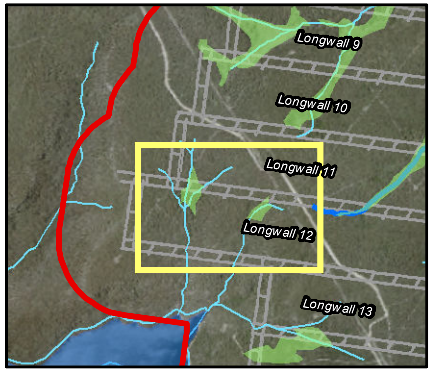
Dendrobium Area 3B

Swamp 3 & 4 Monitoring Sites

Figure 3-3

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Tributaries
- Swamps



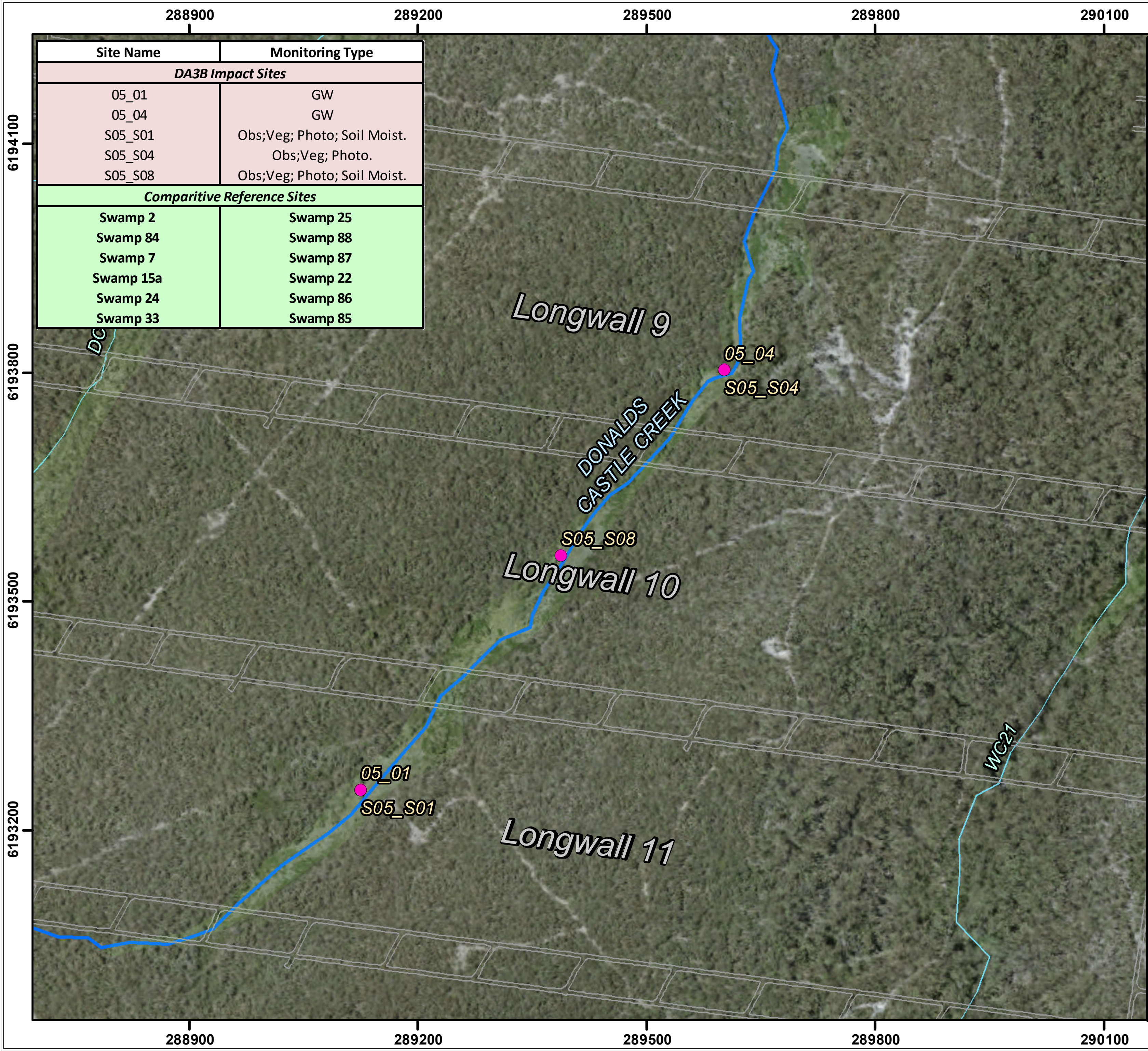
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 50 100

Site Name	Monitoring Type
DA3B Impact Sites	
05_01	GW
05_04	GW
S05_S01	Obs;Veg; Photo; Soil Moist.
S05_S04	Obs;Veg; Photo.
S05_S08	Obs;Veg; Photo; Soil Moist.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**



SOUTH32

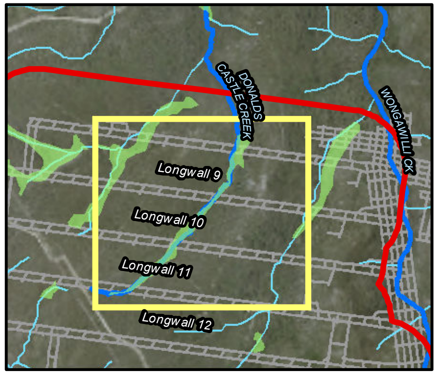
Dendrobium Area 3B

Swamp 5 Monitoring Sites

Figure 3-4

Legend

- Impact Monitoring Locations
- Swamps
- SMP Area
- Mine Workings
- Tributaries
- Creeks

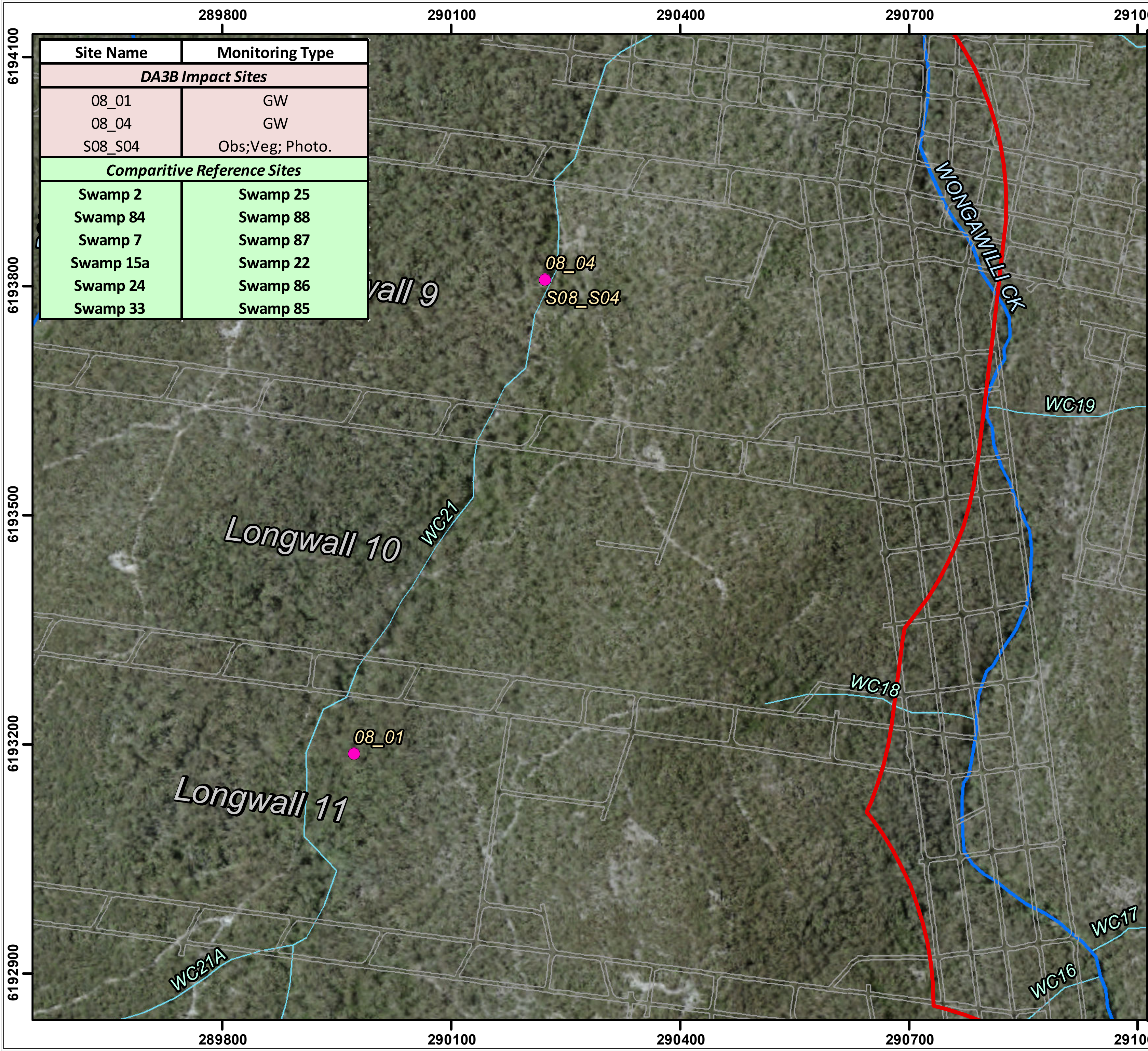


Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N S W E

Meters
0 125 250



Site Name	Monitoring Type
DA3B Impact Sites	
08_01	GW
08_04	GW
S08_S04	Obs;Veg; Photo.
Comparitive Reference Sites	
Swamp 2	Swamp 25
Swamp 84	Swamp 88
Swamp 7	Swamp 87
Swamp 15a	Swamp 22
Swamp 24	Swamp 86
Swamp 33	Swamp 85

SOUTH32

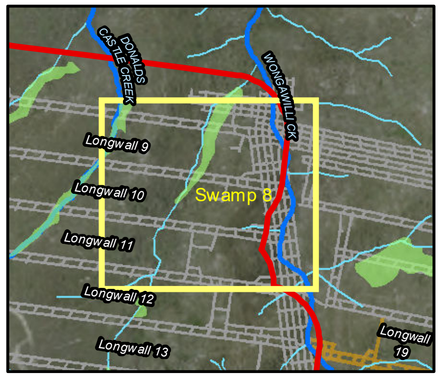
Dendrobium Area 3B

Swamp 8 Monitoring Sites

Figure 3-5

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries
- Creeks

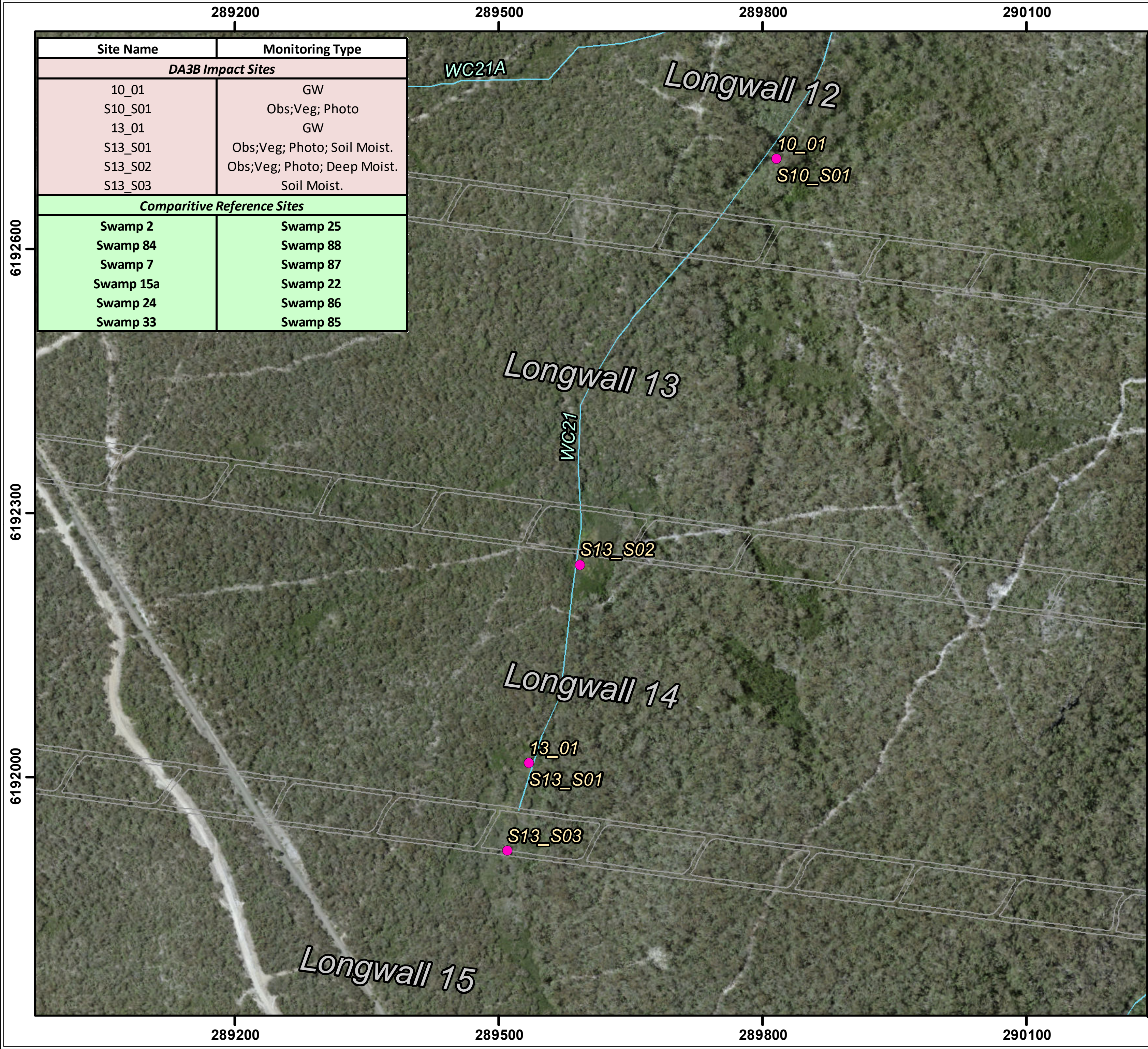


Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 125 250



Site Name	Monitoring Type
DA3B Impact Sites	
10_01	GW
S10_S01	Obs;Veg; Photo
13_01	GW
S13_S01	Obs;Veg; Photo; Soil Moist.
S13_S02	Obs;Veg; Photo; Deep Moist.
S13_S03	Soil Moist.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**

SOUTH32

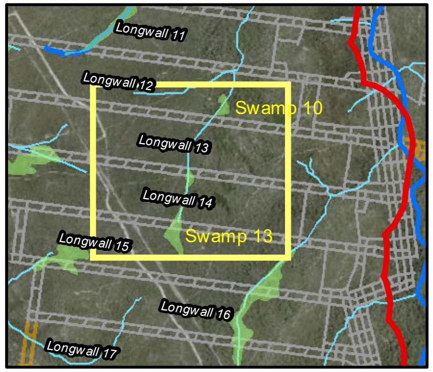
Dendrobium Area 3B

Swamp 10 & 13 Monitoring Sites

Figure 3-6

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries
- Swamps



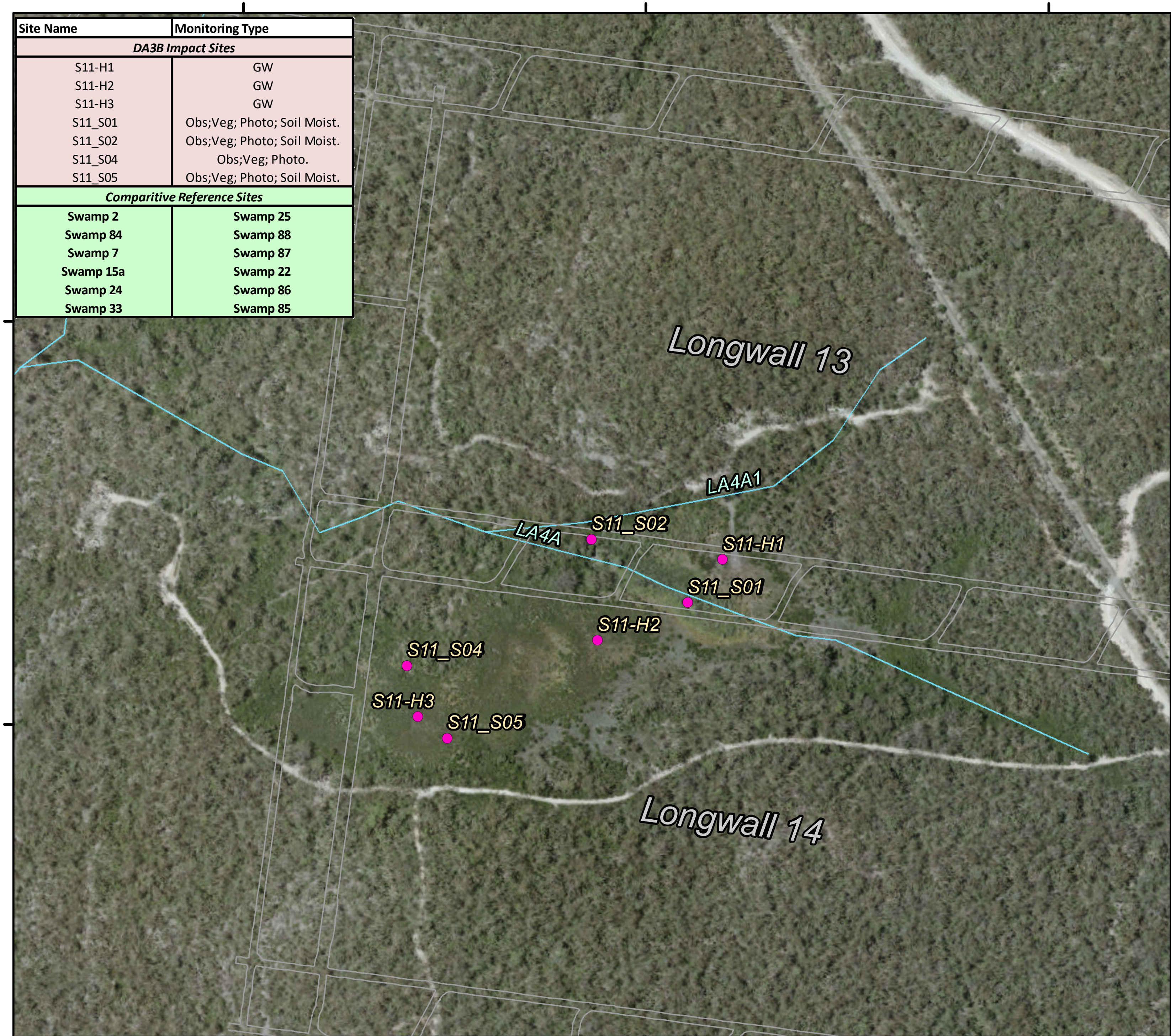
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

Meters
0 125 250

Site Name	Monitoring Type
DA3B Impact Sites	
S11-H1	GW
S11-H2	GW
S11-H3	GW
S11_S01	Obs;Veg; Photo; Soil Moist.
S11_S02	Obs;Veg; Photo; Soil Moist.
S11_S04	Obs;Veg; Photo.
S11_S05	Obs;Veg; Photo; Soil Moist.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**



SOUTH32

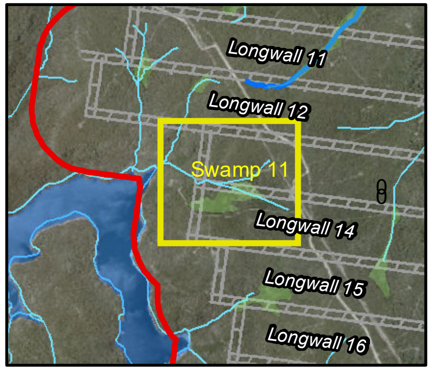
Dendrobium Area 3b

Swamp 11 Monitoring Sites

Figure 3-7

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries



Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

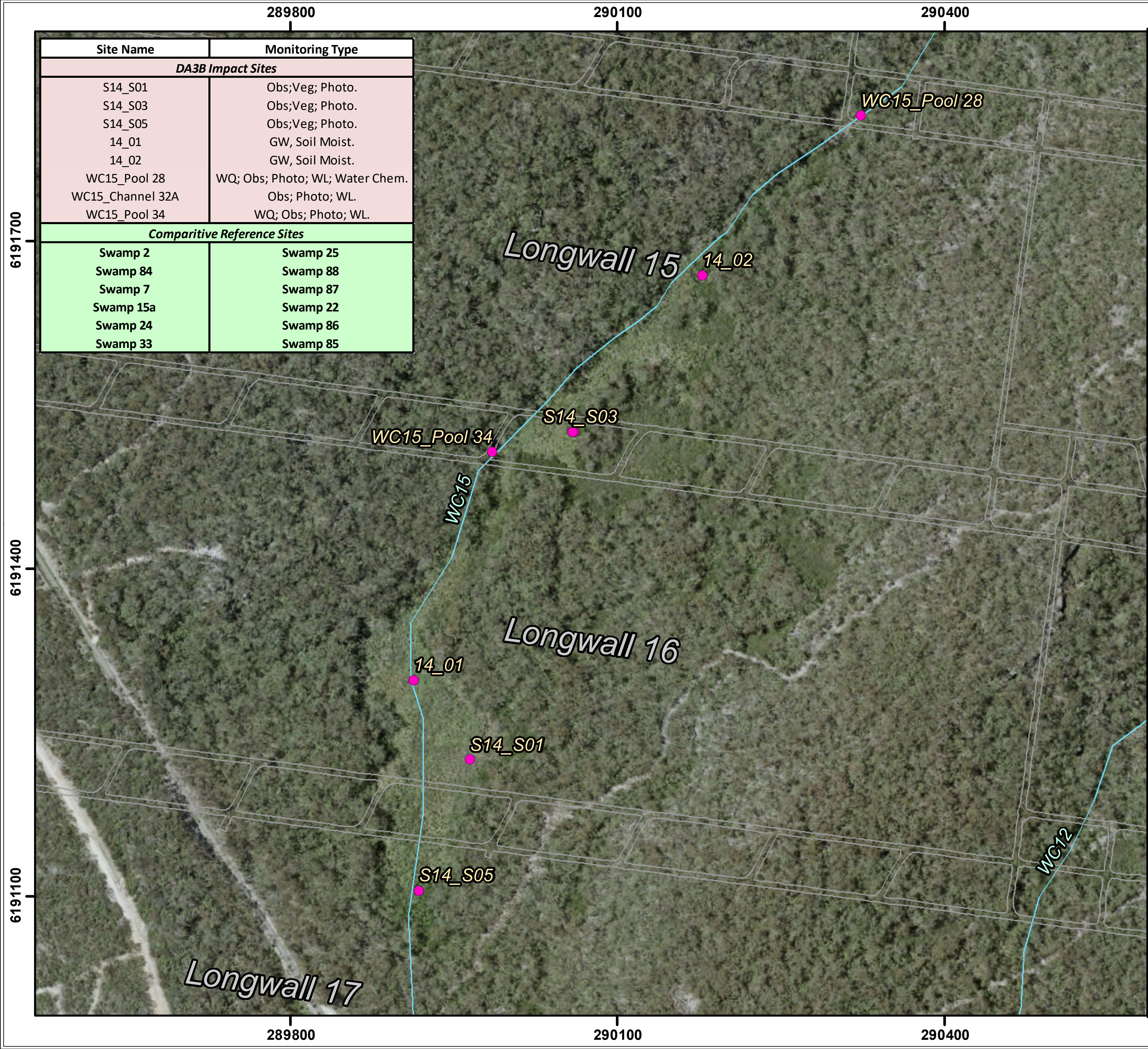
Meters
0 100 200

Dendrobium Area 3B

Swamp 14 Monitoring Sites

Figure 3-8

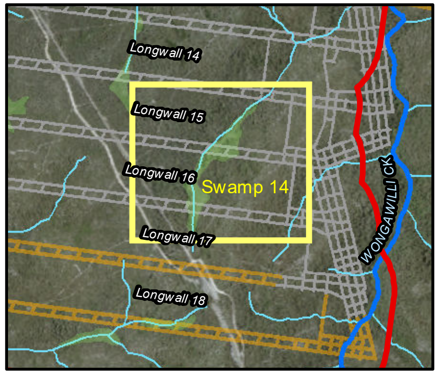
Site Name	Monitoring Type
DA3B Impact Sites	
S14_S01	Obs;Veg; Photo.
S14_S03	Obs;Veg; Photo.
S14_S05	Obs;Veg; Photo.
14_01	GW, Soil Moist.
14_02	GW, Soil Moist.
WC15_Pool 28	WQ; Obs; Photo; WL; Water Chem.
WC15_Channel 32A	Obs; Photo; WL.
WC15_Pool 34	WQ; Obs; Photo; WL.
Comparitive Reference Sites	
Swamp 2	Swamp 25
Swamp 84	Swamp 88
Swamp 7	Swamp 87
Swamp 15a	Swamp 22
Swamp 24	Swamp 86
Swamp 33	Swamp 85



SOUTH32

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries
- Creeks



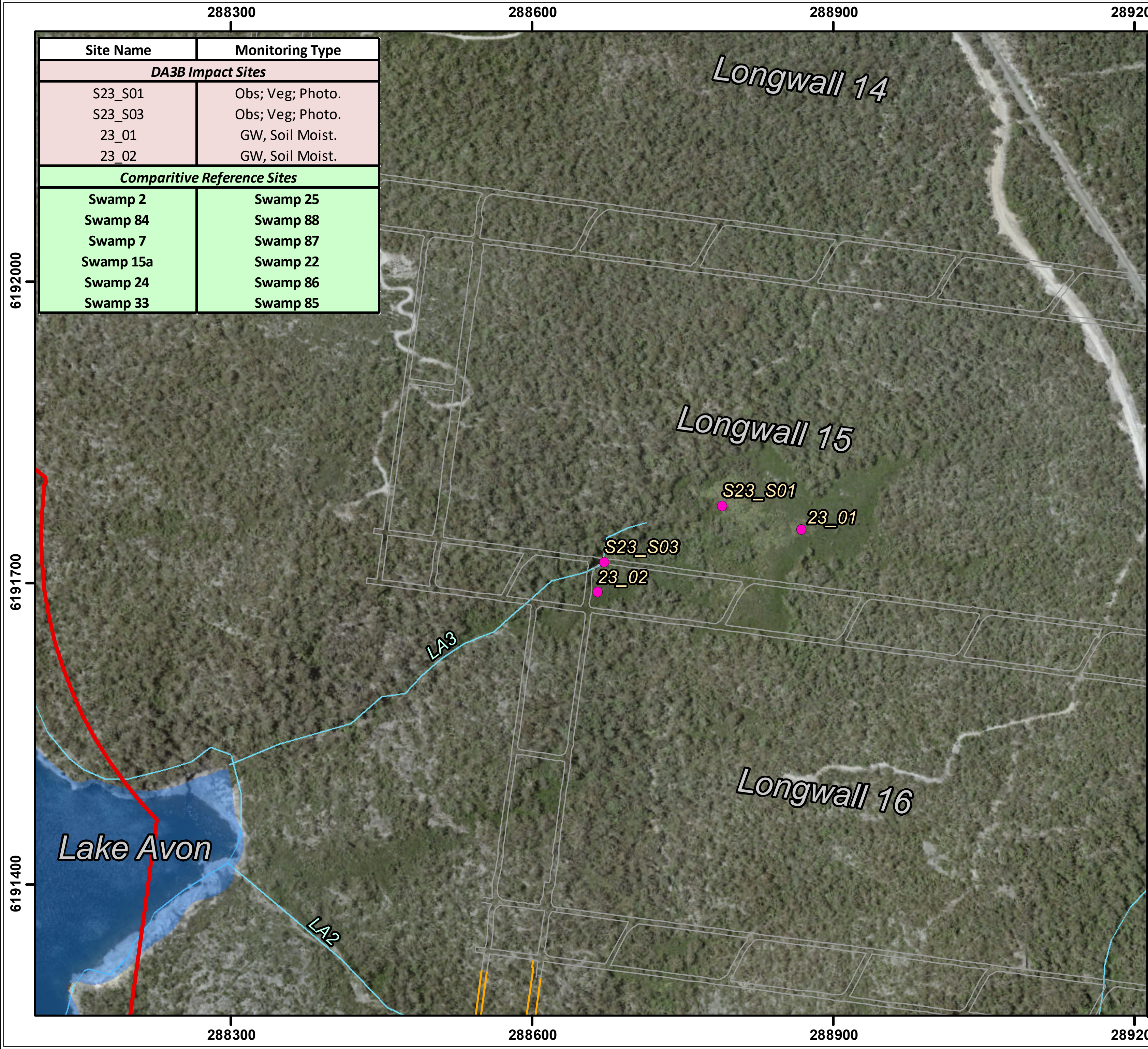
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 100 200

Site Name	Monitoring Type
DA3B Impact Sites	
S23_S01	Obs; Veg; Photo.
S23_S03	Obs; Veg; Photo.
23_01	GW, Soil Moist.
23_02	GW, Soil Moist.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**



SOUTH32

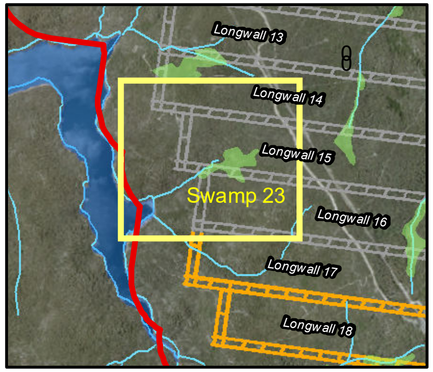
Dendrobium Area 3B

Swamp 23 Monitoring Sites

Figure 3-9

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries
- Swamps



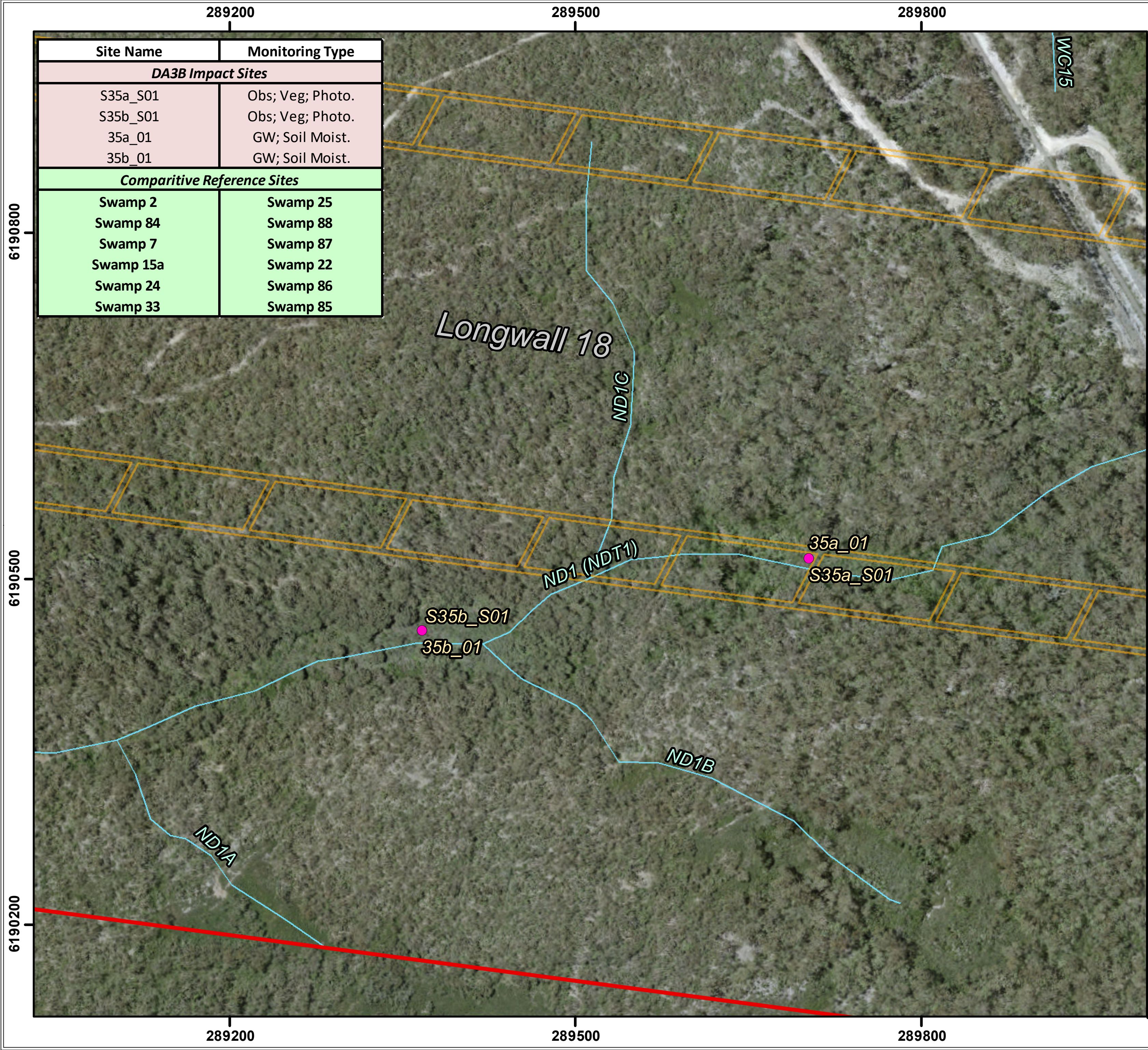
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 125 250

Site Name	Monitoring Type
DA3B Impact Sites	
S35a_S01	Obs; Veg; Photo.
S35b_S01	Obs; Veg; Photo.
35a_01	GW; Soil Moist.
35b_01	GW; Soil Moist.
Comparitive Reference Sites	
Swamp 2	**Swamp 25**
Swamp 84	**Swamp 88**
Swamp 7	**Swamp 87**
Swamp 15a	**Swamp 22**
Swamp 24	**Swamp 86**
Swamp 33	**Swamp 85**



SOUTH32

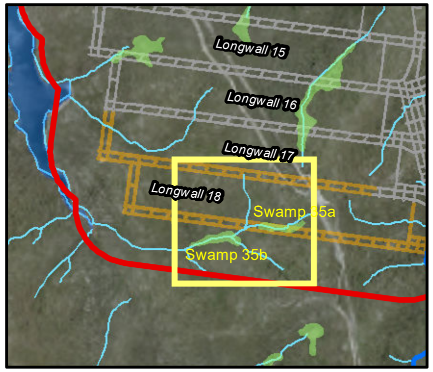
Dendrobium Area 3B

Swamp 35a & 35b Monitoring Sites

Figure 3-10

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries
- Swamps

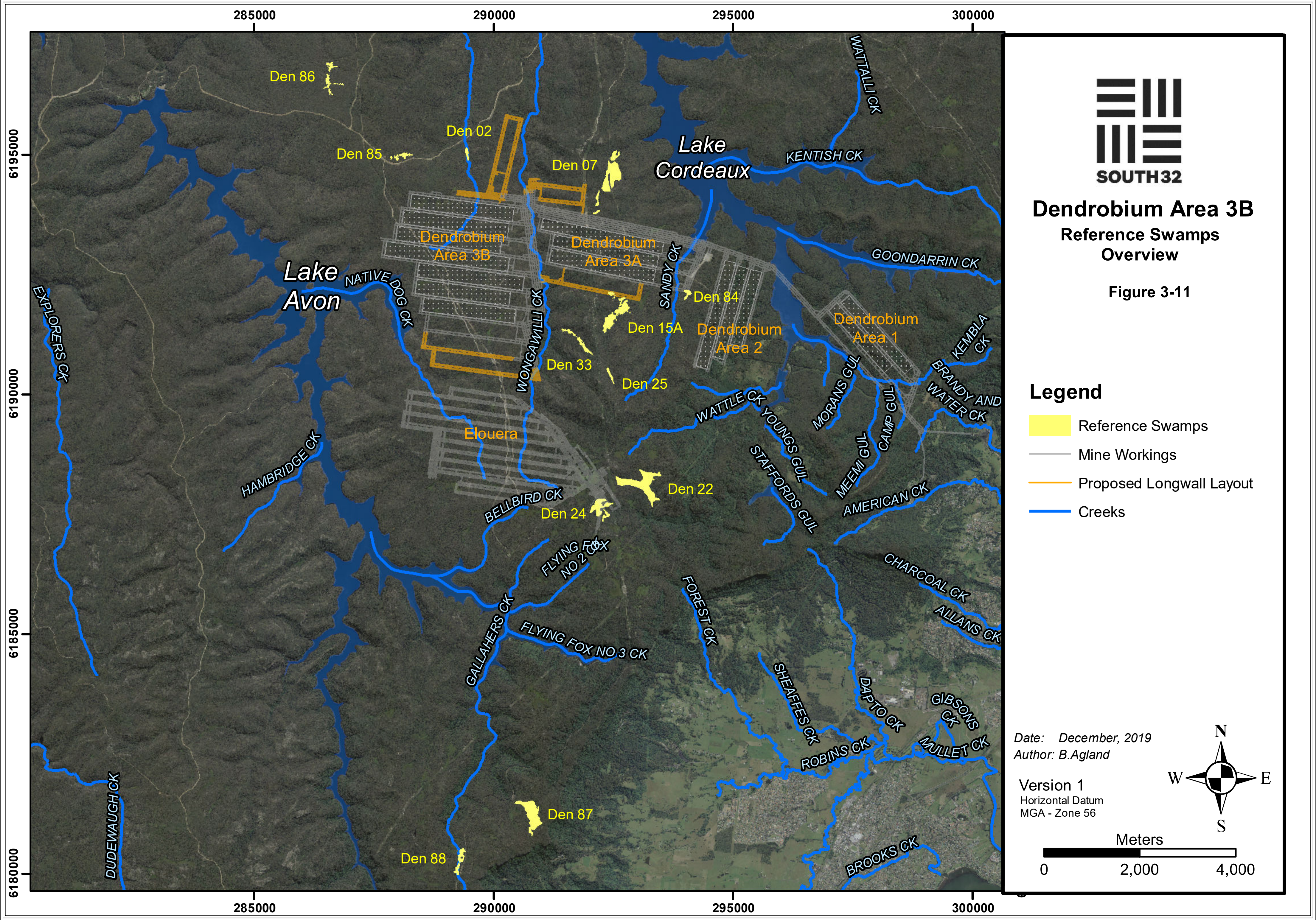


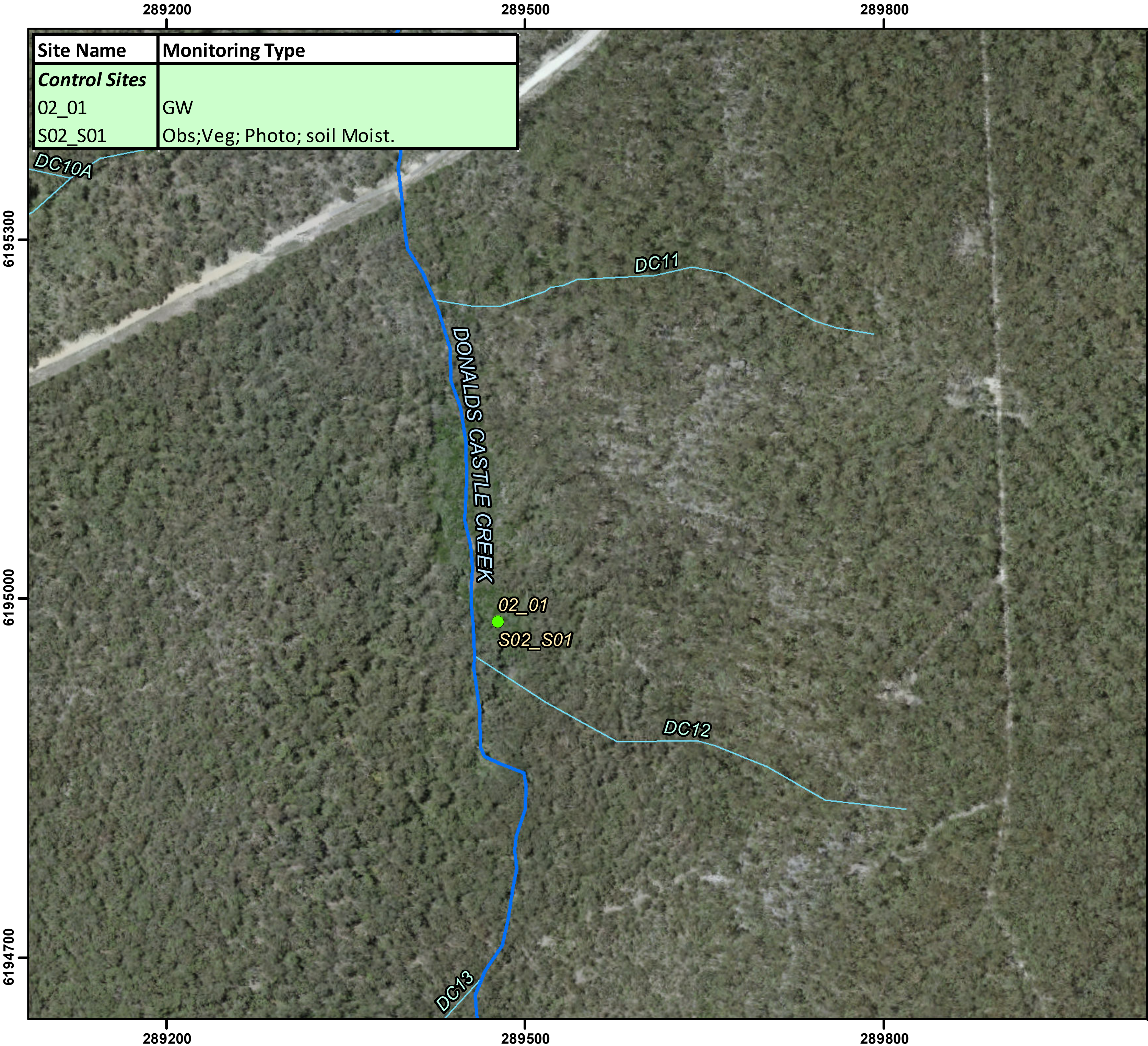
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N S W E

Meters
0 100 200


SOUTH32
Dendrobium Area 3B
Reference Swamps Overview
Figure 3-11
Legend
Reference Swamps
Mine Workings
Proposed Longwall Layout
Creeks
Date: December, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
Meters
0
2,000
4,000
N
S
E
W
285000
290000
295000
300000
6195000
6190000
6185000
6180000
Lake Avon
Lake Cordeaux
Dendrobium Area 3B
Dendrobium Area 3A
Dendrobium Area 2
Dendrobium Area 1
Elouera
Den 86
Den 02
Den 85
Den 07
Den 84
Den 15A
Den 33
Den 25
Den 22
Den 24
Den 87
Den 88
EXPLORERS CK
NATIVE DOG CK
WONGAWILLI CK
SANDY CK
WATTALLI CK
KENTISH CK
GOONDARRIN CK
KEMBLA CK
BRANDY AND WATER CK
MORANS GUL
CAMP GUL
MEEMI GUL
YOUNGS GUL
STAFFORDS GUL
WATTLE CK
AMERICAN CK
HAMBRIDGE CK
BELLBIRD CK
FLYING FOX NO 2 CK
FLYING FOX NO 3 CK
CALLAHERS CK
FOREST CK
CHARCOAL CK
ALLANS CK
SHEAFFES CK
DAPTO CK
GIBSONS CK
MULLET CK
ROBINS CK
BROOKS CK
DUDEWAUGH CK



Site Name	Monitoring Type
Control Sites	
02_01	GW
S02_S01	Obs;Veg; Photo; soil Moist.

SOUTH32

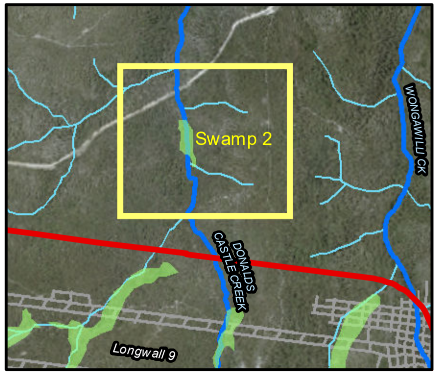
Dendrobium Area 3B

Swamp 2 Monitoring Sites

Figure 3-12

Legend

- Reference Monitoring Locations
- SMP Area
- Mine Workings
- Creeks
- Tributaries
- Swamps

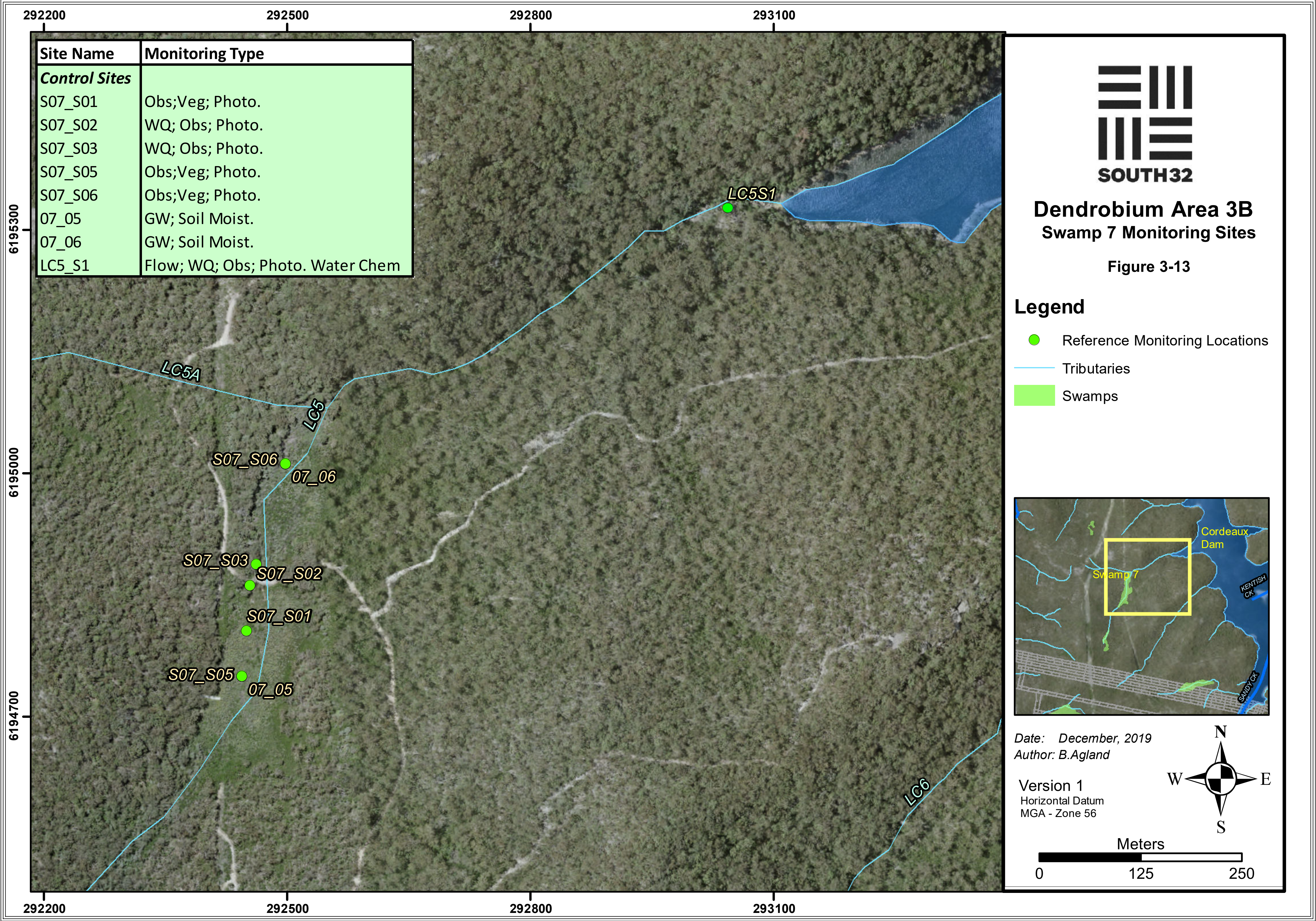


Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

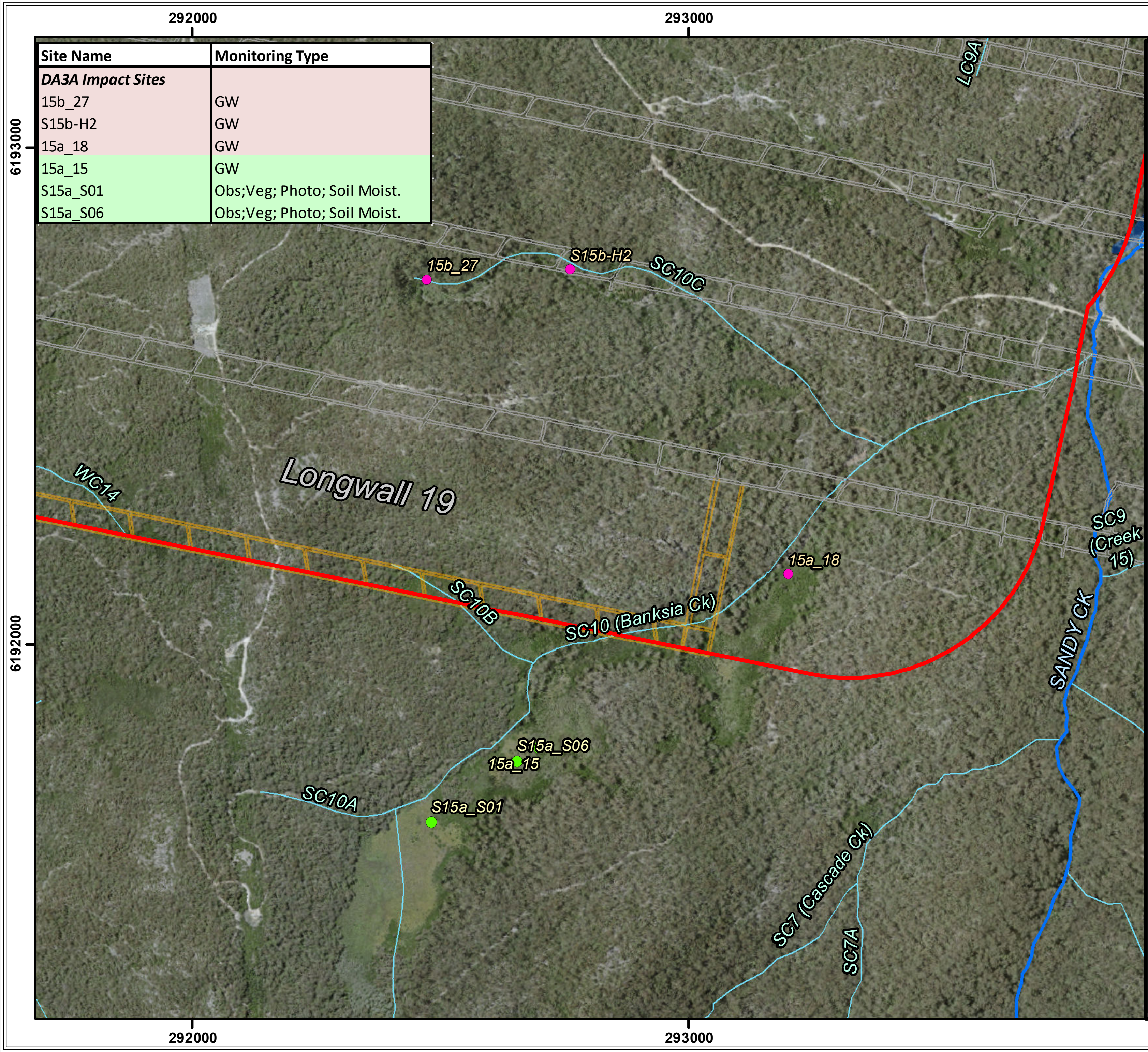
Meters
0 100 200



Site Name	Monitoring Type
Control Sites	
S07_S01	Obs;Veg; Photo.
S07_S02	WQ; Obs; Photo.
S07_S03	WQ; Obs; Photo.
S07_S05	Obs;Veg; Photo.
S07_S06	Obs;Veg; Photo.
07_05	GW; Soil Moist.
07_06	GW; Soil Moist.
LC5_S1	Flow; WQ; Obs; Photo. Water Chem

Dendrobium Area 3B
Swamp 7 Monitoring Sites

Figure 3-13



Site Name	Monitoring Type
DA3A Impact Sites	
15b_27	GW
S15b-H2	GW
15a_18	GW
15a_15	GW
S15a_S01	Obs;Veg; Photo; Soil Moist.
S15a_S06	Obs;Veg; Photo; Soil Moist.

SOUTH32

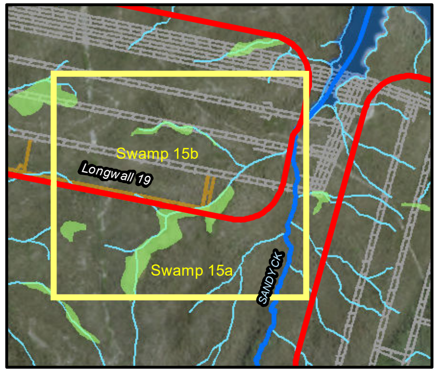
Dendrobium Area 3A

Swamp 15a &15b Monitoring Sites

Figure 3-14

Legend

- Reference Monitoring Sites
- Impact Monitoring Locations
- 400m Zone of Influence
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries
- Swamps

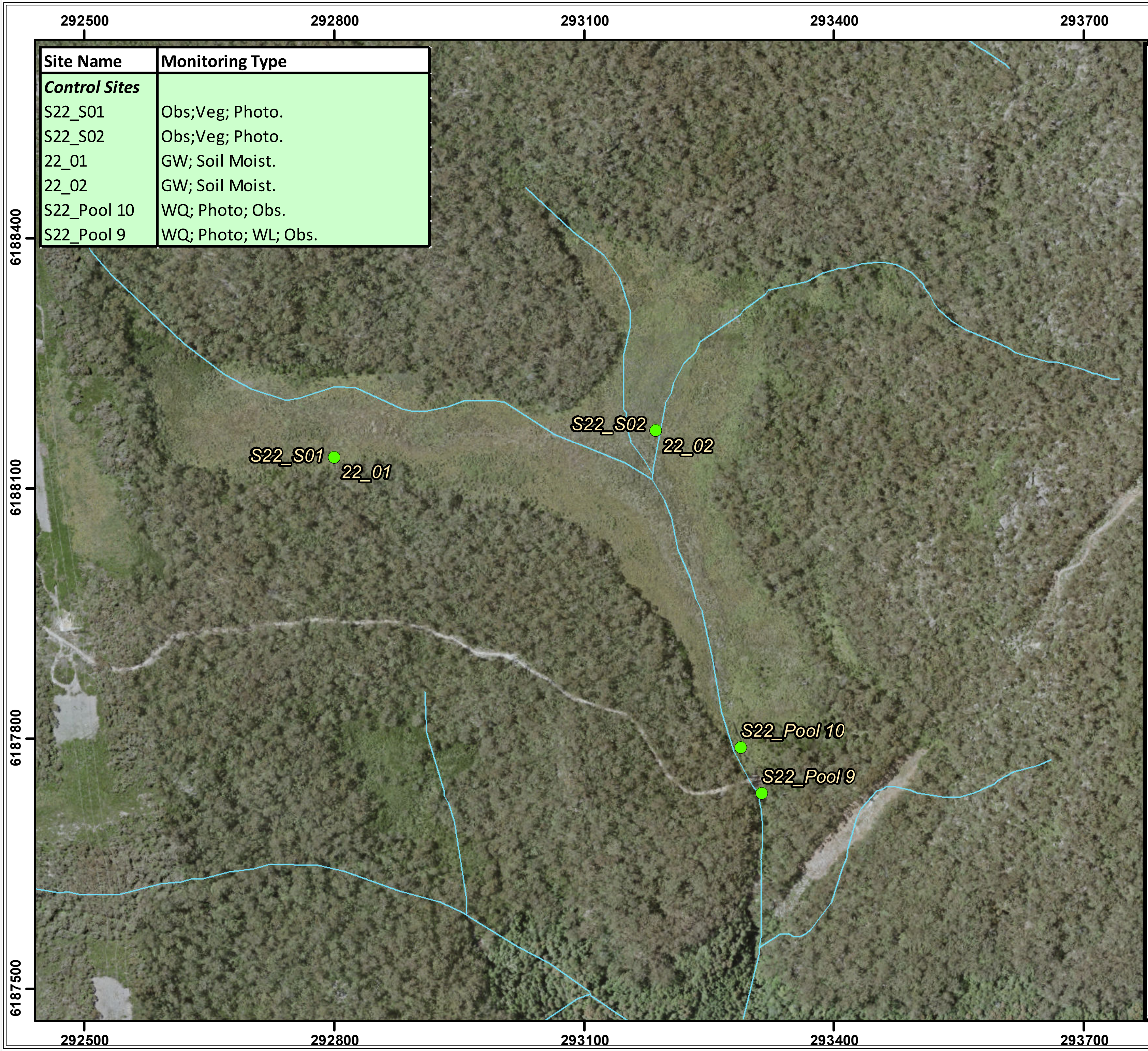


Date: January, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 250 500



Site Name	Monitoring Type
Control Sites	
S22_S01	Obs;Veg; Photo.
S22_S02	Obs;Veg; Photo.
22_01	GW; Soil Moist.
22_02	GW; Soil Moist.
S22_Pool 10	WQ; Photo; Obs.
S22_Pool 9	WQ; Photo; WL; Obs.

SOUTH32

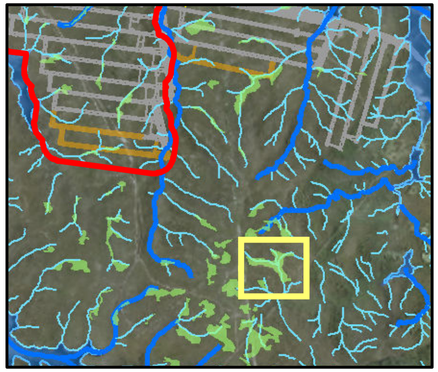
Dendrobium Area 3B

Swamp 22 Monitoring Sites

Figure 3-15

Legend

- Reference Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries
- Swamps



Date: February, 2020

Author: B.Agland

Version 1

Horizontal Datum

MGA - Zone 56

N W E S

Meters

0 125 250

Site Name	Monitoring Type
Control Sites	
D10	WQ; Photo; Obs; Water Chem.
S24_S01	Obs;Veg; Photo; Soil Moist.

SOUTH32

Dendrobium Area 3B

Swamp 24 Monitoring Sites

Figure 3-16

Legend

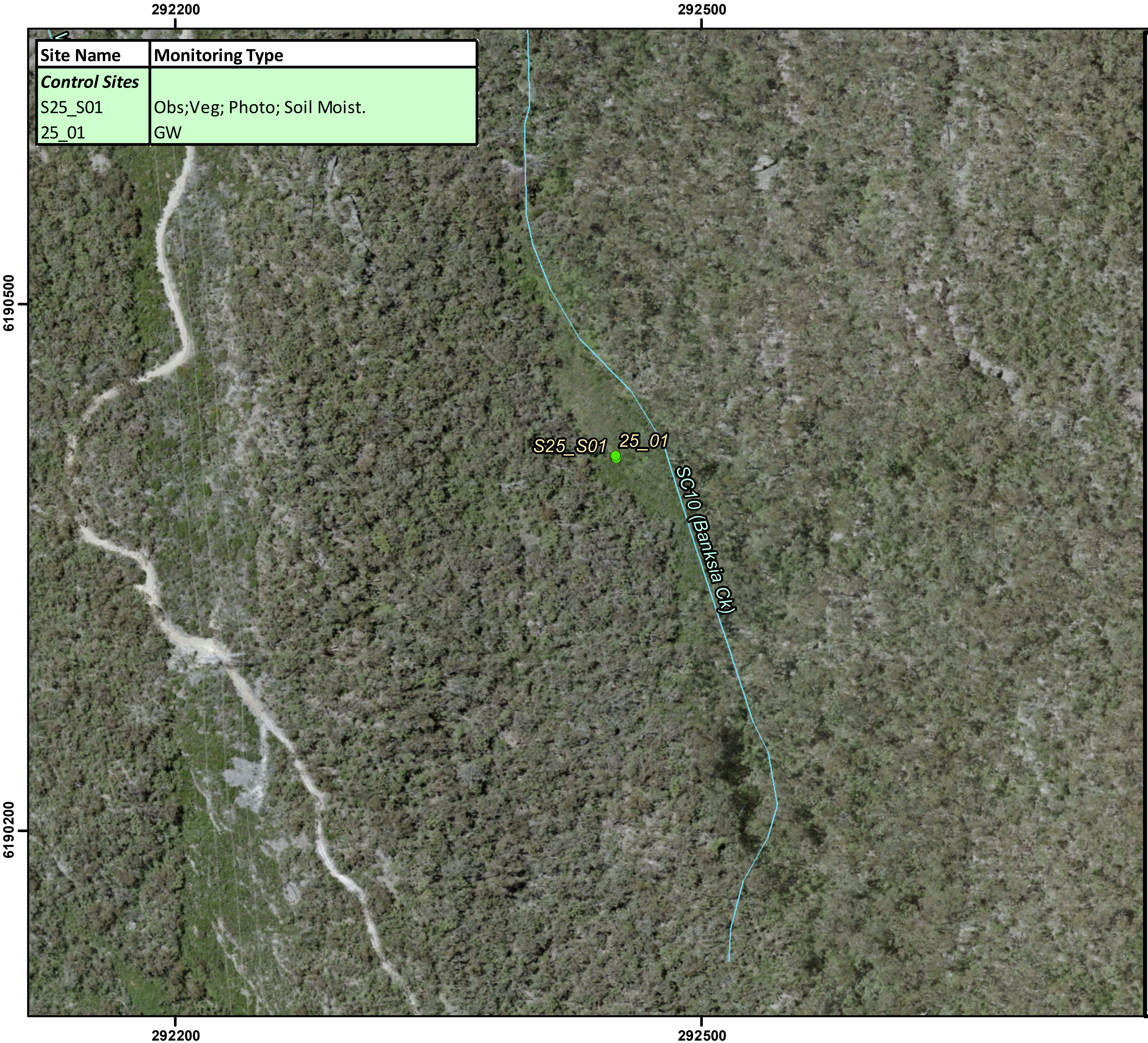
- Reference Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries
- Swamps

Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 75 150



Site Name	Monitoring Type
Control Sites	
S25_S01	Obs;Veg; Photo; Soil Moist.
25_01	GW

SOUTH32

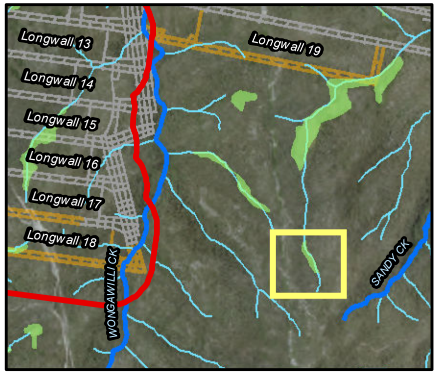
Dendrobium Area 3B

Swamp 25 Monitoring Sites

Figure 3-17

Legend

- Reference Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries
- Creeks
- Swamps



Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

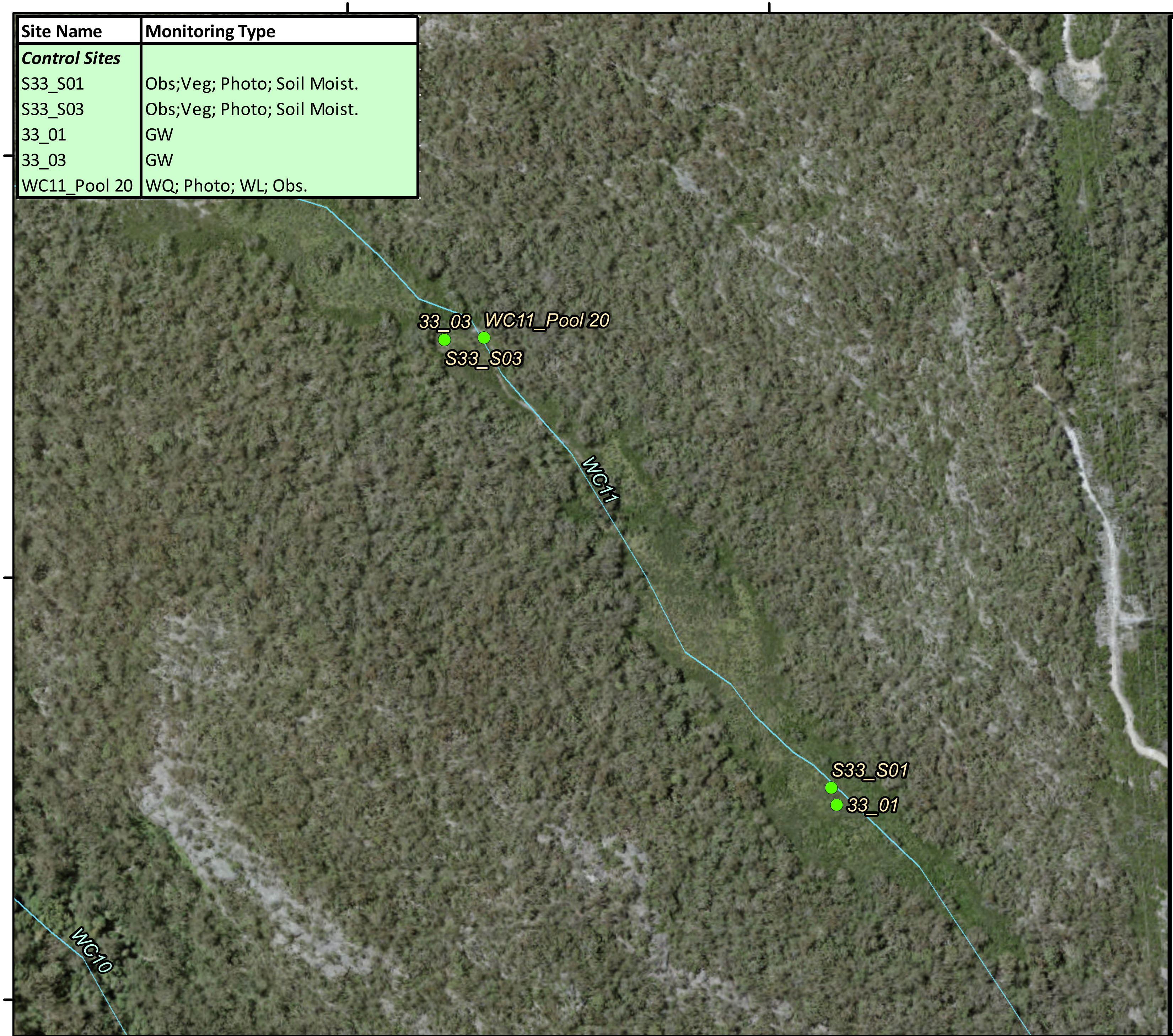
Meters
0 75 150

Dendrobium Area 3B

Swamp 33 Monitoring Sites

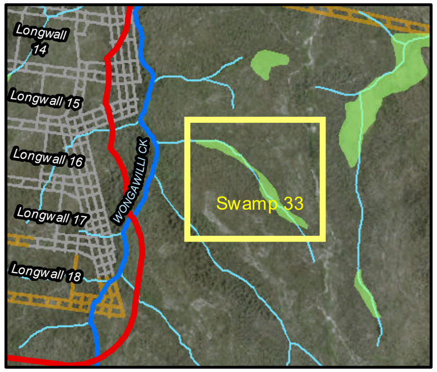
Figure 3-18

Site Name	Monitoring Type
Control Sites	
S33_S01	Obs;Veg; Photo; Soil Moist.
S33_S03	Obs;Veg; Photo; Soil Moist.
33_01	GW
33_03	GW
WC11_Pool 20	WQ; Photo; WL; Obs.



Legend

- Reference Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries
- Swamps



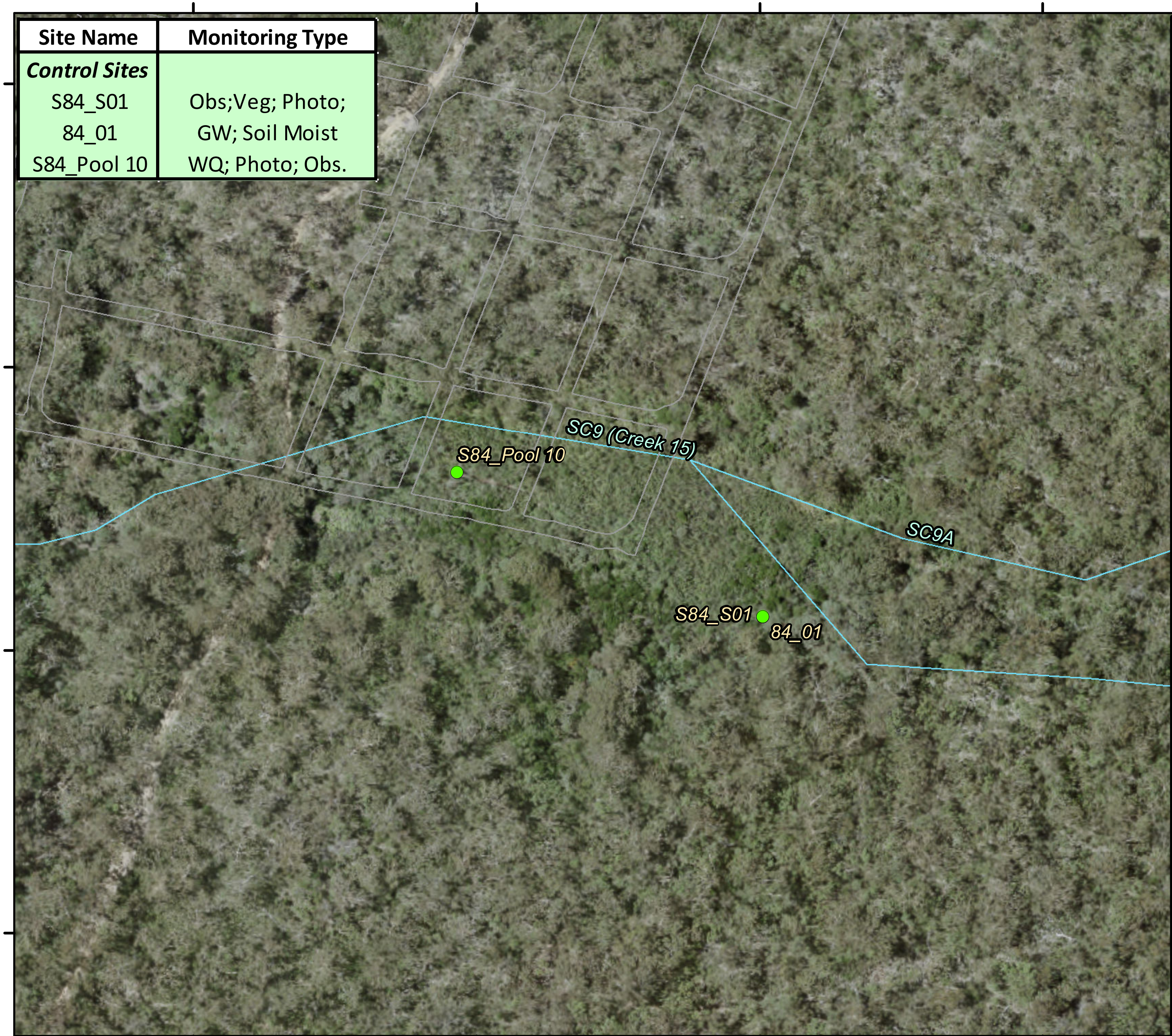
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 75 150

Site Name	Monitoring Type
Control Sites	
S84_S01	Obs;Veg; Photo;
84_01	GW; Soil Moist
S84_Pool 10	WQ; Photo; Obs.



SOUTH32

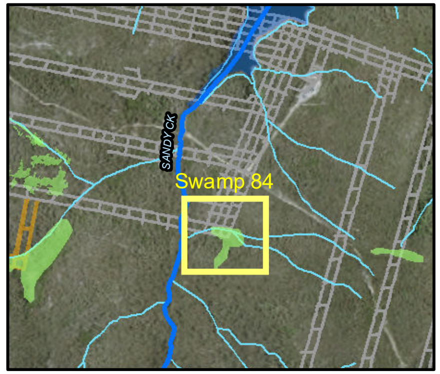
Dendrobium Area 3B

Swamp 84 Monitoring Sites

Figure 3-19

Legend

- Reference Monitoring Locations
- Mine Workings
- Tributaries
- Swamps



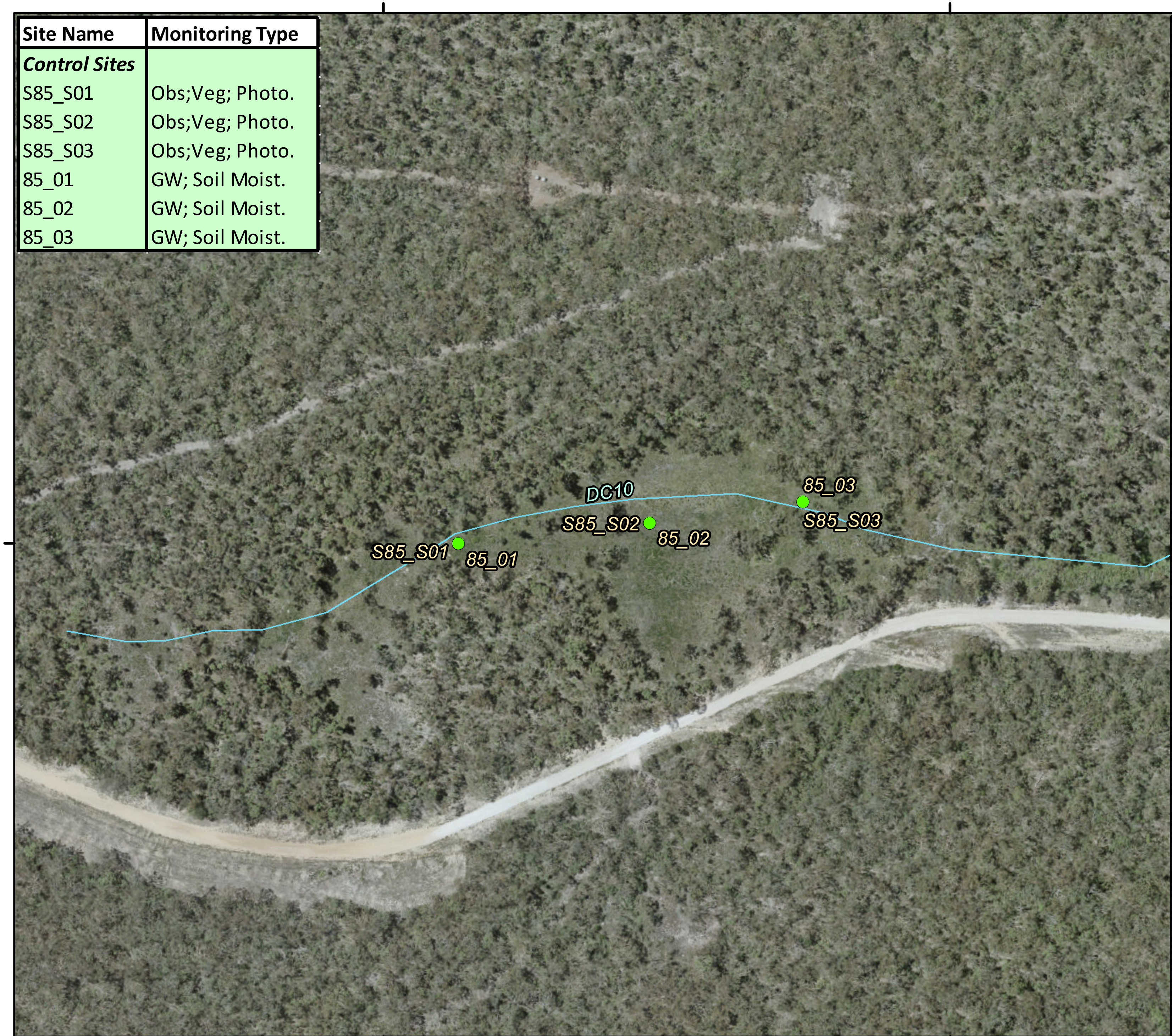
Date: Februray, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 50 100

Site Name	Monitoring Type
Control Sites	
S85_S01	Obs;Veg; Photo.
S85_S02	Obs;Veg; Photo.
S85_S03	Obs;Veg; Photo.
85_01	GW; Soil Moist.
85_02	GW; Soil Moist.
85_03	GW; Soil Moist.



SOUTH32

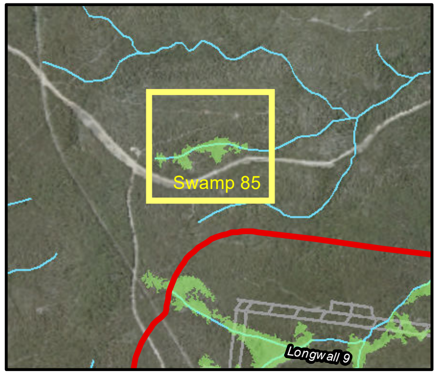
Dendrobium Area 3B

Swamp 85 Monitoring Sites

Figure 3-20

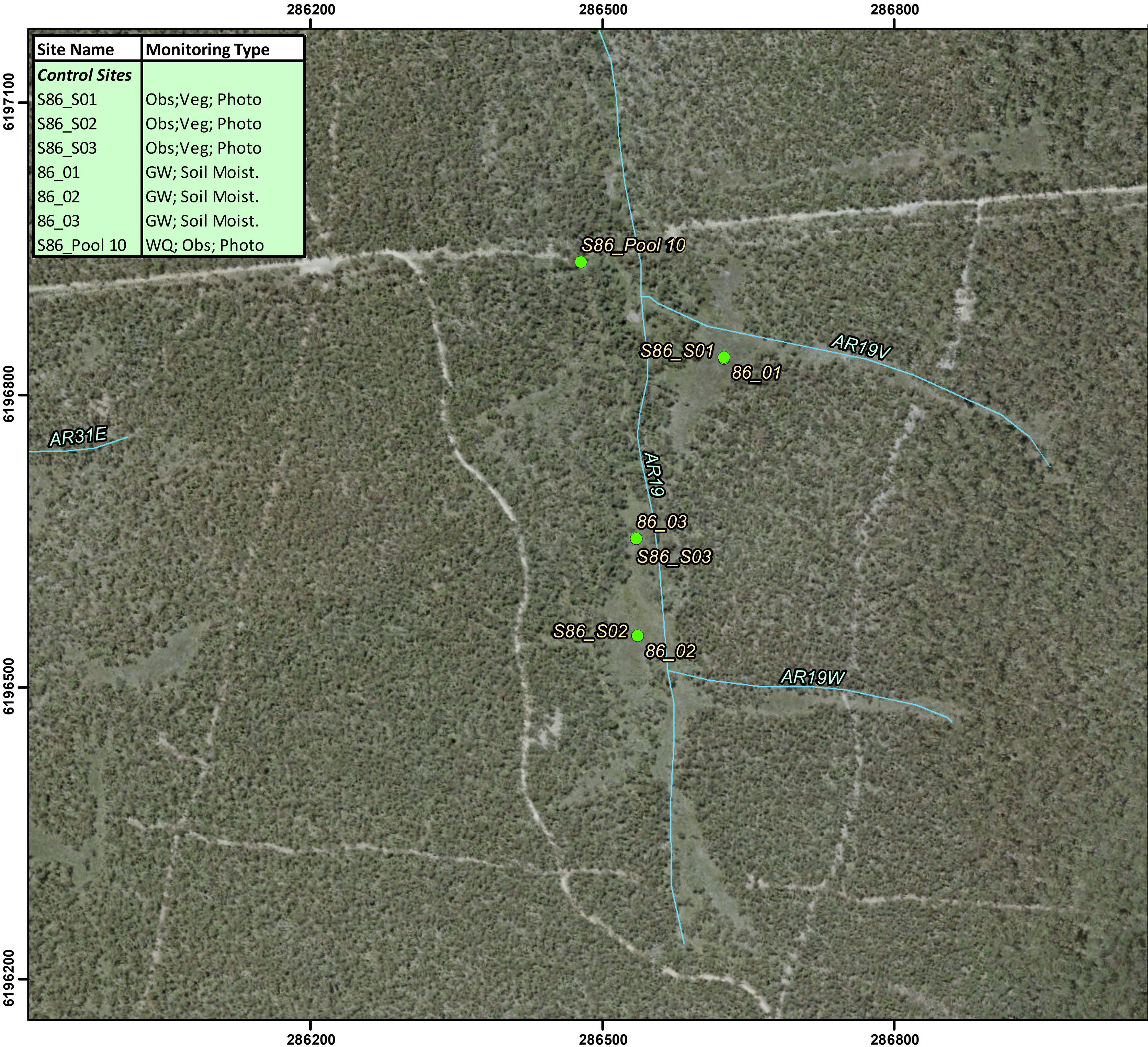
Legend

- Reference Monitoring Locations
- SMP Area
- Mine Workings
- Tributaries
- Swamps



Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56



Site Name	Monitoring Type
Control Sites	
S86_S01	Obs;Veg; Photo
S86_S02	Obs;Veg; Photo
S86_S03	Obs;Veg; Photo
86_01	GW; Soil Moist.
86_02	GW; Soil Moist.
86_03	GW; Soil Moist.
S86_Pool 10	WQ; Obs; Photo

SOUTH32

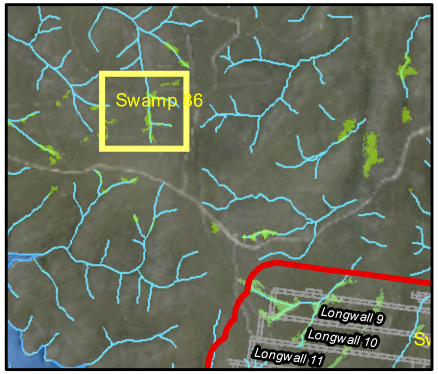
Dendrobium Area 3B

Swamp 86 Monitoring Sites

Figure 3-21

Legend

- Reference Monitoring Locations
- SMP Area
- Mine Workings
- Tributaries
- Creeks
- Swamps

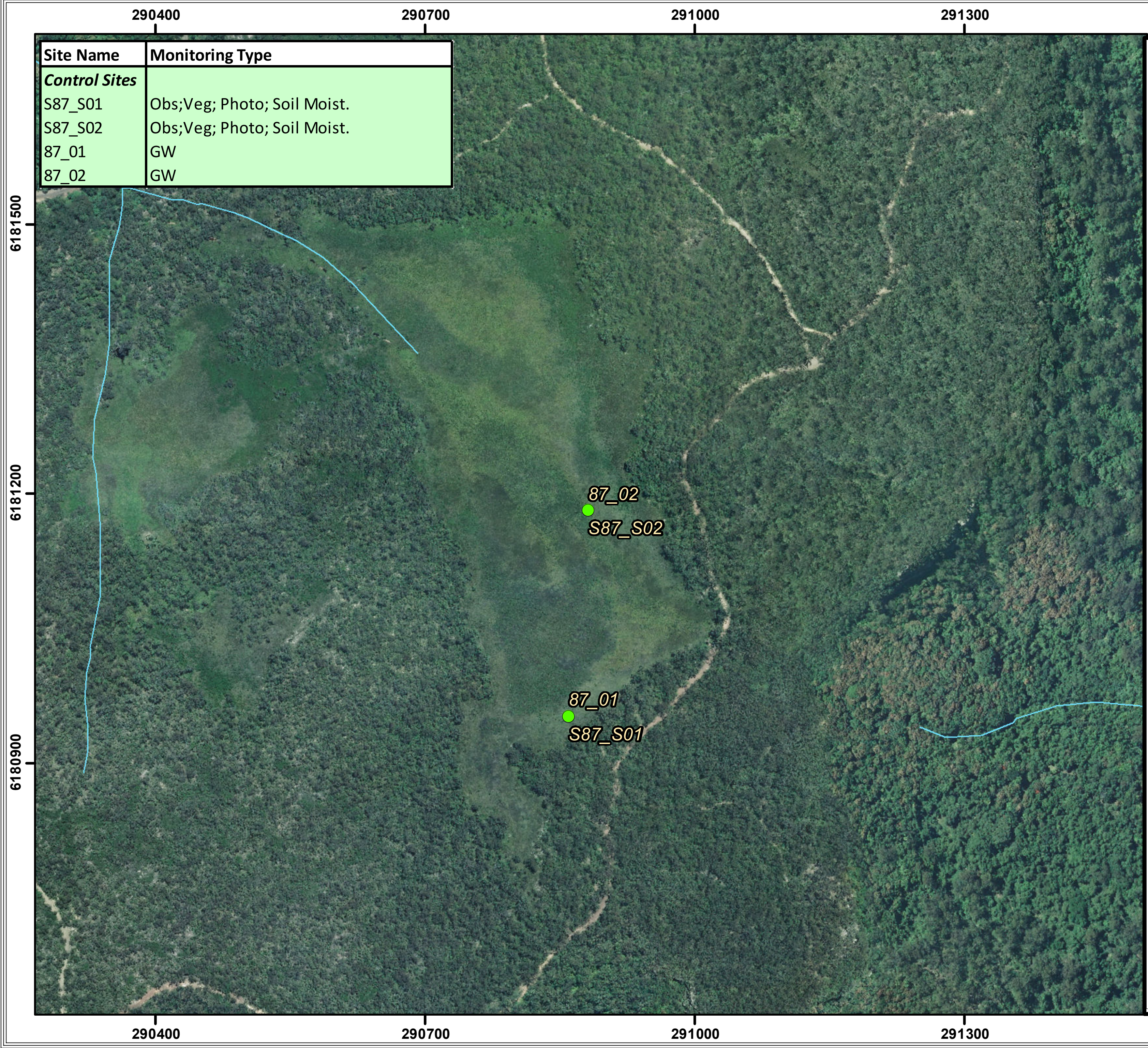


Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 125 250



Site Name	Monitoring Type
Control Sites	
S87_S01	Obs;Veg; Photo; Soil Moist.
S87_S02	Obs;Veg; Photo; Soil Moist.
87_01	GW
87_02	GW

SOUTH32

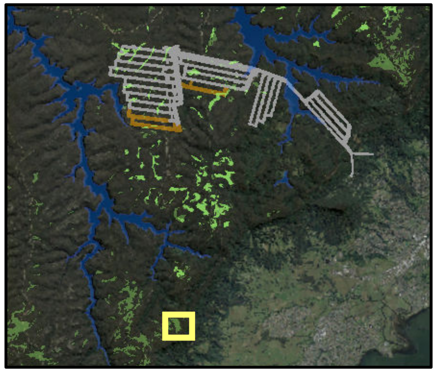
Dendrobium Area 3B

Swamp 87 Monitoring Sites

Figure 3-22

Legend

- Reference Monitoring Locations
- Tributaries
- Swamps



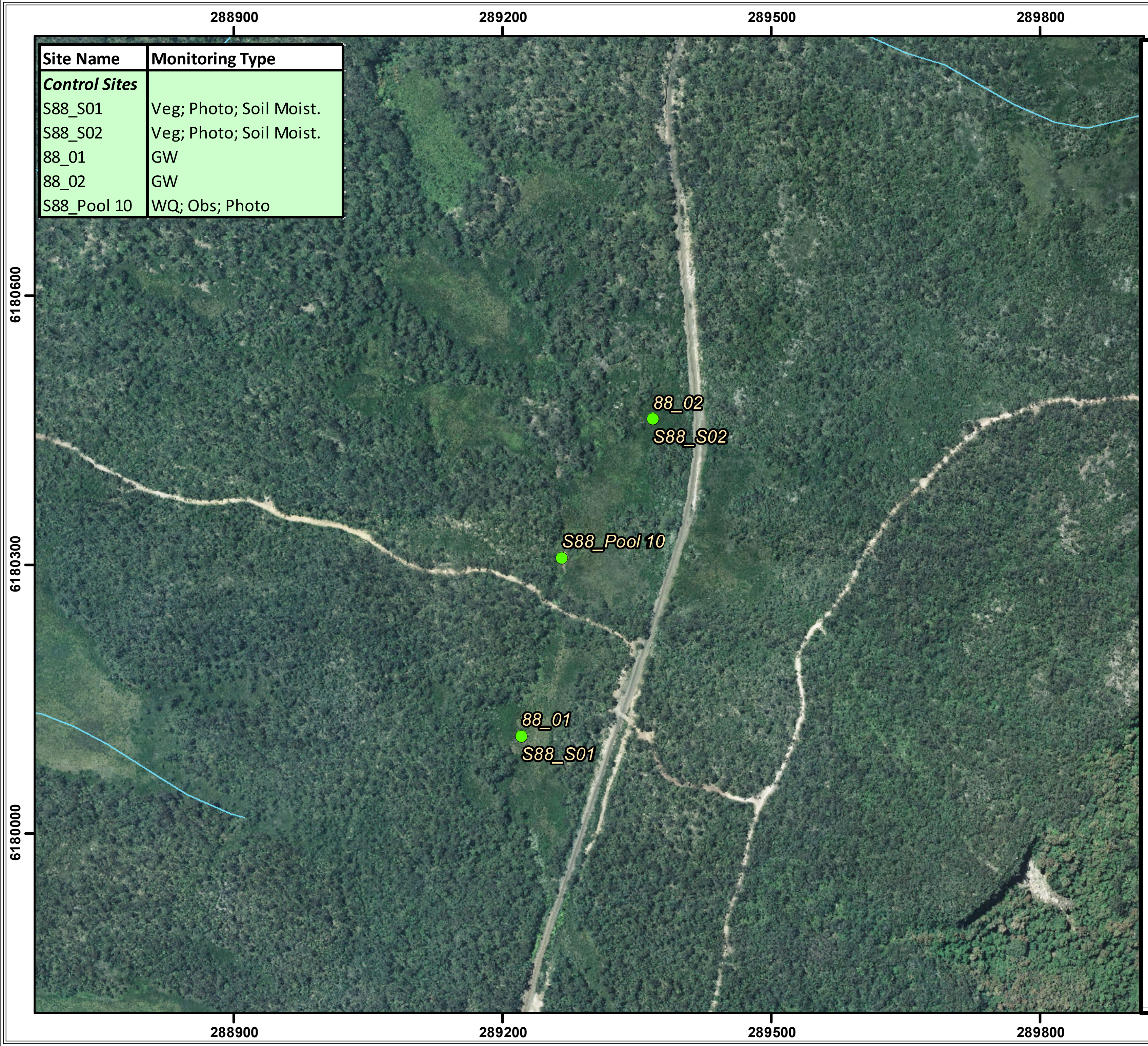
Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 125 250

Site Name	Monitoring Type
Control Sites	
S88_S01	Veg; Photo; Soil Moist.
S88_S02	Veg; Photo; Soil Moist.
88_01	GW
88_02	GW
S88_Pool 10	WQ; Obs; Photo



SOUTH32

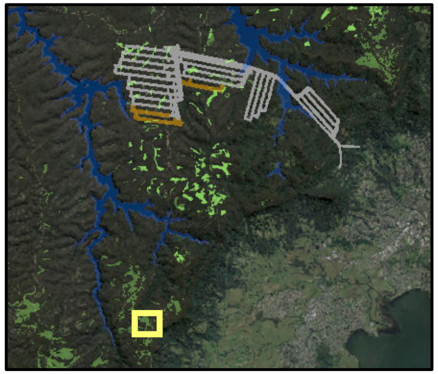
Dendrobium Area 3B

Swamp 88 Monitoring Sites

Figure 3-23

Legend

- Reference Monitoring Locations
- Tributaries
- Swamps



Date: December, 2018
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 125 250

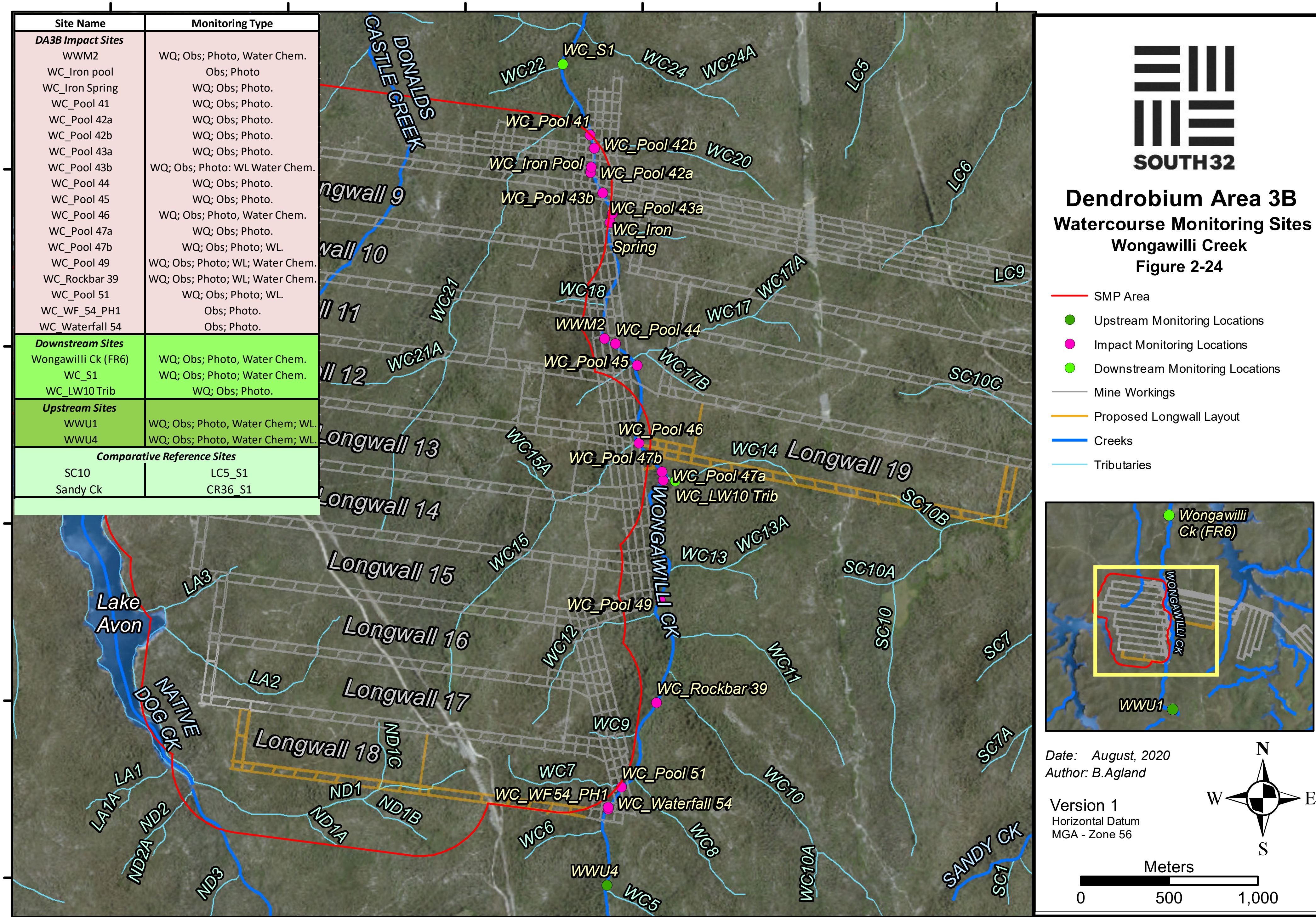
Dendrobium Area 3B

Watercourse Monitoring Sites

Wongawilli Creek

Figure 2-24

Site Name	Monitoring Type
DA3B Impact Sites	
WWM2	WQ; Obs; Photo, Water Chem.
WC_Iron pool	Obs; Photo
WC_Iron Spring	WQ; Obs; Photo.
WC_Pool 41	WQ; Obs; Photo.
WC_Pool 42a	WQ; Obs; Photo.
WC_Pool 42b	WQ; Obs; Photo.
WC_Pool 43a	WQ; Obs; Photo.
WC_Pool 43b	WQ; Obs; Photo: WL Water Chem.
WC_Pool 44	WQ; Obs; Photo.
WC_Pool 45	WQ; Obs; Photo.
WC_Pool 46	WQ; Obs; Photo, Water Chem.
WC_Pool 47a	WQ; Obs; Photo.
WC_Pool 47b	WQ; Obs; Photo; WL.
WC_Pool 49	WQ; Obs; Photo; WL; Water Chem.
WC_Rockbar 39	WQ; Obs; Photo; WL; Water Chem.
WC_Pool 51	WQ; Obs; Photo; WL.
WC_WF_54_PH1	Obs; Photo.
WC_Waterfall 54	Obs; Photo.
Downstream Sites	
Wongawilli Ck (FR6)	WQ; Obs; Photo, Water Chem.
WC_S1	WQ; Obs; Photo; Water Chem.
WC_LW10 Trib	WQ; Obs; Photo.
Upstream Sites	
WWU1	WQ; Obs; Photo, Water Chem; WL.
WWU4	WQ; Obs; Photo, Water Chem; WL.
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1



SOUTH32

- SMP Area
- Upstream Monitoring Locations
- Impact Monitoring Locations
- Downstream Monitoring Locations
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries

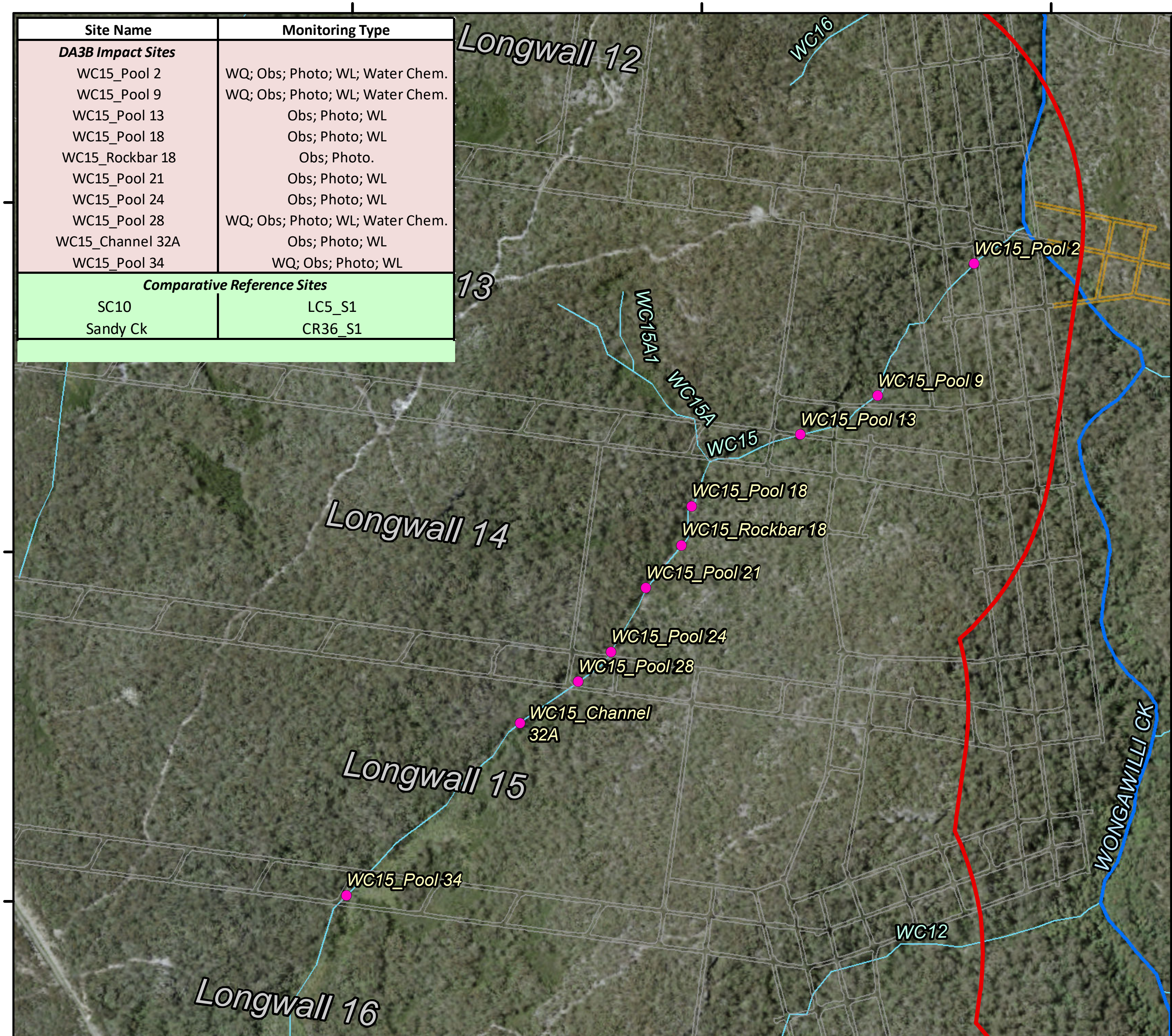
Date: August, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N S W E

Meters
0 500 1,000

Site Name	Monitoring Type
DA3B Impact Sites	
WC15_Pool 2	WQ; Obs; Photo; WL; Water Chem.
WC15_Pool 9	WQ; Obs; Photo; WL; Water Chem.
WC15_Pool 13	Obs; Photo; WL
WC15_Pool 18	Obs; Photo; WL
WC15_Rockbar 18	Obs; Photo.
WC15_Pool 21	Obs; Photo; WL
WC15_Pool 24	Obs; Photo; WL
WC15_Pool 28	WQ; Obs; Photo; WL; Water Chem.
WC15_Channel 32A	Obs; Photo; WL
WC15_Pool 34	WQ; Obs; Photo; WL
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1



SOUTH32

Dendrobium Area 3B

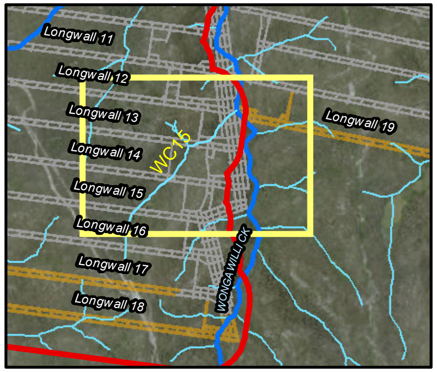
Watercourse Monitoring Sites

WC15

Figure 3-25

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries



Date: February, 2020

Author: B.Agland

Version 1

Horizontal Datum

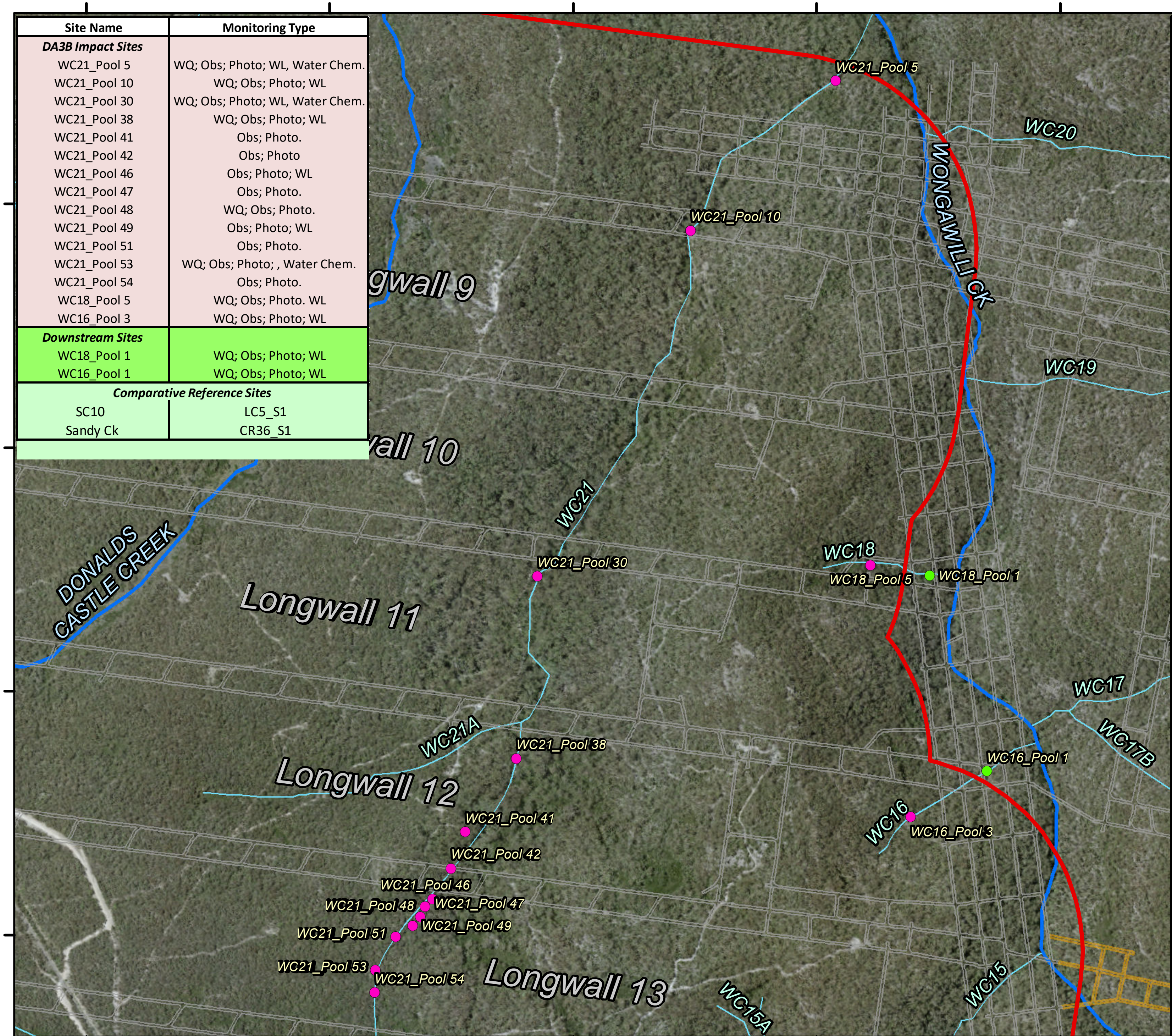
MGA - Zone 56

N W E S

Meters

0 175 350

Site Name	Monitoring Type
DA3B Impact Sites	
WC21_Pool 5	WQ; Obs; Photo; WL, Water Chem.
WC21_Pool 10	WQ; Obs; Photo; WL
WC21_Pool 30	WQ; Obs; Photo; WL, Water Chem.
WC21_Pool 38	WQ; Obs; Photo; WL
WC21_Pool 41	Obs; Photo.
WC21_Pool 42	Obs; Photo
WC21_Pool 46	Obs; Photo; WL
WC21_Pool 47	Obs; Photo.
WC21_Pool 48	WQ; Obs; Photo.
WC21_Pool 49	Obs; Photo; WL
WC21_Pool 51	Obs; Photo.
WC21_Pool 53	WQ; Obs; Photo; , Water Chem.
WC21_Pool 54	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	LC5_S1
Sandy Ck	CR36_S1



SOUTH32

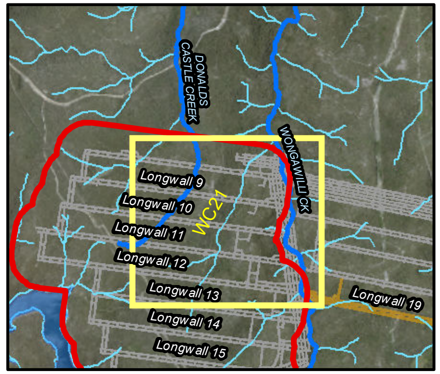
Dendrobium Area 3B

Watercourse Monitoring Sites

WC21, WC18 and WC16 Figure 3-26

Legend

- Downstream Monitoring Locations
- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Creeks
- Tributaries



Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

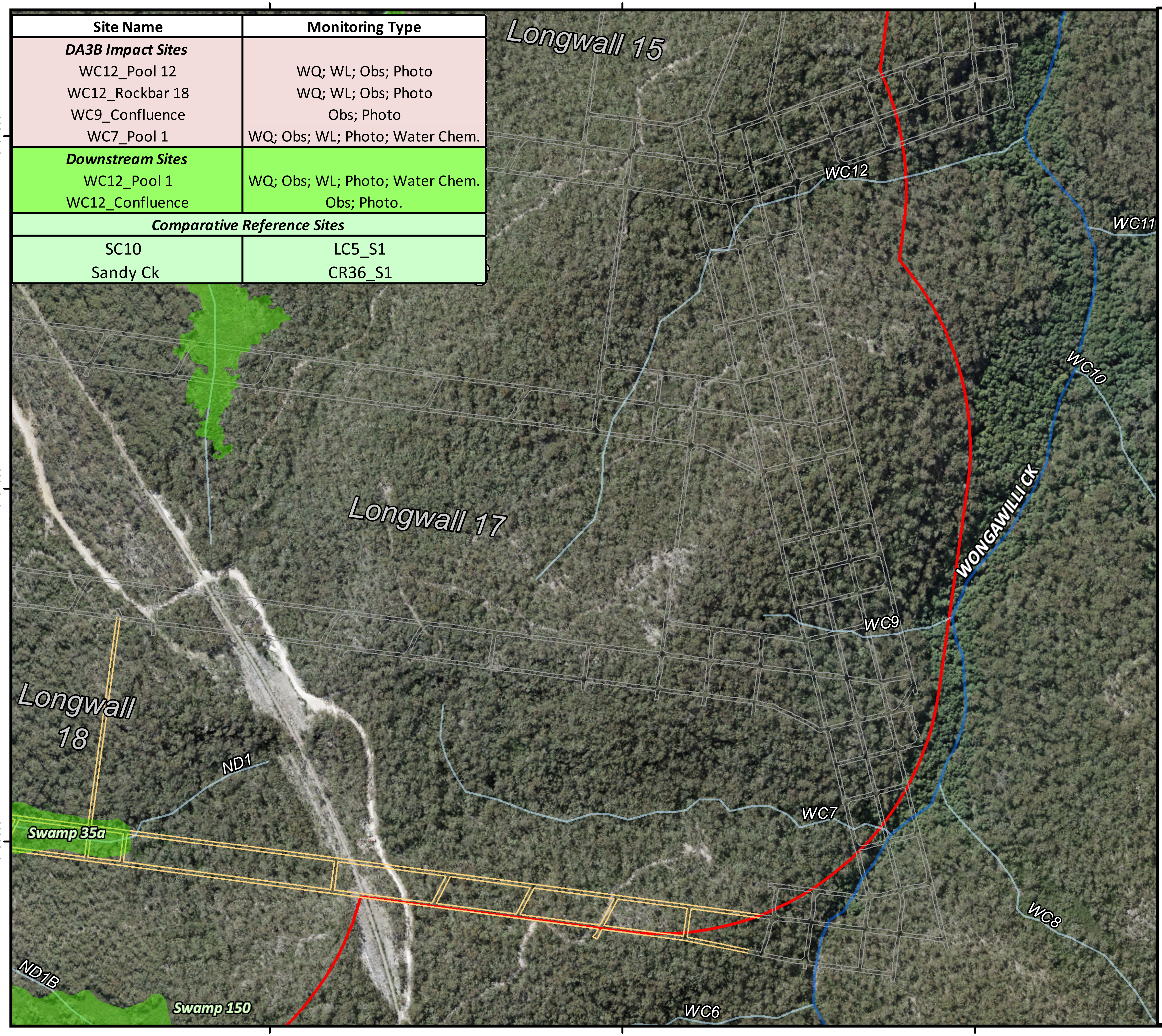
N S W E

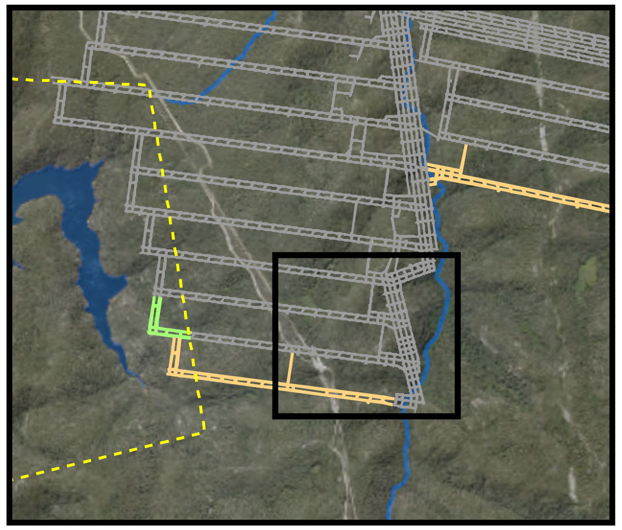
Meters
0 250 500

Dendrobium Area 3B Water Monitoring Sites and Observation Monitoring Sites WC7, WC9, WC12

Figure 3-27

Site Name	Monitoring Type
DA3B Impact Sites	
WC12_Pool 12	WQ; WL; Obs; Photo
WC12_Rockbar 18	WQ; WL; Obs; Photo
WC9_Confluence	Obs; Photo
WC7_Pool 1	WQ; Obs; WL; Photo; Water Chem.
Downstream Sites	
WC12_Pool 1	WQ; Obs; WL; Photo; Water Chem.
WC12_Confluence	Obs; Photo.
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1





SOUTH32

Legend	
Downstream Monitoring Site	
Impact Monitoring Site	
Swamps	
Creeks	
Tributaries	
Existing Mine Workings	
Proposed Longwall Layout	
SMP Area	
DSC Notification Areas	

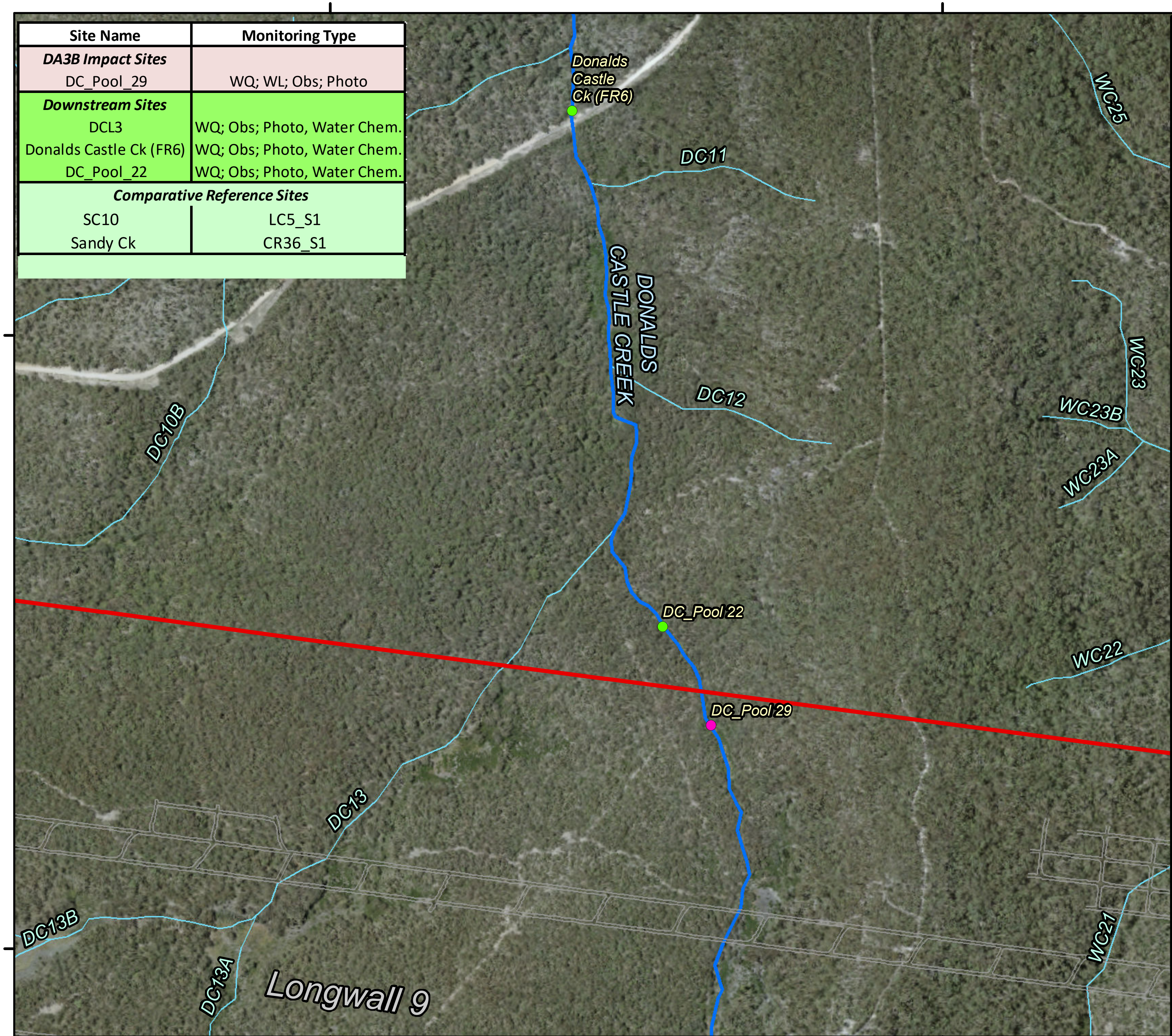
Date: August, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N E S W

Meters
0 150 300

Site Name	Monitoring Type
DA3B Impact Sites	
DC_Pool_29	WQ; WL; Obs; Photo
Downstream Sites	
DCL3	WQ; Obs; Photo, Water Chem.
Donalds Castle Ck (FR6)	WQ; Obs; Photo, Water Chem.
DC_Pool_22	WQ; Obs; Photo, Water Chem.
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1



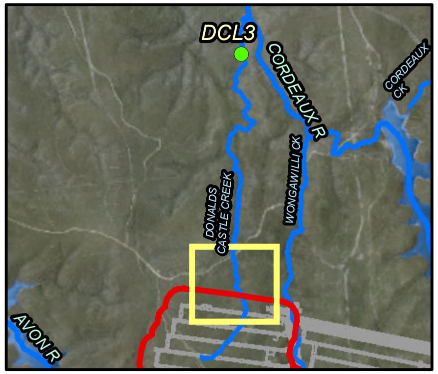
Dendrobium Area 3B

Watercourse Monitoring Sites

Donalds Castle Creek Figure 3-28

Legend

- Downstream Monitoring Locations
- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Creeks and Rivers
- Tributaries



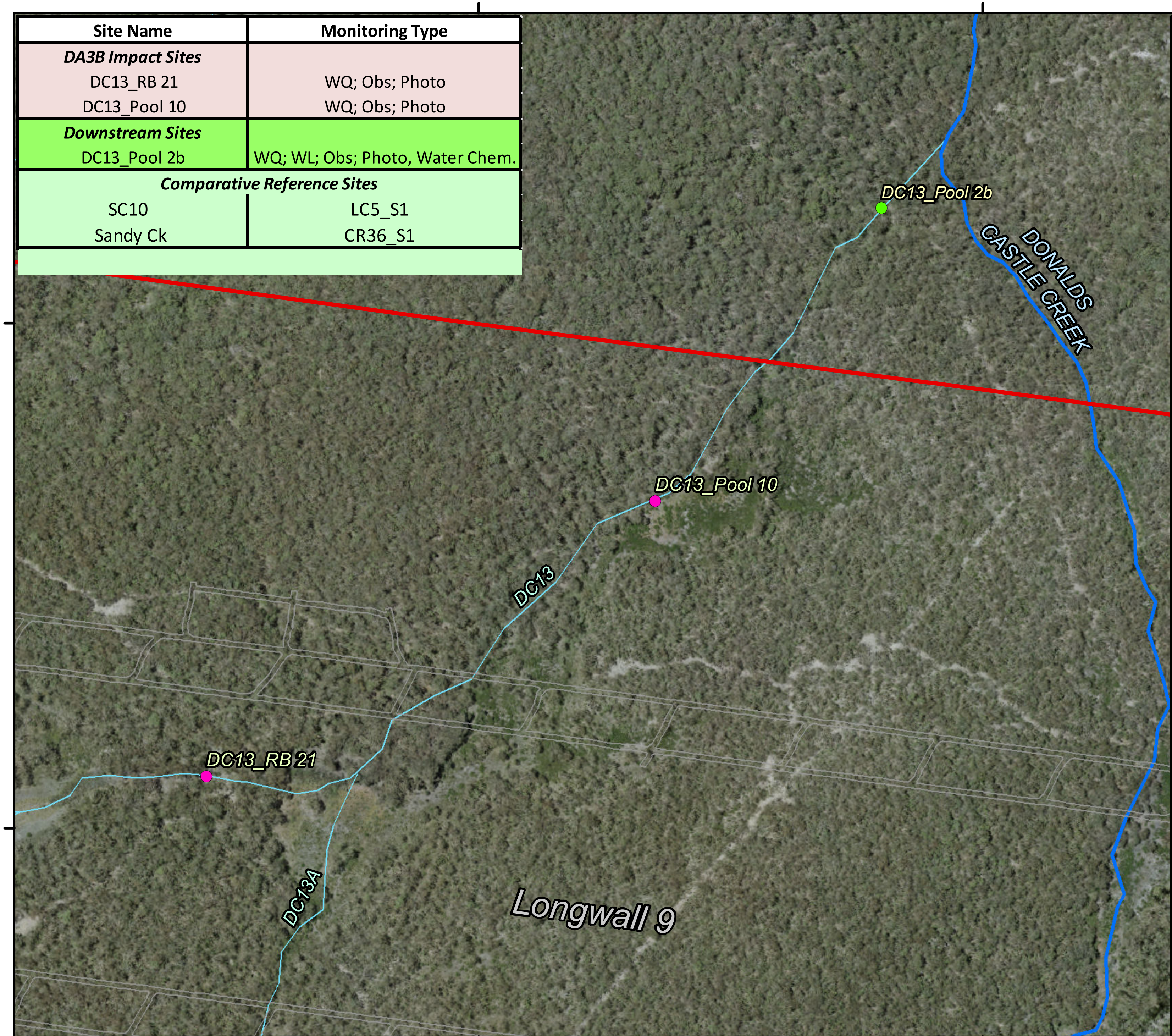
Date: *December, 2019*
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 150 300

Site Name	Monitoring Type
DA3B Impact Sites	
DC13_RB 21	WQ; Obs; Photo
DC13_Pool 10	WQ; Obs; Photo
Downstream Sites	
DC13_Pool 2b	WQ; WL; Obs; Photo, Water Chem.
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1



SOUTH32

Dendrobium Area 3B

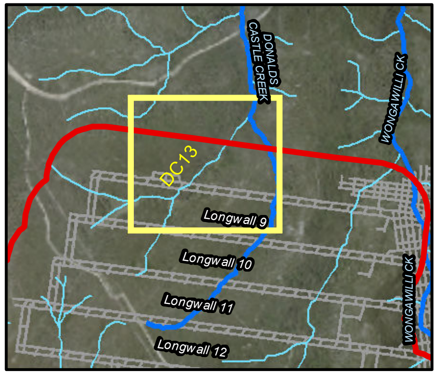
Watercourse Monitoring Sites

DC13

Figure 3-29

Legend

- Downstream Monitoring Site
- Impact Monitoring Site
- SMP Area
- Mine Workings
- Creeks
- Tributaries



Date: December, 2019

Author: B.Agland

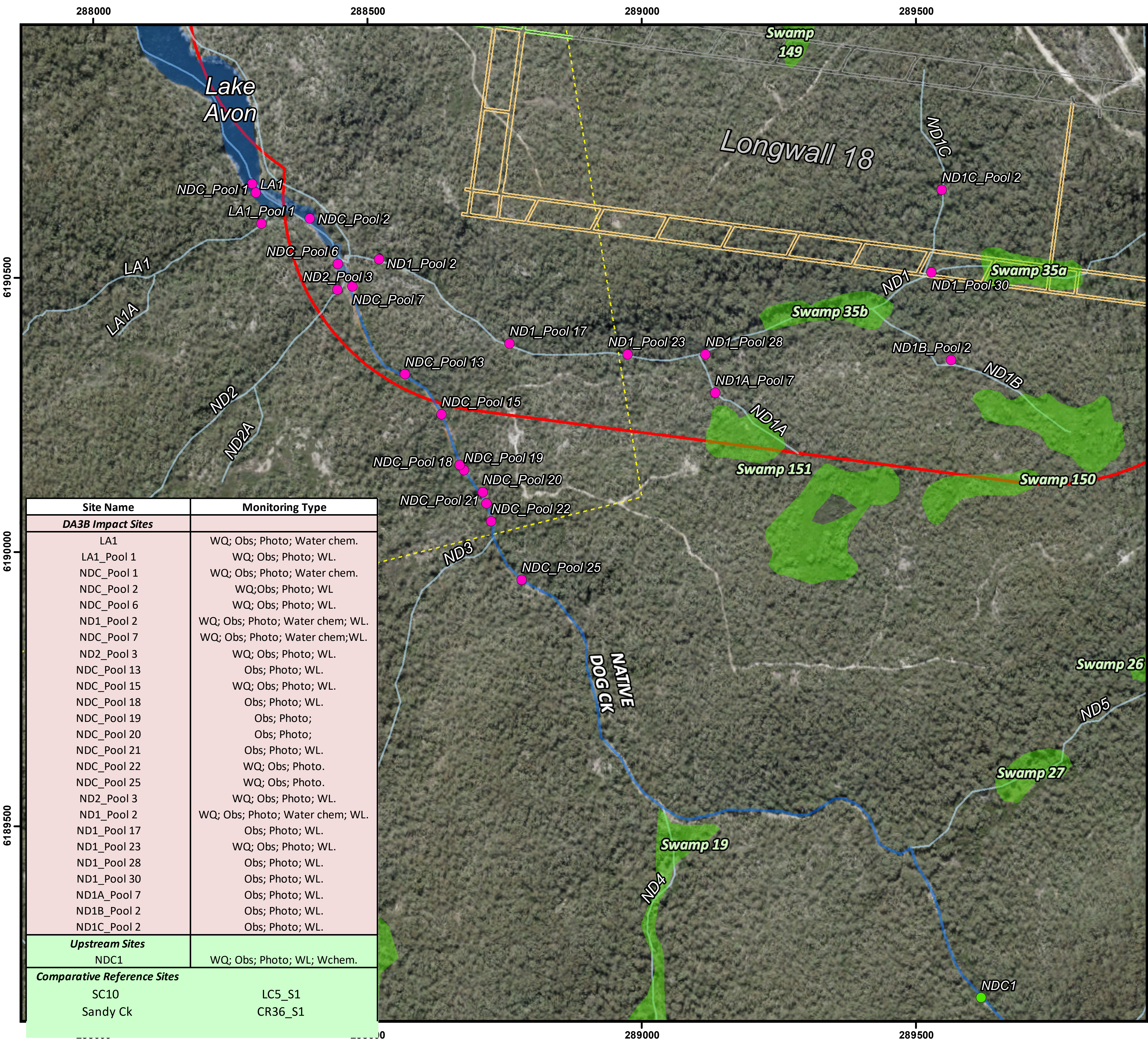
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 125 250

Dendrobium Area 3B Water Monitoring Sites and Observation Monitoring Sites Native Dog Creek LA1, ND1, ND2 Figure 3-30

SOUTH32



Site Name	Monitoring Type
DA3B Impact Sites	
LA1	WQ; Obs; Photo; Water chem.
LA1_Pool 1	WQ; Obs; Photo; WL.
NDC_Pool 1	WQ; Obs; Photo; Water chem.
NDC_Pool 2	WQ;Obs; Photo; WL
NDC_Pool 6	WQ; Obs; Photo; WL.
ND1_Pool 2	WQ; Obs; Photo; Water chem; WL.
NDC_Pool 7	WQ; Obs; Photo; Water chem;WL.
ND2_Pool 3	WQ; Obs; Photo; WL.
NDC_Pool 13	Obs; Photo; WL.
NDC_Pool 15	WQ; Obs; Photo; WL.
NDC_Pool 18	Obs; Photo; WL.
NDC_Pool 19	Obs; Photo;
NDC_Pool 20	Obs; Photo;
NDC_Pool 21	Obs; Photo; WL.
NDC_Pool 22	WQ; Obs; Photo.
NDC_Pool 25	WQ; Obs; Photo.
ND2_Pool 3	WQ; Obs; Photo; WL.
ND1_Pool 2	WQ; Obs; Photo; Water chem; WL.
ND1_Pool 17	Obs; Photo; WL.
ND1_Pool 23	WQ; Obs; Photo; WL.
ND1_Pool 28	Obs; Photo; WL.
ND1_Pool 30	Obs; Photo; WL.
ND1A_Pool 7	Obs; Photo; WL.
ND1B_Pool 2	Obs; Photo; WL.
ND1C_Pool 2	Obs; Photo; WL.
Upstream Sites	
NDC1	WQ; Obs; Photo; WL; Wchem.
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1

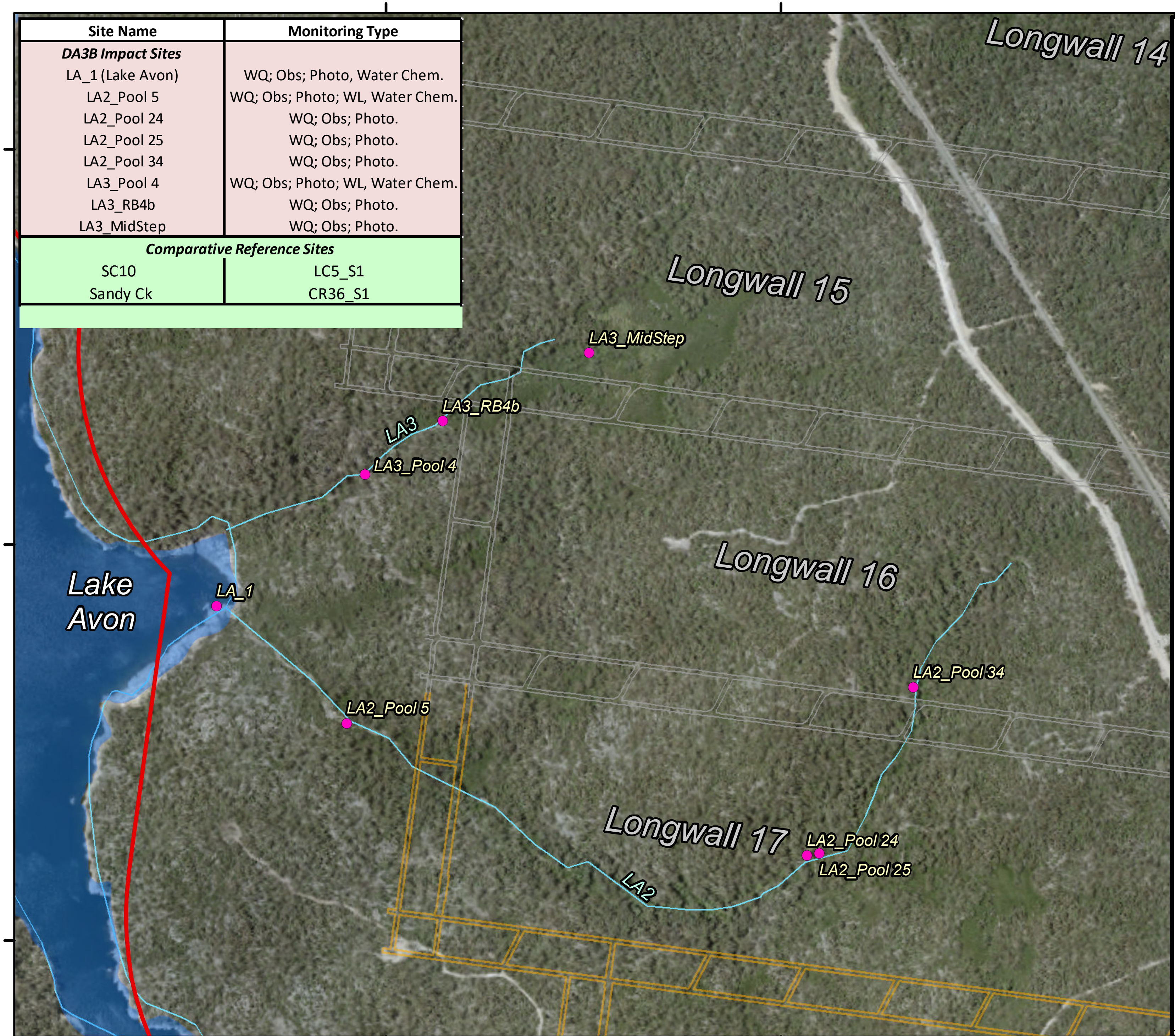
- Upstream Monitoring Site
- Impact Monitoring Site
- Swamps
- Creeks
- Tributaries
- Existing Mine Workings
- Proposed Longwall Layout
- SMP Area
- DSC Notification Areas

Date: August, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N E S W

Meters
0 250 500



Site Name	Monitoring Type
DA3B Impact Sites	
LA_1 (Lake Avon)	WQ; Obs; Photo, Water Chem.
LA2_Pool 5	WQ; Obs; Photo; WL, Water Chem.
LA2_Pool 24	WQ; Obs; Photo.
LA2_Pool 25	WQ; Obs; Photo.
LA2_Pool 34	WQ; Obs; Photo.
LA3_Pool 4	WQ; Obs; Photo; WL, Water Chem.
LA3_RB4b	WQ; Obs; Photo.
LA3_MidStep	WQ; Obs; Photo.
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1

SOUTH32

Dendrobium Area 3B

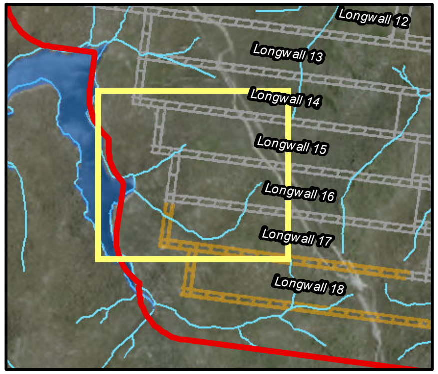
Watercourse Monitoring Sites

Lake Avon, LA2 and LA3

Figure 3-31

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Proposed Longwall Layout
- Tributaries

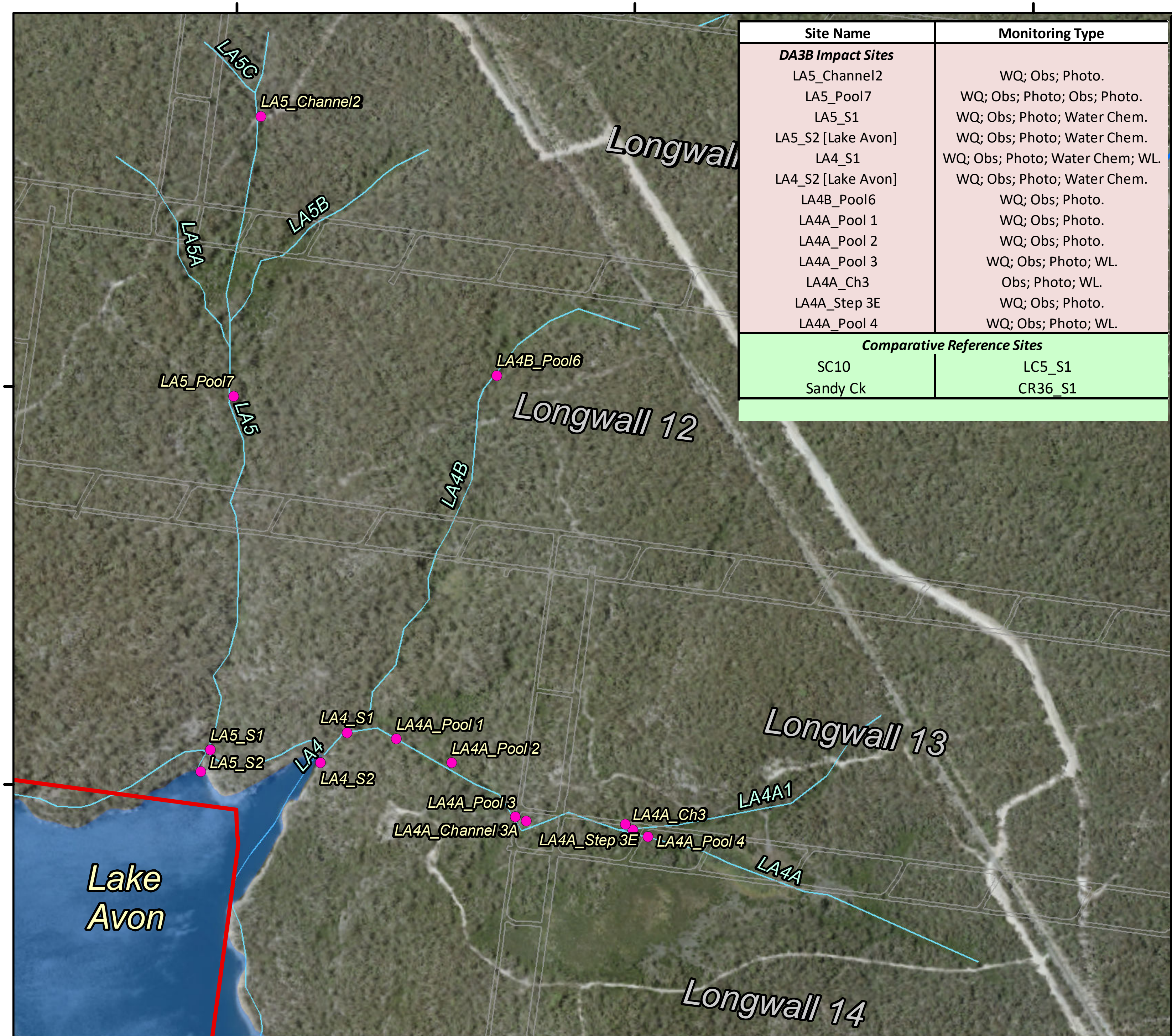


Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 150 300



Site Name	Monitoring Type
DA3B Impact Sites	
LA5_Channel2	WQ; Obs; Photo.
LA5_Pool7	WQ; Obs; Photo; Obs; Photo.
LA5_S1	WQ; Obs; Photo; Water Chem.
LA5_S2 [Lake Avon]	WQ; Obs; Photo; Water Chem.
LA4_S1	WQ; Obs; Photo; Water Chem; WL.
LA4_S2 [Lake Avon]	WQ; Obs; Photo; Water Chem.
LA4B_Pool6	WQ; Obs; Photo.
LA4A_Pool 1	WQ; Obs; Photo.
LA4A_Pool 2	WQ; Obs; Photo.
LA4A_Pool 3	WQ; Obs; Photo; WL.
LA4A_Ch3	Obs; Photo; WL.
LA4A_Step 3E	WQ; Obs; Photo.
LA4A_Pool 4	WQ; Obs; Photo; WL.
Comparative Reference Sites	
SC10	LC5_S1
Sandy Ck	CR36_S1

SOUTH32

Dendrobium Area 3B

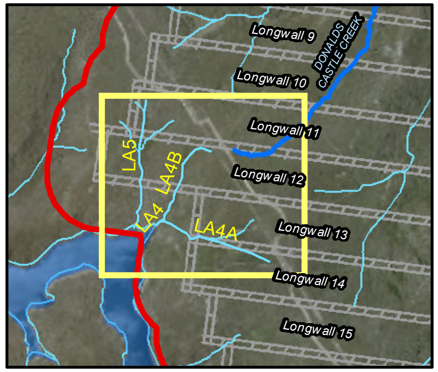
Watercourse Monitoring Sites

Lake Avon, LA4 and LA5

Figure 3-32

Legend

- Impact Monitoring Locations
- SMP Area
- Mine Workings
- Creeks
- Tributaries



Date: December, 2019
Author: B.Agland

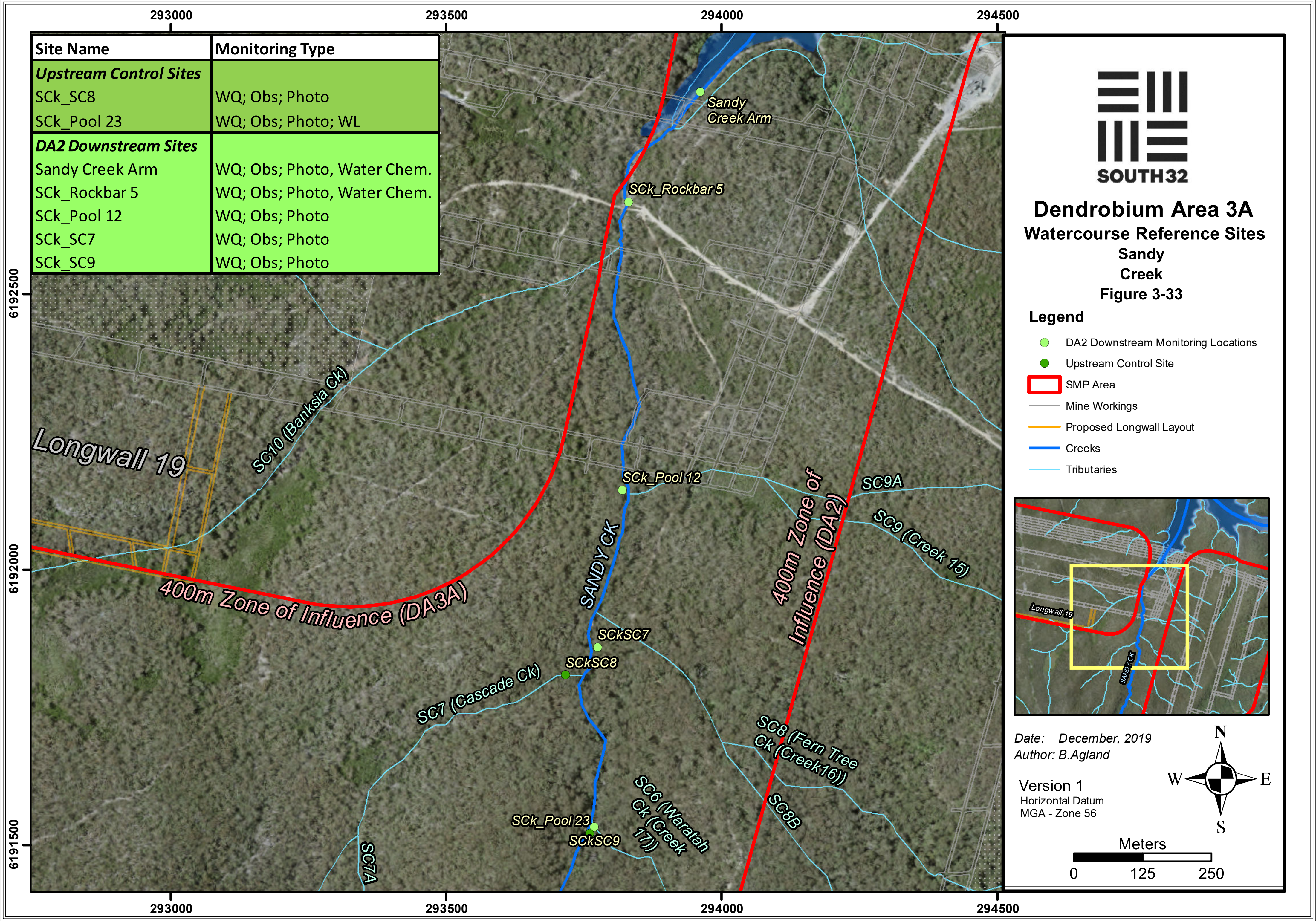
Version 1
Horizontal Datum
MGA - Zone 56

N E S W

Meters
0 150 300

288000 288500 289000

Site Name	Monitoring Type
Upstream Control Sites	
SCk_SC8	WQ; Obs; Photo
SCk_Pool 23	WQ; Obs; Photo; WL
DA2 Downstream Sites	
Sandy Creek Arm	WQ; Obs; Photo, Water Chem.
SCk_Rockbar 5	WQ; Obs; Photo, Water Chem.
SCk_Pool 12	WQ; Obs; Photo
SCk_SC7	WQ; Obs; Photo
SCk_SC9	WQ; Obs; Photo



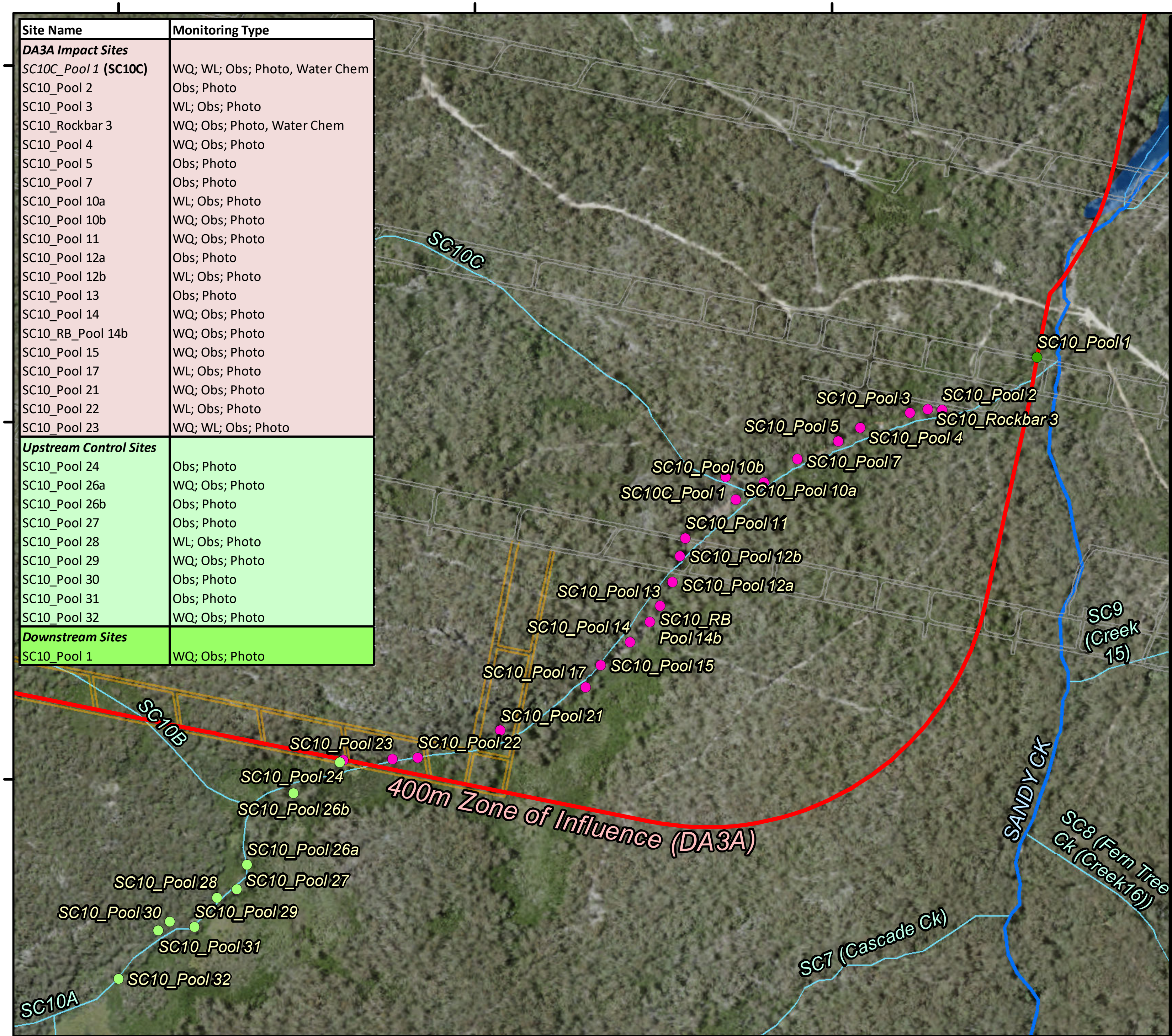
Dendrobium Area 3A

Watercourse Monitoring Sites

SC10

Figure 3-34

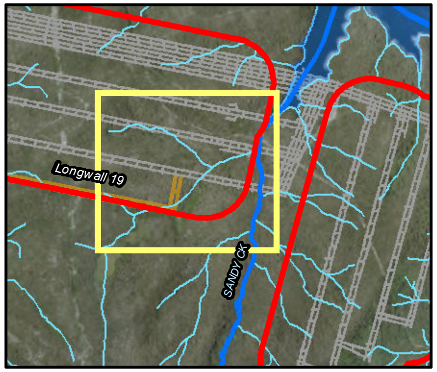
Site Name	Monitoring Type
DA3A Impact Sites	
SC10C_Pool 1 **(SC10C)**	WQ; WL; Obs; Photo, Water Chem
SC10_Pool 2	Obs; Photo
SC10_Pool 3	WL; Obs; Photo
SC10_Rockbar 3	WQ; Obs; Photo, Water Chem
SC10_Pool 4	WQ; Obs; Photo
SC10_Pool 5	Obs; Photo
SC10_Pool 7	Obs; Photo
SC10_Pool 10a	WL; Obs; Photo
SC10_Pool 10b	WQ; Obs; Photo
SC10_Pool 11	WQ; Obs; Photo
SC10_Pool 12a	Obs; Photo
SC10_Pool 12b	WL; Obs; Photo
SC10_Pool 13	Obs; Photo
SC10_Pool 14	WQ; Obs; Photo
SC10_RB_Pool 14b	WQ; Obs; Photo
SC10_Pool 15	WQ; Obs; Photo
SC10_Pool 17	WL; Obs; Photo
SC10_Pool 21	WQ; Obs; Photo
SC10_Pool 22	WL; Obs; Photo
SC10_Pool 23	WQ; WL; Obs; Photo
Upstream Control Sites	
SC10_Pool 24	Obs; Photo
SC10_Pool 26a	WQ; Obs; Photo
SC10_Pool 26b	Obs; Photo
SC10_Pool 27	Obs; Photo
SC10_Pool 28	WL; Obs; Photo
SC10_Pool 29	WQ; Obs; Photo
SC10_Pool 30	Obs; Photo
SC10_Pool 31	Obs; Photo
SC10_Pool 32	WQ; Obs; Photo
Downstream Sites	
SC10_Pool 1	WQ; Obs; Photo



SOUTH32

Legend

- Upstream Control Sites
- DA3A Impact Monitoring Sites
- Downstream Control Site
- 400m Zone of Influence
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries

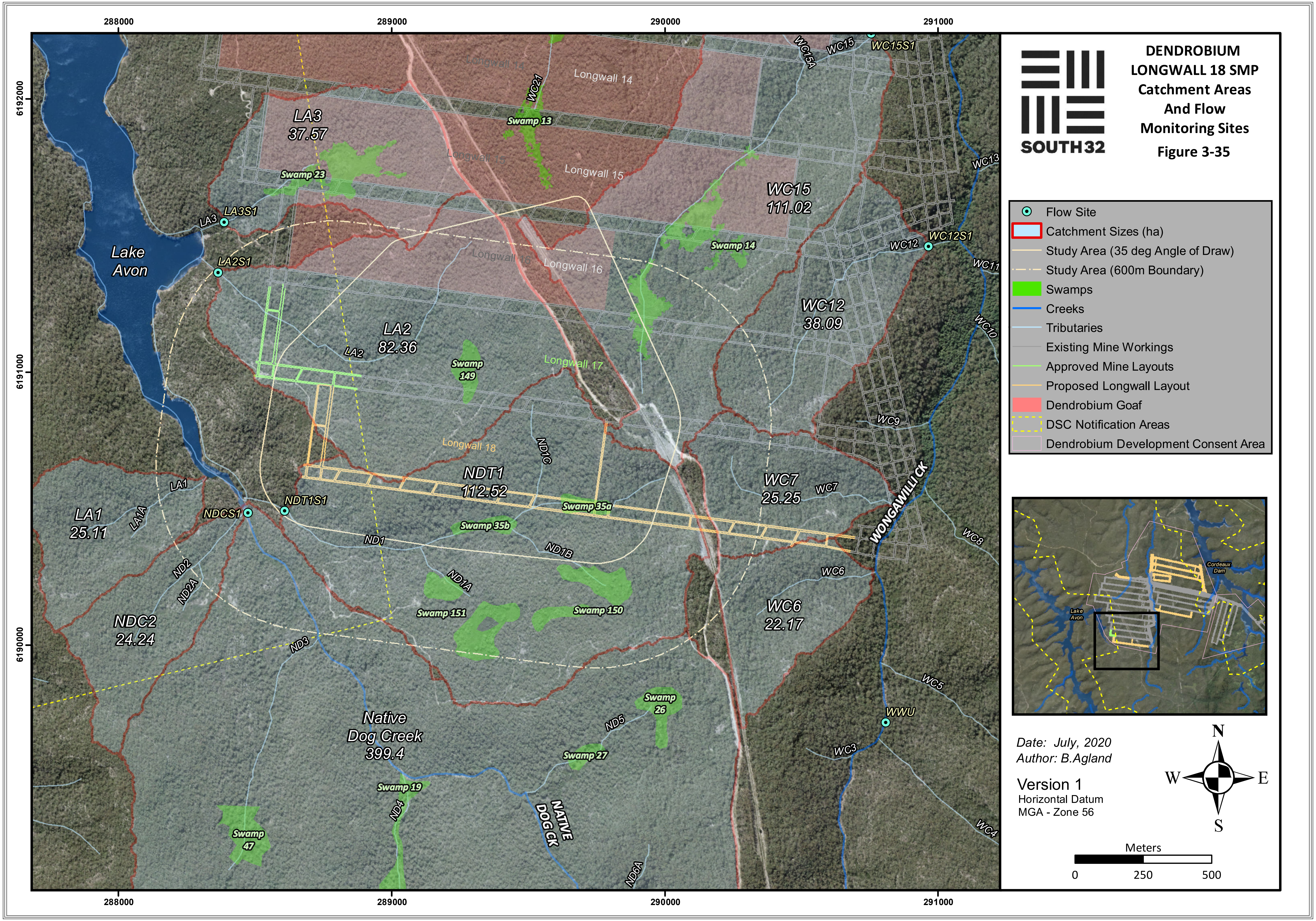


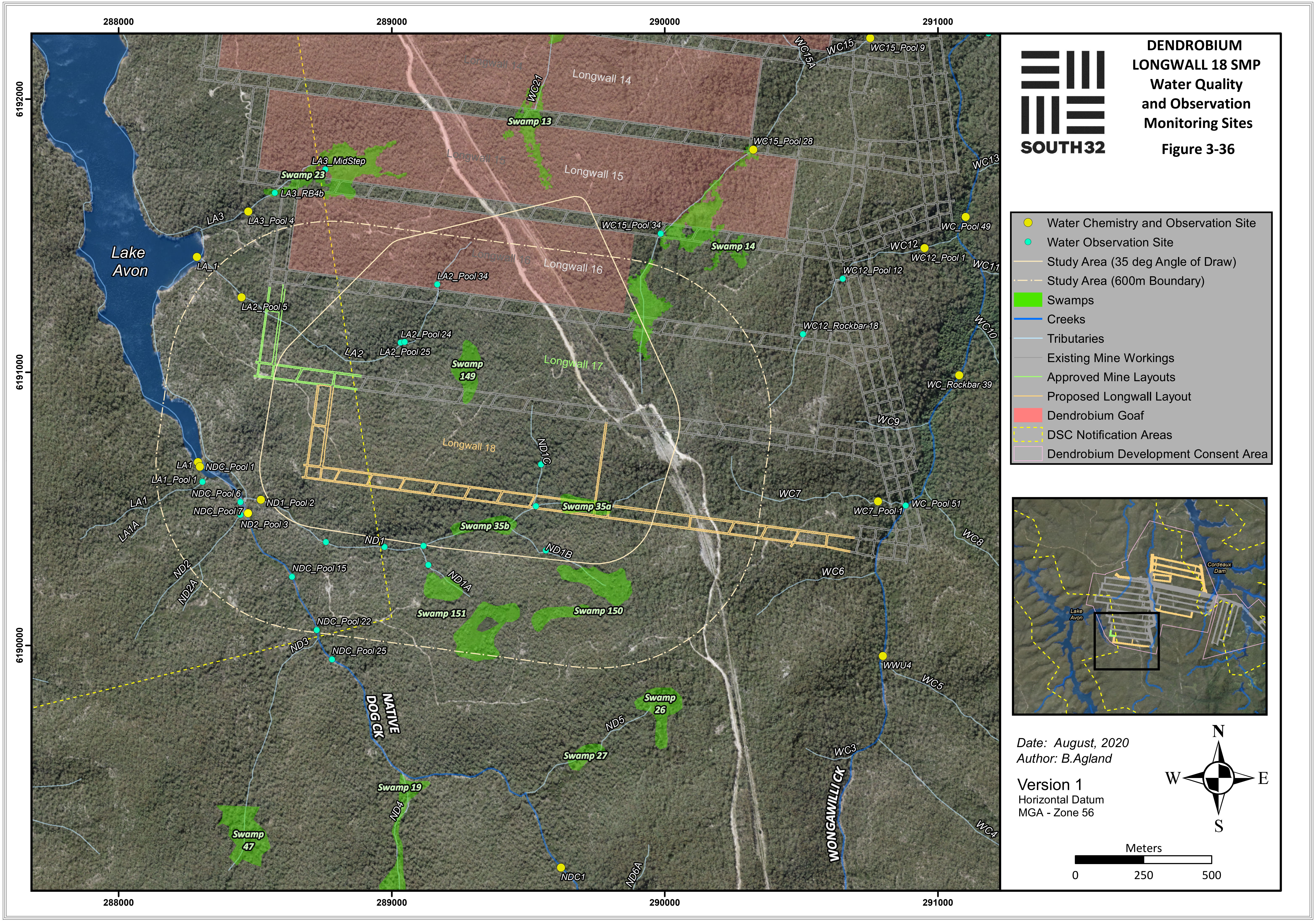
Date: December, 2019
Author: B.Agland

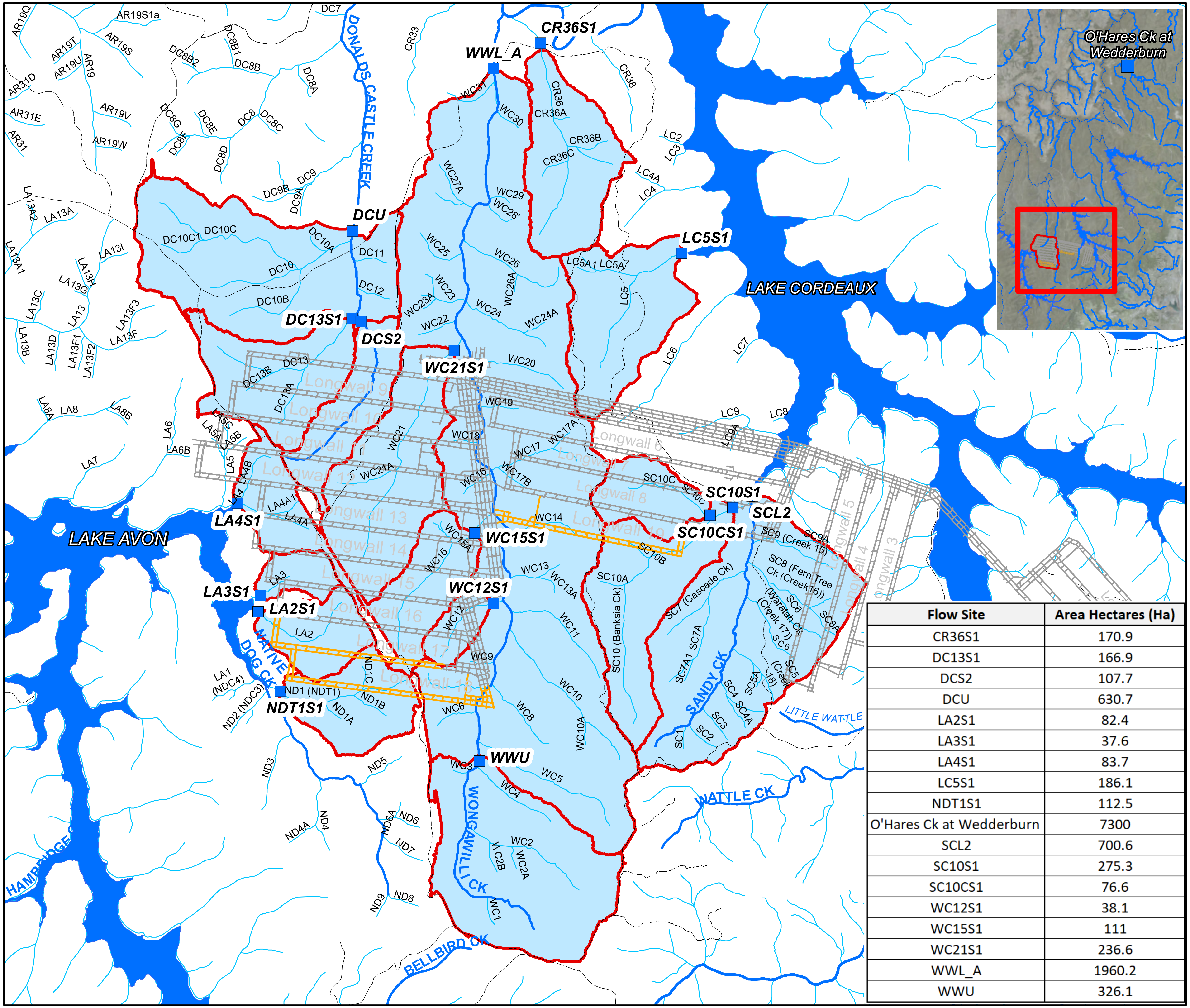
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 150 300


DENDROBIUM
LONGWALL 18 SMP
Catchment Areas
And Flow
Monitoring Sites
Figure 3-35
SOUTH32
Flow Site
Catchment Sizes (ha)
Study Area (35 deg Angle of Draw)
Study Area (600m Boundary)
Swamps
Creeks
Tributaries
Existing Mine Workings
Approved Mine Layouts
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Dendrobium Development Consent Area
Date: July, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
Meters
0
250
500
N
S
E
W
Lake Avon
LA3 37.57
LA2 82.36
LA1 25.11
NDC2 24.24
NDT1 112.52
WC15 111.02
WC12 38.09
WC7 25.25
WC6 22.17
Native Dog Creek 399.4
Longwall 14
Longwall 15
Longwall 16
Longwall 17
Longwall 18
Swamp 13
Swamp 23
Swamp 14
Swamp 149
Swamp 35a
Swamp 35b
Swamp 151
Swamp 150
Swamp 26
Swamp 27
Swamp 19
Swamp 47
LA3S1
LA2S1
NDCS1
NDT1S1
WC15S1
WC12S1
WWU
WONGAWILLI CK
NATIVE DOG CK
Cordeaux Dam
288000
289000
290000
291000
6192000
6191000
6190000


DENDROBIUM
LONGWALL 18 SMP
Water Quality
and Observation
Monitoring Sites
Figure 3-36
SOUTH32
Water Chemistry and Observation Site
Water Observation Site
Study Area (35 deg Angle of Draw)
Study Area (600m Boundary)
Swamps
Creeks
Tributaries
Existing Mine Workings
Approved Mine Layouts
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Dendrobium Development Consent Area
Date: August, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
Meters
0
250
500
N
S
W
E
Lake Avon
Cordeaux Dam
288000
289000
290000
291000
6192000
6191000
6190000
Lake Avon
Longwall 14
Longwall 15
Longwall 16
Longwall 17
Longwall 18
Swamp 13
Swamp 14
Swamp 23
Swamp 149
Swamp 35a
Swamp 35b
Swamp 151
Swamp 150
Swamp 26
Swamp 27
Swamp 19
Swamp 47
LA3_MidStep
LA3_RB4b
LA3_Pool 4
LA3
LA_1
LA2_Pool 5
LA2_Pool 34
LA2_Pool 24
LA2_Pool 25
LA2
LA1
NDC_Pool 1
LA1_Pool 1
NDC_Pool 6
NDC_Pool 7
ND1_Pool 2
ND2_Pool 3
LA1A
ND2
ND2A
ND1
ND1A
ND1B
ND1C
NDC_Pool 15
NDC_Pool 22
NDC_Pool 25
ND3
NATIVE DOG CK
ND4
ND5
ND6A
NDC1
WC21
WC15
WC15A
WC15_Pool 9
WC15_Pool 28
WC15_Pool 34
WC13
WC_Pool 49
WC12
WC12_Pool 1
WC12_Pool 12
WC11
WC12_Rockbar 18
WC10
WC_Rockbar 39
WC9
WC7
WC7_Pool 1
WC_Pool 51
WC8
WC6
WWU4
WC5
WC3
WONGAWILLI CK
WC4



Flow Site	Area Hectares (Ha)
CR36S1	170.9
DC13S1	166.9
DCS2	107.7
DCU	630.7
LA2S1	82.4
LA3S1	37.6
LA4S1	83.7
LC5S1	186.1
NDT1S1	112.5
O'Hares Ck at Wedderburn	7300
SCL2	700.6
SC10S1	275.3
SC10CS1	76.6
WC12S1	38.1
WC15S1	111
WC21S1	236.6
WWL_A	1960.2
WWU	326.1

SOUTH32

Dendrobium Flow Monitoring Catchments and Sites

Figure 3-37

Legend

- Flow Monitoring Sites
- Flow Monitoring Catchments
- Mine Workings
- Proposed Longwall Layout
- Creeks
- Tributaries
- Fire Roads

Date: December, 2019
Author: B.Agland

Version 1
Horizontal Datum MGA - Zone 56

N E S W

0 0.5 1 2 Kms

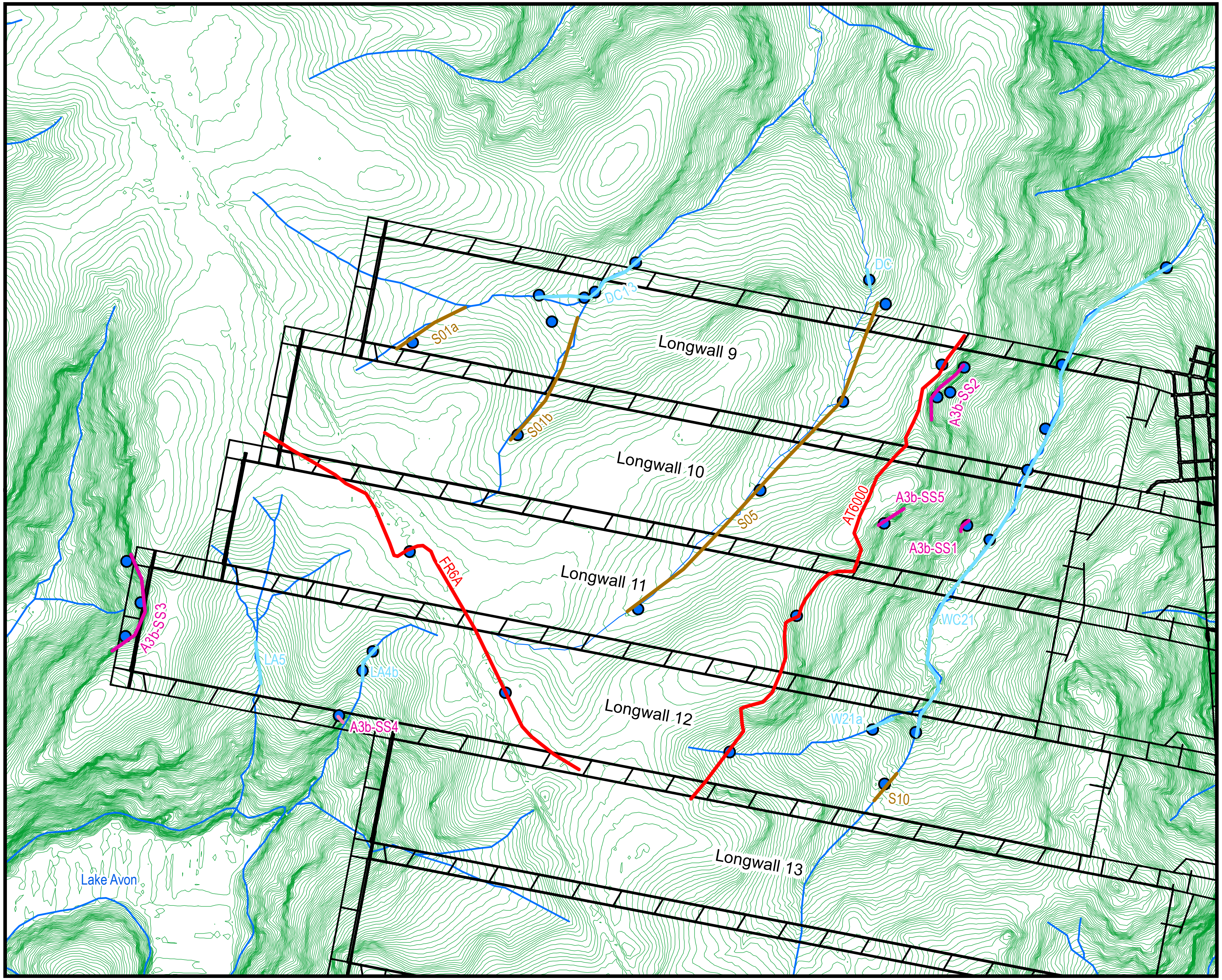


Figure 3-38

Title: SMP Landscape Monitoring Sites Area 3B (Longwall 9 to 12) Baseline Survey

Project: Dendrobium Mine Area 3B

Client: South 32 Illawarra Coal

Legend:

- Access Track/Fire Road
- Steep Slope
- Steep Slope (Rock Ledge Only)
- Swamp
- Watercourse
- Official Photo Site
- Creeklines
- Longwall Plan
- Contours (1metre)

N E S W

Drawing No: BIC01-007_Figure_1

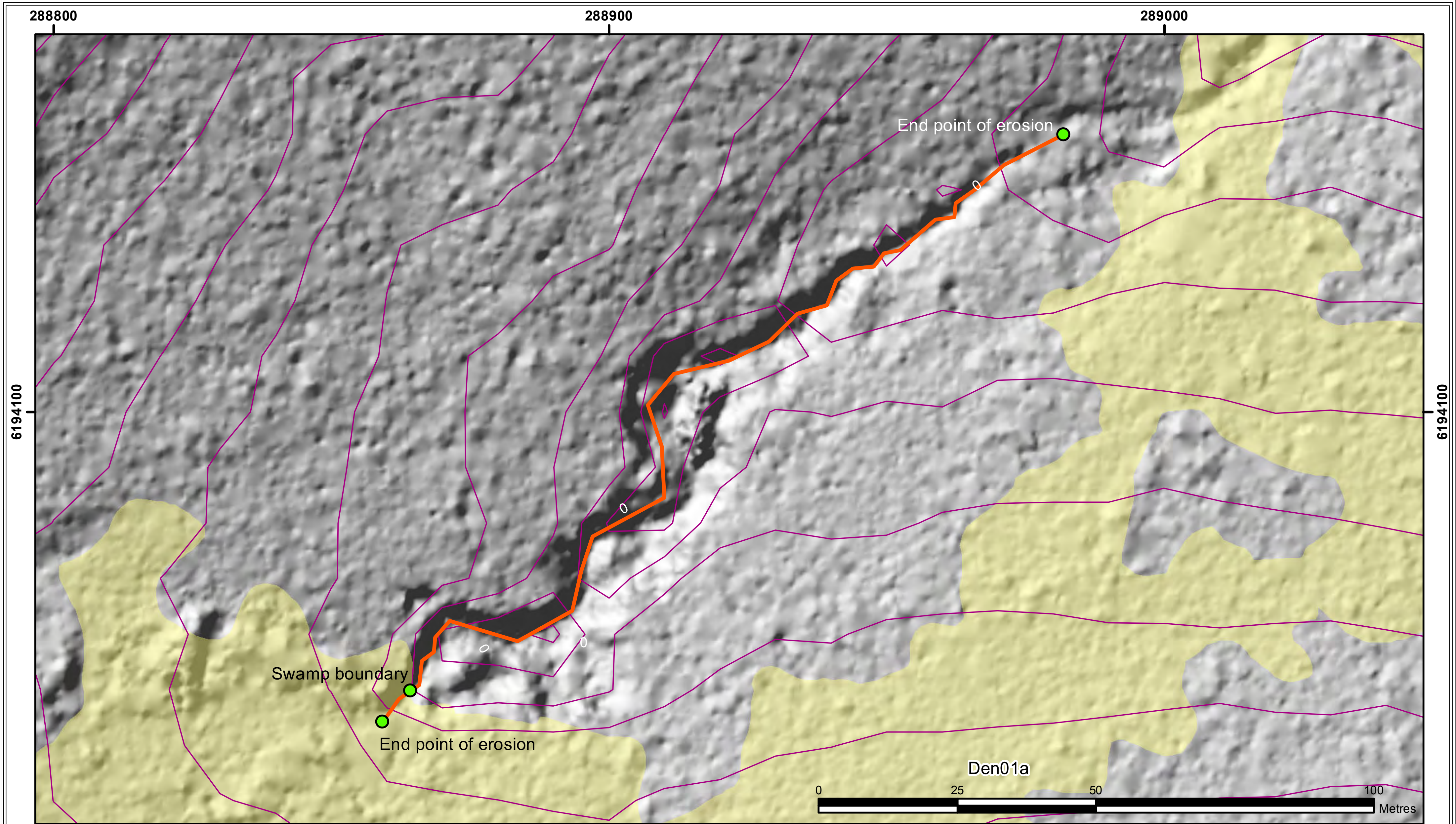
Date: 19/02/2013 **Drawing size:** A4

Drawn by: NT **Reviewed by:** DJ

Scale: 1:15,000

0 0.125 0.25 0.5 Kilometers

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants



SOUTH32
Illawarra Coal

Legend

Total Active Erosion

1m contours

Swamp Subcommunity Mapping

Shaded Relief (derived from ALS imagery)

Dendrobium Area 3B

Mapped Erosion- Swamp 01a

Figure 3.39

Date: 20 May, 2014

Author: T. McMahon

Authoriser: G. Brassington

Version 1

Horizontal Datum

MGA - Zone 56

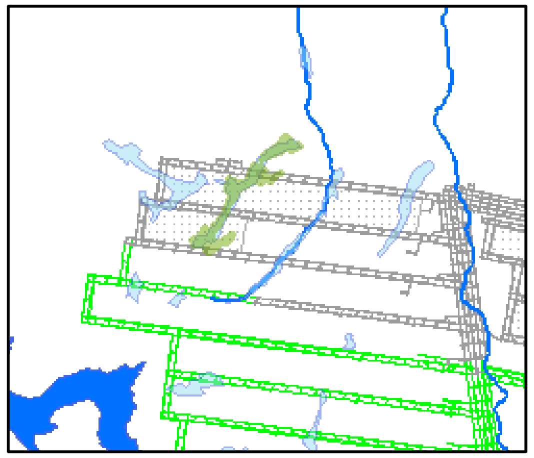
N
W
E
S

Illawarra Coal

Dendrobium Area 3B
Swamp 1A

Figure 3.40
Orthophoto Pre-fire

Swamp 1A in
Regional Context



Date: 10 April, 2014
Author: P.Crowe
Signed Off: G.Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

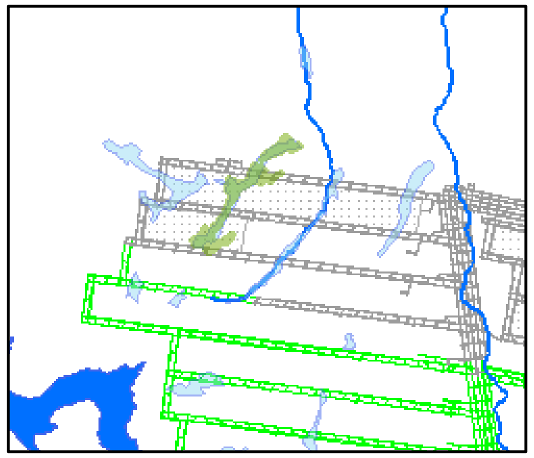
SOUTH32

Illawarra Coal

Dendrobium Area 3B
Swamp 1A

Figure 3.41
Orthophoto Post-fire

Swamp 1A in
Regional Context



Date: 10 April, 2014
Author: P.Crowe
Signed Off: G.Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

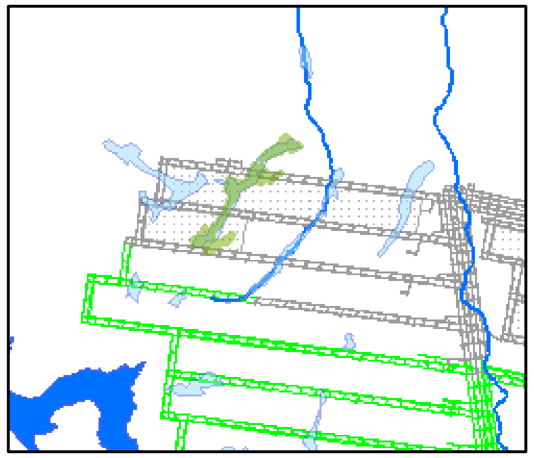
SOUTH32

Illawarra Coal

Dendrobium Area 3B
Swamp 1A

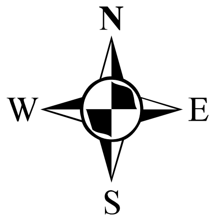
Figure 3.42
Orthophoto May 2013

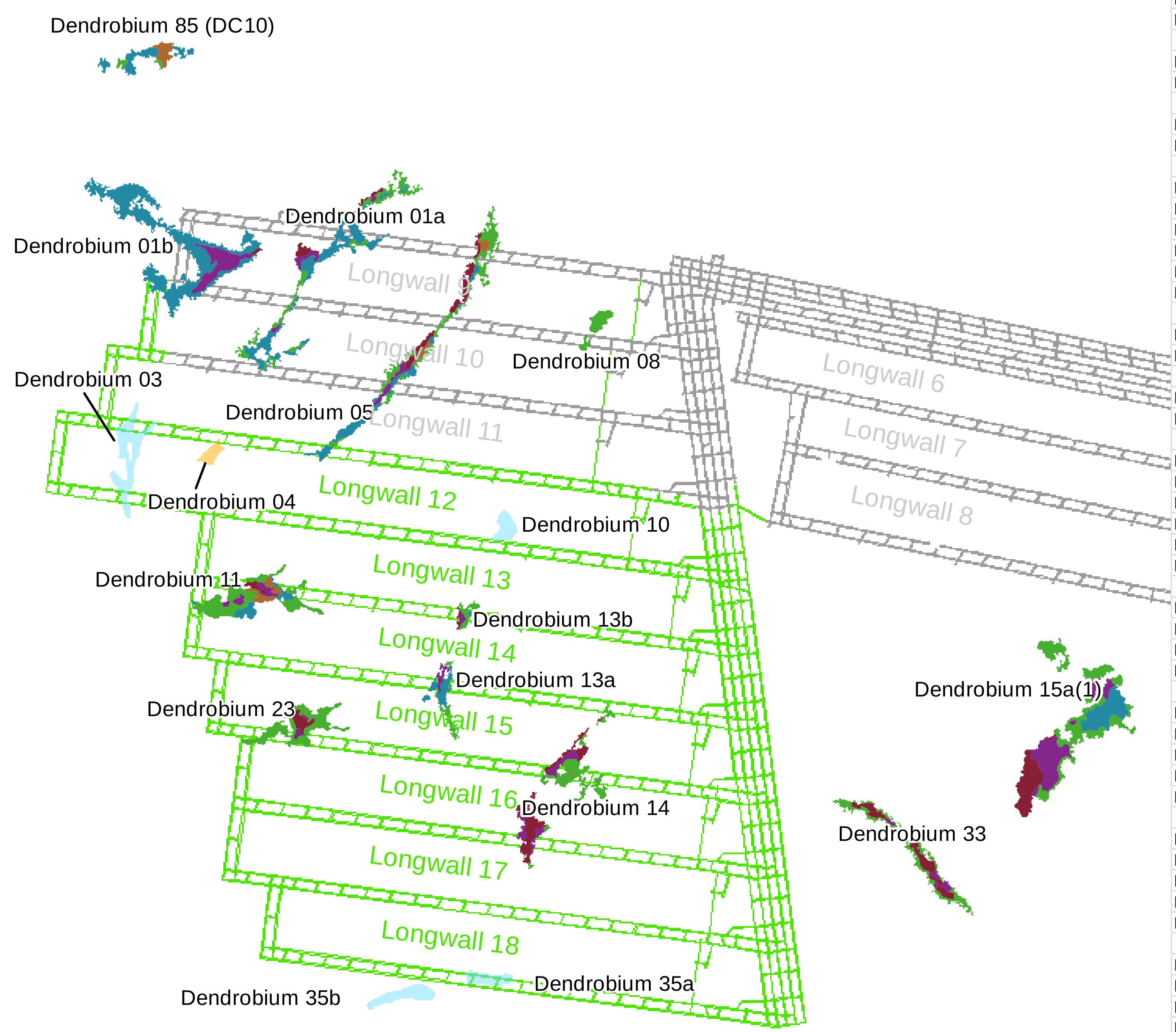
Swamp 1A in
Regional Context



Date: 10 April, 2014
Author: P.Crowe
Signed Off: G.Brassington

Version 1
Horizontal Datum
MGA - Zone 56





Swamp Name	Veg Area (Ha)	Vegetation Community
Dendrobium 01a	4.05	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 01a	2.37	Upland Swamps: Banksia Thicket
Dendrobium 01a	0.5	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 01a	0.55	Upland Swamps: Tea-Tree Thicket
Dendrobium 01a Area	7.47	Length = 1311 mteres
Dendrobium 01b	9.3	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 01b	2.05	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 01b	0.08	Upland Swamps: Tea-Tree Thicket
Dendrobium 01b Area	11.43	Length = 956 metres
Dendrobium 03	3.48	Upland Swamps: Banksia Thicket
Dendrobium 03 Area	3.48	Length = 598 metres
Dendrobium 04	0.75	Not known
Dendrobium 04 Area	0.75	Length = 139 metres
Dendrobium 05	2.22	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 05	2.92	Upland Swamps: Banksia Thicket
Dendrobium 05	0.56	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 05	0.48	Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
Dendrobium 05	1.33	Upland Swamps: Tea-Tree Thicket
Dendrobium 05 Area	7.51	Length = 1610 metres
Dendrobium 08	0.95	Upland Swamps: Banksia Thicket
Dendrobium 08 Area	0.95	Length = 249 metres
Dendrobium 10	1.1	Upland Swamps: Sedgeland-Heath Complex
Dendrobium 10 Area	1.1	Length = 186 metres
Dendrobium 11	0.94	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 11	3.62	Upland Swamps: Banksia Thicket
Dendrobium 11	0.59	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 11	0.7	Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
Dendrobium 11	0.23	Upland Swamps: Tea-Tree Thicket
Dendrobium 11 Area	6.08	Length = 700 metres
Dendrobium 13a	0.89	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 13a	0.65	Upland Swamps: Banksia Thicket
Dendrobium 13a	0.3	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 13a	1.84	Length = 418 metres
Dendrobium 13b	0.06	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 13b	0.49	Upland Swamps: Banksia Thicket
Dendrobium 13b	0.12	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 13b	0.1	Upland Swamps: Tea-Tree Thicket
Dendrobium 13b	0.77	Length = 165 metres
Dendrobium 14	2.37	Upland Swamps: Banksia Thicket
Dendrobium 14	1.15	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 14	0.02	Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
Dendrobium 14	2.18	Upland Swamps: Tea-Tree Thicket
Dendrobium 14 Area	5.72	Length = 982 metres
Dendrobium 15a(1)	2.47	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 15a(1)	5.11	Upland Swamps: Banksia Thicket
Dendrobium 15a(1)	3.48	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 15a(1)	2.4	Upland Swamps: Tea-Tree Thicket
Dendrobium 15a(1) Area	13.46	Length = 1241 metres
Dendrobium 23	3.08	Upland Swamps: Banksia Thicket
Dendrobium 23	0.18	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 23	0.62	Upland Swamps: Tea-Tree Thicket
Dendrobium 23 Area	3.88	Length = 543 metres
Dendrobium 33	2.35	Upland Swamps: Banksia Thicket
Dendrobium 33	0.43	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)
Dendrobium 33	1.58	Upland Swamps: Tea-Tree Thicket
Dendrobium 33 Area	4.36	Length = 948 metres
Dendrobium 35a	1.2	Upland Swamps: Sedgeland-Heath Complex
Dendrobium 35a Area	1.2	Length = 233 metres
Dendrobium 35b	1.8	Upland Swamps: Sedgeland-Heath Complex
Dendrobium 35b Area	1.8	Length = 349 metres
Dendrobium 85 (DC10)	1.36	Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
Dendrobium 85 (DC10)	0.26	Upland Swamps: Banksia Thicket
Dendrobium 85 (DC10)	0.67	Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
Dendrobium 85 (DC10)	2.29	Length = 483 metres

SOUTH32

Illawarra Coal

Dendrobium Swamp Vegetation Types

Figure 3-43

Legend

Biosis detailed community mapping

Upland Swamp Vegetation Communities

- Banksia Thicket
- Sedgeland-Heath Complex (Cyperoid Heath)
- Sedgeland-Heath Complex (Restioid Heath)
- Sedgeland-Heath Complex (Sedgeland)
- Tea-Tree Thicket

NPWS Woronora Plateau Mapping

- Upland Swamp: Sedgeland-Heath Complex

Illawarra Coal Mapping

- Dendrobium Area 3B SMP Approval Figure 1

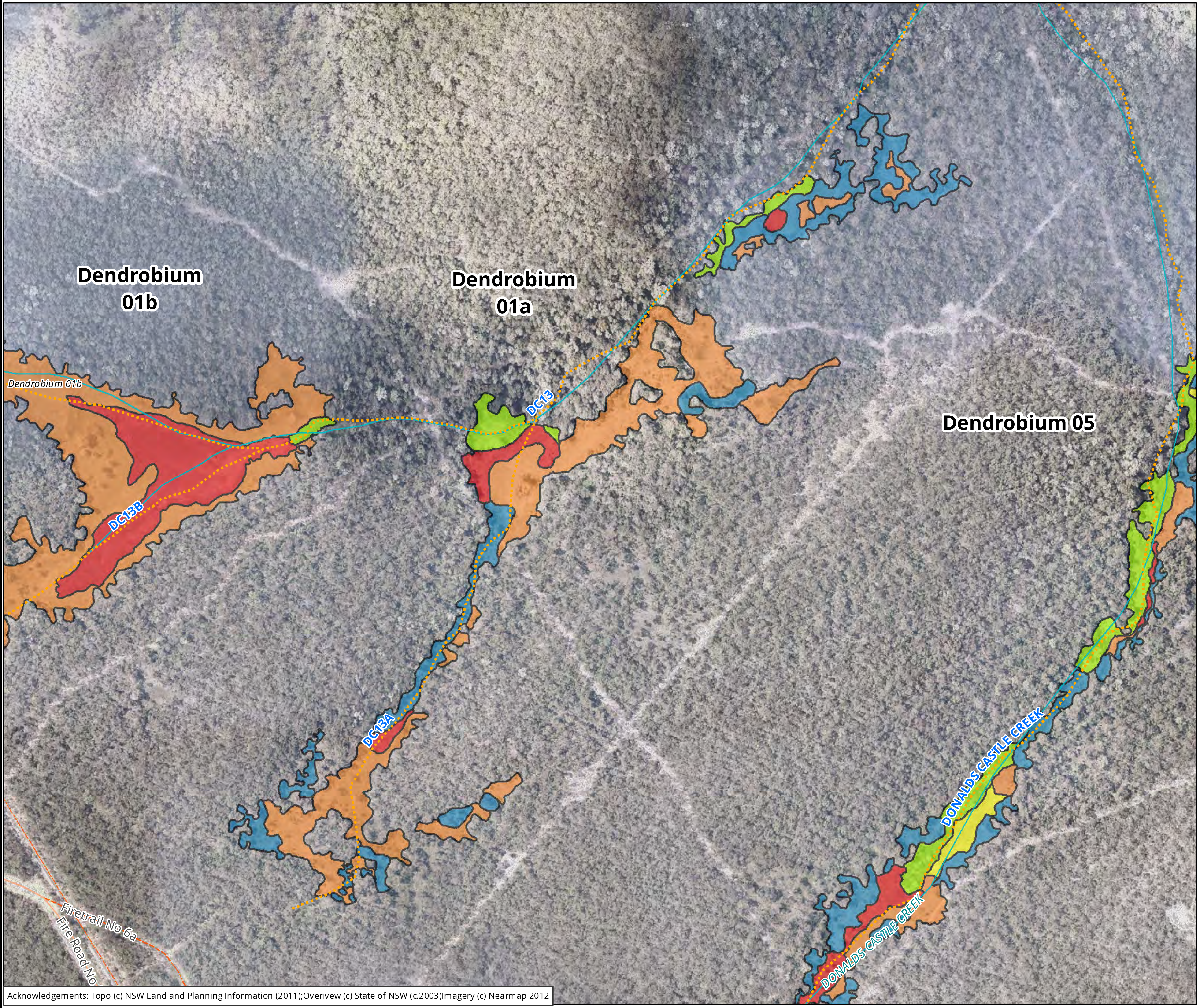
Date: 25 June, 2014
Author: P.Crowe
Signed Off: G.Brassington

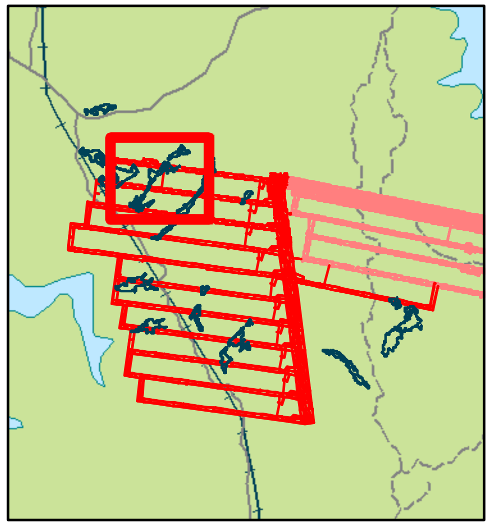
Version 5

Horizontal Datum
MGA - Zone 56

N W E S

0 250 500 1,000 Metres





Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44a, Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-44 Dendrobium 01a

0 40 80 120 160 200

Metres

Scale: 1:4,340 @ A3

Coordinate System: GDA 1994 MGA Zone 56

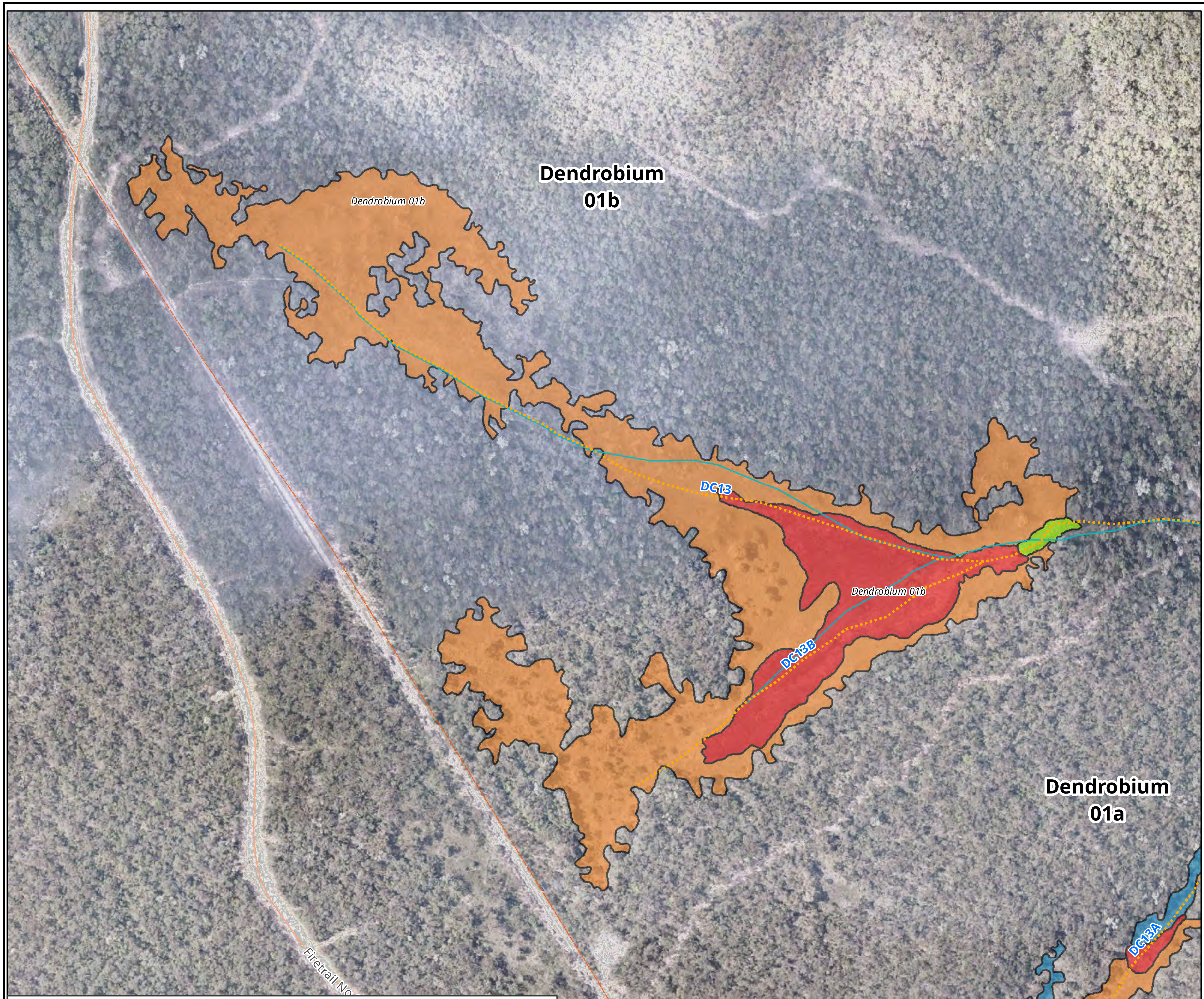
biosis.

Biosis Pty Ltd

N

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 LiDAR Swamps



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

Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-45: Dendrobium 01b

0 30 60 90 120 150

Metres

Scale: 1:3,210 @ A3

Coordinate System: GDA 1994 MGA Zone 56

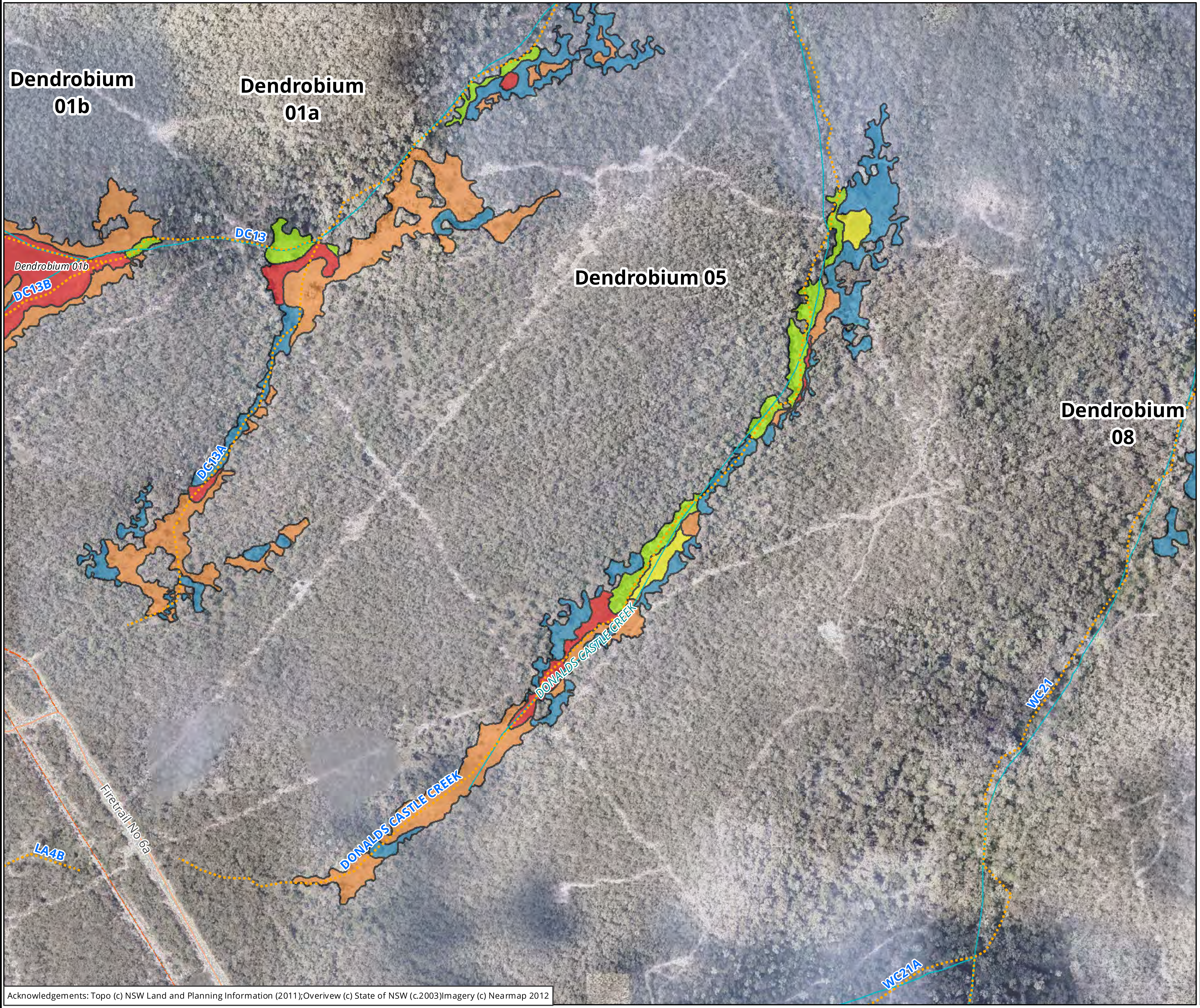
N

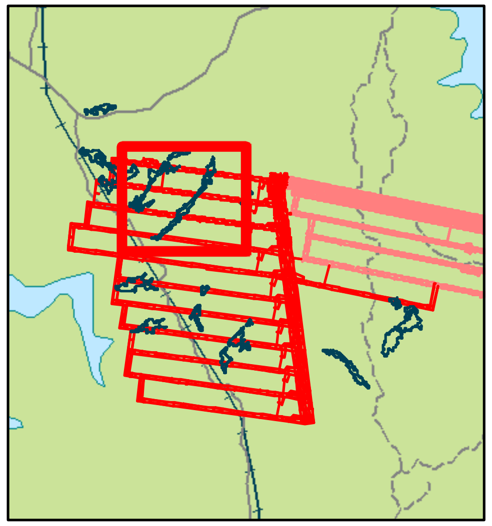
biosis

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 LiDAR Swamps





Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44a, Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-46: Dendrobium 05

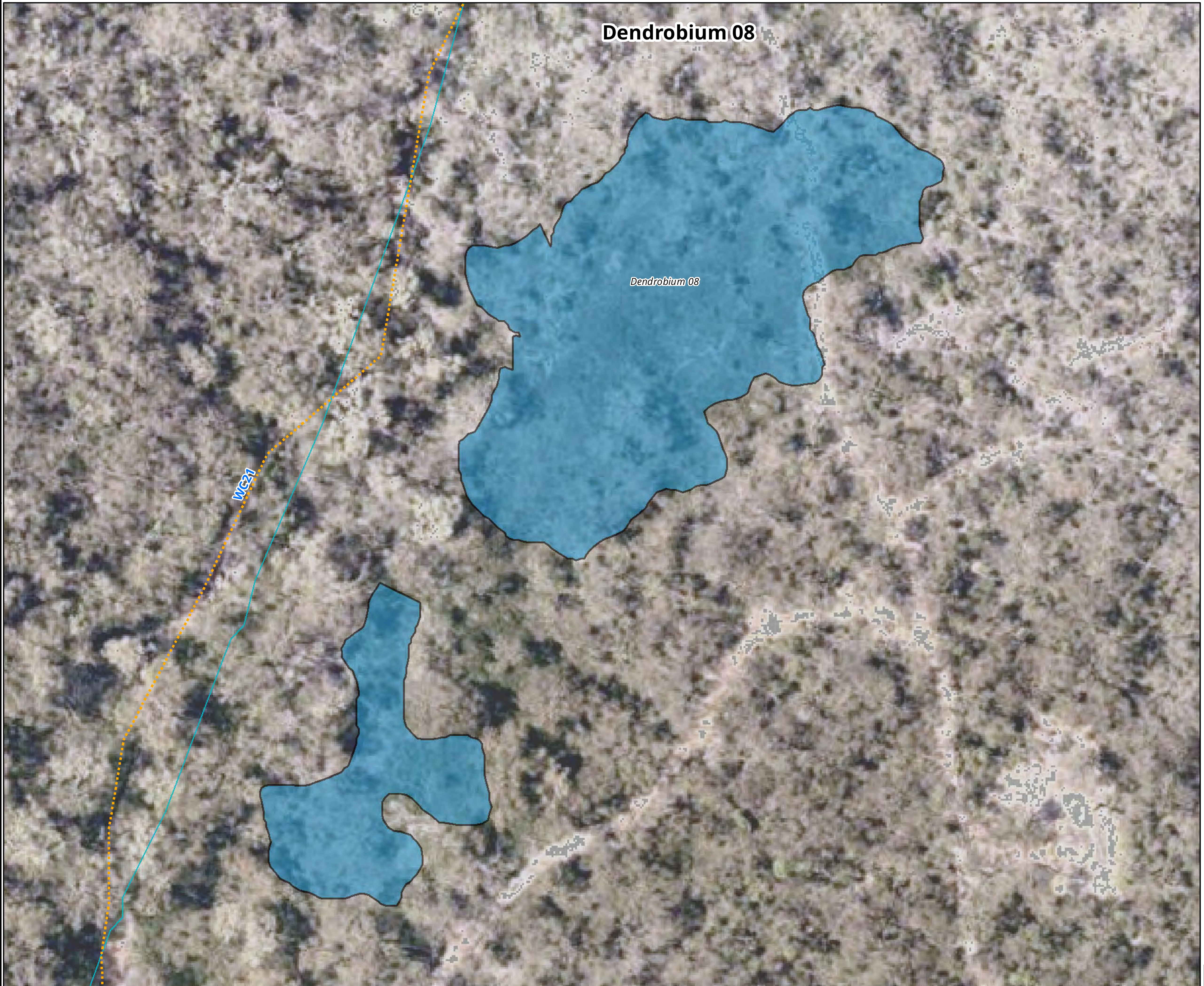
0 50 100 150 200 250
Metres
Scale: 1:5,490 @ A3
Coordinate System: GDA 1994 MGA Zone 56

N

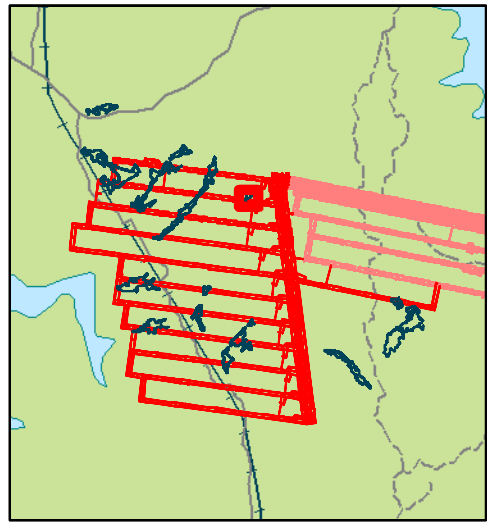
biosis.
Biosis Pty Ltd

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 LiDAR Swamps



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



Legend

Swamp Vegetation Communities

MU42, Upland Swamps: Banksia Thicket

BHP Creek and Swamp Naming

BHP Creekline

Figure 3-47: Dendrobium 08

0 9 18 27 36 45

Metres

Scale: 1:880 @ A3

Coordinate System: GDA 1994 MGA Zone 56

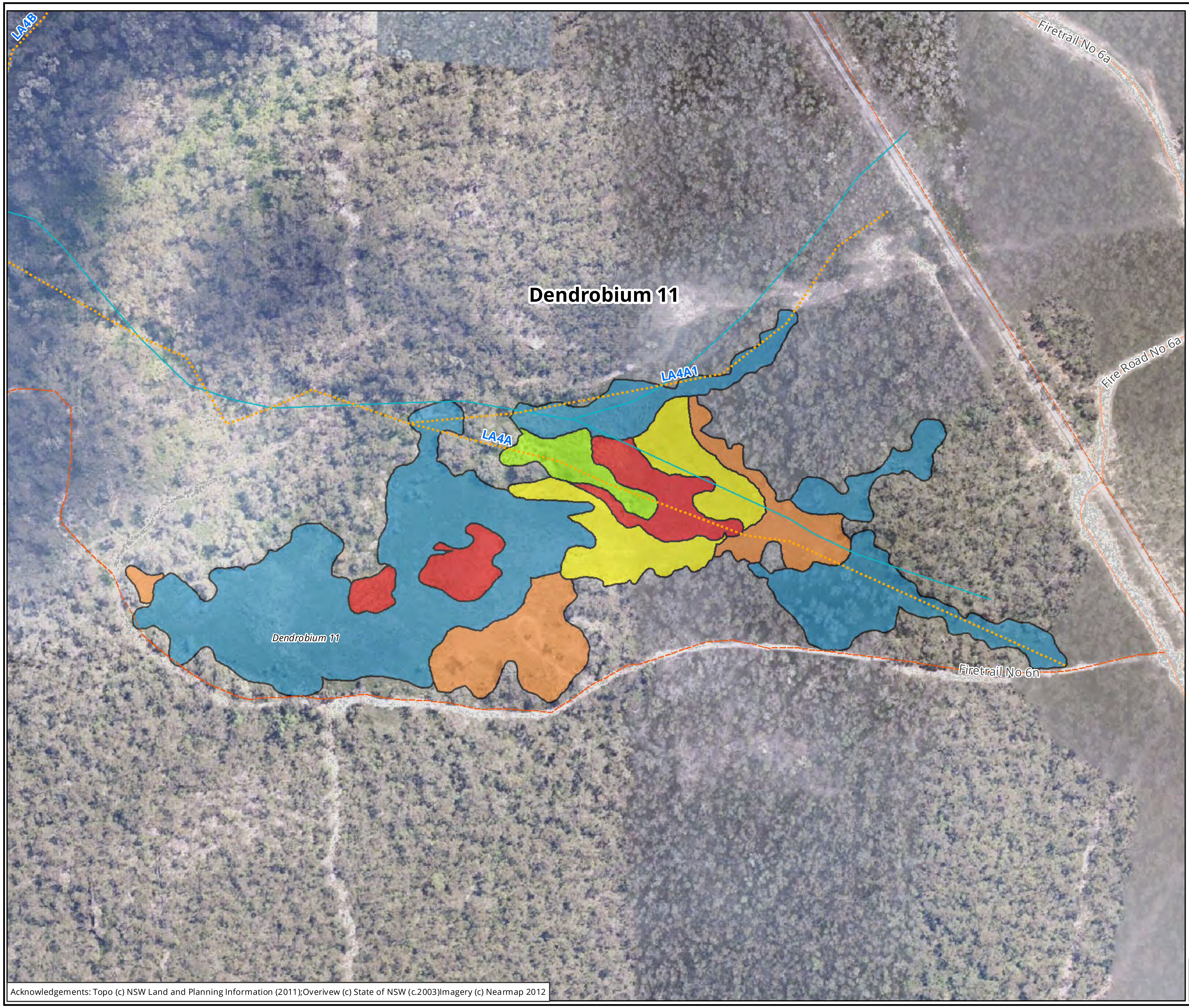
N

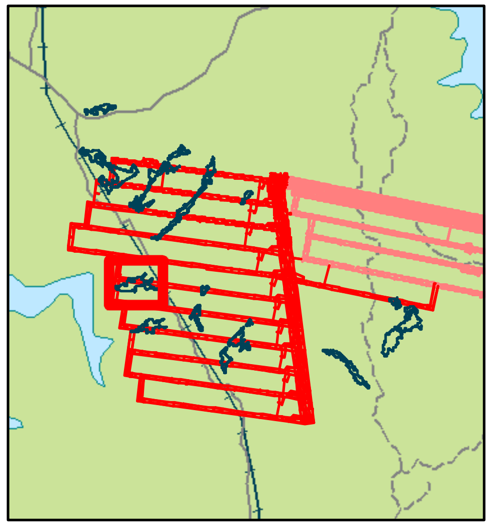
biosis

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 LIDAR Swamps





Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44a, Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-48: Dendrobium 11

0 20 40 60 80 100

Metres

Scale: 1:2,390 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

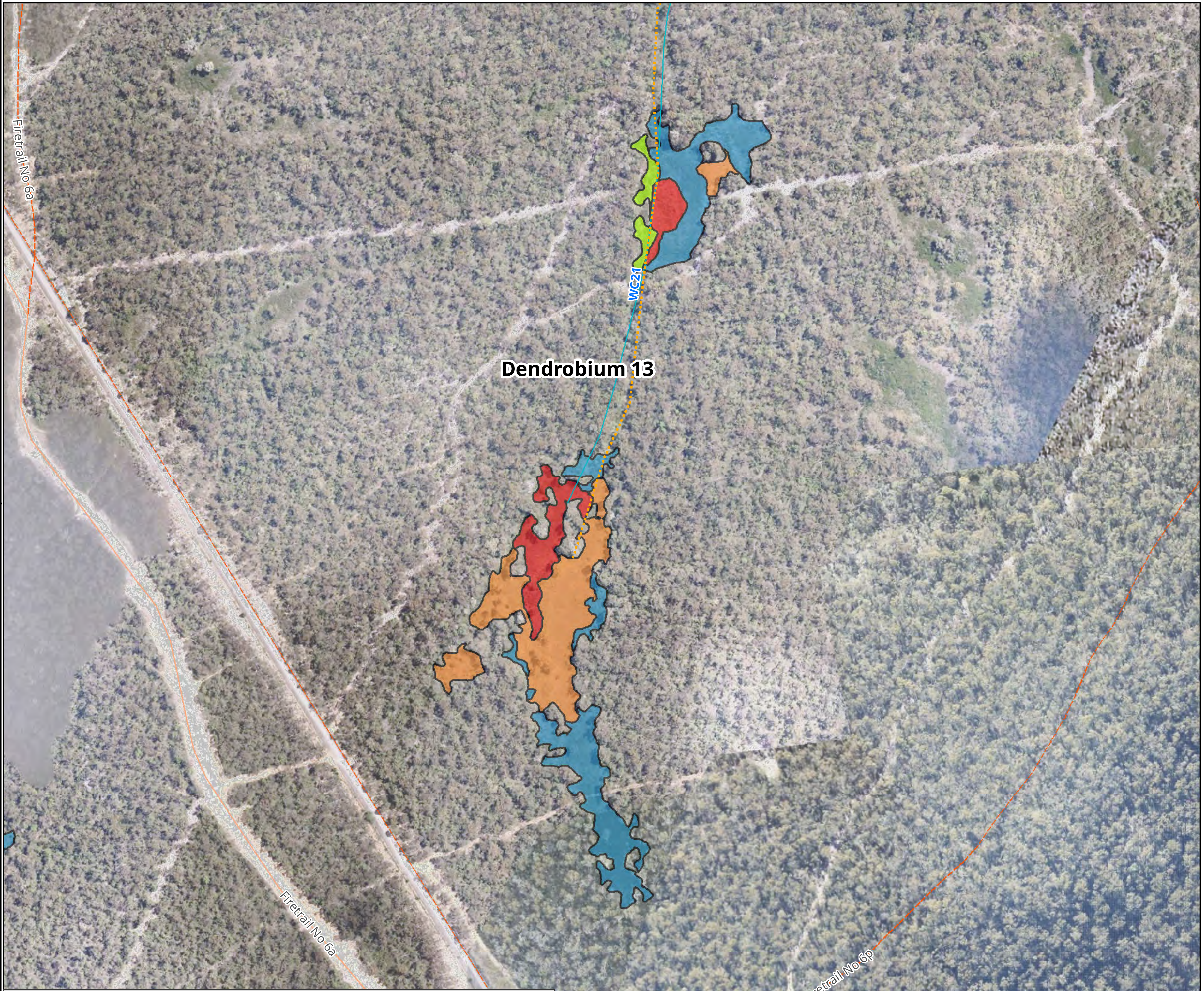
biosis

Biosis Pty Ltd

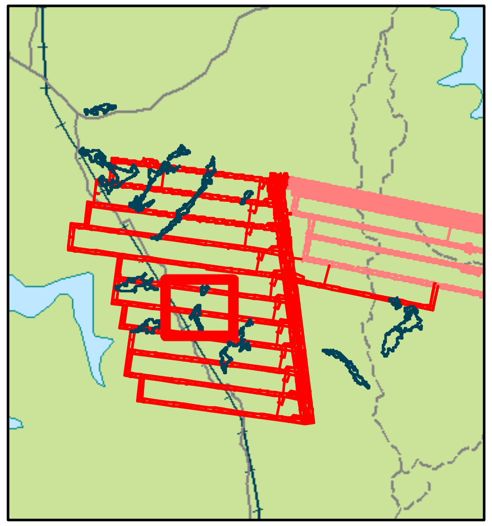
Ballarat, Brisbane, Canberra, Melbourne, Sydney, Wangaratta & Wollongong

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

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



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



Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-49: Dendrobium 13

0 30 60 90 120 150

Metres

Scale: 1:2,980 @ A3

Coordinate System: GDA 1994 MGA Zone 56

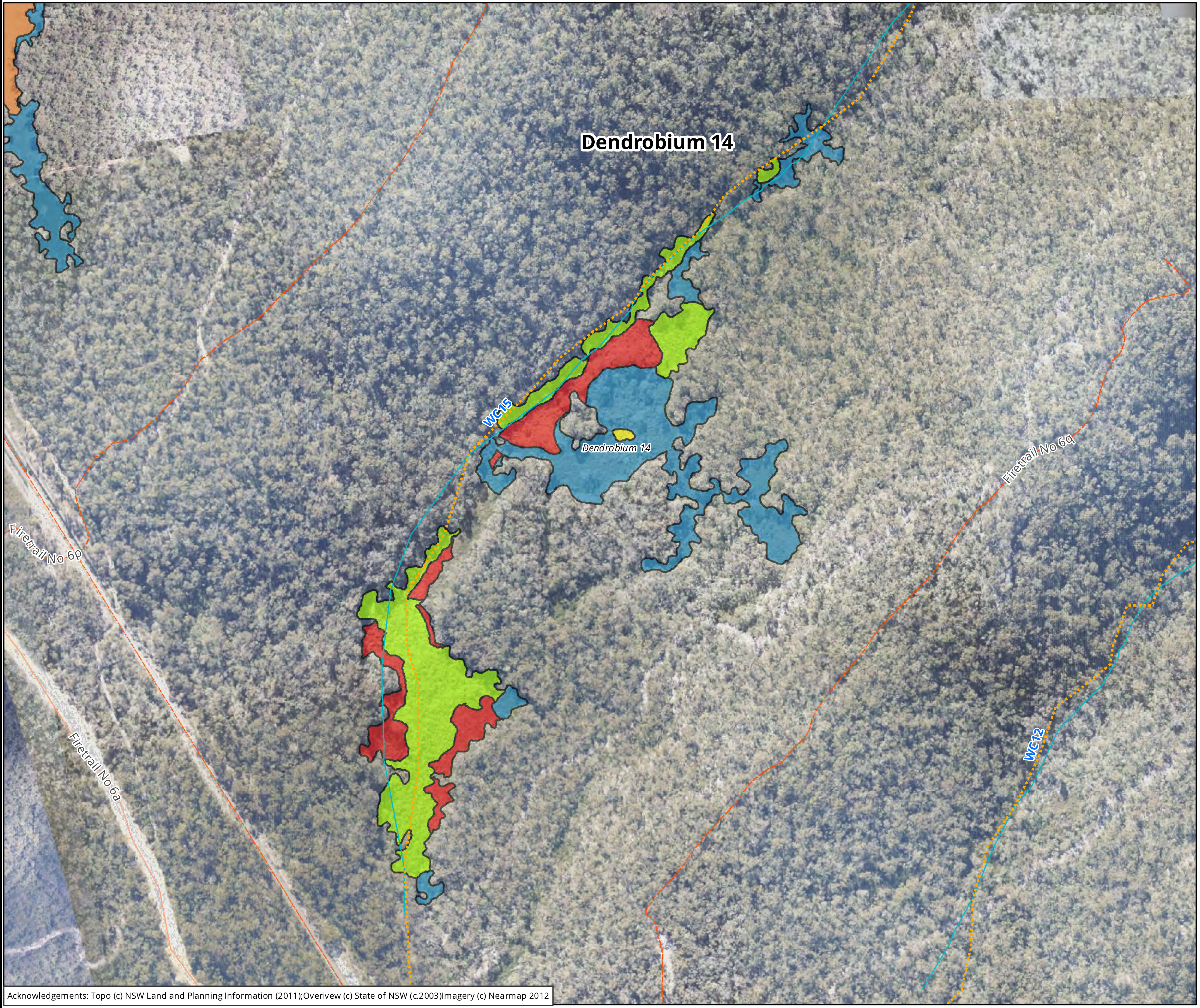
N

biosis

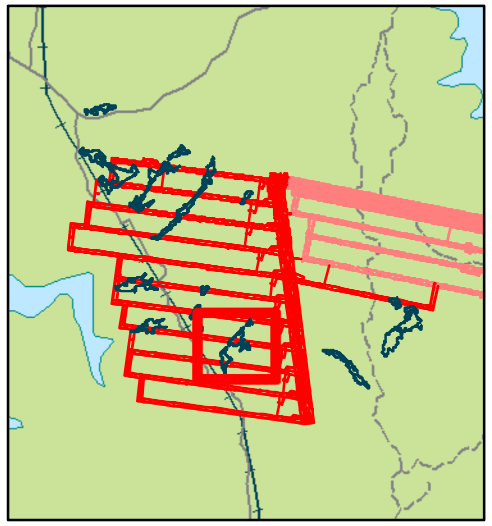
Biosis Pty Ltd

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 LiDAR Swamps



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



Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44a, Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-50: Dendrobium 14

0 30 60 90 120 150

Metres

Scale: 1:3,510 @ A3

Coordinate System: GDA 1994 MGA Zone 56

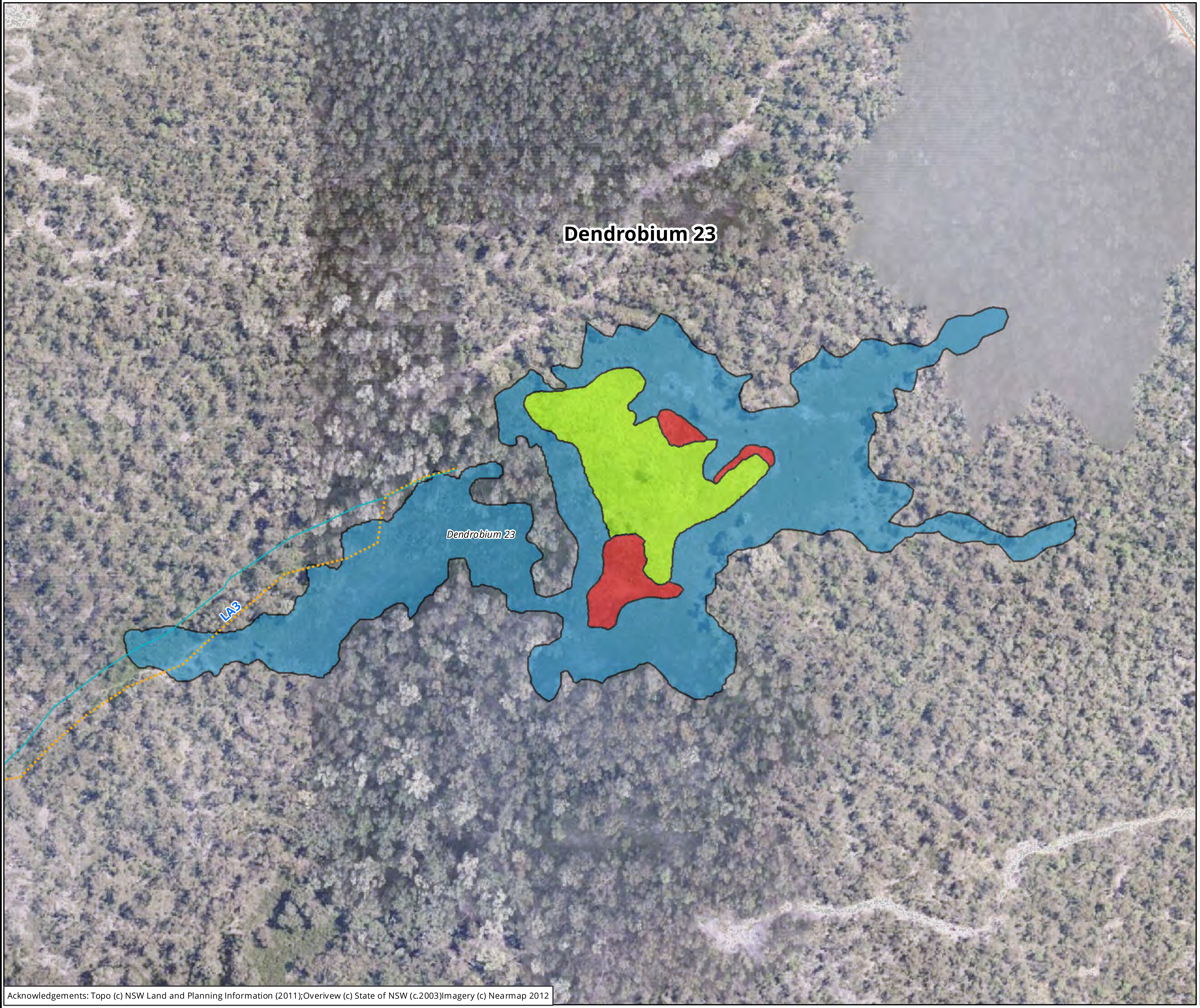
biosis

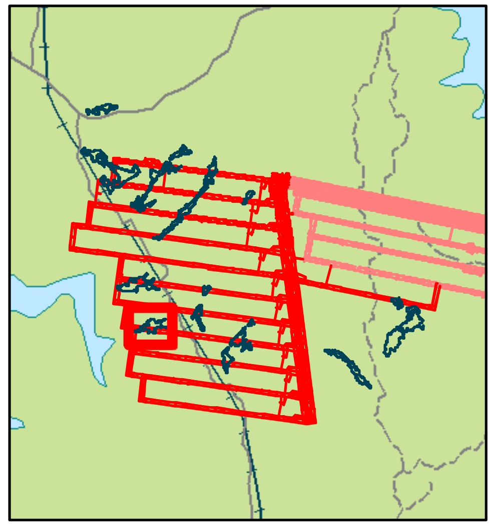
N

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 LiDAR Swamps





Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-51: Dendrobium 23

0 10 20 30 40 50

Metres

Scale: 1:1,950 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

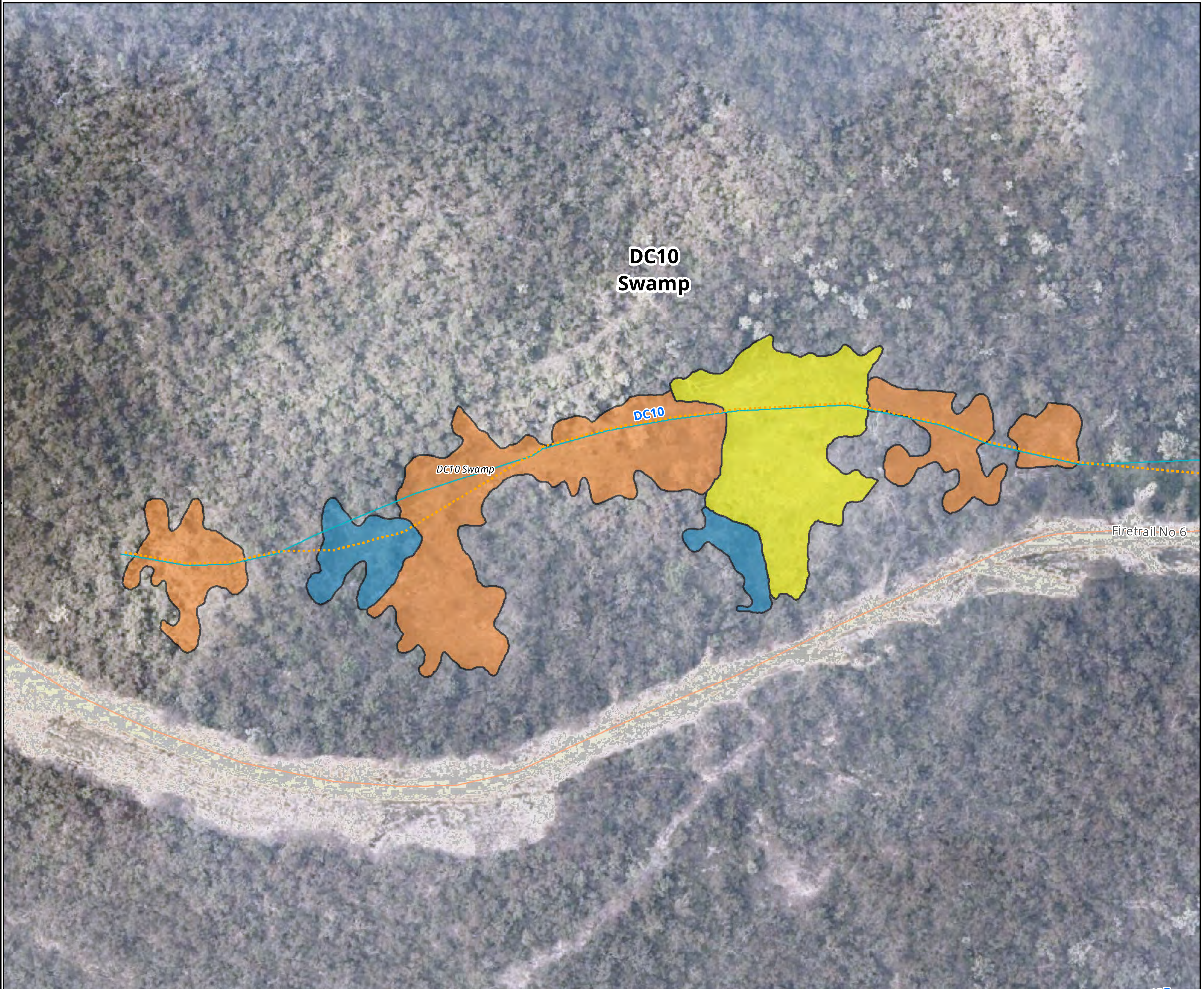
biosis

Biosis Pty Ltd

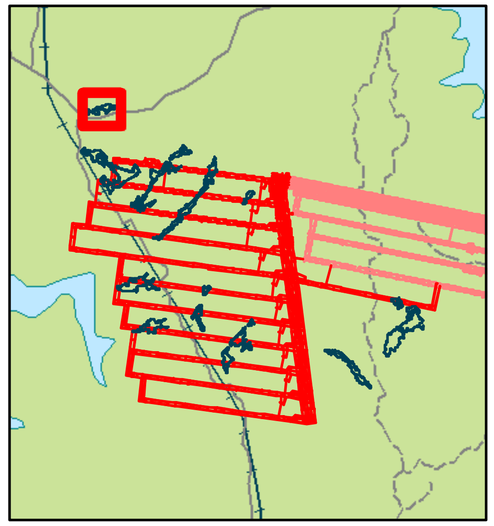
Ballarat, Brisbane, Canberra, Melbourne, Sydney, Wangaratta & Wollongong

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

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



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



Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU44a, Upland Swamps: Sedgeland-Heath Complex (Sedgeland)
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-52: DC10 Swamp 85

0 10 20 30 40 50

Metres

Scale: 1:1,730 @ A3

Coordinate System: GDA 1994 MGA Zone 56

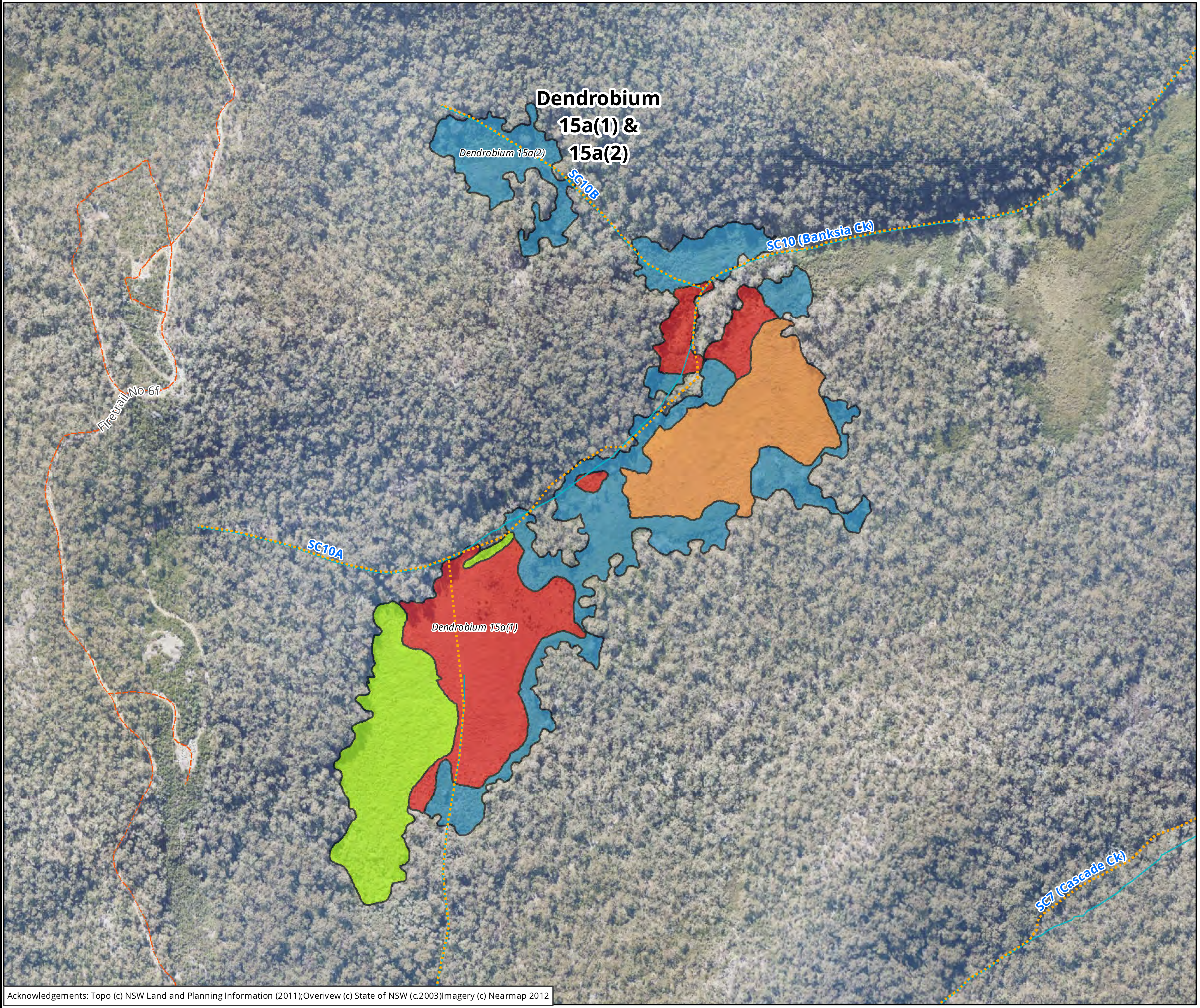
N

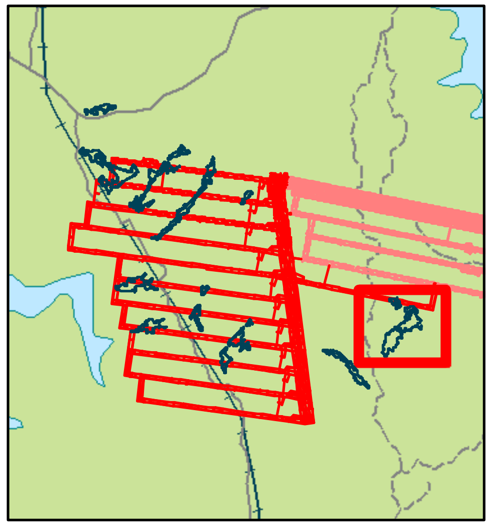
biosis

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 LiDAR Swamps





Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44b, Upland Swamps: Sedgeland-Heath Complex (Restioid Heath)
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-53: Dendrobium 15a(1) & 15a(2)

0 30 60 90 120 150
Metres
Scale: 1:3,850 @ A3
Coordinate System: GDA 1994 MGA Zone 56

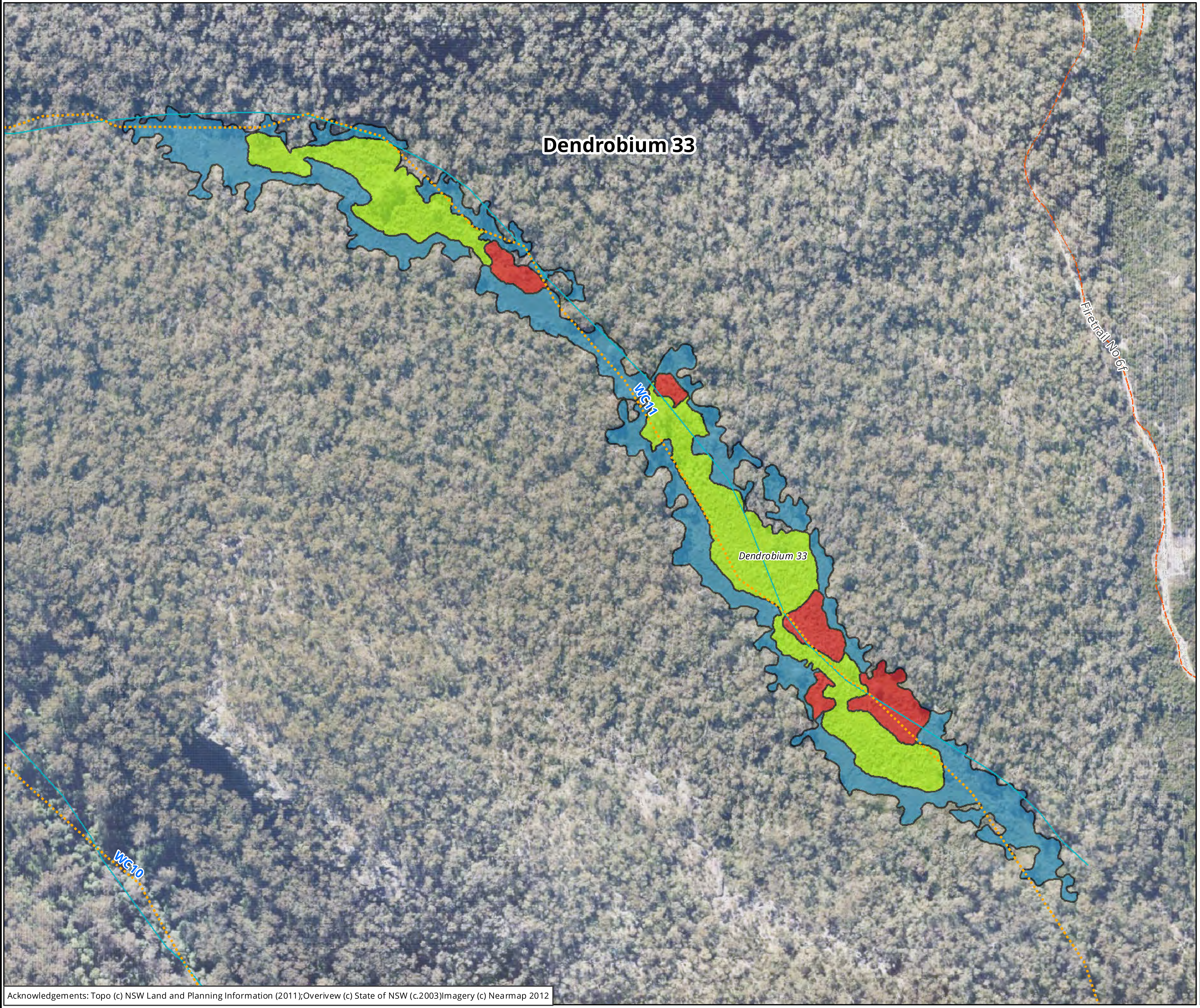
N

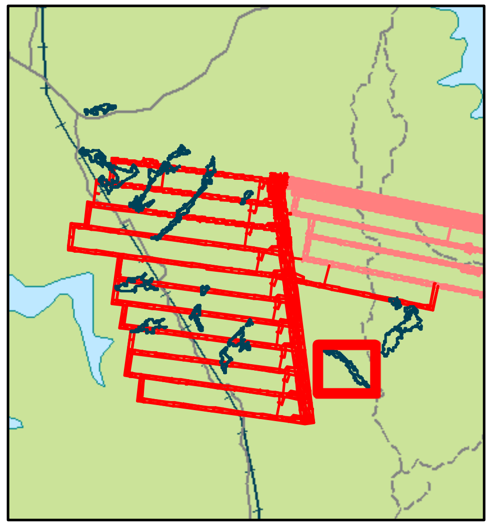
biosis.
Biosis Pty Ltd

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 LiDAR Swamps

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





Legend

Swamp Vegetation Communities

- MU42, Upland Swamps: Banksia Thicket
- MU43, Upland Swamps: Tea-Tree Thicket
- MU44c, Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-54 Dendrobium 33

0 25 50 75 100 125

Metres

Scale: 1:2,530 @ A3

Coordinate System: GDA 1994 MGA Zone 56

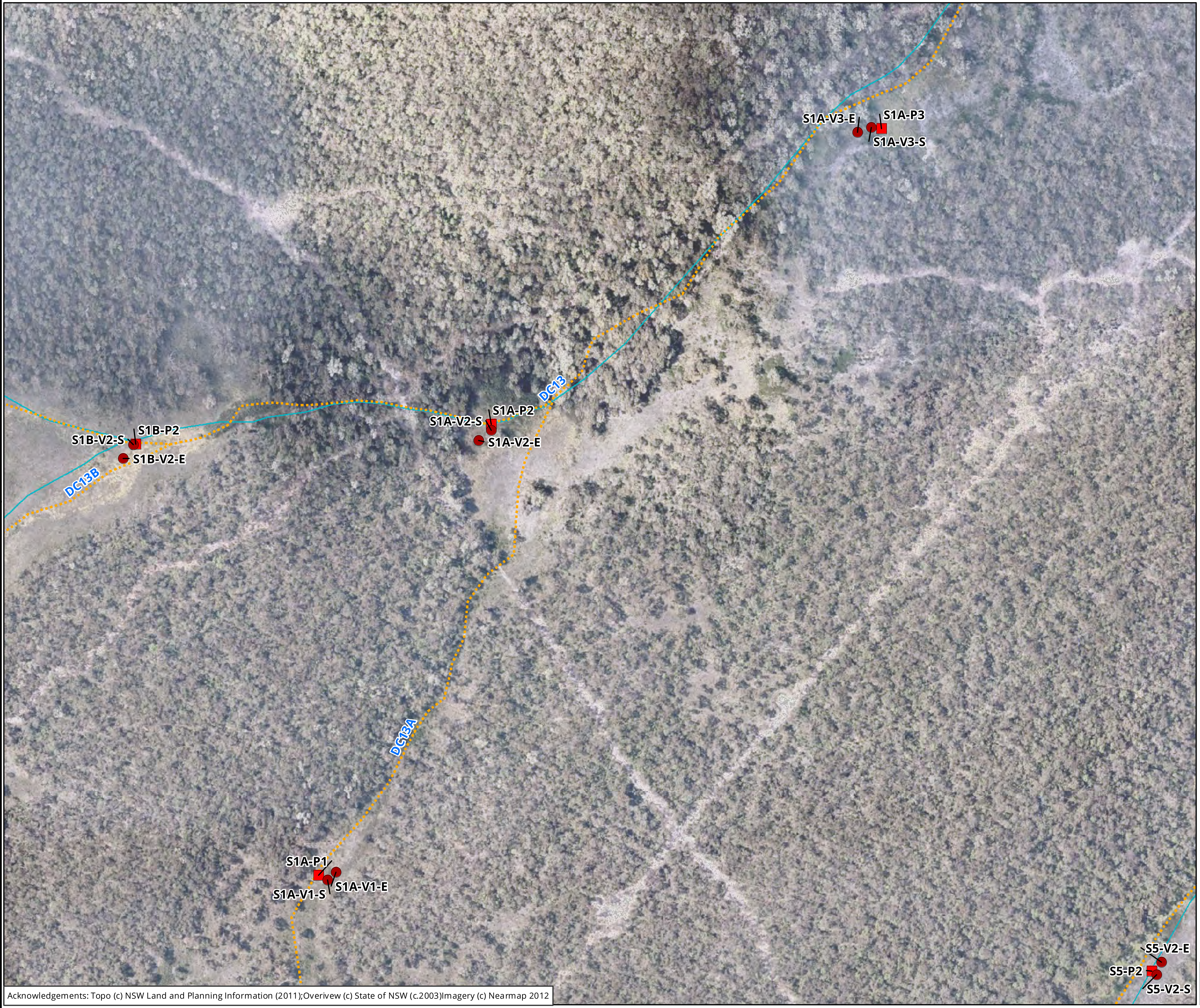
N

biosis

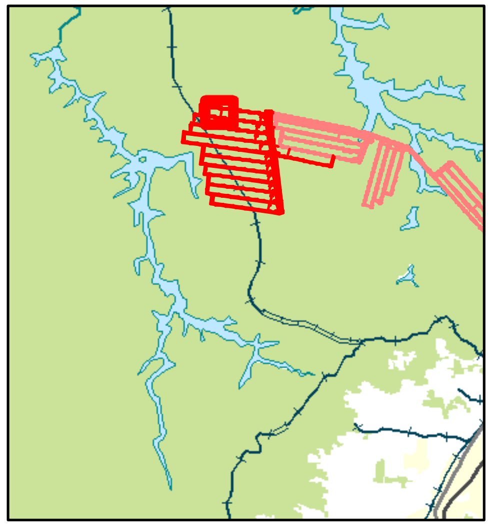
Biosis Pty Ltd

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 LiDAR Swamps



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



Legend

Flora Monitoring Site

- Swamp Impact Site - Transect End
- Swamp Impact Site - Photo Point

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-55: Swamp 1A

0 30 60 90 120 150

Metres

Scale: 1:3,100 @ A3

Coordinate System: GDA 1994 MGA Zone 56

biosis

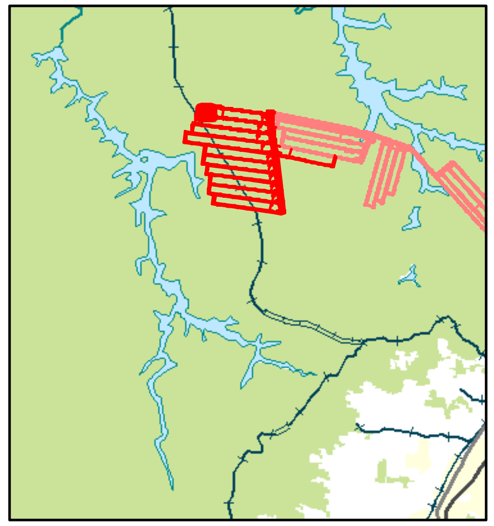
Biosis Pty Ltd

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

N

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring

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



Legend

Flora Monitoring Site

- Swamp Impact Site - Transect End
- Swamp Impact Site - Photo Point

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-56: Swamp 1B

0 10 20 30 40 50

Metres

Scale: 1:1,200 @ A3

Coordinate System: GDA 1994 MGA Zone 56

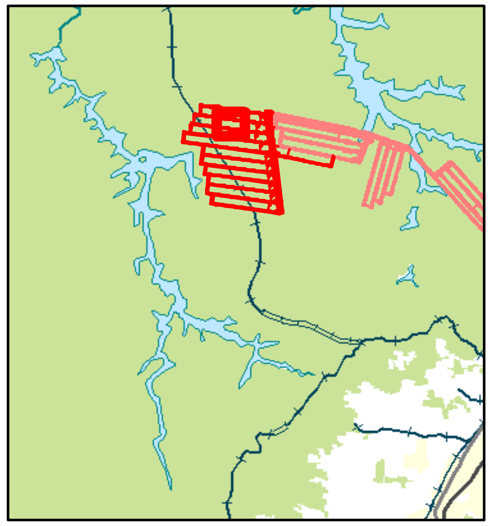
N

Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring

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



Legend

Flora Monitoring Site

- Swamp Impact Site - Transect End
- Swamp Impact Site - Photo Point

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-57: Swamp 5

0 30 60 90 120 150

Metres

Scale: 1:3,100 @ A3

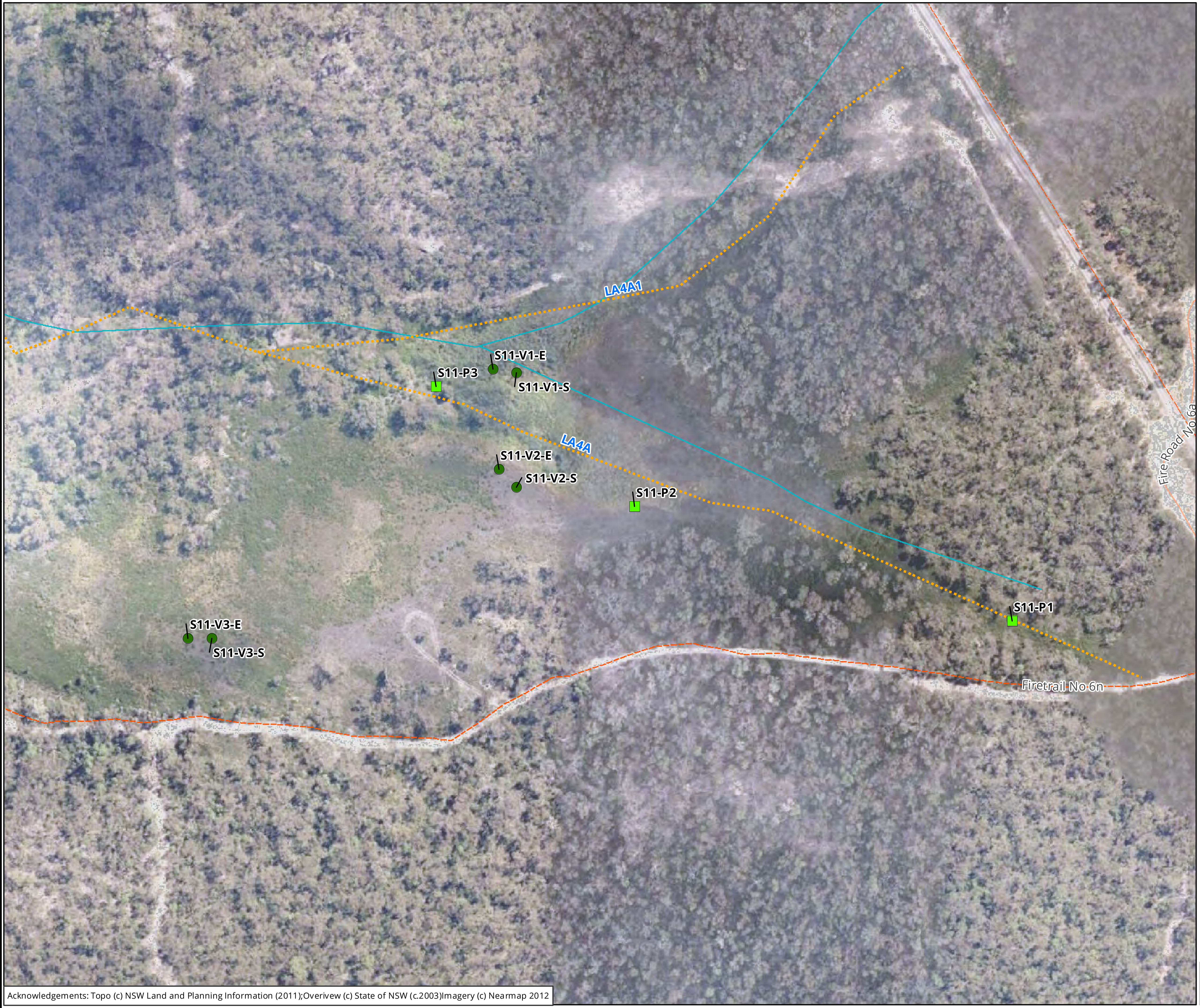
Coordinate System: GDA 1994 MGA Zone 56

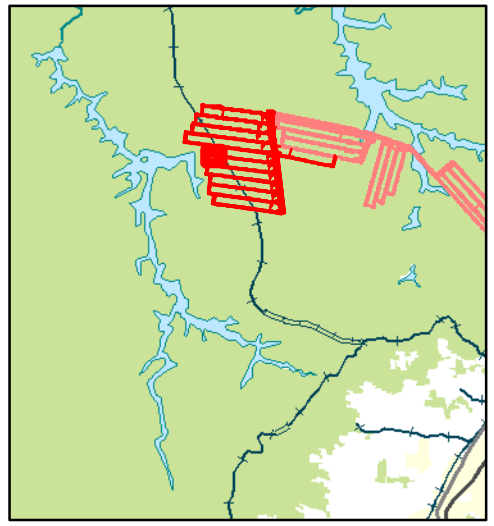
N

Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring





Legend

Flora Monitoring Site

- Swamp Control Site - Transect
- Swamp Control Site - Photo Point

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-58: Swamp 11

0 10 20 30 40 50

Metres

Scale: 1:1,800 @ A3

Coordinate System: GDA 1994 MGA Zone 56

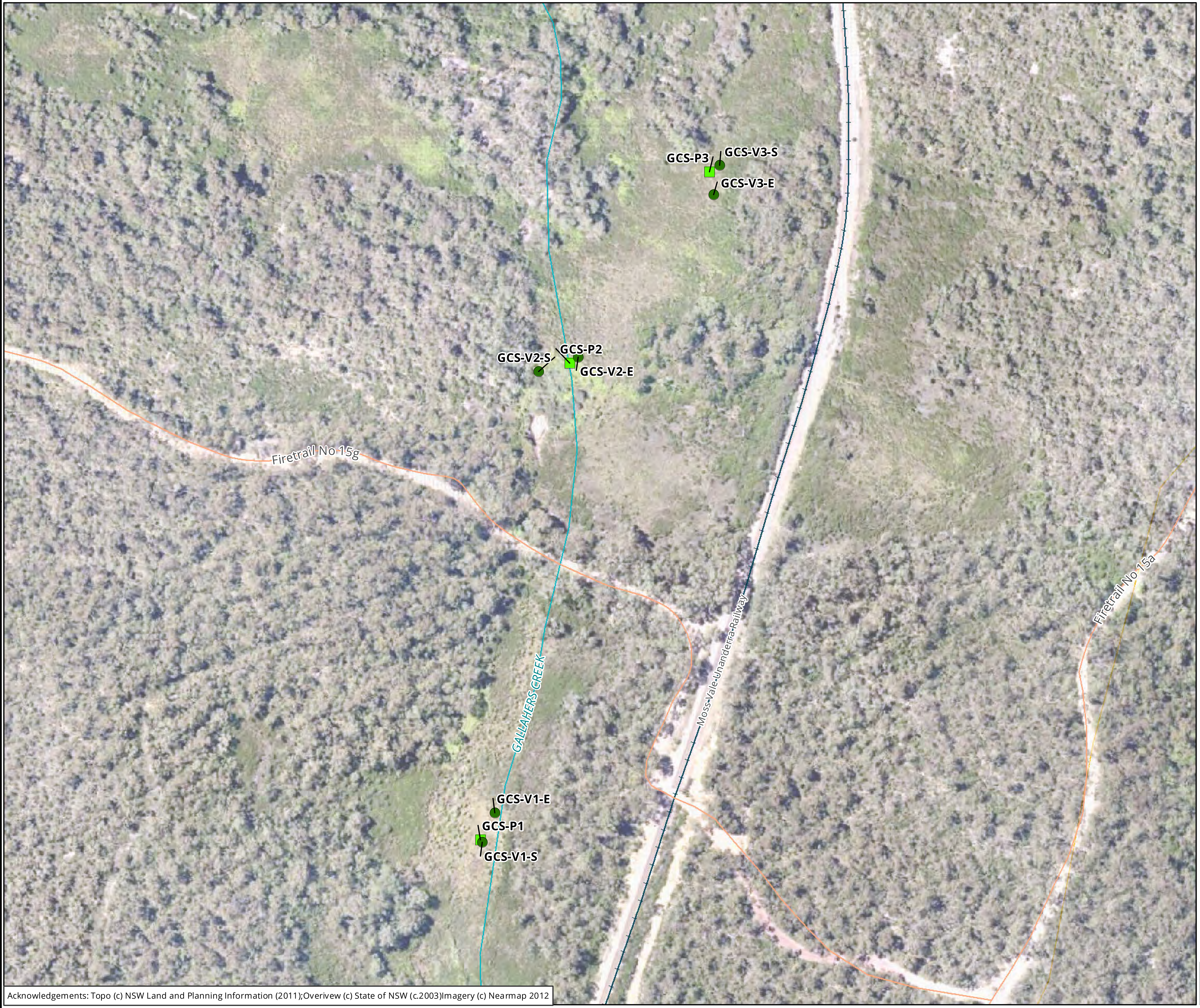
N

biosis

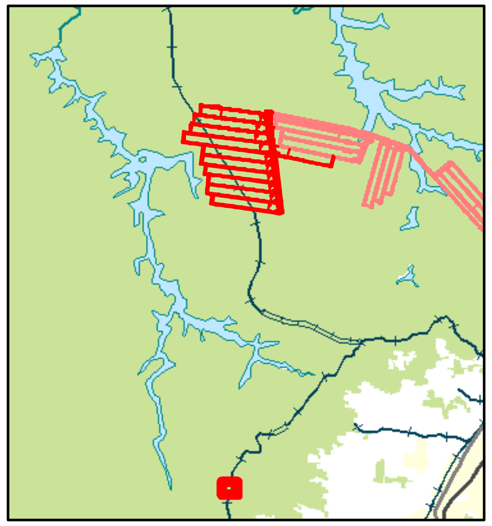
Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring



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



Legend

Flora Monitoring Site

- Swamp Control Site - Transect
- Swamp Control Site - Photo Point

Figure 3-59: Gallahers Creek Swamp 88

0 10 20 30 40 50

Metres

Scale: 1:1,700 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

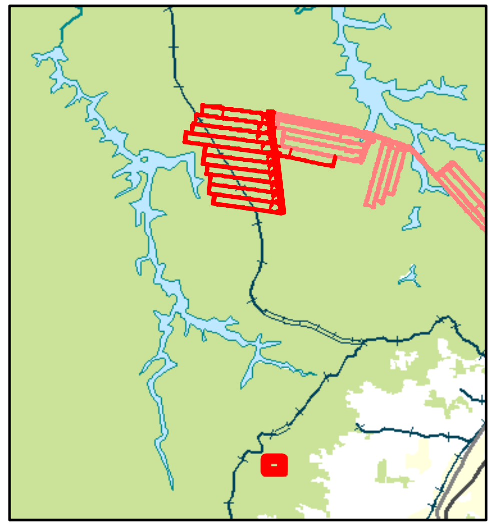
biosis

Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring

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



Legend

Flora Monitoring Site

- Swamp Control Site - Transect
- Swamp Control Site - Photo Point

Figure 3-60: Firetrail 15E Swamp 87

0 10 20 30 40 50

Metres

Scale: 1:1,700 @ A3

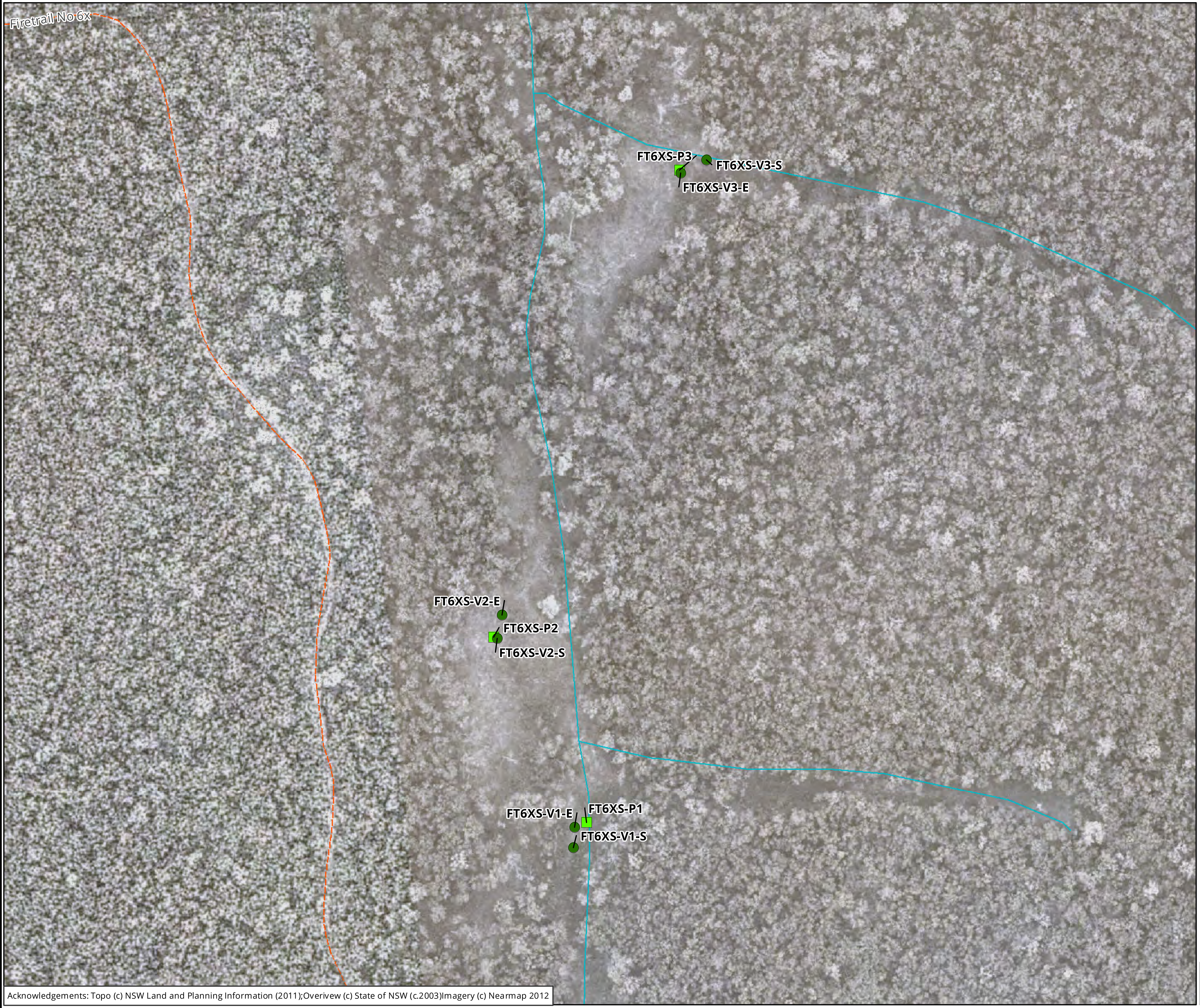
Coordinate System: GDA 1994 MGA Zone 56

N

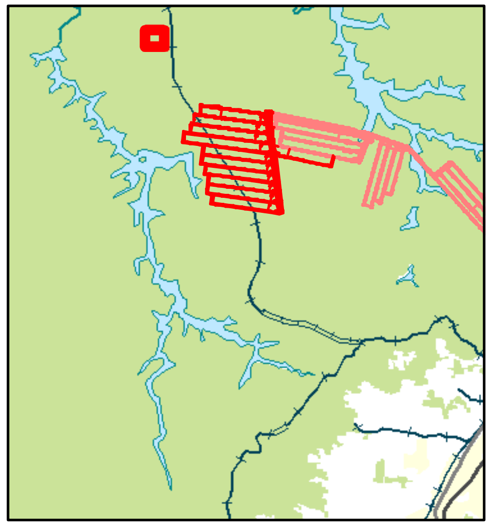
Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring



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



Legend

Flora Monitoring Site

- Swamp Control Site - Transect
- Swamp Control Site - Photo Point

Figure 3-61: Firetrail 6X Swamp 86

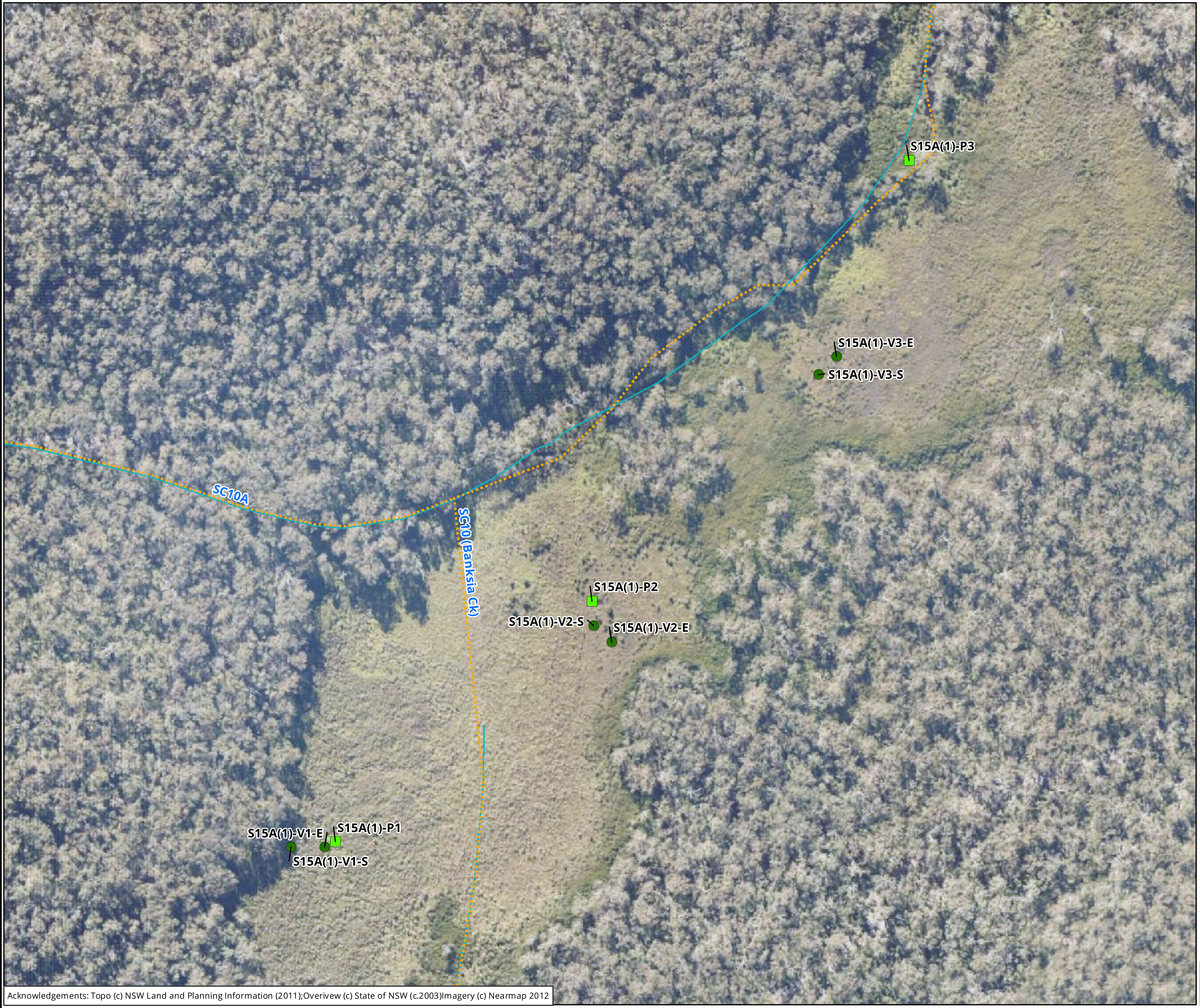
0 20 40 60 80 100
Metres
Scale: 1:2,100 @ A3
Coordinate System: GDA 1994 MGA Zone 56

N

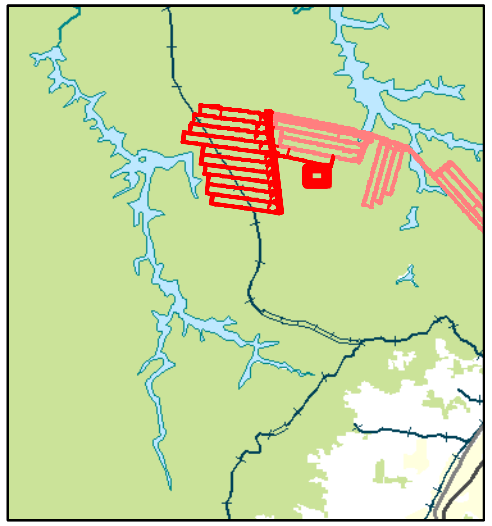
Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring



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



Legend

Flora Monitoring Site

- Swamp Control Site - Transect
- Swamp Control Site - Photo Point

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-62: Swamp 15A(1)

0 20 40 60 80 100

Metres

Scale: 1:2,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

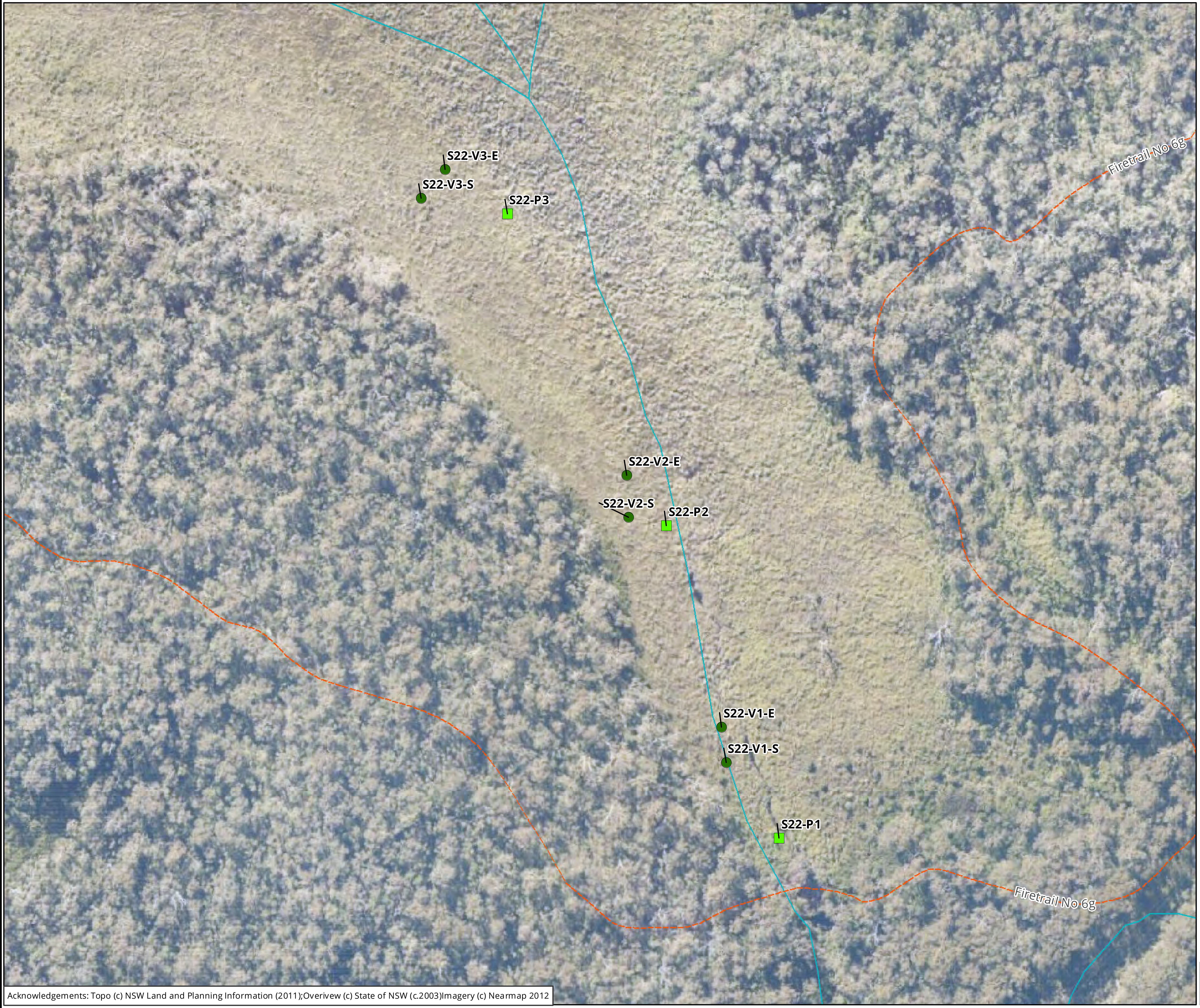
N

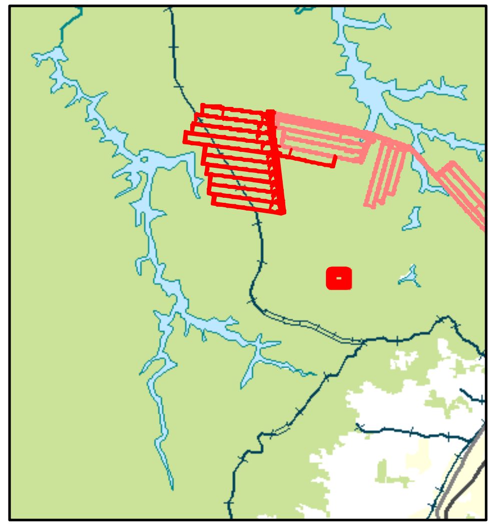
biosis.

Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring





Legend

Flora Monitoring Site

- Swamp Control Site - Transect
- Swamp Control Site - Photo Point

Figure 3-63: Swamp 22

0 10 20 30 40 50

Metres

Scale: 1:1,600 @ A3

Coordinate System: GDA 1994 MGA Zone 56

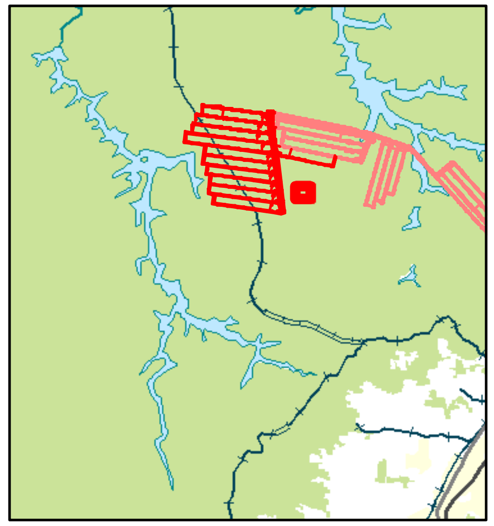
N

Biosis Pty Ltd

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring

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



Legend

Flora Monitoring Site

- Swamp Control Site - Transect
- Swamp Control Site - Photo Point

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-64: Swamp 33

0 10 20 30 40 50

Metres

Scale: 1:1,600 @ A3

Coordinate System: GDA 1994 MGA Zone 56

biosis

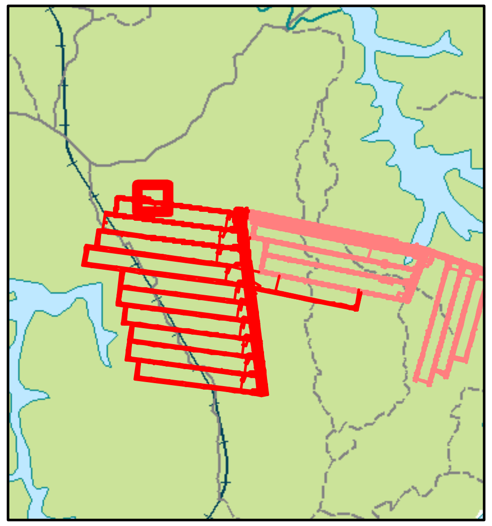
Biosis Pty Ltd

N

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

Matter: 17994
Date: 25 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B Flora Monitoring

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



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 3-65: DC13 Transect

0 10 20 30 40 50

Metres

Scale: 1:1,820 @ A3

Coordinate System: GDA 1994 MGA Zone 56

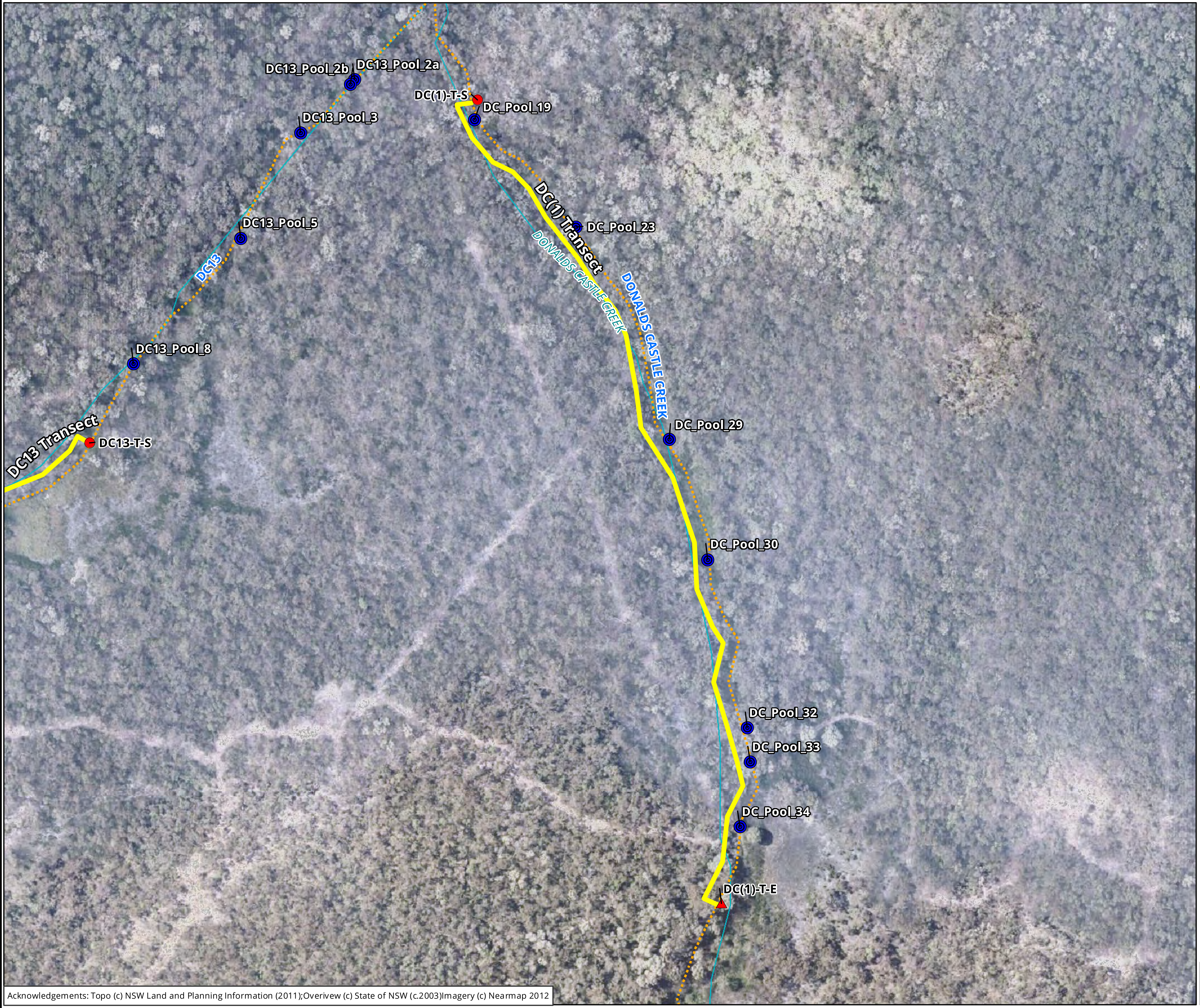
N

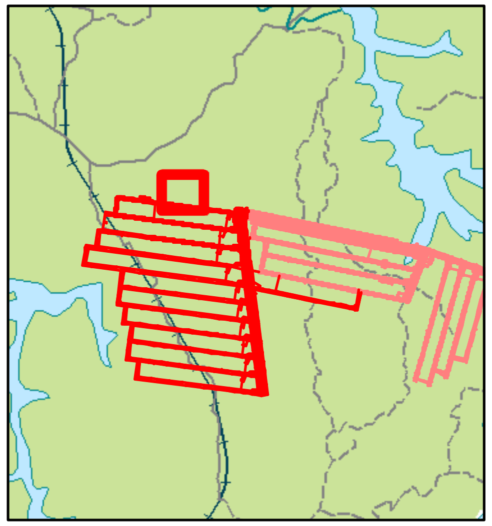
biosis

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





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 3-66: DC(1) Transect

0 25 50 75 100 125

Metres

Scale: 1:2,480 @ A3

Coordinate System: GDA 1994 MGA Zone 56

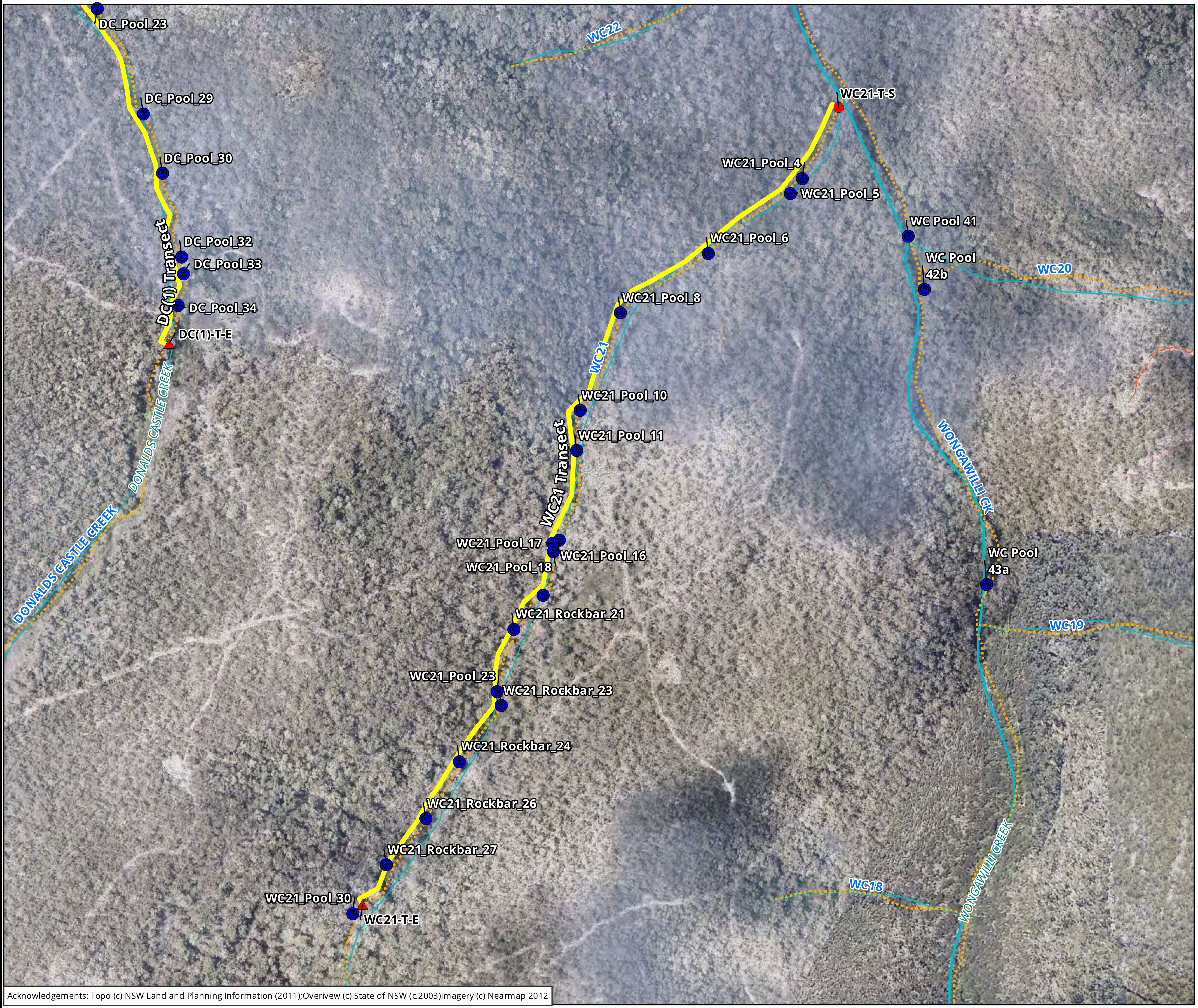
N

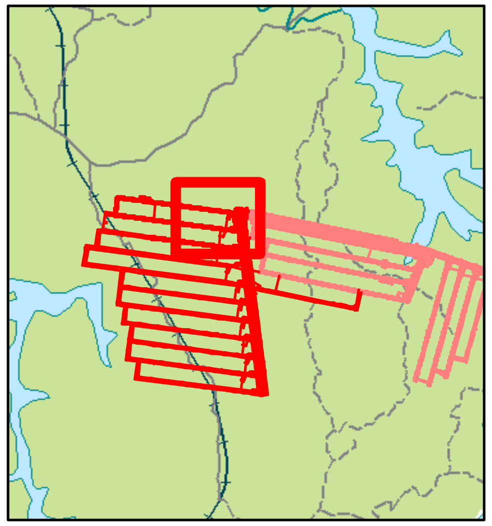
biosis

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





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 3-67: WC21 Transect

0 50 100 150 200 250

Metres

Scale: 1:5,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

biosis

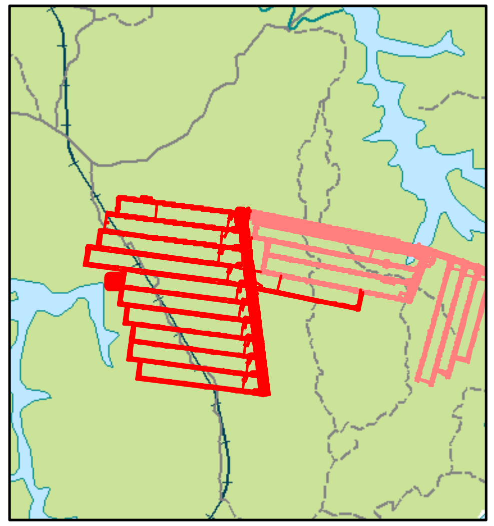
Biosis Pty Ltd

N

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-68: LA4A Transect

0 6 12 18 24 30

Metres

Scale: 1:610 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

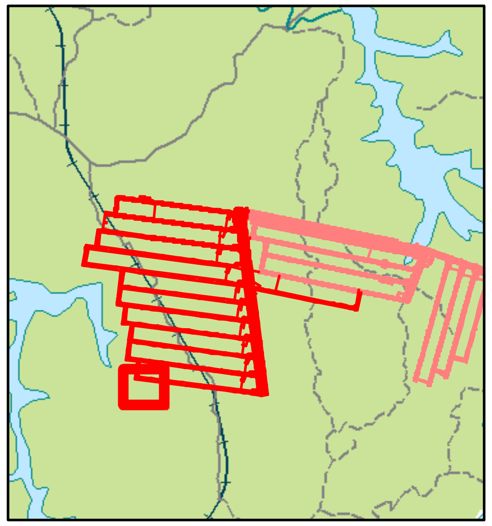
biosis

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-69: ND1 Transect

0 25 50 75 100 125

Metres

Scale: 1:2,470 @ A3

Coordinate System: GDA 1994 MGA Zone 56

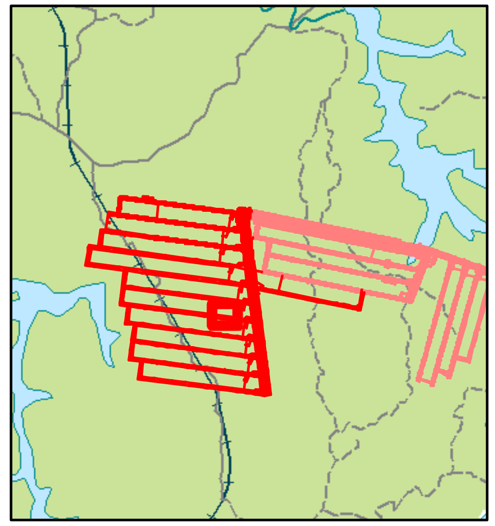
N

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



Legend

Pool Level Monitoring Sites

Threatened Frog Monitoring

Control - Transect Start

Control - Transect End

Threatened Frog Transect

BHP Creek and Swamp Naming

BHP Creekline

Figure 3-70: WC15 Transect

0 10 20 30 40 50

Metres

Scale: 1:1,550 @ A3

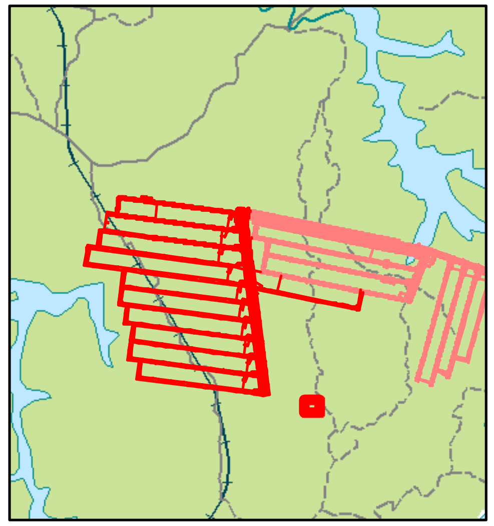
Coordinate System: GDA 1994 MGA Zone 56

N

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-71: WC10 Transect

0 9.5 19 28.5 38 47.5

Metres

Scale: 1:940 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

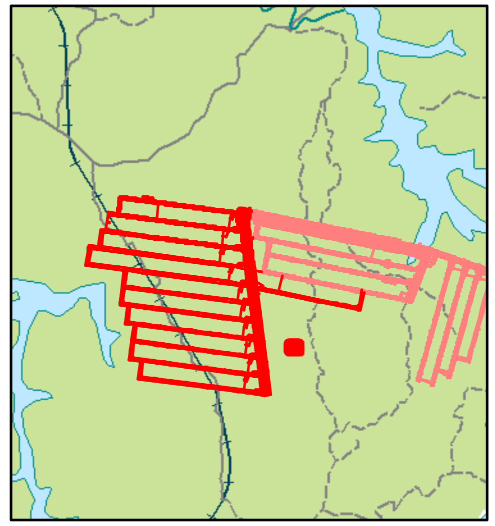
biosis

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-72: WC11 Transect

0 5.5 11 16.5 22 27.5

Metres

Scale: 1:550 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

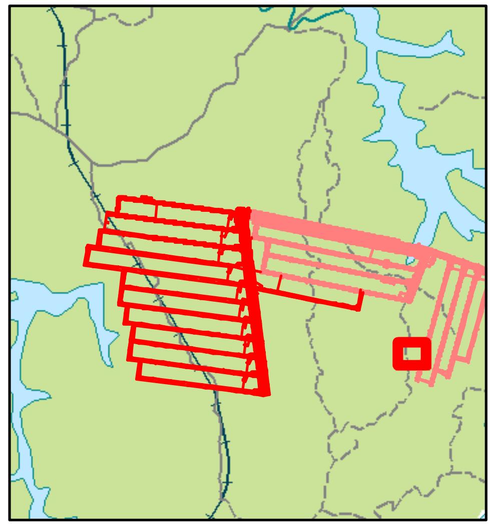
biosis

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-73: SC6 Transect

0 10 20 30 40 50

Metres

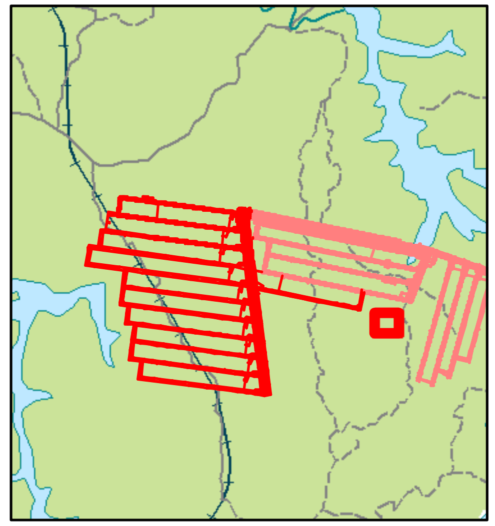
Scale: 1:1,620 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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



Legend

Pool Level Monitoring Sites

Threatened Frog Monitoring

Control - Transect Start

Control - Transect End

Threatened Frog Transect

BHP Creek and Swamp Naming

BHP Creekline

Figure 3-74: SC7(1) Transect

0 10 20 30 40 50

Metres

Scale: 1:1,420 @ A3

Coordinate System: GDA 1994 MGA Zone 56

biosis

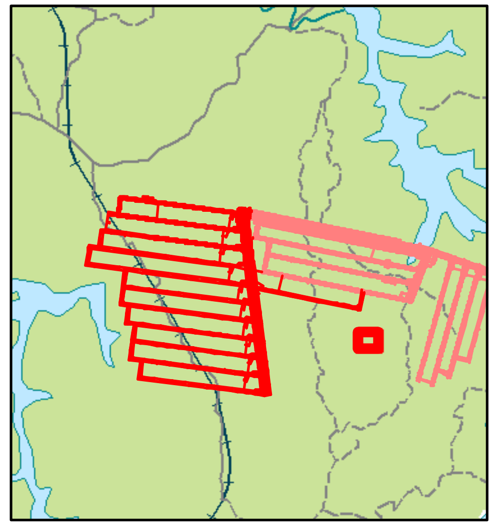
Biosis Pty Ltd

N

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-75: SC7(2) Transect

0 10 20 30 40 50

Metres

Scale: 1:1,210 @ A3

Coordinate System: GDA 1994 MGA Zone 56

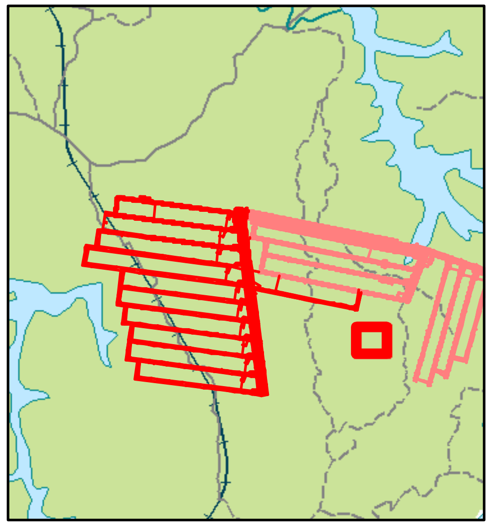
N

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-76: SC7A Transect

0 10 20 30 40 50

Metres

Scale: 1:1,830 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

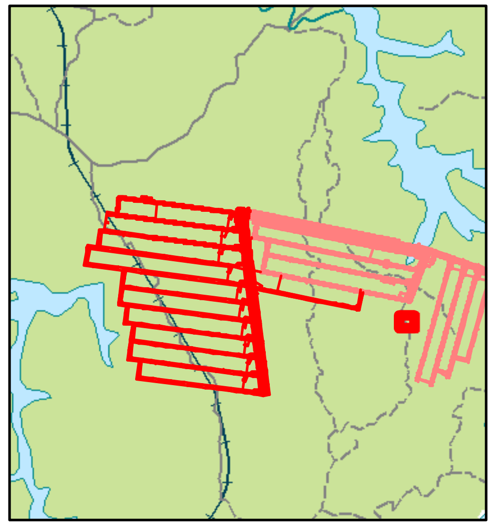
biosis.

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-77: SC8 Transect

0 9 18 27 36 45

Metres

Scale: 1:890 @ A3

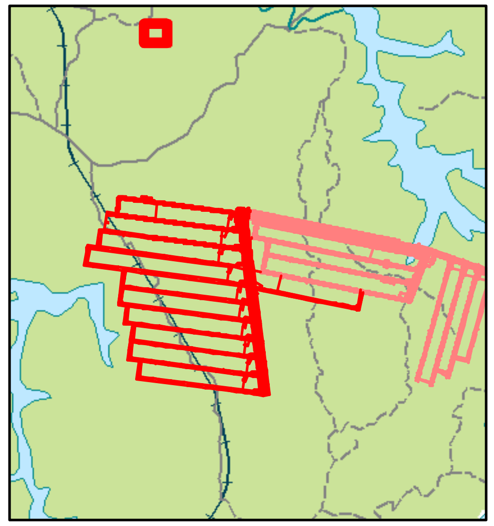
Coordinate System: GDA 1994 MGA Zone 56

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-78: DC8 Transect

0 10 20 30 40 50

Metres

Scale: 1:1,370 @ A3

Coordinate System: GDA 1994 MGA Zone 56

biosis

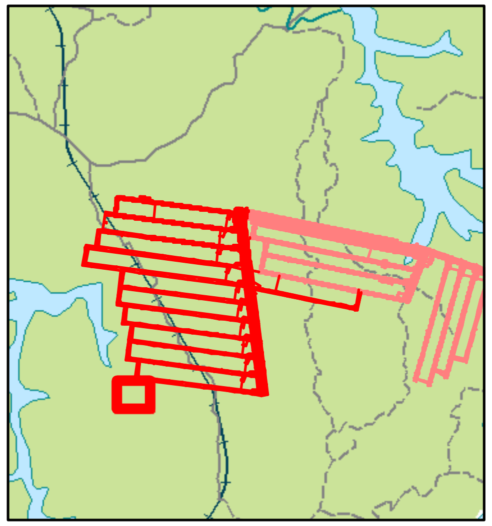
Biosis Pty Ltd

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

N

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



Legend

Threatened Frog Monitoring

- Control - Transect Start
- Control - Transect End
- Threatened Frog Transect

BHP Creek and Swamp Naming

- BHP Creekline

Figure 3-79: NDC Transect

0 20 40 60 80 100

Metres

Scale: 1:1,970 @ A3

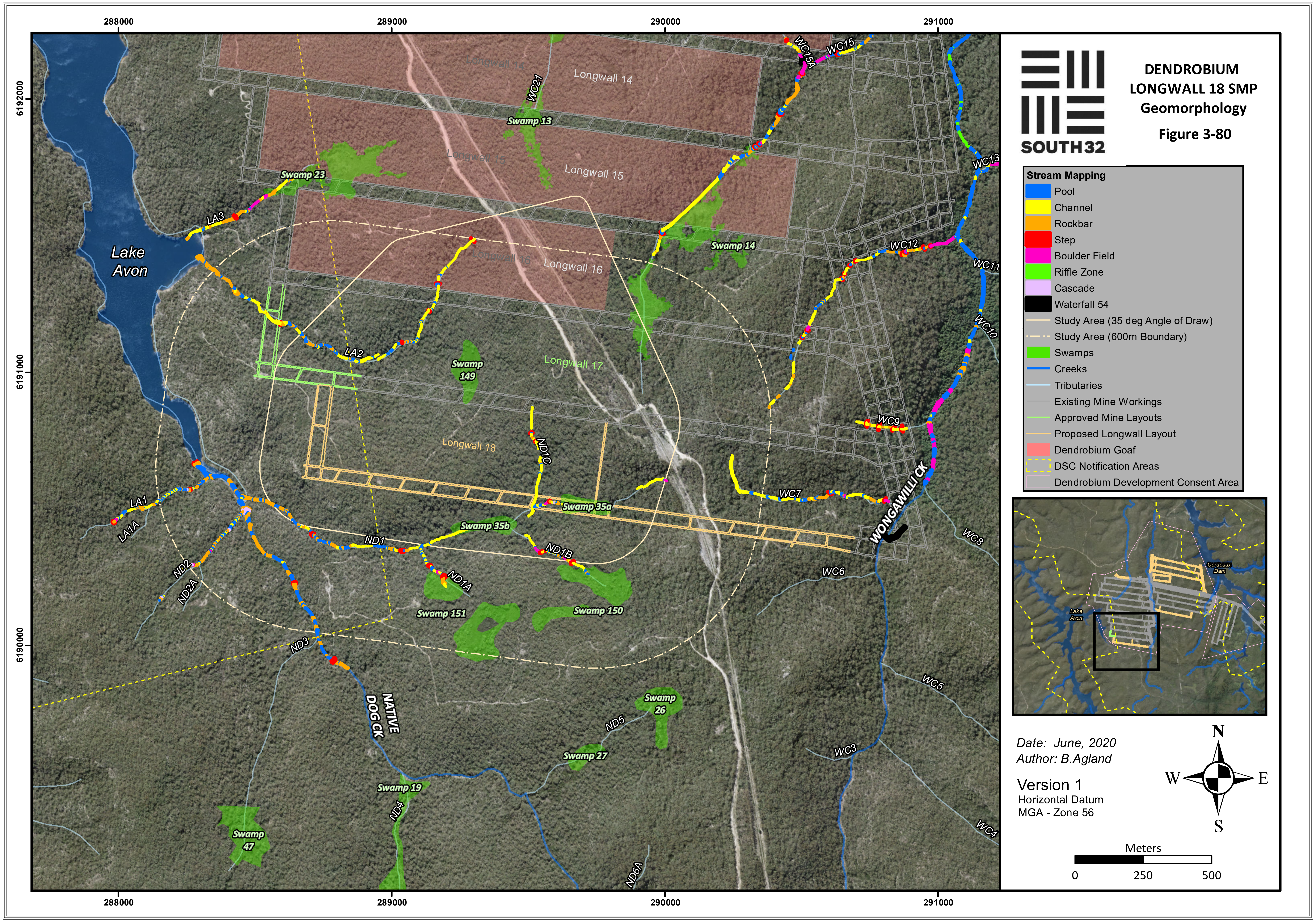
Coordinate System: GDA 1994 MGA Zone 56

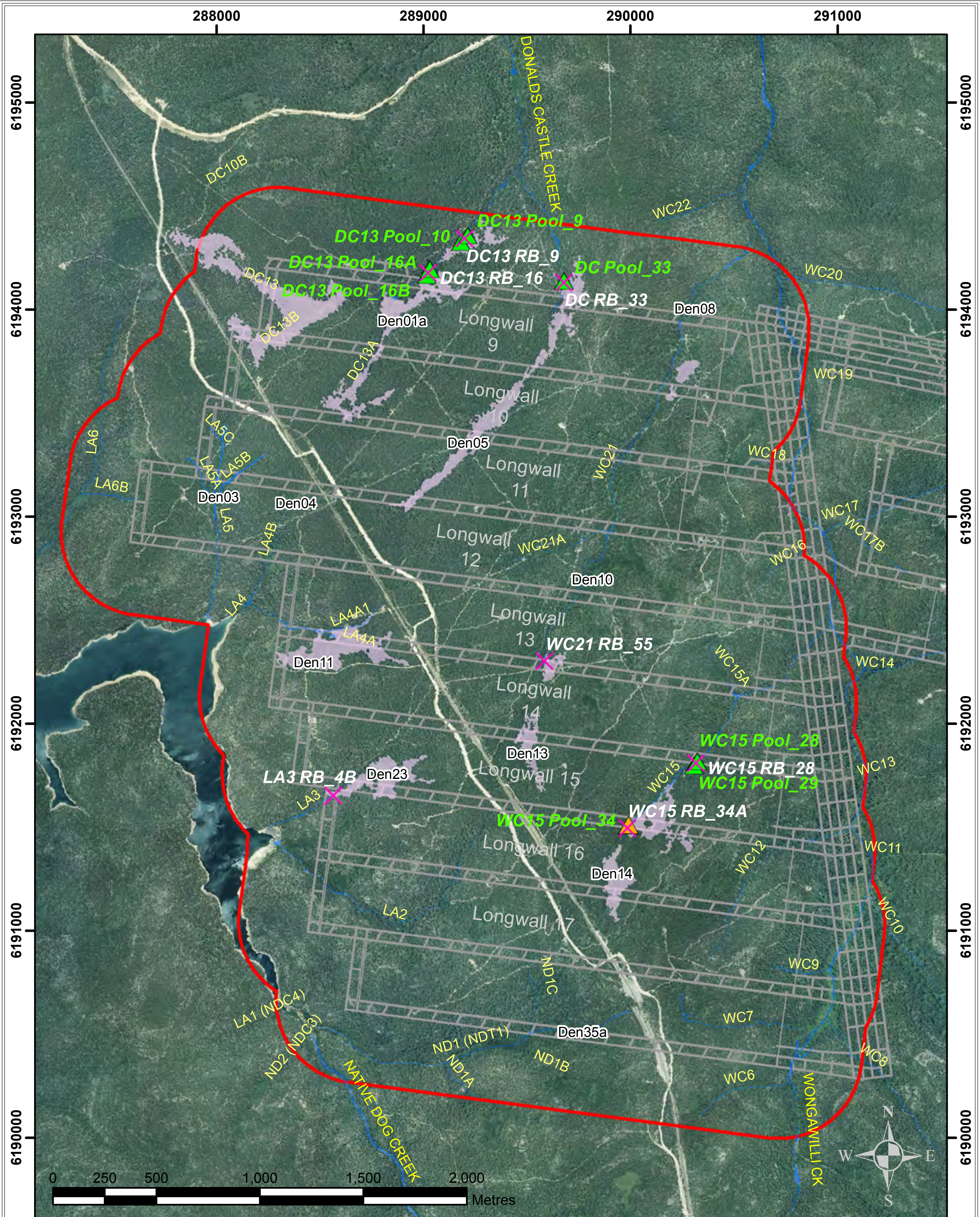
biosis

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


DENDROBIUM
LONGWALL 18 SMP
Geomorphology
Figure 3-80
SOUTH32
Stream Mapping
Pool
Channel
Rockbar
Step
Boulder Field
Riffle Zone
Cascade
Waterfall 54
Study Area (35 deg Angle of Draw)
Study Area (600m Boundary)
Swamps
Creeks
Tributaries
Existing Mine Workings
Approved Mine Layouts
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Dendrobium Development Consent Area
Lake Avon
Cordeaux Dam
Date: June, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
Meters
0
250
500
288000
289000
290000
291000
6192000
6191000
6190000
Lake Avon
Longwall 14
Longwall 15
Longwall 16
Longwall 17
Longwall 18
Swamp 13
Swamp 23
Swamp 14
Swamp 149
Swamp 35a
Swamp 35b
Swamp 151
Swamp 150
Swamp 26
Swamp 27
Swamp 19
Swamp 47
LA1
LA1A
LA2
LA3
ND1
ND1A
ND1B
ND1C
ND2
ND2A
ND3
ND4
ND5
ND6A
NATIVE DOG CK
WONGAWILLI CK
WC3
WC4
WC5
WC6
WC7
WC8
WC9
WC10
WC11
WC12
WC13
WC15
WC15A
WC21



SOUTH32
Illawarra Coal

Legend

- Significant Permanent Pool in Swamps
- Pools in/adjacent to Swamps >6m long and >4m wide (max)
- Basal Rockbars
- Swamp Mapping
- 400m from Area 3B longwall extraction

Dendrobium Area 3B

Figure 3.81

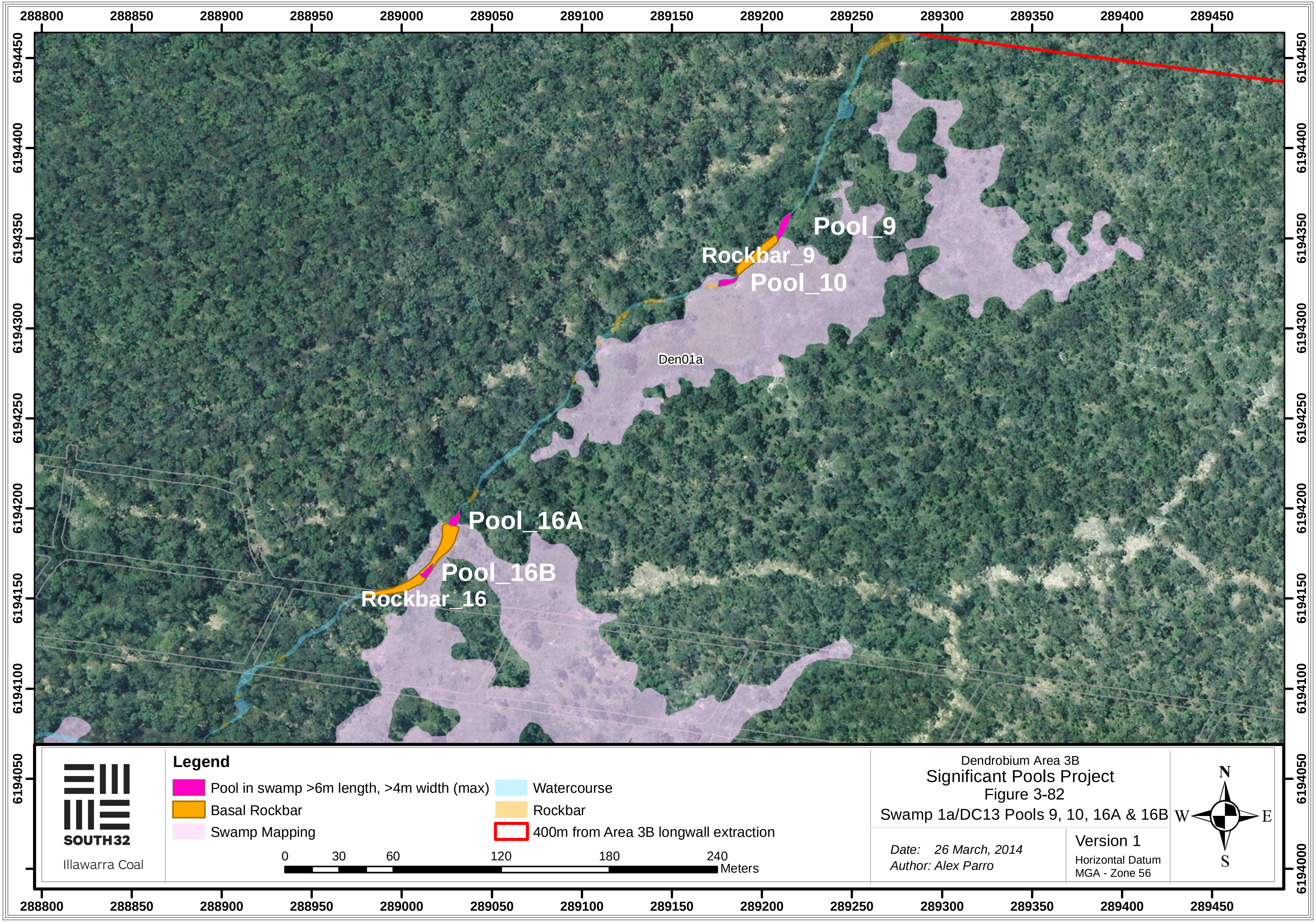
Pools in Swamps >6m long & >4m wide and Basal Rockbars

Date: *26 March, 2014*

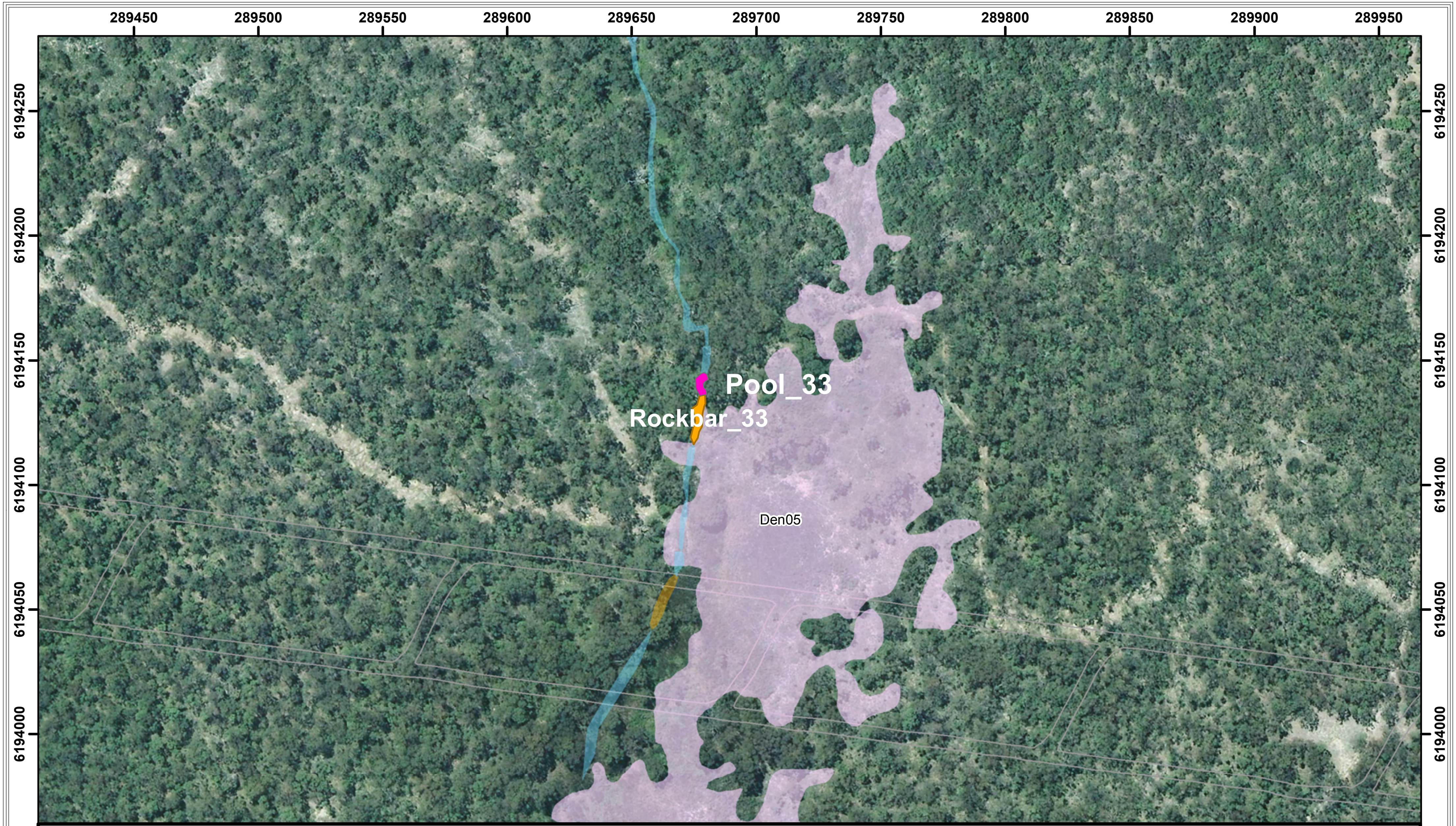
Author: Alex Parro

Version 1

Horizontal Datum MGA - Zone 56



288800
288850
288900
288950
289000
289050
289100
289150
289200
289250
289300
289350
289400
289450
6194450
6194400
6194350
6194300
6194250
6194200
6194150
6194100
6194050
6194000
Pool_9
Rockbar_9
Pool_10
Den01a
Pool_16A
Pool_16B
Rockbar_16
Legend
Pool in swamp >6m length, >4m width (max)
Basal Rockbar
Swamp Mapping
Watercourse
Rockbar
400m from Area 3B longwall extraction
0
30
60
120
180
240
Meters
SOUTH32
Illawarra Coal
Dendrobium Area 3B
Significant Pools Project
Figure 3-82
Swamp 1a/DC13 Pools 9, 10, 16A & 16B
Date: 26 March, 2014
Author: Alex Parro
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S



Legend

- Pool in swamp >6m length, >4m width (max)
- Basal Rockbar
- Swamp Mapping
- Watercourse
- Rockbar
- Mine Workings

0 25 50 100 150 200 Meters

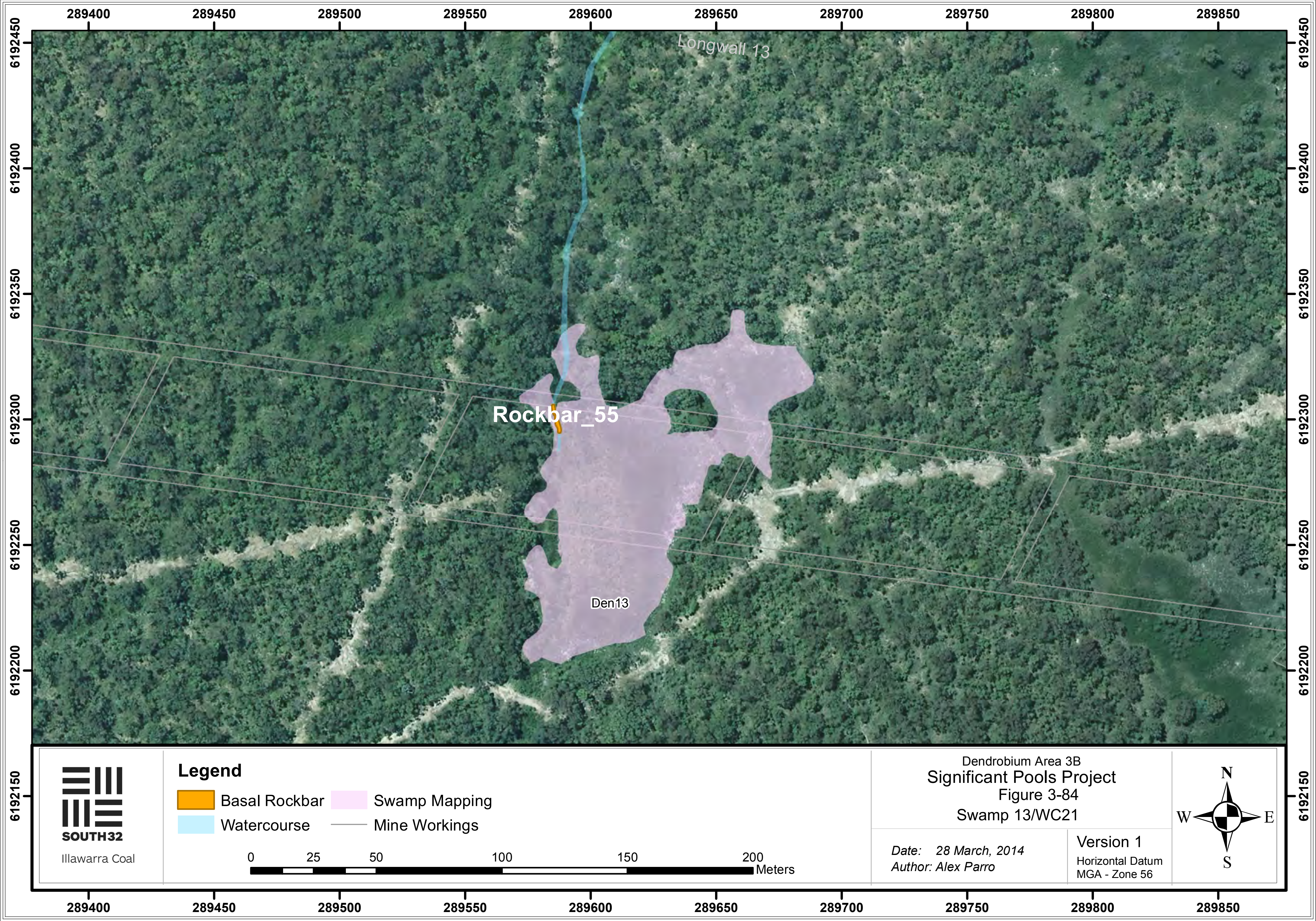
SOUTH32
Illawarra Coal

Dendrobium Area 3B
Significant Pools Project
Figure 3-83
Swamp 5/Donald's Castle Creek Pool 33

Date: 26 March, 2014
Author: Alex Parro

Version 1
Horizontal Datum
MGA - Zone 56

N W E S



Legend

Basal Rockbar
Swamp Mapping
Watercourse
Mine Workings

0 25 50 100 150 200 Meters

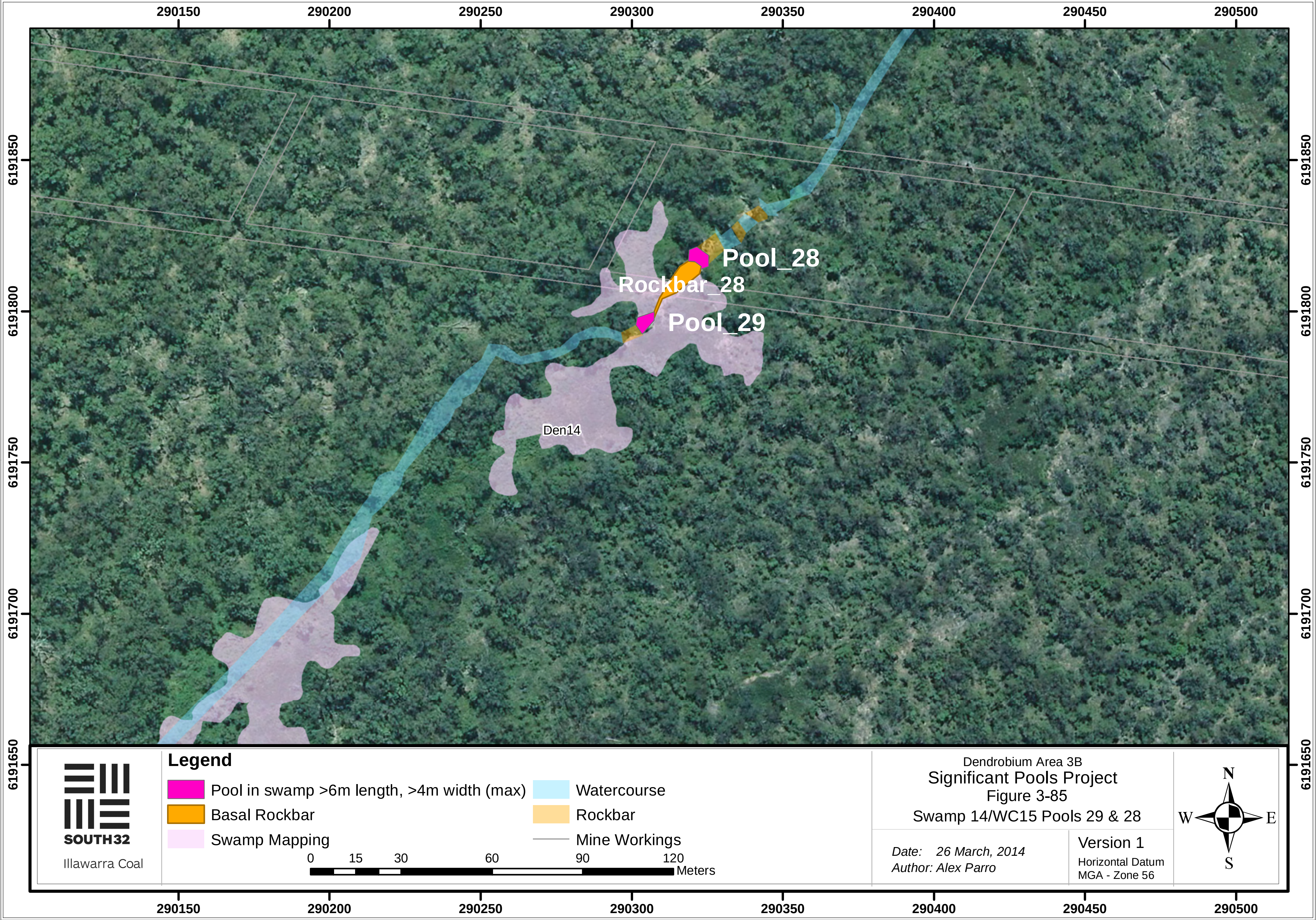
SOUTH32
Illawarra Coal

Dendrobium Area 3B
Significant Pools Project
Figure 3-84
Swamp 13/WC21

Date: 28 March, 2014
Author: Alex Parro

Version 1
Horizontal Datum
MGA - Zone 56

N W E S



Legend

- Pool in swamp >6m length, >4m width (max)
- Basal Rockbar
- Swamp Mapping
- Watercourse
- Rockbar
- Mine Workings

0 15 30 60 90 120 Meters

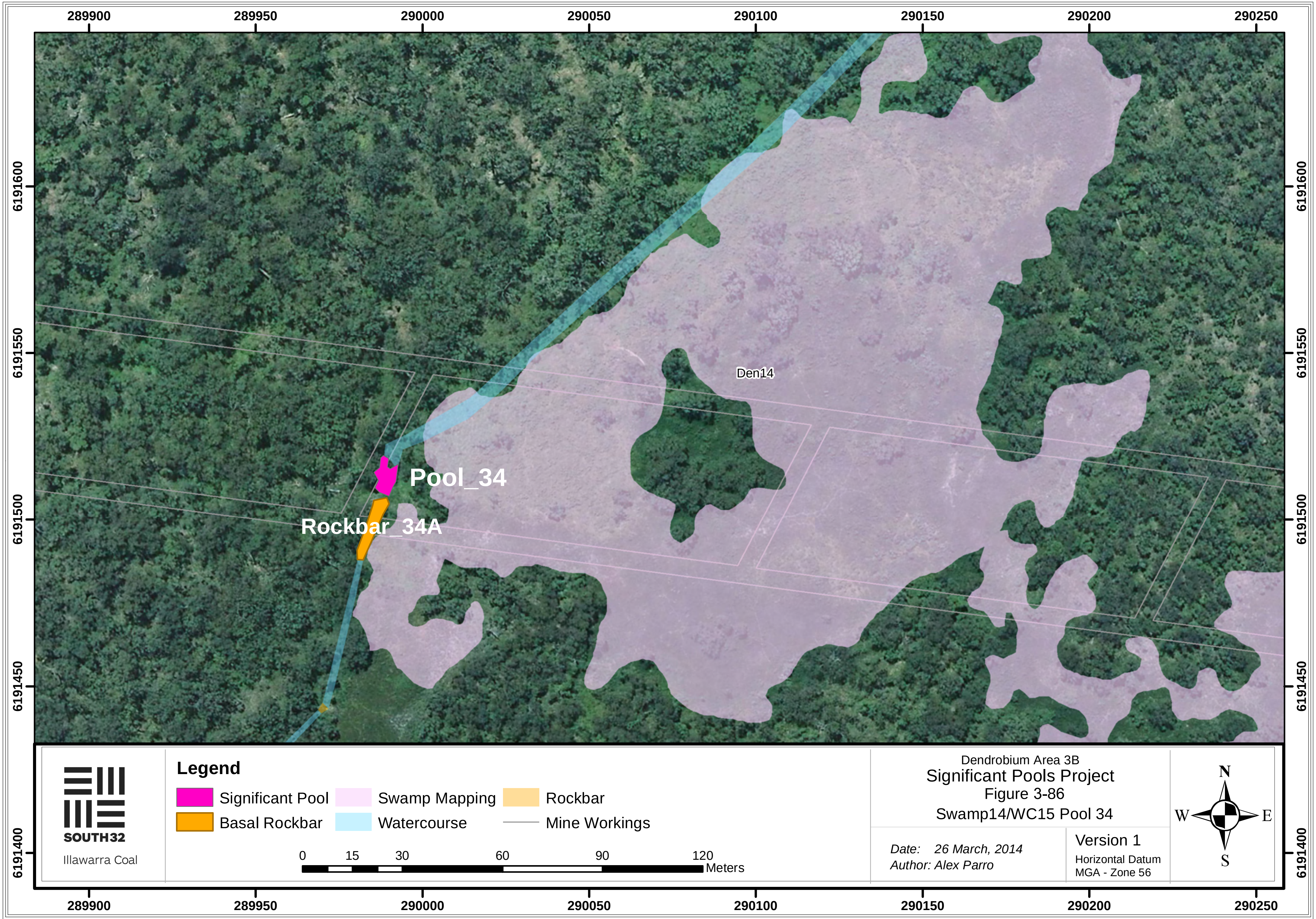
SOUTH32
Illawarra Coal

Dendrobium Area 3B
Significant Pools Project
Figure 3-85
Swamp 14/WC15 Pools 29 & 28

Date: 26 March, 2014
Author: Alex Parro

Version 1
Horizontal Datum
MGA - Zone 56

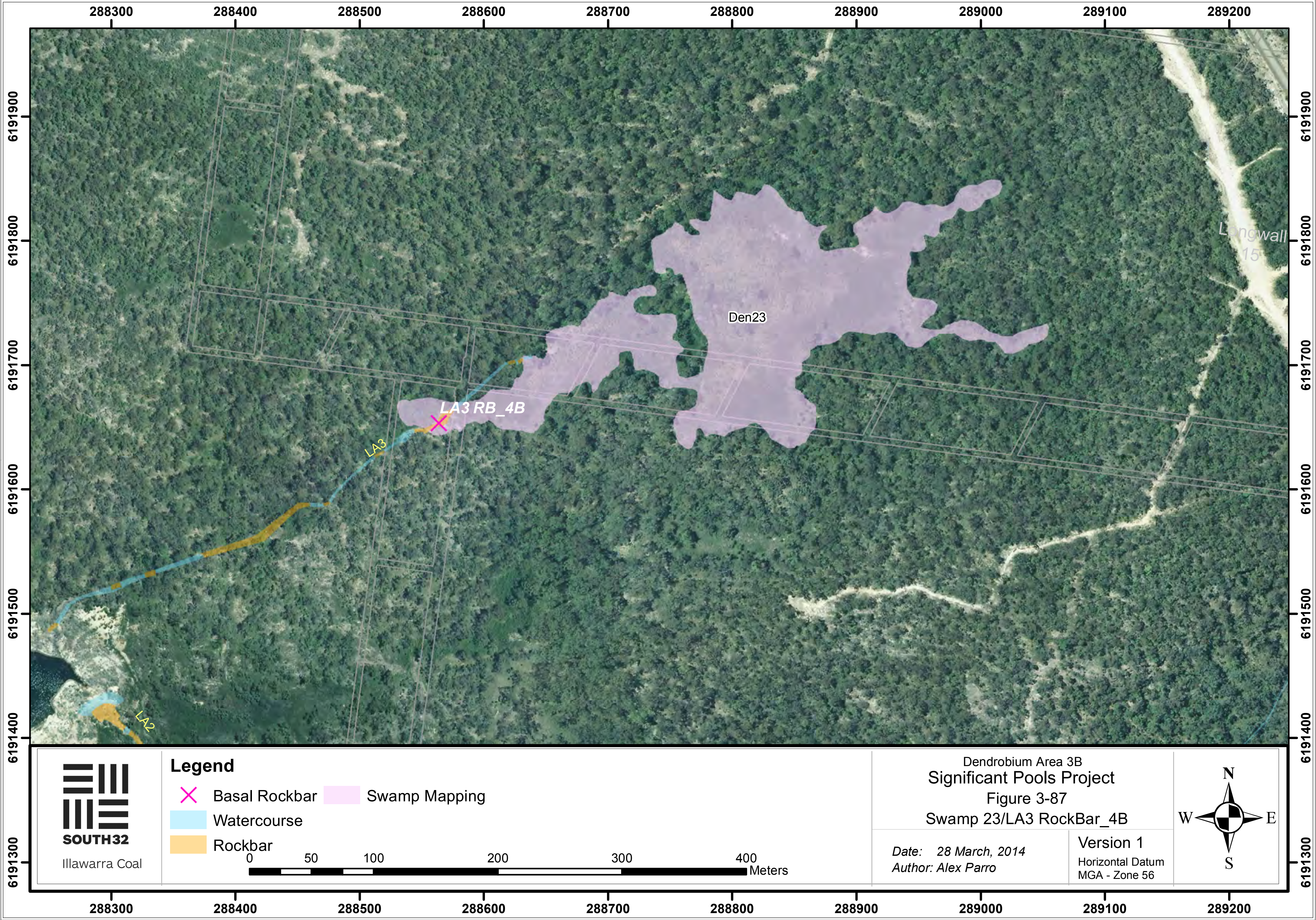
N
W E
S



Dendrobium Area 3B
Significant Pools Project
Figure 3-86
Swamp14/WC15 Pool 34

Date: 26 March, 2014
Author: Alex Parro

Version 1
Horizontal Datum
MGA - Zone 56



SOUTH32

Illawarra Coal

Legend

Basal Rockbar

Swamp Mapping

Watercourse

Rockbar

0 50 100 200 300 400 Meters

Dendrobium Area 3B

Significant Pools Project

Figure 3-87

Swamp 23/LA3 RockBar_4B

Date: 28 March, 2014

Author: Alex Parro

Version 1

Horizontal Datum MGA - Zone 56

N S W E


Swamp 1A Pool 9 (10m x 4m)


Swamp 1A Pool 10 (12m x 4m)


Swamp 1A Pool 16A (7.5m x 5m)


Swamp 1A Pool 16B (10m x 6m)


Swamp 1A Rockbar 9


Swamp 1A Rockbar 16

Swamp 5 Pool 33 (10m x 5m)

Swamp 5 Rockbar 33

Swamp 13 Rockbar 55

Swamp 14 Pool 28 (8m x 7m)

Swamp 14 Rockbar 28

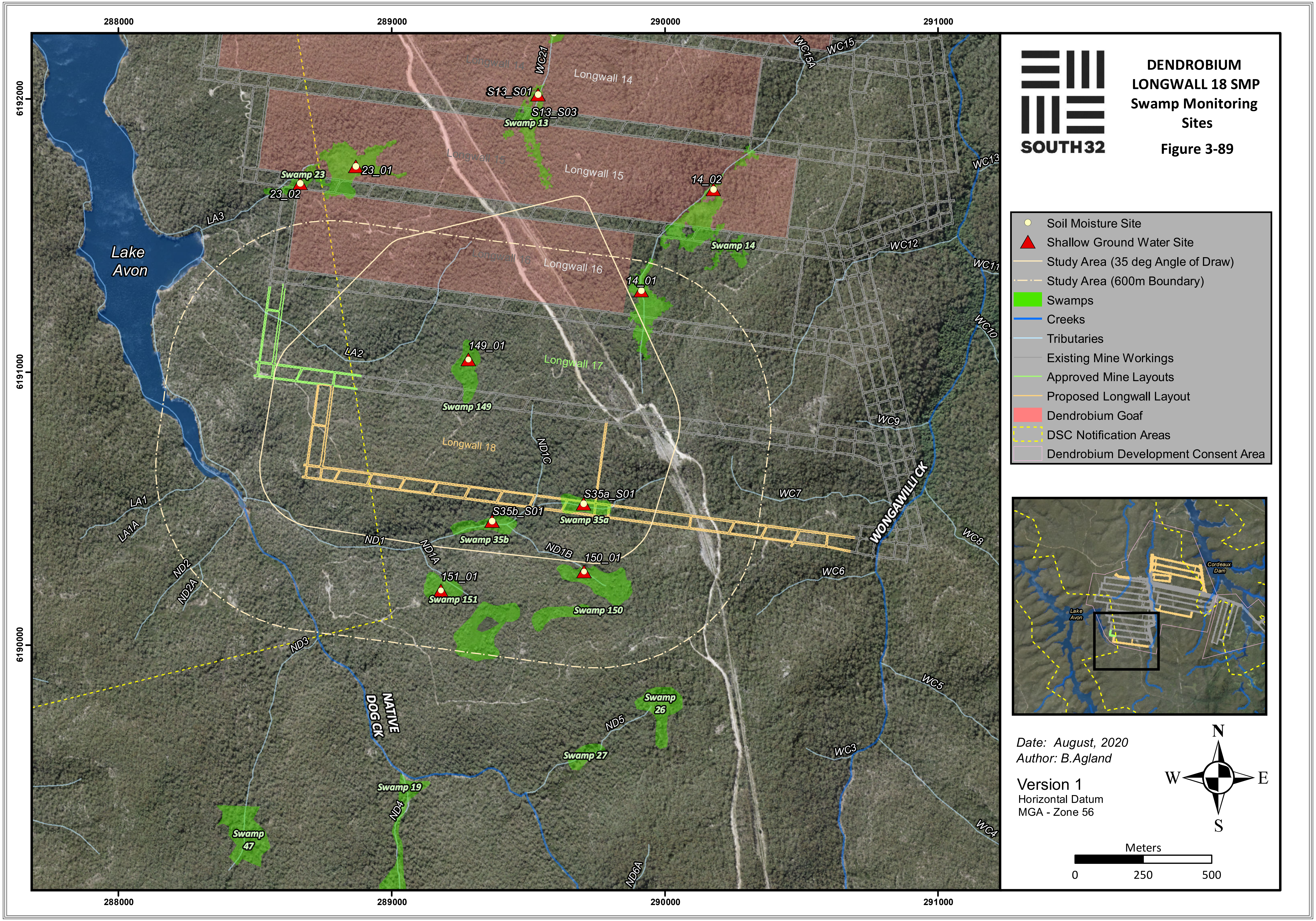
Swamp 14 Pool 29 (6m x 6m)

Swamp 14 Pool 34 (12m x 9m)

Swamp 14 Rockbar 34A

Swamp 23 Rockbar 4B

Figure 3-88 Photos of Swamp Pools and Basal Rockbars



DENDROBIUM LONGWALL 18 SMP Swamp Monitoring Sites

Figure 3-89

4 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium Development Consent and the Area 3B SMP Approval (2019). These performance measures will be applied to the Dendrobium Area 3B mining area and specifically include Swamps 1a, 1b, 3, 4, 5, 8, 10, 11, 13, 14, 23, 35a and 35b. These performance measures are presented in **Table 4-1**.

Table 4-1 Subsidence Impact Performance Measures

Swamps 1a, 1b, 5, 8, 11, 14 and 23
Minor environmental consequences including: • negligible erosion of the surface of the swamps; • minor changes in the size of the swamps; • minor changes in the ecosystem functionality of the swamp; • no significant change to the composition or distribution of species within the swamp; and • maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.
Swamps 3, 4, 10, 13, 35a 35b, 149, 150 and 151
• No significant environmental consequences beyond predictions in the Subsidence Management Plan.

A detailed list of performance measures and triggers is included in the TARPs in **Appendix A**.

4.1 Impact Mechanisms

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 can result in changes to the hydrology of watercourses.

Changes to watercourse hydrology and water quality can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The potential consequences of mining on groundwater and surface water in the Special Areas are (IEP 2019a):

- Groundwater depressurisation
  - The creation of an excavation below the water table can affect groundwater in a number of basic ways. In all cases, because the fluid pressure in an excavation is much lower than that of the fluid that originally occupied the space, a flow system is established with the excavation acting as a sink into which surrounding groundwater flows. The rate of flow and observed extent of depressurisation depend on the hydrogeological properties of the rock mass. If the excavated area is sufficiently large, the spatial extent and rate of flow into the sink can be enhanced by the formation of fractures.
- Surface water diversions
  - Diversions into a shallow, localised fracture network, where loss of flow from a surface water is likely to return to the system at some point downstream, which based on observations of the SCI (2008) may vary from 20 m for specific rockbars to more than 200 m.
- Surface water permanent losses
  - Diversions into deeper, dilated shear surfaces on bedding planes, where these form a conduit for lateral water flow, which may or may not report to the same catchment (i.e. it may become a permanent loss).
- Groundwater depressurisation

- Groundwater within the Hawkesbury Sandstone and Narrabeen Group as well as the Permian coal measures is recharged from rainfall and water bodies where the lithologies occur at outcrop, as well as potential downward leakage from overlying strata (Hydrosimulations 2018).

- Water quality
  - Water quality within watercourses is affected by numerous factors including runoff from swamps and interactions between bedrock and water, with fracturing of bedrock due to mining causing local water quality impacts.

The environmental consequences which could relate to changes in hydrology and water quality include:

- Species composition change and/or changes in vegetation communities.
- Loss of aquatic ecology and/or changes in aquatic habitat resulting from a reduction of surface water quality and/or flows and standing pools.
- Water-borne inputs to Lake Avon, Lake Cordeaux and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates.

Reduced inflows into Lake Avon and Cordeaux River.

An overview of the potential impacts and consequences of mining on swamps, surface flows and storages is presented in **Table 4-2**.

Table 4-2 Summary of subsidence effects, impacts and consequences for surface flows, storages and swamp hydrology (IEP 2019b)

Subsidence effects	Impacts	Consequences
• Tensile cracking, tensile, compressive or shear movement of joint and bedding plane • Fracturing of sandstone blocks • Buckling and localised upsidence in the stream bed below the swamp • Tilting of bedrock	• Cracking of rock bars • Lowered water tables and soil moisture • Potential erosion and scouring • Altered water chemistry e.g. enhanced release of iron • Change to the size of swamps	• Loss of surface flow and storage through leakage • Loss of baseflow generation including from swamps • Vulnerability of swamps to fire and further erosion and reduction in baseflow generation capacity • Increased loads of contaminants to water storages

Changes to swamp hydrology can result in environmental consequences, particularly drying of swamps. The likelihood and timing of these consequences relate to the size and duration of the effect. The possible impacts of the drying of swamps due to mining-induced changes in hydrology include (IEP 2019b):

- reduction of soil moisture levels and loss of cohesiveness of the swamp sediments.
- enhanced risk of channelization and consequent susceptibility to erosion of swamp sediments, with potential water quality implications.
- decline of groundwater-dependent plant species and consequent changes in vegetation structure.
- decline of groundwater-dependent fauna including macroinvertebrates and stygofauna.
- oxidation of peaty sediments resulting in increased hydrophobicity, lower water-holding capacity and potential changes in nutrient status and cycling.
- increased risk of erosion, which may lead to gully formation.
- swamps have less resilience to bushfires which, in turn, can lead to an increased susceptibility to erosion and loss of baseflow (NSW Threatened Species Scientific Committee, 2012).

4.2 Potential for Connectivity to the Mine Workings

The fracture zone comprises in-situ material lying immediately above the caved zone which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation (Singh and Kendorski, 1981; Forster, 1995). Where the panel width-to-depth ratio is high and the depth of cover is shallow, the fracture zone would extend from the seam to the surface. Where the panel width-to-depth ratio is low, and where the depth of cover is high, the fracture zone would not extend from the seam to the surface.

The possible height of the fracture zone is dependent upon the angle of break, the width of the panel, the thickness of seam extracted and the spanning capacity of a competent stratum at the top of the fracture zone (MSEC 2012). Based on mining geometry, the height of the fracture zone equals the panel width, minus the span, divided by twice the tangent of the angle of break.

It should be noted that the height of the fracture zone should be viewed in the context of fracturing and should not necessarily be directly associated with an increase in vertical permeability. There are numerous models for the height of fracturing and height of desaturation. A review of these matters was conducted for the Bulli Seam Operations Project Response to PAC deliberations (Hebblewhite 2010).

The Regional Groundwater Models at Dendrobium uses site specific data to determine the height of desaturation. Dendrobium monitors in excess of 1,000 piezometers in ~100 boreholes (including a comprehensive array of piezometers above the centreline of longwall goafs) and has analysed many thousands of samples for field parameters, laboratory analysis, algae and isotopes.

The results of water analysis and the interpretation of the height of connective fracturing was peer reviewed by Parson Brinckerhoff (2012). The peer review states that "the use of standard hydrogeochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux". Although the report acknowledged limitations of the available data, this review is based on one of the most comprehensive datasets available in the Southern Coalfield. On the basis of the available data and the Parson Brinckerhoff (2012) review it is considered that the height of desaturation used by Heritage Computing (2009 & 2011) is conservative.

In January 2015, SRK Consulting conducted a detailed independent review of the Dendrobium water chemistry data to:

- Assess the level of detail, quality of science, depth and technical appropriateness of the water chemistry data.
- Evaluate associated interpretations in relation to underground operations of Dendrobium Mine, with specific focus on how these address the question of hydraulic connectivity between the mined areas and the reservoirs.

Based on the review SRK concluded that the observed geochemical trends are not consistent with a high degree of hydraulic connectivity between the underground workings and the surface water bodies.

As reported in Coffey (2012) most of the change in aquifer properties occurs within the collapsed zone. Changes in aquifer properties above the collapsed zone are less severe and largely restricted to increases in storativity. Groundwater drawdown due to sudden storativity increases will ultimately impact the surface, either directly (as seepage from watercourses or lakes to satisfy the drawdown), or by intercepting baseflow.

Predictions of fracture zone dimensions for Dendrobium (MSEC 2012 and Coffey 2012) refer to geotechnical fracturing behaviour, and are not necessarily directly related to a groundwater response resulting from increased vertical permeability.

Parson Brinckerhoff and IMC have completed testing to characterise the pre- and post-mining permeability above Longwall 9, the first longwall in a new domain, not affected by previous mining. After Longwall 9 mined under the site it was tested to quantify the change to vertical and horizontal permeability of the strata, including the Bulgo and Hawkesbury Sandstones and the Bald Hill Claystone. The testing involved core, packer and borehole interference testing, groundwater flow and tracer testing.

Mining of Longwall 9 resulted in a significant increase in subsurface fracturing compared with pre-mining. Down-hole camera surveys identified a number of open horizontal and inclined fractures with apertures of several centimetres. Groundwater ingress was noted at several open fractures.

Most post-mining test bores showed decreases in groundwater level and strong downward hydraulic gradients, particularly in the lower Bulgo Sandstone. Significantly however, groundwater levels in the shallow Hawkesbury Sandstone remained perched at the study site.

Horizontal hydraulic conductivity increased between one to three orders of magnitude due to mine subsidence and strata fracturing. Increases in hydraulic conductivity are observed in every geological unit, but are greatest below the base of the Hawkesbury Sandstone.

In contrast to pre-mining testing in which no breakthrough was observed, horizontal tracer testing after the passage of Longwall 9 resulted in breakthrough in about 40 minutes. This indicates a bulk hydraulic conductivity in the order of 10m/day; at least two orders of magnitude higher than pre-mining conditions.

No breakthrough in tracer was observed in either the pre-mining or the post-mining tests of the Bald Hill Claystone and this indicates that the vertical conductance at the research site was below the detection limit of the test, estimated to be approximately 0.7 m/day.

Activated carbon samplers deployed in streams adjacent to the research site detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths either existing or induced between the research site and adjacent streams.

Sampling of water from the underground mine detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths induced between the research site and the workings.

Although current observations do not allow a precise definition of the height of intense fracturing using any criteria (and the boundaries are gradational in any case), most evidence suggests that the zone of most intense and vertically connected fracturing within Area 3B extends into the Bulgo Sandstone.

Estimates for the height of fracturing at Dendrobium based on published methods range from 122 m to 357 m. This range in estimates is large and presents a challenge to those wishing to model hydrogeological impacts of mining on a regional scale based on mine site data.

The pre- and post-mining investigations carried out in this research study provide important constraints on the extent of mining related disturbance and its effect on groundwater systems.

In August 2015 HydroSimulations' completed an assessment of the estimated height of connected fracturing at Dendrobium. The assessment included:

- The effects of longwall mining and subsidence on overburden strata;
- A summary of previous research in relation to estimating the extent of the deformed strata above longwall mining, both in general and at Dendrobium; and
- Revised estimates of the height of connected fracturing for Dendrobium longwalls using the Ditton 'Geology Model' (Ditton and Merrick, 2014) and the Tammetta (2013) method.

The assessment concluded that the Ditton 'Geology model', as outlined in Ditton and Merrick (2014), is the most appropriate method for estimating the vertical extent of connected fracturing above longwalls at Dendrobium. This is supported by the research above Longwall 9 by Parsons Brinkerhoff (2015) and earlier studies by GHD (2007) and Heritage Computing (2011).

A review of methods for estimating the height of fracturing above longwall panels at Dendrobium Mine was commissioned by DPE, and carried out by geotechnical consultants Pells Sullivan Meynink (PSM). The PSM report was finalised in June 2017 and made available to South32 on 7 September 2017.

Recommendations by PSM regarding additional monitoring and research to add to our understanding of the catchment are generally sensible and many of these have already been acted on.

The PSM report appears to be limited by the fact that they may not have had access to all data or may simply have lacked time to check all available data and literature. Importantly, the analysis of mine water chemistry (water fingerprinting) is not given due regard. Scientific method should always consider multiple lines of evidence where these are available.

HydroSimulations believe there is a flaw in PSM's hydrogeological conceptual model, which leads to some errors in their conclusions about the extent of connective fracturing. PSM seems to have assumed vertical connected fracturing on the strength of pressure reductions at piezometers, when pressure reductions could occur due to several factors, including increased horizontal permeability, increased porosity or increasing downward hydraulic gradient due to depressurisation in the goaf.

The IEP (2019b) Part 2 Report further considered mining operations within the special areas and reiterated its earlier position stated in IEP (2019a):

The Panel has given detailed consideration to the equations in the Part 1 Report and concluded that it cannot endorse either at this point in time. For a range of reasons, neither or either may ultimately prove to be sufficiently reliable. It recommended erring on the side of caution and deferring to the Tammetta equation until:

i. field investigations quantify the height of complete drainage at Metropolitan and Dendrobium mines; and/or

ii. geomechanical modelling of rock fracturing and fluid flow are shown to be sufficiently reliable for informing the calibration of groundwater models at mine sites in the catchment.

The Regional Groundwater Model for Dendrobium Mine has been revised to consider the findings of the PSM report and IEP Reports (2019a), including the use of the Tammetta model and modelling connectivity to the surface. HydroSimulations state that regardless of the method used to assess fracturing, they believe the current groundwater modelling approach is sound.

In accordance with Schedule 3, Condition 19(c) of the Area 3B SMP Approval, height of connective fracturing investigations across longwalls in Area 3B are undertaken and reported to the Department prior to each longwall extraction. The most recent report, Hebblewhite (2020) states:

… comments and conclusions are drawn in relation to the overall concept of height of depressurisation, and the status of predictive models:

- *… 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.*
- *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.*
- *In spite of the reduced longwall panel width in Area 3A (LW6 and LW7), the height of depressurisation has still effectively extended to the surface, albeit with a reduced strata fracture density above the mined panels. It is likely that a more significant panel width reduction and or mining height reduction would be necessary to cause a significant reduction in height of depressurisation in this particular mining region.*
- *The lack of significant differential in height of depressurisation with the reduced panel widths means that the range of the dataset available to assist with developing an improved prediction model remains inconsistent, and insufficient to enable any further model development based on empirical methods.*
- *There is strong evidence at all locations of significant depressurisation occurring ahead of under-mining, due to the effect of adjacent mining panels, and earlier mining development. These effects are evident at most of the strata horizons, extending towards the surface.*
- *… the Tammetta model is clearly the most appropriate one to continue using in the future. It provides a reasonably accurate prediction – given the variability of factors such as depth across any particular panel.*

4.3 Potential for Fracturing Beneath the Swamps

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2012, 2015, 2018 and 2020) the bedrock below the swamps and any significant permanent pools within the swamps are likely to fracture as a consequence of subsidence induced strains.

Surface flows captured by the surface subsidence fracture network resulting from valley related movements which do not connect to a deeper aquifer or the mine workings will re-emerge further downstream (see **Section 4.2**). This prediction is based on an assessment of the depth of valley closure induced vertical fracturing from the surface and measurements of water balance during the modelled periods of recessional, baseflow and small storm unit hydrograph periods downstream of mining areas.

The depth of fracturing in the “surface zone” is addressed in the Bulli Seam Operations Environmental Assessment: Section 5.2.1, Appendix A, Appendix B and Appendix C as well as in the Response to Submissions and Response to the NSW Planning Assessment Commission.

The BSO Independent Peer Review of strata deformation provided by Professor Bruce Hebblewhite concurs with the concept of the “surface zone” fracture network related to down-slope or valley movements. Several studies have determined the depth of these vertical fracture networks are restricted to approximately 15 m to 20 m below the surface.

The depth and other attributes of the surface fracture zone have been comprehensively determined using the following instruments and techniques:

- Calliper logging;
- Straddle packer permeability testing;
- Overcore stress measurements;
- Core logging and geotechnical testing;
- Geophysical testing;
- Water level monitoring;
- Borehole cameras;
- Subsidence, extensometer monitoring and shear deformation monitoring;
- Stress change and fracture logging;
- Permeability testing and falling head tests; and
- Mapping of pressured air drilling fines.

The following sites have been comprehensively investigated to demonstrate the dimensions of the “surface fracture zone”:

- Two rockbars on the Waratah Rivulet; and
- Four rockbars on Georges River.

Monitoring from Dendrobium Mine indicates the surface fracture network over the goaf connects to or is concurrent with the fracture network which propagates from the seam to the surface (IEP 2019a). In this instance the diversion of surface flow to deep strata or the mine relates to vertical permeability increases associated with this fracturing.

Prior to any remediation works within Area 3B that target surface/shallow fracture networks, the depth of the fracturing will be characterised by standard techniques such as drilling, down hole cameras and calliper measurements. The hydraulic conductance of these fracture networks will also be determined prior to implementing any rehabilitation.

The effects of mining on surface water flow following the completion of Longwall 15 was modelled and assessed in the Longwall 15 EoP Report using the revised surface flow TARPs. The assessments indicate that sub-catchments in the upper part of the Donalds Castle Creek catchment (i.e. DC13S1 and DCS2) have been and continue to be affected by mining, as is the tributary LA4 of Lake Avon (at LA4S1) and probably in the neighbouring tributary LA3 (although analysis is hampered by a very short baseline flow record) (HGEO 2020). The findings for DC13, DCS2 (both at Level 3 for all three flow assessments), and LA4 (effects identified by all three assessments) are similar to those for the EoP report for Longwall 14, as presented in Watershed Hydrogeo (2019). LA3 has been affected by mining for the first time by Longwall 15.

Similarly, the flow characteristics at WC21S1 and WC15S1 within the Wongawilli Creek catchment have altered as a result of mining, with these sites triggering Levels 2 and 3 for the three assessments. As with the sub-catchments above, the effects at WC21 and WC15 are similar to those for the previous longwall. WC12 is as yet unaffected by mining (HGEO 2020).

Changes to stream flow characteristics are not evident at the downstream gauge on Wongawilli Creek Lower (WWL), despite mining-related effects being clear and significant at upstream tributaries (e.g. WC21, WC15). This suggests that some or all flow lost in headwater catchments is returned downgradient, or that upstream diversions or losses are not significant in relation to the larger catchment water balance given the natural variability and the accuracy of flow measurements. Analysis of available surface water flow observation records for Wongawilli Creek triggered a Level 2 TARP in February 2020. Assessment D was carried out, and indicated that flow reductions due to mining were in the order of 0.008 to 0.015 ML/d.

The assessment concluded that the Performance Measures for Donalds Castle Creek, Wongawilli Creek, Lake Avon and Cordeaux River were all met (HGEO 2020).

4.4 Potential for Erosion Within the Swamps

Tilting, cracking, desiccation and/or changes in vegetation health could result in concentration of runoff and erosion which intern could alter water distribution in the swamp. Changes to swamp hydrology can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The possible impacts of the drying of swamps due to mining-induced changes in hydrology include (IEP 2019b):

- reduction of soil moisture levels and loss of cohesiveness of the swamp sediments
- enhanced risk of channelization and consequent susceptibility to erosion of swamp sediments, with potential water quality implications
- decline of groundwater-dependent plant species and consequent changes in vegetation structure
- decline of groundwater-dependent fauna including macroinvertebrates and stygofauna
- oxidation of peaty sediments resulting in increased hydrophobicity, lower water-holding capacity and potential changes in nutrient status and cycling
- increased risk of erosion, which may lead to gully formation.
- swamps have less resilience to bushfires which, in turn, can lead to an increased susceptibility to erosion and loss of baseflow (NSW Threatened Species Scientific Committee, 2012).

Subsidence predictions were carried out to assess the potential impacts of longwall mining in Area 3B. The assessment indicated that the levels of impact on the natural features were likely to be similar to the impacts observed within Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the swamps is provided in **Section 5**.

Tilting of sufficient magnitude could change the catchment area of a swamp or re-concentrate runoff leading to scour and erosion, potentially reducing the water flowing onto a swamp or allowing water to escape from the swamp margins. These effects could be observed within the whole swamp or alter water distribution in parts of the swamp, thus favouring some flora species associations over others.

Changes in gradients predicted to occur following mining are shown in **Section 5**. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2012, 2015, 2017 and 2018). The assessment takes into account the nature of the drainage channel and whether the predicted tilt is significant when compared to the existing slopes.

Landscape monitoring commenced in 2004 for Dendrobium Area 1. This monitoring program has been continued and updated throughout the mining period for Areas 2, 3A and 3B. The monitoring includes inspections of swamps at regular intervals prior to mining, during active subsidence and following the completion of subsidence movements. In addition to erosion (increased incision and/or widening), these observations target any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, slope and gradient changes, the condition of rock-bars and peat condition.

The observed impacts on natural features above Longwalls 1 – 15 have been generally consistent with those predicted in the assessments undertaken prior to mining.

In Area 3B, one surface impact (cracking) has been observed in swamps. To date there has been no instance of erosion resulting from this cracking. No erosion of the surface of the swamps as a result of mining observed to date. For Area 3B to completion of Longwall 14, 154 surface impacts have been identified. Many of these are very minor impacts and of very limited environmental consequence. For example, 91% of the cracking identified at the surface has a width of less than 100 mm. To date there has been no instance of erosion resulting from this cracking (Illawarra Coal 2018).

Swamp 18 is a swamp that some have reported to be impacted by mining. An important observation of Tomkins and Humphreys (2006) is that in 1951, Swamp 18 was more extensive and included a continuous, intact swampy unit infilling the valley of Native Dog Creek for several hundred meters downstream of the main body of the swamp to link with Swamp 19. Furthermore, the gully erosion of the lower extension of the swamp had commenced before 1951 and had reached the main body of Swamp 18 by 1990, well before underground coal mining in this area.

In 2003 approximately 450 m of gully erosion was identified in Swamps 1A and 1B and the associated stream before any mining influence in the area. These case studies demonstrate that erosion within swamps can be active without any influence of mining.

4.5 Potential for Vegetation Changes Within the Swamps

Where there are changes to swamp hydrology that are large and persistent there is likely to be a vegetation response. Swamp vegetation is likely to be relatively resilient to short term changes in groundwater level and soil moisture, demonstrated by the persistence of the swamp vegetation communities during extended periods of drought. For this reason, any response to changes in swamp hydrology are likely to be over the medium to longer time period. Vegetation change may be observed in the rates of species composition change and/or changes in vegetation communities over and above what is measured in nearby swamps due to natural variation.

Flora monitoring in swamps includes collection of data on species abundance within thirty 0.5 m x 0.5 m quadrats along a 15 m transect. Data is also collected from a number of control sites, to allow comparison both pre- and post-mining with control sites as a part of a BACI experimental design.

Nineteen years of post-mining monitoring is available for Dendrobium Area 2, 7 to 13 years in Dendrobium Area 3A and 8 years in Dendrobium Area 3B. Monitoring includes a minimum of two years baseline surveys for pre-impact sites within Area 2 and Area 3. Monitoring of control sites has been occurring for a minimum of three years for Dendrobium Area 3B and up to a maximum of 11 years for Area 2.

The program includes monitoring and analysis of seven upland swamp sites as post-mining sites:

- Dendrobium Area 3A
  - Swamp 15A(2);
  - Swamp 15B;
- Dendrobium Area 3B;
  - Swamp 1A;
  - Swamp 1B;
  - Swamp 5;
  - Swamp 11; and
  - Swamp 13.

The remaining swamps were monitored and analysed as controls or pre-mining sites (Swamp 14 and Swamp 23). Parameters analysed include Total Species Richness (TSR) and species composition as well as swamp size and the extent of groundwater dependent swamp sub-communities.

Data analysis continues to show that TSR across all sites, irrespective of mining status, is generally variable. However, a period of stability in TSR between 2010 and 2016 is discernible when considering pooled TSR data from control swamps. While this variation occurs, trends of stability are evident at all control sites paired with impact swamp located within Dendrobium Area 3A and 3B (Biosis 2019).

Yearly changes in species composition were detected in most swamp monitoring sites, regardless of area or treatment. This variation is likely a function of natural turnover of species in response to climatic variability, stochastic events and successional changes (particularly the time period post-fire). When accounting for yearly effects, a statistically significant change in species composition in post-mining data to pre-mining data was found at Swamp 15B and Swamp 15A(2) during 2018 surveys, consistent with the findings from 2017. As with TSR, these changes were observed immediately following undermining and have continued at Swamp 15B and Swamp 15A(2) for at least four years post-mining. No statistically significant declines in species composition were detected for Dendrobium Area 3B swamps.

Medium to longer term impacts to swamps may be influenced by changes in groundwater availability and soil moisture. Piezometric data for 2018 terrestrial ecology sampling indicates changes in shallow groundwater levels at Swamps 15A(2) and 15B following extraction of longwalls in Dendrobium Areas 3A and 3B. Therefore, it is possible that the observed statistically significant declines in TSR at these swamps is attributed to alterations in retention of shallow groundwater (Biosis 2019). At Swamp 15A(2), the decline in TSR post-mining was not statistically different to TSR pre-mining and at control swamps immediately after mining but by 2013 became statistically significant, with the level of significance continuing to increase.

This trend towards an increasingly significant difference between TSR compared with TSR before mining and at control swamps is suggestive of a lag-effect, whereby the impacts of mining have been gradual, accumulating over time. The analysis of data sets and observations of Swamp 15B present an identical change as observed at Swamp 15A(2), over the same time frame, in regards to TSR, floristic composition and reduction in shallow groundwater level (Biosis 2019).

The 2018 results of the TSR analysis demonstrate the response to mining at individual swamps is complex, with Swamp 15A(2) and Swamp 15B generally showing a decline in TSR following mining and changes in shallow groundwater, and Swamp 1A, Swamp 1B and Swamp 5 showing no statistically significant decline in TSR despite observed changes in shallow groundwater availability (Biosis 2019).

Analysis of LiDAR data in the 2018 terrestrial ecology monitoring period was used to assess the extent of upland swamps and their composite vegetation communities. It identified that the extent of all upland swamps included in this study (impact and control swamps) have decreased from the 2014 baseline substantially during 2018.

The results of the 2018 LiDAR data analysis has identified continued declines in the extent of vegetation communities that comprise upland swamps, recorded in 2017 (Biosis 2019). These are MU43 (Tee-tree Thicket) and MU44c (Sedgeland). Declines in the extent of MU44c, while triggering a Level 1 TARP, require further investigation to determine why this community is increasing in extent at some swamps and decreasing at others. MU44b (Sedgeland-Heath Complex) was also identified as being reduced in extent at a number of impact sites in 2018.

Caution is urged when interpreting the results of the swamp size and ecosystem functionality LiDAR monitoring given that a number of factors unrelated to mining-induced impacts may drive some of the observed decreases in swamp size and extent of groundwater dependent sub-communities. Changes in swamp size and extent of groundwater dependent communities observed at each swamp may be the result of responses to natural phenomena such as recent and long-term climate conditions, fire patterns and stochastic events (e.g. storm damage).

Monitoring is continuing to further define any vegetation changes likely to result from reduced groundwater levels.

The IEP Report (2019b) recognised that improvements in monitoring data supported by a substantial body of research has improved understanding of the impacts and consequences of longwall mining for swamps. The report also established that longwall mining directly under swamps in the Southern Coalfield can result in significant changes to swamp hydrology and redirection of surface runoff which currently appear to be irreversible. Additionally the IEP Report (2019b) concluded:

- Impacts on swamps and on the streams exiting from them are evident, however currently there is no strong evidence to date of consequences of swamp impacts on catchment-scale water supplies.
- When shallow groundwater levels in a swamp decline, soil moisture levels also decline, with a lag time of weeks or months.
- Quantifying the consequences of changes for flows in exit streams requires the development of water balance models of the swamps.
- Mining-induced changes to upland swamp vegetation communities are still not able to be differentiated from natural changes.
- Vegetation change assessment does not provide a clear and timely measure of possible changes in ecosystem functionality of the upland swamps. While changes in methodology, such as using targeted obligate swamp-dependent species (either plants or animals) may improve assessment, the decadal nature of many changes remains.

4.6 Achievement of Performance Measures

Due to the relatively recent inclusion of BACI designed monitoring programs related to long-term monitoring parameters there is some uncertainty related to the achievement of long-term performance measures. However, mining has been occurring for a number of years beneath swamps and this allows an opportunity to do some relatively simple back analysis of impacts to these features over the long-term. This approach has the disadvantage of a relatively simple experimental design whereby only obvious changes as a result of the mining are likely to be identified.

Subsidence predictions for swamps in historic mining areas were reviewed as part of the Bulli Seam Project Environmental Assessment (Resource Strategies 2009).

Field investigations were carried out in these swamps to assess impacts and consequences from various levels of back-predicted levels of subsidence movement. This data was used to inform the assessment of risk of impacts and environmental consequences for the Bulli Seam Operation Project. A summary of the review findings is provided below.

Back predictions have been undertaken for 34 swamps previously subject to subsidence in the Southern Coalfield. The back predictions indicate that six of these swamps would have been subject to closure values of greater than 200mm, namely:

- Swamp STC-S4 (221mm predicted closure) at West Cliff;
- Swamp STC-S1c (276mm predicted closure) at West Cliff;
- Swamp STC-S1a (278mm predicted closure) at West Cliff;
- Swamp 12 (335mm predicted closure) at Dendrobium;
- Swamp STC-S1b (461mm predicted closure) at West Cliff; and
- Swamp STC-S2 (542mm predicted closure) at West Cliff.

Site inspections have been conducted of the swamps listed above. An additional ten swamps predicted to have been previously subject to less than 200mm valley closure were also inspected.

The inspection methods included walking the length of the swamp and recording observations of any significant environmental impacts or consequences, for example:

- Significant subsidence-induced buckling or cracking.
- Any significant erosion or scour.
- Significant vegetation dieback on a broad scale.
- Significant desiccation of vegetation or peat materials on a broad scale.

It is recognised that there are limitations associated with the assessment. As stated above, the assessment is based on back predictions of subsidence effects, as opposed to observed (i.e. monitored) subsidence effects. However, these back predictions are being compared with predictions using the same methodology for analysis at Dendrobium, thus ensuring consistency within the comparative assessment.

Evidence of cracking and minor erosion was observed during the site inspections; however, no evidence of significant environmental consequences was observed.

Observational monitoring of upland swamps on the Woronora Plateau has been conducted by IMC since 2003. The results of this observational monitoring are in the report Understanding Swamp Conditions (BHPBIC 2010).

The report identifies any morphological, geological, hydrological and/or botanical changes observed in the swamps since inspections were initiated in winter 2003. Data is collected and analysed in such a way to identify and record any episodic or temporal changes to these swamp features.

Data is collected with the use of field instruments and through visual inspections of the dominant features within each swamp. The monitoring includes location and extent of any surface water or moisture, the health and location of vegetation, sediment and peat distributions and depths, as well as any cracking, erosion or sedimentation. Observation sites are recorded and plotted on plans with relevant comments.

A total of 28 swamps were visited and inspected between October 2010 and November 2010. A field sheet and plan with defined “Swamp Characteristics” were used to collect the data. Field officers visit each swamp and photograph and record data at various accessible sites. Data collection methodologies are consistent with previous swamp inspections. Swamp characteristics photographed and recorded include:

- Water: Location, volume and flow characteristics.
- Vegetation: Location, species, height and observed health.
- Sediment: Composition, depth and moisture.

The data is used to compare the conditions of sites in swamps before and after mining and under different climatic conditions. Data is also used to outline differences in swamp conditions due to geological and morphological conditions.

5 PREDICTED IMPACTS

Subsidence has the potential to impact swamps overlying the proposed longwalls due to either transient or relatively permanent changes in porosity and permeability of a swamp or hillslope aquifer. Underlying sandstone substrate is likely to fracture as a result of the predicted differential subsidence movements.

If a swamp overlies a longwall panel it may undergo temporary extensional “face line” cracking (perpendicular to the long axis of the panel) as the panel retreats, followed by re-compression as the maximum subsidence occurs.

In addition, a swamp may also undergo 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.

Non-conventional movements can also occur, and have occurred, in the NSW Coalfields as a result of, amongst other things, anomalous movements, valley closure and downslope movements. MSEC1034 (2019) analysed the effects of surface lineaments on the measured ground movements at Dendrobium Area 3B based on the measured LiDAR contours. No interactions or anomalous movements were found in between the surface lineaments and the subsidence movement. Many of the swamps are located in the bases of drainage lines and, therefore, could experience valley and slope related movements. The predicted valley related movements are provided in the subsidence assessment (MSEC 2020). The maximum valley related movements are predicted to occur in the bases of the streams within the extents of the valley fill swamps. The headwater swamps are located partly up the valley sides and, therefore, in these cases the predicted valley related movements (upsidence and closure) for these swamps are less than the maxima provided in MSEC (2020).

Conventional closures result from sagging curvature; these predictions are provided separately to the valley related closures, as the associated conventional strains are distributed across the longwalls, as opposed to the valley related compressive strains, which are concentrated in the valley bases. Generally, the valley related closures and conventional closures are orientated obliquely to each other.

Fracturing would be visible at the surface where the bedrock is exposed, or where the thickness of the overlying sediment is relatively shallow. It is predicted that fractures would develop beneath any sediments within the swamps of a similar nature and magnitude to those observed at the surface on exposed bedrock.

In accordance with the findings of the Southern Coalfield Inquiry and IEP (2019a):

- **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.

5.1 Description of Upland Swamps Within the Study Area

There are four swamps that have been identified wholly or partially within the Study Area based on the 35° angle of draw line. There are two additional swamps that are located wholly or partially within the Study Area based on the 600 m boundary.

The swamps within the Study Areas are typically valley infill swamps that have formed along the drainage lines. However, Swamp 149 and parts of Swamps 150 and 151 are headwater swamps located further up the valley sides.

Table 5-1: Swamps located within the Study Area based on the 600 m boundary

Reference	Location	Description
Swamp 14	Directly above LW16 and LW17 Upper reaches of WC15	Upper reaches of WC15
Swamp 35a	Directly above the maingate of LW18 Upper reaches of ND1	Upper reaches of ND1
Swamp 35b	85 m south of the maingate of LW18 Middle reaches of ND1	Middle reaches of ND1
Swamp 149	Directly above LW17 and partially above LW18 Valley side of LA2	Valley side of LA2
Swamp 150	225 m south of the maingate of LW18 Upper reaches of ND1B	Upper reaches of ND1B
Swamp 151	325 m south of the maingate of LW18 Upper and lower reaches of ND1A	Upper and lower reaches of ND1A

5.2 Subsidence Predictions

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the swamps located within the Study Area is provided in **Table 5-2**. The values are the maximum predicted subsidence effects within 20 m of the mapped extents of each of the swamps due to the mining of Longwalls 9 to 18.

Table 5-2: Maximum predicted total vertical subsidence, tilt and curvatures for the swamps (MSEC 2020)

Reference	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Swamp 14	2850	25	0.50	0.70
Swamp 35a	225	8	0.17	0.04
Swamp 35b	20	<0.5	<0.01	<0.01
Swamp 149	3000	25	0.70	0.60
Swamp 150	<20	<0.5	<0.01	<0.01
Swamp 151	<20	<0.5	<0.01	<0.01

Swamps 14 and 149 are located above the previous Longwalls 16 and 17 and, therefore, the predicted subsidence effects are predominately due to these previous longwalls.

Swamp 14 is predicted to experience less than 20 mm incremental vertical subsidence due to the mining of the proposed Longwall 18. While this swamp could experience very low levels of incremental vertical subsidence, it is not expected to experience measurable incremental tilts, curvatures or strains.

Swamps 14, 35a, 35b, 150 and 151 are located near the bases of the drainage lines and, therefore, they could experience valley related effects. Swamp 149 is located further up the valley side and, therefore, it is not expected to experience upsidence or compressive strain due to valley closure.

A summary of the maximum predicted incremental upsidence and closure for these swamps is provided in **Table 5-3**.

Table 5-3: Maximum predicted total upsidence and closure for the swamps (MSEC 2020)

Location	Maximum predicted total valley related upsidence (mm)	Maximum predicted valley related total closure (mm)	Maximum predicted conventional closure (mm)
Swamp 14	275	400	400
Swamp 35a	125	200	100
Swamp 35b	175	425	25
Swamp 149	N/A	N/A	400
Swamp 150	40	50	<20
Swamp 151	30	40	<20

The maximum predicted total closures (i.e. valley plus conventional) after the extraction of Longwall 18 are 800 mm for 14, 300 mm for 35a, 450 mm for 35b and 400 mm for 149. While 35b is located outside the mining area, the predicted valley related effects for this swamp are greater than the predicted values for 35a, as it is located within the more incised valley along the middle reaches of drainage line ND1.

The swamps will also experience compressive strains due to the valley related effects where they are located near the valley bases. The predicted total compressive strains for the swamps, due to the valley related effects, are in the order of 10 mm/m to 20 mm/m.

Swamps 14 and 149 are located above the previous Longwall 16 and 17 and, therefore, the predicted valley related effects are predominately due to these previous longwalls.

Further details on the subsidence predictions for swamps is provided in the subsidence assessment (MSEC 2020).

5.3 Impact Assessment

5.3.1 Potential for changes in surface water flows due to the mining-induced tilts

Mining induced tilt can potentially affect surface water flows through swamps, if the mining-induced tilts are much greater than the natural gradients, potentially resulting in increased levels of ponding or scouring, or affecting the distribution of water within the swamps.

The maximum predicted total tilt for the swamps within the Study Area is 25 mm/m (i.e. 2.5 %, or 1 in 40) for 14 and 149. The tilts at these swamps develop predominately due to the previous Longwall 16 and 17, with the predicted incremental tilt due to Longwall 18 being less than 0.5 mm/m (i.e. 0.05 %, or 1 in 2000) for 14 and 5.5 mm/m (i.e. 0.55 %, or 1 in 180) for 149. Swamp 35a is predicted to experience a total tilt of 8 mm/m (i.e. 0.8 %, or 1 in 125).

Swamps 14, 35a, 35b, 150 and 151 are located near the bases of the drainage lines. While there are predicted reversals in grade along LA2, there are no swamps located near the base of this drainage line and the predicted changes predominately occur due to the previous Longwalls 16 and 17. Swamp 149 is located further up the valley side of LA2 where the natural grades are considerably greater than the mining-induced tilts.

There are no predicted reversals of stream grade along the remaining drainage lines within the Study Area nor within the extents of the swamps. There are small reductions in grades along the drainage lines, upstream of the chain pillars and the edges of the mining area. There is potential for minor and localised increased ponding upstream of these locations and near to Swamps 14 and 35a. However, Swamp 14 is located above the previous Longwalls 16 and 17, therefore, the potential for increased ponding occurs due to these previous longwalls rather than the proposed Longwall 18. Swamp 35a is located above the maingate of Longwall 18 and only low-level changes in grade are predicted.

It is considered unlikely, therefore, that there would be adverse changes in the levels of ponding or scouring for the swamps within the Study Area as a result of the predicted tilt.

5.3.2 Potential for cracking in Upland Swamps and fracturing of bedrock

Fracturing of the bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than approximately 0.5 mm/m or where the compressive strains have been greater than approximately 2 mm/m.

Swamps 14 and 149 are located above the previous Longwalls 16 and 17 and Swamp 35a is partially located above the proposed Longwall 18. The maximum predicted compressive strains for these swamps due to the valley related effects are in the order of 10 mm/m to 20 mm/m. Swamp 35b is located outside the mining area at a minimum distance of 85 m from the proposed Longwall 18.

However, this swamp is located in the more incised valley along the middle reaches of drainage line ND1 and, therefore, it could also experience compressive strains due to valley related effects in the order of 10 mm/m to 20 mm/m. It is likely, therefore, that fracturing would occur in the bedrock beneath Swamps 14, 35a, 35b and 149.

The typical fracture widths in the bedrock beneath Swamps 14, 35a and 149 could be similar to the surface deformations previously observed at the Mine, as described in Section 4.7. The soil crack and rock fracture widths were generally observed to be less than 50 mm (i.e. 88 % of the cases).

However, the widths of the surface deformations were between 50 mm and 150 mm in 7 % of cases, between 150 mm and 300 mm in 3 % of cases and greater than 300 mm in 2 % of cases. Fracturing would only be visible at the surface where the bedrock is exposed, or where the thickness of the overlying soil is relatively shallow.

Swamp 35b is located outside the mining area at a minimum distance of 85 m from the proposed Longwall 18. Fracturing has been observed in streams located outside the extents of previously extracted longwalls in the NSW coalfields. Fracturing has been observed in the drainage lines at the Mine at distances of up to 290 m from the previously extracted longwalls in Area 3B. Minor and isolated fractures have also been observed up to 400 m outside of longwalls extracted elsewhere in the Southern Coalfield. Fracture widths in the order of 20 mm to 50 mm have been observed due to valley closure effects at similar distances as Swamp 35b from the proposed Longwall 18. It is possible that a series of smaller fractures, rather than one single fracture, could develop in the bedrock.

Swamps 150 and 151 are located outside the mining area at minimum distances of 225 m and 325 m, respectively, from the proposed Longwall 18. Fracturing could occur at these swamps, as has been observed at similar distances from the previously extracted longwalls in Area 3B. Fracture widths in the order of 20 mm could develop at Swamps 150 and 151.

Swamps 14, 35a and 35b are predicted to experience total upsidence ranging between 175 mm and 275 mm. These valley related effects could result in the dilation of the strata beneath these swamps. It has been previously observed that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley related movements, is generally in the order of 10 m to 15 m (Mills 2003, Mills 2007, and Mills and Huuskes 2004).

The dilated strata beneath the drainage lines upstream of Swamps 14, 35a and 35b could result in the diversion of some surface water flows beneath parts of these swamps. The drainage lines upstream of these swamps flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation. Swamp 14 is located directly above the previous Longwall 16 and 17 and, therefore, the potential impacts predominately occur due to these previous longwalls, rather than the proposed Longwall 18. Only a small area of Swamp 35a is located directly above the proposed Longwall 18 and Swamp 35b is located outside the mining area.

5.3.3 Potential changes to Upland Swamp Hydrology

Swamps that have been mined beneath commonly display hydrological changes shortly following the passage of the longwall beneath the shallow groundwater monitoring site; specifically:

- A decrease in the average shallow groundwater elevation;
- A decrease in the duration of saturation of the swamp sediments following a significant rainfall event; or
- A change in the shape of saturation peak and recession curves in response to significant rainfall events (HGEO 2020).

Hydrological changes at swamps are most likely due to the development of surface fracturing and bedding plane openings in the sandstone substrate of the swamp and/or a rockbar at the swamp outlet. The formation of fractures in the substrate may change the swamp from a perched system to a connected system. The impact on the swamp will be dependent on the head difference between the swamp sediments and the sandstone substrate. Where the hydraulic gradient is downwards (into the sandstone, which is common) then the fracturing will lead to greater flows of water from the swamp and a decline in average swamp groundwater levels. It is not yet known whether the hydrological characteristics recover to some degree as fractures are filled with fine sediments and on-going monitoring is required to assess longer-term impacts. Drying of upland swamps can result in further impacts, including:

- reduction of soil moisture levels and loss of cohesiveness of the swamp sediments.
- decline of groundwater-dependent plant species and consequent changes in vegetation structure.
- decline of groundwater-dependent fauna including macroinvertebrates and stygofauna.
- oxidation of peaty sediments resulting in increased hydrophobicity, lower water holding capacity,
- potential changes in nutrient cycling, and changes in water quality.
- increased risk of channelization and gully erosion.
- reduced resilience to bushfires.

A recent assessment of shallow groundwater impacts due to mining at Dendrobium was carried out by (Watershed Hydrogeo, 2019b). The assessment concluded that almost all shallow piezometers that are directly mined under by longwalls extracted in Dendrobium Area 3A and 3B show responses to mining. Changes in shallow groundwater levels or groundwater fluctuation characteristics are not evident in shallow piezometers located in swamp sediments more than 60 m from the extracted longwall margin.

Observations at the Springvale Mine in the Western Coalfield show that hydrological impacts can occur in swamps overlying connected geological structures (faults or other lineaments) at distances greater than 1200 m from the longwall (Galvin *et al.*, 2016). The same effect is not apparent at Dendrobium. Recent studies have identified no anomalous subsidence specifically related to mapped lineaments (MSEC, 2019), and no hydrological impacts at swamp piezometers located near mapped lineaments that are greater than 60 m from the goaf (Watershed Hydrogeo, 2019b). However, it is prudent to consider the possibility of distant impacts where swamps overlie mapped lineaments that intersect the mine footprint.

Table 5-4: Summary of predicted impacts to Upland Swamps (HGEO 2020)

Swamp	Area (Ha)	Vegetation communities	Distance from LW18 goaf (m)	Likelihood of shallow groundwater effects
Swamp 14	1.93	Banksia thicket, Tea-tree thicket, Sedgeland-Heath Complex	280	Previously impacted
Swamp 35a	1.09	Tea-tree thicket,	0	Likely
Swamp 35b	1.02	Tea-tree thicket	90	Possible
Swamp 149	1.42	Banksia thicket	0	Likely impacted by Longwall 17
Swamp 150	3.15	Banksia thicket, Tea-tree thicket	235	Unlikely
Swamp 151	3.98	Banksia thicket	330	Unlikely

5.3.4 Potential impacts on Upland Swamp Ecology

The majority of impacts to Upland Swamps will take place where they occur above the proposed longwall (0.17 ha of upland swamps). The severity and risk of impacts will reduce with distance from longwalls up to the 35° angle of draw study area, which includes the 20 mm subsidence contour (3.94 ha of upland swamp within 35° angle of draw study area). Beyond the 35 angle of draw study area, impacts to features such as swamps and watercourses are expected to be minor or negligible.

A recent assessment at Dendrobium Mine concluded that hydrological change in Upland Swamps is not evident in shallow groundwater piezometers located more than 60 m from the extracted longwall margin (Watershed Hydrogeo, 2019). Where streams flowing into swamps are located above or in close proximity to longwalls this may have impacts on swamps downstream of impacted streams. An assessment of the potential ecological impacts of subsidence on Upland Swamps was completed by Niche (2020) and is summarised below (**Table 5-5)**.

Table 5-5: Ecological impact predictions for upland swamps within and adjacent to the study area (Niche 2020); subsidence predictions from MSEC (2020)

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2020)	Conclusion (Niche 2020)
14	Large complex swamp with pools within or on edges of swamp. Swamp follows alignment of watercourse WC15.	Within the angle of draw. Directly above LW16 and LW17.	There is potential for minor and localised increased ponding near to Swamp 14. However, Swamp 14 is located above the previous LW16 and LW17, therefore, the potential for increased ponding occurs due to these previous longwalls rather than the proposed LW18. It is considered unlikely that there would be adverse changes in the levels of ponding or scouring for the swamps within the study area based on the predicted vertical subsidence and tilt. It is likely that fracturing would occur in the bedrock beneath Swamp 14. The typical fracture widths in the bedrock beneath Swamp 14, could be similar to the surface deformations previously observed at the Mine. The potential soil crack and rock fracture widths were generally observed to be less than 50 mm (i.e. 88 % of the cases). However, the widths of the surface deformations were between 50 mm and 150 mm in 7 % of cases, between 150 mm and 300 mm in 3 % of cases and greater than 300 mm in 2 % of cases. Fracturing would only be visible at the surface where the bedrock is exposed, or where the thickness of the overlying soil is relatively shallow. Predicted total upsidence in Swamp 14 (ranging between 175 mm and 275 mm) could result in the dilation of the strata beneath the swamp. It has been previously observed that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley related movements, is generally in the order of 10 m to 15 m. The dilated strata beneath the drainage lines upstream of Swamp 14, could result in the diversion of some surface water flows beneath parts of the swamp. The drainage lines upstream of the swamp flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation. Swamp 14 is located directly above the previous LW16 and LW17 and, therefore, the potential impacts predominately occur due to these previous longwalls, rather than the proposed LW18.	Unlikely to be measurable additional impacts (after impacts from LW16 and LW17) to this swamp or associated species including threatened species from the current proposal. Monitoring of impacts likely to be confounded from previous direct undermining (LW16 and LW17). A known population of Giant Dragonfly occurs within Swamp Den14.
35a	Small simple swamp. Swamp follows alignment of upper reaches of ND1	Directly above the maingate of LW18, within angle of draw.	There is potential for minor and localised increased ponding near to Swamp 35a. Swamp 35a is located above the maingate of LW18 and only low-level changes are predicted. It is considered unlikely that there would be adverse changes in the levels of ponding or scouring for Swamp 35a within the study area based on the predicted vertical subsidence and tilt. It is likely that fracturing would occur in the bedrock beneath Swamp 35a. The typical fracture widths in the bedrock beneath Swamp 35a could be similar to the surface deformations previously observed at the Mine. The soil crack and rock fracture widths were generally observed to be less than 50 mm (i.e. 88 % of the	Possible ecological impacts including changes in vegetation and threatened species habitat for the area of swamp directly above and adjacent the proposed longwall. Areas may trend towards Banksia Thicket or Fringing Eucalypt Forest if changes are long-term.

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2020)	Conclusion (Niche 2020)
			cases). However, the widths of the surface deformations were between 50 mm and 150 mm in 7 % of cases, between 150 mm and 300 mm in 3 % of cases and greater than 300 mm in 2 % of cases. Fracturing would only be visible at the surface where the bedrock is exposed, or where the thickness of the overlying soil is relatively shallow. Swamps 35a is predicted to experience total upsidence ranging between 175 mm and 275 mm. These valley related effects could result in the dilation of the strata beneath the swamp. It has been previously observed that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley related movements, is generally in the order of 10 m to 15 m. The dilated strata beneath the drainage lines upstream of Swamp 35a could result in the diversion of some surface water flows beneath parts of the swamp. The drainage lines upstream of the swamp flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation. Only a small area of Swamp 35a is located directly above the proposed LW18.	
35b	Small simple swamp. Swamp follows middle reaches of ND1.	Within angle of draw, 85 m south of the maingate of LW18.	It is considered unlikely that there would be adverse changes in the levels of ponding or scouring for the swamps within the study area based on the predicted vertical subsidence and tilt. Swamp 35b is located outside the mining area at a minimum distance of 85 m from the proposed LW18. However, this swamp is located in the more incised valley along the middle reaches of drainage line ND1 and, therefore, it could experience compressive strains due to valley related effects in the order of 10 mm/m to 20 mm/m. It is likely, therefore, that fracturing would occur in the bedrock beneath Swamp 35b. Fracturing has been observed in the drainage lines at the Mine at distances of up to 290 m from the previously extracted longwalls in DA3B. Minor and isolated fractures have also been observed up to 400 m outside of longwalls extracted elsewhere in the Southern Coalfield. Fracture widths in the order of 20 mm to 50 mm have been observed due to valley closure effects at similar distances as Swamp 35b from the proposed LW18. It is possible that a series of smaller fractures, rather than one single fracture, could develop in the bedrock. Swamp 35b is predicted to experience total upsidence ranging between 175 mm and 275 mm. These valley related effects could result in the dilation of the strata beneath the swamp. It has been previously observed that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley related movements, is generally in the order of 10 m to 15 m. The dilated strata beneath the drainage lines upstream of Swamp 35b could result in the diversion of some surface water flows beneath parts of the swamp. The drainage lines upstream of these swamps flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog, which is known to occur downstream of Swamp 35b, along watercourse ND1). Potential breeding habitat for this population may be impacted through reductions in water retention from pools after fracturing. Areas may trend towards Banksia Thicket or Fringing Eucalypt Forest if changes are long-term.

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2020)	Conclusion (Niche 2020)
			is likely that surface water flows will re-emerge at the limits of fracturing and dilation. Swamp 35b is located outside the mining area.	
149	Small simple swamp. Valley side of LA2.	Directly above LW17 and partially above LW18.	It is considered unlikely that there would be adverse changes in the levels of ponding or scouring for the Swamp 149 within the study area based on the predicted vertical subsidence and tilt. It is likely that fracturing would occur in the bedrock beneath Swamp 149. The typical fracture widths in the bedrock beneath Swamp 149 could be similar to the surface deformations previously observed at the Mine. The soil crack and rock fracture widths were generally observed to be less than 50 mm (i.e. 88 % of the cases). However, the widths of the surface deformations were between 50 mm and 150 mm in 7 % of cases, between 150 mm and 300 mm in 3 % of cases and greater than 300 mm in 2 % of cases. Fracturing would only be visible at the surface where the bedrock is exposed, or where the thickness of the overlying soil is relatively shallow.	Unlikely to be measurable additional impacts (after impacts from LW17) to this swamp or associated species including threatened species from the current proposal. Monitoring of impacts likely to be confounded from previous direct undermining (LW17). A population of Pultenaea aristata is associated with this swamp.
150	Small simple swamp along upper reaches of ND1B.	Within 600 m boundary, 225 m south of the maingate of LW18.	It is considered unlikely that there would be adverse changes in the levels of ponding or scouring for Swamp 150 within the study area based on the predicted vertical subsidence and tilt. Swamp 150 is located outside the mining area at a minimum distance of 225 m from the proposed LW18. Fracturing could occur at this swamp, as has been observed at similar distances from the previously extracted longwalls in DA3B. Fracture widths in the order of 20 mm could develop at Swamp 150.	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog, which is known to occur downstream of Swamp 150, along watercourse ND1B). Potential breeding habitat for this population may be impacted through reductions in water retention from pools after fracturing. Areas may trend towards Banksia Thicket or Fringing Eucalypt Forest if changes are long-term.
151	Small simple swamp, along upper and lower reaches of ND1A.	Within 600 m boundary, 325 m south of the maingate of LW18.	It is considered unlikely that there would be adverse changes in the levels of ponding or scouring for Swamp 151 within the study area based on the predicted vertical subsidence and tilt. Swamp 151 is located outside the mining area at a minimum distance 325 m from the proposed LW18. Fracturing could occur at this swamp, as has been observed at similar distances from the previously extracted longwalls in DA3B. Fracture widths in the order of 20 mm could develop at Swamp 151.	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog, which is known to occur downstream of Swamp 151, along watercourse ND1A). Potential breeding habitat for this population may be impacted through reductions in water retention from pools after fracturing. Areas may trend towards Fringing Eucalypt Forest if changes are long-term. Swamp 151 likely already impacted by mining of LW8. Monitoring of impacts likely to be confounded from previous direct undermining (LW8).

5.3.5 Potential Impacts to Threatened Flora

Eleven threatened flora species have been determined to have a moderate to high likelihood of occurring within the Study Area (Niche 2020). However, a limited number have potential habitat likely to be impacted by subsidence (Niche 2019).

Four species (*Epacris purpurascens var. purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius*) are considered to have habitat within the Study Area that may be impacted by subsidence. Each of these species has potential habitat within upland swamps or creek vegetation communities, however none of these species are reliant on such habitat and occur throughout a range of other habitats within the Study Area.

5.3.6 Potential Impacts to Fauna

Subsidence may have a direct impact on known and potential habitat for threatened fauna such as watercourses, upland swamps, riparian vegetation, rock overhangs, rocky outcrops, cliffs and crevices.

Woodland and forest habitat types make up the majority of the Study Area. These habitat types which are not dependent on groundwater are unlikely to be impacted by subsidence. Microhabitat features such as tree hollows and exfoliating bark are also unlikely to be impacted (Niche 2020).

5.3.7 Potential Impacts to Threatened Fauna

Fifty-four threatened fauna were considered during the likelihood of occurrence assessment. Thirty-seven of these species were determined to have a moderate or high likelihood of occurrence within the Study Area. Nine threatened fauna species are considered to be potentially impacted by subsidence impacts resulting from the mining Longwall 18 comprising:

- Frogs: Littlejohn’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet.
- Reptiles: Broad-headed Snake, Rosenberg’s Goanna.
- Mammals: Eastern Bentwing Bat, Little Bentwing Bat, Southern Myotis.
- Invertebrates: Giant Dragonfly.

From the above species, it is considered that significant cumulative impacts (due to mining of Longwall 18 and other longwalls within area DA3B) could occur for the three frog species and the Giant Dragonfly.

An assessment of potential impacts for each of the identified threatened species likely to be impacted is provided in the Longwall 18 Terrestrial Ecology Assessment (Niche 2020).

6 MANAGEMENT AND CONTINGENCY PLAN

The potential impacts of mine subsidence to upland swamps in Area 3B are provided below, together with a summary of the avoidance, minimising, mitigation and remediation measures proposed.

6.1 Objectives

The aims and objectives of this Plan include:

- Avoiding and minimising impacts to significant environmental values where possible.
- Implementing TARPs and reporting to identify, assess and respond to impacts to swamps.
- Carrying out mitigation and remediation works in a manner that protects to the greatest practicable extent the environmental values of the area.
- Achieving the Performance Measures outlined in the Area 3B SMP Approval, to the satisfaction of the Secretary.
- Implementing environmental offsets where applicable.
- Monitoring and reporting effectiveness of the Plan.

To achieve these aims, monitoring, management, mitigation, remediation and offsetting has been incorporated into the mining activity proposed by IMC.

6.2 Trigger Action Response Plan

The TARPs relate to identifying, reporting, assessing and responding to potential impacts to swamps (including impacts greater than predicted) from subsidence in Dendrobium Area 3B including Swamps 01a, 01b, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35a and 35b. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for Area 3B swamps are included in **Appendix A**.

The TARPs represent actions (including reporting) to be taken upon reaching each defined trigger level. If required, a Corrective Management Action (CMA) is developed in consultation with stakeholders in order to manage an observed impact in accordance with relevant approvals. The SIMMCP provides a basis for the design and implementation of any mitigation and remediation. Generic CMAs will be developed as required, in consultation with WaterNSW, to provide for a prompt response to a specific impact that requires a specific CMA. If appropriate these discussions will consider whether pre-approvals for the CMA can be obtained where immediate implementation is required.

Monitoring of environmental aspects provides key data when determining any requirement for a CMA, including mitigation or rehabilitation. The triggers are based on comparison of baseline and impact monitoring results. Specific triggers will continue to be reviewed and developed in consultation with key stakeholders as the impact monitoring phase matures. Where required the triggers will be reviewed and changes proposed in impact assessment reports provided to government agencies or in EoP Reports.

Level 1 TARPs typically relate to the routine impacts from mining and/or natural (non-mining) variability in the monitoring data. TARP level 1 impacts are reported to key stakeholders via a variety or mechanisms, including an Impact Update Report provided to Government Agencies.

Level 2 and 3 TARPs result in further investigations and reporting. Impact assessment reports will include:

- Study scope and objectives;
- Consideration of relevant aspect from this Plan;
- Analysis of trends and assessment of any impacts compared to prediction;
- Root cause analysis of any change or impact;
- Assessment of the need for contingent measures and management options;
- Any recommended changes to this Plan; and
- Appropriate consultation.

The Level 2 and 3 TARPs may require the development of site specific CMAs which include:

- A description of the impact to be managed;
- Results of specific investigations;
- Aims and objections for any corrective actions;
- Specific actions required to mitigate/manage and timeframes for implementation;
- Environmental offsetting;
- Roles and responsibilities;
- Gaining appropriate approvals from landholders and government agencies; and
- Reporting, consultation and communication.

6.3 Avoiding and Minimising

Mine layouts for Dendrobium Area 3B have been developed using IMC's Integrated Mine Planning Process (IMPP). This process considers mining and surface impacts when designing mine layouts.

IMC has assessed mining layout options for Dendrobium Area 3B against the following criteria:

- Extent, duration and nature of any community, social and environmental impacts;
- Coal customer requirements;
- Roadway development and longwall continuity;
- Mine services such as ventilation;
- Recovery of the resource for the business and the State; and
- Gas drainage, geological and geotechnical issues.

Several layout alternatives for Area 3B have been assessed by IMC using a multi-disciplinary team including environment, community, mining and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and setbacks of the longwalls from key features. These options are reviewed, analysed and modified until an optimised longwall layout in Area 3B is achieved.

Area 3B is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from Areas 1, 2 and 3A to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of Area 3B including major surface water features such as Lake Avon, and Wongawilli Creek; and a number of geological constraints such as dykes, faults, and particularly the Dendrobium Nepheline Syenite Intrusion. The process of developing the layout for Area 3B has considered the impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints.

No contingent mining areas containing Wongawilli Seam Coal resources with the possibility for extraction are available to IMC.

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features, including limiting the maximum extraction height to 3.9m. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues are taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3B mine layout incorporates the hierarchy of avoid/minimise/mitigate as requested by the DPIE and BCD during the consultation process. Mine plan changes result in significant business and economic impact, including:

- Reduction in coal extracted;
- Reduction in royalties to the State;
- Additional costs to the business;
- Risks to longwall production due to additional roadway development requirements; and
- Constraints on blending which can disrupt the supply of coal to meet customer requirements.

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;

- Increased safety risks such as risk of frictional ignition on the longwall due to less than optimal ventilation;
- Increased power usage, reduced fan lifespan and a requirement to install booster fans;
- Requirement for heavy secondary support density;
- Potential for horizontal stress and vertical abutment concentrations;
- The risk of strata control associated with increased roadway development and longwall install and take-off faces;
- Exposes the workforce to higher risk environments more frequently;
- Results in a large number of equipment movements and interaction with workers and infrastructure; and
- Requires specialised equipment and skilled personnel with limited availability.

The longwalls have been setback between 130 m and 680 m from Wongawilli Creek and a minimum of 300 m from Lake Avon. This reduction in extraction also reduces subsidence movements at surface features in proximity to Wongawilli Creek and Lake Avon, including the streams LA2, LA3, LA4, LA5, WC7, WC9, WC12, WC15, WC16, WC18, and Swamps 23 and 11.

The mining layout of Longwall 18 is designed to avoid Lake Avon, Wongawilli Creek, the Nepheline Syenite Intrusion as well as other geological constraints. The length of Longwall 18 has been reduced at the eastern end to avoid an in seam geological feature. Longwall 18 contains a significant structurally disturbed zone along MG18 between cut-throughts 7-8 which also extends into the longwall block (South32, 2020). This zone appears to consist of a series of three faults with displacements 10 – 15 m, downthrown to the south and middle and has been investigated via a variety of exploration methods. A summary of the geology of Longwall 18 is available in Attachment G. Inseam drilling data suggests that conditions for the shortened Longwall 18 block are likely similar to those previously experienced in Area 3B with only minor impacts from geological features expected.

Detailed analysis was conducted into options for having no impacts to swamps, including options for not mining under the swamps. This analysis demonstrated that the reduction in resource recovery necessary to achieve this outcome was approximately 45% of the total resource available within Area 3B. This analysis was conducted with a 150 m setback from the swamps.

Longwall 18 is proposed to be 305 m wide and the EA undertaken to support the SMP was undertaken on that basis. The EA and SMP are based on extensive empirical data collected during the mining in Areas 1, 2, 3A and 3B, including Longwalls 8 – 14, which have been successfully extracted with a width of 305 m. The SIMMCP has been revised to take into account a revised subsidence model for Dendrobium (MSEC 2020) based on measured subsidence resulting from the extraction of Longwalls 9 to 15.

Detailed analysis was conducted into options for reducing impacts to swamps, including reducing the widths of the longwalls to a maximum of 180 m. This analysis demonstrated that the reduction in subsidence movements achieved through reducing the longwall width to 180 m would not significantly reduce the potential for impacts to the swamps. The analysis included an assessment of the reduced subsidence movements against the Draft BCD criteria for assessing impacts to swamps that may be at risk of negative environmental outcomes:

- Systematic tensile strains >0.5 mm/m;
- Systematic compressive strains >2 mm/m;
- Depth of cover less than 1.5 times longwall panel width;
- Transient or final tilt >4 mm/m;
- Valley closure >200 mm; and
- Maximum closure strain >7.0 mm/m.

A summary of the analysis (MSEC459) is provides in **Table 6-1** below.

Table 6-1 Predicted Subsidence Parameters at Swamps for 180 m Wide Longwalls

Swamp	Max predicted Cumulative Subsidence (mm)	Max predicted Cumulative Valley Closure (mm)	Max predicted Cumulative Closure Strain (mm/m)	Number of the Six OEH Draft Assessment Triggers Exceeded
1a	800	200	19.8	4
1b	800	100	10.5	4
3	850	100	11.0	4
4	850	150	17.0	4
5	850	300	>20	5
8	1000	550	>20	5
10	950	250	>20	5
11	850	250	>20	5
13	850	350	>20	5
14	950	600	>20	5
23	950	200	>20	4
35a	1150	350	>20	5
35b	<20	400	>20	3
Max for 180 m (MSEC459)	1150	600	>20	-
Max for 305 m (MSEC459)	2550	650	>20	-
Max for 305 m (MSEC792)	3500	650	-	-
Max for 305 m (MSEC914)	2750	650	-	-

6.4 Mitigation and Rehabilitation

If the performance measures in the Development Consent and Area 3B SMP Approval are not met, then following consultation with BCD, WaterNSW and Mining, Exploration and Geosciences (MEG), the Secretary of DPIE 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.

Coastal Upland Swamps were determined to be an endangered ecological community under the then *Threatened Species Conservation Act 1995*, (repealed by the *Biodiversity Conservation Act 2016 [*BC Act]) by the NSW Scientific Committee in 2012. As indicated in Schedule 2 Conditions 1 and 14 of the Development Consent (Minister for Planning 2008) and Condition 14, Schedule 3 of the Area 3B SMP Approval (DPIE 2019), the mitigation and rehabilitation described in this Plan is 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 BC 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 EPA Act. At the time of grant of the Dendrobium Development Consent there was a requirement for consultation with the Minister administering the then *TSC Act* and this consultation was undertaken.

6.4.1 Sealing of Rock Fractures

Where the bedrock base of any significant permanent pool or controlling rockbar within swamps 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 cementitious (or alternative) grout. Grouting will be focused where fractures result 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 directly mined under the river and pool water level loss was observed.

A number of grouts are available for use including cement and Poly-urethane Resin (PUR), with various additives. These grouts can be used with or without fillers such as clean sand. Grouts can be mixed on-site and injected into a fracture network or placed by hand. Hand placed and injection grouting of large fractures were successfully implemented in the Georges River near Appin.

Such operations do have the potential to result in additional environmental impacts and are carefully planned to avoid any contamination. Mixing areas will be restricted to cleared seismic lines or other open areas wherever possible. Bunds are used to contain any local spillage at mixing points. Temporary cofferdams can be built downstream of the grouting operations to collect any spillage or excess grouting materials for disposal off-site. The selection of grouting materials is based on demonstrated effectiveness and ensuring that there is no significant impact to water quality or ecology.

6.4.2 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 controlling rockbar.

Where alluvial materials overlie sandstone, grouts may be injected through grout rods to seal voids in or under the soil or peat material. This technique was successfully used at Pool 16 in the Georges River to rehabilitate surface flow by-pass to Pool 17. In this case 1-2 m of loose sediment was grouted through using purpose built grouting pipes.

Grouting holes are drilled in a pattern, usually commencing at a grid spacing of 1 m x 1 m to 2 m x 2 m. The most efficient way to drill the holes taking into account potential environmental impact is by using handheld drills. The drills are powered by compressed air which is distributed to the work area from a compressor. The necessary equipment will be sited on cleared seismic lines or other clear areas wherever possible with hoses run out to target areas.

Grout is delivered from a small tank into the ground via mechanical packers installed at the surface. All equipment can be transported with vehicles capable of travelling on tracks similar to seismic lines. If necessary, equipment or materials can be flown to nearby tracks or open spaces by a helicopter. Helicopter staging has previously occurred from Cordeaux Mine where there is appropriate logistical support. The grout is mixed and pumped according to a grout design. A grout of high viscosity will be used if vertical fracturing is believed to be present since it has a shorter setting time. A low viscosity grout will be used if cross-linking is noted during grouting. Once the grout has been installed the packers are removed and the area cleaned.

After sufficient time for the product to set the area may be in-filled with additional grouting holes that target areas of significant grout take from the previous pass.

The grouting program can normally be completed with hand held equipment. Wherever possible the setup and mixing areas will be restricted to cleared seismic lines and other open areas. Bunds are used to contain any local spillage at mixing points.

Grouting volumes and locations are recorded and high-volume areas identified. Once the grout take in the area is reduced and the material has set, the grouted section of the pool is isolated and tested with local or imported clean water. 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.

If flow diversion through a swamp rockbar occurs it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via directional drilling technologies.

Grouting should preferentially be undertaken at the completion of subsidence movements in the area to reduce the risk of the area being re-impacted. **Figure 6-1** shows grouting operations in progress within the Georges River.

(a) Drilling into the bedrock

(b) Grout pump station setup

(c) Injecting grout into bedrock via a specially designed packer system

Figure 6-1 Rockbar Grouting In The Georges River

6.4.3 Erosion Control

The types of erosion which could manifest within swamps are sheet, rill, gully, tunnel and stream channel. These types of erosion will be monitored in swamps in the mining area as well as in reference swamps not in the mining area. The types and magnitude of any erosion identified in swamps in the mining area will be compared to any erosion away from the mining area.

Erosion can create preferred flow paths and where this erosion creates a topographic low point within a swamp it could act to dewater the swamp sediments. To arrest this type of erosion, ‘coir log dams’ are installed at knick points, channelised flow paths and/or at the inception of tunnel/void spaces (**Figure 6-2**). The square coir logs used for the construction of these small dams were developed specifically for swamp rehabilitation and have been successfully used during a number of swamp rehabilitation programs of recent years in the Blue Mountains and Snowy Mountains.

Figure 6-2 Square Coir Logs For Knick Point Control

As the coir log dams silt up they are regularly added to by the placement of additional layers of logs until the pooled water behind the 'dams' is at or above the level of the bank of the eroded channel, or the peat bed of the swamp. The coir logs are held in place by 50 x 50mm wooden tree stakes and bound together with wire (**Figure 6-3**).

The coir log dam slows the flows in the eroding drainage line such that the drainage line will silt up and water in the swamp will once again flow through the swamp rather than being concentrated in the eroding channel.

Figure 6-3 Installation of Square Coir Logs

The most important aspect of these coir dams is the positioning of the first layer of coir logs. A trench is cut into the swamp soil so the first layer sits on the underlying substrate or so the top of the first coir log is at ground level (**Figure 6-4**).

Figure 6-4 Trenching & Positioning of the First Layer of Coir Logs and Construction of a Small Dam in an Eroding Swamp Channel

The coir log dams are constructed at intervals down the eroding channel, the intervals being calculated on the depth of erosion and predicted peak flows and added to until the pooled water behind the 'dams' is at or above the level of the bank of the erosion. At this point the stream becomes, once again, a net water contributor to the swamp and not a net drainer of water from the swamp. Where increased filtering of flows is required the coir logs are wrapped in fibre matting (**Figure 6-5**).

Figure 6-5 Small Coir Log Dams with Fibre Matting

6.4.4 Water Spreading

Where sheet and rill erosion forms, these processes can reduce vegetation on the surface and/or be a precursor to the formation of gully and stream channel erosion. Treatment of these areas can prevent the formation of channels and maintain swamp moisture. The treatment proposed includes water spreading techniques, involving long lengths of coir logs and hessian 'sausages' linked together across the contour such that water flow builds up behind them and slowly seeps through the water spreaders (**Figure 6-6**). Where required the water spreaders would be installed in shallow trenches within the swamp and along the higher margins.

Figure 6-6 Round Coir Logs Installed to Spread Water

Erosion control and water spreading involves soft-engineering materials that will contribute to and function as part of the swamp system but will eventually degrade (biodegradable) and become integrated into the soil of the swamps. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the swamp. This also removes the requirement for any post-rehabilitation removal of structures or materials.

6.4.5 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 PUR and other grouting materials. IMC is consulting with Metropolitan Colliery in relation to these technologies. Should rehabilitation be necessary in Dendrobium Area 3B, the best option available at the time of the rehabilitation work will be identified and with appropriate approval, implemented by IMC.

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.

6.4.6 Monitoring Remediation Success

Baseline studies have been completed within the Study Area in order to record biophysical characteristics of the mining area. Monitoring is conducted in the area potentially affected by subsidence from the Area 3B extraction as well as areas away from mining to act as control sites. The studies in these areas are based on the BACI design criteria.

A comprehensive swamp monitoring program is in place for swamps identified in this Plan. A summary of swamp monitoring within Dendrobium Area 3B is provided in Section 2. In the event that monitoring reveals impacts greater than what is authorised by the approval, modifications to the project, mitigation measures and environmental offsets would be considered to minimise impacts.

The monitoring program would remain in place prior to, during and following the implementation of any mitigation measures in Area 3B.

The monitoring program is based on a BACI design with sampling undertaken at impact and control locations prior to the commencement of mitigation, during mitigation and after the completion of the mitigation actions. The monitoring locations/points for swamps within Dendrobium Area 3B will be reviewed as required and can be modified (with agreement) accordingly.

Data will be analysed according to the BACI design. Statistical analyses between control, impact and mitigation sites will be used to determine whether there are statistically significant differences between these sites. This analysis will assist in determining the success of any mitigation or natural reduction of mining impacts over time.

Observation data will also be collected as part of the monitoring program and be used to provide contextual information to the above assessment approach. Monitoring data and observations will be mapped, documented and reported.

The water levels of all significant permanent pools within swamps will be monitored prior to and during mining. These pool water levels will provide a direct comparison of pre-mining and post mining conditions within the pool. Where rehabilitation activities are required to restore the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar, the pool water level will also be monitored after the CMAs are implemented. The rehabilitation will be successful if the measured pool water levels after a rainfall recharge event are re-established to pre-mining conditions. The rainfall recharge event is required to fill the pool so that the success of the CMA can be tested. A rainfall recharge event is where the watercourse flows into the significant permanent pool to such an extent that it is filled.

6.5 Biodiversity Offset Strategy

A biodiversity offset strategy has been developed in consultation with BCD and WaterNSW for the approval of the Secretary of DPIE. The Secretary DPIE approved the Strategic Biodiversity Offset in accordance with Condition 15 of Schedule 2 of the Development Consent for the Dendrobium Coal Mine 16th December 2016. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of Condition 9 of the SMP for Area 3B. The strategy:

- provides a suitable offset for all the predicted impacts of the Project on upland swamps;
- gives priority to like-for like physical environmental offsets, but also consider measures that result in beneficial effect on water quality, water quantity, aquatic ecosystems and/or the ecological integrity of the special areas or water catchments, other potential physical environmental offsets, and potential financial environmental offset contributions payable to a relevant public trust or authority, where physical offsets or other measures are unavailable or insufficient to provide a suitable offset;
- proposes a process whereby the actual impacts of the development on upland swamps are regularly reviewed (at least every 2 years) against predicted impacts and reported on to all affected agencies, including detailed consideration of the predictions in the SMP, performance measures in the SMP Approval, monitoring results, application, success and predicted success of measures to mitigate or remediate subsidence impacts and/or associated environmental consequences, predicted and actual long-term impacts, and views of BCD and WaterNSW; and
- proposes a process whereby a suitable residual environmental offset is provided where the actual impacts on upland swamps exceed those predicted in the SMP.

6.6 Research

To assist in further understanding the impacts of subsidence and rehabilitation of swamps IMC will undertake research to the satisfaction of the Secretary. The research is directed to improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences to swamps.

The program of research will continue through the mining of Area 3B and be adaptive to results as the program is implemented. The research will be conducted as provided by a Swamp Rehabilitation Research Program. This Program will:

- be prepared in consultation with BCD, WaterNSW and MEG;
- be submitted by 31 October 2013 to the Secretary for approval;
- investigate methods to rehabilitate swamps subject to subsidence impacts and environmental consequences within Area 3A and 3B, with the aim of restoring groundwater levels and groundwater recharge response behaviour to pre-mining levels;

- establish a field trial (for a 5 year duration or longer) for rehabilitation techniques at a swamp or swamps that have been impacted by subsidence;
- provide for the expenditure of at least $3.5 million over this period; and
- include a schedule of subsequent trials, development of work plans and ongoing reporting.

6.7 Contingency and Response Plan

In the event the TARP parameters are considered to have been exceeded, or are likely to be exceeded, IMC will implement a Contingency Plan to manage any unpredicted impacts and their consequences. This contingency and response plan is applicable for all swamps within Area 3B, including Swamps 1a, 1b, 3, 4, 5, 8, 10, 11, 13, 14, 23, 35a, 35b, 149, 150 and 151.

This would involve the following actions:

- Identify and record the event.
- Notify Government agencies and specialists as soon as practicable.
- Conduct site visits with stakeholders as required.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Establish weekly monitoring frequency for the site until stabilised.
- Inform relevant Government agencies of investigation results.
- Develop site CMA in consultation with key stakeholders and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting following CMA completion.
- Review the SIMMCP in consultation with key Government agencies.
- Report in EoP Report and AEMR.

A site-specific rehabilitation action plan detailing the location and specific works to be implemented will be prepared following the identification of mining induced swamp degradation that exceeds the trigger levels specified in the TARPS.

The site-specific swamp rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. All works and environmental controls will be approved by WaterNSW prior to implementation.

Table 6-2 provides a summary of the avoidance, mitigation and contingency measures proposed to manage mining impacts where predicted impacts are exceeded.

Table 6-2 Performance Measures, Potential Impacts, Mitigation and Contingent Measures for Swamps

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
Swamps 1a, 1b, 5, 8, 11, 14 and 23	**Negligible** erosion of the surface of the swamp	Gully erosion or similar	• Observation of swamps for new erosion or changes to existing erosion • Identification and measurements of erosion via airborne laser scanning (ALS) and on ground survey	a) upfront mine planning b) erosion monitoring (i.e. ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting i) investigation and review j) update future predictions	Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase >5% of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (i.e. increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is >5%).	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective. This period can be extended to 5 years, with the agreement of the Secretary.
	Minor changes in the size of the swamps **Minor** changes in the ecosystem functionality of the swamps **No significant change** to the composition or distribution of species within the swamps	Swamp vegetation changes: • Swamp size • Species richness, distribution, composition and diversity • Vegetation sub-communities	• Repeat mapping of swamp boundaries • Repeat mapping of groundwater dependent community boundaries • Statistical analyses of species richness and diversity	a) upfront mine planning b) vegetation monitoring c) water spreading d) seeding/planting e) weeding f) fauna monitoring g) fire management h) grouting of controlling of controlling rockbars and bedrock	• Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the standard error of the Control Group. • Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring periods, greater than observed in the Control Group, and	Offset required immediately, if no remediation considered practicable. Offset required 5 years following remediation, if it is ineffective.

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
				base and/or use of other remediation techniques i) reporting j) investigation and review k) update future predictions	exceeding the standard error of the Control Group. • Mining results in a >10% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for five consecutive years.	This period can be extended to 10 years, with the agreement of the Secretary.
	Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps	Subsidence impacts (i.e. cracking) on bedrock base or controlling rockbar	• Observation of swamps, streams and pools • Measurements of pool water level	a) upfront mine planning b) subsidence monitoring c) surface water monitoring d) groundwater monitoring e) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques f) CMAs g) reporting h) investigation and review i) update future predictions	Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, i.e. pool water level within the swamp after CMAs continues to be >20% lower than baseline for >20% of the time over a period of 1 year.	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective. This period can be extended to 5 years, with the agreement of the Secretary.

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
Swamps 3, 4, 10, 13, 35a, 35b, 149, 150 and 151	**No significant environmental consequences** beyond predictions in the Subsidence Management Plan	Gully erosion or similar	• Observation of swamps for new erosion or changes to existing erosion • Identification and measurements of erosion via ALS and on ground survey	k) upfront mine planning l) erosion monitoring (i.e. ALS, observation) m) coir logs n) knickpoint control o) water spreading p) weeding q) fire management r) reporting s) investigation and review t) update future predictions	Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase >5% of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (i.e. increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is >5%).	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective. This period can be extended to 5 years, with the agreement of the Secretary.
		Subsidence impacts (i.e. cracking) on bedrock base or controlling rockbar	• Observation of swamps, streams and pools • Measurements of pool water level	j) upfront mine planning k) subsidence monitoring l) surface water monitoring m) groundwater monitoring n) grouting of controlling of controlling rockbars and bedrock base and/or use of	Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, i.e. pool water level within the swamp after CMAs continues to be >20% lower than baseline for >20% of the time over a period of 1 year.	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective.

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
				other remediation techniques o) CMAs p) reporting q) investigation and review r) update future predictions		This period can be extended to 5 years, with the agreement of the Secretary.

Note: The mitigation measures will be assessed for appropriateness (in consultation with key stakeholders), as the need arises, on the individual swamps being impacted to ensure significant additional impacts to the swamps are not created by the carrying out of these mitigation measures. The provision of residual environmental offsets will be considered where the potential impacts of mitigation measures are greater than the impacts of mining or where the mitigation measures are not successful. Additional actions are required as per the TARPs, including informing stakeholders, review of monitoring and further assessments as required. The upland swamps in the Study Area are groundwater dependent communities which fit the description of Coastal Upland Swamps in the Sydney Basin Bioregion. Changes in area of the Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex are considered in the assessment of ecosystem functionality of the swamps.

7 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

7.1 Incidents

IMC will notify DPIE and other relevant agencies of any incident associated with Area 3B operations as soon as practicable after IMC becomes aware of the incident. IMC will provide DPIE and any relevant agencies with a report on the incident within seven days of confirmation of any event.

7.2 Complaints Handling

IMC will:

- Provide a readily accessible contact point through a 24-hour toll-free Community Call Line (1800 102 210). The number will be displayed prominently on IMC sites in a position visible by the public as well as on publications provided to the local community.
- Respond to complaints in accordance with the IMC Community Complaints and Enquiry Procedure.
- Maintain good communication lines between the community and IMC.
- Keep a register of any complaints, including the details of the complaint with information such as:
    - Time and date.
    - Person receiving the complaint.
    - Complainant's name and phone number.
    - Description of the complaint and where complaint relates to.
    - Details of any response where appropriate.
    - Details of any corrective actions.

7.3 Non-Conformance Protocol

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 Dendrobium Mine operations. Regular inspections, internal audits and initiation of any remediation/rectification work in relation to this Plan will be undertaken by the Principal Approvals.

Non-conformities, corrective actions and preventative actions are managed in accordance with the following process:

- Identification and recording of non-conformance and/or non-compliance.
- Evaluation of the non-conformance and/or non-compliance to determine specific corrective and preventative actions.
- Corrective and preventative actions to be assigned to the responsible person.
- Management review of corrective actions to ensure the status and effectiveness of the actions.

An Annual Review will be undertaken to assess IMC's compliance with all conditions of the Dendrobium Development Consent, Mining Leases and other approvals and licenses.

An independent environmental audit will be undertaken in accordance with Schedule 8, Condition 6 to review the adequacy of strategies, plans or programs under these approvals and if appropriate, recommend actions to improve environmental performance. The independent environmental audit will be undertaken by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary of DPIE.

8 PLAN ADMINISTRATION

This SIMMCP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Development Consent conditions. A summary of the administrative requirements is provided below.

8.1 Roles and Responsibilities

Statutory obligations applicable to Dendrobium Mine operations are identified and managed via an online compliance management system (TICKIT). The online system can be accessed by the responsible IMC managers from the link below.

https://illawarracoal.tod.net.au/login.

The overall responsibility for the implementation of this SIMMCP resides with the Approvals Manager who shall be the SIMMCP's authorising officer.

Responsibilities for environmental management in Dendrobium Area 3 and the implementation of the SIMMCP include:

Approvals Manager

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

Principal Approvals

- To document any approved changes to the SIMMCP.
- Provide regular updates to IMC on the results of the SIMMCP.
- Arrange information forums for key stakeholders as required.
- Prepare any report and maintain records required by the SIMMCP.
- Organise and participate in assessment meetings called to review mining impacts.
- Respond to any queries or complaints made by members of the public in relation to aspects of the SIMMCP.
- Organise audits and reviews of the SIMMCP.
- Address any identified non-conformances, assess improvement ideas and implement if appropriate.
- Arrange implementation of any agreed actions, responses or remedial measures.
- Ensure surveys required by this SIMMCP are conducted and record details of instances where circumstances prevent these from taking place.

Coordinator Environment

- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Investigate significant subsidence impacts.
- Identify and report any non-conformances with the SIMMCP.
- Participate in assessment meetings to review subsidence impacts.

Survey Coordinator

- Collate survey data and present in an acceptable form for review at assessment meetings.
- Bring to the attention of the Principal Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Principal Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the SIMMCP.

Technical Experts

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

Person(s) Performing Inspections

- Inform the Coordinator Environment of any non-conformances identified with the Plan, or ideas aimed at improving the SIMMCP.
- Conduct inspections in a safe manner.

8.2 Resources Required

The Approvals Manager provides resources sufficient to implement this SIMMCP.

Equipment will be needed for the TARP provisions of this SIMMCP. Where this equipment is of a specialised nature, it will be provided by the supplier of the relevant service. All equipment is to be appropriately maintained, calibrated and serviced as required in operations manuals.

The Approvals Manager shall ensure personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

8.3 Training

All staff and contractors working on IMC sites 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).

It is the responsibility of the Approvals Manager to ensure that all persons and organisations having responsibilities under this SIMMCP are trained and understand their responsibilities.

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.

8.4 Record Keeping and Control

Environmental Records are maintained in accordance with the IMC document control requirements.

IMC document control requirements include:

- Documents are approved for adequacy by authorised personnel prior to use.
- Obsolete documents are promptly removed from circulation.
- Documents are reissued, or made available, to relevant persons in a timely fashion after changes have been made and the authorisation process is complete.

The SIMMCP and other relevant documentation will be made available on the IMC website.

8.5 Management Plan Review

A comprehensive review of the objectives and targets associated with the Dendrobium Area 3 operations is undertaken on an annual basis via the planning process. These reviews, which include involvement from senior management and other key site personnel, assess the performance of the mine over the previous year and develop goals and targets for the following period.

An annual review of the environmental performance of Dendrobium Area 3 operations will also be undertaken in accordance with Condition 5 Schedule 8. More specifically this SIMMCP will be subject to review (and revision if necessary, to the satisfaction of the Secretary) following:

- The submission of an annual review under Condition 5 Schedule 8.
- The submission of an incident report under Condition 3 Schedule 8.
- The submission of an audit report under Condition 6 Schedule 8.

- Any modification to the conditions of the Dendrobium Development Consent or SMP Approval.

If deficiencies in the EMS and/or SIMMCP are identified in the interim period, the plans will be modified as required. This process has been designed to ensure that all environmental documentation continues to meet current environmental requirements, including changes in technology and operational practice, and the expectations of stakeholders.

9 REFERENCES AND SUPPORTING DOCUMENTATION

ACARP, 2009. Damage Criteria and Practical Solutions for Protecting River Channels. Project Number C12016. Ken Mills SCT May 2009.

Axys, 2019. Risk Assessment: Review of Dendrobium Longwall 17 Subsidence Management Plan. AR2573 (Revision 3) 4 March 2019.

Axys, 2020. Risk Assessment: Review of Dendrobium Longwall 18 Subsidence Management Plan, Risk Assessment Report. AR2944 (Revision E) 4 March 2019.

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

BHP Billiton Illawarra Coal, 2011. Understanding Swamp Conditions - Field Inspection Report - September 2010 to November 2010. BHP Billiton Illawarra Coal, April, 2011.

Biosis Research 2007. Dendrobium Area 3 Species Impact Statement, Prepared for BHP Billiton Illawarra Coal, Biosis Research Pty Ltd.

Biosis Research 2007. Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006, Biosis Research Pty Ltd.

Biosis Research, 2009. Revision of the Dendrobium Coal Mine Flora and Fauna Monitoring Program. February 2009.

Biosis Research, 2012(a). Elouera and Dendrobium Ecological Monitoring Program. Annual Monitoring Report Financial Year 2010/2011. August 2012.

Biosis Research, 2012(b). Swamp 15b TARP Assessment – Ecology. Ref:15462, 10 October 2012.

Biosis, 2014. Dendrobium Ecological Monitoring Program, Annual Report for 2012/2013 Financial Year. February 2014. Prepared for Illawarra Coal.

Biosis, 2015. Dendrobium Terrestrial Ecology Monitoring Program, Annual Report for 2014. September 2015. Prepared for Illawarra Coal.

Biosis, 2019. Dendrobium Areas 2, 3A and 3B: Terrestrial Ecology Monitoring Program Annual Report 2018, Final Report, Prepared for Illawarra Coal, 21 June 2019.

Boughton W, 2004. The Australian water balance model. Environ Model Softw 19:943–956. doi: doi:10.1016/j.envsoft.2003.10.007.

Cardno, 2018. Dendrobium Area 3B Aquatic Ecology Monitoring 2010 to 2017. 8 December 2019.

Cardno Ecology Lab, 2012. Aquatic Flora and Fauna Assessment. Prepared for BHPBIC, February 2012.

Cardno Ecology Lab, 2012. Swamp 15b and SC10C Aquatic Flora and Fauna Review. Ref: NA49913032, 5 October 2012.

Cardno Ecology Lab, 2013. Dendrobium Area 3A Aquatic Ecology Monitoring 2008-2012. Job Number: EL1112073 Prepared for BHP Billiton – Illawarra Coal, February 2013.

Cardno Ecology Lab, 2013. Review of Sandy Creek Pools Aquatic Flora and Fauna. 25 February 2013.

Cardno Ecology Lab, 2013. SC10C Level 3 Aquatic Ecology Trigger Assessment. 11 June 2013.

Cardno Ecology Lab, 2015. Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014. 30 March 2015.

Cardno Forbes Rigby, 2007. Landscape Impact Assessment and Monitoring Site Optimisation. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Area 3A Subsidence Management Plan Longwalls 6 to 10. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Dendrobium Area 3 Environmental Assessment. Prepared for BHPBIC.

Cardno, 2020. Aquatic Flora and Fauna Review. Illawarra Coal Holdings Pty Ltd, August 2020.

Chafer, C., Noonan, M and Macnaught, E. 2004. The Post-Fire Measurement of Fire Severity and Intensity in the Christmas 2001 Sydney Wildfires. International Journal of Wildland Fire Vol. 13; pp. 227-240.

Chiew, F, Wang, Q. J., McConachy, F., James, R., Wright, W, and deHoedt, G. 2002. Evapotranspiration Maps for Australia. Hydrology and Water Resources Symposium, Melbourne, 20-23 May, 2002, Institution of Engineers, Australia.

Coffey, 2012. Groundwater Study Area 3B Dendrobium Coal Mine: Numerical Modelling. GEOTLCOV24507AA-AB2 2 October 2012.

Ditton, S., and Merrick, N.P. 2014. A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields. Paper presented at the Australian Earth Science Convention, Newcastle, NSW.

Doherty, J. 2010. PEST: Model-Independent Parameter Estimation User Manual (5th ed.): Watermark Numerical Computing, Brisbane, Queensland, Australia.

EarthTech Engineering Pty Ltd, 2005. Thresholds for Swamp Stability. Prepared for BHPBIC, January 2005.

The Ecology Lab, 2007. Dendrobium Area 3 Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota. October 2007.

Ecoengineers, 2006. Assessment of Surface Water Chemical Effects of Mining by Elouera Colliery. January - December 2005. February 2006.

Ecoengineers, 2006. Assessment of Catchment Hydrological Effects by Mining by Elouera Colliery Stage 1: Establishment of a Practical and Theoretical Framework. August 2006.

Ecoengineers, 2007. Surface Water Quality and Hydrology Assessment to Support SMP Application for Dendrobium Area 3.

Ecoengineers, 2010. End of Panel Surface and Shallow Groundwater Impacts Assessment Dendrobium Area 2 Longwall 5. Document Reference No. 2010/01A. April 2010.

Ecoengineers, 2012. Surface Water Quality and Hydrological Assessment: Dendrobium Area 3B Subsidence Management Plan Surface and Shallow Groundwater Assessment.

Ecoengineers, 2012. Level 2 TARP Independent Review and Recommendations Swamp 15b Dendrobium Area 3A. 25 September 2012.

Ecoengineers, 2013. Level 3 TARP Independent Review and Recommendations Sandy Creek Catchment Pool 7 (Dendrobium Area 3A). 12 February 2013.

Ecoengineers, 2013. Level 2 TARP Specialist Review and Recommendations Donalds Castle Creek. 22 May 2013.

Ecoengineers, 2014. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 9. June 2014.

Ecoengineers, 2015. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 10. February 2015.

Eco Logical Australia, 2004. The Impacts of Longwall Mining on the Upper Georges River Catchment: Report to Total Environment Centre, 2004.

Forster, 1995. Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

GHD, 2007. Dendrobium Area 3A Predicted Hydrogeologic Performance. Report for BHP Billiton, Illawarra Coal. November 2007.

GSS Environmental, 2013. Baseline and Pre-Mining Land Capability Survey. Dendrobium Mine, Area 3B. February 2013.

Hazelton P.A. and Tille P.J. 1990. Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet map and report, Soil Conservation Service of NSW, Sydney.

Hebblewhite, 2010. BHP Billiton Illawarra Coal: Bulli Seam Operations Project – Independent Review. 31 March 2010.

Helensburgh Coal Pty Ltd, 2007. Submission to: Independent Expert Panel - Inquiry into NSW Southern Coalfield July 2007, Helensburgh Coal Pty Ltd.

Heritage Computing, 2009. Dendrobium Colliery Groundwater Assessment: Mine Inflow Review, Conceptualisation and Preliminary Groundwater Modelling. Merrick, N.P., Heritage Computing Report HC2009/2, February 2009.

Heritage Computing, October 2011. Recalibration of the Dendrobium Local Area Groundwater Model after Completion of Longwall 6 (Area 3A). Report prepared for Illawarra Coal. Report HC2011/13.

HGEO, 2019. Dendrobium Mine End of Panel Surface Water and Shallow Groundwater Assessment: Longwall 14 (Area 3B), September 2019, Project number: J21474, Report: D19327.

HGEO, 2020. Assessment of surface water flow and quality effects of proposed Dendrobium Longwall 18. Report: D18301. August 2020.

HGEO, 2020. Structure and hydrogeology of the Elouera Fault (No. D20365), Report by HGEO Pty Ltd for South32 Illawarra Metallurgical Coal.

HGEO, 2020. Investigation into the height of fracturing above extracted longwalls in Area 3, Dendrobium (No. D19341), Report by HGEO Pty Ltd for Illawarra Metallurgical Coal.

HGEO, 2020. Dendrobium Mine End of Panel surface water and shallow groundwater assessment: Longwall 15 (Area 3B) (No. D20358), Report by HGEO Pty Ltd for South32 Illawarra Coal.

HydroSimulations, 2014. Dendrobium Area 3B Groundwater Model Revision: Swamps, Stream Flows and Shallow Groundwater Sata. Report: HC2014/4 March 2014.

HydroSimulations, 2019. Dendrobium Area 3B Longwall 17 Groundwater Assessment. Report: HC2018 March 2019.

Illawarra Coal, 2014. Longwall 9 End of Panel Report.

Illawarra Coal, 2015. Longwall 10 End of Panel Report.

Illawarra Coal, 2016. Longwall 11 End of Panel Report.

Illawarra Coal, 2017. Longwall 12 End of Panel Report.

Illawarra Coal, 2018. Longwall 13 End of Panel Report.

Illawarra Metallurgical Coal, 2019. Longwall 14 End of Panel Report.

Independent Expert Panel for Mining in the Catchment, 2018. Initial report on specific mining activities at the Metropolitan and Dendrobium coal mines. 12 November 2018.

Independent Expert Panel for Mining in the Catchment, 2019a, Independent Expert Panel for Mining in the Catchment Report: Part 1. Review of specific mining activities at the Metropolitan and Dendrobium coal mines, Prepared for the NSW Department of Planning, Industry and Environment.

Independent Expert Panel for Mining in the Catchment, 2019b, Independent Expert Panel for Mining in the Catchment Report: Part 2. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment, Prepared for the NSW Department of Planning, Industry and Environment.

Kirchner, J. W. 2009. Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modelling, and doing hydrology backwards. Res., W02429.

Manly Hydraulics Laboratory, 2006. BHP Billiton Dendrobium Mine Area 2 Subsidence Environmental Management Plan Water Monitoring and Management Program. Prepared for BHPBIC. Version 1.4 January 2006.

McMahon, 2014. Dendrobium Community Consultative Committee Report: Review of Surface Water Study. An independent review of surface water hydrological modelling associated with Illawarra Coal's Dendrobium Area 3, conducted by Emeritus Professor Thomas McMahon, University of Melbourne. 4 June 2014.

MSEC, 2007. Dendrobium Mine Area 3A Longwalls 6 to 10. Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of proposed Longwalls 6 to 10 in Area 3A at Dendrobium Mine in Support of the SMP and SEMP Applications. September 2007.

MSEC, 2012. Dendrobium Area 3B Subsidence Predictions and Assessments for Natural Features and Surface Infrastructure in Support of the SMP Application.

MSEC, 2015. Dendrobium Area 3B – Longwalls 12 to 18 Review of the Subsidence Predictions and Impact Assessments for Natural and Built Features in Dendrobium Area 3B based on Observed Movements and Impacts during Longwalls 9 and 10.

MSEC, 2017. Dendrobium mine – Area 3B. The Effects of the Proposed Modified Commencing Ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. MSEC914 August 2017.

MSEC, 2018. Dendrobium – Longwalls 17 and 18. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of Longwalls 17 and 18 in Area 3B at Dendrobium Mine. MSEC992 November 2018.

MSEC, 2019. Report on the effects of surface lineaments on the measured ground movements at Dendrobium Area 3B based on the measured LiDAR contours. Report No. MSEC1034.

MSEC, 2020. Dendrobium – Longwall 18 Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwall 18 in Area 3B at Dendrobium Mine. MSEC1103 Rev C. July 2020.

Niche Environment and Heritage, 2012. Terrestrial Ecological Assessment. Prepared for BHP Billiton Illawarra Coal. February, 2012.

Niche Environment and Heritage, 2020. Dendrobium Longwall 18 Terrestrial Ecological Assessment. South 32 Illawarra Metallurgical Coal. August 2020.

NPWS, 2003. The Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments. Central Conservation Programs and Planning Division NSW National Parks and Wildlife Service; August 2003.

NSW Threatened Species Scientific Committee, 2012. Coastal Upland Swamp in the Sydney Basin Bioregion - endangered ecological community listing. NSW Scientific Committee - final determination.

OEC, 2001. Environmental Impact Statement Dendrobium Coal Project. Olsen Environmental Consulting, Figtree, N.S.W.

Parkhurst. D.L., and Appelo, C.A.J. 2012. Description of Input and Examples for PHREEQC Version 3 – A Computer Program for Speciation, Batch-Reaction, One- Dimensional Transport and Inverse Geochemical Calculations. US Department of Interior/US Geological Survey.

Parson Brinckerhoff, 2012. Independent Review of Dendrobium Area 2 and 3A Hydrochemical Data. August 20012.

Parsons Brinckerhoff, 2015. Connected fracturing above longwall mining operations, Part 2: Post-longwall investigation. For BHP Billiton Illawarra Coal. Document number 2172268F-WAT-REP-002 RevB. 6 March 2015.

Petersen, 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology Vol 27, Issue 2, April 1992.

Resource Strategies, 2009. Bulli Seam Operations Environmental Assessment. Report in support of an application for the continued operations of the Appin and West Cliff Mines.

Singh & Kendorski, 1981. Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments, Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

South32, 2020. Wongawilli Creek Waterfall 54 Management Strategy. August 2020.

SRK, 2020. Geological structures comparison investigation (No. STH055 RevE), Report by SRK Consulting for Illawarra Metallurgical Coal.

Tammetta, P. (2013). Estimation of the height of complete groundwater drainage above mined longwall panels. Groundwater, 51(5), 723-734.

Tomkins, K.M. and Humphries, G.S. 2006. Technical report 2: Upland Swamp development and erosion on the Woronora Plateau during the Holocene. January 2006. Sydney Catchment Authority – Macquarie Collaborative Research Project.

Tozer, M. et el 2002. Native Vegetation Maps of the Cumberland Plain Western Sydney. NSW National Parks and Wildlife Service 2002.

Waddington, A.A. and Kay, D.R. 2001. Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs. Gorges and River Systems. Final Report on ACARP Research Project C8005, March 2001.

Waddington, A.A. and Kay, D.R. 2002. Management Information handbook on the Undermining of Cliffs, Gorges and River Systems. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Watershed Hydrogeo, 2018. Analysis of low flow and pool levels on Wongawilli Creek. Report r003i2, October 2018.

Watershed Hydrogeo, 2019. Discussion of Surface Water Flow TARPs. Report r011i5, December 2019.

Watershed Hydrogeo, 2020. Dendrobium Mine Longwall 18 Groundwater Assessment. Prepared for Illawarra Coal Pty Ltd. August 2020.

Zhang, L. Dawes, W.R. and Walker, G.R. 1999. Predicting the effect of Vegetation Changes on Catchment Average Water Balance. Technical Report No. 99/12, Cooperative Research Centre for Catchment Hydrology.

Appendix A – Swamp Monitoring and Trigger Action Response Plan

Appendix A: Table 1.1

Swamp monitoring within Dendrobium Area 3 will be installed ahead of mining to achieve at least 2-years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring is generally conducted through the mining period and for 2-years following active subsidence. Where impacts are observed the monitoring period will be reviewed and this review 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 is conducted in consultation with key stakeholders. The location of monitoring sites is indicated on the figures of the relevant SIMMCP.

Table 1.1 – Dendrobium Area 3 Swamp Monitoring Program

Monitoring Site		Site Type	Monitoring Frequency	Parameters
OBSERVATIONAL, PHOTO POINT AND WATER MONITORING				
Area 3A	Swamps 12, 15A, 15B, 34, 95, 96, 146, 147 and 148 *Reference Sites* Swamps, 2, 22, 24, 25, 33, 84, 85, 86, 87 and 88	Observation and photo point monitoring: • Sites based on an assessment of risk • Swamps • Pools and rockbars • Steep slopes and rock outcrops • Previously observed impacts that warrant follow-up inspection	Pre and post mining for 2 years, monthly when longwall is within 400 m of monitoring site Weekly inspection and pool water levels when longwall is within 400 m of monitoring site Reference sites 6-monthly	Visual signs of impacts to swamps 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 Key water quality parameters in pools within and downstream of swamps analysed to identify any changes resulting from mining
AREA 3B	Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A, 35B, 149, 150 and 151 *Reference Sites* Swamps 2, 7[1], 15A[2], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Swamps 7, 9, 144 and 145 General observation of swamps in active mining areas when longwall is within 400 m of swamp *Reference Sites* Swamps, 2, 15A[3], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
EROSION MONITORING				
Area 3A	Swamps 12, 15A[4], 15B, 34, 95, 96, 146, 147 and 148 *Reference Sites* Swamps 2, 7[5], 22, 24, 25, 33, 84, 85, 86, 87 and 88	Airborne Laser Scanning Surveyed cross-sections, areas and lengths	ALS base surveys were completed in December 2005, with a verification base survey performed in 2013, immediately prior to the commencement of Longwall 9 extraction	Raw ground strike ALS data will be contoured with a 0.2 m interval after the completion of subsidence at each longwall to provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to assess for new or increases in existing erosion. The maximum area/length and depth of any

[1] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[2] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*

[3] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*

[4] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*

[5] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

			Ground based surveys to be completed for each longwall after each longwall or to define any new erosions identified by ALS survey	erosion identified by ALS will be measured by standard survey methods
AREA 3B	Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A,35B, 149, 150 and 151. *Reference Sites* Swamps 2, 15A[6], 7[7], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Swamps 2, 5, 7[8], 9, 124, 140, 141, 142, 144 and 145 *Reference Sites* Swamps 2, 15a, 7, 22, 24, 25, 33, 84, 85, 86, 87 and 88			
SHALLOW GROUNDWATER LEVEL				
AREA 3A	Swamp 15A: 15a_03, 15a_04, 15a_07, 15a_12, 15a_15a_15, 15a_17 Swamp 15B: 15b_H1, 15b_H2, 15b_H3 Swamp 12: 12_01, 12_03, 12_04 Swamp 146: DA2A_01 Swamp 34, 95, 96, 147 and 148 At least one piezometer site per swamp if sediment depth is appropriate. *Reference Sites* Swamp 2: 02_01 Swamp 7[9]: 07_05, 07_06 Swamp 22: 22_01, 22_02 Swamp 24: 24_01 Swamp 25: 25_01 Swamp 33: 33_01, 33_03 Swamp 84: 84_02 Swamp 85: 85_01, 85_02 Swamp 86: 86_01, 86_02 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02	Monitoring bore drilled into the soil profile	For open hole sites: • Monthly monitoring pre, during and post mining for two years to be reviewed annually • Reference sites 6 monthly For instrumented sites: • Automatic groundwater level monitoring pre, during and post mining (1-hour interval or similar) • Monitoring post mining for five years to be reviewed annually	Piezometric and dip meter monitoring of shallow groundwater level

[6] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*

[7] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[8] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[9] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

AREA 3B	Swamp 01A: 01a_01, 01a_02, 01a_03, 01a_04, 01a_04i, 01a_04ii, 01a_04iii, 01a_04iv, 01a_04v Swamp 01B: 01b_01, 01b_02, 01b_02i, 01b_02ii, 01b_02iii, 01b_02iv, 01b_03 Swamp 03: 03_01 Swamp 04: (thin soil profile) Swamp 05: 05_01, 05_02, 05_03, 05_03i, 05_03ii, 05_03iii, 05_04, 05_05, 05_06 Swamp 08: 08_01, 08_02, 08_03, 08_04, 08_05, 08_06 Swamp 10: 10_01 Swamp 11: S11-HI, S11-H2, S11-H3 Swamp 13: 13_01 Swamp 14: 14_01, 14_02 Swamp 23: 23_01, 23_02 Swamp 35A: 35A_01 Swamp 35B: 35B_01 Note: Swamp 4 is too shallow for a piezometer to be installed. Swamp 149, 150 and 151 At least one piezometer site per swamp if sediment depth is appropriate. *Reference Sites* Swamp 2: 02_01 Swamp 7[10]: 07_05, 07_06 Swamp 22: 22_01, 22_02 Swamp 24: 24_01 Swamp 25: 25_01 Swamp 33: 33_01, 33_03 Swamp 84: 84_02 Swamp 85: 85_01, 85_02 Swamp 86: 86_01, 86_02 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02			

[10] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

AREA 3C	Swamps, 7[11], 9, 141, 142, 144 and 145 At least one piezometer site per swamp if sediment depth is appropriate. *Reference Sites* Swamp 2: 02_01 Swamp 7*(1)*: 07_05, 07_06 Swamp 22: 22_01, 22_02 Swamp 24: 24_01 Swamp 25: 25_01 Swamp 33: 33_01, 33_03 Swamp 84: 84_02 Swamp 85: 85_01, 85_02 Swamp 86: 86_01, 86_02 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02			

[11] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

SOIL MOISTURE				
Area 3A	Install soil moisture at existing shallow groundwater sites Swamp 15A: 15a_03, 15a_04, 15a_07, 15a_12, 15a_15a_15, 15a_17 Swamp 15B: 15b_H1, 15b_H2, 15b_H3 Swamp 12: 12_01, 12_03, 12_04 Swamp 34, 95, 96, 146, 147 and 148 Generally one Soil Moisture site per swamp if sediment depth is appropriate.			

AREA 3B	Swamp 03: (thin soil profile) Swamp 04: (thin soil profile) Swamp 05: S05_S01, S05_S02, S05_S05, S05_S08 Swamp 08: S08_S05 Swamp 11: S11_S01, S11_S02, S11_S05 Swamp 13: S13_S01, S13_S02, S13_S03 Swamp 14: 14_01, 14_02 Swamp 23: 23_01, 23_02 Swamp 35A: 35a_01 Swamp 35B: 35b_01 Swamp 149, 150 and 151 Generally one Soil Moisture site per swamp if sediment depth is appropriate. *Reference Sites* *Swamp 2: S02_S01* *Swamp 7[12]: S07_S05, S07_S06* *Swamp 22: 22_01, 22_02* *Swamp 24: S24_S01* *Swamp 25: S25_S01* *Swamp 33: S033_S01, S033_S03* *Swamp 84: S84_S02* *Swamp 85: S85_S01, S85_S02* *Swamp 86: S86_S01, S86_S02* *Swamp 87: S87_S01, S87_S02* *Swamp 88: S88_S01, S88_S02*	Monitoring bore drilled into the soil profile	For manually measured sites: • Monthly monitoring for 2 years baseline and post mining and 6-monthly reference sites • Weekly monitoring when longwall is within 400 m of monitoring site For instrumented sites: • Automatic soil moisture monitoring pre, during and post • Monitoring post mining for five years to be reviewed annually	Installed dielectric soil moisture sites down to 1.5 m to measure deep soil moisture
AREA 3C	Swamps 7, 9, 124, 140, 141, 142, 144 and 145 Soil moisture sites will be paired with sites with piezometers			

[12] *Reference site for Area 3B; impact site when mining commences in Area 3C.*

TERRESTRIAL FLORA – COMPOSITION AND DISTRIBUTION OF SPECIES				
AREA 3A	Swamps 15B and 15A *Reference Sites* *Swamp 88, Swamp 87, Swamp 86, Swamp 22 and Swamp 33*	Swamp vegetation transects	Two baseline monitoring campaigns 1 year prior to mining during autumn and spring (Autumn - Photo points; spring - Photo points & transects/quadrat) Quarterly monitoring during mining 6-monthly monitoring post mining for two years or as otherwise required General observation of active mining areas during all other monitoring	15 m transects consisting of thirty 0.5 m x 0.5 m quadrats. The monitoring records: • Presence of all species within each quadrat • Percentage foliage cover and vegetation height • Observations of dieback or changes in community structure • Photo point monitoring at each transect
AREA 3B	Swamps 01A, 01B, 05, 11 *Reference Sites* *Swamp 88, Swamp 87, Swamp 86, Swamp 22 and Swamp 33*			
AREA 3C	Swamps 9, 144 and 145 (Sites yet to be determined) *Reference Sites* *Swamp 88, Swamp 87, Swamp 86, Swamp 22 and Swamp 33*			
TERRESTRIAL FLORA – SWAMP SIZE AND ECOSYSTEM FUNCTION				
Area 3A	Swamp 15A and 15B *Reference Sites* *Swamps 85 (DC10) and 33*	Size of the groundwater dependent communities (Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex) and the total size of the swamps	Baseline mapping prior to mining with repeat mapping after each longwall or as determined by observational monitoring i.e. if dieback or invasion of non-swamp species is observed	Detailed mapping including the use of LiDAR data to indicate the location and extent of upland swamp boundaries. Ground-truthing of these boundaries and the vegetation sub-communities will be undertaken if subsequent Lidar data shows swamp boundary movements
AREA 3B	Swamps 01A, 01B, 05, 8, 11, 13, 14 and 23 *Reference Sites* *Swamps 85 (DC10) and 33*			
AREA 3C	Swamps 9, 144 and 145 *Reference Sites* *Swamps 85 (DC10) and 33*			
TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3A	Swamps 15B and 15A *Reference Sites* *WC10, WC11, SC7(1), SC7(2), SC7A, SC8, DC8 and NDC*	Frog monitoring	Surveys are undertaken in winter each year to target active breeding periods (these can be variable depending on prevailing conditions) To address recommendation from Niche (2019), rainfall or hydrometric trigger values for surveys will be developed for surveys to allow for greater consistency between years which would aid in comparison of results (pre- versus post- mining and impact versus control)	For swamps frog surveys are conducted along associated 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 recorded 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
AREA 3B	DC13, DC1, WC21, LA4A, ND1 and WC15 *Reference Sites* *WC10, WC11, SC7, SC7(2), SC7A, SC8, DC8 and NDC*			

AREA 3C	Swamps 9, 144 and 145 (sites yet to be determined) *Reference Sites* *WC10, WC11, SC7(1), SC7(2), SC7A, SC8, DC8 and NDC*		To address recommendation from Niche (2019), a baseline survey focussed on tadpole survey for Littlejohn's Tree Frog and aural detection of Red-crowned Toadlet is proposed to be conducted after sufficient rainfall and within the appropriate season	
AQUATIC ECOLOGY				
AREAS 3A, 3B and 3C	**Sandy Creek Catchment** Sites 8, 9, 10, 11, 12 and 13 (Sandy Creek) *Reference Sites* Site 7 (Sandy Creek) **Wongawilli Creek Catchment** Sites 2, 3, 4, 5[13], 19[14], 20[15], X4, X5 and X6 (Wongawilli Creek) Sites X2 and X3 (WC21) *Reference Sites* Site 1 (Wongawilli Creek until LW15) Site 5[(1)] (Wongawilli Creek) Site 6 (WC21) Site X7 (Wongawilli Creek) Site X8 (Wongawilli Creek) **Donalds Castle Creek Catchment** Site X1, 17 and 18 (Donalds Castle Creek) *Reference Sites* Site 14 (Donalds Castle Creek) **Kentish Creek Catchment** *Reference Sites* Sites 15 and 16 (Kentish Creek) ***Note** - Additional impact and reference monitoring sites to be established at least 2 years prior to the extraction of Longwalls 20 and 21.*	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 and Sydney Hawk Dragonfly, individuals of the genus *Austrocorduliidae* and *Gomphomacromiidae* are identified to species level if possible Fish are sampled by visual observations and dip netting in Area 3A and sampled using baited traps in Area 3B

[13] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[14] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[15] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

In accordance with Condition 13, Schedule 3 of the Area 3B SMP Approval, the performance measures stated in Table 1.2 below are applicable to Swamps 1a, 1b, 5, 8, 11, 14 and 23 in Dendrobium Area 3B.

Table 1.2 - Dendrobium Area 3 Swamp TARP

Performance Measures	***Potential Impacts***	***Performance Triggers***	***Management Strategies***	***Offsets***	***Other Actions***
Negligible erosion of the surface of the swamp	Gully erosion or similar	*Level 1:* The increase in length of erosion within a swamp (compared to its pre-mining length) is **2%** of the swamp length or area; and/or 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. *Level 2*: The increase in length of erosion within a swamp (compared to its pre-mining length) is **3%** of the swamp length or area; and/or Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention; and/or Gully knickpoint forms or an existing gully knickpoint becomes active. *Level 3:* The increase in length of erosion within a swamp (compared to its pre-mining length) is **4%** of the swamp length or area; and/or Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention. *Exceeding Prediction* Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase **>5%** of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (i.e. increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is **>5%**).	a) upfront mine planning b) erosion monitoring (i.e. ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting i) investigation and review j) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the size of the swamps **Minor changes** in the ecosystem functionality of the swamps **No significant change** to the composition or distribution of species within the swamps	Swamp vegetation changes: - Swamp size - Species richness, distribution, composition and diversity - Vegetation sub-communities	**Swamp Size** *Level 1:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the standard error (SE) of the Control Group. *Level 2:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 3:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem Functionality**	a) upfront mine planning b) vegetation monitoring c) water spreading d) seeding/planting e) weeding f) fauna monitoring g) fire management h) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques i) reporting j) investigation and review	Offset required **immediately**, if no remediation considered practicable. Offset required **5 years** following remediation, if it is ineffective. This period can be extended to **10 years**, with the agreement of the Secretary.	Monitoring period for swamp size is related to capture of Lidar data at the end of each longwall ~ 1 year Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring

		Level 1: A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 2:* A trending decline in the extent of any groundwater dependent community within a swamp for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 3:* A trending decline in the extent of any groundwater dependent community within a swamp for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Species Composition and Distribution** *Level 1:* A **2%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **two** consecutive years; and/or *Level 2:* A **5%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **three** consecutive years. *Level 3:* An **8%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **four** consecutive years. *Exceeding Prediction:* Mining results in a **>10%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **five** consecutive years.	k) update future predictions		
Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps	Subsidence impacts (i.e. cracking) on bedrock base or controlling rockbar	*Level 1:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **10%** compared to baseline for the pool (in addition to any decrease in reference pools). *Level 2:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **20%** compared to baseline for the pool (in addition to any decrease in reference pools). *Level 3:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **20%** compared to baseline for the pool for **>20%** of the time over a period of **1** year (in addition to any decrease in reference pools). *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 swamp after CMAs continues to be **>20%** lower than baseline for **>20%** of the time over a period of **1** year.	a) upfront mine planning b) subsidence monitoring c) surface water monitoring d) groundwater monitoring e) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques f) CMAs g) reporting h) investigation and review	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	

			i) update future predictions		
Minor changes in the ecosystem functionality of the swamps	Falls in surface or near-surface groundwater levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*Level 1:* Groundwater level lower than baseline level at any monitoring site within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/day during the recession curve). *Level 2:* Groundwater level lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at a **50%** of monitoring sites (within 400m of mining) within the swamp. *Level 3:* Groundwater level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **>80%** of monitoring sites (within 400 m of mining) within the swamp.	a) upfront mine planning b) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions		Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
Minor changes in the ecosystem functionality of the swamps	Falls in soil moisture levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*Level 1:* Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps). *Level 2:* Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps). *Level 3:* Soil moisture level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps).	a) upfront mine planning b) soil moisture monitoring c) water spreading d) weeding e) fire management f) reporting g) update future predictions		Triggers of soil moisture decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars

SOUTH32

ADDENDUM A

OCTOBER 2020

AREA 3B

SWAMP IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

Table of Contents

Tables

Figures

Review History

Revision	Description of Changes	Date	Approved
A	New Document - Addendum A	October 2020	GB

Persons involved in the development of this document include:

Name	Title	Company
Cody Brady	Principal Approvals	Illawarra Metallurgical Coal
Gary Brassington	Approvals Manager	Illawarra Metallurgical Coal

1 CUMULATIVE IMPACTS

Six swamps have been identified within the Longwall 18 Study Area (based on the 600 m boundary). Two of these have been impacted by previous longwalls in Area 3B, Swamps 149 and 14.

Niche (2020) undertook further detailed mapping which included ground-truthing and verification as part of the terrestrial ecology assessment for the Longwall 18 SMP application. Swamps 149, 150 and 151 were identified during this process. Due to the timing of these supplementary surveys, the minimum two years baseline monitoring cannot be achieved for these swamps. Additionally, due to the recent mapping of Swamp 149, it was not considered in previous assessments and is not presented in the Longwall 18 SMP application cumulative impact summary. This addendum to the Swamp Impact Monitoring Management and Contingency Plan (SIMMCP) updates and provides the cumulative impact assessment for these swamps.

1.1 Swamp 14 Predictions – Longwall 17

Swamp 14 has been directly mined under by Longwalls 15 and 16, with Longwall 17 still to be extracted. Longwall 17 is the most recently approved longwall in Area 3B.

Predicted subsidence at Swamp 14 is provided by MSEC (2018) and is based on the layout of the longwalls in Area 3B. Predictions for Swamp 14 are summarised in **Table 1** and **Table 2**.

Table 1 Maximum predicted subsidence parameters at Swamp 14 after the completion of Longwall 17

Max predicted Cumulative Subsidence (mm)	Max predicted cumulative or travelling tilt (mm/m)	Max predicted cumulative or travelling hogging curvature (km-1)	Max predicted cumulative or travelling sagging curvature(km-1)
3100	30	0.60	0.75

Table 2 Maximum predicted upsidence and closure at Swamp 14 after the completion of Longwall 17

Max predicted total valley related upsidence (mm)	Max predicted total valley related closure (mm)	Max predicted total conventional closure (mm)
3100	30	

Conventional strains at the swamp can be determined by applying a factor of 15 to the predicted conventional curvatures (MSEC 2012, 2015 and 2018). Observed strains greater than the predicted conventional strains can occur as the result of, a number of factors, including non-systematic anomalous movements and valley related movements. The predicted conventional curvatures at Swamp 14 are illustrated in **Figure 1**.

Tensile strains greater than 0.5 mm/m may be of sufficient magnitude to result in fracturing in the bedrock. Compressive strains greater than 2 mm/m may be of sufficient magnitude to result in bedrock fracturing, buckling and dilating. Based on the predicted maximum tensile and compressive strains induced by conventional subsidence that will occur in Swamp 14, as a result of the extraction of Longwalls 15, 16 and 17, fracturing in the bedrock of the swamp and WC15 is likely to occur. Fracturing is likely to be more pronounced where the compressive and tensile strains are at their greatest as shown in **Figure 1**.

The lower reaches of Swamp 14 are located in close proximity to drainage lines and, therefore, these locations are likely to experience valley and slope related movements. The predicted valley related movements are provided in **Table 2**.

The maximum movements and therefore fracturing is predicted to occur in the base of the stream WC15. The headwater sections of Swamp 14 are located on the valley sides and flatter headwater areas and, therefore, in these areas the predicted upsidence and closure movements are less than the maxima provided in **Table 2**.

1.2 Environmental Consequences of Swamp 14 – Longwall 17

There is a local reduction in grade along Drainage Line WC15, adjacent to the tailgate of Longwall 15, i.e. at the downstream end of Swamp 14. However, only low-level vertical subsidence (i.e. in the order of 20 mm) is predicted in this location due to the extraction of Longwall 17. It is unlikely that there would be adverse changes in the levels of ponding or scouring at the downstream end of Swamp 14 due to the predicted additional subsidence induced tilt from Longwall 17.

Lowering of the shallow groundwater is likely from the diversion of water flows and increased void space created by the fracturing and dilation of strata due to subsidence. The predicted curvature and strain for Swamp 14 are shown in **Figure 1**.

Predicted subsidence for Swamp 14 were derived through a comparison of the pre-mining and predicted postmining surface level contours. Predicted changes in post-mining grade along WC15, within and near Swamp 14, are shown in **Figure 2**.

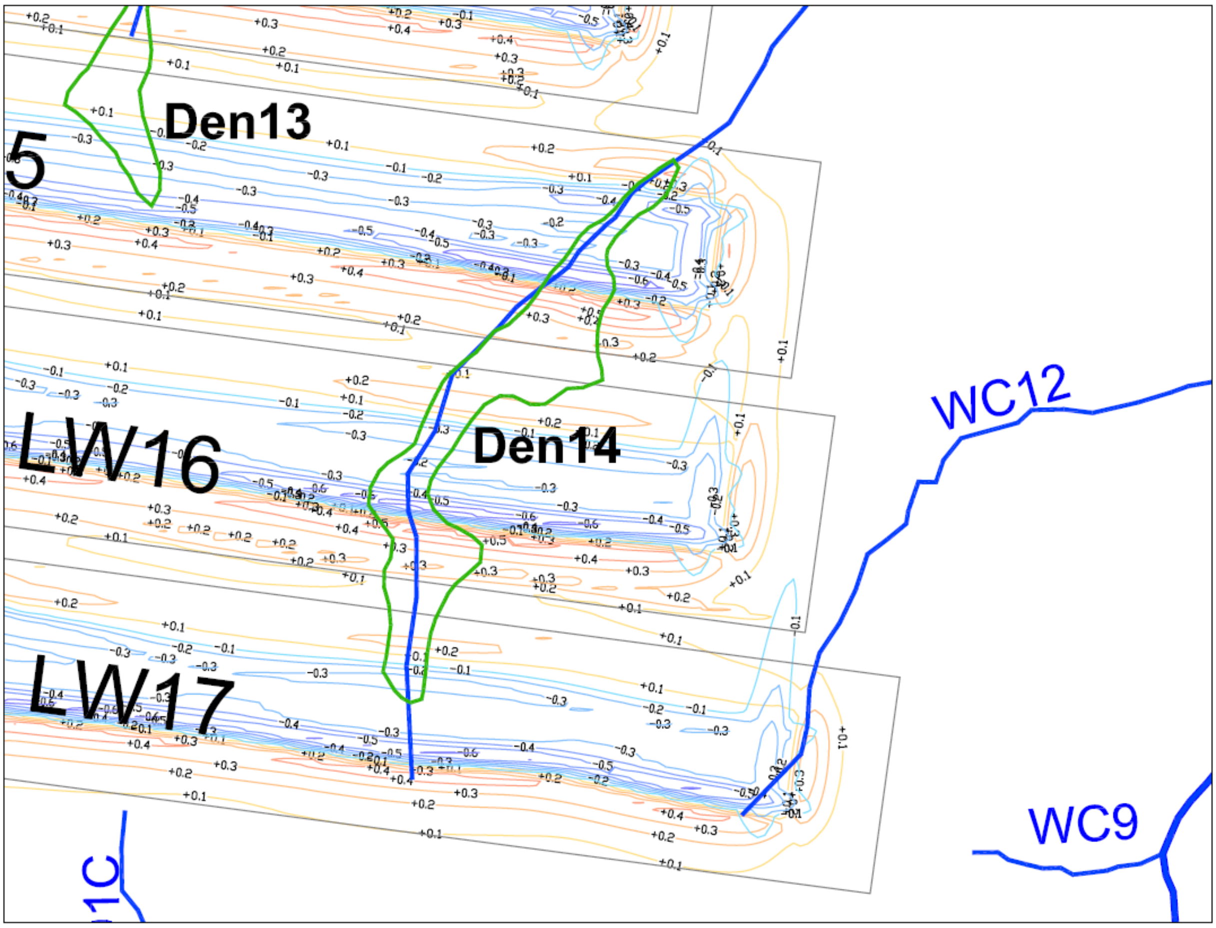


Figure 1 Predicted total hogging and sagging curvatures for Swamp 14 after Longwall 17

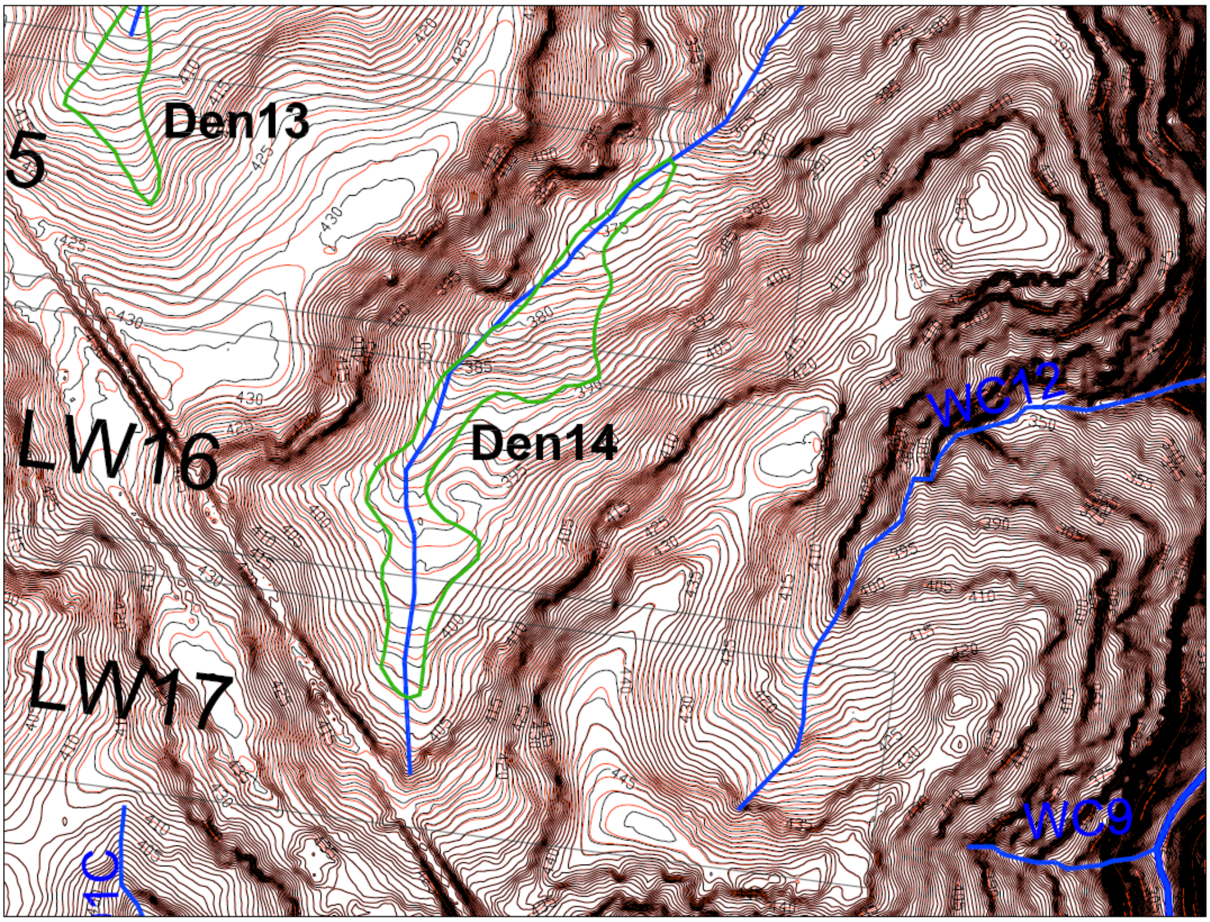


Figure 2 Existing and predicted post-mining surface levels for Swamp 14 after Longwall 17

1.3 Swamp 35a and 35b Predictions – Longwall 17

Swamps 35a and 35b will not be directly mined under by Longwall 17. Predicted subsidence at Swamps 35a and 35b is provided by MSEC (2018) and is based on the layout of the longwalls in Area 3B. Predictions for Swamps 35a and 35b are summarised in **Table 3** and **Table 4**.

Table 3 Maximum predicted subsidence parameters at Swamps 35a and 35b after the completion of Longwall 17

Swamp	Max predicted Cumulative Subsidence (mm)	Max predicted cumulative or travelling tilt (mm/m)	Max predicted cumulative or travelling hogging curvature (km-1)	Max predicted cumulative or travelling sagging curvature(km-1)
35a	< 20	< 0.5	< 0.01	< 0.01
35b	< 20	< 0.5	< 0.01	< 0.01

Table 4 Maximum predicted upsidence and closure at Swamps 35a and 35b after the completion of Longwall 17

Swamp	Max predicted total valley related upsidence (mm)	Max predicted total valley related closure (mm)	Max predicted total conventional closure (mm)
35a	75	100	<50
35b	50	100	<50

Conventional strains at the swamp can be determined by applying a factor of 15 to the predicted conventional curvatures. Observed strains greater than the predicted conventional strains can occur as the result of, a number of factors, including non-systematic anomalous movements and valley related movements. The predicted conventional curvatures at Swamps 35a and 35b are illustrated in **Figure 3**.

Tensile strains greater than 0.5 mm/m may be of sufficient magnitude to result in fracturing in the bedrock. Compressive strains greater than 2 mm/m may be of sufficient magnitude to result in bedrock fracturing, buckling and dilating. Based on the predicted maximum tensile and compressive strains induced by conventional subsidence that will occur in Swamp 35a and the valley related movements predicted for Swamps 35a and 35b, as a result of the extraction of Longwall 17, it is likely that fracturing in the bedrock will occur.

The maximum predicted tilt for Swamp 35b, which is located outside the extents of the longwalls, is less than 0.5 mm/m (i.e. less than 0.1 %, or 1 in 2000).

Swamp 35b is located outside of the mining area. This swamp is predicted to experience a tilt of less than 0.5 mm/m (i.e. less than 0.5 %, or 1 in 2000). It is unlikely, therefore, that this swamp would experience adverse changes in the levels of ponding or scouring based on the predicted tilt.

As Swamp 35b will not be mined beneath, it is likely any fracturing within this swamp will be concentrated in the lower sections of the valley where closure movements are expected to occur shown in **Table 4**.

1.4 Environmental Consequences of Swamps 35a and 35b – Longwall 17

Fracturing is likely to result in diversion of water into the dilated strata leading to loss of pool water level and surface flow. Any diverted surface water flow which is not captured into deeper storage is likely to re-emerge at the surface. This would occur at the limit of subsidence induced fracturing downstream of Swamps 35a and 35b in ND1. Lowering of the shallow groundwater is likely to result from diversion of water flows and increased void space created by the fracturing and dilation of strata due to subsidence. The predicted curvature and strain for Swamps 35a and 35b are shown in **Table 3**.

Predicted subsidence for Swamps 35a and 35b were derived through a comparison of the pre-mining and predicted post-mining surface level contours and this is provided in **Figure 4**.

Predicted changes in post-mining grade along ND1, within and near Swamps 35a and 35b, are similar to the natural grades and, therefore, it is not expected that there would be adverse changes in the levels of ponding or scouring within the swamp due to mining induced tilt.

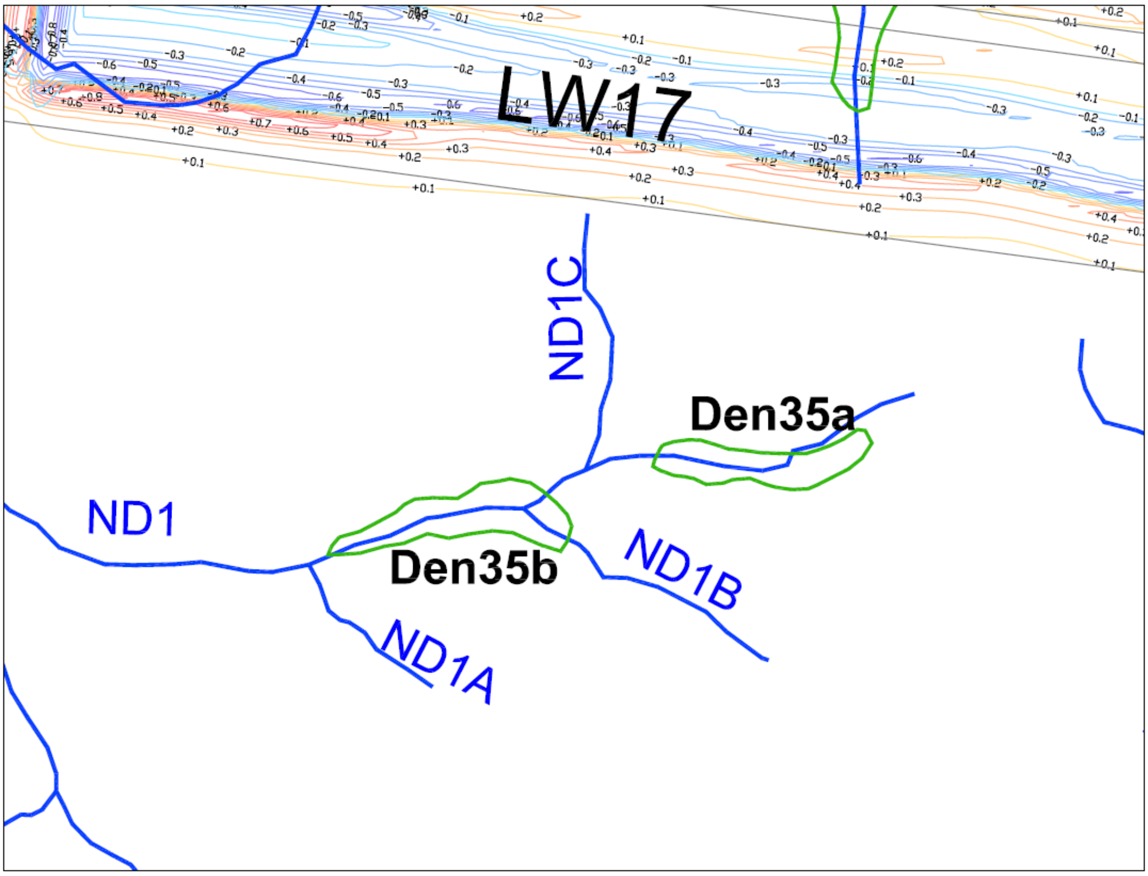


Figure 3 Predicted total hogging and sagging curvatures for Swamp 35a after Longwall 17

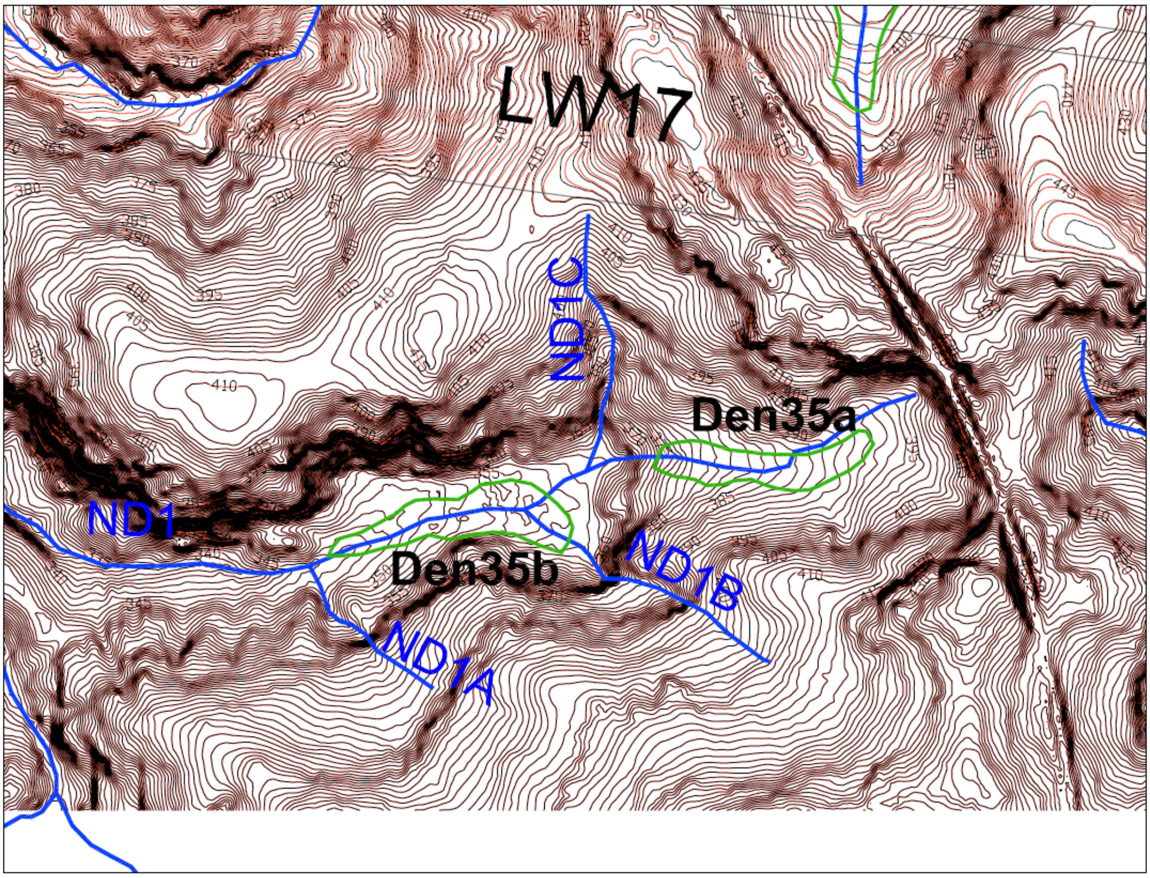


Figure 4 Existing and predicted post-mining surface levels for Swamp Den35a after Longwall 17

1.5 End of Panel Longwall 15 (HGEO 2020)

Shallow Groundwater Levels

Longwall 15 passed directly beneath Swamp 14 piezometer 14_02 on 24 November 2019 and passed piezometer 14_01 at 260 m (at its closest point) on 13 October 2019. Previously, Longwall 14 passed within 400 m of piezometer 14_02 in late January 2019. Swamp 14 at piezometer 14_02 indicated saturated conditions for most of the time between July 2015 and late 2017 and, like several reference sites, recorded groundwater levels below the base of the piezometer for more than 50% of the time during the 2017-2020 drought period.

Moderate rainfall events in early to mid-2019 resulted in saturation of swamp sediments and groundwater recession rates similar to the pre-drought period. The large rainfall event in February 2020 resulted in saturation for a short period with a relatively quick recession (>100 mm/day) compared with previous similar rainfall events (**Figure 5**). It is concluded that fracturing of the sandstone substrate has resulted in a change in swamp sediment saturation duration at Swamp 14 piezometer 02. The effects are in line with those at other directly undermined swamp piezometers and triggers a Level 2 TARP.

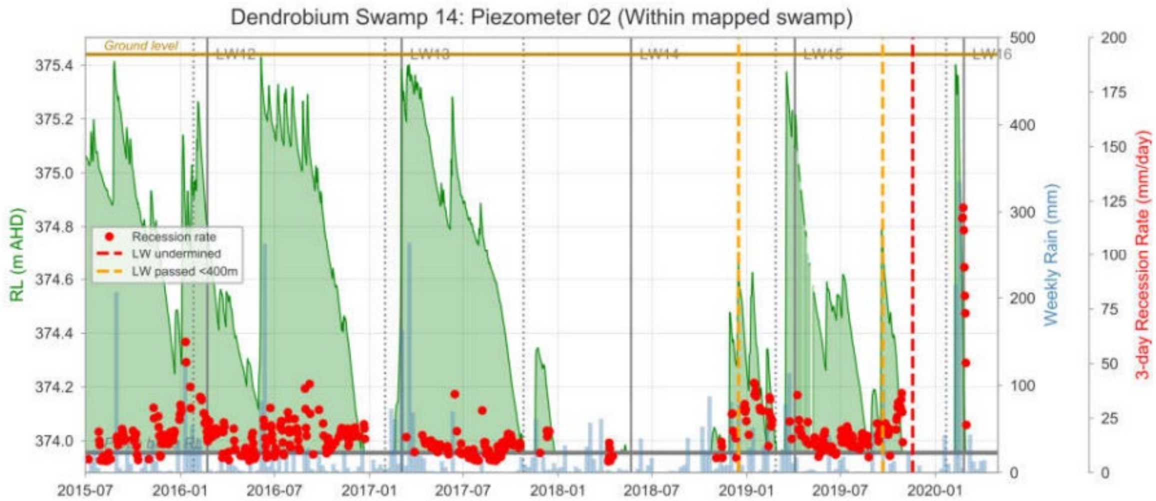


Figure 5 Shallow groundwater hydrograph for Swamp 14, piezometer 02

Swamp 14 piezometer 01 is located up-gradient of piezometer 02. Longwall 15 passed within 400 m of the site between September and December 2019 (closest approach 260 m on 13/10/2019).

Piezometer 01 records permanent saturation of swamp sediments between mid-2015 and 2020 with characteristics similar to the reference Swamp 22 piezometer 01. Piezometers installed to monitor groundwater levels within the sandstone substrate (HBSS) adjacent to Swamp 14 (S2351 and S2354) record piezometric levels that range between ~390 mAHD and ~393.5 MAHD with transient responses to rainfall in the order of 1 m to 1.5 m. The range in piezometric level within the sandstone overlaps with the elevation of the base of the swamp at 14_01 indicating that swamp sediment saturation is partially sustained by discharge from the adjacent and underlying sandstone (**Figure 6**).

The lowest shallow groundwater levels at piezometer 14_01 were recorded in late 2019 during the close approach of Longwall 15. Slight compression (groundwater level rise) then depressurisation is noted in the sandstone substrate following the passage of Longwall 15 (**Figure 7**) which potentially could have influenced groundwater levels within the swamp. However, the period also coincides with a low rainfall period towards the end of a prolonged drought. Recession rates remained similar to pre-Longwall 15 rainfall events. It is concluded that there has been no significant (detectable) change to saturation characteristics at piezometer 14_01 following the passage of Longwall 15.

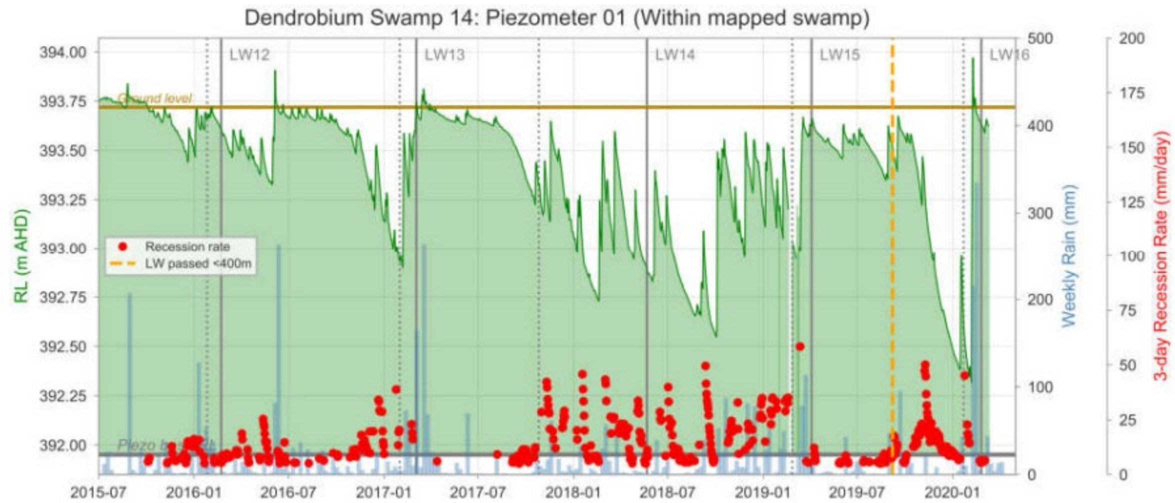


Figure 6 Shallow groundwater hydrograph for Swamp 14, piezometer 01

Figure 7 Groundwater hydrograph for S2354 (215 m from Swamp 14 piezometer 01)

Longwall 15 passed directly beneath Swamp 14 piezometer 14_02 on 24/11/2019 and passed piezometer 14_01 at 260 m on 13/10/2019. Previously, Longwall 14 passed within 400 m of piezometer 02 in late January 2019. Swamp 14 at piezometer 02 was saturated most of the time between July 2015 and late 2017 and, like several reference sites, recorded groundwater levels below the base of the piezometer for more than 50% of the time during the 2017-2020 drought period.

Soil Moisture

Significant changes in soil moisture characteristics compared with baseline monitoring is identified as an indicator of potential changes in ecosystem functionality of the swamps. Performance criteria and TARPs related to soil moisture at swamp monitoring sites are listed in the SIMMCP.

The TARP has been assessed by comparing the average moisture content of the soil profile during the longwall assessment period against that of the baseline period. If the average soil moisture level drops below the minimum level recorded during the baseline period, a TARP is triggered. Soil moisture hydrographs for all active monitoring locations are presented in Appendix E of HGEO (2020).

Average soil moisture declined to below baseline levels at Swamp 14 locations S01 and S02 triggering a Level 3 TARP.

Summary

It was predicted that Swamp 14 would be affected by mine subsidence due to mining in Area 3B. Both shallow groundwater levels and soil moisture levels in reference swamps were anomalously low during the assessment period in response to drought conditions. Rapid recovery in both shallow groundwater and soil moisture occurred in response to rain in early 2020.

Longwall 15 passed beneath parts of Swamp 14 during 2019. The saturation and recession behaviour at Swamp 14 piezometer 02 was affected by Longwall 15. Impact triggered a Level 2 TARP and are in line with impacts anticipated in the SMP. Average soil moisture declined to below baseline levels at Swamp 14 locations S01 and S02 triggering a Level 3 TARP.

1.6 Terrestrial Flora Assessment

Longwall 15 passed directly beneath Swamp 14 in November 2019. As Swamp 14 would have been impacted by mining from this month it has been included as an impact site in the Dendrobium Terrestrial Ecology Monitoring Program to monitor against the swamp size, ecosystem functionality and species composition and distribution TARPs. Assessment of Swamp 14 against these TARPs will be presented in the 2020 terrestrial ecology report.

1.7 End of Panel Longwall 16

Longwall 16 passed directly beneath Swamp 14 in August of 2020. Impacts from mining will be presented in the Longwall 16 End of Panel report, available in April 2021.

2 REFERENCES AND SUPPORTING DOCUMENTATION

HGEO, 2020. Dendrobium Mine End of Panel surface water and shallow groundwater assessment: Longwall 15 (Area 3B) (No. D20358), Report by HGEO Pty Ltd for South32 Illawarra Coal.

MSEC, 2007. Dendrobium Mine Area 3A Longwalls 6 to 10. Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of proposed Longwalls 6 to 10 in Area 3A at Dendrobium Mine in Support of the SMP and SEMP Applications. September 2007.

MSEC, 2012. Dendrobium Area 3B Subsidence Predictions and Assessments for Natural Features and Surface Infrastructure in Support of the SMP Application.

MSEC, 2015. Dendrobium Area 3B – Longwalls 12 to 18 Review of the Subsidence Predictions and Impact Assessments for Natural and Built Features in Dendrobium Area 3B based on Observed Movements and Impacts during Longwalls 9 and 10.

MSEC, 2017. Dendrobium mine – Area 3B. The Effects of the Proposed Modified Commencing Ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. MSEC914 August 2017.

MSEC, 2018. Dendrobium – Longwalls 17 and 18. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of Longwalls 17 and 18 in Area 3B at Dendrobium Mine. MSEC992 November 2018.

Niche Environment and Heritage, 2020. Dendrobium Longwall 18 Terrestrial Ecological Assessment. South 32 Illawarra Metallurgical Coal. August 2020.