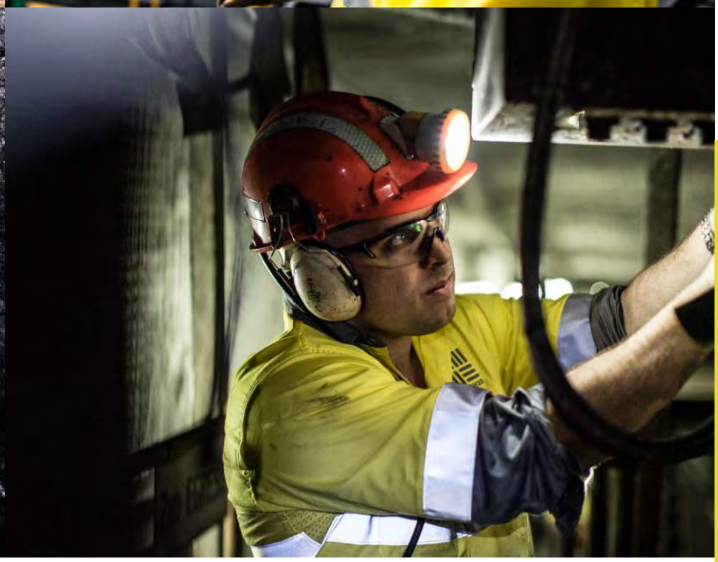
SOUTH32

DENDROBIUM
AREA 3B

OCTOBER 2015



WATERCOURSE IMPACT MONITORING MANAGEMENT AND CONTINGENCY PLAN

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Attachments

Attachment 1 – TARP 137

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	November 2013	GB
1.2	Updated to address Agency Feedback December 2013 – March 2014	June 2014	GB
1.3	Updated to address DoPE Feedback October 2014	December 2014	GB
1.4	Updated to address DoPE Feedback May 2015	May 2015	GB
1.5	Updated to address Longwalls 14 – 18 requirements	October 2015	GB

Persons involved in the development of this document include:

Name	Title	Company
Josh Carlon	Environmental Coordinator	Illawarra Coal
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1 INTRODUCTION

1.1 PROJECT BACKGROUND

Illawarra Coal (IC) 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.

IC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007 IC 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 IC submitted a Subsidence Management Plan (SMP) for approval from the Director Generals (now Secretaries) of the Department of Planning and Infrastructure (now the Department of Planning and Environment, DoPE) 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 DoPE 6 February 2013.

1.2 SCOPE

The WIMMCP has been prepared to comply with the Dendrobium Consent and the SMP Approval in respect to surface water management within Dendrobium Area 3B.

The Dendrobium Mine revised Consent requires a WIMMCP subject to Schedule 3 Condition 4 as provided below.

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

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

The SMP Area for the WIMMCP is defined in accordance with Mine Subsidence Engineering Consultants (MSEC 2012), as the surface area that is likely to be affected by the proposed mining of Longwalls 9 to 18 in Dendrobium Area 3B. The extent of the SMP Area has been calculated by combining the areas bounded by the following limits:

- A 35 degree angle of draw from the proposed extents of Longwalls 9 to 18,
- The predicted limit of vertical subsidence, taken as the 20mm subsidence contour resulting from the extraction of the proposed Longwalls 9 to 18,
- The natural features within 600m of the extent of the longwall mining area, in accordance with Condition 8(d) of the 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 watercourses 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 location of the watercourses in respect of Dendrobium Area 3B is shown in **Figure 1-1**.

This WIMMCP addresses:

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

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

1.3 OBJECTIVES

The objectives of this WIMMCP are to identify at risk watercourse features and characteristics within the Dendrobium 3B Study Area (**Figure 1-1**) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on watercourses. The WIMMCP is to comply with the Area 3B SMP Approval Conditions including Condition 9 Performance Measures for Area 3B.

1.4 CONSULTATION

This WIMMCP was developed by IC, with drafts distributed for comment to:

- DoPE; OEH; NoW; T&I; and
- Water NSW (previously SCA).

The WIMMCP and other relevant documentation are available on the IC website (*Condition 11 Schedule 8*).

1.4.1 SMP and SIMMCP Consultation

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

1.4.2 SMP Condition 11 WIMMCP Revision

The Secretary of DoPE approved the Dendrobium Area 3B SMP 6 February 2013. Condition 11 of this approval requires the WIMMCP be reviewed to the satisfaction of the Secretary by 31 May 2013. The WIMMCP was redrafted to take into account feedback during SMP consultation as well as the conditions and performance measures included in the Area 3B SMP Approval. The revised WIMMCP was provided to DoPE, OEH, NoW, WATER NSW and T&I 10 May 2013. The WIMMCP (Rev 1.4) was approved by the Secretary 10 August 2015.

1.4.3 Agency Workshop - May

The Wollongong Office of T&I hosted a joint agency workshop with IC to discuss the WIMMCP. The workshop was held 27 May 2013 with the following agencies attending DoPE, OEH, Water NSW and T&I.

Following the workshop the agencies provided submissions:

- Minutes of the workshop 5 June 2013;
- DoPE 4 June 2013;
- Water NSW 13 June 2013; and
- OEH 14 June 2013.

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

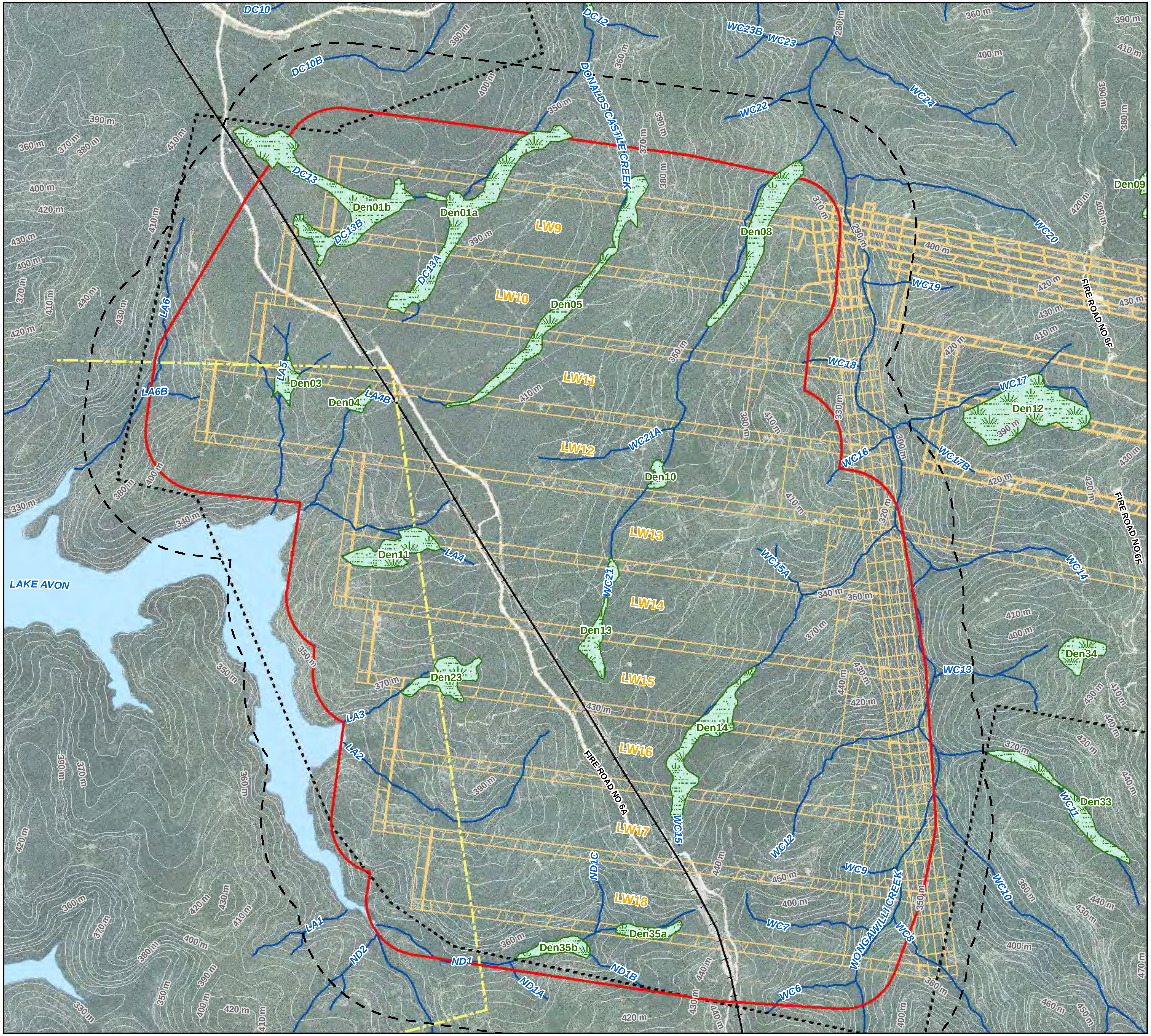
1.4.4 Agency Workshop - December

The Wollongong Office of T&I hosted a second joint Agency workshop with Illawarra Coal to discuss the WIMMCP. The workshop was held 16 December 2013 with the following agencies attending DoPE, OEH, Water NSW and T&I.

Following the workshop the Agencies provided submissions:

- T&I 10 January 2014;
- OEH 17 January 2014; and
- Water NSW 7 February 2014.

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



bhpbilliton
ILLAWARRA COAL

Site Plan

DENDROBIUM AREA 3B SMP

Legend

- 600m Study Boundary - Condition 8(d)
- SMP Area
- Dendrobium Area 3
- DSC Notification Zone
- Maldon to Dombarton Rail
- Proposed Longwall Layout (BHPBIC, 2012)
- Stream Features
- Waterbodies (LPI)
- Area 3B Swamps (BHPBIC, 2011)

N
W E
S

FIGURE 1-1

1:17,500 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-28
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1039_SitePlan.mxd 02

Data supplied by MSEC (2012) unless otherwise stated
Aerial imagery supplied by BHPBIC (2009)

2 PLAN REQUIREMENTS

Extraction of coal from Longwalls 9 to 18 will be in accordance with the conditions set out in the Dendrobium Area 3 Modified Approval and the requirements of the Area 3B SMP as well as conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds in order 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.

Details of surface water monitoring incorporating detailed provisions for water quality and hydrographic monitoring and the interpretation of data are provided in Appendix A of the Surface Water Quality and Hydrology Assessment (Attachment B of the SMP). The monitoring program is incorporated into this plan and the Area 3B SMP.

The Area 3B monitoring and assessment programs will provide ongoing water-related monitoring of the streams and sub-catchments potentially affected by the mining of Dendrobium Area 3B and allow assessment of the magnitude of any developing trends in overland and subsurface flow and water quality effects as a result of the mining. The Dendrobium Area 3B watercourse monitoring is summarised as Attachment 1.

The Strahler stream classification system is commonly used to define the class of a watercourse and was used in the Southern Coalfield Inquiry. Streams are classified based on the number of contributing tributaries, with headwater streams classed as first and second order streams and third and higher order streams being given the classification as ‘streams of significance’. The Southern Coalfield Inquiry recommends that assessments should focus on these higher order streams. Within Area 3B, Wongawilli Creek is classed as a third order stream and Donalds Castle Creek is classed as a second order stream. Other unnamed drainage lines within Area 3B are first or second order streams.

The baseline assessments on first, second and third order streams as well as associated features such as swamps are summarised below and comprehensively described in the Dendrobium Area 3B SMP (Cardno 2012). The monitoring locations for watercourses within Dendrobium Area 3B will be reviewed as required and can be modified (with agreement) accordingly.

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.

2.1 DENDROBIUM MODIFIED DA60-03-2001 APPROVAL

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 WIMMCP and where the conditions are addressed.

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

Project Approval Condition	***Relevant WIMMCP Section***
Condition 2 – Schedule 3 The Applicant shall ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than “minor impacts” (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.	Sections 3, 4 and 5

Project Approval Condition	***Relevant WIMMCP Section***
Condition 3 – Schedule 3 The Applicant shall ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.	Sections 3, 4 and 5
Condition 4 – Schedule 3 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;	Sections 3, 4 and 5
(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) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;	Section 2 and Attachment 1
(c) include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function;	Section 2 and Attachment 1
(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses; include a tabular contingency plan (based on the Trigger Action Response Plan structure) which focuses on measures for remediating both predicted and unpredicted impacts on watercourses;	Section 5 and Attachment 1
(e) address third and higher order streams individually but address first and second order streams collectively;	Sections 4
(f) be prepared in consultation with DECC, Water NSW and DPI;	Section 1.4
(g) incorporate means of updating the plan based on experience gained as mining progresses;	Section 7.6
(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and	Section 1.4.2
(i) be implemented to the satisfaction of the Secretary.	

2.2 DENDROBIUM AREA 3B SMP

The Dendrobium Mine Area 3B SMP Schedule 3 Condition 4 requires the WIMMCP to be revised as provided below.

Watercourse Impact Monitoring, Management and Contingency Plan

11. By 31 May 2013, the Applicant shall review the Watercourse Impact Monitoring, Management and Contingency Plan for Area 3B prepared under Condition 4 of Schedule 3 of DA 60-03-2001 to provide for achievement of the performance measures listed in Table 1, to the satisfaction of the Secretary.

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

Performance Measures for Area 3B

9. The Applicant shall ensure that the development does not cause any exceedance of the performance measures in Table 1, to the satisfaction of the Secretary.

Waterfall WC-WF54

- *Negligible environmental consequences including:*
  - *no rock fall occurs at the waterfall or from its overhang;*
  - *no impacts on the structural integrity of the waterfall, its overhang and its pool;*
  - *negligible cracking in Wongawilli Creek within 30m of the waterfall; and*
  - *negligible diversion of water from the lip of the waterfall.*

Wongawilli Creek and Donalds Castle Creek

- *Minor environmental consequences including:*
  - *minor fracturing, gas release and iron staining; and*
  - *minor impacts on water flows, water levels and water quality.*

2.3 LEASES AND LICENCES

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

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

Table 2-2 Dendrobium Leases

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

2.4 AREA 3B WATERCOURSES

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of the watercourses (**Figure 1-1**).

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, 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 the Study Area is Wongawilli Creek which is located between Areas 3A and 3B. The headwaters of Wongawilli Creek are located along a drainage divide separating runoff and shallow groundwater outflow from Native Dog Creek and Lake Avon to the west.

Donalds Castle Creek and its tributaries also drain the north western part of Area 3B through a weakly incised plateau.

The south-western area drains directly to Lake Avon via five 1st and 2nd order streams designated as Native Dog Creek tributary No. 1, LA2, LA3, LA4 and LA5.

The geomorphology of 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.

Wongawilli and Donalds Castle Creeks are permanent to perennial flowing streams with small base flows and increased flows for short periods of time during and after significant rain events.

Table 2-3 Summary of Watercourses within the Study Area

Watercourse	Catchment	Monitoring
Donalds Castle	Donalds Castle	Water Quality, Observations, Photo, Water Level, Flow
DC13	Donalds Castle	Water Quality, Observations, Photo, Water Level, Flow
Wongawilli	Wongawilli	Water Quality, Observations, Photo, Water Level, Flow
WC21	Wongawilli	Water Quality, Observations, Photo, Water Level, Flow
WC18	Wongawilli	Water Quality, Observations, Photo, Water Level (sites to be determined)
WC16	Wongawilli	Water Quality, Observations, Photo, Water Level (sites to be determined)
WC15	Wongawilli	Water Quality, Observations, Photo, Water Level
WC12	Wongawilli	Water Quality, Observations, Photo, Water Level (sites to be determined)
WC9	Wongawilli	Water Quality, Observations, Photo, Water Level (sites to be determined)
WC8	Wongawilli	Water Quality, Observations, Photo, Water Level (sites to be determined)
WC7	Wongawilli	Water Quality, Observations, Photo, Water Level (sites to be determined)
WC6	Wongawilli	Water Quality, Observations, Photo, Water Level (sites to be determined)
Native Dog	Native Dog	Water Quality, Observations, Photo, Water Level
ND1	Native Dog	Water Quality, Observations, Photo, Water Level (sites to be determined)
LA2	Lake Avon	Water Quality, Observations, Photo, Water Level

LA3	Lake Avon	Water Quality, Observations, Photo, Water Level
LA4	Lake Avon	Water Quality, Observations, Photo, Water Level, Flow
LA5	Lake Avon	Water Quality, Observations, Photo, Water Level

2.5 OBSERVATIONAL AND PHOTO POINT MONITORING

IC has conducted ongoing monitoring of watercourses in the Dendrobium area since 2001 (**Figure 2-1**). This monitoring builds upon the understanding of processes within the watercourses, along with identifying and assessing any episodic or temporal changes.

This monitoring (along with other monitoring programs described in the WIMMCP) is consistent with (in part) Condition 4 – Schedule 3 "*include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function*".

The IC Environmental Field Team is continuing to undertake a structured monitoring assessment, including:

- 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 (Attachment 1)**. Additional monitoring within Dendrobium Area 3B will be installed ahead of mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring).

Observations of any surface water and vegetation health for prominent species are made at observation sites. Where surface water is present within a swamp or a watercourse the data collected includes water quality parameters (using a monitoring probe) and water levels from installed benchmarks established at the pool. Observations of any surface flow are also made during monitoring.

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

The following Area 3B impact (**Figure 2-2 to Figure 2-11 and Figure 2-25 to Figure 2-32**) and reference (**Figure 2-12 to Figure 2-25, Figure 2-28 to Figure 2-30, Figure 2-33 to Figure 2-35**) sites are included in the observational and photo point monitoring program:

- Impact sites:
  - WC21, Native Dog, Wongawilli and Donalds Castle Creeks (commenced 2001);
  - Swamps 5, 10, 11, 13, 14, 23, 35a, and 35b (commenced March 2005);
  - WC15 and LA4 (commenced 2006);
  - DC13 (commenced 2011);
  - Swamps 1a and 1b (commenced May 2012);
  - Swamp 8 (commenced February 2013); and
  - LA4 and LA5 (commenced May 2013);

  - Swamp 4 (commenced December 2013);
  - Swamp 3 (commenced January 2014);
  - WC16 and WC18 (commenced October 2015); and
  - ND1, WC6, WC7, WC8, WC9, WC12, (to commence prior to mining).
- Reference sites:
  - Swamps 2, 7, 15a, 22 (tributary to Cordeaux River), 24, 25, 33, 84, 85, 86, 87 and 88.
  - Wongawilli Creek, Sandy Creek, LC7B (tributary to Lake Cordeaux), WC11 (Swamp 33), SC9A (Swamp 84), SC10A, NDC1, DC10 (Swamp 85), D10 and Gallahers Creek (Swamp 88).

2.6 SURFACE WATER LEVELS AND FLOWS

Pool water levels in swamps and streams are measured using installed benchmarks in impact sites (**Figure 2-25 to Figure 2-32**) and reference sites (**Figure 2-16, Figure 2-19, Figure 2-25, Figure 2-28 to Figure 2-30, Figure 2-33 and Figure 2-34**). Water level/flow gauges and data loggers are installed at key stream flow monitoring sites (**Figure 2-35**). Data has been collected since 2003 and has been compiled within monitoring and field inspection reports (IC 2011), End of Panel 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, on a weekly basis during active subsidence and in response to any identified impacts. 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 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 key data to assess the Wongawilli and Donalds Castle Creek Performance Measure; "Minor environmental consequences including":

- Minor fracturing; and
- Minor impacts on flows and pool water levels.

This monitoring also provides key data to assess the Waterfall WC_WF54 Performance Measure; "Negligible environmental consequences including":

- Negligible cracking in Wongawilli Creek within 30m of the waterfall; and
- Negligible diversion of water from the lip of the waterfall.

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.

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. Due to the general requirement to not install V notch weirs or other large artificial flow controls within the catchment areas, the sites are predominately installed using natural flow control features such as rockbars. For this reason, the monitoring program focuses largely on recessional, baseflow and small storm periods where the flow data is of sufficient quality i.e. lies below the upper limit of validity of the rating curve. These sites are not installed directly over the longwalls as mining induced surface fracture networks typically result in receding flows being entirely diverted below the surface. The downstream monitoring sites are specifically designed to answer the question: do diverted flows within the surface fracture network return to the surface downstream of the mining area.

Hydrologic modelling and assessments in the area have used the Free University of Amsterdam non-linear hydrologic model RUNOFF2005. The model is similar to other popular lumped-parameter models e.g. the Australian SIMHYD. This model has been successfully used for the Native Dog, Sandy, Wongawilli, Donalds Castle Creek and a number of sub-catchments (**Figure 2-36**). Hydrologic assessment will continue to be based on application of the RUNOFF2005 model or other suitable model as circumstances require.

Hydrographic monitoring is based on sites located within the main channels of the principal creeks (Wongawilli and Donalds Castle) as well as some key tributaries (e.g. tributaries flowing directly to Lake Avon). The reasons for adopting this monitoring plan are as follows:

- RUNOFF2005 requires a continuous dataset of valid daily flows which in turn mandates that a monitoring site be wet or flowing for extended periods;
- There is a requirement to monitor main channels contributing to catchment water supply; and
- Main channel sites are more amenable to instrumentation and automatic flow monitoring (once a rating curve is established).

The present hydrographic monitoring and the hydrologic assessment methodology build on lessons learnt from earlier assessments in Areas 2 and 3A. It is designed to detect statistically significant hydrologic impacts of mine subsidence within the catchments which include swamps and streams. Multiple modelled periods of recessional, baseflow and small storm unit hydrograph periods have produced mean estimated water balances lying within about ±6% of average annual precipitation at the one standard deviation level and within about ±12% at the two standard deviation level.

It is important to note that these mean (statistical) errors have been established by many model runs and the mix of errors is both positive and negative when modelling discrete periods. A finding of a statistically significant (i.e. >6% change at one standard deviation) catchment water balance discrepancy during modelled periods of recessional, baseflow and small storm unit hydrograph periods (as defined in the TARP) will result in assessment and checking for an explanation for the event.

The variation has many sources but particularly arises because the precision of flow gauging is largely dictated by the restrictions on height and type of gauging structures and hence on the (upper) limits of validity of the measured rating curves.

There are also other confounding effects such as; fouling of gauging locations by natural woody and leaf materials, spatial heterogeneity of rainfall between a specific subcatchment and the Area 3 Centroid pluviometer, spatial heterogeneity of evapotranspiration (ET) due to variation in cloud cover (irradiance) and wind etc., all contributing to those estimated values of ±6%, ±12% and ±18% for one, two and three standard deviations in water balance.

Furthermore, Area 3B is an environment where ET is comparable to precipitation (P). Environments such as this, lying in the transition zone between humid and semi-arid are the most difficult to model quantitatively due to the closeness of P and ET.

Because the modelled periods are mostly restricted to periods of recession and baseflow and only offer (for model fitting) the smallest discrete storms (and hence whole unit hydrographs) lying within the limit of validity of the rating curves (for mostly natural controls and or only very low profile weirs) it may be inferred such periods are those where the above variations are maximal. Conversely, the much shorter, un-modellable peak periods when flows lie above the limits of validity of the rating curves represent the larger storm events/outflow periods wherein possible (available) variation in the water balance is least because then Q (outflow) almost equals P (rainfall) over a few days.

Hence, estimates of the precision of water balances for validly gauged periods listed above are, by definition, conservative i.e. they must err on the positive side when annualized to cover a period within which non-gaugeable/non-modellable higher storm-based outflows occur.

Water NSW have expressed concerns that a statistically significant change of 6% of average annual precipitation would in reality mean 12% change due to catchment yield corresponding to 50% of the average annual precipitation. However, it is the case that by annualizing modelled catchment yield error (discrepancy) based on the mid to late recessional and small storm catchment flows only, effectively scales up the stated annual error, and therefore overstates the error rather than understates the error i.e. it is a conservative approach.

If one assumed annual catchment yield corresponds to (say) 50% mid to late stage recession and base flows, then we can assume that the remaining 50% of the annual precipitation would be made up of high storm flows which are unable to be gauged. If you were to assume to a good first approximation that that portion of the water balance has no significant errors at all (by comparison with the low flow gauged and modelled periods) then the effective error in the real overall water balance would be almost halved over the approach adopted, not doubled i.e. 6% would become 3%, 12% would become 6% and so on.

IC commissioned the development of a regional-scale numerical groundwater flow model in support of the approval process for mining of Area 3B at Dendrobium Colliery (Coffey Geotechnics 2012). The Area 3B SMP Approval Condition 13 requires review of the Area 3B Groundwater Model to the satisfaction of the Secretary. IC commissioned HydroSimulations (2014) to undertake this review and enhancements to the Model.

One of the enhancements to the Model was to interchange the MODFLOW Drain boundary condition, which was previously used to simulate creeks and rivers, for the Stream Flow Routing (SFR1; Prudic et al., 2004) boundary condition. This provides a ‘stepping stone’ toward integrated groundwater and surface water flow modelling, which is a critical avenue for potential mining impacts to water supply reservoirs around Dendrobium Mine. It also provides a more rigorous tool for simulating potential impacts on swamps, creeks and rivers than does the Drain boundary. Furthermore, it is better suited to achieving adequate calibration to shallow groundwater level data.

This SFR1 boundary condition has the ability to route accumulated stream flows (baseflow plus runoff) down the stream network from headwaters to catchment outlets; i.e. it maintains both the groundwater and surface water balance. It can also simulate extractions from and discharges to watercourses. The SFR1 boundary operates distinctly differently to the Drain boundary condition, which operates as a simple head-dependent drain on the groundwater system, from which water is removed from the model once it discharges into the drain. The Drain boundary does not maintain the surface water and groundwater balance throughout the catchment, as does the SFR1 boundary.

The SFR1 boundary therefore enables more rigorous assessment of potential risks to creeks, rivers and water supply reservoirs, and provides a stepping stone towards integrated groundwater-surface water flow modelling and calibration to gauged stream flows for future model development as required.

Calibration of the Model to the gauged stream flows was undertaken for the four gauges which possess observations over the calibration model time period (WWL (300022), DCU (300023), WWU (300024) and SCL (Water NSW data). This was achieved through the incorporation of the EcoEngineers (2013) rainfall-runoff model outputs into the SFR1 boundary outputs of the groundwater model. That is, ‘quickflow’ (i.e. runoff and interflow) from the EcoEngineers models was added to the baseflow simulated by the SFR1 boundaries in the groundwater model.

2.7 NEAR SURFACE GROUNDWATER AND SOIL MOISTURE

The surface area above the Dendrobium Area 3B longwalls 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). A knowledge of the interaction between water infiltration mechanisms (on the ridges, slopes and depressions), water storage capacity, and water transmission properties of the sediments, underlying strata and surface water system is essential to understand any potential effects of longwall mining on watercourses.

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 within and around a number of swamps and associated watercourses in Area 3 (**Figure 2-1**), including the hill-slope aquifers on the eastern side of Sandy Creek; within Swamp 15b (SC10C) and Swamp 12 (WC17). Within Area 3B long-term piezometer records are available for Swamp 11 (LA4A1) as well as additional sites installed since 2011 (**Figure 2-2 to Figure 2-11**). Swamps 2 (Donalds Castle Creek), 7 (LC7B Lake Cordeaux tributary), 15a (SC10), 22, 24, 25, 33 (WC11), 84 (SC9A), 85 (DC10), 86, 87 and 88 (Gallahers Creek) have been selected as reference monitoring sites (**Figure 2-12 to Figure 2-24**). This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Sites that will not be mined under are also monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles. The soil moisture probes previously used for monitoring multiple sites from surface to 1.1m depth have failed and are no longer supported by the manufacturer and have been discontinued. Replacement soil moisture probes have been installed and these monitor to a depth of 1.5m (**Figure 2-5 to Figure 2-24**). Key monitoring sites have been installed with loggers to provide a continuous soil moisture record.

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).

The most appropriate rainfall data will be used in reporting, taking into account an appropriate station for deriving long term (25 year plus) mean monthly rainfalls and hence cumulative residuals.

The mean monthly groundwater heads above the bottom of the piezometer will be plotted against estimated Cumulative Monthly Rainfall Residuals to identify longer term local wetting and drying phases taking into account the characteristic times of response (efolding time, reservoir coefficient) of shallow groundwater systems. This technique enables identification of those piezometers which are truly embedded in a shallow groundwater system and those which respond transiently to storm events. This assessment is undertaken for the site using data from the baseline period of monitoring such that it excludes any influence of mining.

Shallow piezometers embedded into the swamp/hill-slope aquifer will identify mine subsidence which results in changes to shallow aquifers. Where a piezometer is not embedded into the hill-slope aquifer they can provide less data on changes to the near surface groundwater response as there can be long periods where there is little or no free water within the borehole. It can take up to 12 months to determine whether a piezometer is totally embedded within the near surface hill-slope aquifer and this assessment will be reported in impact assessment and End of Panel Reports. Data from all piezometers will be reported, irrespective of whether it is embedded within the hill-slope aquifer or not.

The regional-scale numerical groundwater flow model enhancements HydroSimulations (2013) included the addition of a thin (nominally 2m thick) superficial layer to represent swamp deposits where they exist, and regolith otherwise. This allows inclusion of swamp and other 'shallow' groundwater level data for calibration, which were not utilised by Coffey (2012).

A combination of manual and automated (PEST; Doherty, 2012) calibration methods were used to alter the hydraulic conductivity (horizontal and vertical), specific yield and residual saturation of model layers 1 and 2 (i.e. swamp deposits, regolith and Upper Hawkesbury Sandstone), and Drain conductance within the mined Dendrobium area. All other parameters remained unchanged from those of Coffey (2012).

The calibration objective was to maintain as close a calibration (to deep groundwater levels and mine inflows) as possible (or better) to that reported by Coffey (2012), whilst altering model parameters as little as possible from those applied by Coffey (2012).

This approach was aimed at maintaining as consistent a predictive model as possible to that of the earlier modelling, whilst enhancing the model's capability in terms of simulating potential mining impacts on surface water systems.

The model was calibrated using the 96 shallow groundwater monitoring sites which possess recorded groundwater levels for the model calibration period. The groundwater model will be subject of ongoing development and calibration. IC has commissioned HydroSimulations (2014) to undertake these reviews and enhancements to the Model.

2.8 WATER QUALITY

Monitoring undertaken by IC since 2003 (**Figure 2-35**) 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 2-25 to Figure 2-32**) will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from mining (**Figure 2-25, Figure 2-28 to Figure 2-30 and Figure 2-33 to Figure 2-35**) are monitored to allow for a comparison against sites not influenced by mining. Over time some water quality-specific site names have changed. These changes have been implemented to align monitoring site's names with mapped stream features. These changes are shown in **Table 2-4** below.

Table 2-4 Changes to Water Quality site names

Previous Site Name	Current Site Name	Watercourse
SCL	SCk_Rockbar 5	*Sandy Creek*
WWL2	Wongawilli Ck (FR6)	*Wongawilli Creek*
WWM1	WC_Pool 46	*Wongawilli Creek*
WWM3	WC_Pool 43b	*Wongawilli Creek*
DC_S2	DC_Pool 22	*Donalds Castle Creek*
DCU3	Donalds Castle Ck (FR6)	*Donalds Castle Creek*
WC15_S1	WC15_Pool 9	*WC15*
WC21_S1	WC21_Pool 5	*WC21*
DC13_S1	DC13_Pool 2b	*DC13*

Pools within streams will be measured monthly before and following mining, weekly during active subsidence and in response to any observed impacts. The monitoring of water quality parameters provides a means of detecting and assessing the effects of streambed fracturing or induction of ferruginous springs. Assessment of water quality data will be supported by geochemical modelling using PHREEQC (Parkhurst and Appelo 1999) where required.

Trigger values are proposed for water quality parameters in the TARP (**Attachment 1**). The TARPs are based on the field parameters pH, EC and DO due to the ability of these parameters to indicate potential mining impacts on water quality, the rapid and in situ nature in which they are determined, and the quantity of baseline data available, which for Wongawilli and Donalds Castle Creeks is greater than 10 years (since August 2001).

Three standard deviations (enclosing approximately 99.7% of the baseline data assuming a normal distribution) from the respective parameter means will be used for determining potential exceedances of water quality performance measures.

Statistical analysis of baseline and impact period data will be provided in End of Panel (EoP) Reports, including clearly specifying the duration of the baseline monitoring period. Any historical mining outside the project area (e.g. Wongawilli Creek undermined by Elouera) will be acknowledged and if required reflected in the baseline monitoring assessment.

Exceedances of these levels have occurred occasionally in the baseline period. This is to be expected assuming a normal statistical distribution of the data, in addition to random natural environmental effects on water quality such as storms (effects of decomposition of detrital organic matter), wildfires (ash wash off and dissolution effects), prolonged dry weather and drought (evaporative concentration effects).

As such, exceedance of the water quality performance measures will be quantitatively defined by “mining resulting in exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean, for a minimum of two consecutive monitoring events”.

In a small number of cases an increase in pH has occurred as a result of fracturing within 1st and 2nd order streams. This has previously been reported in WC17 (Longwall 8 EoP Report) and WC21 (Longwall 9 Level 2 TARP Assessment Report).

Weathered Hawkesbury Sandstone contains Siderite ($FeCO_3$) which includes ferrous iron (Fe^{+2}) which oxidizes to create acidity where subsidence induced fracturing occurs. However, in a regional context the Sandstone can incorporate increased amounts of Ca and Mg in particular as Ankerite (an isomorphous with Siderite).

When this increased incidence of Ankerite applies it is likely the higher carbonate alkalinity released will both counteract and buffer (stabilize) any higher pHs caused by increased CO_2 outgassing due to increased turbulence overriding the tendency to low pH caused by the oxidation of the released Fe.

The core mechanistic issues behind an increased pH regime post-fracturing are:

- Higher order stream channels producing increased dissolved CO_2 outgassing due to increased turbulence which raises pH and opposes the tendency towards acidification caused by the released Fe; and
- The fracturing in this area has exposed less Siderite, but more Ankerite, with higher amounts of Mg, Mn and Ca relative to Fe and hence generating more carbonate alkalinity which buffers (stabilizes) the resulting higher pH.

The proposed water quality TARPs are based on environmental protection and in particular the pH TARP is based on potential ecotoxicity for the Area 3B waters resulting from lower pH levels. In the very dilute Area 3B waters, pool pH increases of the type seen in WC 17 and 21 will not impact ecotoxicity in the same way as a lower pH will.

The water chemistry, algae and level of water in Avon Reservoir will be monitored as a basis for comparison to the mine water. The locations of the samples and the testing procedure have been developed in consultation with the Dams Safety Committee (DSC) and Water NSW.

2.9 SLOPES AND GRADIENTS

Slopes within Area 3B have been mapped according to their gradients and are identified on Drawing 9 in MSEC (2012) as **Attachment A** of the SMP. Monitoring of landscape features such as cliffs, slopes and rock outcrop is undertaken in Area 3B (**Figure 2-37**).

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

The inspection and monitoring includes the following:

- 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.

It should be noted that not all attributes for Landform Element and Land Surface referred to in the Field Handbook are recorded for each monitoring site. The previous monitoring experience for Areas 1, 2 and 3A indicate that many of the attributes are of little importance to subsidence, and the monitoring for Area 2 and Area 3 has focused on recording those attributes and characteristics that are most relevant to subsidence impacts.

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, 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 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.

2.10 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). Landscape monitoring of slopes is undertaken in Area 3B to identify any erosion of the surface (**Figure 2-37**).

The Subsidence Monitoring Program proposed for Dendrobium Area 3B has been approved by the Principal Subsidence Engineer (T&I). An extensive survey network has been implemented which includes relative and absolute horizontal and vertical movements. Additional sites will be added to the monitoring program prior to subsidence movements impacting the sites.

Due to terrain, vegetation and access restrictions, the primary method of identifying any 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 erosion. The maximum areas, length and depth of erosion will be measured by standard survey methods.

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 pre-mining landscape model from the ALS scan of Swamp 1A is provided as **Figure 2-38**. This landscape model identifies active pre-mining erosion of 179m in DC13, adjacent to Swamp 1A, and 8m within the swamp. The erosion is not visible in orthophotos (**Figure 2-39**) prior to the area being burnt in 2001-2002. The erosion was identified in 2003 (**Figure 2-40**) and has persisted during and following extraction of Longwall 9 in 2013 (**Figure 2-41**).

The nominal accuracy of ALS derived subsidence contours are 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 the mining area will be undertaken at regular intervals, during active subsidence. 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 incorporates both impact (**Figure 2-2 to Figure 2-11 and Figure 2-25 to Figure 2-32**) and reference (**Figure 2-12 to Figure 2-24 and Figure 2-33 to Figure 2-35**) sites:

- Impact sites:
  - WC21, Native Dog, Wongawilli and Donalds Castle Creeks (commenced 2001);
  - Swamps 5, 10, 11, 13, 14, 23, 35a, and 35b (commenced March 2005);
  - WC15 and LA4 (commenced 2006);
  - DC13 (commenced 2011);
  - Swamps 1a and 1b (commenced May 2012);
  - Swamp 8 (commenced February 2013);
  - Swamp 4 (commenced December 2013); and
  - Swamp 3 (commenced January 2014).
- Reference sites:
  - Swamps 2, 7, 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88.
  - Wongawilli Creek, Sandy Creek, SC10, NDC1 and D10.

2.11 FLORA, FAUNA AND ECOSYSTEM FUNCTION

Terrestrial flora and vegetation communities in the Study Area are described in the SMP Terrestrial Ecology Assessment (Niche 2012). Aquatic flora and fauna in the Study Area are described in the SMP Aquatic Ecology Assessment (Cardno Ecology Lab 2012).

A monitoring program designed to detect potential impacts to ecology and ecosystem function from subsidence has been implemented for Area 3B. 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 (**Figure 2-1**).

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 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).

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 following frog monitoring is undertaken in Area 3B streams:

- DC13 commenced 2007 (**Figure 2-42**);
- DC(1) commenced 2012 (**Figure 2-43**);
- WC21 commenced 2012 (**Figure 2-44**);
- LA4A commenced 2007 (**Figure 2-45**);
- ND1 commenced 2011 (**Figure 2-46**); and
- WC15 commenced 2011 (**Figure 2-47**)

Additional monitoring will commence 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 2-48 to Figure 2-56**). 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.

Along each transect the monitoring includes: counts of frogs, an assessment of pools being used for breeding as well as counts of tadpoles and egg masses. 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 2-42 to Figure 2-47**). Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

Aquatic ecology monitoring includes direct measures of aquatic flora and fauna as well as biophysical measures. Aquatic ecology monitoring sites for Area 3B are shown in (**Figure 2-57**). These sites are located in watercourses that contain “significant” or “moderate” aquatic habitat and are suitable for AUSRIVAS assessment (i.e. are at least 100m long).

During the baseline study the condition of the aquatic habitat at each site was assessed using a modified version of the Riparian, Channel and Environmental Inventory method (RCE) (Chessman et al. 1997).

At each site where instream aquatic macrophytes are present, their species composition and total area of coverage is recorded. Features such as the presence of algae or flocculent on the surface of macrophytes would also be noted.

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

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 any confusion, 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.

Fish are sampled using a back-pack electrofisher (model LR-24 Smith-Root) and baited traps. At each site, eight baited traps are deployed in a variety of habitats such as amongst aquatic plants and snags, in deep holes and over bare substratum. The back-pack electrofisher is operated around the edge of pools and in riffles. At each site, four, two minute shots are performed. Fish stunned by the current are collected in a scoop net, identified and measured. Native species are released unharmed while exotics are not returned to the water.

Ongoing monitoring uses the BACI design with two types of monitoring sites included in the program:

- Potential impact sites - these may be subject to mine subsidence impacts during and after longwall extraction; and
- Control sites - these will provide a measure of background environmental variability within the catchments as distinct from any mine subsidence impacts.

The "potential impact" sites are as follows:

- Wongawilli Creek - Sites 2, 3 and 4 situated adjacent to the eastern ends of Longwall 13, 11 and 9, respectively and Sites X4, X5 and X6, distributed adjacent to the eastern ends of Longwalls 17 and 18;
- Donalds Castle Creek – Site X1 situated adjacent to Longwall 9 (where the creek emerges from an upland swamp); and
- WC21 - Sites X2 and X3 which are located above Longwalls 9 and 11 where there is suitable aquatic habitat.

Sites 2, 3 and 4 are also "potential" impact sites for Dendrobium Area 3A. The control sites for Area 3B are the same as those for Area 3A and are as follows:

- Wongawilli Creek – Sites 1 (up until Longwall 15) and 5 downstream of the potential impact zone;
- Donalds Castle Creek - Site 14;
- WC21 - Site 6 situated near the confluence of WC21 and Wongawilli Creek;
- Sandy Creek - Site 7 situated well upstream of the potential impact zone for Dendrobium Area 3A; and
- Kentish Creek - Sites 15 and 16.

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.

2.12 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 120m. 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 2-58**).

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 the Study Area is Wongawilli Creek (**Figure 2-25**) 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.

Donalds Castle Creek and its tributaries (**Figure 2-28 and Figure 2-29**) 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 tributary No. 1 (**Figure 2-30**) and LA2, LA3, LA4 and LA5 (**Figure 2-31 and Figure 2-32**).

The geomorphology of tributary sub-catchments in Area 3B is typically characterised 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 rainfall events.

Wongawilli, Sandy and Donalds Castle Creeks are permanent to 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 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 Creeks:

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 depression of 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 surrounding pools and 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).

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 sediment and debris accumulations.

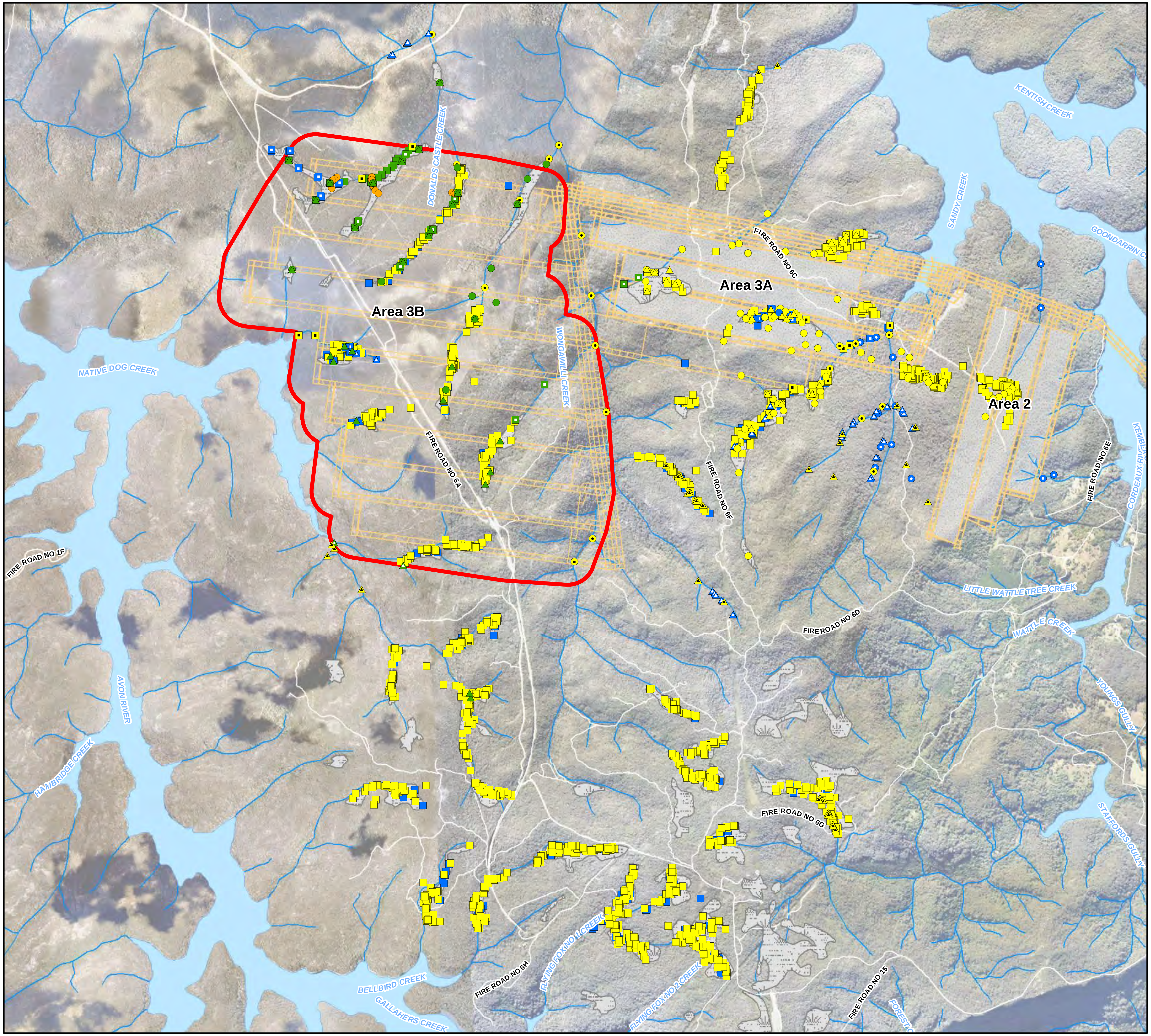
Rockbars and pools in Donalds Castle and Wongawilli Creeks (**Figure 2-58**) have been mapped. Donalds Castle Creek Pool 33 (**Figure 2-59**) is a significant permanent pool within the mining area. All mapped rockbar controlled pools in Wongawilli Creek are significant permanent pools.

2.13 REPORTING

End of Panel Reports are prepared in accordance with *Condition 9 Schedule 3* of the Dendrobium Area 3 Modification Approval. Results from the monitoring program are included in the End of Panel Report and in the Annual Environmental Management Report (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 IC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Manager Approvals will initiate the requirements of the TARPs (**Attachment 1)**.

Monitoring results are included in the Annual Reporting requirement under *Condition 5 Schedule 8* in accordance with the Dendrobium Area 3 Modification Approval and are made publicly available in accordance with *Condition 11 Schedule 8.*



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Dendrobium Area 3 Monitoring

Gopher Sites
- Commenced between 2006 - 2010 (23)
- Commenced between 2011 - 2012 (28)

Shallow Groundwater Sites
- Commenced between 2001 - 2005 (3)
- Commenced beween 2006 - 2010 (62)
- Commenced between 2011 - 2012 (23)
- Commenced 2013 (12)

Terrestrial Monitoring Reference Sites (Biosis, 2013)
- Commenced between 2001 - 2005 (43)
- Commenced between 2006 - 2010 (36)
- Commenced between 2011 - 2012 (2)

Aquatic Monitoring Sites (Cardno, 2013)
- Commenced between 2001 - 2005 (34)
- Commenced between 2006 - 2010 (20)

Terrestrial Monitoring Sites (Biosis, 2013)
- Commenced between 2001 - 2005 (36)
- Commenced between 2006 - 2010 (19)
- Commenced between 2011 - 2012 (16)

Observational and Photo Point Monitoring Sites
- Commenced between 2001 - 2005 (206)
- Commenced between 2006 - 2010 (2,117)
- Commenced between 2011 - 2012 (26)

- Watercourses (LPI)
- SMP Area (MSEC 2012)
- Longwall Layout (BHPBIC, 2012)
- Waterbodies (LPI)
- Area 3 Swamps
- Dendrobium Goaf

N E S W

FIGURE 2.1

1:35,000 Scale at A3

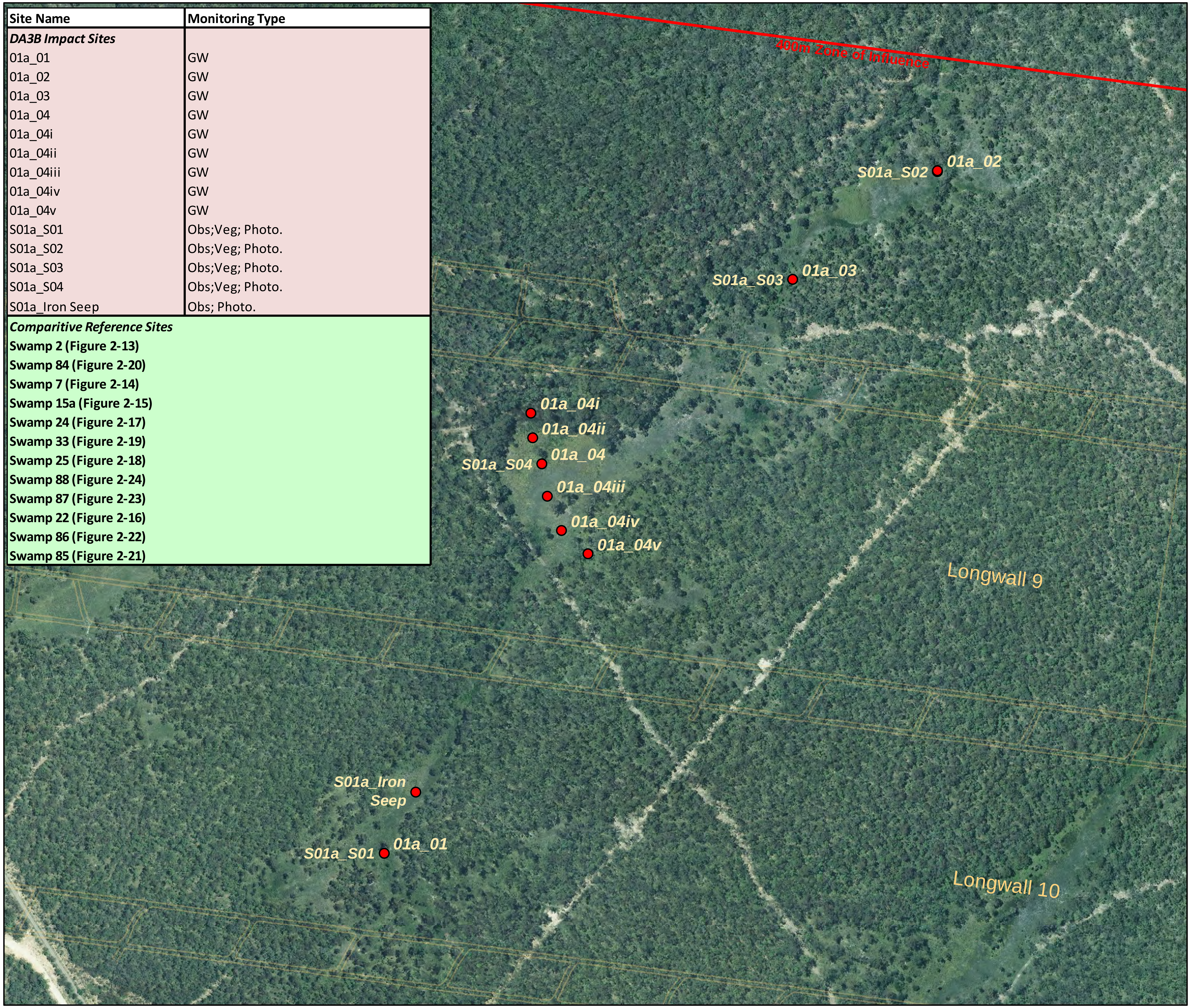
Kilometres
0 0.5 1 1.5 2 2.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2013-02-04
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1065_MonitoringSwamps.mxd 04

Aerial imagery supplied by NearMap

Site Name	Monitoring Type
DA3B Impact Sites	
01a_01	GW
01a_02	GW
01a_03	GW
01a_04	GW
01a_04i	GW
01a_04ii	GW
01a_04iii	GW
01a_04iv	GW
01a_04v	GW
S01a_S01	Obs;Veg; Photo.
S01a_S02	Obs;Veg; Photo.
S01a_S03	Obs;Veg; Photo.
S01a_S04	Obs;Veg; Photo.
S01a_Iron Seep	Obs; Photo.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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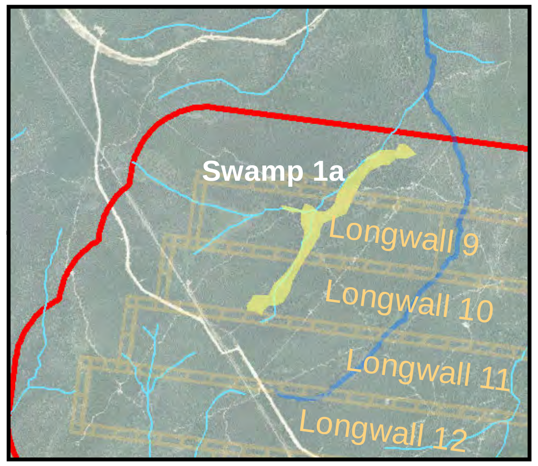
Dendrobium Area 3B
Swamp Monitoring Sites
Swamp 1a

Figure 2-2

Legend

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

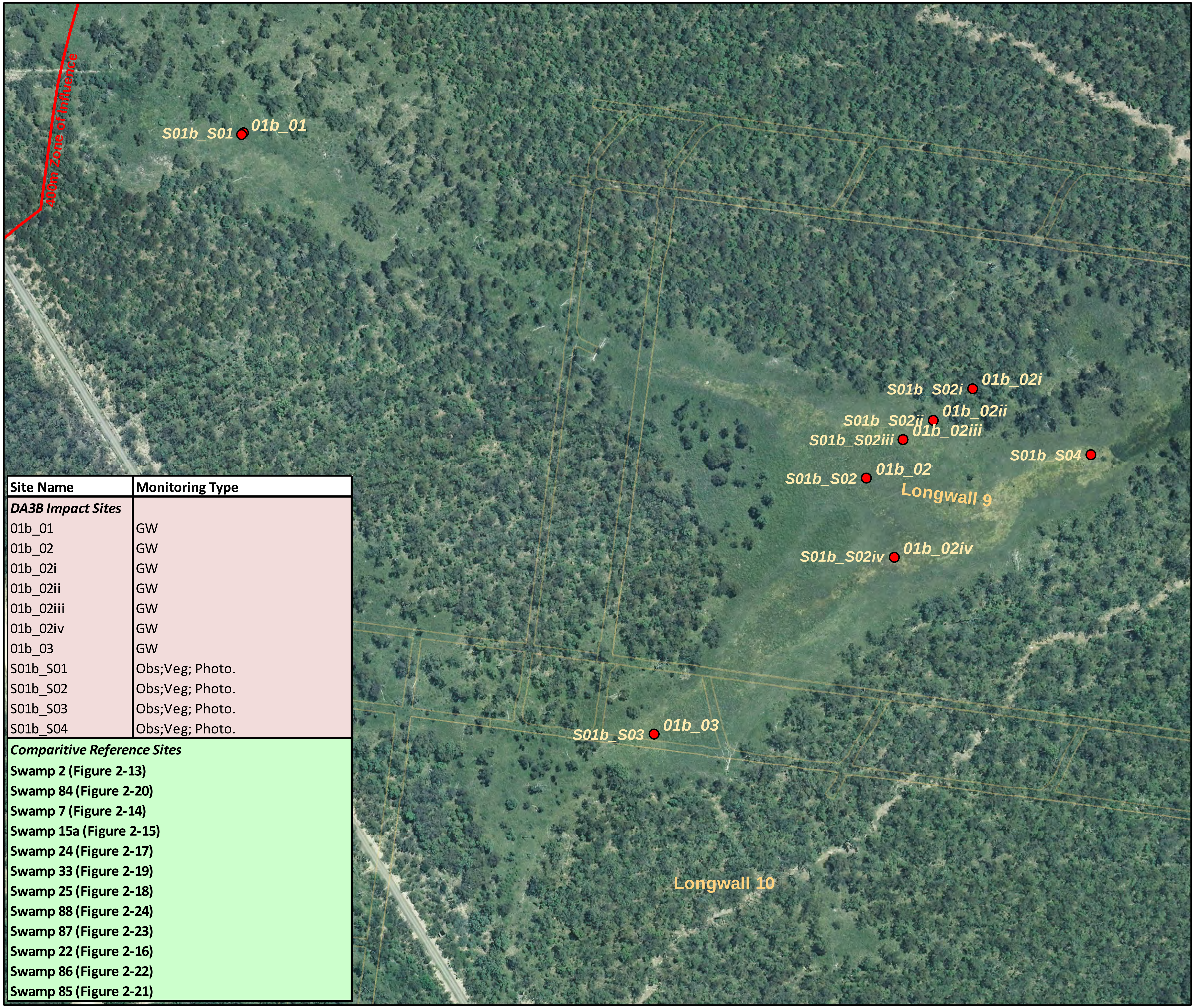


Date: December, 2014
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N S W E

0 50 100 200 Meters



Site Name	Monitoring Type
DA3B Impact Sites	
01b_01	GW
01b_02	GW
01b_02i	GW
01b_02ii	GW
01b_02iii	GW
01b_02iv	GW
01b_03	GW
S01b_S01	Obs;Veg; Photo.
S01b_S02	Obs;Veg; Photo.
S01b_S03	Obs;Veg; Photo.
S01b_S04	Obs;Veg; Photo.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	

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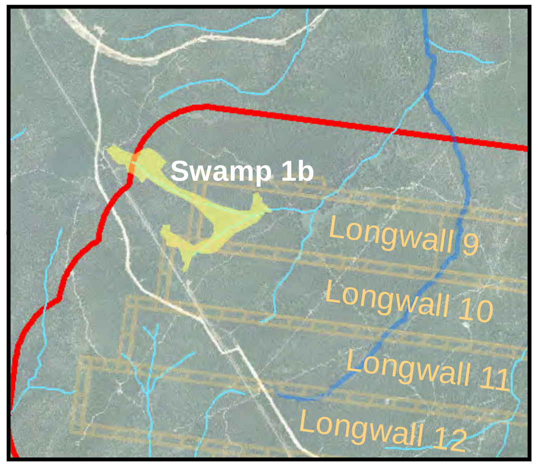
Dendrobium Area 3B
Swamp Monitoring Sites
Swamp 1b

Figure 2-3

Legend

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



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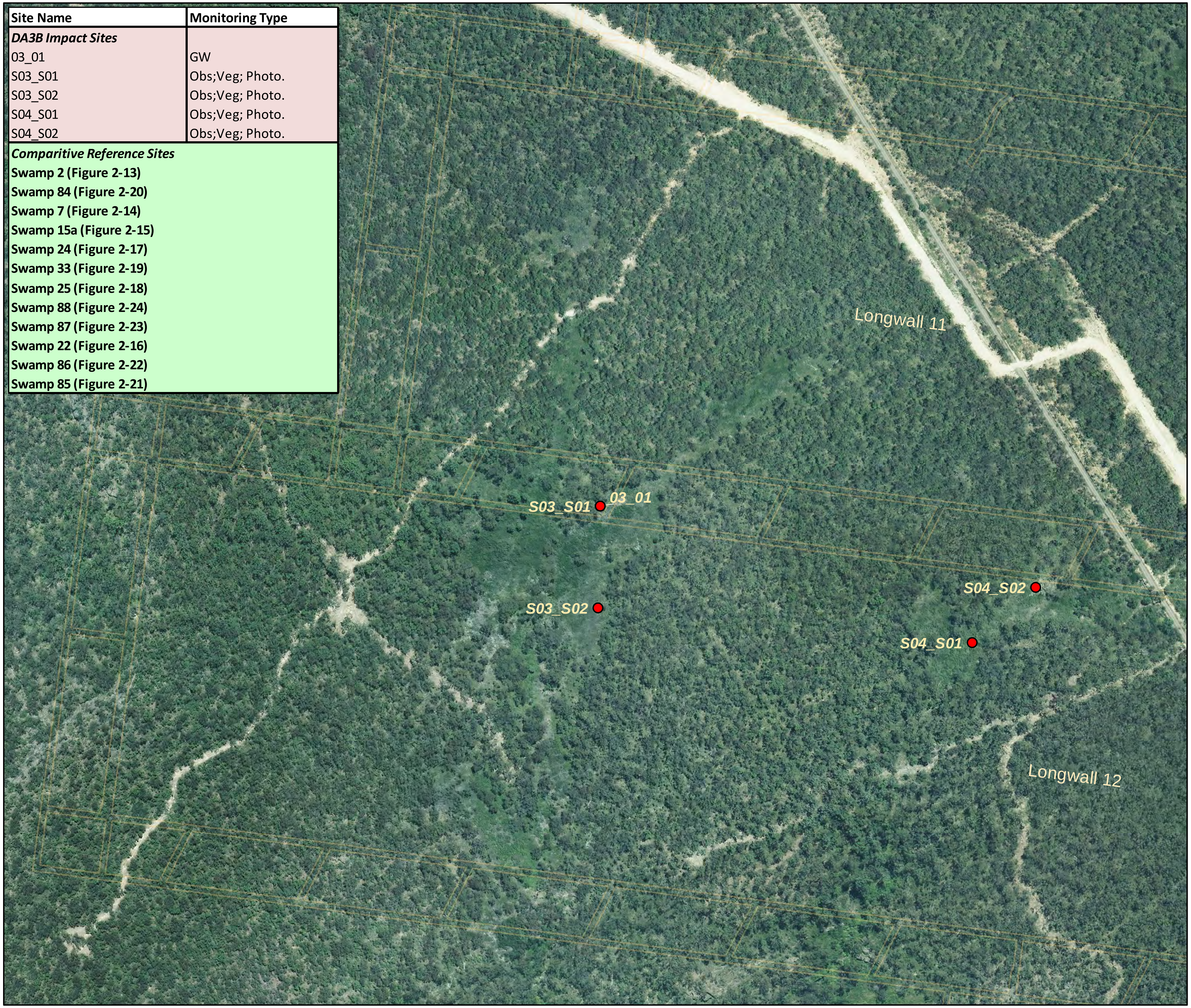
MGA - Zone 56

N W E S

50 25 0 50 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
03_01	GW
S03_S01	Obs;Veg; Photo.
S03_S02	Obs;Veg; Photo.
S04_S01	Obs;Veg; Photo.
S04_S02	Obs;Veg; Photo.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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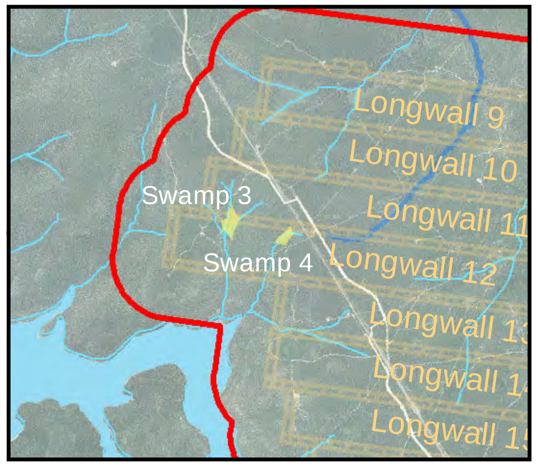
Dendrobium Area 3B
Swamp Monitoring Sites
Swamp 3 and 4

Figure 2-4

Legend

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



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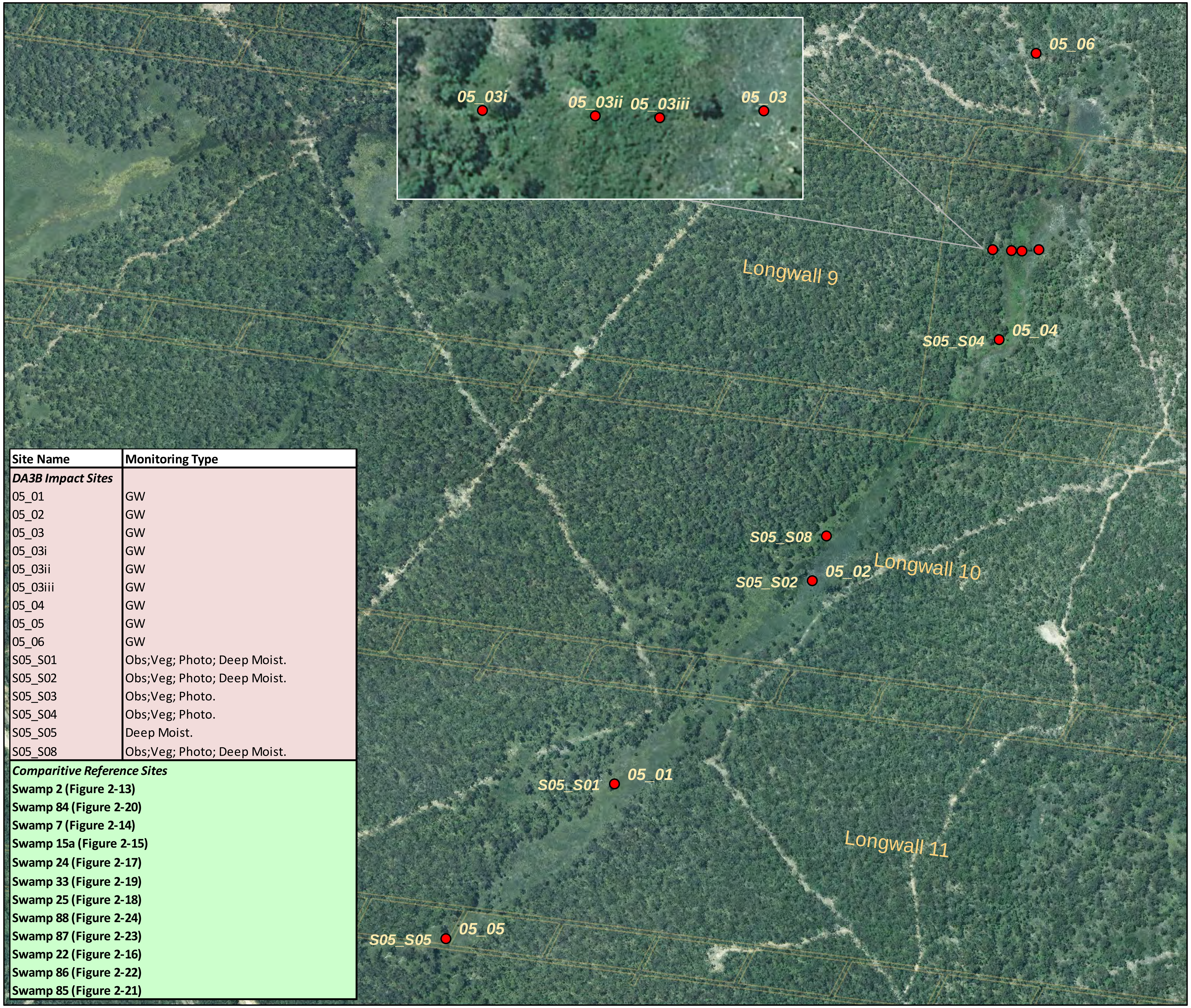
Version 1
Horizontal Datum
MGA - Zone 56

N S W E

0 25 50 100 150 Meters



Site Name	Monitoring Type
DA3B Impact Sites	
05_01	GW
05_02	GW
05_03	GW
05_03i	GW
05_03ii	GW
05_03iii	GW
05_04	GW
05_05	GW
05_06	GW
S05_S01	Obs;Veg; Photo; Deep Moist.
S05_S02	Obs;Veg; Photo; Deep Moist.
S05_S03	Obs;Veg; Photo.
S05_S04	Obs;Veg; Photo.
S05_S05	Deep Moist.
S05_S08	Obs;Veg; Photo; Deep Moist.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	

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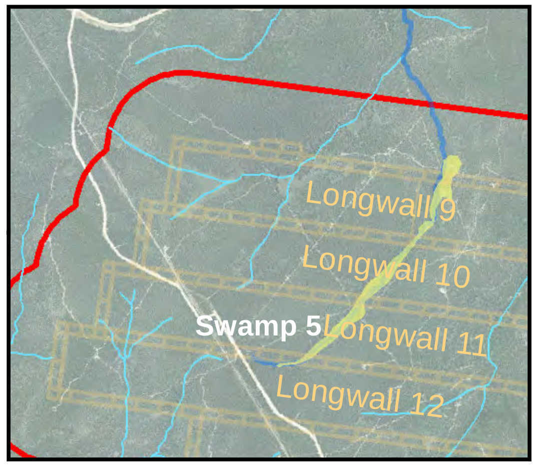
Dendrobium Area 3B
Swamp Monitoring Sites
Swamp 5

Figure 2-5

Legend

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



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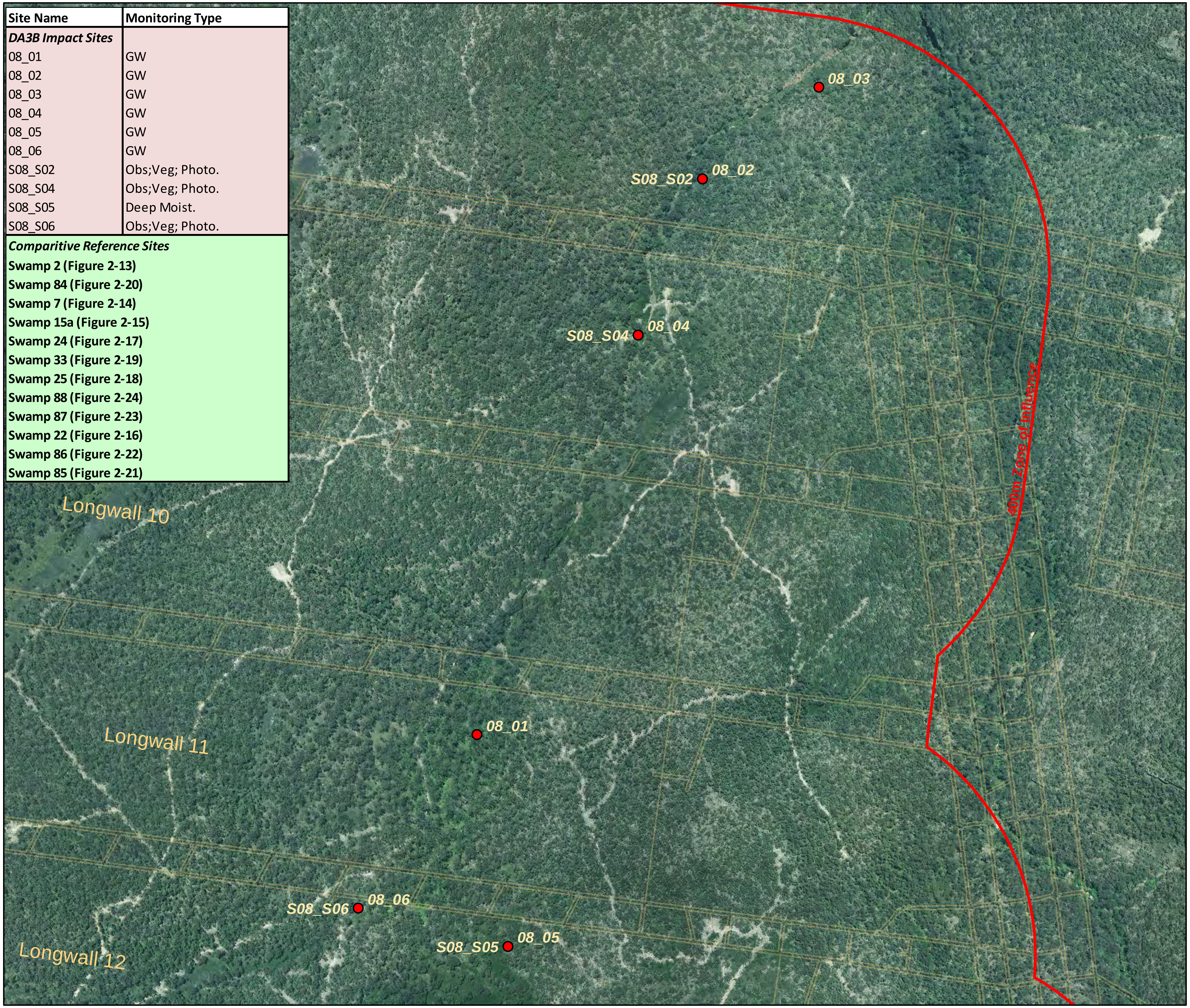
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

0 50 100 200 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
08_01	GW
08_02	GW
08_03	GW
08_04	GW
08_05	GW
08_06	GW
S08_S02	Obs;Veg; Photo.
S08_S04	Obs;Veg; Photo.
S08_S05	Deep Moist.
S08_S06	Obs;Veg; Photo.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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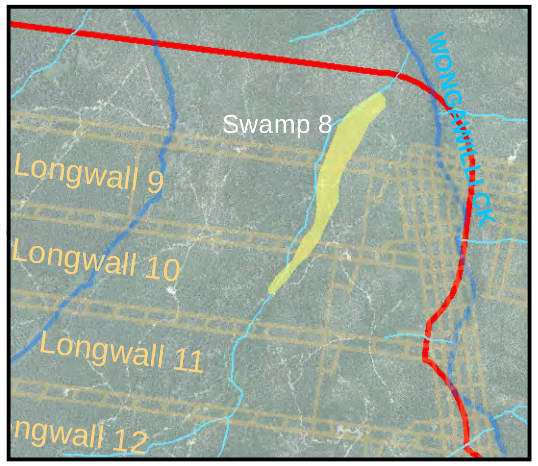
Dendrobium Area 3B
Swamp Monitoring Sites
Swamp 8

Figure 2-6

Legend

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



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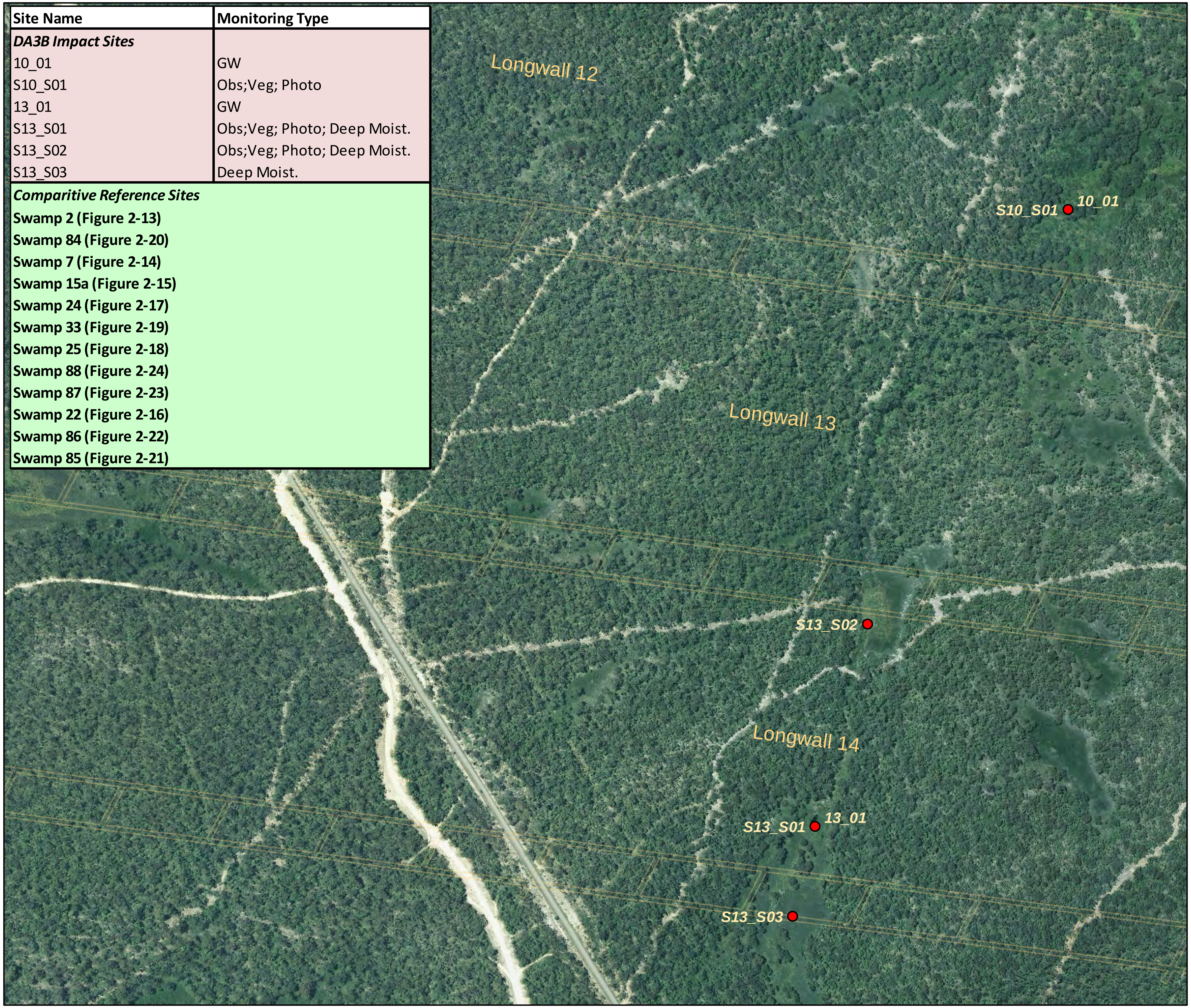
Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

0 50 100 200 300 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
10_01	GW
S10_S01	Obs;Veg; Photo
13_01	GW
S13_S01	Obs;Veg; Photo; Deep Moist.
S13_S02	Obs;Veg; Photo; Deep Moist.
S13_S03	Deep Moist.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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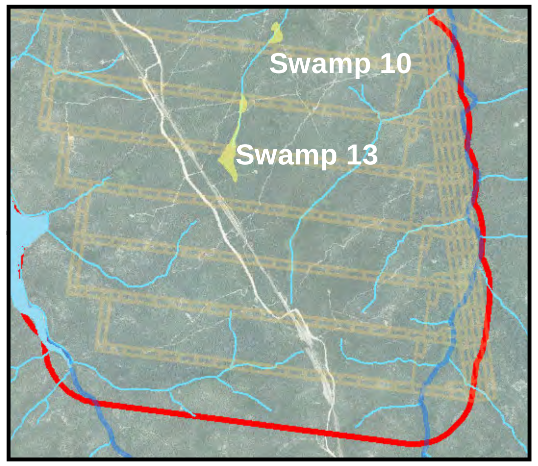
Dendrobium Area 3B
Swamp Monitoring Sites
Swamp 10 and 13

Figure 2-7

Legend

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



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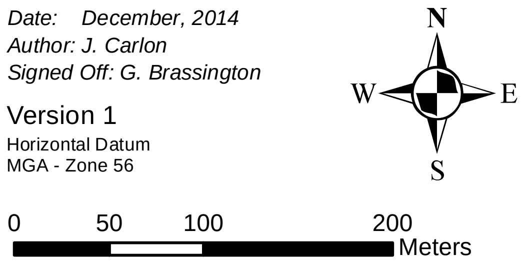
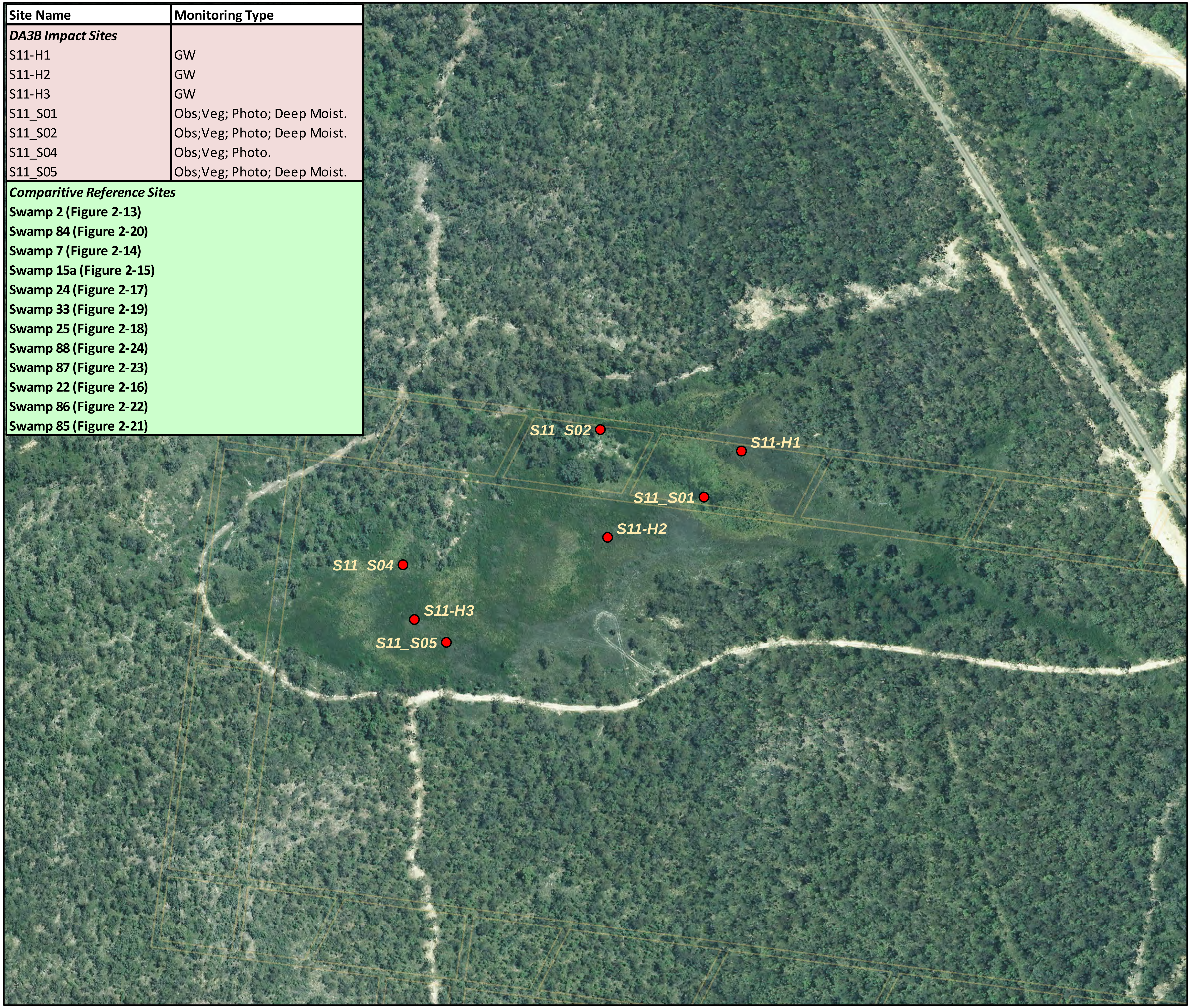


Site Name	Monitoring Type
DA3B Impact Sites	
S11-H1	GW
S11-H2	GW
S11-H3	GW
S11_S01	Obs;Veg; Photo; Deep Moist.
S11_S02	Obs;Veg; Photo; Deep Moist.
S11_S04	Obs;Veg; Photo.
S11_S05	Obs;Veg; Photo; Deep Moist.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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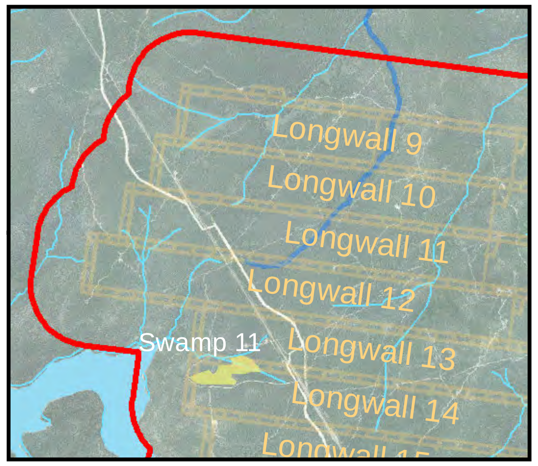
Dendrobium Area 3B
Swamp Monitoring Sites

Swamp 11

Figure 2-8

Legend

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



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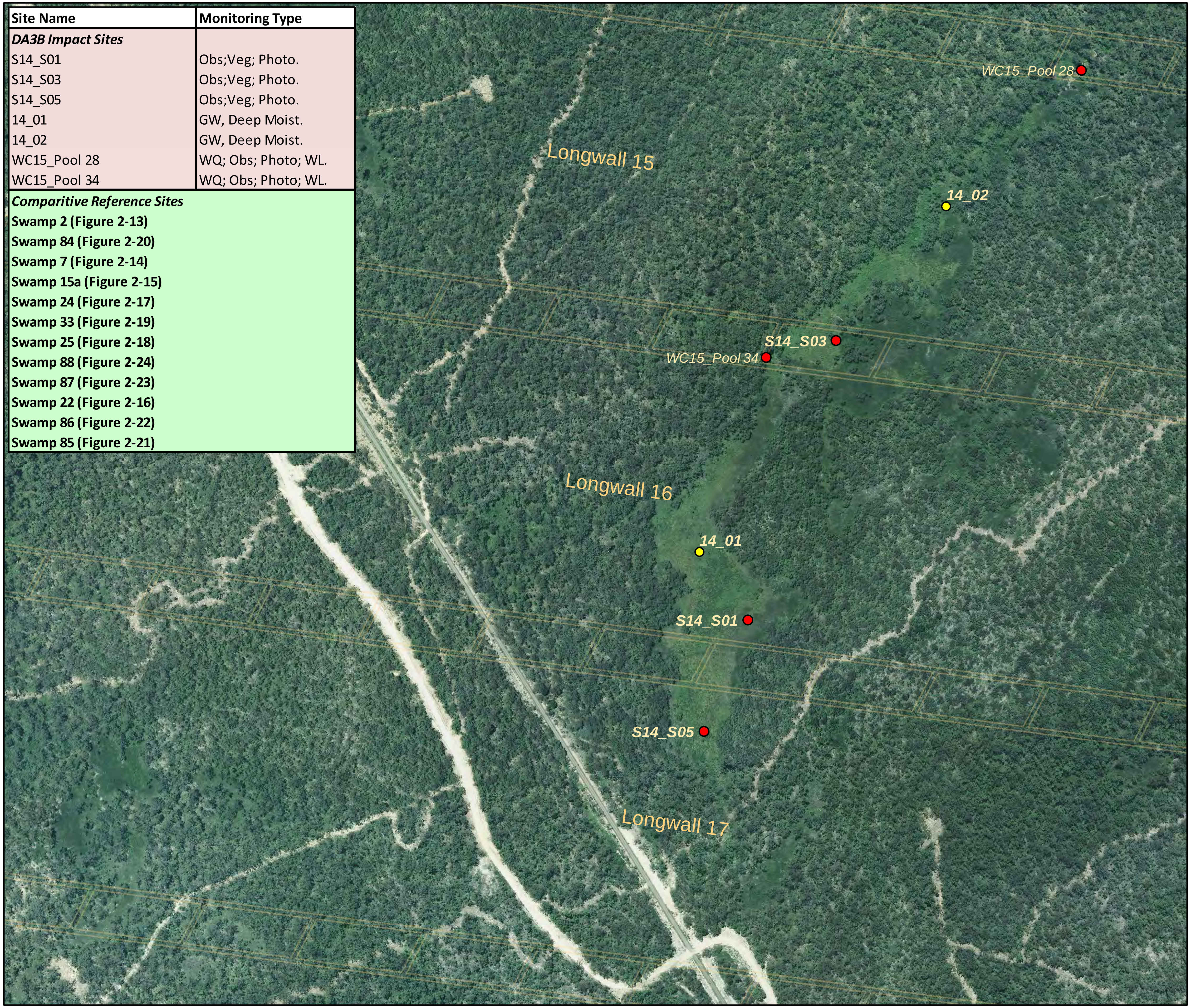
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

0 25 50 100 Meters

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, Deep Moist.
14_02	GW, Deep Moist.
WC15_Pool 28	WQ; Obs; Photo; WL.
WC15_Pool 34	WQ; Obs; Photo; WL.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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Dendrobium Area 3B

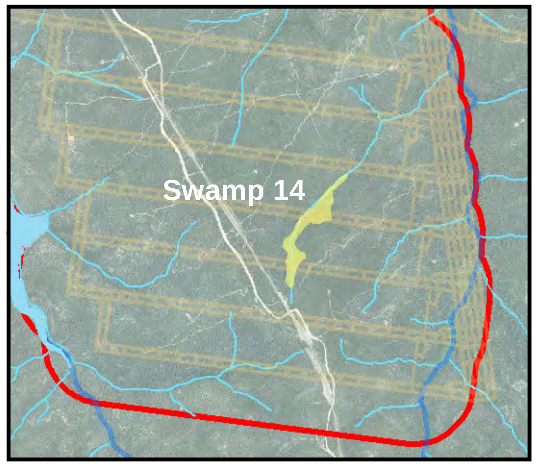
Swamp Monitoring Sites

Swamp 14

Figure 2-9

Legend

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



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Author: J. Carlon
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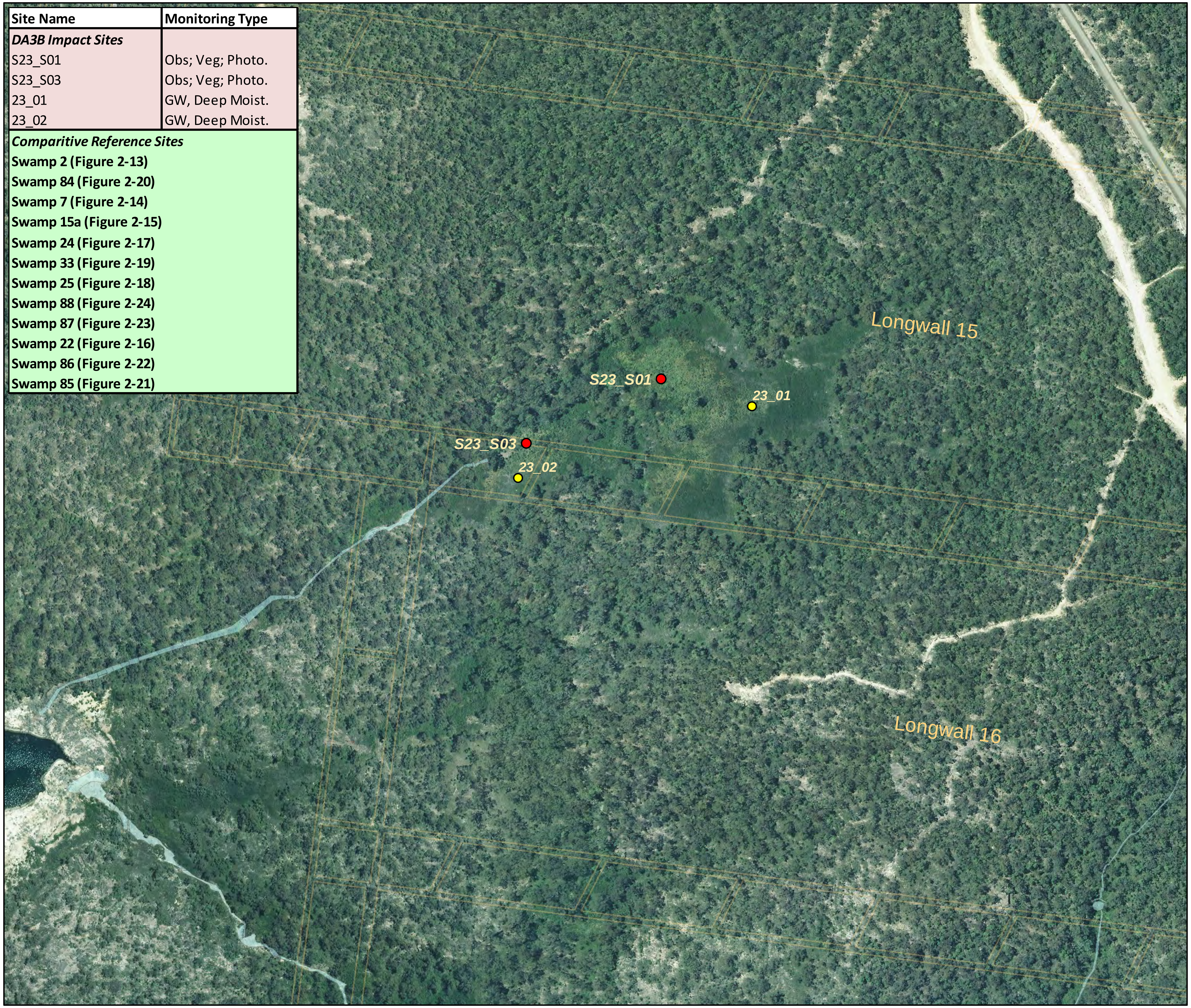
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

0 50 100 200 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
S23_S01	Obs; Veg; Photo.
S23_S03	Obs; Veg; Photo.
23_01	GW, Deep Moist.
23_02	GW, Deep Moist.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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Dendrobium Area 3B

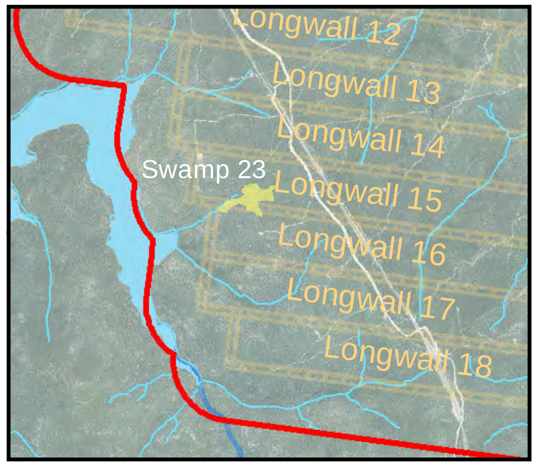
Swamp Monitoring Sites

Swamp 23

Figure 2-10

Legend

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



Date: December, 2014
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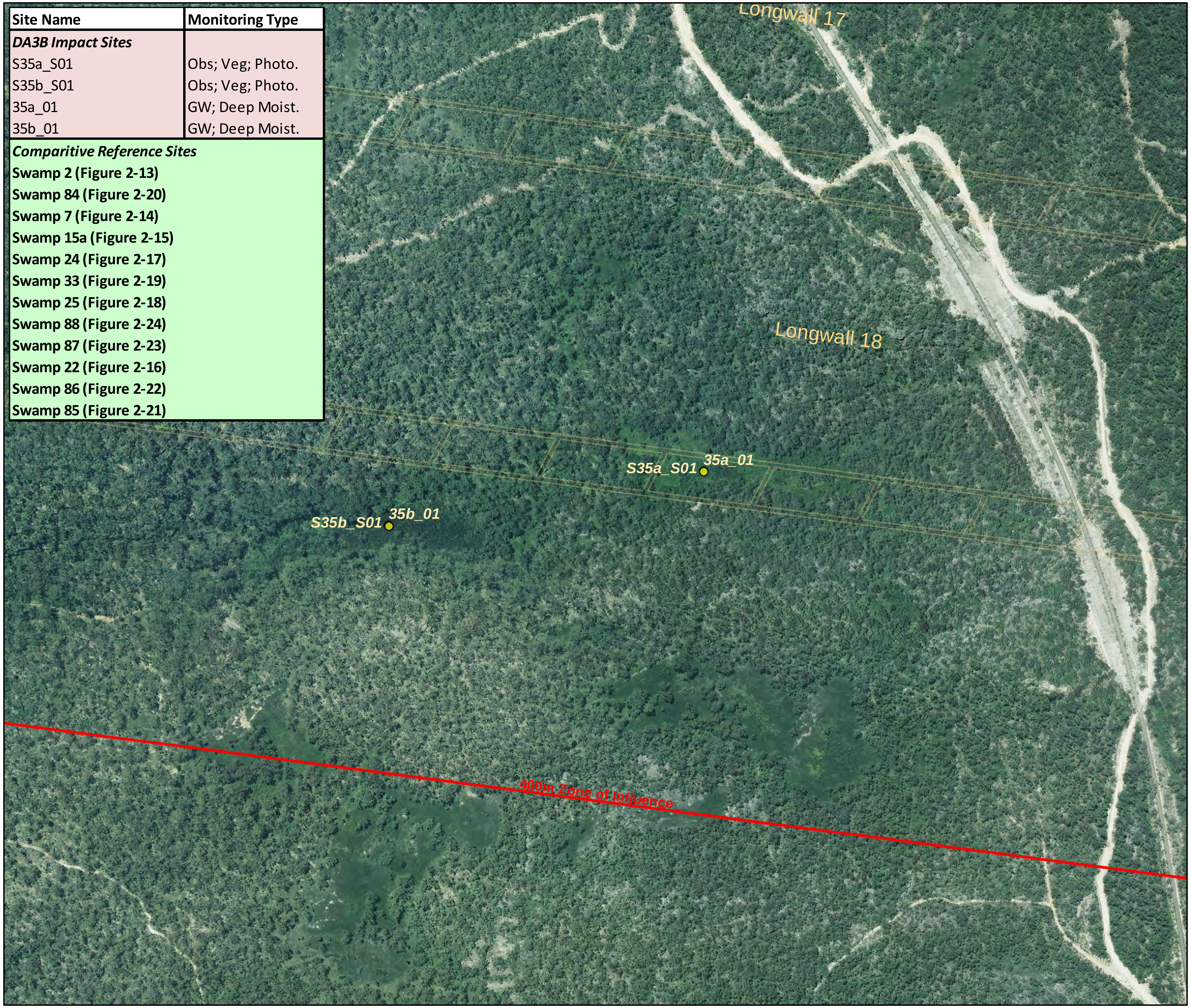
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

0 25 50 100 150 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
S35a_S01	Obs; Veg; Photo.
S35b_S01	Obs; Veg; Photo.
35a_01	GW; Deep Moist.
35b_01	GW; Deep Moist.
Comparitive Reference Sites	
Swamp 2 (Figure 2-13)	
Swamp 84 (Figure 2-20)	
Swamp 7 (Figure 2-14)	
Swamp 15a (Figure 2-15)	
Swamp 24 (Figure 2-17)	
Swamp 33 (Figure 2-19)	
Swamp 25 (Figure 2-18)	
Swamp 88 (Figure 2-24)	
Swamp 87 (Figure 2-23)	
Swamp 22 (Figure 2-16)	
Swamp 86 (Figure 2-22)	
Swamp 85 (Figure 2-21)	



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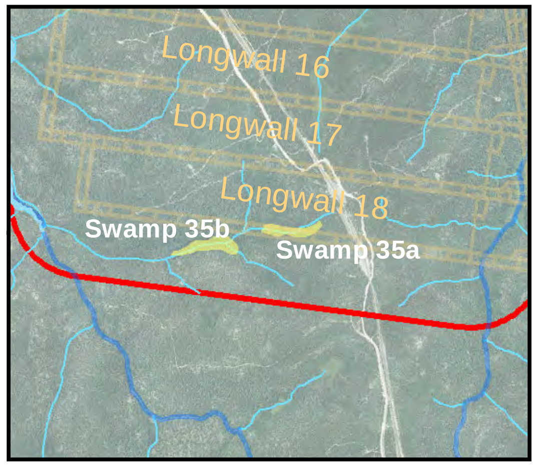
Dendrobium Area 3B
Swamp Monitoring Sites
Swamp 35a and 35b

Figure 2-11

Legend

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



Date: Decembery, 2014
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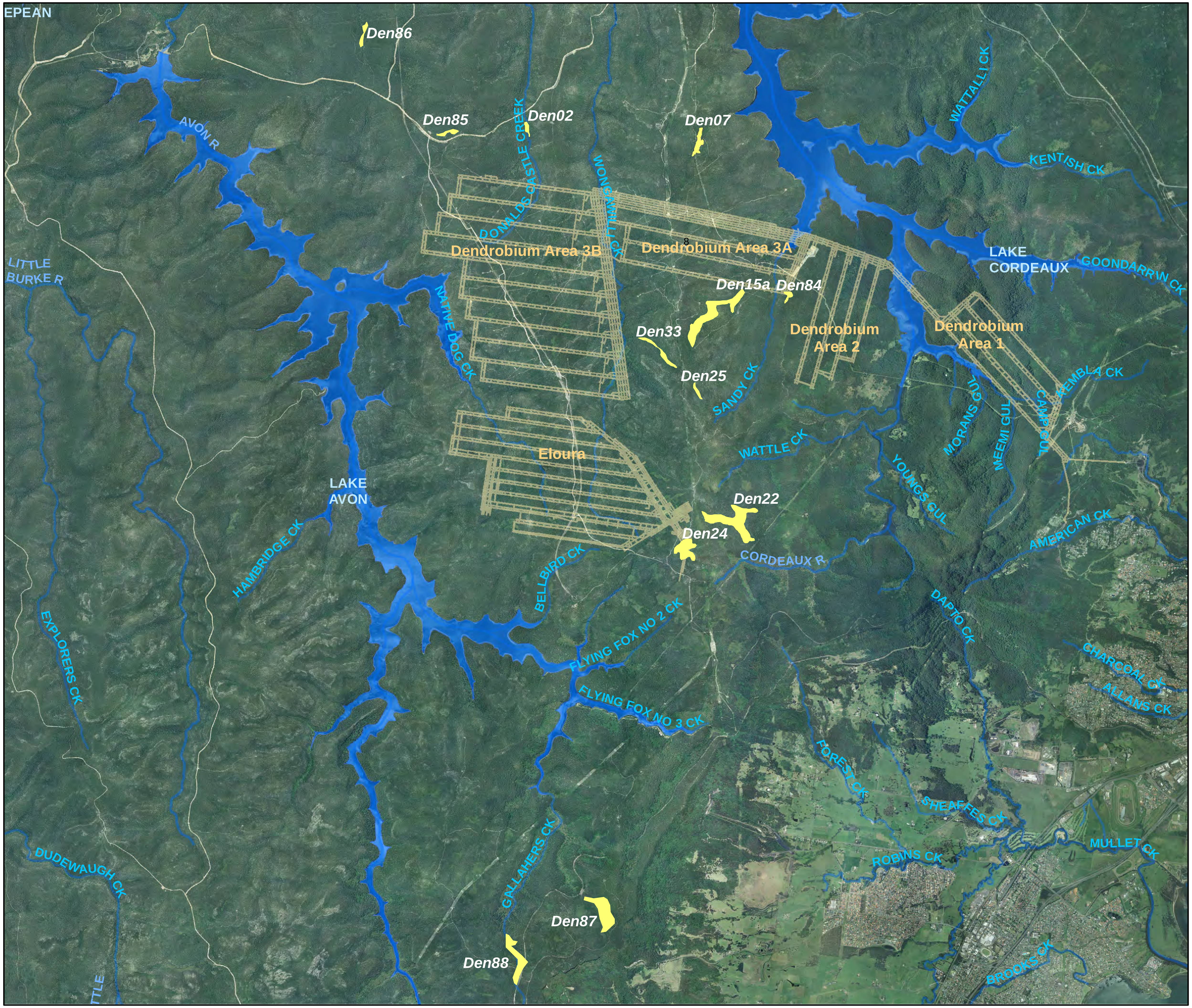
Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

0 50 100 200 Meters



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Dendrobium Area 3B

Reference Swamps

Figure 2-12

Legend

- Reference Swamps
- Creeks
- Rivers
- Dendrobium and Eloura Workings

Date: December, 2014
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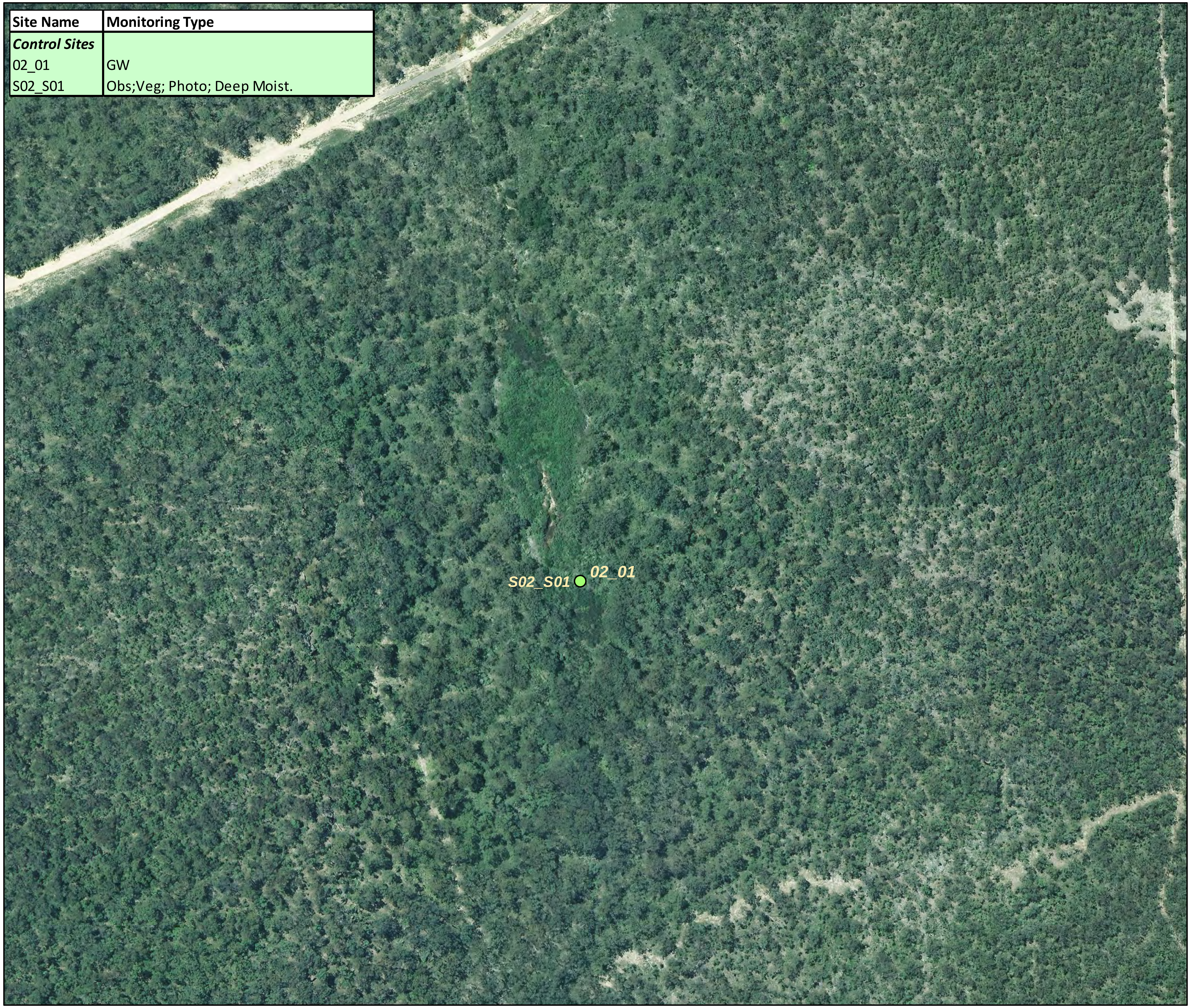
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

0 500 1,000 2,000 3,000 Meters

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



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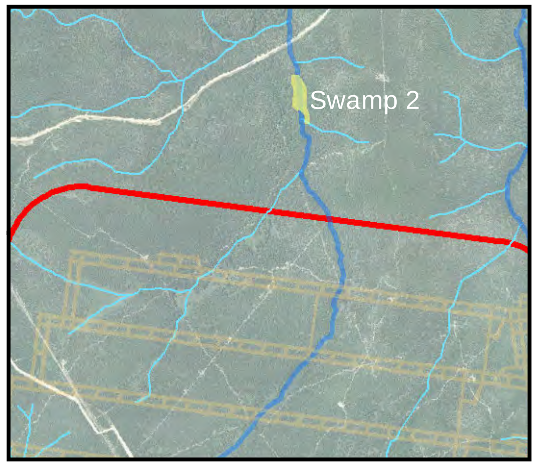
Dendrobium Area 3B
Swamp Monitoring
Reference Sites

Swamp 2

Figure 2-13

Legend

- Existing Reference Monitoring Site
- Dendrobium Layout
- Tributaries
- Creeks
- 400m Zone of Influence (DA3B)



Date: December, 2014
Author: J. Carlon
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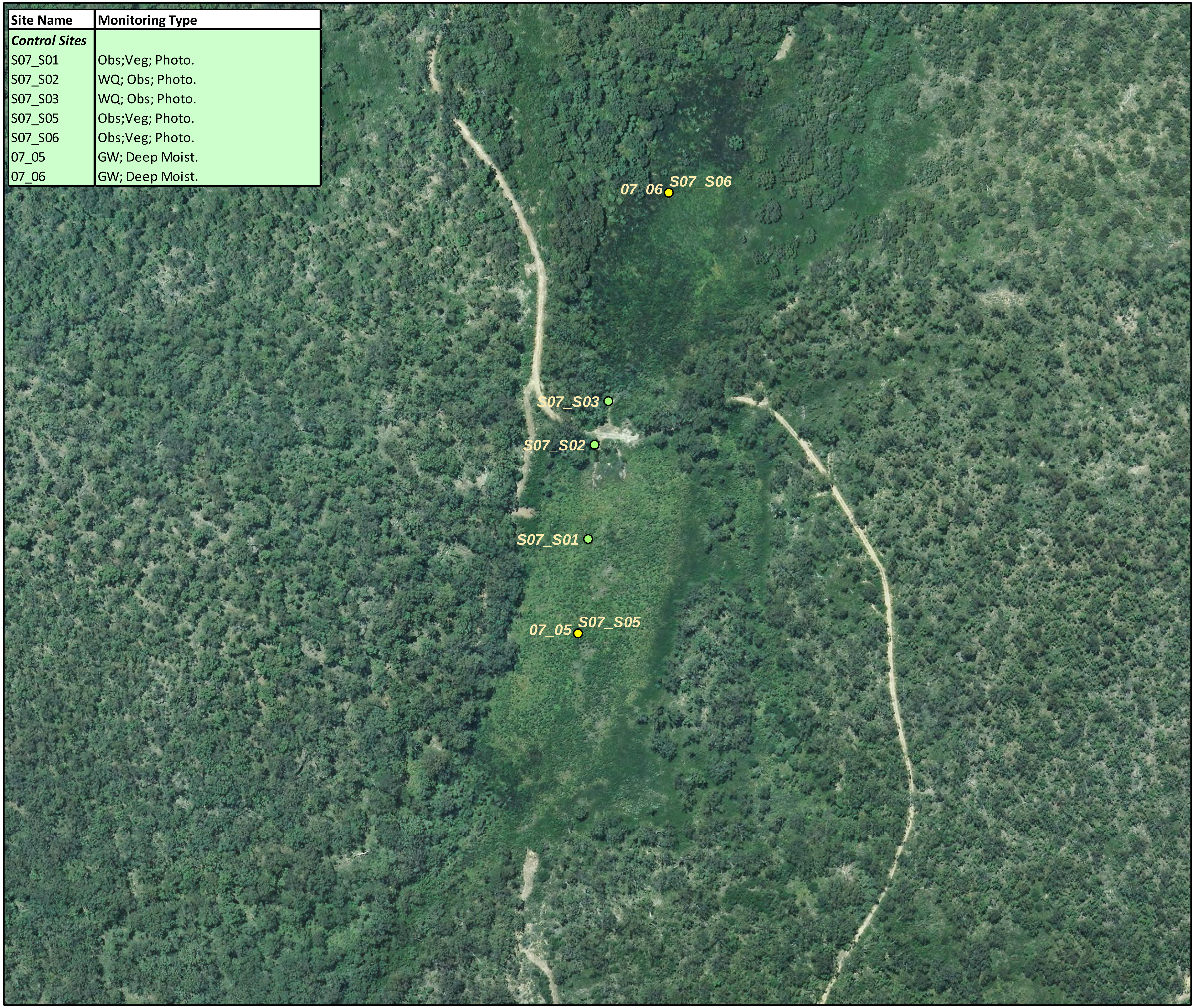
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

0 25 50 100 150 Meters



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; Deep Moist.
07_06	GW; Deep Moist.

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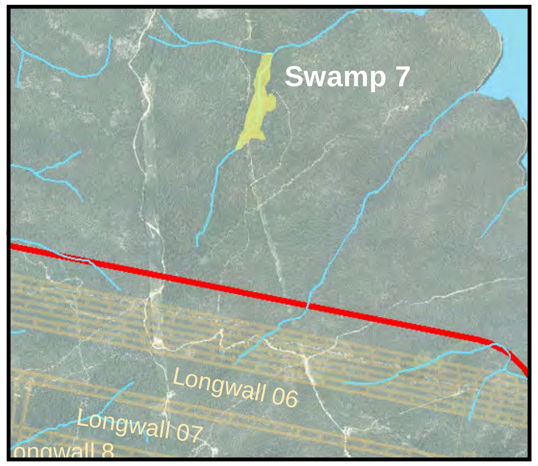
Dendrobium Area 3B
Swamp Monitoring Reference Sites
Swamp 7

Figure 2-14

Legend

- Proposed Reference Monitoring Site
- Existing Reference Monitoring Site
- Dendrobium Layout
- 400m Zone of Influence (DA3A)
- Tributaries



Date: December, 2014
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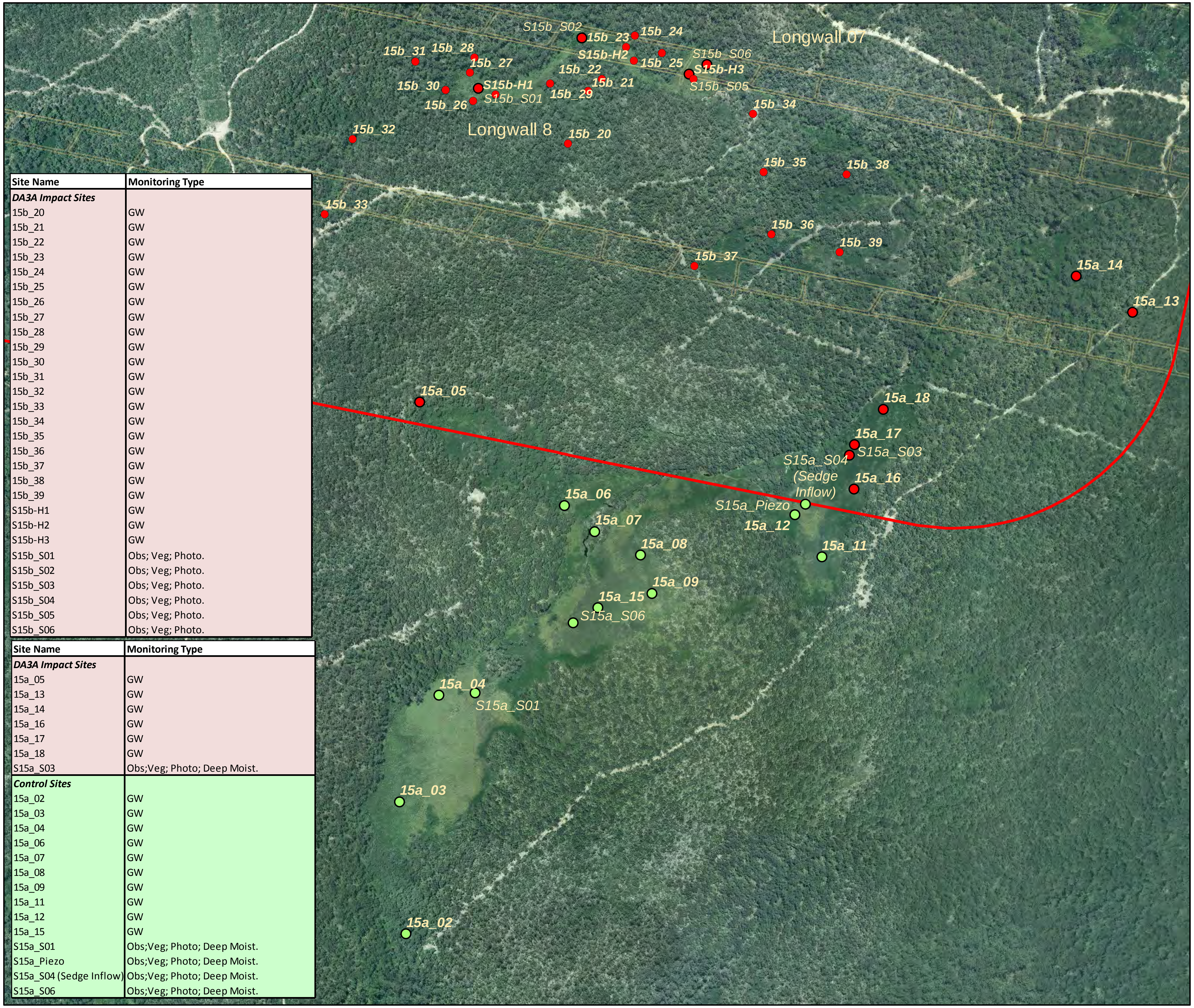
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

50 25 0 50 Meters



Site Name	Monitoring Type
DA3A Impact Sites	
15b_20	GW
15b_21	GW
15b_22	GW
15b_23	GW
15b_24	GW
15b_25	GW
15b_26	GW
15b_27	GW
15b_28	GW
15b_29	GW
15b_30	GW
15b_31	GW
15b_32	GW
15b_33	GW
15b_34	GW
15b_35	GW
15b_36	GW
15b_37	GW
15b_38	GW
15b_39	GW
S15b-H1	GW
S15b-H2	GW
S15b-H3	GW
S15b_S01	Obs; Veg; Photo.
S15b_S02	Obs; Veg; Photo.
S15b_S03	Obs; Veg; Photo.
S15b_S04	Obs; Veg; Photo.
S15b_S05	Obs; Veg; Photo.
S15b_S06	Obs; Veg; Photo.

Site Name	Monitoring Type
DA3A Impact Sites	
15a_05	GW
15a_13	GW
15a_14	GW
15a_16	GW
15a_17	GW
15a_18	GW
S15a_S03	Obs;Veg; Photo; Deep Moist.
Control Sites	
15a_02	GW
15a_03	GW
15a_04	GW
15a_06	GW
15a_07	GW
15a_08	GW
15a_09	GW
15a_11	GW
15a_12	GW
15a_15	GW
S15a_S01	Obs;Veg; Photo; Deep Moist.
S15a_Piezo	Obs;Veg; Photo; Deep Moist.
S15a_S04 (Sedge Inflow)	Obs;Veg; Photo; Deep Moist.
S15a_S06	Obs;Veg; Photo; Deep Moist.

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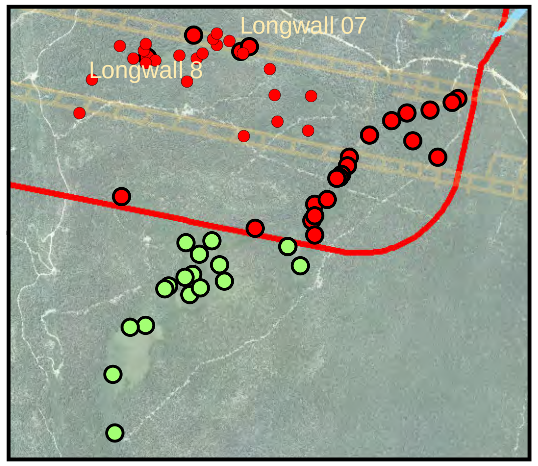
Dendrobium Area 3B
Swamp Monitoring
Reference Sites
Swamp 15a

Figure 2-15

Legend

- Existing Reference Monitoring Site
- Existing DA3A Impact Monitoring Site
- 400m Zone of Influence (DA3A)
- Dendrobium Layout



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N W E S

Version 1
Horizontal Datum
MGA - Zone 56

100 50 0 100 200 Meters

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

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Dendrobium Area 3B

Swamp Monitoring Refrence Sites

Swamp 22

Figure 2-16

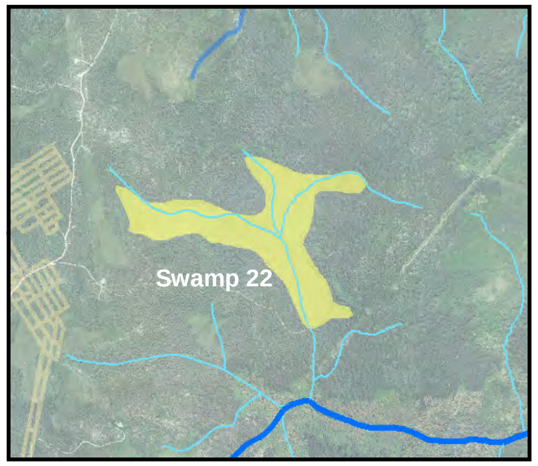
Legend

Proposed Reference Monitoring Site

Elouera Workings

Creeks

Tributaries



Date: December, 2014
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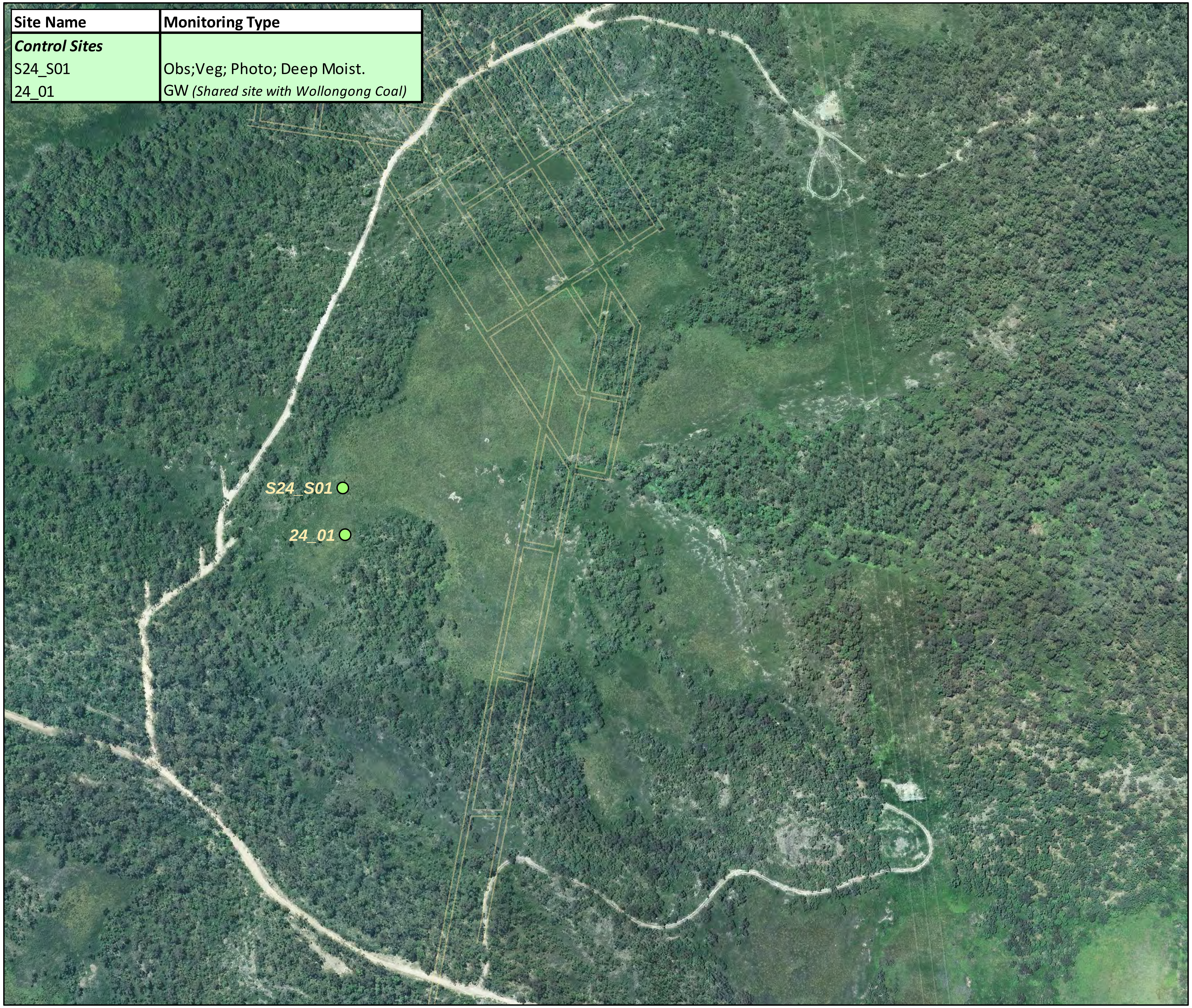
Version 1

Horizontal Datum
MGA - Zone 56

N W E S

50 25 0 50 100 Meters

Site Name	Monitoring Type
Control Sites	
S24_S01	Obs;Veg; Photo; Deep Moist.
24_01	GW *(Shared site with Wollongong Coal)*



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Dendrobium Area 3B

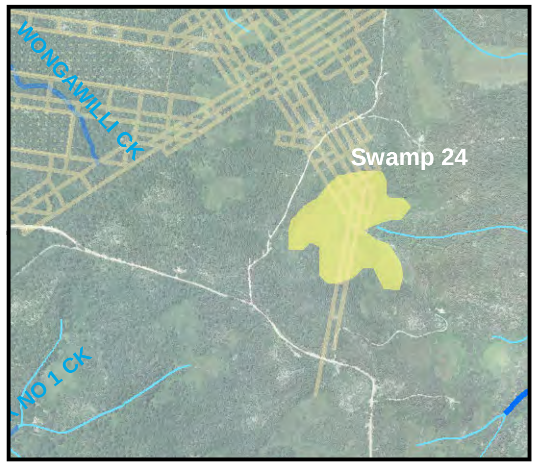
Swamp Monitoring Refrence Sites

Swamp 24

Figure 2-17

Legend

- Existing Reference Monitoring Site
- Elouera Workings
- Creeks
- Tributaries



Date: December, 2014
Author: J. Carlon
Signed Off: G. Brassington

Version 1

Horizontal Datum
MGA - Zone 56

N S W E

50 25 0 50 100
Meters

Site Name	Monitoring Type
Control Sites	
S25_S01	Obs;Veg; Photo; Deep Moist.
25_01	GW *(Existing)*

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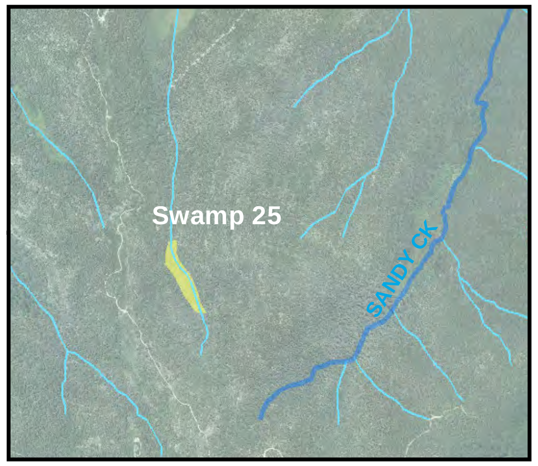
Dendrobium Area 3B
Swamp Monitoring Reference Sites
Swamp 25

Figure 2-18

Legend

- Proposed Reference Monitoring Site
- Dendrobium Layout
- 400m Zone of Influence
- Creeks
- Tributaries



Date: December, 2014
Author: J. Carlon
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Version 1
Horizontal Datum
MGA - Zone 56

N S W E

50 25 0 50
Meters

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

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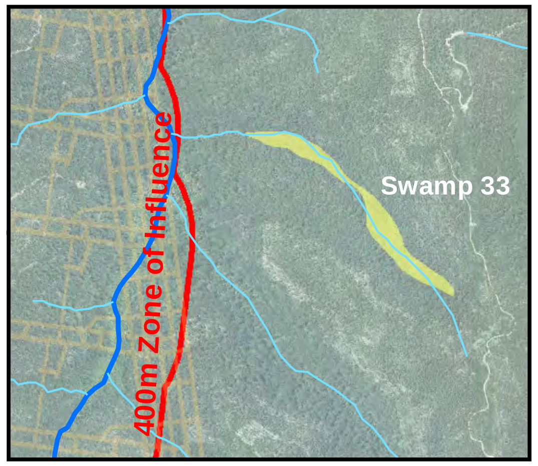
Dendrobium Area 3B
Swamp Monitoring Reference Sites
Swamp 33

Figure 2-19

Legend

- Proposed Reference Monitoring Site
- Existing Reference Monitoring Site
- Dendrobium Layout
- Creeks
- Tributaries
- 400m Zone of Influence (DA3B)



Date: December, 2014
Author: J. Carlon
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Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

0 25 50 100
Meters

Site Name	Monitoring Type
Control Sites	
S84_S01	Obs;Veg; Photo;
S84_S02	Obs;Veg; Photo; Deep Moist.
84_02	GW
S84_Pool 10	WQ; Photo; Obs.

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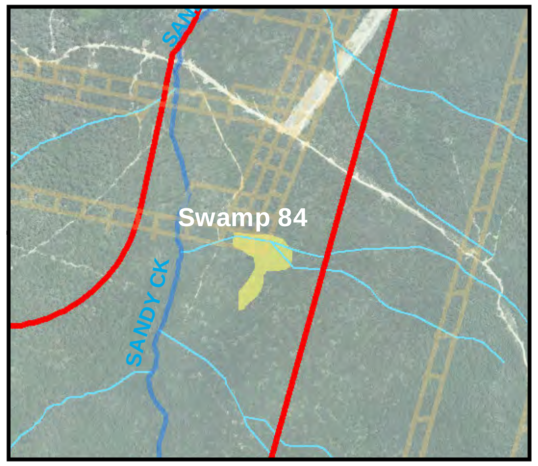
Dendrobium Area 3B
Swamp Monitoring
Reference Sites
Swamp 84

Figure 2-20

Legend

- Proposed Reference Monitoring Site
- Existing Reference Monitoring Site
- Creeks
- Dendrobium Layout
- 400m Zone of Influence



Date: December, 2014
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

20 10 0 20 Meters

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

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Dendrobium Area 3B

Swamp Monitoring Refrence Sites

Swamp 85

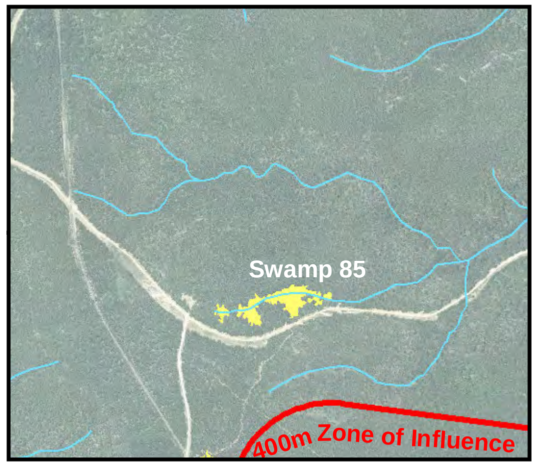
Figure 2-21

Legend

Proposed Reference Monitoring Site

Tributaries

400m Zone of Influence (DA3B)



Date: December, 2014
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

50 25 0 50
Meters

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

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Dendrobium Area 3B

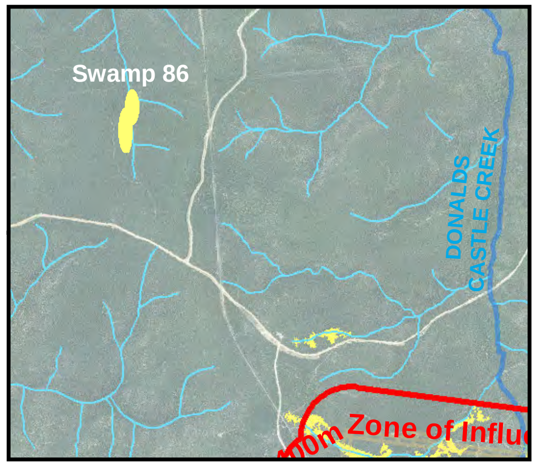
Swamp Monitoring Refrence Sites

Swamp 86

Figure 2-22

Legend

- Proposed Reference Monitoring Site
- Creeks
- Tributaries
- 400m Zone of Influence (DA3B)



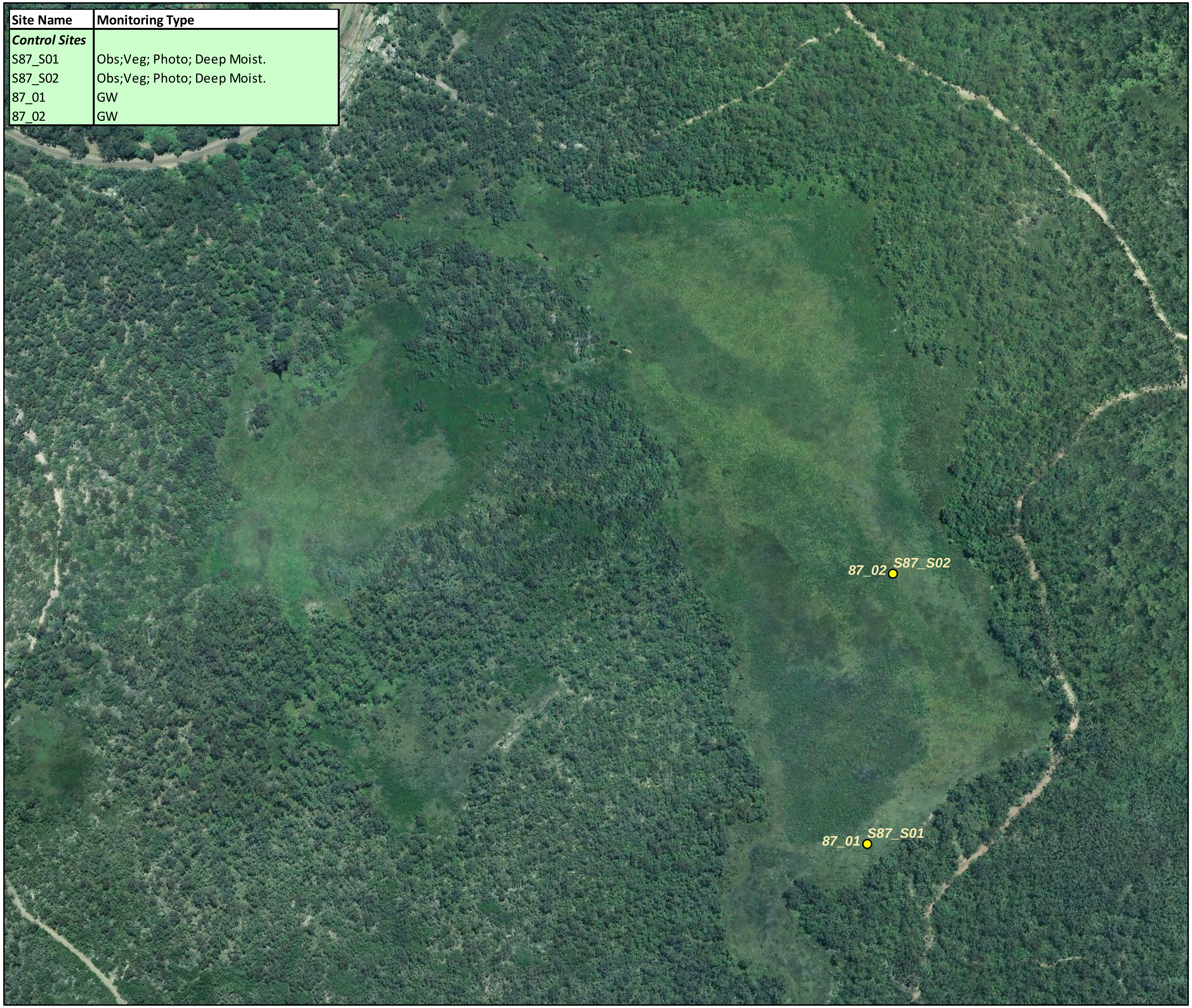
Date: December, 2014
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N E S W

100 50 0 100 Meters

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



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Dendrobium Area 3B

Swamp Monitoring Refrence Sites

Swamp 87

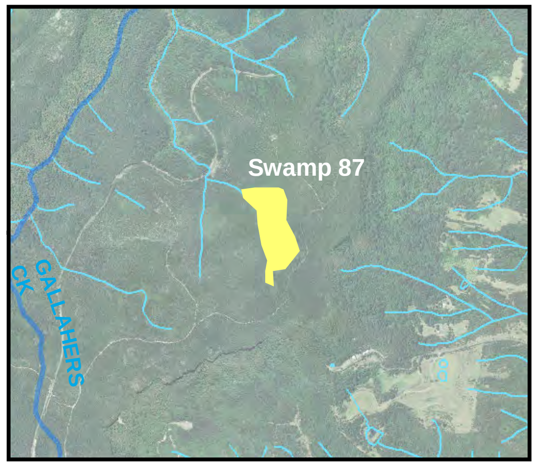
Figure 2-23

Legend

Proposed Reference Monitoring Site

Creeks

Tributaries



Date: December, 2014
Author: J. Carlon
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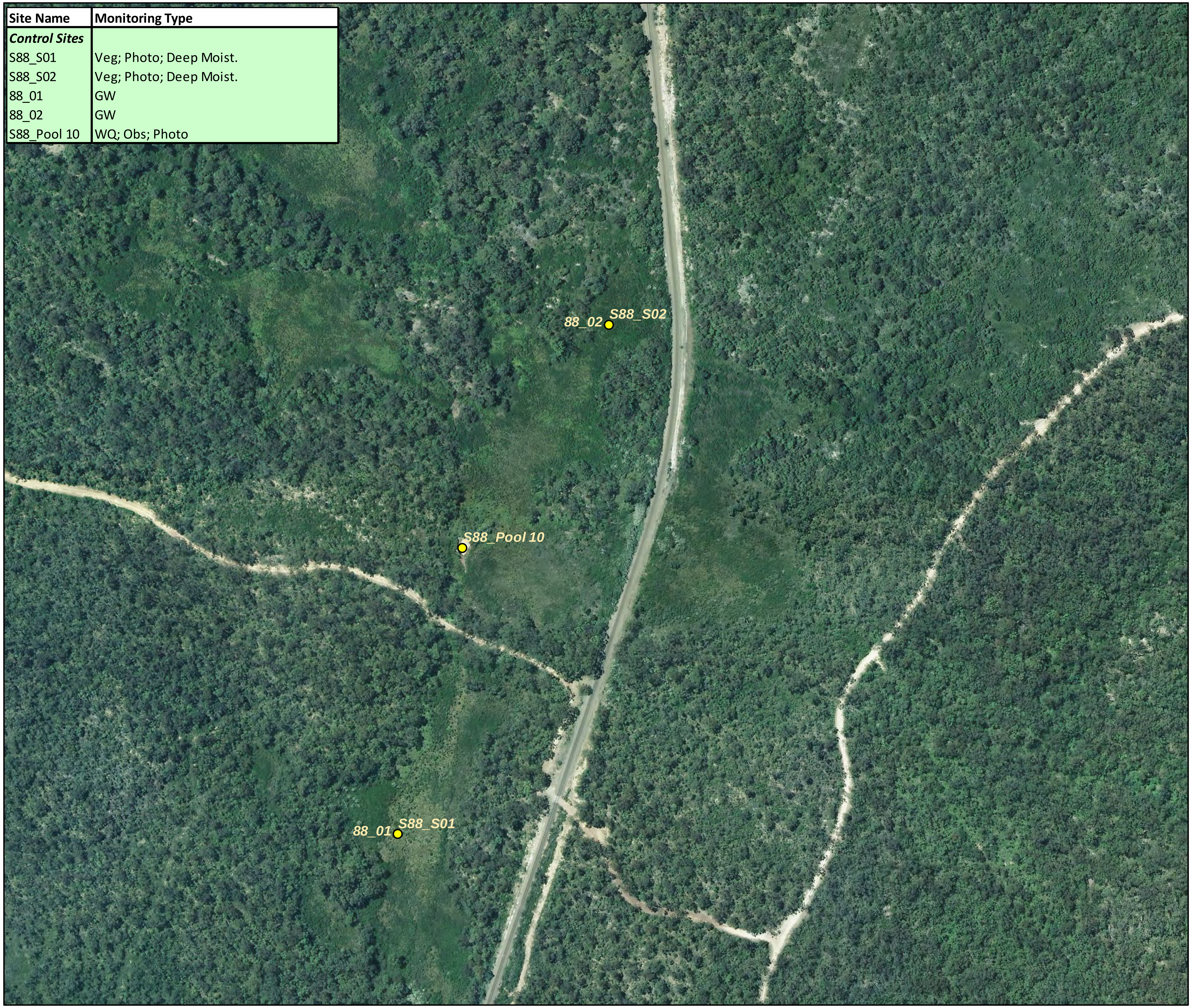
Version 1
Horizontal Datum
MGA - Zone 56

N W E S

0 25 50 100 150 Meters

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



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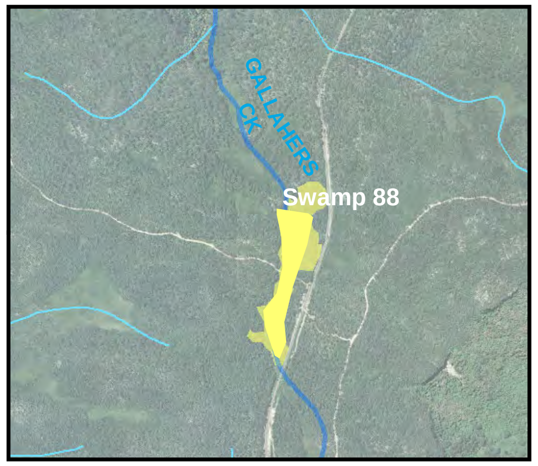
Dendrobium Area 3B

Swamp Monitoring Refrence Sites
Swamp 88

Figure 2-24

Legend

- Proposed Reference Monitoring Site
- Creeks
- Tributaries



Date: December, 2014
Author: J. Carlon
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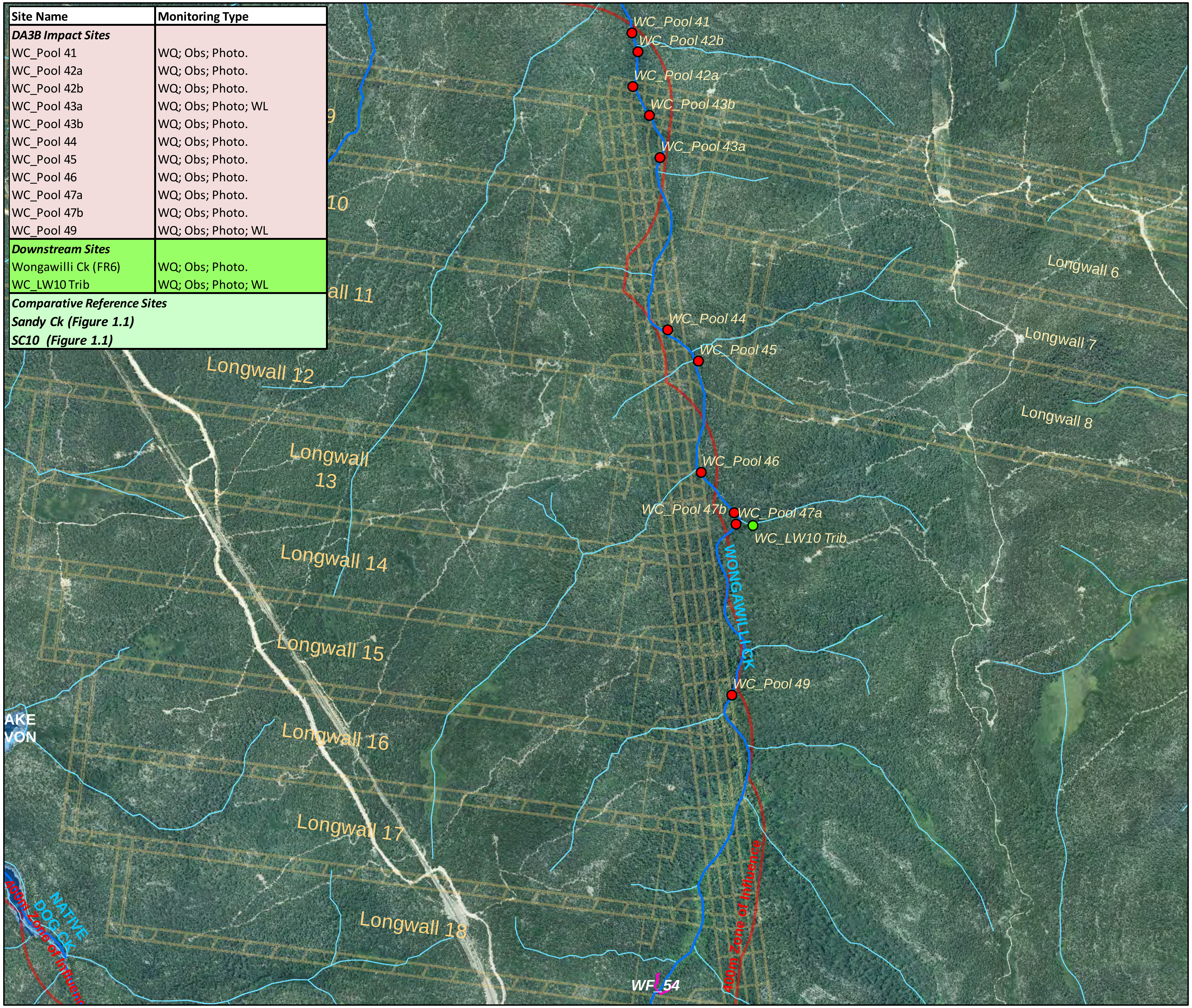
Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

0 25 50 100 150 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
WC_Pool 41	WQ; Obs; Photo.
WC_Pool 42a	WQ; Obs; Photo.
WC_Pool 42b	WQ; Obs; Photo.
WC_Pool 43a	WQ; Obs; Photo; WL
WC_Pool 43b	WQ; Obs; Photo.
WC_Pool 44	WQ; Obs; Photo.
WC_Pool 45	WQ; Obs; Photo.
WC_Pool 46	WQ; Obs; Photo.
WC_Pool 47a	WQ; Obs; Photo.
WC_Pool 47b	WQ; Obs; Photo.
WC_Pool 49	WQ; Obs; Photo; WL
Downstream Sites	
Wongawilli Ck (FR6)	WQ; Obs; Photo.
WC_LW10 Trib	WQ; Obs; Photo; WL
Comparative Reference Sites	
Sandy Ck (Figure 1.1)	
SC10 (Figure 1.1)	



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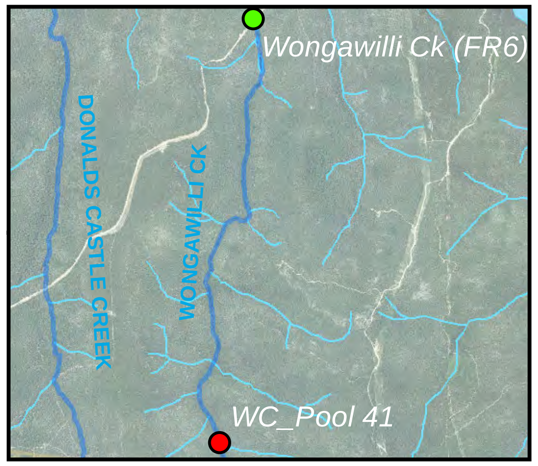
Dendrobium Area 3B
Watercourse Monitoring Sites
Wongawilli Ck

Figure 2-25

Legend

- Downstream Monitoring Site
- Impact Monitoring Site
- Wongawilli Ck Waterfall (WF_54)
- 400m Zone of Influence (DA3B)
- Creeks
- Tributaries
- Dendrobium Layout



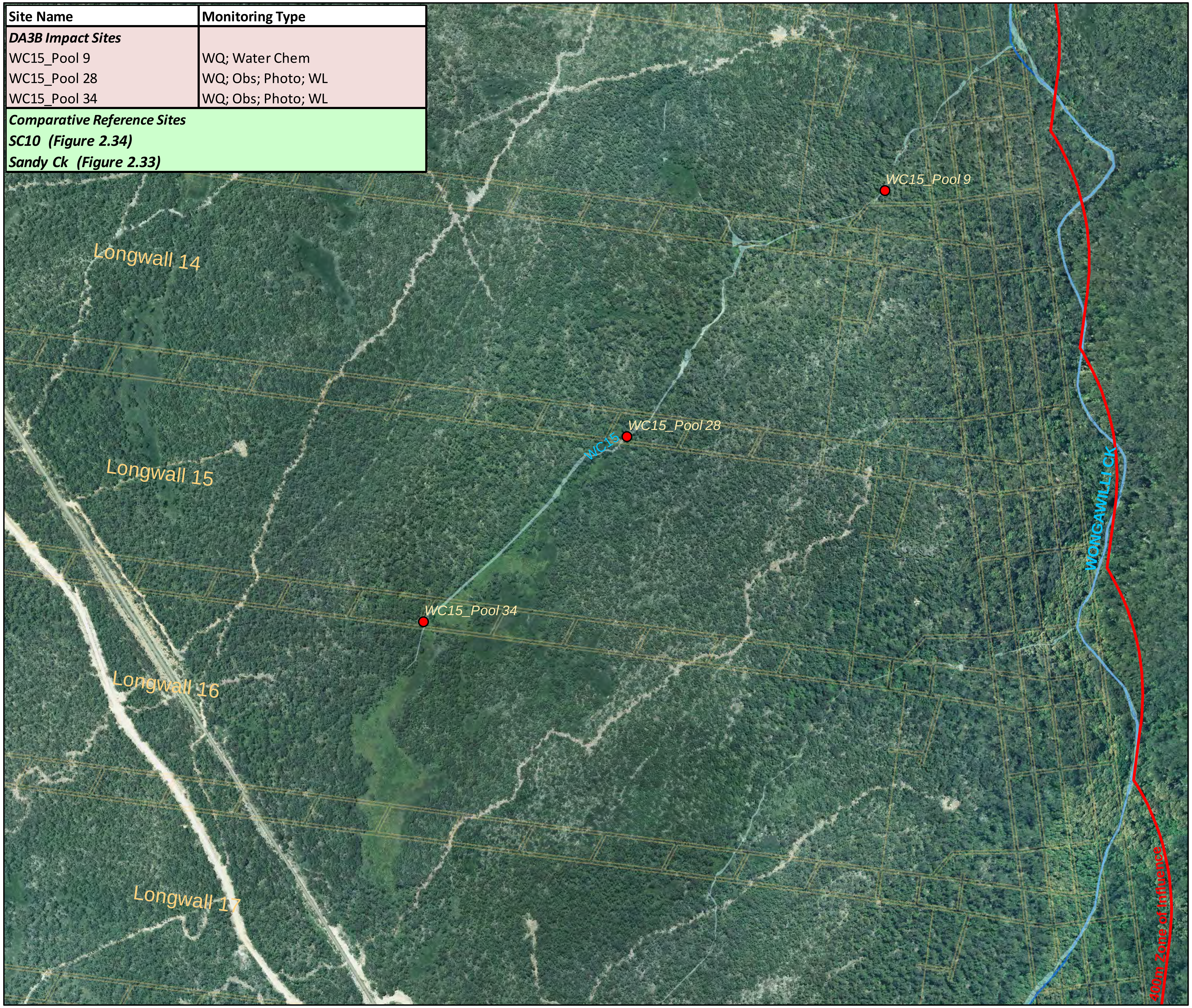
Date: December, 2014
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N S W E

500 250 0 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
WC15_Pool 9	WQ; Water Chem
WC15_Pool 28	WQ; Obs; Photo; WL
WC15_Pool 34	WQ; Obs; Photo; WL
Comparative Reference Sites	
SC10 (Figure 2.34)	
Sandy Ck (Figure 2.33)	



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Dendrobium Area 3B

Watercourse Monitoring Sites

WC15

Figure 2.26

Legend

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

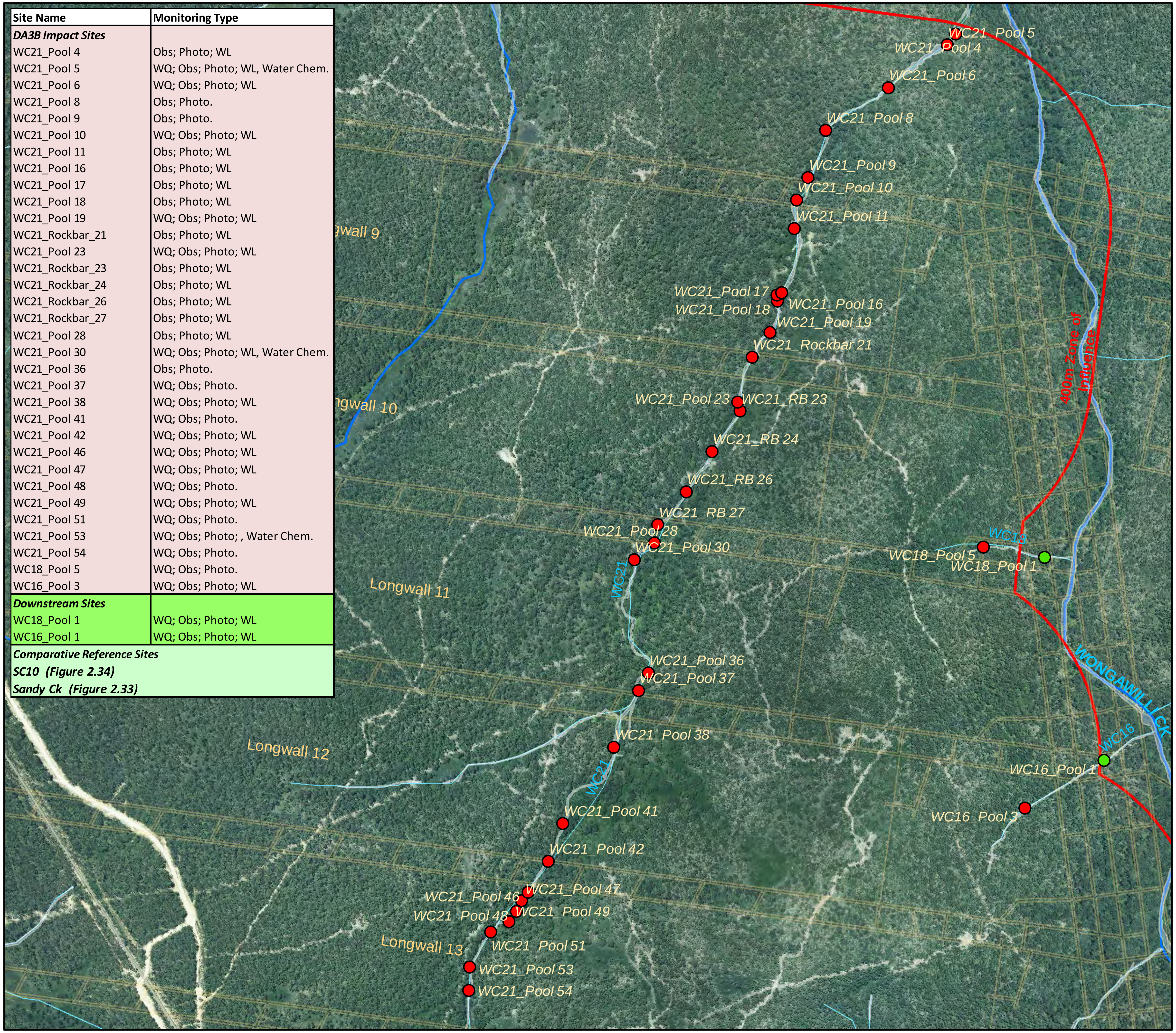
Date: March, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N E S W

170 85 0 170
Meters

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



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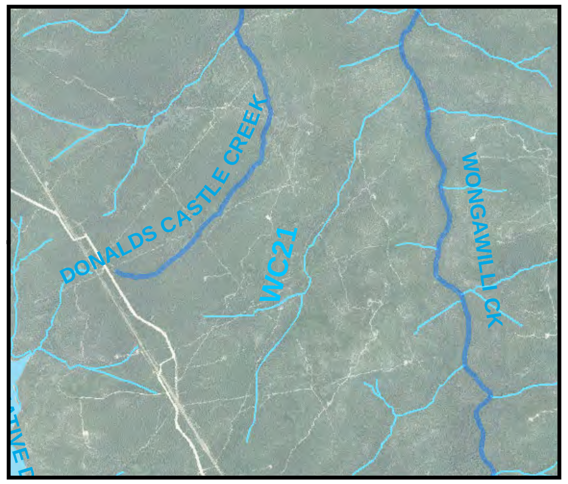
Dendrobium Area 3B
Watercourse Monitoring Sites
WC21, WC18 and WC16

Figure 2-27

Legend

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



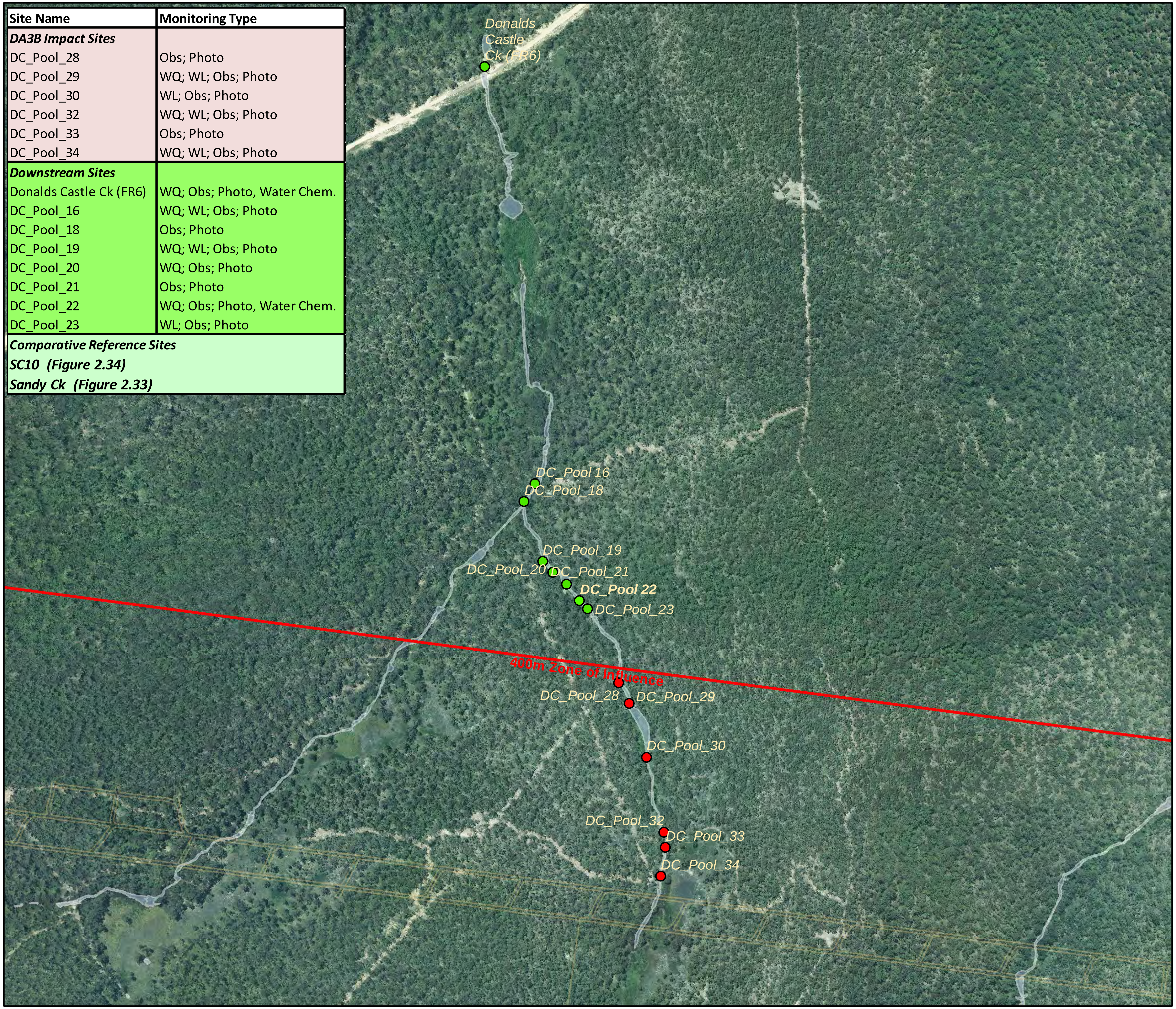
Date: October, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N E S W

0 50 100 200 300 400 Metres

Site Name	Monitoring Type
DA3B Impact Sites	
DC_Pool_28	Obs; Photo
DC_Pool_29	WQ; WL; Obs; Photo
DC_Pool_30	WL; Obs; Photo
DC_Pool_32	WQ; WL; Obs; Photo
DC_Pool_33	Obs; Photo
DC_Pool_34	WQ; WL; Obs; Photo
Downstream Sites	
Donalds Castle Ck (FR6)	WQ; Obs; Photo, Water Chem.
DC_Pool_16	WQ; WL; Obs; Photo
DC_Pool_18	Obs; Photo
DC_Pool_19	WQ; WL; Obs; Photo
DC_Pool_20	WQ; Obs; Photo
DC_Pool_21	Obs; Photo
DC_Pool_22	WQ; Obs; Photo, Water Chem.
DC_Pool_23	WL; Obs; Photo
Comparative Reference Sites	
SC10 (Figure 2.34)	
Sandy Ck (Figure 2.33)	



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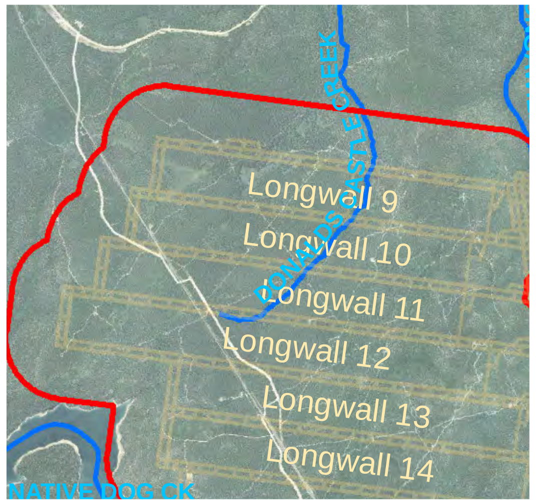
Dendrobium Area 3B
Watercourse Monitoring Sites
Donalds Castle Creek

Figure 2.28

Legend

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



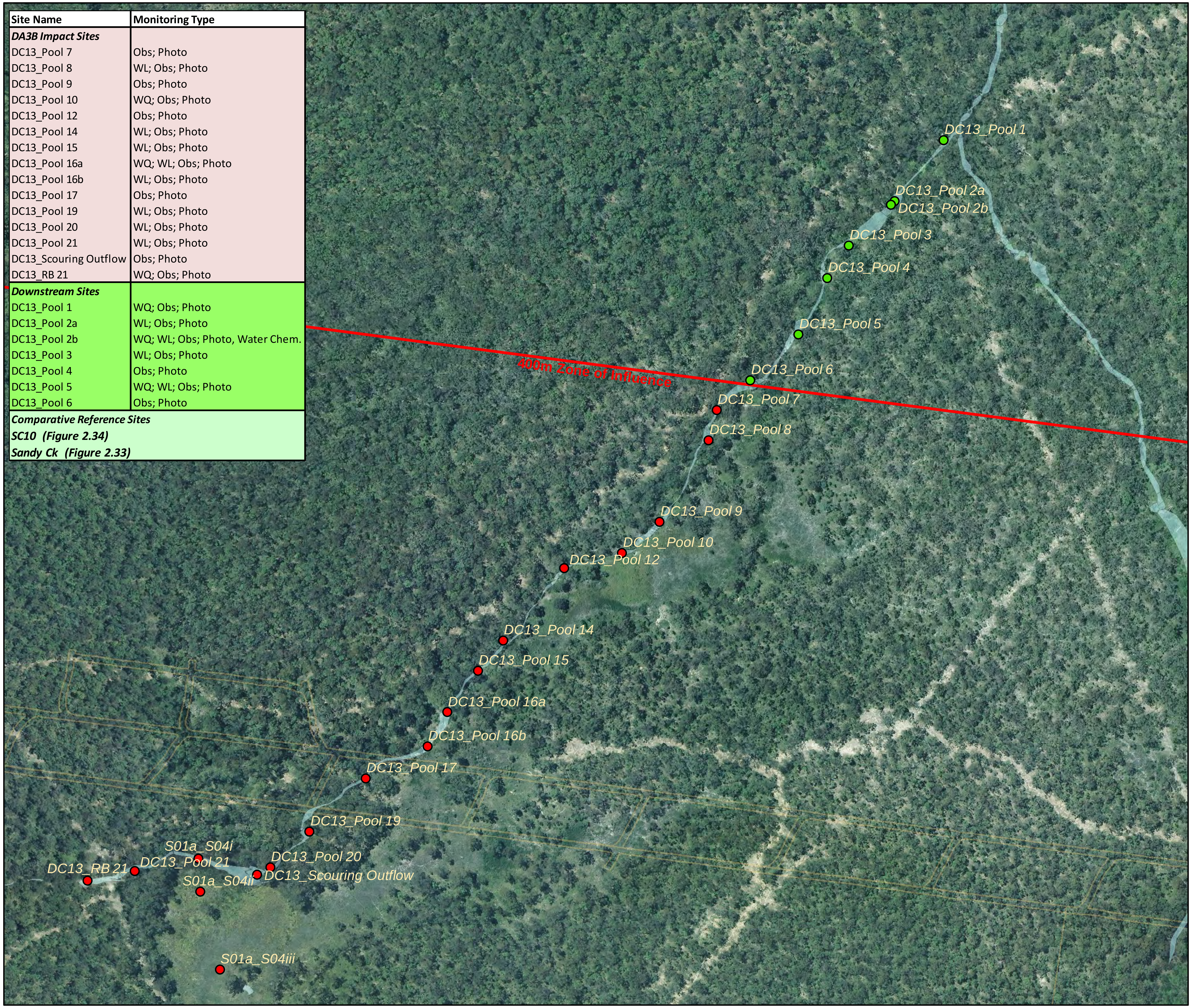
Date: March, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N S W E

0 50 100 200 300 Metres

Site Name	Monitoring Type
DA3B Impact Sites	
DC13_Pool 7	Obs; Photo
DC13_Pool 8	WL; Obs; Photo
DC13_Pool 9	Obs; Photo
DC13_Pool 10	WQ; Obs; Photo
DC13_Pool 12	Obs; Photo
DC13_Pool 14	WL; Obs; Photo
DC13_Pool 15	WL; Obs; Photo
DC13_Pool 16a	WQ; WL; Obs; Photo
DC13_Pool 16b	WL; Obs; Photo
DC13_Pool 17	Obs; Photo
DC13_Pool 19	WL; Obs; Photo
DC13_Pool 20	WL; Obs; Photo
DC13_Pool 21	WL; Obs; Photo
DC13_Scouring Outflow	Obs; Photo
DC13_RB 21	WQ; Obs; Photo
Downstream Sites	
DC13_Pool 1	WQ; Obs; Photo
DC13_Pool 2a	WL; Obs; Photo
DC13_Pool 2b	WQ; WL; Obs; Photo, Water Chem.
DC13_Pool 3	WL; Obs; Photo
DC13_Pool 4	Obs; Photo
DC13_Pool 5	WQ; WL; Obs; Photo
DC13_Pool 6	Obs; Photo
Comparative Reference Sites	
SC10 (Figure 2.34)	
Sandy Ck (Figure 2.33)	



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Illawarra Coal

Dendrobium Area 3B

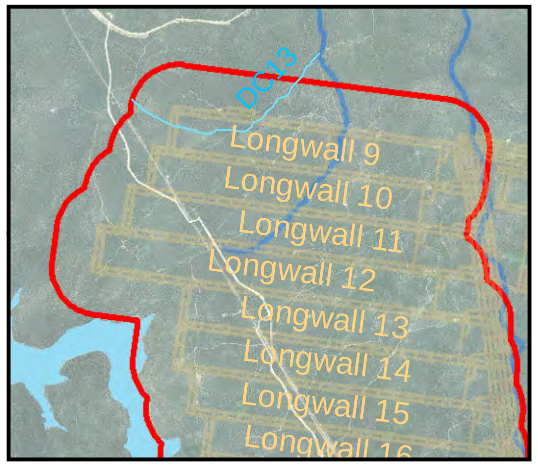
Watercourse Monitoring Sites

DC13

Figure 2.29

Legend

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



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

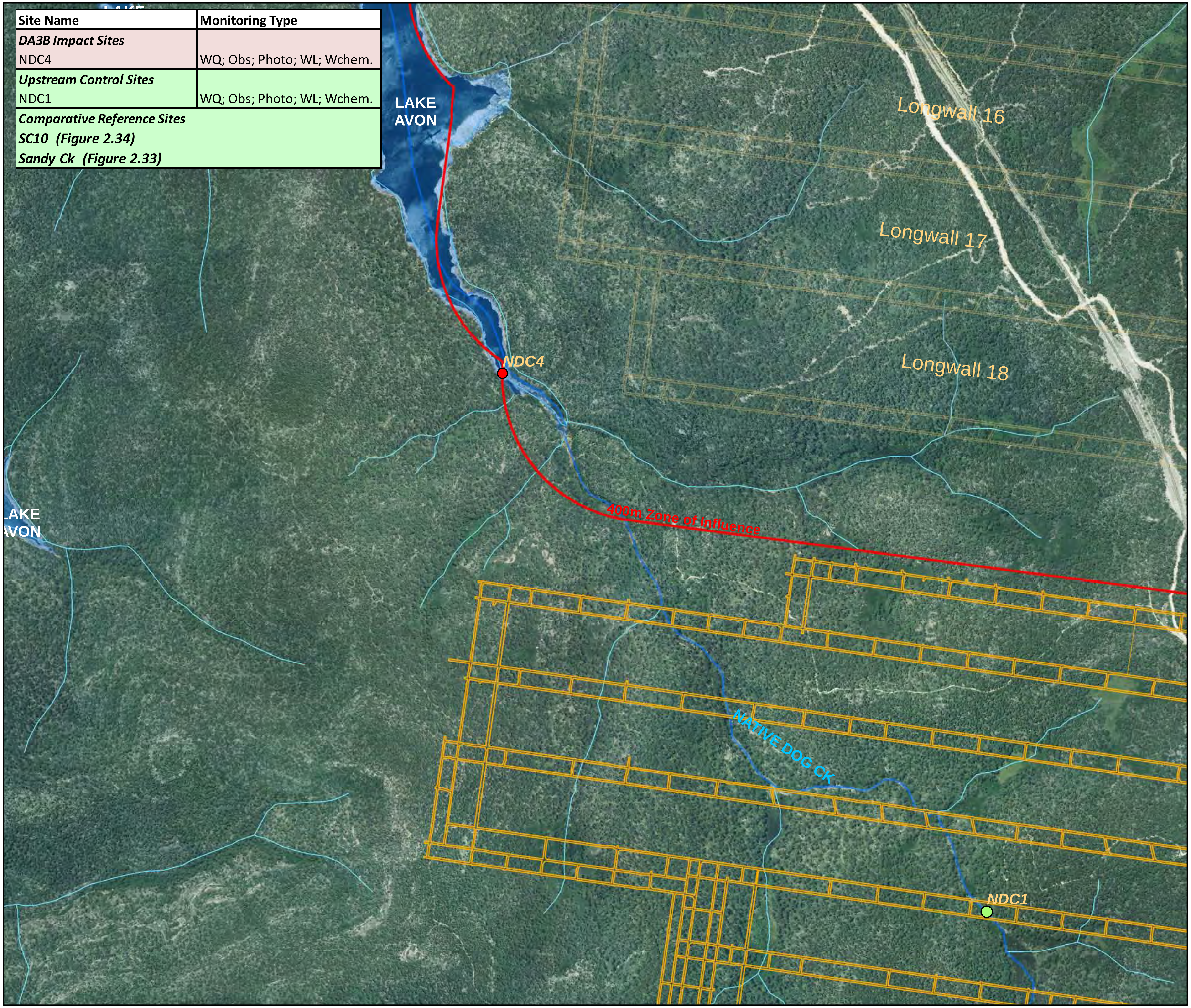
Version 1

Horizontal Datum
MGA - Zone 56

N W E S

50 25 0 50 100
Meters

Site Name	Monitoring Type
DA3B Impact Sites	
NDC4	WQ; Obs; Photo; WL; Wchem.
Upstream Control Sites	
NDC1	WQ; Obs; Photo; WL; Wchem.
Comparative Reference Sites	
SC10 (Figure 2.34)	
Sandy Ck (Figure 2.33)	



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Dendrobium Area 3B

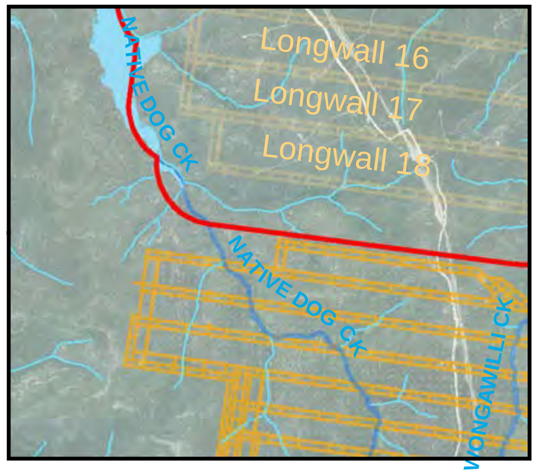
Watercourse Monitoring Sites

Native Dog Creek

Figure 2.30

Legend

- Impact Monitoring Site
- Control
- Creeks
- Tributaries
- Dendrobium Layout
- Elouera Workings
- 400m Zone of Influence (DA3B)



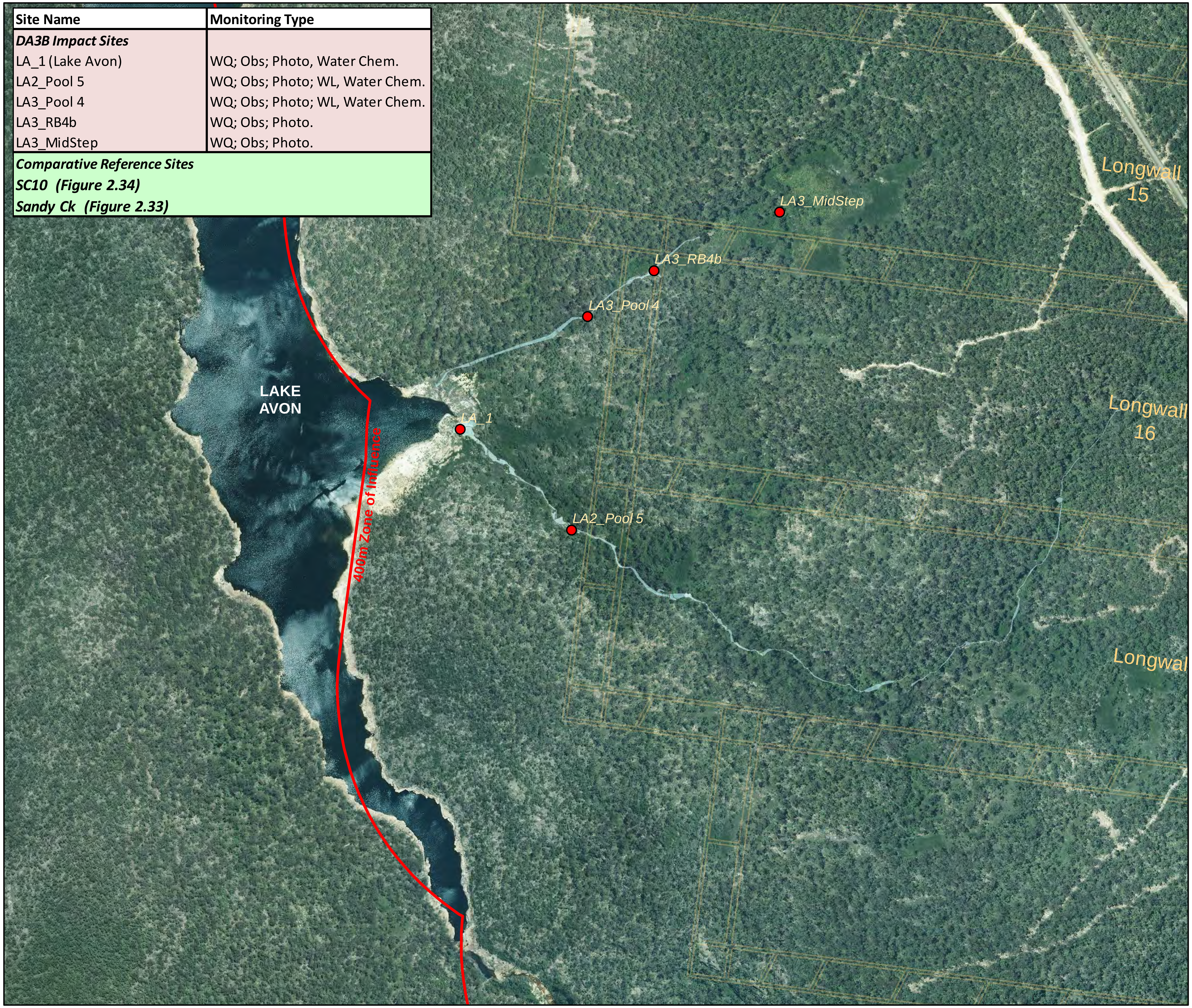
Date: 24 July, 2013
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

280 140 0 280 Meters

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.
LA3_Pool 4	WQ; Obs; Photo; WL, Water Chem.
LA3_RB4b	WQ; Obs; Photo.
LA3_MidStep	WQ; Obs; Photo.
Comparative Reference Sites	
SC10 (Figure 2.34)	
Sandy Ck (Figure 2.33)	



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Dendrobium Area 3B

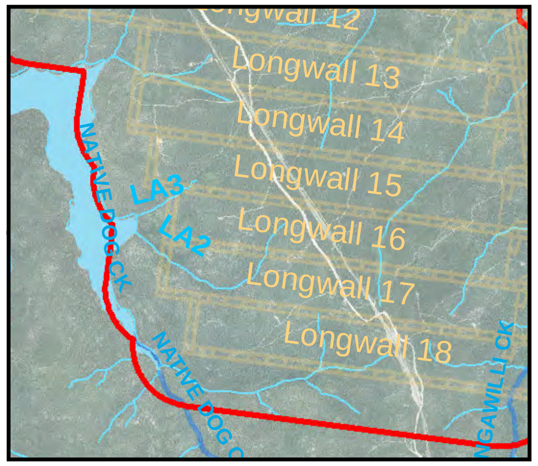
Watercourse Monitoring Sites

Lake Avon, LA2 and LA3

Figure 2.31

Legend

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



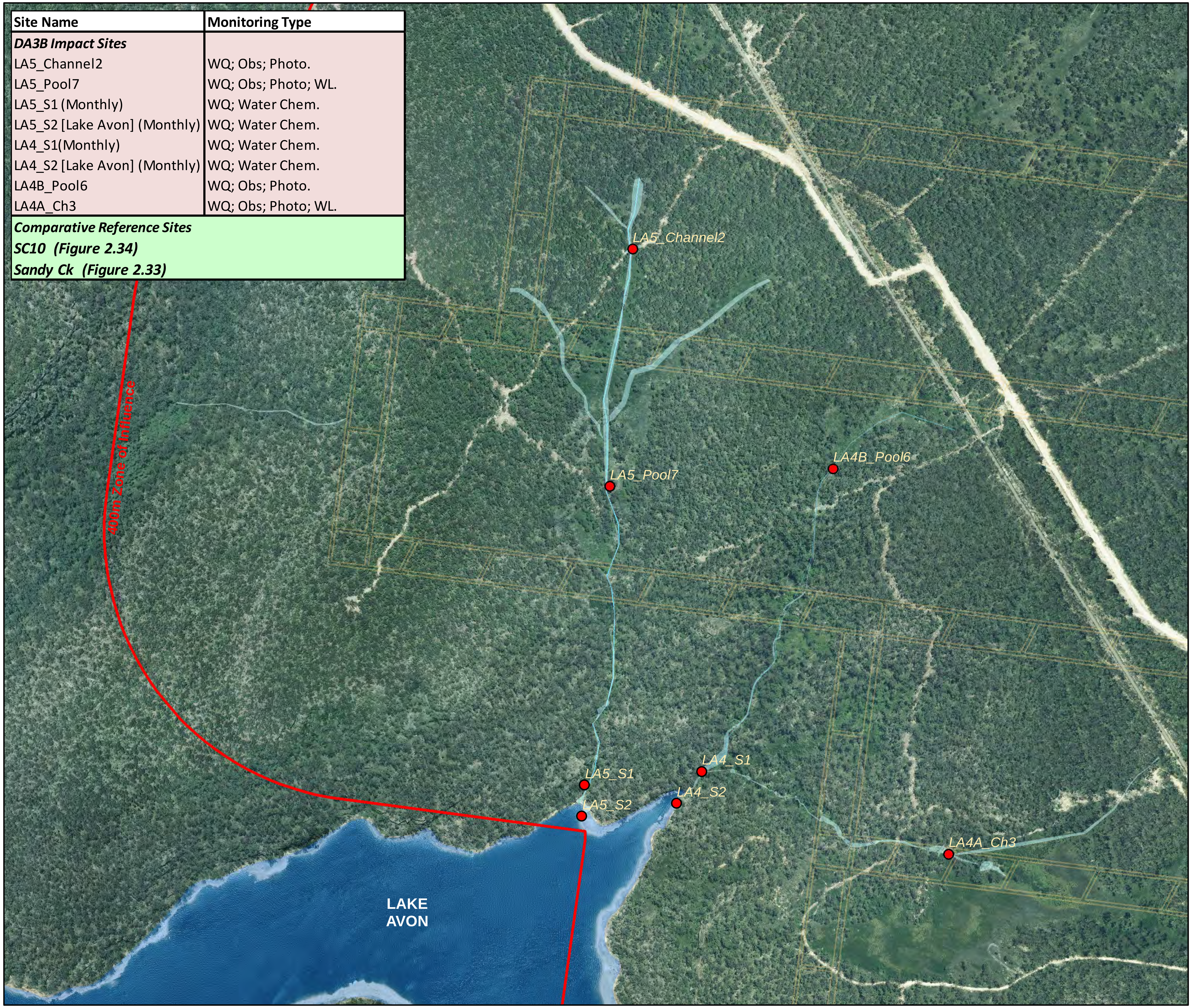
Date: March, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N E S W

150 75 0 150 Meters

Site Name	Monitoring Type
DA3B Impact Sites	
LA5_Channel2	WQ; Obs; Photo.
LA5_Pool7	WQ; Obs; Photo; WL.
LA5_S1 (Monthly)	WQ; Water Chem.
LA5_S2 [Lake Avon] (Monthly)	WQ; Water Chem.
LA4_S1(Monthly)	WQ; Water Chem.
LA4_S2 [Lake Avon] (Monthly)	WQ; Water Chem.
LA4B_Pool6	WQ; Obs; Photo.
LA4A_Ch3	WQ; Obs; Photo; WL.
Comparative Reference Sites	
SC10 (Figure 2.34)	
Sandy Ck (Figure 2.33)	



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Illawarra Coal

Dendrobium Area 3B

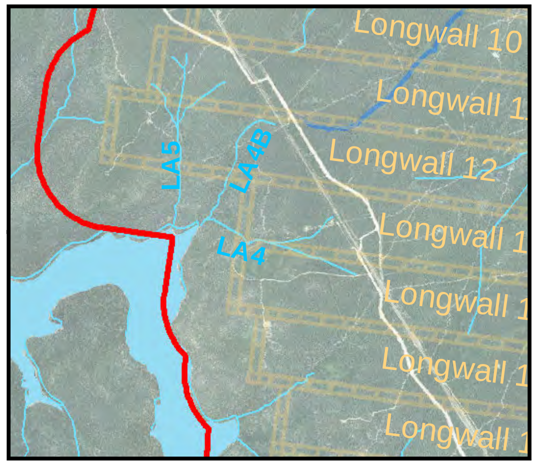
Watercourse Monitoring Sites

Lake Avon, LA4 and LA5

Figure 2-32

Legend

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



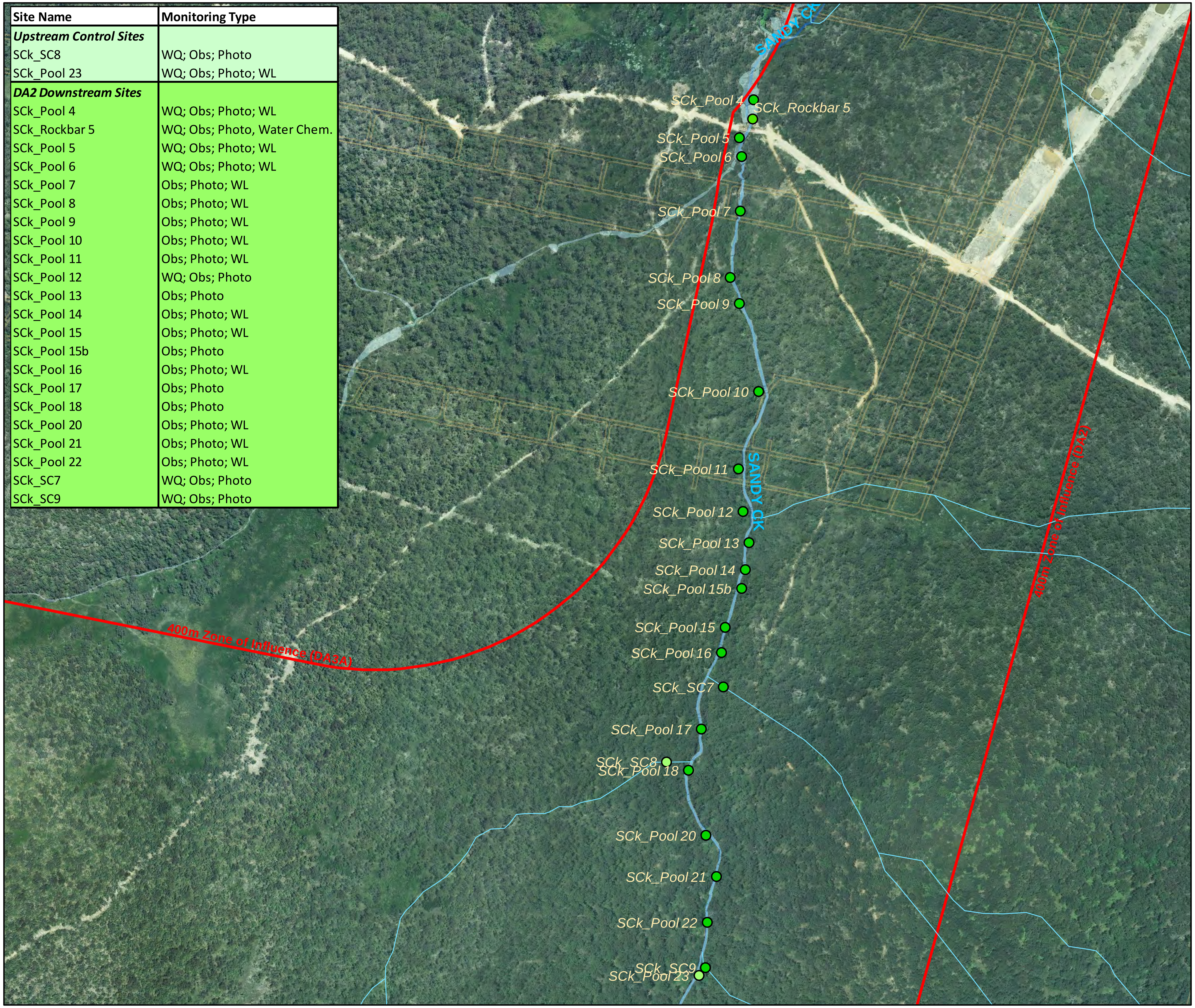
Date: March, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

150 75 0 150 Meters

Site Name	Monitoring Type
Upstream Control Sites	
SCk_SC8	WQ; Obs; Photo
SCk_Pool 23	WQ; Obs; Photo; WL
DA2 Downstream Sites	
SCk_Pool 4	WQ; Obs; Photo; WL
SCk_Rockbar 5	WQ; Obs; Photo, Water Chem.
SCk_Pool 5	WQ; Obs; Photo; WL
SCk_Pool 6	WQ; Obs; Photo; WL
SCk_Pool 7	Obs; Photo; WL
SCk_Pool 8	Obs; Photo; WL
SCk_Pool 9	Obs; Photo; WL
SCk_Pool 10	Obs; Photo; WL
SCk_Pool 11	Obs; Photo; WL
SCk_Pool 12	WQ; Obs; Photo
SCk_Pool 13	Obs; Photo
SCk_Pool 14	Obs; Photo; WL
SCk_Pool 15	Obs; Photo; WL
SCk_Pool 15b	Obs; Photo
SCk_Pool 16	Obs; Photo; WL
SCk_Pool 17	Obs; Photo
SCk_Pool 18	Obs; Photo
SCk_Pool 20	Obs; Photo; WL
SCk_Pool 21	Obs; Photo; WL
SCk_Pool 22	Obs; Photo; WL
SCk_SC7	WQ; Obs; Photo
SCk_SC9	WQ; Obs; Photo



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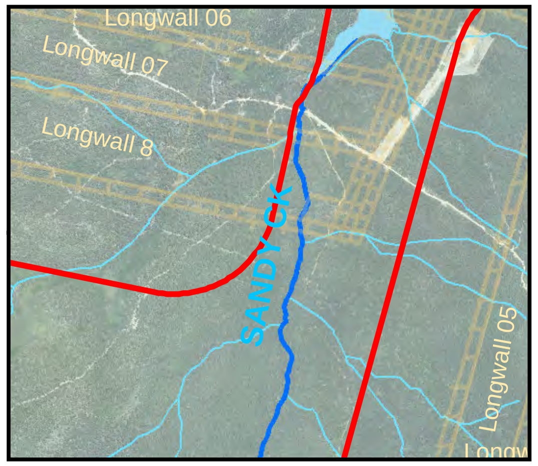
Dendrobium Area 3B
Watercourse Reference Sites
Sandy Creek

Figure 2.33

Legend

- Upstream Control Site
- DA2 Downstream Monitoring Site
- Tributaries
- Creeks
- Stream Mapping
- Dendrobium Layout
- 400m Zone of Influence



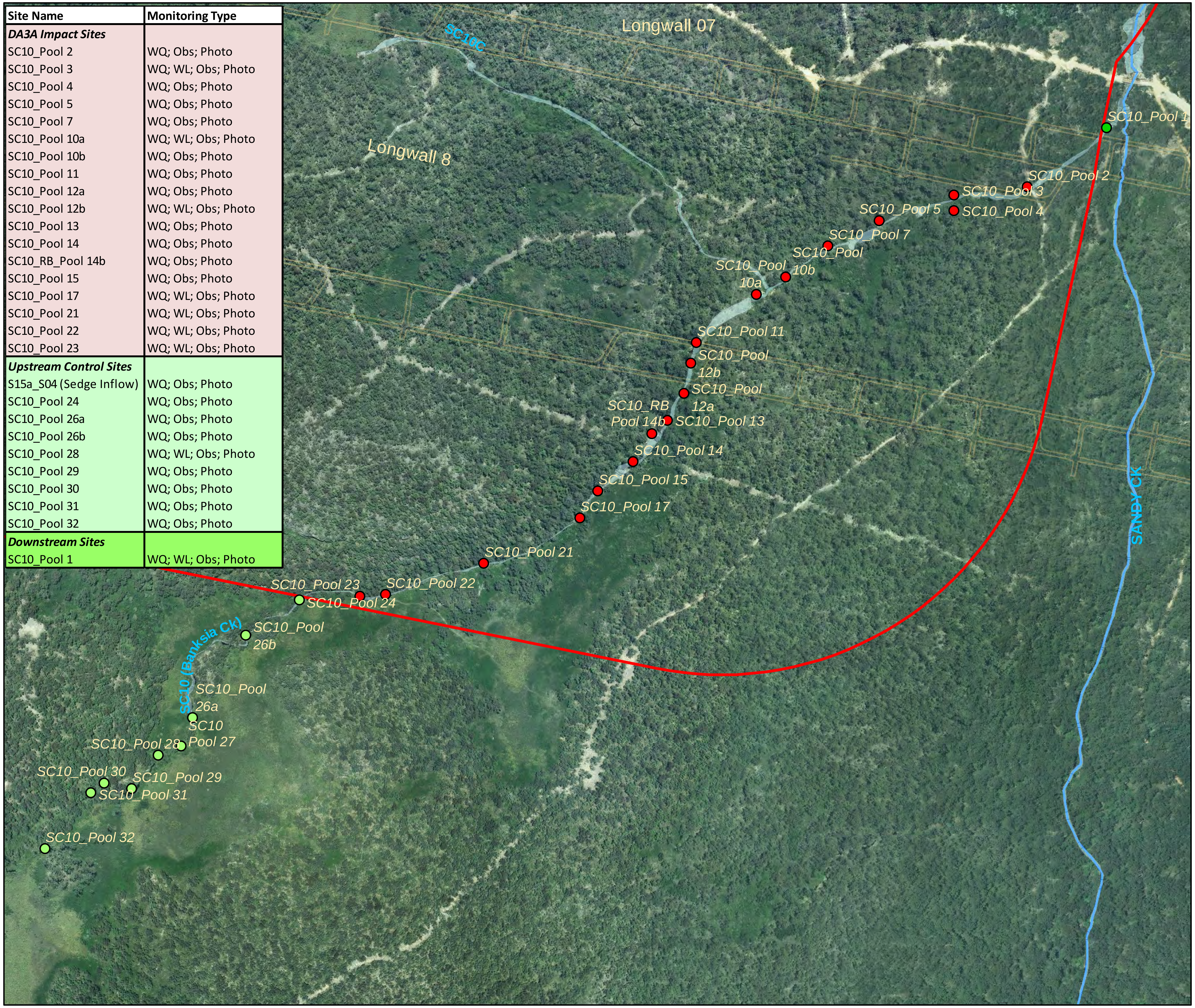
Date: March, 2015
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N
W E
S

50 25 0 50 100 150 200 Meters

Site Name	Monitoring Type
DA3A Impact Sites	
SC10_Pool 2	WQ; Obs; Photo
SC10_Pool 3	WQ; WL; Obs; Photo
SC10_Pool 4	WQ; Obs; Photo
SC10_Pool 5	WQ; Obs; Photo
SC10_Pool 7	WQ; Obs; Photo
SC10_Pool 10a	WQ; WL; Obs; Photo
SC10_Pool 10b	WQ; Obs; Photo
SC10_Pool 11	WQ; Obs; Photo
SC10_Pool 12a	WQ; Obs; Photo
SC10_Pool 12b	WQ; WL; Obs; Photo
SC10_Pool 13	WQ; Obs; Photo
SC10_Pool 14	WQ; Obs; Photo
SC10_RB_Pool 14b	WQ; Obs; Photo
SC10_Pool 15	WQ; Obs; Photo
SC10_Pool 17	WQ; WL; Obs; Photo
SC10_Pool 21	WQ; WL; Obs; Photo
SC10_Pool 22	WQ; WL; Obs; Photo
SC10_Pool 23	WQ; WL; Obs; Photo
Upstream Control Sites	
S15a_S04 (Sedge Inflow)	WQ; Obs; Photo
SC10_Pool 24	WQ; Obs; Photo
SC10_Pool 26a	WQ; Obs; Photo
SC10_Pool 26b	WQ; Obs; Photo
SC10_Pool 28	WQ; WL; Obs; Photo
SC10_Pool 29	WQ; Obs; Photo
SC10_Pool 30	WQ; Obs; Photo
SC10_Pool 31	WQ; Obs; Photo
SC10_Pool 32	WQ; Obs; Photo
Downstream Sites	
SC10_Pool 1	WQ; WL; Obs; Photo



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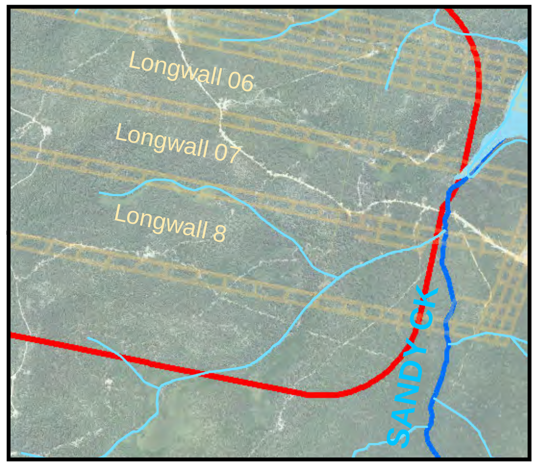
Dendrobium Area 3B
Watercourse Reference Sites
SC10

Figure 2-34

Legend

- Upstream Control Site
- DA3A Downstream Monitoring Site
- DA3A Impact Monitoring Site
- Stream Mapping
- Dendrobium Layout
- 400m Zone of Influence (DA3A)

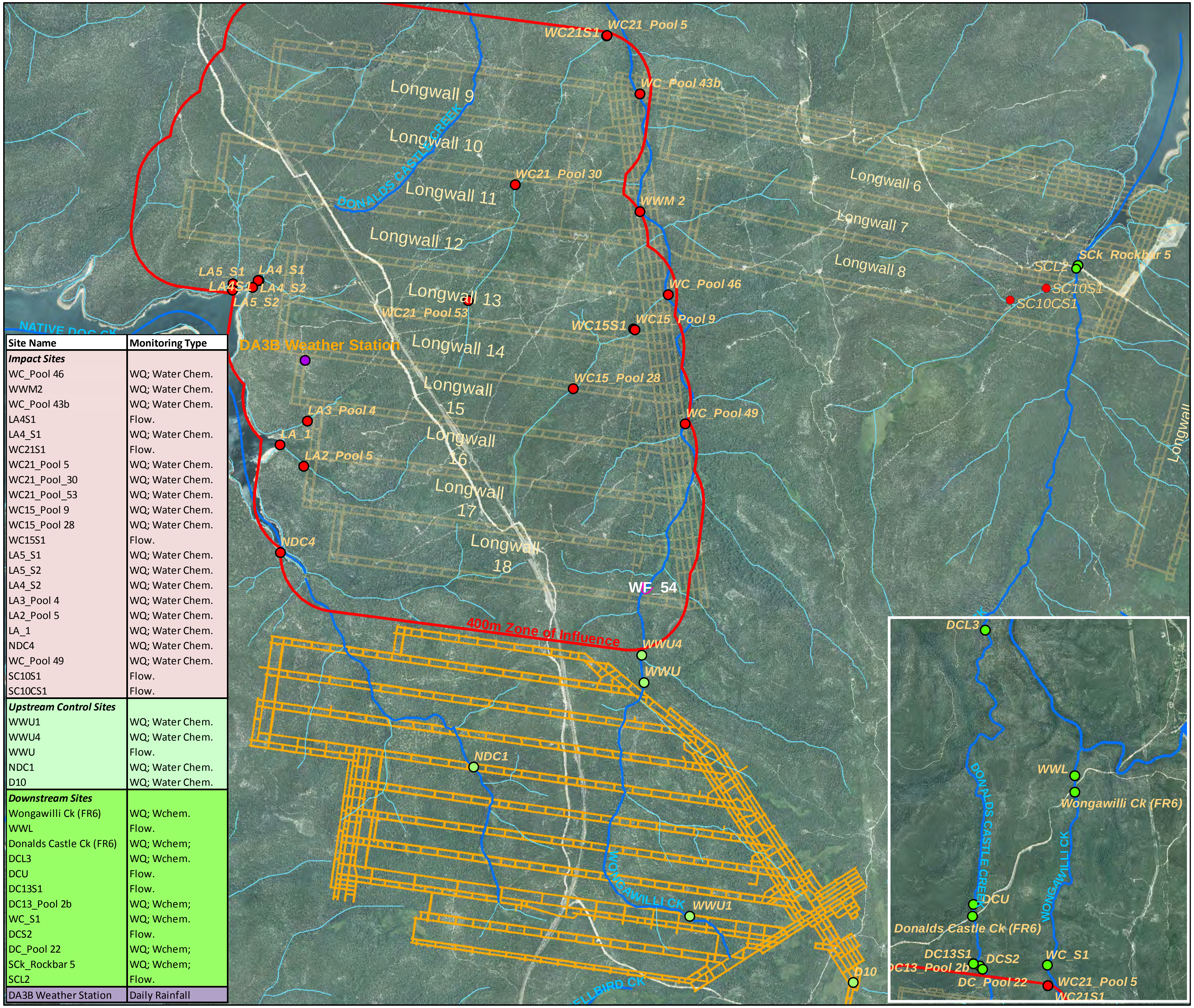


Date: December, 2014
Author: J. Carlon
Signed Off: G. Brassington

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

50 25 0 50 100 150 200 Meters



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

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Dendrobium Area 3B Water Quality and Flow Monitoring

Figure 2.35

Legend

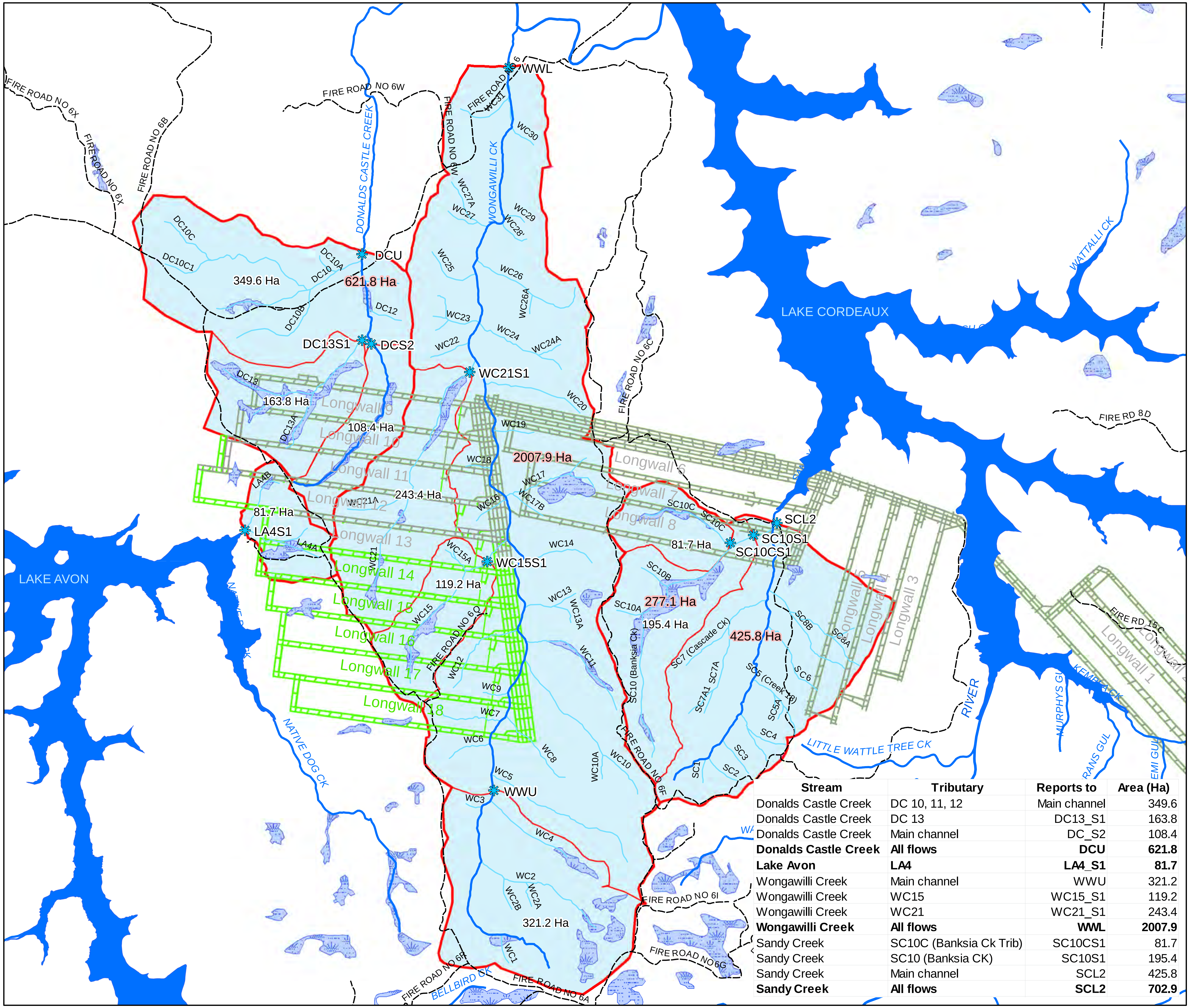
- Upstream Control Site
- Downstream Reference Site
- Impact Site
- DA3B Weather Station
- Wongawilli Creek Waterfall (WF_54)
- 400m Zone of Influence (DA3B)
- Creeks
- Tributaries
- Dendrobium Layout
- Elouera Workings

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

Version 1
Horizontal Datum
MGA - Zone 56

N E S W

0 500 1,000 Metres



Stream	Tributary	Reports to	Area (Ha)
Donalds Castle Creek	DC 10, 11, 12	Main channel	349.6
Donalds Castle Creek	DC 13	DC13_S1	163.8
Donalds Castle Creek	Main channel	DC_S2	108.4
Donalds Castle Creek	**All flows**	**DCU**	**621.8**
Lake Avon	**LA4**	**LA4_S1**	**81.7**
Wongawilli Creek	Main channel	WWU	321.2
Wongawilli Creek	WC15	WC15_S1	119.2
Wongawilli Creek	WC21	WC21_S1	243.4
Wongawilli Creek	**All flows**	**WWL**	**2007.9**
Sandy Creek	SC10C (Banksia Ck Trib)	SC10CS1	81.7
Sandy Creek	SC10 (Banksia CK)	SC10S1	195.4
Sandy Creek	Main channel	SCL2	425.8
Sandy Creek	**All flows**	**SCL2**	**702.9**

Dendrobium Flow Monitoring Points

Figure 2.36

Legend

- Water flow monitoring sites
- Fire Roads
- Flow monitoring catchments
- Sub-catchments

Date: 29 May, 2015
Author: P.Crowe
Signed Off: G.Brassington

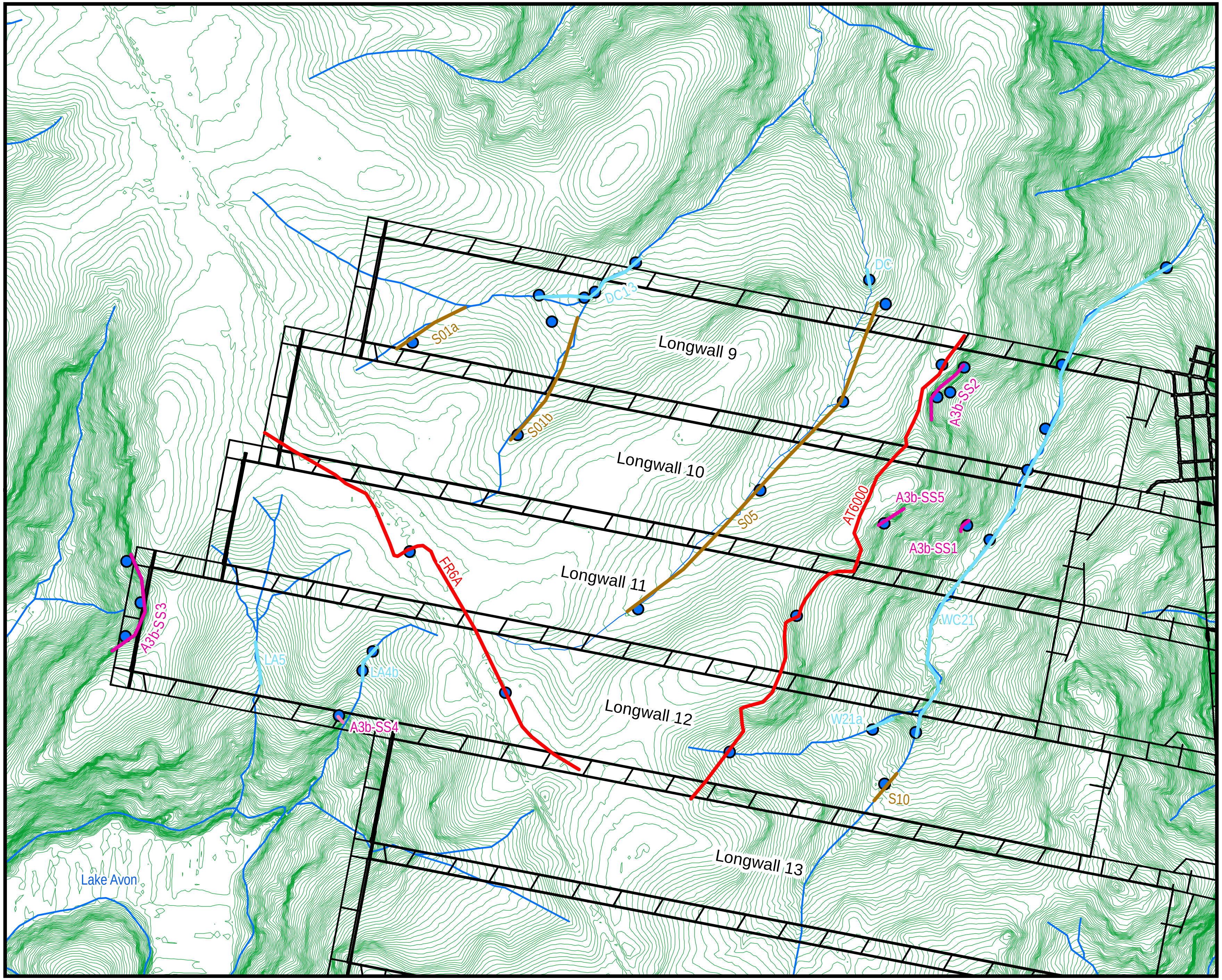
Version 2
Horizontal Datum
MGA - Zone 56

0 0.5 1 2 Kms

N S E W

Document Path: W:\Workspace\External_Affairs\Mining_Approvals\Field_Team\DA3b Maps\DA3B_MGMT_Plan_Maps_Gary\DA3B_MGMT_Plan_Catchments.mxd

Figure 2-37



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

Project: Dendrobium Mine Area 3B

Client: BHP Billiton Illawarra Coal

Legend:

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

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

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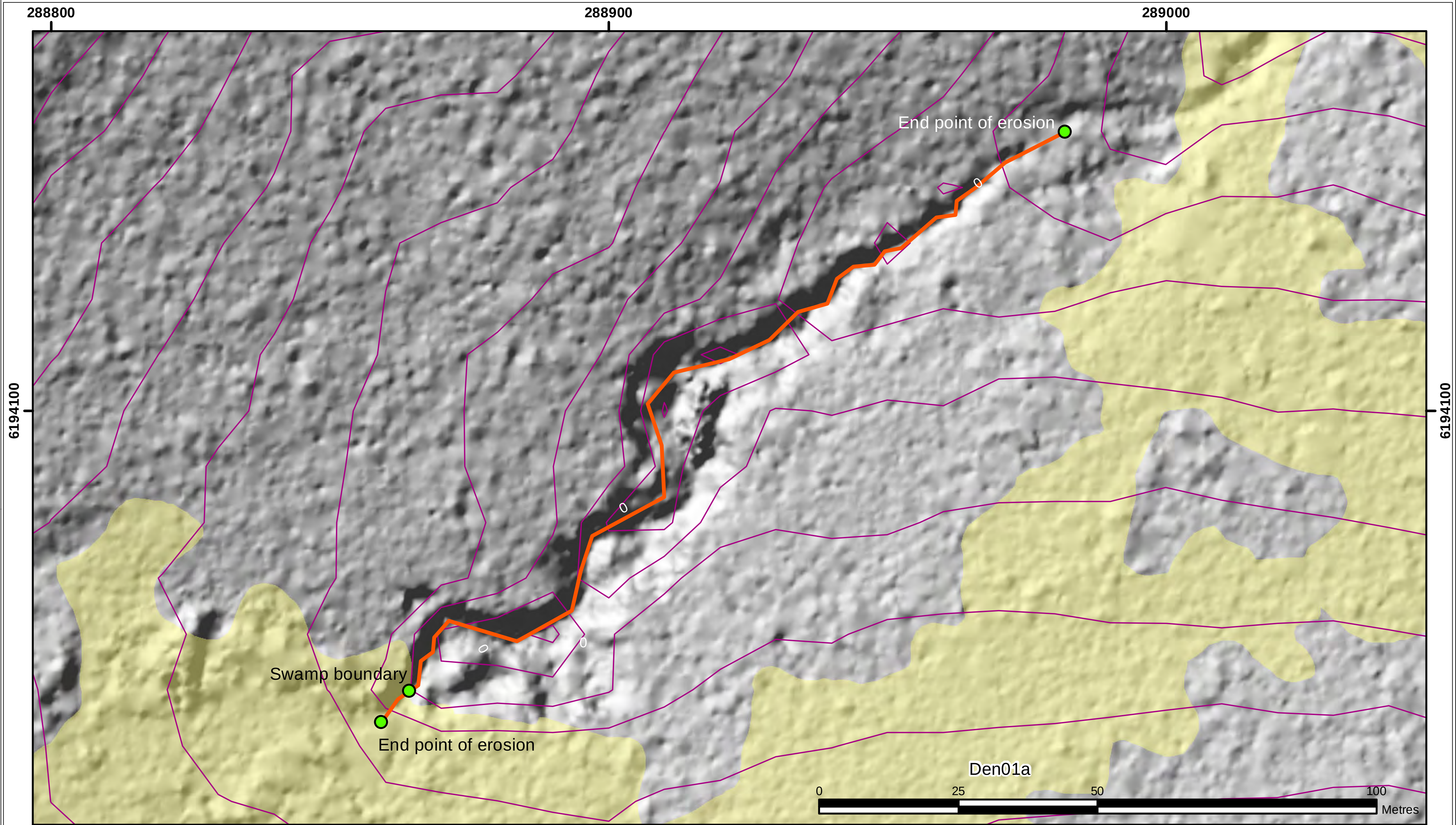
GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

Document Path: V:\BIC01-007\Figures\ArcGIS\Map Documents\BIC01-007_Figure_1.mxd



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Legend

- Total Active Erosion
- 1m contours
- Swamp Subcommunity Mapping

Shaded Relief (derived from ALS imagery)

Dendrobium Area 3B

Mapped Erosion- Swamp 01a

Figure 2.38

Date: 20 May, 2014
Author: T. McMahon
Authoriser: G. Brassington

Version 1

Horizontal Datum
MGA - Zone 56

N
W E
S

288800 288900 289000

6194000

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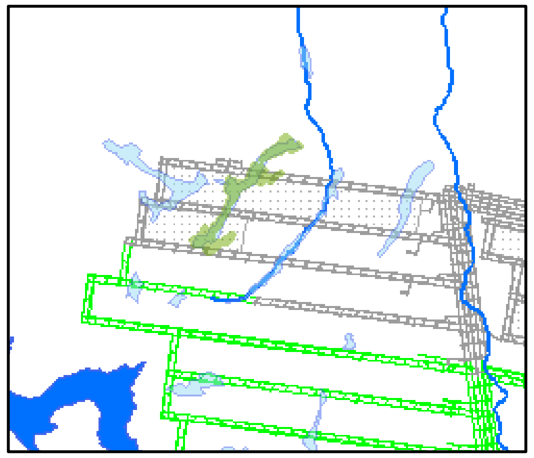
Dendrobium Area 3B
Swamp 1A

Figure 2.39
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

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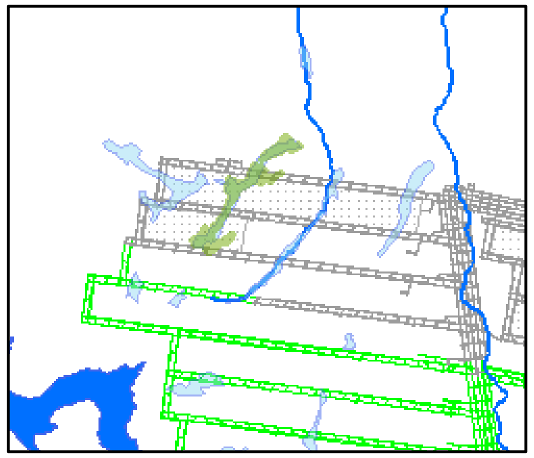
Dendrobium Area 3B
Swamp 1A

Figure 2.40
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

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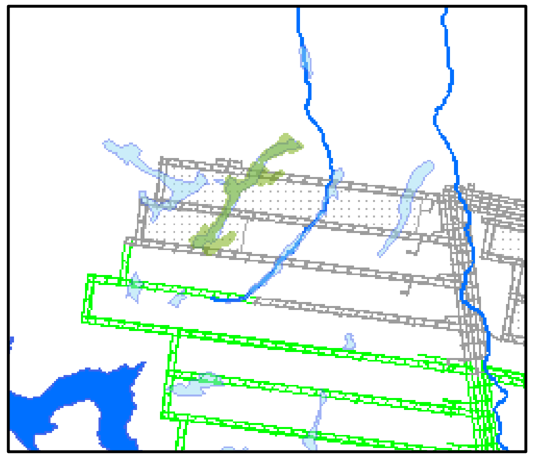
Dendrobium Area 3B
Swamp 1A

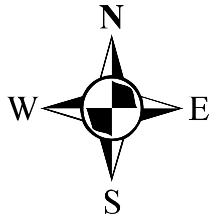
Figure 2.41
Orthophoto May 2013

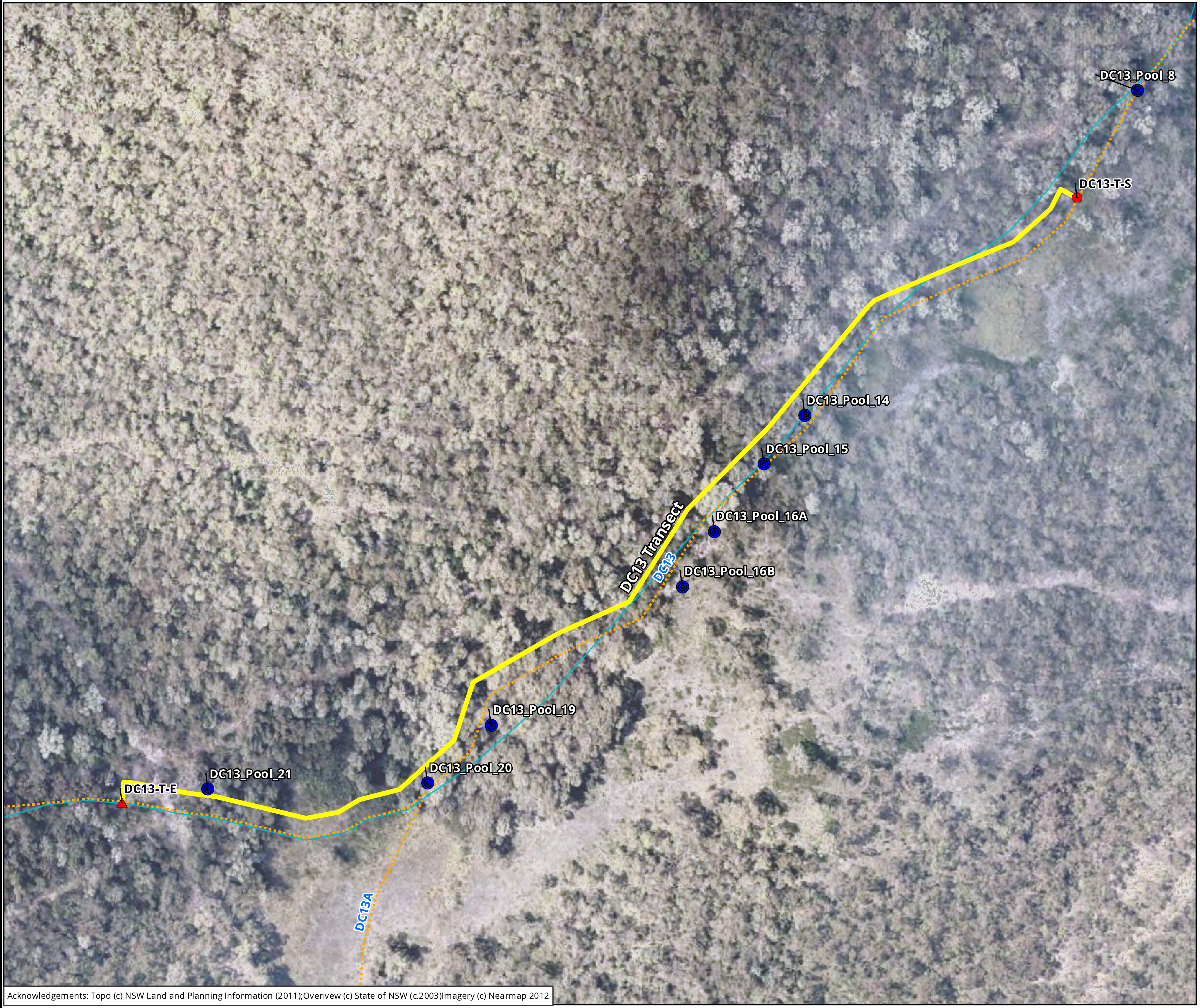
Swamp 1A in
Regional Context



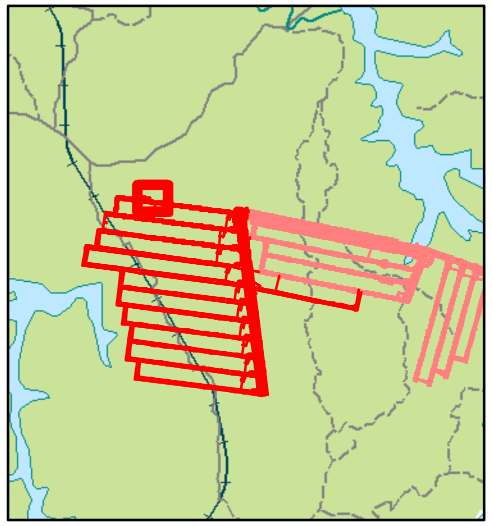
Date: 10 April, 2014
Author: P.Crowe
Signed Off: G.Brassington

Version 1
Horizontal Datum
MGA - Zone 56





Acknowledgements: Topo (c) NSW Land and Planning Information (2011);Overview (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 2.42: DC13 Transect

0 10 20 30 40 50

Metres

Scale: 1:1,820 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

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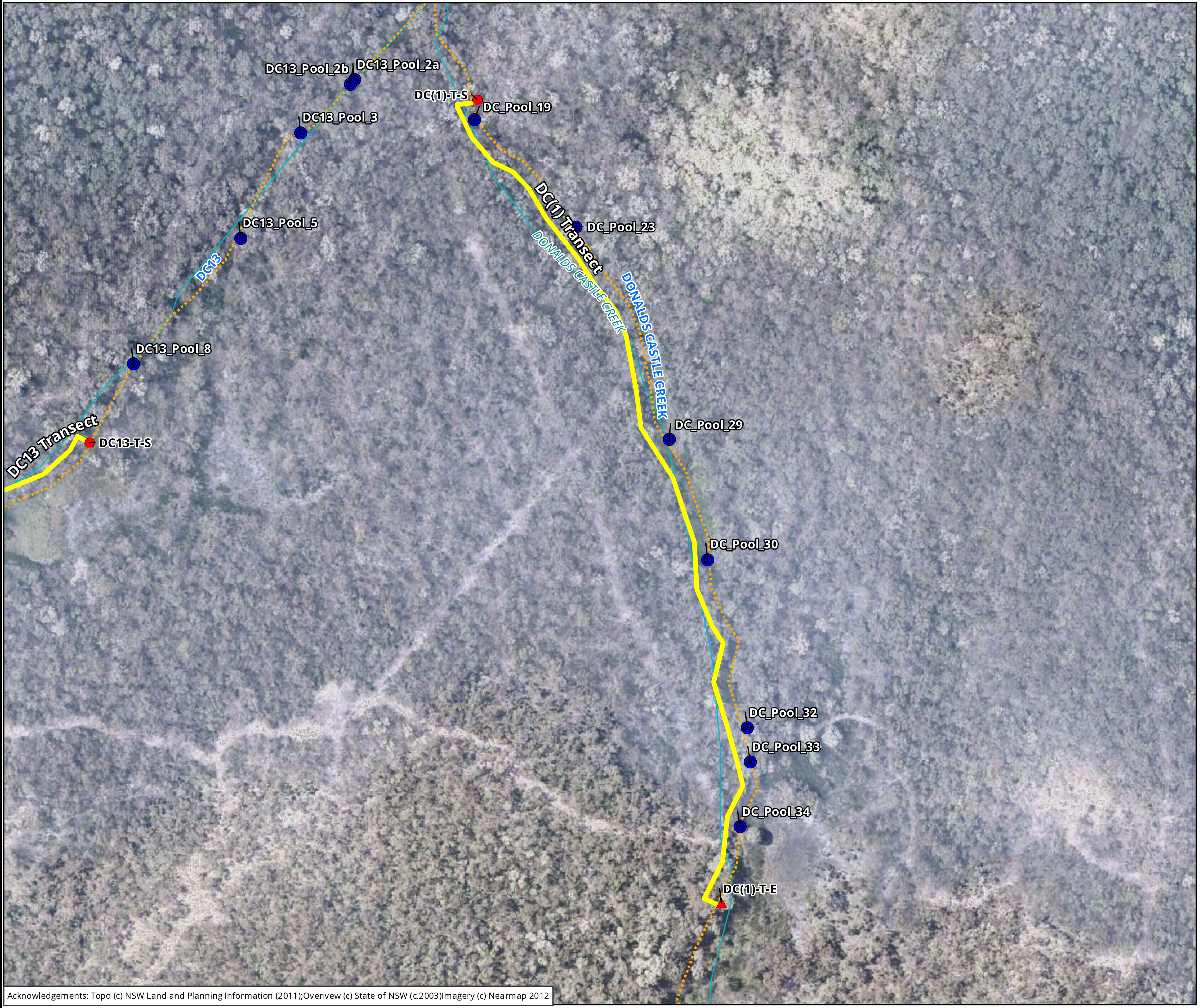
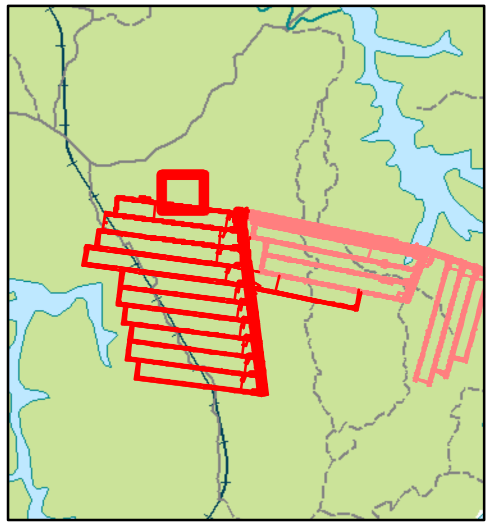
Matter: 17994
Date: 19 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B TF Transects





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 2.43: DC(1) Transect

0 25 50 75 100 125

Metres

Scale: 1:2,480 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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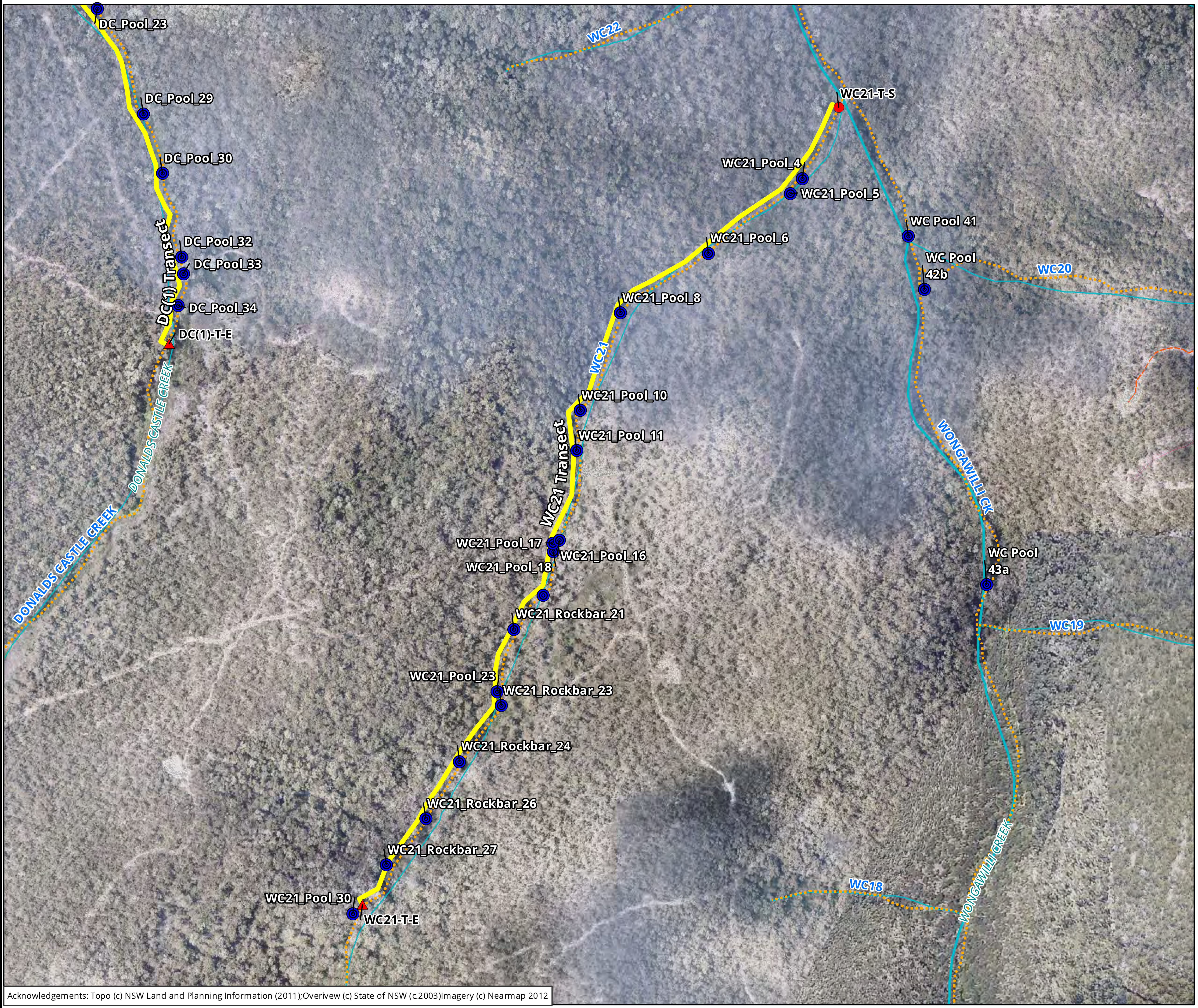
Matter: 17994
Date: 19 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B TF Transects



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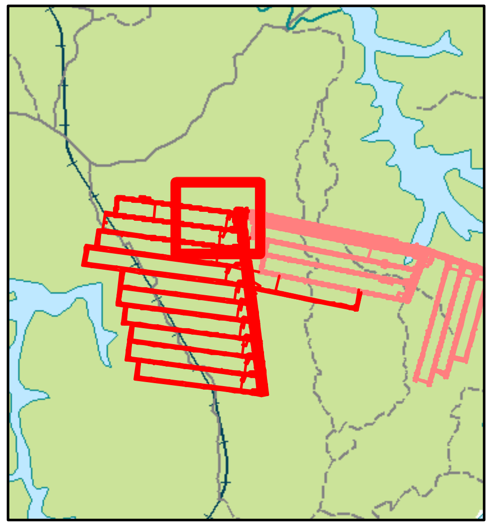

Legend

Pool Level Monitoring Sites

Threatened Frog Monitoring

Impact - Transect Start

Impact - Transect End

Threatened Frog Transect

BHP Creek and Swamp Naming

BHP Creekline

Figure 2.44: WC21 Transect

0 50 100 150 200 250

Metres

Scale: 1:5,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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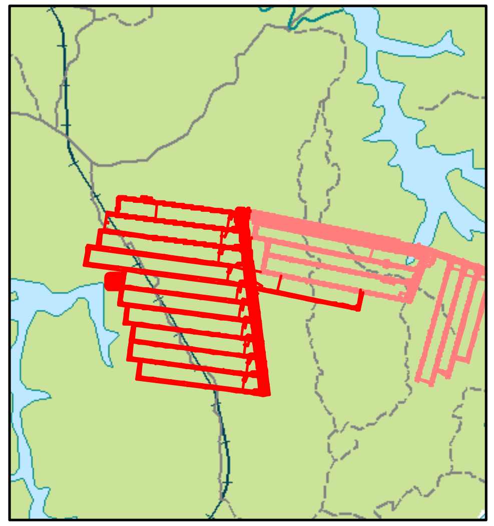
Matter: 17994
Date: 19 March 2014,
Checked by: ANP, Drawn by: ANP, Last edited by: apritchard
Location:P:\17900s\17994\Mapping
17994 Dend 3B TF Transects



Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.45: LA4A Transect

0 6 12 18 24 30

Metres

Scale: 1:610 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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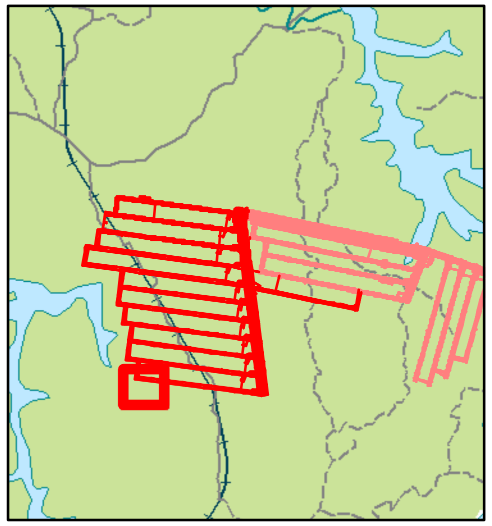

Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.46: ND1 Transect

0 25 50 75 100 125

Metres

Scale: 1:2,470 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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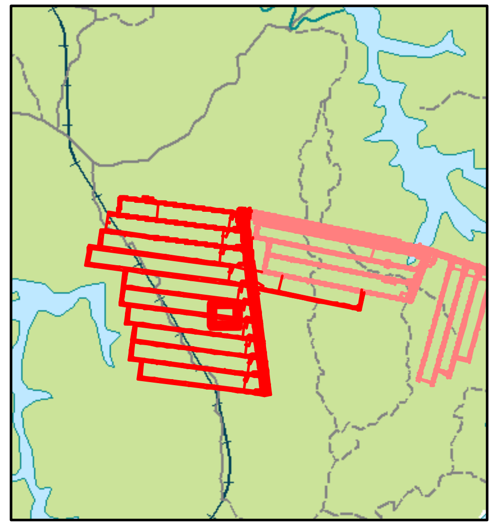
Acknowledgements: Topo (c) NSW Land and Planning Information (2011);Overivew (c) State of NSW (c.2003)Imagery (c) Nearmap 2012



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 2.47: WC15 Transect

0 10 20 30 40 50

Metres

Scale: 1:1,550 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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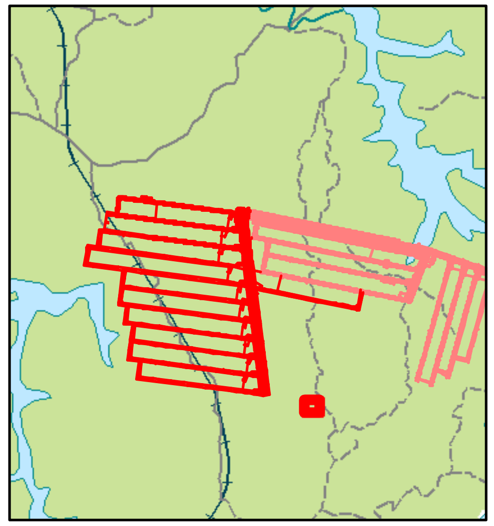
17994 Dend 3B TF Transects



Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.48: WC10 Transect

0 9.5 19 28.5 38 47.5

Metres
Scale: 1:940 @ A3
Coordinate System: GDA 1994 MGA Zone 56

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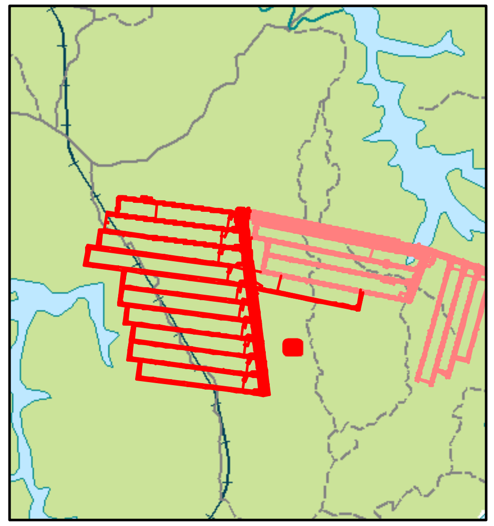
Location:P:\17900s\17994\Mapping
17994 Dend 3B TF Transects



Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.49: WC11 Transect

0 5.5 11 16.5 22 27.5

Metres

Scale: 1:550 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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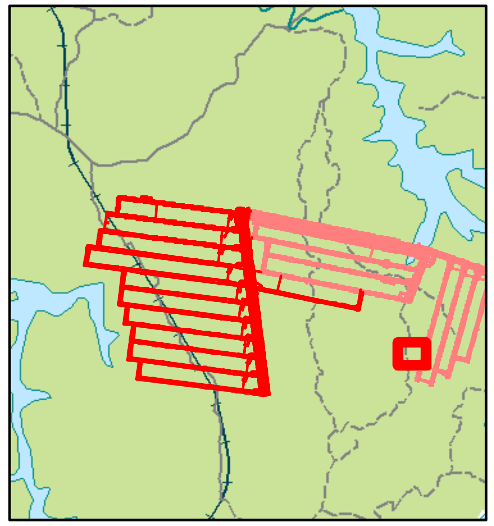

Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.50: SC6 Transect

0 10 20 30 40 50

Metres

Scale: 1:1,620 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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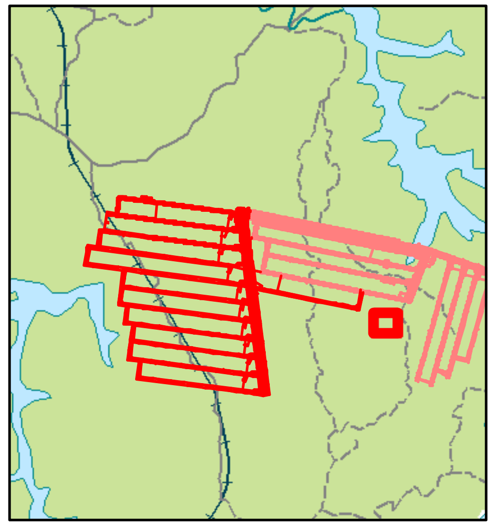
Acknowledgements: Topo (c) NSW Land and Planning Information (2011);Overivew (c) State of NSW (c.2003)Imagery (c) Nearmap 2012



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 2.51: SC7(1) Transect

0 10 20 30 40 50

Metres

Scale: 1:1,420 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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Date: 19 March 2014,
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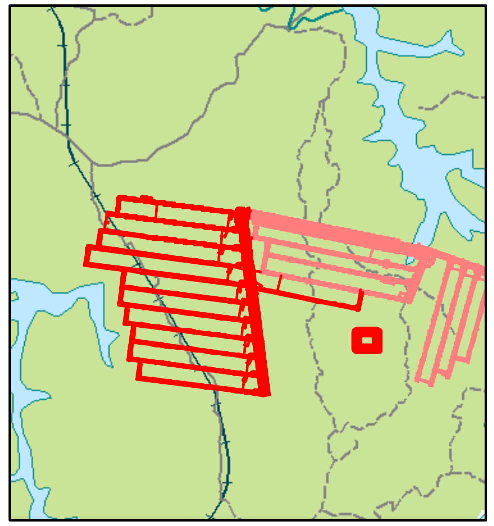
Location:P:\17900s\17994\Mapping
17994 Dend 3B TF Transects

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 2.52: SC7(2) Transect

0 10 20 30 40 50

Metres

Scale: 1:1,210 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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Matter: 17994
Date: 19 March 2014,
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Location:P:\17900s\17994\Mapping
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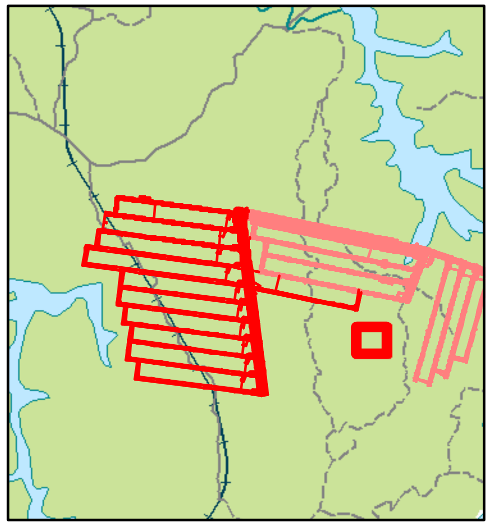
Acknowledgements: Topo (c) NSW Land and Planning Information (2011);Overivew (c) State of NSW (c.2003)Imagery (c) Nearmap 2012



Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.53: SC7A Transect

0 10 20 30 40 50

Metres

Scale: 1:1,830 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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Date: 19 March 2014,
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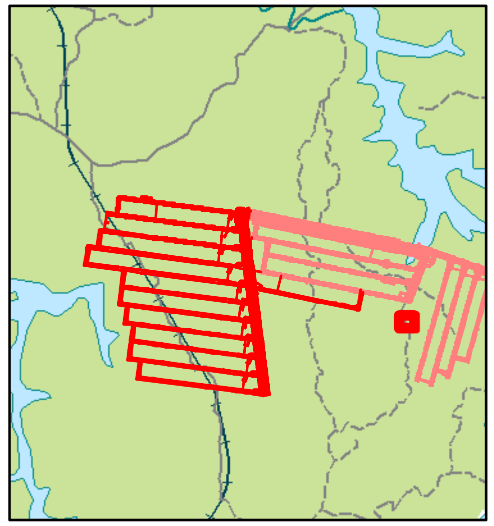
Location:P:\17900s\17994\Mapping
17994 Dend 3B TF Transects



Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.54: SC8 Transect

0 9 18 27 36 45

Metres

Scale: 1:890 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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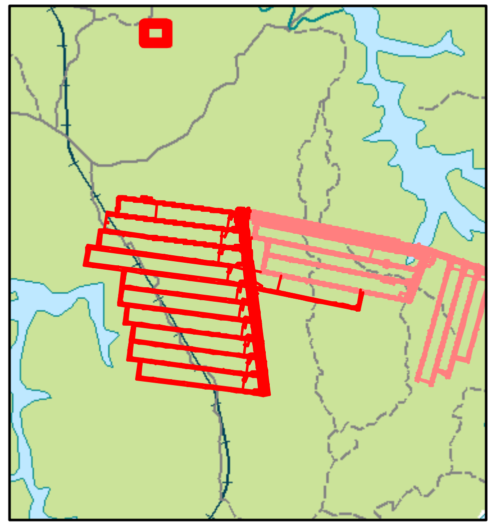

Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.55: DC8 Transect

0 10 20 30 40 50

Metres

Scale: 1:1,370 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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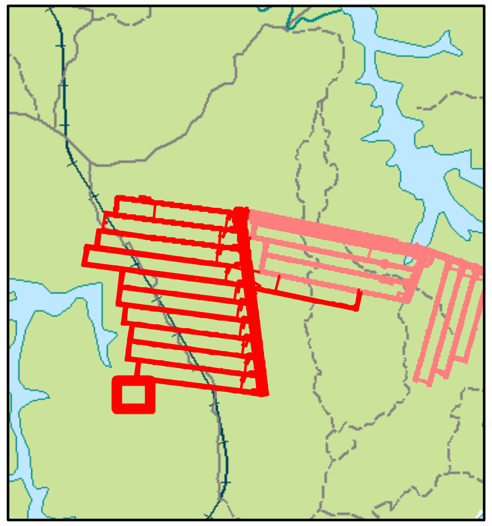
Acknowledgements: Topo (c) NSW Land and Planning Information (2011);Overivew (c) State of NSW (c.2003)Imagery (c) Nearmap 2012



Legend

Threatened Frog Monitoring

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

BHP Creek and Swamp Naming

- BHP Creekline

Figure 2.56: NDC Transect

0 20 40 60 80 100

Metres

Scale: 1:1,970 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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Matter: 17994
Date: 19 March 2014,
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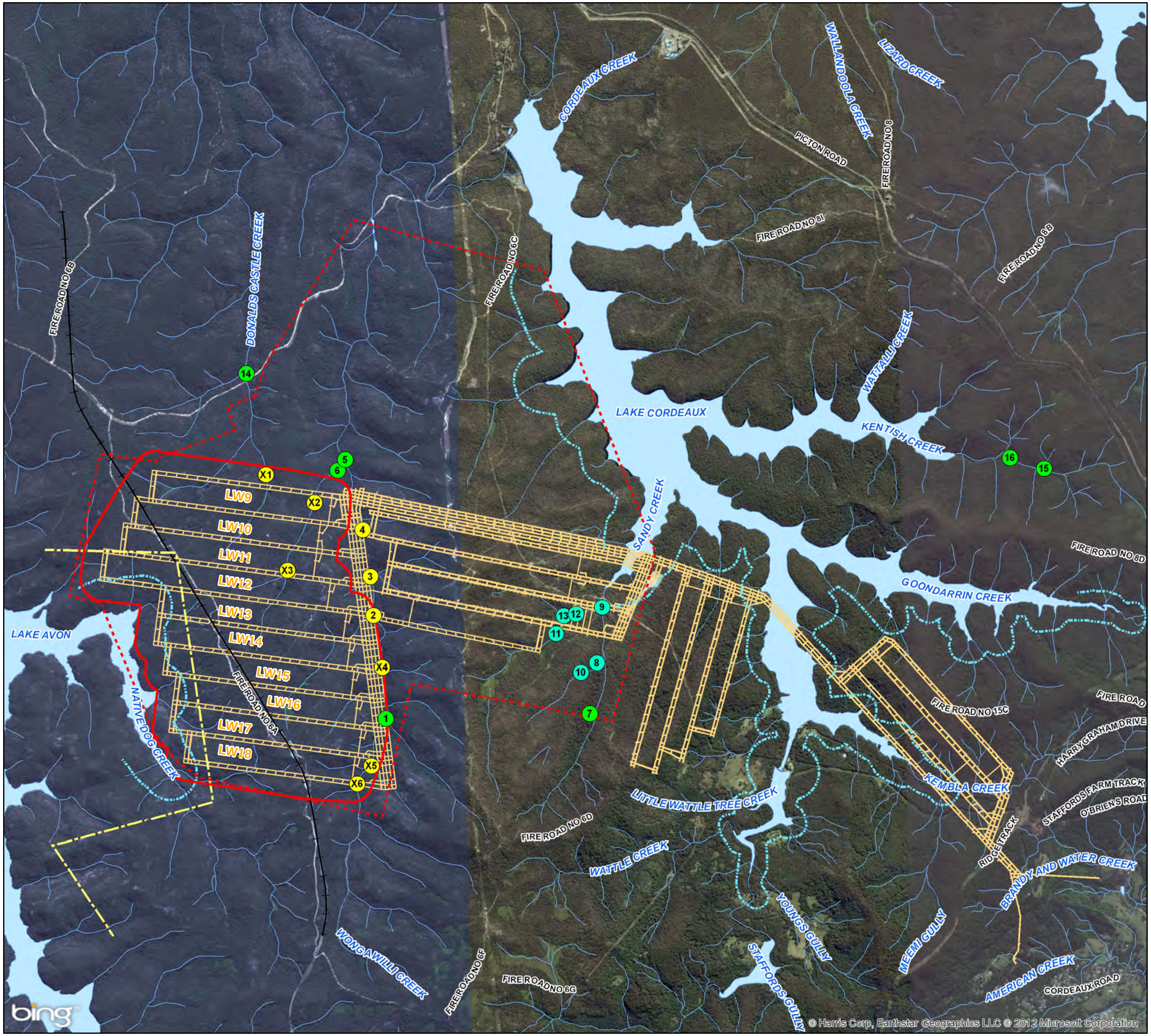

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ILLAWARRA COAL

Aquatic Ecology Monitoring Locations

DENDROBIUM AREA 3B SMP

Legend

Monitoring Sites (Cardno Ecology Lab)

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

N
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FIGURE 2-57

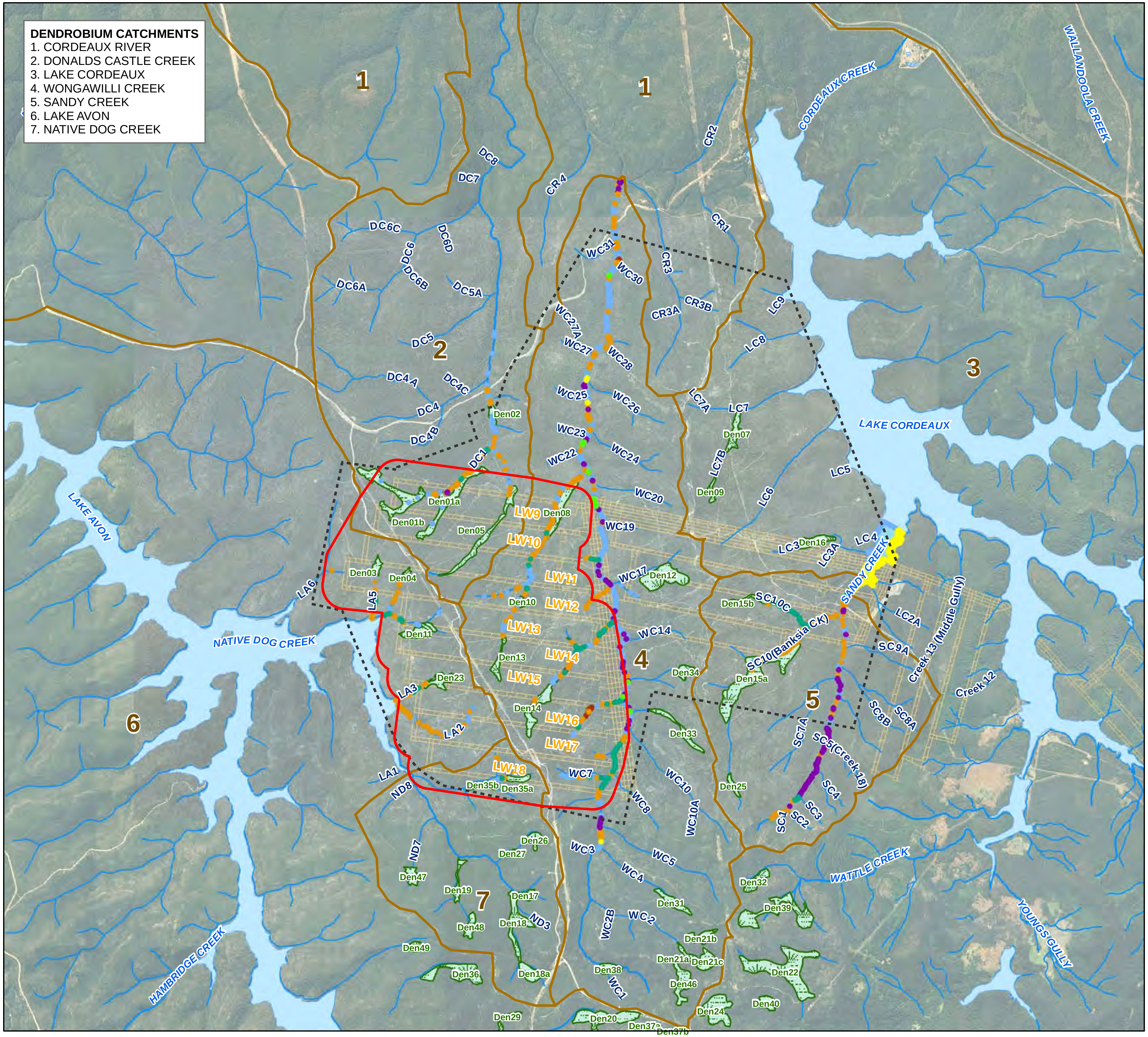
1:45,000 Scale at A3

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

Cardno

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

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



Geomorphic Features

DENDROBIUM AREA 3

Legend

- SMP Area (1,199 ha)
- Maximum Footprint Area 3
- Longwall Layout (BHPBIC, 2012)
- Major Catchments (Cardno)
- Rivers & Creeks (LPI)
- Waterbodies (LPI)

Stream Features (Illawarra Coal)

- Swamp
- Cliff Line
- Island
- Boulder field
- Riffle
- Rock Bar
- Rock Shelf
- Sand Bar
- Lake or Pool

FIGURE 2.58

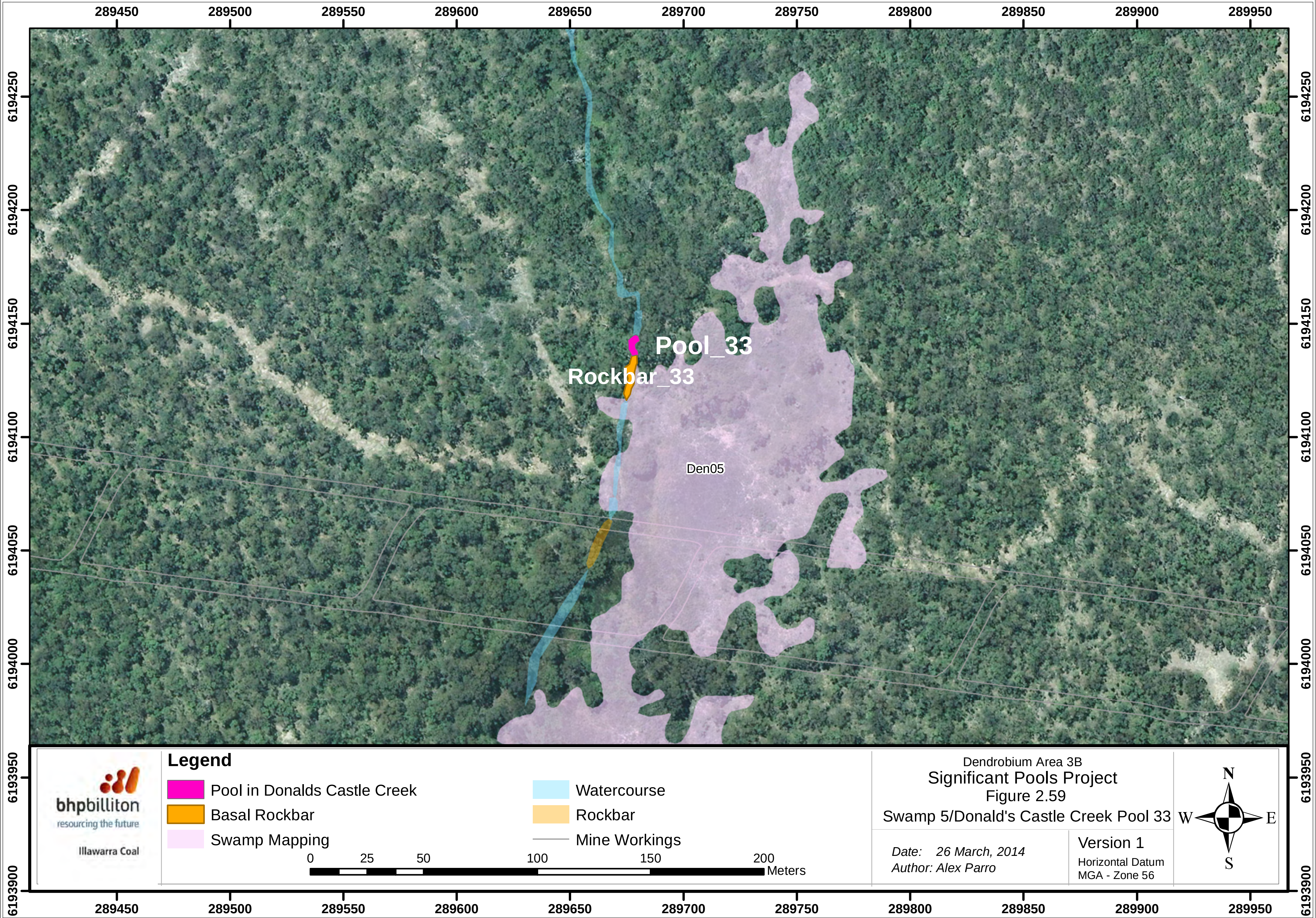
1:45,000 Scale at A3

Metres

0 500 1,000 1,500 2,000

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-26
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1006_HydrologicalFeaturesCopy.mxd 04

Aerial imagery supplied by BHPBIC (2009) and LPI



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Illawarra Coal

Legend

- Pool in Donalds Castle Creek
- Basal Rockbar
- Swamp Mapping
- Watercourse
- Rockbar
- Mine Workings

0 25 50 100 150 200 Meters

Dendrobium Area 3B
Significant Pools Project
Figure 2.59
Swamp 5/Donald's Castle Creek Pool 33

Date: 26 March, 2014
Author: Alex Parro

Version 1
Horizontal Datum
MGA - Zone 56

N S W E

3 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium modified Consent (2008) and the Area 3B SMP Approval (2013). These performance measures are presented in **Table 3-1** and will be applied to the Dendrobium Area 3B mining area.

Table 3-1 Subsidence Impact Performance Measures

Dendrobium Modified Development Consent
• Operations shall not cause subsidence impacts at Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality); • Operations will not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.
Area 3B SMP Approval
Waterfall WC-WF54: Negligible environmental consequences including: • no rock fall occurs at the waterfall or from its overhang; • no impacts on the structural integrity of the waterfall, its overhang and its pool; • negligible cracking in Wongawilli Creek within 30m of the waterfall; and • negligible diversion of water from the lip of the waterfall. Wongawilli Creek and Donalds Castle Creek: Minor environmental consequences including: • minor fracturing, gas release and iron staining; and • minor impacts on water flows, water levels and water quality.

A detailed list of performance measures and triggers is included in the TARPs in **Attachment 1**.

3.1 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.

There are two broad mechanisms by which subsidence could cause changes in watercourse hydrology and water quality:

- The bedrock below the watercourse fractures as a consequence of strains and water drains into the fracture zone. The extent and permanence of these changes relate to the size of the fracture zone (increase in porosity/storage) and whether the fractures are connected to a deeper aquifer, the mine workings or bedding shear pathway to the surface lower in the catchment. Surface water diverted through freshly fractured sandstone and/or groundwater that returns to the surface through the fracture network may contain increases in iron concentrations and other minerals.
- Tilting, cracking, desiccation and/or changes in vegetation health result in concentration of runoff and erosion which alters water distribution in the watercourse.

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 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 and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates.
- Reduced inflows into Lake Avon and Cordeaux River.

3.2 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 theoretical height of the fracture zone should be viewed in the context of fracturing only and should not be directly associated with an increase in permeability. It is possible that with the blocky nature of the sandstone strata and the presence of aquatards within the strata, the height of the fracture zone could extend up to near the theoretical height without an associated increase in vertical permeability.

Longwall 8 has been successfully extracted from Area 3A with a width of 300m. Monitoring of groundwater inflows to the mine support the original Dendrobium 3D Groundwater Model (Heritage Computing 2009), which is based on no direct connection via enhanced vertical permeability resulting from the formation of the goaf.

The Groundwater Model (Coffey 2012) is very conservative and could be equated to a worst case situation. This is due to the height of desaturation above the goaf adopted by the author. The desaturation zone adopted for the model has been established by conducting a literature review. 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 and has analysed many thousands of samples for field parameters, laboratory analysis, algae and isotopes. Heritage Computing (2009 & 2011) modelled Dendrobium Areas 2 and 3, using the knowledge of the complete dataset and in this model zero head pressure extends to the Scarborough Sandstone (~ 200m below the surface), which is consistent with the worst case monitoring data collected i.e. only observed once in five longwalls.

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 responses resulting from increased vertical permeability. Evidence from piezometer monitoring can provide useful data points to ascertain whether there is direct connectivity to the collapsed zone or not. The following relationship between caving/fracture zones and groundwater effects can be noted:

- The collapsed zone will consist of broken rock material through which there is potential for significant increases in both horizontal and vertical permeability.
- Above the collapsed zone there is potential for significant increases in horizontal permeability.
- There is not expected to be open-path continuous vertical fracturing above the collapsed zone.

On this basis there will be no direct connective fracturing to any deeper storage and therefore it is expected that there will be no reduction (other than negligible reduction) in the quantity of surface water or groundwater inflows to Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

The height of fracturing based on significant bed separation and vertical dilation measured by extensometers does not necessarily imply that vertical permeability is increased. Extensometer readings of fracturing and bed separation resulting in horizontal permeability increases can occur without corresponding increases in vertical permeability.

Parson Brinckerhoff and IC 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 as well as the significant aquiclude, 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 premining. 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 0.7m/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 suggests there is no strong connection between the shallow water bearing zones and the goaf.

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 extends into the base or bottom half of the Bulgo Sandstone. The Hawkesbury Sandstone, particularly the mid- to upper exposed levels would be best assigned to the “constrained zone”.

Estimates for the height of fracturing at Dendrobium based on published methods range from 122m to 357m. 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. It provides evidence that the significant aquiclude, the Bald Hill Claystone remains as an aquiclude post mining and that the Hawkesbury Sandstone includes a significant “constrained zone” where vertical permeability is not significantly increased as a result of mining.

IC commissioned the development of a regional-scale numerical groundwater flow model in support of the approval process for mining of Area 3B at Dendrobium Mine (Coffey Geotechnics 2012). The Area 3B SMP Approval Condition 13 requires review of the Area 3B Groundwater Model to the satisfaction of the Secretary. HydroSimulations (2014) has completed this review and enhancement of the regional model (see **Section 2.6**).

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;
- 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).

3.3 POTENTIAL FOR FRACTURING BENEATH THE WATERCOURSES

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

It is predicted that surface flows captured by the surface subsidence fracture network which do not connect to a deeper aquifer or the mine workings (see **Section 3.2**) will re-emerge further downstream. This prediction is based on an assessment of the depth of subsidence 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. A number of studies have determined the depth of the surface vertical fracture network to be restricted to approximately 15 to 20m 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.

The data from these sites clearly demonstrates the depth of the fracture network within the “surface zone” (ACARP Report C12016). The Dendrobium Longwall 9 research (see **Section 3.2**) also confirmed the existence of a “constrained zone” in the upper Hawkesbury Sandstone following mining.

Prior to any remediation works within Area 3B that target these 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.

Water balances during the mid to late stage recession in Dendrobium Areas 2 and 3 have been assessed downstream of mining areas using the Free University of Amsterdam mature small catchment hydrologic model RUNOFF2005.

Ecoengineers conducted a review of monitoring data in response to a Level 2 TARP indicating mine subsidence-related near-surface water loss effects from within and around Swamp 15b. Key government agencies were provided this review in September 2012.

The review reports on the pre and post mining hydrologic performance of the small catchment SC10C using the RUNOFF2005 model (Ecoengineers 2012). The pre-mining hydrologic model was established prior to the mining of Longwalls 6 and 7 using a 297 and 118 day continuous data set with a goodness of fit of 75.2%.

Following mining the hydrologic performance was estimated for a number of continuous periods of flow data using the pre-mining model. A period of 118 days to 3 December 2011 was compared to the pre-mining model and there was evidence of some flow not reporting to the gauging station which was equivalent to about 9.3% of precipitation. For the period 10 April 2012 to 11 June 2012 the amount of flow not reporting to the gauging station had reduced to about 3.2% of total precipitation, which is well within measurement error.

This analysis provides some evidence that by April 2012 any effect of mine subsidence-induced fracturing leading to loss of surface water or shallow groundwater outflow from the catchment was reducing or undergoing amelioration.

This is a similar pattern to the small FTC catchment mined under by Area 2 Longwall 5 in December 2008/January 2009 where, by late 2009, the catchment productivity effect (due to loss to deep storage) had largely disappeared (Ecoengineers 2010).

Due to constraints of the program the measurements and modelling are both operating within margins of error. However, to date the stream flow monitoring indicates that a relatively small percentage of water captured by subsidence induced fractures is entering connected deeper storage or bedding shear pathways and that the measurable effect is temporary.

Uncertainties in the model were discussed during a meeting between EcoEngineers, IC and Water NSW (including a Water NSW Peer Reviewer) on 16 November 2012. At this meeting the levels of uncertainty were identified along with the level of precision assumed from the flow measurements and modelling. This level of precision is stated in the Dendrobium Area 3B TARPs as follows:

- Model reliability is maintained only for catchments in excess of $1km^2$ in area.
- Average annual precipitation is modelled using the most recent 4 – 5 years of local record.
- Hydrologic modelling routinely produces mean estimated water balances for modelled periods of recessional, baseflow and small storm unit hydrograph periods lying within about ±6% of average annual precipitation at the one standard deviation level and within about ±12% at the two standard deviation level.

Evapotranspiration is the key closure term in the water balance and the adopted approach of comparison of the RUNOFF2005 model-predicted ET output (for a validly gauged model period) is with the independent CSIRO Land and Water (Zhang et al., 1999) method. It is considered a reasonable criterion of acceptable ET i.e. without significant deep percolation loss to create an ET-immune water fraction.

At the Dendrobium Management Plan Workshop 27 May 2013 Water NSW indicated that it does not believe current proposed measurements are adequate to measure catchment water balances. Water NSW indicated they would like more monitoring rather than use of a model which has potential errors and inaccuracies. The current monitoring program includes both measurements at downstream monitoring points and modelling of individual catchments. IC have previously requested feedback from Water NSW about superior modelling methods which could be used, none have been identified to date.

Community representatives of the Dendrobium Community Consultative Committee (DCCC) sought a peer review of surface water hydrological modelling and interpretation at the Dendrobium Mine. This work was conducted by Emeritus Professor Thomas McMahon, Department of Infrastructure Engineering at the University of Melbourne. The following conclusions are provided by Professor McMahon (4 June 2014).

> *It should be noted that four of the six model parameters in the RUNOFF2005 model deal with the shallow groundwater/baseflow system. This is in contrast to nearly all the daily hydrologic models used in Australia in which most of the parameters deal with non-baseflow components; for example, in SIMHYD only two of the seven parameters directly affect baseflow (Chiew et al., 2002). Because of this feature, and the baseflow routines are based on a sound theoretical basis (Kirchner, 2009; Better et al, 2009), RUNOFF2005 appears to be a more appropriate model to assess the impact of longwall mining on surface hydrology and shallow groundwater than a traditional rainfall-runoff model like SIMHYD.*

The comparative analysis of pre to post mining needs to account for differing catchment attributes, rainfall events, preceding catchment conditions and post event conditions as these are rarely the same. Without modelling there is no way to undertake a direct comparison of before and after mining or compare an impact catchment to a control site. With this in mind, the proposed approach is to measure change from pre to post mining by comparing actual flow data post mining with a model of the expected pre-mining catchment flows from that same rainfall event. The model is developed from actual flow data prior to mining. IC flow data is made available to Water NSW for the pursuit of alternative comparative approaches. IC will continue to work with Water NSW to identify alternative methods to better measure and compare catchment yields prior to and following mining.

3.4 POTENTIAL FOR EROSION WITHIN THE WATERCOURSES

Tilting, cracking, desiccation and/or changes in vegetation health could result in erosion within the watercourses. The likelihood and timing of these consequences relate to the size and duration of the effect.

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. A summary of the maximum predicted values of subsidence, tilt and strain at the watercourses is provided in Section 4.

Tilting of sufficient magnitude could change the catchment area of a watercourse or re-concentrate runoff leading to scour and erosion.

Changes in gradients predicted to occur following mining are shown in Section 4. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2012 and 2015). The assessment takes into account the nature of the drainage channel and whether the predicted tilt is significant when compared to the existing slopes.

Longwall 8 within Area 3A has been extracted and the width of this longwall is 300m. The 300m wide longwalls in Area 3B would lead to subsidence impacts similar to those observed in watercourses which were directly mined under by Longwall 8.

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 watercourses 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 and the condition of rockbars.

The observed impacts on natural features above Longwall 8 were generally consistent with those predicted in the assessments undertaken prior to mining. Twenty six new and four reactivated impacts were identified during the extraction of Longwall 8. This included a section of overhanging rock outcrop overlying Longwall 8 which was observed to have fallen and four impacts involving man-made infrastructure including surface cracking adjacent to the cruciform base of Tower 15 of the 330kV transmission line and impacts on Fire Road 6F.

A total of nine impacts, including three reassessed and one reactivated, were recorded in watercourses. Rock fracturing was observed in both WC17 and SC10C.

For the Dendrobium mining area since longwall operation commenced in 2005 to the completion of Longwall 8 IC has identified 317 surface impacts. Many of these are very minor impacts and of very limited environmental consequence. For example, 77% of the cracking identified at the surface has a width of less than 100mm. To date there has been no instance of erosion resulting from this cracking.

3.5 POTENTIAL FOR AQUATIC ECOLOGY CHANGES WITHIN THE WATERCOURSES

Where there are changes to watercourse hydrology that are large and persistent there is likely to be an aquatic ecology response. Aquatic species which do not have life-cycles adapted to temporary loss of aquatic habitat are likely to be relatively susceptible to changes in pool water level. In comparison, riparian vegetation is likely to be relatively resilient to short term changes in groundwater level and soil moisture, demonstrated by the persistence of the these vegetation communities during extended periods of drought.

The data collected prior to and following the extraction in Dendrobium Area 3A provides little evidence to suggest mining-related impacts have had more than local impacts to the aquatic ecology of the area. There was evidence at some impact sites of changes to aquatic ecology, however, these impacts appeared transient and were observed in only some indicators (Cardno Ecology Lab 2012). There is evidence of a local impact to aquatic ecology at Site 13 on SC10C associated with mining related fracturing and pool water loss further upstream.

In the Southern Coalfield, impacts to riparian vegetation as a result of subsidence are minor in occurrence. Furthermore, no impacts to riparian vegetation have been observed in Dendrobium Mine to date (Niche 2012). Previous examples of impacts include: dieback of riparian vegetation as a result of subsidence of the Cataract River during the 1990s (Eco Logical Australia, 2004 in TEC 2997), and small localised changes to riparian vegetation along a section of the Waratah Rivulet (Helensburgh Coal 2007).

3.6 POTENTIAL FOR RAW WATER QUALITY CHANGES

From five years of monitoring there has been no evidence of significant effect in the short or long term on either bulk raw water quality or drinking water quality in the Native Dog Creek arm of Lake Avon, despite Native Dog Creek being directly undermined by Elouera Colliery longwalls, causing bedrock fracturing.

Due to the standoffs from Wongawilli Creek of the Area 3B longwalls, it is not expected any significant fracturing and sub-bed flow diversions will occur in Wongawilli Creek to alter flows or water quality other than minor impacts. Due to the substantial distance downstream it is predicted there will be no reduction (other than negligible reduction) in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

Due to the standoffs from Lake Avon of the Area 3B longwalls, it is not expected there will be a reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Avon. In addition, due to the substantial size of the Lake Avon system, it is predicted that there will be no measurable reduction in the quality or quantity of water in Lake Avon resulting from surface water or groundwater inflows.

Based on past experience from Wongawilli and Native Dog Creeks which were directly mined under by Elouera Colliery longwalls, it is also considered highly unlikely that there would be any adverse effect on bulk drinking water supply quality in the Lake Avon or Cordeaux River (into which Donalds Castle and Wongawilli Creeks discharge) systems.

Any water-borne inputs to Lake Avon and Cordeaux River would likely be restricted to a possible erosive export of fine sands and clays and/or ferruginous precipitates near the mouths of minor creeks designated LA2, LA3, LA4 and LA5 (Lake Avon) during mining of Area 3B. It is predicted that these water-borne inputs will result in negligible environmental consequences.

These creeks are all remote from their respective dam off-takes and outflows. Such zones would be localised around the point of input to the Lake and would be unlikely to have any detrimental effect on local freshwater ecology and unable to affect bulk water supply quality.

3.7 ACHIEVEMENT OF PERFORMANCE MEASURES

Longwall mining can result in surface cracking, heaving, buckling and stepping at the surface. Surface deformations can also develop as the result of downslope movements where longwalls are extracted beneath steep slopes. In these cases, the downslope movements can result in the development of tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes. Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley closure movements. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, geomorphology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

A number of large surface cracks were observed at the commencing end of Longwall 3 in Area 2 at Dendrobium Mine. The depth of cover at the commencing end of Longwall 3 was as shallow as 145m, which is less than that above Longwalls 9 to 18 in Area 3B, which varies between 310m and 450m. It is expected, therefore, that the widths of surface cracking resulting from the extraction in Area 3B would be generally less than that observed above the commencing end of Longwall 3.

The experience gained from mining in Dendrobium Areas 1, 2 and 3A indicate that mining-induced fracturing in bedrock and rockbars are commonly found in sections of streams that are located directly above extracted longwalls. However, minor fracturing has also been observed in some locations beyond extracted longwall goaf edges, the majority of which have been within the limit of conventional subsidence or associated with valley closure.

3.7.1 Wongawilli Creek

The maximum predicted total conventional tensile and compressive strains for Wongawilli Creek, based on applying a factor of 15 to the maximum predicted conventional curvatures, are in the order of survey tolerance (i.e. less than 0.3mm/m). The creek is likely to also experience elevated compressive strains, resulting from the valley related movements, which could be in the order of 5mm/m based on observations at valleys with similar heights at similar distances from extracted longwalls.

An empirical database has been developed of pool and rockbar sites in the Southern Coalfield that have experienced mining induced valley related movements. The upsidence and closure movements at these sites have been predicted, using the ACARP Method of predicting valley closure, at the time when the first pool impact occurred, or after this time, when pool water loss was first recorded.

An analysis of impact rates has been undertaken using the currently available database of pools and rockbar case studies. This database is being continually developed and, to date, research has mainly concentrated on collating knowledge on the known pool and rockbar impact sites, whilst less data has been included for sites that had no impacts as a result of mining. The current reference to the 200mm predicted total closure value should therefore be viewed as an indication of low probability of impact (i.e. around 10%).

It has been assessed, therefore, that it is unlikely that significant fracturing or surface water flow diversions would occur along Wongawilli Creek as a result of the extraction. This assessment has been based on limiting the predicted closure at the mapped rockbars and riffles to 200mm and, as a result, the proposed longwalls have been setback more than 150m from the majority of the mapped rockbars and more than 150m from all of the mapped riffles.

It should be noted, however, that minor fracturing has occurred and is expected in the bed of Wongawilli Creek as a result of the extraction of the proposed longwalls. Fracturing that does occur in the bed of the creek would be isolated and of a minor nature and not result in any significant surface water flow diversions.

After the extraction of Longwalls 6 to 8 in Area 3A to the east of Wongawilli Creek and the extraction of Longwall 9 in Area 3B to the west of Wongawilli Creek a fracture was identified in Wongawilli Creek. The rock fracture is in the base of WC_Pool 43a and has a length of approximately 2m and a width of up to 0.02m. There was no observed flow diversion associated with the fracture and the pool remains full and flowing. This fracturing is consistent with the impact model described above.

3.7.2 Waterfall WC-WF54

The Waterfall WC-WF54 is located 75m east of the finishing end of Longwall 18. The waterfall is predicted to experience less than 20mm subsidence as a result of the extraction of the longwalls. While it is possible that the waterfall could experience subsidence slightly greater than 20mm, it would not be expected to experience any significant conventional tilts, curvatures or strains.

The maximum predicted valley related movements at the waterfall are 100mm upsidence and 150mm closure. As described in the previous section, minor fracturing has occurred in the bed of Wongawilli Creek. Fracturing resulting in surface water flow diversions has not occurred and the likelihood of this occurring is considered low. The method of assessment for surface water flow diversions has been predominately based on the previous experience of mining near to and beneath relatively flat streams in the Southern Coalfield. The impact assessments for the pools immediately upstream of the waterfall, therefore, need to take into account the steep gradient (i.e. the waterfall) immediately downstream.

The waterfall is a “horse-shoe” shaped cliff which wraps around both sides of the valley of Wongawilli Creek. A similar shaped cliff is located at Elouera Colliery, on a tributary to Wongawilli Creek, where mining has occurred on both sides of this cliff. The Elouera longwalls were extracted on the western side of the cliff, with Longwall 2 located at a distance of 160m from the cliff, at the closest point. Delta Longwall 17 was extracted on the eastern side of the cliff, which was located at a distance of 120m from the cliff, at its closest point. The predicted valley related movements for the cliff at Elouera Colliery, resulting from the existing mining, are 60mm upsidence and 80mm closure. There have been no observed impacts on the cliff at Elouera Colliery after the completion of the Elouera longwalls and Delta Longwall 17.

Another “horse-shoe” shaped cliff is the waterfall on Sandy Creek in Dendrobium Area 3A, which has a length around 75m long and an overall height of around 17m. The waterfall has an overhang of up to 20m, which varies in thickness from a maximum around 6m to less than 1 metre at the edge. Dendrobium Longwalls 6 and 7 have been mined to within 350m and 400m, respectively, of the waterfall with no adverse impacts observed.

There is also other extensive experience of mining in the vicinity of cliffs in the Southern Coalfield, including Appin Longwalls 301 and 302, which mined to within 50m of the cliffs along the Cataract River, and Tower Longwalls 18 to 20 and Appin Longwalls 701 and 702, which mined to within 50m of cliffs along the Nepean River. In these cases, there were no large cliff instabilities where the longwalls at Appin and Tower Collieries mined to within 50m of the cliffs (i.e. not directly mined beneath). There were, however, some minor rock falls or disturbances which occurred during mining, of which, some were considered likely to have occurred due to a significant rainfall event and natural instability of the cliff.

A comprehensive monitoring and management plan will be developed for WC-WF54, including the implementation of suitable management strategies such as a TARP similar to that which was implemented for Sandy Creek Waterfall.

3.7.3 Donalds Castle Creek

The upper reaches of Donalds Castle Creek are located in the northern part of the SMP Area. The creek is located above Longwalls 9 to 12. The total length of the creek located directly above the proposed longwalls is around 1.5 kilometres. The length of the creek within the predicted limits of 20mm total upsidence and 20mm total closure is approximately 2.4 kilometres. There are no predicted reversals of grade along Donalds Castle Creek resulting from the extraction of the longwalls. The creek's grades are predicted to increase immediately downstream of the longwall chain pillars. However, the post-mining grades in these locations are similar to the natural grades elsewhere above the proposed longwalls and, therefore, increased scouring of the banks is not anticipated along the creek.

The maximum predicted valley related upsidence and closure movements for Donalds Castle Creek are 370mm and 280mm, respectively. Elevated compressive strains across the alignment of the creek are also likely to result from the valley related movements.

The rockbars which were identified along Donalds Castle Creek are all located outside the extents of the proposed longwalls. The closest rockbar, being DC-RB35, is located 25m north of Longwall 9. The maximum predicted subsidence for the rockbar is 180mm. The maximum predicted valley related movements for this rockbar, resulting from the extraction of the longwalls, are 120mm upsidence and 180mm closure.

Fracturing and diversion of surface water flows has occurred at DC-RB33. On the basis that there is no connective fracturing to any deeper storage it is likely that any diverted surface water will re-emerge at the surface. This would occur at the limit of subsidence induced fracturing downstream within Donalds Castle Creek.

In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows are diverted into the dilated strata.

Remedial measures targeting the surface fracturing at DC-RB33 have been proposed as part of the Swamp Rehabilitation Research Plan. The proposed remediation includes grouting the bedrock, similar to the methods which have been previously undertaken in the Georges River.

3.7.4 Water Storages

The western ends of Longwalls 11 to 18 lie within the Avon Notification Area. As was the case for Areas 1, 2 and 3A, none of the current and proposed Area 3B longwall extraction is undertaken below stored waters. Longwalls 9 and 10 are outside the Avon DSC Notification Area and Longwall 11 is just inside the Area. Longwalls 12 to 18 are set back from the Avon Reservoir Full Storage Level (FSL) a minimum of 214m to 301m.

The depth of cover to the Wongawilli Seam directly above the proposed longwalls varies between a minimum of 310m, above the eastern end of Longwall 9, and a maximum of 450m, above the eastern ends of Longwalls 17 and 18.

The potential for loss of stored water from Avon Reservoir whilst mining Area 3B was considered in a risk assessment held in February 2014 which was conducted by AXYS Consulting. The objective of the assessment was to assist IC control identified risks associated with the mining of Area 3B longwalls which may cause loss of stored water.

Dendrobium Mine has DSC Endorsement for Longwall 11 extraction and development workings for Longwalls 12 and 13. An application for the extraction of Longwalls 12 to 18 within the DSC Avon Notification Area has been made. The application was supported by the following documents and data:

- Avon and Cordeaux Reservoirs DSC Notification Area Management Plan;
- Geology report for Area 3B;
- Geochemical review of connectivity between Lake Cordeaux and Dendrobium Area 2 and 3A and implications for monitoring Lake Avon and Area 3B;
- Dendrobium Area 3B Regional Groundwater Model;
- Hydrogeoleogical analysis regarding DSC's requirements for mining within the Avon Notification Area;
- Qualitative risk assessment for loss of stored water from Avon Reservoir from the mining of Longwalls 12-18; and
- Plans.

The Area 3B SMP approval conditions stipulated further development of the Dendrobium numerical groundwater model by 31 October 2013. Conditions 13 states:

- By 31 October 2013, the Applicant shall review the Area 3B Groundwater Model to the satisfaction of the Secretary. The revised model must:
  a) include detailed consideration of surficial aquifers, swamps and watercourses;
  b) include all available data on groundwater levels; and
  c) model baseflow contributions for all sub-catchments from baseline (i.e. prior to the extraction of Longwall 9) until 30 years post-mining, using 5-yearly increments.
- The Applicant must address the following water storage performance measures for Avon Reservoir including:
  a) negligible reduction in the quantity of surface water inflows to the reservoir;
  b) negligible reduction in the quantity of groundwater inflows to the reservoir; and
  c) negligible leakage from the reservoir to underground mine workings.
- The Applicant shall ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

To address the SMP requirements, the groundwater model was enhanced, as follows by HydroSimulations (2013):

- Addition of a thin (2m thick) surficial layer to represent the swamp deposits where they exist, and regolith otherwise;
- Inclusion of swamp and other 'shallow' groundwater level data for calibration, which were not utilised by Coffey (2012a). The model was re-calibrated to these data;
- Interchange of the MODFLOW Drain boundary condition, which was previously used to simulate creeks and rivers, for the Stream Flow Routing (SFR1; Prudic et al., 2004) boundary condition. This was used to calibrate modelled stream flows to gauged data. It also provided the utility for simulating potential impacts of mining Area 3B on swamps, creeks and rivers, as required by the SMP approval conditions, and helped in achieving adequate calibration to the shallow (swamp) groundwater level data.

Following this work further enhancements of the HydroSimulations (2013) model were requested by DoPE:

- Revise the simulated height of fracturing used by HydroSimulations (2013), using a method such as that of Ditton (2012).

- Revise the method used to simulate the fractured zone by HydroSimulations (2013), using time-varying material properties to simulate an enhanced permeability zone (EPZ) rather than stacked MODFLOW drain boundaries.
- Extend the calibration period to include shallow groundwater calibration sites in Area 3B. HydroSimulations limited the calibration to the same period as used by Coffey (2012b), namely 1 March 2005 to 4 November 2009.
- Extend some streams up-gradient. Clarify the order of streams to be simulated. Justify why some streams are excluded. Use the IC field team mapping of streams to differentiate where there is overland flow, swamps and preferred flow streams with bedrock bases (the latter to be included in the stream model).
- Check the attribution of piezometers to formations and model layers. Some piezometers that would have been installed in the Bulli Seam and Wongawilli Seam appear to be allocated to adjacent formations.
- Extend the mine inflow calibration data set from 2009 to 2013.
- Assess the reason for some preferential drawdown in the area north-west of Area 3B simulated in HydroSimulation (2013).
- Include the results of the HydroSimulation (2013) report as an Addendum to this report to show the effects of the Coffey (2012b) assumption on fractured zone height based on the Tammetta (2012a) formula.

These additional requirements have been addressed and the Dendrobium Regional Groundwater Model was updated based on the assessment. The following results were obtained from the revised groundwater model:

- Upon commencement of mining Area 3B, inflows increase gradually to around 6-7ML/day (by mid-2015), after which they rise to around 11ML/day until mining of the last panel (Longwall 19 in Area 3A). Upon cessation of mining in early 2023, inflows decline and stabilise at approximately 7ML/day, and continue to very slowly decline towards a steady state as time progresses.
- In the case of the Avon Reservoir, the simulated maximum total reduction in reservoir storage as a result of mining Area 3B is 0.56ML/day; of this, the induced leakage from the reservoir is about 0.13ML/day; the remainder is due to diverted baseflow and reduction in surface water inflows. This maximum is reached approximately 20 years post-mine cessation (i.e. post-2023). The maximum cumulative impact on Avon Reservoir leakage to groundwater from Dendrobium mine Areas 1, 2 and 3 is 0.13 ML/day, whilst the maximum total cumulative impact is 0.94 ML/day.
- In the case of the Cordeaux Reservoir, the simulated maximum total reduction in reservoir storage as a result of mining Area 3B is 0.045ML/day; of this, the induced leakage from the reservoir is about 0.004ML/day. This maximum is reached approximately 25 years post-mine cessation (i.e. post-2023). The maximum cumulative impact on Cordeaux Reservoir leakage to groundwater from Dendrobium mine Areas 1, 2 and 3 is 0.03ML/day, whilst the maximum total cumulative impact is 0.8ML/day.
- The estimated effects on groundwater discharge to and leakage from Lake Avon are considered negligible.
- In terms of water quality impacts to the reservoirs, the simulated impacts will if anything pose a net benefit, given that the electrical conductivity of groundwater in the area is typically higher than that of runoff and water in reservoir storage, and hence any reduction in groundwater discharge into the reservoirs is likely to have a positive, albeit unmeasurable effect on water quality.

The successful mining within Dendrobium Area 1, Area 2 and Area 3A with no significant inflow of water from the Cordeaux Reservoir provides confidence that mining adjacent to the Avon Reservoir has an acceptable risk. The systems and management plans developed in consultation with the DSC for Areas 1, 2, and 3A have enabled the DSC to confirm in its 2012/13 Annual Report that "the Dendrobium Mine completed further extraction from Cordeaux Dam Notification Areas without adverse effects".

Area 3B is a relatively simple sequence of sedimentary stratigraphy and there are no complications associated with overlying workings. The longwall domain is between geological features that have negligible risk of providing a conduit from the reservoir to the workings. Longwall mining over a period of 10 years has not resulted in any measurable reservoir water reporting to the mine.

Dendrobium has installed and is currently monitoring an extensive array of piezometers in the area. In addition, the underground water balance and chemistry sampling provides data that can be used to trigger actions within the Avon and Cordeaux Reservoir Notification Area Contingency Plan. IC is convinced that the Avon and Cordeaux Reservoir Notification Area Monitoring, Contingency and Closure Plans provide excellent tools for minimising the risk to the reservoir.

IC believes the proposed mining in Area 3B presents a tolerable risk to Avon Reservoir and that the Area 3B SMP performance measures for Lake Avon will be met.

4 PREDICTED IMPACTS

Subsidence has the potential to affect watercourses overlying and adjacent to the proposed longwalls due to either transient or relatively permanent changes in porosity and permeability of the soil matrix and bedrock. Sandstone is likely to fracture as a result of the differential subsidence movements predicted.

If a watercourse overlies a longwall panel it is likely to 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 at any one location.

In addition, where a watercourse overlies a longwall, it is likely 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.

Predicted impacts were assessed for Wongawilli Creek (third order), Donalds Castle Creek (second order) and all other drainage lines (first and second order) within Area 3B.

In accordance with the findings of the Southern Coalfield Inquiry:

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

Impact predictions have been completed within the Study Area in order to record potential and likely impacts from the proposed mining. The predictions are based on mathematical and empirical models and utilise the best available information for the Southern Coalfield and in particular Dendrobium Mine conditions. The impact predictions have been compared with previous predictions for Dendrobium Mine and the Conditions of Consent to ensure compliance of the proposed mining. This comprehensive impact assessment is provided in the Dendrobium Area 3B SMP (Cardno 2012).

Monitoring is conducted in the area potentially affected by subsidence and in reference areas. Data collected in the impact zone will be compared to baseline and reference sites to determine any impacts from subsidence.

4.1 SUBSIDENCE EFFECTS

The maximum predicted subsidence parameters resulting from the extraction of Longwalls 9 to 18 are provided in MSEC (2012 and 2015). The predicted subsidence parameters including; vertical subsidence, tilt and curvature have been used in the impact assessment for Dendrobium Area 3B.

The predicted strains were determined by analysing the strains measured at Dendrobium Mine and other NSW Collieries, where the longwall width-to depth ratios and extraction heights were similar to Longwalls 9 to 18. The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of joints in bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

The maximum predicted conventional strains resulting from the extraction of Longwalls 9 to 18, based on applying a factor of 15 to the maximum predicted curvatures, are both 20mm/m tensile and compressive. These predicted levels of strain a likely to result in fracturing of the surface bedrock.

4.1.1 Wongawilli Creek

The proposed longwalls are located at a minimum distance of 70m from the centreline of Wongawilli Creek. Associated tributaries of Wongawilli Creek, which pass through Area 3B include (MSEC 2012 and 2015) WC6, WC7, WC12, WC15, WC15A, WC16, WC21 and WC21A. **Table 4-1** provides a summary of the maximum predicted values of total subsidence, upsidence and closure at Wongawilli Creek following completion of each longwall.

Table 4-1 Maximum Predicted Total Subsidence, Valley Related Upsidence and Closure at Wongawilli Creek Resulting from the Extraction of the Proposed Longwalls

Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
After LW8 (Area 3A)	<20	110	140
After LW9	<20	130	170
After LW10	<20	130	200
After LW11	<20	140	210
After LW12	<20	140	210
After LW13	<20	140	210
After LW14	<20	140	210
After LW15	<20	140	210
After LW16	<20	140	210
After LW17	<20	140	210
After LW18	<20	160	210
After LW19 (Area 3A)	<20	160	210

The maximum predicted total conventional tensile and compressive strains for Wongawilli Creek, based on applying a factor of 15 to the maximum predicted conventional curvatures, are in the order of survey tolerance (i.e. less than 0.3mm/m). The creek is likely to also experience elevated compressive strains, resulting from the valley related movements.

The natural gradient of Wongawilli Creek, excluding Waterfall WC-WF54, varies between approximately 1mm/m and a maximum of 200mm/m, with an average natural gradient of approximately 10mm/m. Although the creek has a relatively shallow natural gradient, it is unlikely that there would be any significant increases in the levels of ponding, flooding, or scouring of the creek banks, as the maximum predicted changes in grade along the creek is very small, being less than 1%.

The waterfall (WC-WF54) on Wongawilli Creek is predicted to experience less than 20mm subsidence as a result of the extraction of the proposed longwalls. While it is possible that the waterfall could experience subsidence slightly greater than 20mm, it would not be expected to experience any significant conventional tilts, curvatures or strains.

4.1.2 Donalds Castle Creek

The proposed longwalls are located directly below Donalds Castle Creek. Associated tributaries of Donalds Castle Creek which pass through Area 3B include (MSEC 2012 and 2015) DC13, DC13A and DC13B. **Table 4-2** provides a summary of the maximum predicted values of total subsidence, upsidence and closure at Donalds Castle Creek following completion of each longwall.

Table 4-2 Maximum Predicted Total Subsidence, Valley related Upsidence and Closure at Donalds Castle Creek Resulting from the Extraction of the Proposed Longwalls

Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
After LW9	1850	150	100
After LW10	2250	280	190
After LW11	2600	320	230
After LW12	2650	340	260
After LW13	2700	360	280
After LW14 - 18	2700	370	280

The maximum predicted conventional strains for Donalds Castle Creek, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 8mm/m tensile and compressive. The creek is also likely to experience elevated compressive strains, resulting from the valley related movements.

The maximum predicted increasing and decreasing tilts along Donalds Castle Creek are 20mm/m (i.e. 2.0%) and 25mm/m (i.e. 2.5%) respectively. The natural gradient of Donalds Castle Creek, directly above the proposed longwalls, varies between a minimum of 10mm/m and a maximum of 100mm/m, with an average natural gradient of 30mm/m. The maximum predicted changes in grade are similar orders of magnitude to the natural grades in the flatter sections of the creek.

There are no predicted reversals of grade along Donalds Castle Creek resulting from the extraction of the proposed longwalls. Whilst it is possible that some localised increased ponding could occur, immediately upstream of the longwall chain pillars, it is not anticipated that there would be any significant increase in the potential for wider spread ponding.

The creek's grades are predicted to increase immediately downstream of the longwall chain pillars. The post-mining grades in these locations are similar to the natural grades elsewhere above the proposed longwalls and, therefore, increased scouring of the banks is not anticipated along the creek.

4.1.3 Drainage Lines

The profiles of subsidence, upsidence and closure along drainage lines DC13, ND1 (Native Dog Creek), WC15 and WC21 which run across Area 3B were predicted. A summary of the maximum predicted values of total subsidence, upsidence and closure at these drainage lines, after the extraction of the proposed longwalls is provided in **Table 4-3**.

Table 4-3 Maximum Predicted Total Subsidence, Valley Related Upsidence and Closure at the Drainage Lines Resulting from the Extraction of the Proposed Longwalls

Name	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
DC13	2050	250	225
ND1	2750	275	425
WC15	3600	725	700
WC21	3500	700	700

The maximum predicted tilt for the drainage lines within the SMP Area is 50mm/m (i.e. 5.0%), which represents a change in grade of 1 in 20. The average natural gradients of the drainage lines, directly above the proposed longwalls, typically vary between 25mm/m (i.e. 2.5%, or 1 in 40) and 100mm/m (i.e. 1%, or 1 in 10). The natural gradients in some locations, however, are less than 10mm/m (i.e. less than 1%, or 1 in 100) or more than 200mm/m (i.e. more than 20%, or 1 in 50).

The maximum predicted change in grade is a similar order of magnitude as the natural gradients in the flatter sections of the drainage lines.

There are predicted reversals in grade along DC13 adjacent to the tailgate of Longwall 9 and WC21 adjacent to the tailgates of the previously extracted Longwalls 10 and 11. There are no predicted reversals of grade along WC21 above the future Longwalls 12 to 15. A reversal in grade could also occur along WC15 adjacent to the tailgate of Longwall 15.

It is possible that there could be localised areas along the drainage lines which could experience small increases in the levels of ponding and flooding, in the locations of predicted maximum decreasing tilts, such as upstream of the longwall chain pillars and goaf edges. It is also possible, that there could be localised areas which experience increased scouring of the banks, in the locations of the predicted maximum increasing tilts, such as downstream of the longwall chain pillars.

Any changes in the levels of ponding, flooding and scouring of the banks of the drainage lines would be expected to be localised in areas of predicted maximum tilts, or where the existing natural gradients are relatively flat. The impacts resulting from these changes in surface water flows are expected to be small in comparison with those which occur during natural flooding conditions.

The maximum predicted conventional strains for the drainage lines, based on applying a factor of 15 to the maximum predicted conventional curvatures, are both 20mm/m tensile and compressive. The drainage lines are also likely to experience elevated compressive strains, resulting from the valley related movements, which is discussed further in the impact assessments.

4.2 SUBSIDENCE IMPACTS

MSEC (2012 and 2015) has identified potential water related subsidence effects and impacts for Wongawilli and Donalds Castle Creeks and second and third order streams. These include:

- Changes in the natural gradient and stream alignment;
- Changes in the levels of ponding, flooding and scouring of the banks;
- Surface fracturing; and
- Induction of ferruginous springs.

4.2.1 Sites of Highest Risk of Impact

In most cases where pool water levels are observed to drop by more than expected after considering rainfall conditions, this has occurred after the streams were directly mined beneath. Longwalls 9 to 18 have been setback from Wongawilli Creek resulting in minimisation of the potential for these types of impacts along this creek.

Fracturing can occur anywhere along the creeks and drainage lines in proximity to the longwalls. However, the areas most likely to be impacted are Donalds Castle Creek and other incised drainage lines which have predicted upsidence and closure movements similar to those which have resulted in fracturing of the bedrock in the past (MSEC 2012). Surface cracking would tend to be filled with the soil and alluvial materials during subsequent flow events, especially during times of heavy rainfall, however this effect is relatively slow with impacts typically continuing for an extended period.

4.2.2 Changes in Gradient and Surface Water Levels

Subsidence can change the gradient and alignment of streams and the outflow characteristics of pools. If these changes are significant when compared to existing landscape alignment and stream gradients there can be changes to flows, stream powers and pool water levels. As described below, these effects are not predicted to be significant for Area 3B.

4.2.3 Maximum Effects of Upsidence of the River Bed

Stream bed fracturing as a result of longwall mining is most likely to occur within incised and rock bedded streams that have been directly mined beneath. Longwalls 9 to 18 do not mine directly under Wongawilli Creek and have been set back from the main channel. Ecoengineers (2012) have assessed that minor fracturing could occur along Wongawilli Creek, with larger fractures to develop within Donalds Castle Creek and drainage lines.

Based on a review of other sites within the Southern Coalfield it is predicted that if adequate setbacks from longwalls to major watercourses are provided, upsidence related hydrologic and geochemical effects such as the oxidative dissolution of exposed marcasite can be avoided (Ecoengineers 2012).

4.2.4 Stream Bed Fracturing Effects

Subsidence resulting from longwall mining beneath creeks and riverbeds can produce a complex suite of physico-chemical effects. Hydrological measurements, visual observations and water quality monitoring in the Southern Coalfield indicate the principal effects are:

- Compressive and tensile failure fracturing of bedrock;
- Diversion of stream flows through the fractured bedrock;
- Oxidative dissolution of accessory marcasite within freshly fractured bedrock; and
- Leaching of minerals by water flowing through the fracture network.

4.2.5 Ferruginous Springs

Based on a review of impacts on springs resulting from previous longwall extraction in the Southern Coalfield, Ecoengineers (2012) predict that the proposed mining may generate individual ferruginous springs discharging up to a maximum of approximately 0.4ML/day, with a mean discharge rate of 0.1ML/day.

4.3 ENVIRONMENTAL CONSEQUENCES

Ecoengineers (2012) have predicted the following possible water related environmental consequences due to the extraction of Longwalls 9 to 18:

- Environmental consequences from streambed fracturing;

- Environmental consequences from ferruginous springs;
- Environmental consequences from reduced stream flows and pool water levels;
- Environmental consequences from water quality changes;
- Environmental consequences from changes in grade and erodibility; and
- Potential impacts to flora and fauna (including threatened species).

These environmental consequences are further defined below and quantified in the TARP (**Attachment 1**).

4.3.1 Streambed Fracturing

Subsidence can induce bedrock fracturing or movements along joints and planes of weakness. This is likely to lead to an increase in hydraulic conductance. Where these increases in conductance are greater than low flow conditions the pools within streams will reduce in level or become dry.

MSEC (2012 and 2015) predicts that maximum tensile strains greater than 0.5mm/m may be of sufficient magnitude to result in fracturing of the beds of drainage lines in Area 3B. Compressive strains greater than 2mm/m may be of sufficient magnitude to result in the bedrock buckling and fracturing, which can induce fractures in the beds of watercourses (Ecoengineers 2012).

Longwalls 9 to 18 will not mine under Wongawilli Creek by a minimum distance of 70m. The rationale for this is described in detail in the report by Mine Subsidence Engineering Consultants (2010) titled *Dendrobium Area 3B – Longwalls 9 to 18: Subsidence Predictions and Impact Assessments for Natural Features in Support of the SMP Application (Report Number MSEC 459, Revision A).*

Streambed fracturing as a result of longwall mining is most likely to occur within incised and rock bedded streams that have been directly mined beneath. Ecoengineers (2012) have assessed that minor fracturing could occur along Wongawilli Creek, with larger fractures and surface water diversion to develop within Donalds Castle Creek and drainage lines. This is supported by the fracturing and diversion of flow from Longwalls 9 and 10 which can be observed in drainage lines DC13 and WC21. One impact has been identified in Wongawilli Creek at the base of WC_Pool 43a (Longwall 9 EoP Report). The fracture has a length of approximately 2m and a width of up to 0.02m. There was no observed flow diversion associated with the fracture.

Due to the distance between Wongawilli Creek and Area 3B, downstream water quality impacts for this creek system are predicted to be negligible. Fracturing and water quality changes are likely in the tributaries of Wongawilli Creek in Area 3B.

An area of fracturing and flow diversion was observed at the basal step of Swamp 5, in the upper section of Donalds Castle Creek (Longwall 9 EoP Report). The fractures are up to 0.015m wide and 2m long and have a maximum uplift of 0.040m. Flow returned to the surface approximately 10m downstream at the bottom of the basal step. No additional rockbars within Donalds Castle creek are proposed to be mined beneath by Area 3B longwalls and no further impacts to rockbars in Donalds Castle Creek are expected.

If impacts are greater than those predicted, a range of mitigation and rehabilitation techniques may be applicable and will be implemented in consultation with and the approval of relevant agencies. These techniques are described in **Section 5**. Rehabilitation of the fracturing within Donalds Castle Creek below Swamp 5 is proposed as part of the Swamp Rehabilitation Research Plan.

4.3.2 Ferruginous Springs

A substantial portion of Area 3B is mantled by the outcropping Mittagong Formation-based clay-rich soils occupying several catchments at the 1 – 2km^2 scale. It is predicted therefore, that shallow ferruginous springs may be induced in the slopes of some sub-catchments over Area 3B with maximum discharge rates of approximately 0.4ML/day per km^2 and average flows in the order of 0.1ML/day. Such an effect, if it does occur, is likely to be largely aesthetic rather than posing any adverse impact on stream ecology. The ferruginous springs are predicted to result in no more than negligible environmental consequences. No ferruginous springs have been observed to date (Longwall 9 and 10 EoP Reports).

Observational, water quality as well as aquatic and terrestrial ecology monitoring as outlined in the TARP (**Attachment 1**) will be implemented to confirm this prediction. If impacts are greater than those predicted, a range of mitigation and rehabilitation techniques may be applicable and will be implemented in consultation with and the approval of relevant agencies. These techniques are described in **Section 5**.

4.3.3 Watercourse Gradient and Alignment

Subsidence can change the gradient of streams and the outflow characteristics of pools. If these changes are significant when compared to existing landscape and stream gradients there can be changes to flows, stream powers and pool water levels. As described below, these effects are not predicted to be significant for Area 3B.

The natural gradient of Wongawilli Creek, excluding Waterfall WC-WF54, varies between approximately 1mm/m and a maximum of 200mm/m, with an average natural gradient of approximately 10mm/m. Although the creek has a relatively shallow natural gradient, it is unlikely that there would be any significant increases in the levels of ponding, flooding, or scouring of the creek banks, as the maximum predicted changes in grade along the creek are very small, being less than 1%.

It is possible, however, that there could be some very localised changes in the levels of ponding or flooding where the maximum changes in grade coincide with existing pools, steps or cascades along the creek, however, any changes are not expected to result in adverse impacts as these changes would still be small in comparison with those which occur during natural flooding conditions (MSEC 2012 and 2015).

The maximum predicted increasing and decreasing tilts along Donalds Castle Creek are 20mm/m (i.e. 2.0%) and 25mm/m (i.e. 2.5%) respectively. The natural gradient of Donalds Castle Creek, directly above the proposed longwalls, varies between a minimum of 10mm/m and a maximum of 100mm/m, with an average natural gradient of 30mm/m.

The maximum predicted changes in grade are similar orders of magnitude to the natural gradients in the flatter sections of the creek. Accordingly, there are no predicted reversals of grade along the creek resulting from the extraction of the proposed longwalls.

The maximum predicted tilt for the drainage lines and tributaries within Area 3B is 50mm/m (i.e. 5.0%), which represents a change in grade of 1 in 20. The average natural gradients of the drainage lines vary considerably, directly above the proposed longwalls, from less than 10mm/m (i.e. less than 1% or 1 in 100) to more than 200mm/m (i.e. more than 20%, or 1 in 50).

The maximum predicted changes in grade are a similar order of magnitude as the natural gradients in the flatter sections of the drainage lines. There is a possible reversal in grade along DC13 adjacent to the tailgate of Longwall 9 and WC21 adjacent to the tailgates of Longwalls 10 and 11.

It is possible that there could be localised areas along the drainage lines which could experience small increases in the levels of ponding and flooding, in the locations of predicted maximum decreasing tilts, such as upstream of the longwall chain pillars and goaf edges. Any changes in the levels of ponding, flooding and scouring of the banks would be expected to be localised to areas of predicted maximum tilts or where the existing natural gradients are relatively flat.

4.3.4 Surface Water Flows

Fracturing may result in diversion of surface stream flow into the dilated strata leading to loss of flow in the stream. A number of studies have determined the depth of the surface vertical fracture network resulting from valley related closure to be restricted to approximately 15 to 20m below the surface. On the basis that there is no connective fracturing to any deeper storage it is likely that any diverted surface water will re-emerge at the surface (see **Sections 2.6 and 3.2**). This would occur at the limit of subsidence induced fracturing downstream within the watercourses.

The maximum predicted total conventional tensile and compressive strains at Wongawilli Creek resulting from the extraction of the longwalls in Areas 3A and 3B are less than 0.3mm/m. The fracturing of sandstone due to conventional subsidence movements has generally not been observed in the Southern Coalfield where the conventional tensile and compressive strains are less than 0.5mm/m and 2mm/m, respectively.

It is unlikely that fracturing resulting in surface water flow diversion would occur along Wongawilli Creek as a result of the proposed extraction of Longwalls 9 to 18. Minor fracturing may occur in the bed of Wongawilli Creek as a result of the extraction of the proposed longwalls. Minor fracturing has been observed within 400m of the extracted goaf. Any fracturing that does occur in the bed of the creek is expected to be isolated and of a minor nature such that water flow diversion is unlikely. One impact has been identified in Wongawilli Creek at the base of WC_Pool 43a (Longwall 9 EoP Report). The fracture has a length of approximately 2m and a width of up to 0.02m. There was no observed flow diversion associated with the fracture.

The maximum predicted conventional strains for Donalds Castle Creek, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 8mm/m tensile and compressive. The creek is also likely to experience elevated compressive strains, resulting from the valley related movements. Based on previous experience at the mine it is expected that fracturing and surface water flow diversion would occur along Donalds Castle Creek and the drainage lines which are directly mined beneath. This is supported by the fracturing and diversion of flow from Longwalls 9 and 10 which can be observed in Donalds Castle Creek and in drainage lines DC13 and WC21.

The section of Donalds Castle Creek which supports Swamp 5 has soil accumulations and alluvial deposits and it is likely that fracturing in the bedrock of the swamp would not be seen at the surface.

4.3.5 Water Quality

Mine subsidence can impact the quality of water in streams due to leaching of minerals from freshly fractured bedrock and from increased inputs from groundwater to surface water flow. Such impacts tend to be temporary, localised and associated with low flow conditions. An investigation into the potential impacts of mine subsidence on water quality in watercourses has been undertaken and described in the report by Ecoengineers (2012) and is summarised below.

Due to the setback distance of the Area 3B longwalls from Wongawilli Creek, it is not expected that any significant fracturing and sub-bed flow diversions will occur in Wongawilli Creek to alter flows or water quality other than minor impacts. Due to the substantial distance downstream it is predicted there will be no measurable reduction in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek. No water quality impacts have been observed in Wongawilli Creek as a result of mining Longwalls 9 and 10 (Longwall 9 and 10 EoP Reports).

The Area 3B longwalls have mined directly under the upper reaches of Donalds Castle Creek and as expected fracturing and sub-bed flow diversions and water quality impacts have occurred (Longwall 9 and 10 EoP Reports). Due to the substantial distance downstream there has been no measurable reduction in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Donalds Castle Creek (Longwall 9 and 10 EoP Reports).

As the Area 3B longwalls will mine directly under the first and second order streams it is expected that fracturing and sub-bed flow diversions will occur and this is likely to alter flows and water quality in these areas. Monitoring of past mining impacts where streams were directly mined under indicate that these effects are naturally attenuated within approximately 600m of downstream flow. Given the distances between the first and second order streams that are mined under and Wongawilli Creek it is predicted that some attenuation of these impacts will occur. With the substantial distance downstream to Cordeaux River it is predicted there will be no measurable reduction in the quality or quantity of surface water inflow to the River. Observation and monitoring during and after the extraction of Longwalls 9 and 10 support this prediction (Longwall 9 and 10 EoP Reports).

4.3.6 Water Supply Reservoirs and the Cordeaux River

Condition 3, Schedule 3 of the modified Consent 60-03-2001 requires a review of potential water quality and quantity impacts. There has been no significant effect in the short or long term on either bulk raw water quality or drinking water quality in the Native Dog Creek arm of Lake Avon, despite Native Dog Creek being directly mined under by Elouera Colliery longwalls, causing creek bedrock fracturing. Similarly, monitoring undertaken at Dendrobium Areas 1 and 2 indicated there was no effect in the short or long term on bulk raw water (used for drinking water) quality in Lake Cordeaux.

Any water-borne inputs to Lake Avon from Dendrobium Area 3B will likely be restricted to a possible erosive export of fine sands and clays and/or ferruginous precipitates near the mouths of minor stream designated LA2, LA3, LA4 and LA5. Due to the localised areas of influence any impact on freshwater ecology is considered unlikely and the remoteness of these areas from water off-takes from the dam ensures any impact in water supply quality would be undetectable.

It is unlikely there would be any more than a negligible reduction in flow to Avon Reservoir or the Cordeaux River due to the Area 3B longwalls. It is unlikely that fracturing resulting in sub-bed flow diversion and pool water level loss will occur in Wongawilli Creek. Fracturing and diversion of surface water flows has occurred at Donalds Castle Creek at DC-RB33. On the basis that there is no connective fracturing to any deeper storage it is likely that any diverted surface water will re-emerge at the surface. This would occur at the limit of subsidence induced fracturing downstream within Donalds Castle Creek.

The Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield found that:

> ***Subsidence Impacts on Water Supply for Sydney and the Illawarra***
>
> *The Panel is not aware of any scientific evidence supporting the view that subsidence impacts on rivers and significant streams, valley infill or headwater swamps, or shallow or deep aquifers have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region.*

Area 3B is located upstream of the junction of Wongawilli Creek and Cordeaux River. At the junction, any change in water quality in Cordeaux River is predicted to be negligible. This is on the basis that the majority of flow in the Cordeaux River results from dam release, environmental flows and/or overflow from Cordeaux Reservoir. As demonstrated above, inflow and quality impacts to the reservoir from Dendrobium Mine are predicted to be negligible. Water quality impacts within Wongawilli Creek are predicted to be minor within the reach of the Creek adjacent to Area 3B. Wongawilli Creek extends a further 4.5km to the confluence of the Cordeaux River. Additional catchment inflows to Wongawilli Creek occur in this reach and will mitigate any minor water quality impacts that do occur. For this reason any minor water quality impacts in Wongawilli Creek will give rise to no more than negligible change in water quality or flow at Cordeaux River.

4.3.7 Surface Slopes and Gradient

For the purposes of this Plan a steep slope has been defined as an area of land having a natural gradient greater than 1 in 3 (i.e. a grade of 33%, or an angle to the horizontal of 18˚). The steepest slopes within Area 3B, not including the cliffs and rock outcrops, were identified within the valley of Wongawilli Creek. These slopes have grades of up to 1 in 1, or angles to the horizontal of 45˚. Steep slopes were also identified directly above the proposed longwalls in Area 3B, along Donalds Castle Creek and the other major drainage lines, which have grades of up to 1 in 1.5, or angles to the horizontal of 34˚.

The maximum predicted tilt at the steep slopes, resulting from the extraction of the proposed longwalls, is 50mm/m (i.e. 5%). The predicted changes in grade are small when compared to the natural grades of the steep slopes, which are greater than 1 in 3 and, therefore, the predicted tilts are unlikely to result in any significant impact on the stability of the steep slopes.

4.3.8 Erodibility

Ground movements caused by mine subsidence may increase erosion and loss of soil materials through rock falls and cracking of the surface. Rock falls and soil cracking has occurred as a result of mining Dendrobium Areas 1, 2, 3A and 3B.

Monitoring and inspections show there has been no evidence of sustained subsidence-induced erosion of the valley slopes of previous mining areas in Dendrobium. Based on that experience, no significant erosive effects or consequences such as changes to water quality from the mining of Area 3B are expected.

4.3.9 Aquatic Flora and Fauna

The fracturing of bedrock and reductions of pool water levels and flow in SC10C associated with the extraction of Longwalls 7 and 8 represent a local loss of aquatic habitat and probably also biota. Statistical differences between macroinvertebrate collector assemblages sampled at Site 13 within SC10 and the controls post-extraction are probably due to the statistical differences detected in the abundances of Leptophlebiids and Chironomids. There is also some evidence in SIGNAL2 Index data derived from AUSRIVAS of an impact to aquatic ecology at Site 13, however, changes in SIGNAL2 Indices were not statistically significant.

An increase in Chironomid abundance at Site 9 on Sandy Creek after extraction could suggest that impacts also occurred further downstream. However, in the absence of any impacts to water quality in Sandy Creek this observation appears more likely due to natural variation, suggesting that impacts to aquatic ecology associated with the extraction of Longwalls 7 and 8 are limited to SC10C. In addition, there was evidence of a slight improvement in the SIGNAL2 Index at Site 13 following completion of extraction and none of the trends described in AUSRIVAS data collected from the SC10C impact Site 13 were statistically significant. Impacts to aquatic ecology in SC10C are likely short term and relatively minor in the context of the Sydney Catchment Area (Cardno, 2015). Similar impacts are likely to occur in Area 3B, particularly where mining results in diversion of surface water flow. The X2 Aquatic Ecology Monitoring Site on WC21 has been impacted as a result of extraction of longwalls 9 and 10 (Longwalls 9 and 10 EoP Reports).

4.3.10 Threatened Species

Twenty-five threatened plant species and seventy-one threatened animal species have been recorded within a 10km radius of Dendrobium Area 3B. Of these, eleven plant species and fifty-three animal species are considered to have a moderate to known likelihood of occurrence in the study area. 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 was likely. The possible mechanisms and physical effects of subsidence was determined to have a direct impact on known and potential habitat for the species, as these species are reliant upon Donalds Castle Creek and drainage lines (Niche 2012).

Assessments of Significance were undertaken for the threatened aquatic species the Adams Emerald Dragonfly, the Sydney Hawk Dragonfly and the Macquarie Perch and these assessments concluded that it is unlikely that the proposed project will have a significant impact on the species as they would only be subject to temporary, localised and minor impacts.

5 MANAGEMENT AND CONTINGENCY PLAN

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

5.1 OBJECTIVES

The aims and objectives of the Plan include:

- Avoiding and minimising impacts to significant environmental values where possible.
- Implementing TARPs to identify, assess and responding to impacts to watercourses.
- 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.
- Monitoring and reporting effectiveness of the Plan.

To achieve these aims, monitoring, management, mitigation and remediation techniques have been incorporated into the mining activity proposed by IC.

5.2 TRIGGER ACTION RESPONSE PLAN

The TARPs relate to identifying, assessing and responding to the potential impacts to watercourses (including impacts greater than predicted) from subsidence in Dendrobium Area 3B. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for Area 3B watercourses are included in **Attachment 1**.

It should be noted that the TARPs represent actions to be taken upon reaching each defined trigger level. A Corrective Management Action (CMA) is developed in consultation with stakeholders in order to manage an observed impact in accordance with relevant approvals. The WIMMCP provides a basis for the design and implementation of any mitigation and remediation. Generic CMAs will be developed as required, in consultation with Water NSW, 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 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 2 and 3 TARPs result in further investigations and reporting by appropriately qualified people. 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 objectives for any corrective actions;
- Specific actions required to mitigate/manage and timeframes for implementation;
- Roles and responsibilities;
- Gaining appropriate approvals from landholders and government agencies; and
- Reporting, consultation and communication.

5.3 AVOIDING AND MINIMISING

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

IC 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 were assessed by IC 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 surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3B was 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 predicted 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 IC.

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3B mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DoPE and OEH 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 75m and 500m from Wongawilli Creek and between 214m and 301m 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.

A Wongawilli Creek Waterfall Management Plan will be developed to ensure the performance measures required by the SMP Approval for WC-WF54 are met. The Wongawilli Creek Waterfall Management Plan will be implemented similar to the successful Sandy Creek Waterfall Management Plan for Dendrobium Area 3A.

5.4 MITIGATION AND REHABILITATION

If the performance measures in Table 1 of the SMP Approval are not met, then following consultation with OEH, Water NSW and T&I, the Secretary of DoPE 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.

As indicated in Schedule 2 Conditions 1 and 14 of the Development Consent (Minister for Planning 2008) and Condition 10 of the Area 3B SMP Approval (Secretary DoPE 2013), 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 TSC 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 Consent there was a requirement for consultation with the Minister administering the TSC Act and this consultation was undertaken.

5.4.1 Sealing of Rock Fractures

Where the bedrock base of any significant permanent pool or controlling rockbar within Wongawilli Creek or Donalds Castle Creeks 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 cementatious (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 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 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.

5.4.2 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 profile. This technique was successfully used at Pool 16 in the Georges River to rehabilitate surface flow by-pass to Pool 17. In this case 1-2m 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 1m x 1m to 2m x 2m. 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 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 set up 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 large rockbar occurs it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via traditional or directional drilling 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 5-1** 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 5-1 Rockbar Grouting in the Georges River

5.4.3 Erosion Control

Erosion can occur along preferred flow paths where subsidence induced tilts increase a catchment area. To arrest this type of erosion, 'coir log dams' are installed at knick points in the channelised flow paths or at the inception of tunnel/void spaces (**Figure 5-2**).

Figure 5-2 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. The coir logs are held in place by 50mm x 50mm wooden stakes and bound together with wire (**Figure 5-3**).

The coir log dam slows the flows in the eroding drainage line such that the drainage line will silt up.

Figure 5-3 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 soil so the first layer sits on the underlying substrate or so the top of the first coir log is at ground level (**Figure 5-4**).

Figure 5-4 Trenching and Positioning of the First Layer of Coir Logs and Construction of a Small Dam in a Channel

The coir log dams are constructed at intervals down the eroding flow line, 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. Where increased filtering of flows is required the coir logs are wrapped in fibre matting (**Figure 5-5**).

Figure 5-5 Small Coir Log Dams with Fibre Matting

5.4.4 Surface Treatments

Where cracking develops in significant areas and natural infilling is not occurring, the cracks may require forking over and compacting to prevent erosion. Larger cracks may require more work to repair them, for example, mulch or other protection to prevent the development of erosion channels. Surface protection will remain in place until revegetation covers the disturbed area. In some cases, if the cracks are wider they may require gravel or sand filling up to surface level and revegetation using brush matting. Maintenance of moisture in rehabilitation areas can be enhanced by additional 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 5-6**).

Figure 5-6 Round Coir Logs Installed to Spread Water

Erosion control and water spreading involves soft-engineering materials that are biodegradable and become integrated into the soil profile. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the soil. This also removes the requirement for any post-rehabilitation removal of structures or materials. However, rehabilitation measures have the potential to cause impact through the materials used and the disturbance associated with access. Relevant approvals will be obtained to ensure the protection of the environment as works are implemented.

5.4.5 Gas Release

A typical driver of gas release at the surface is pressure changes, dilation and/or fracturing of the rock mass and associated release to the surface, with or without groundwater flows. Grouting techniques discussed above can reduce these associated gas flows at specific sites. In all identified circumstances in the Southern Coalfield the gas releases have diminished over time. Typically this time is a number of months but it can be a number of years. Long running gas releases significantly reduce in quantity over time. Where vegetation is impacted by gas releases the areas affected will be revegetated once monitoring determines the gas releases have ceased or reduced to an extent that vegetation is no longer affected.

Very few gas releases have been observed within the Dendrobium mining area.

5.4.6 Water Quality

In Appendix A of Attachment B (see SMP, Vol.1), Ecoengineers (2012) outline mitigation measures that would be considered if unpredicted water quality impacts were detected. Any works on Water NSW land requires prior approval from Water NSW to access the land and there is a requirement for compliance with the Sydney Catchment Authority Water Supply Catchment Special Areas Standard Conditions for Entry (Water NSW 2001). These requirements ensure strict limits are placed on any impacts associated with undertaking rehabilitation works on Water NSW land.

With respect to mitigating the effects of decreased pH and metals mobilisation through fracturing of stream bedrock and/or rockbars, liming of streams and rivers is generally the technique of first choice for aquatic ecosystem mitigation under stress from acidification and metals.

A contingency measure for this proposal is to use a granular agricultural grade limestone (CaCO3) to treat any proven point of chronic emergence of acidic, Fe and Mn rich upsidence-induced sub-bed diversion flows, especially if such pools were located within proximity to Lake Avon.

Emplacement of limestone would provide a continual reactive surface for:

- The neutralisation of excessive acidity.
- The localized precipitation of Fe and Mn hydrous oxides with consequent adsorptive removal of potential eco-toxic metals.
- Increased hardness of the water and rapid settling of dispersed sodic 2:1 layer clays accelerating the rate of natural remediation of cracks in the bases of the pools.

Limestone is relatively insoluble except when pHs fall below about 6.5 and the dissolved products (calcium and carbonate alkalinity) are non-toxic, and would have no effect on bulk water supply quality and hence would not adversely affect waters in Lake Cordeaux or Cordeaux River.

Excessive precipitation of hydrous iron and manganese oxides and the consequent generation of local acidity from the induction of ferruginous springs result from a reaction with atmospheric oxygen. In this case, the location of the zone of maximal oxygen can be moved upslope closer to the spring source. This would involve the deposition of rocks and boulders closer to the spring. This material could be obtained from local Hawkesbury Sandstone outcrops nearby and moved to the spring emergence point by manual labour. This will greatly increase turbulence and hence rates of oxygenation, precipitation of hydrous oxides and acid generation, allowing natural effects downslope to ameliorate the effects of the spring.

5.4.7 Alternative Remediation Approaches

IC has successfully implemented a subsidence rehabilitation program in the Georges River where there were impacts associated with mining directly under streams. This rehabilitation focused on grouting of mining induced fractures and strata dilation to reinstate the structural integrity and water holding capacity of the bedrock. Metropolitan Colliery is currently undertaking work aimed at rehabilitating areas impacted by subsidence using Poly-urethane Resin (PUR) and other grouting materials. IC is actively consulting with Metropolitan Colliery in relation to these new and emerging 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 IC.

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.

5.4.8 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 monitoring program is in place for watercourses identified in this Plan. A summary of watercourse 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 the 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 watercourses 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.

5.5 BIODIVERSITY OFFSET STRATEGY

Where impacts are greater than predicted or not within approved levels, compensatory measures will be considered. Any compensatory measure will consider the level of impact requiring compensation, the compensatory measures available and the practicality and cost of implementing the measure.

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

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

It has been agreed to transfer 33ha of land adjacent to the Cataract River to Water NSW to meet the above condition.

A biodiversity offset strategy has been developed in consultation with OEH and Water NSW for the approval of the Secretary of DoPE. The strategy proposes a process whereby suitable residual environmental offset can be provided where the actual impacts on watercourses exceed those predicted in the SMP.

5.6 RESEARCH

To assist in further understanding the impacts of subsidence and rehabilitation of swamps IC will undertake research to the satisfaction of the Secretary. The research will be directed to improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences to swamps. The knowledge and techniques developed through this research will assist with any requirement for rehabilitation within watercourses.

5.7 CONTINGENCY AND RESPONSE PLAN

In the event the TARP parameters are considered to have been exceeded, or are likely to be exceeded, IC will implement a Contingency Plan to manage any unpredicted impacts and their consequences.

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.
- Updates from specialists on investigation process.
- 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 WIMMCP in consultation with key government agencies and seek approval for any modifications.
- 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 degradation that exceeds the trigger levels specified in the TARPS.

The site specific rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. Authority to access the land to conduct works and implement environmental controls will be approved by Water NSW.

Table 5-1 provides a summary of the avoidance, mitigation and contingency measures proposed to manage impacts where predicted impacts are exceeded.

Table 5-1 Performance Measures, Predicted Impacts, Mitigation and Contingent Measures for Watercourses

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
Wongawilli Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	• Observation of Wongawilli Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	The longwalls have been setback between 75m and 500m from Wongawilli Creek Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period	Mining results in more than minor environmental consequences in Wongawilli Creek, including: • fracturing within Wongawilli Creek resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period • measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River that is greater than predicted by the groundwater model (to the satisfaction of the Secretary - Condition 13 of the SMP) that cannot be attributed to natural variation • gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Ck (FR6) • ±3 standard deviation change (positive for EC, negative for pH and DO) from the baseline mean, for a minimum of two consecutive monitoring events that cannot be attributed to natural variation	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
Donalds Castle Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	• Observation of Donalds Castle Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	The longwalls mine under the first and second order upper reaches of Donalds Castle Creek only Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period	Mining results in more than minor environmental consequences in Donalds Castle Creek, including: • fracturing within Donalds Castle Creek resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period • measured surface water flow reduction in Donalds Castle Creek at its confluence with Cordeaux River that is greater than predicted by the groundwater model (to the satisfaction of the Secretary - Condition 13 of the SMP) that cannot be attributed to natural variation • gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Ck (FR6) • ±3 standard deviation change (positive for EC, negative for pH and DO) from the baseline mean, for a minimum of two consecutive monitoring events that cannot be attributed to natural variation	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
Waterfall WC-WF54	**Negligible environmental consequences** including: no rock fall occurs at the waterfall or from its overhang; no impacts on the structural integrity of the waterfall, its overhang and its pool; negligible cracking in Wongawilli Creek within 30m of the waterfall; and negligible diversion of water from the lip of the waterfall	Negligible environmental consequences including: no rock fall occurs at the waterfall or from its overhang; no impacts on the structural integrity of the waterfall, its overhang and its pool; negligible cracking in Wongawilli Creek within 30m of the waterfall; and negligible diversion of water from the lip of the waterfall	• Observation of Waterfall WC-WF54 for rock falls, impacts on structural integrity and cracking • Measurement of pool water levels	Implementation of a TARP similar to that which was implemented for Sandy Creek Waterfall	Mining results in more than negligible environmental consequences including: • rock fall at the waterfall or its overhang • impacts on the structural integrity of the waterfall, its overhang or its pool • cracking in Wongawilli Creek within 30m of the waterfall which results in observable flow diversion • cracking in Wongawilli Creek which results in observable flow diversion from the lip of the waterfall	Grouting of fractures within 30m of the waterfall where flow diversion is observed (where it is safe to do so) Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent
Lake Avon	Operations do not result in reduction (other than **negligible reduction**) in the quality or quantity of surface water or groundwater inflows to Lake Avon	Negligible reduction in the quality and quantity of surface water and groundwater inflows to Lake Avon	• Measurement of surface water flow • Measurement of water quality • Groundwater model calibrated to groundwater levels, surface water flows and mine water budget	The longwalls have been setback between 230m and 310m from the full supply level of Lake Avon	Mining results in more than negligible reduction in the quality or quantity of surface water or groundwater inflows to Lake Avon, including: • surface water flow reduction into Lake Avon is greater than predicted by the groundwater model (to the satisfaction of the Secretary - Condition 13 of the SMP) that cannot be attributed to natural variation • ±3 standard deviation change (positive for EC, negative for pH and DO) from the baseline mean of the Lake Avon inflows, for a minimum of two consecutive monitoring events	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
					that cannot be attributed to natural variation	Consent
Cordeaux River	Operations do not result in reduction (other than **negligible reduction**) in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	Negligible reduction in the quality and quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	• Observation of Wongawilli Creek for iron staining • Measurement of surface water flow • Measurement of surface water quality	The longwalls have been setback between 75m and 500m from Wongawilli Creek	Mining results in more than negligible reduction in the quality or quantity of surface water inflows to the Cordeaux River at its confluence with Wongawilli Creek, including: • measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River is greater than predicted by the groundwater model (to the satisfaction of the Secretary - Condition 13 of the SMP) that cannot be attributed to natural variation • ±3 standard deviation change (positive for EC, negative for pH and DO) from the baseline mean of Wongawilli Creek at its confluence with Cordeaux River, for a minimum of two consecutive monitoring events that cannot be attributed to natural variation	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

Note: The mitigation measures will be assessed for appropriateness (in consultation with key stakeholders), as the need arises, on the individual watercourses being impacted to ensure significant additional impacts to the watercourses 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.

6 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

6.1 INCIDENTS

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

6.2 COMPLAINTS HANDLING

IC 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 IC 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 IC Community Complaints and Enquiry Procedure.
- Maintain good communication lines between the community and IC.
- 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.
  - Area where complaint relates to.
  - Details of any response where appropriate.
  - Details of any corrective actions.

6.3 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 Area 3 operations. Regular inspections, internal audits and initiation of any remediation/rectification work in relation to this Plan will be undertaken by the Manager Approvals.

Non-conformities, corrective actions and preventative actions are managed in accordance with the IC *Non-Conformance, Preventative and Corrective Action Procedure (ICHP0107)*. This procedure details the processes to be utilized with respect to the identification of non-conformances, the application of appropriate corrective action(s) to address non-conformances and the establishment of preventative actions to avoid non-conformances.

The key elements of the process include:

- 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 IC’s compliance with all conditions of the Dendrobium Development Consent, Mining Leases and other approvals and licenses.

An independent environmental audit will also be undertaken (*Condition 6 Schedule 8*) 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 DoPE.

7 PLAN ADMINISTRATION

This WIMMCP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Area 3 Approval Conditions. A summary of the administrative requirements is provided below.

7.1 ROLES AND RESPONSIBILITIES

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

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

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

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

General Manager Energy and Engineering

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

Manager Approvals

- Authorise the WIMMCP and any amendments thereto.
- To document any approved changes to the WIMMCP.
- Provide regular updates to IC on the results of the WIMMCP.
- Arrange information forums for key stakeholders as required.
- Prepare any report and maintain records required by the WIMMCP.
- 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 WIMMCP.
- Organise audits and reviews of the WIMMCP.
- Address any identified non-conformances, assess improvement ideas and implement if considered appropriate.
- Arrange implementation of any agreed actions, responses or remedial measures.
- Ensure surveys required by this WIMMCP are conducted and record details of instances where circumstances prevent these from taking place.

Environmental Field Team Coordinator

- 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 WIMMCP.
- 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 Manager Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Manager Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the WIMMCP.

Technical Experts

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

Person(s) Performing Inspections

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

7.2 RESOURCES REQUIRED

The General Manager Energy and Engineering provides resources sufficient to implement this WIMMCP.

Equipment will be needed for the TARPs provisions of this WIMMCP. 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 Manager Approvals shall ensure personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

7.3 TRAINING

All staff and contractors working on IC sites are required to complete the IC training program which includes:

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

All training records are maintained by the IC Safety and Training Department (STAX database system), which can be accessed by IC staff via the online information system iPick.

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

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

7.4 RECORD KEEPING AND CONTROL

Environmental Records are maintained in accordance with the IC procedure *Records Management (ICHP0108)*.

7.5 DOCUMENT CONTROL

The IC *Document Control Procedure (ICHP0103)* outlines the method for control of defined 'business critical' documentation for all IC operations. The system has been designed in such a manner to ensure that:

- 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 WIMMCP and other relevant documentation will be made available on the IC website.

7.6 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 IC Balanced Planning (1 year outlook) and Balanced Strategy (5 year outlook) processes. 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 WIMMCP 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 this approval.

If deficiencies in the EMS and/or WIMMCP 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.

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Attachment 1 – TARP

Table 1.1 – Dendrobium Area 3 Watercourse Monitoring

Watercourses monitoring within Dendrobium Area 3B will be installed ahead of mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring 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 Figures 2-1 to 2-57.

	MONITORING SITE	SITE TYPE	MONITORING FREQUENCY	PARAMETERS
OBSERVATIONAL, PHOTO POINT AND WATER MONITORING				
AREA 3A	Sandy Creek and tributaries (including SC7 and SC10) *Refer to Figure 2-1*	Observation and photo point monitoring: • Sites based on an assessment of risk • Streams and swamps • Pools and rockbars • Previously observed impacts that warrant follow-up inspection	• Monthly 2 years pre and post mining, weekly when longwall is within 400m of monitoring site • Reference sites 6 monthly	Visual signs of impacts to creeks and drainage lines (i.e. cracking, vegetation changes, increased erosion, changes in water colour, soil moisture etc.) determined by comparing baseline photos with photos during the mining period Key water quality parameters in pools analysed to identify any changes resulting from mining Pool water levels to identify any changes resulting from mining
AREA 3B	**Impact Sites:** • Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC15, LA4, DC13, LA5, ND1, WC6, WC7, WC8, WC9, WC12, WC16 and WC18 • Swamps 5, 10, 11, 13, 14, 23, 35a, 35b, 1a, 1b, 8, 3 and 4 *Refer to Figures 2-2 to 2-11 and 2-25 to 2-32* **Reference Sites:** • Wongawilli Creek, Sandy Creek, LC7B, WC11, SC9A, SC10A, NDC1, DC10 and D10 •Swamps 2, 7, 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88 *Refer to Figures 2-12 to 2-25, 2-28 to 2-30 and 2-33 to 2-35*			
WATER QUALITY				
AREA 3A	**Wongawilli Creek** WWU1, WWU4, WC_Pool 46, WWM2, WC_Pool 43b and Wongawilli Ck (FR6) **Sandy Creek** SCk_Rockbar 5 (Sandy Creek adjacent to LW7) *Refer to Figure 2-1*	• Grab sample • Field water quality	• Monthly monitoring pre, during and post mining for two years	Manual Field Testing: • Field pH, Temp, EC, DO and ORP • Lab. analytes (incl. lab check of pH, lab. check of EC, DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si)

AREA 3B	**Wongawilli Creek** WWU1 (Wongawilli Creek headwaters) WWU4 (Wongawilli Creek upstream) WC Pool 49 (Wongawilli Creek adjacent to LW15) WC_Pool 46 (Wongawilli Creek adjacent to LW12) WWM2 (Wongawilli Creek adjacent to LW11) WC_Pool 43b (Wongawilli Creek downstream of LW9) Wongawilli Ck (FR6) (Wongawilli Creek downstream) WC21_Pool 5 (Wongawilli Creek tributary downstream of mining) WC21 Pools 30 and 53 (Wongawilli Creek tributaries over mining) WC15_Pool 9 (Wongawilli Creek tributary downstream of mining) **Lake Avon** LA4_S1, LA4_S2, LA5_S1, LA5_S2, LA3 Pool 4, LA2 Pool 5 and LA_1 (Lake Avon tributaries downstream of mining) NDC4 (Native Dog Creek downstream of mining) NDC1 (Native Dog Creek upstream of Area 3B) **Donalds Castle Creek** Donalds Castle Ck (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek @ Cordeaux River) DC_Pool 22 (Donalds Castle Creek downstream of mining) DC13_Pool 2b (Donalds Castle Creek tributary downstream of mining) *Refer to Figure 2-35*			

WATER FLOW				
AREA 3A	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL (Wongawilli Creek downstream) **Sandy Creek** SCL2(Sandy Creek at downstream) SC10S1 and SC10CS1 (Sandy Creek tributary) *Refer to Figures 2-35 and 2-36*	• Pressure transducer with data logger	• Continuous 1 hour logging intervals	Automatic pool water level measurements which are converted to flows by calculation of rating curves using measured creek cross sections/measured flows at the monitoring point
AREA 3B	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL (Wongawilli Creek downstream) WC21S1 (Wongawilli Creek tributary downstream of mining) WC15S1 (Wongawilli Creek tributary downstream of mining) **Donalds Castle Creek** DCU (Donalds Castle Creek @ FR6) DC13S1 (Donalds Castle Creek tributary downstream of mining) DCS2 (Donalds Castle Creek downstream of mining) **Lake Avon** LA4S1 (Lake Avon tributary downstream of mining) *Refer to Figures 2-35 and 2-36*			
AQUATIC ECOLOGY				
AREA 3A	Sandy Creek Catchment: Sites 8, 9, 10, 11, 12 and 13 *Refer to Figure 2-57*	• Quantitative and observational monitoring	• Two baseline monitoring campaigns prior to mining during autumn and spring • Monitoring during mining in autumn and spring • Monitoring post mining for two years or as otherwise required • 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 a back-pack electrofisher and baited traps in Area 3B
AREA 3B	**Impact Sites:** Sites 2, 3, 4, X4, X5 and X6 (Wongawilli Creek) Sites X2 and X3 (WC21) Site X1 (Donalds Castle Creek) **Reference Sites:** Site 1 (Wongawilli Creek – until LW15) Site 5 (Wongawilli Creek) Site 14 (Donalds Castle Creek)			

	Site 6 (WC21) Site 7 (Sandy Creek) Sites 15 and 16 (Kentish Creek) *Refer to Figure 2-57*			
TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3B	**Impact Sites:** DC13 (Donalds Castle Creek tributary) DC(1) (Donalds Castle Creek) WC15 and 21 (Wongawilli Creek tributaries) LA4A (Lake Avon tributary) ND1 (Native Dog Creek tributary) *Refer to Figures 2-42 to 2-47* **Reference Sites:** WC10 and 11 (Wongawilli Creek tributaries) SC6, SC7-1, SC7-2, SC7A and SC8 (Sandy Creek tributaries) DC8 (Donalds Castle Creek tributary) NDC (Native Dog Creek) *Refer to Figures 2-48 to 2-56*	• Standardised transects in potential breeding habitat for two threatened frog species, Littlejohn's Tree Frog and Giant Burrowing Frog	• Surveys are undertaken in optimal periods over the season (i.e. when frogs are calling and/or active at known sites)	Frog surveys are conducted along creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn's Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals 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

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

<table>
<tr><th>Monitoring</th><th>Trigger</th><th>Action</th></tr>
<tr><td colspan="3">OBSERVATIONAL, PHOTO POINT AND WATER MONITORING</td></tr>
<tr><td rowspan="4">Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC15, LA4, DC13, LA5, ND1, WC6, WC7, WC8, WC9, WC12, WC16 and WC18

General observation of streams in active mining areas when longwall is within 400m

Relevant Performance Measure(s):
• Wongawilli Creek - minor environmental consequences
• Donalds Castle Creek - minor environmental consequences
• Waterfall WC-WF54 – negligible environmental consequences</td><td>Level 1 *
• Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion
• Crack or fracture up to 10m length with no observable loss of surface water or erosion
• Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring
• Observable release of strata gas at the surface
• Observable increase in iron staining within the mining area</td><td>• Continue monitoring program
• Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers
• Report in the End of Panel Report
• Summarise actions and monitoring in AEMR</td></tr>
<tr><td>Level 2 *
• Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion
• Crack or fracture between 10 and 50m length
• Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention
• Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall</td><td>• Actions as stated for Level 1
• Review monitoring frequency
• Notify relevant technical specialists and seek advice on any CMA required
• Implement agreed CMAs as approved (subject to stakeholder feedback)</td></tr>
<tr><td>Level 3 *
• Crack or fracture over 300mm width at its widest point
• Crack or fracture over 50m length
• Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water
• Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention
• Gas release results in vegetation dieback, mortality or loss of aquatic habitat
• Observable increase in iron staining within the mining area continues more than 600m from the longwall</td><td>• Actions as stated for Level 2
• Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested)
• Implement additional monitoring or increase frequency if required
• Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders
• Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
• Review relevant TARP and Management Plan in consultation with key stakeholders</td></tr>
<tr><td>Exceeding Prediction
• Structural integrity of the bedrock base of any significant pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period
• Gas release results in vegetation dieback that does not</td><td>• Actions as stated for Level 3
• Investigate reasons for the exceedance
• Update future predictions based on the outcomes of the investigation
• Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the</td></tr>
</table>

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
	revegetate • Gas release results in mortality of threatened species or ongoing loss of aquatic habitat • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site WONGAWILLI CK (FR6) • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Ck (FR6) • Rock fall at WC-WF54 or its overhang • Impacts on the structural integrity of WC-WF54, its overhang or its pool	Development Consent
WATER QUALITY		
Wongawilli Creek Wongawilli Ck (FR6) Baseline means: • pH 5.98 • EC 98.8 uS/cm • DO 89.5% Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		baseline period • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two conecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Donalds Castle Creek Donalds Castle Ck (FR6) Baseline means: • pH 5.41 • EC 116.0 uS/cm • DO 85.6% Relevant Performance Measure(s): • Donalds Castle Creek - minor environmental consequences	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to stakeholder feedback). This may include:

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		– Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two conecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Lake Avon Lake Avon tributary (LA4_S1) Baseline means: • pH 5.38 • EC 90.8 uS/cm • DO 89.9% (24 months of baseline data available - to be updated with additional baseline data) Relevant Performance Measure(s): • Lake Avon - negligible reduction in the quality of surface water inflows to Lake Avon	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		– Filterable suite of metals • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two conecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean of the Lake Avon inflows during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
POOL WATER LEVEL		
Mapped pools in the mining area: • Wongawilli Creek • Donalds Castle Creek Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences	***Level 1*** * • Fracturing not resulting in diversion of flow	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Fracturing resulting in diversion of flow	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		• Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Waterfall WC-WF54 Relevant Performance Measure(s): • Waterfall WC-WF54 – negligible environmental consequences	***Exceeding Prediction*** • Fracturing in Wongawilli Creek within 30m of the waterfall which results in observable flow diversion • Fracturing in Wongawilli Creek which results in observable flow diversion from the lip of the waterfall	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
MODELLED PERIODS OF RECESSIONAL, BASEFLOW AND SMALL STORM UNIT HYDROGRAPH PERIODS		
Subcatchments of Wongawilli and Donalds Castle Creeks and Lake Avon tributaries **	***Level 1 **** • Change 6-12% less than average annual precipitation ***	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Change 12-18% less than average annual precipitation ***	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Change >18% less than average annual precipitation ***	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		• Review relevant TARP and Management Plan in consultation with key stakeholders
Inflows to Lake Avon and Cordeaux River ** Relevant Performance Measure(s): • Lake Avon - negligible reduction in the quantity of surface water inflows to Lake Avon • Cordeaux River - negligible reduction in the quantity of surface water flows from Wongawilli Creek to Cordeaux River	***Exceeding Prediction*** • Measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River that is greater than predicted by the groundwater model (to the satisfaction of the Director General - Condition 13 of the SMP) that cannot be attributed to natural variation • Surface water flow reduction into Lake Avon is greater than predicted by the groundwater model (to the satisfaction of the Director General - Condition 13 of the SMP) that cannot be attributed to natural variation	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
AQUATIC ECOLOGY		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 8 sites • Donalds Castle Creek catchment – 1 site	***Level 1 **** • Reduction in aquatic habitat for 1 year	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Reduction in aquatic habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
TERRESTRIAL FAUNA – THREATENED FROG SPECIES		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of	***Level 1 **** • Reduction in habitat for 1 year	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
habitat • Wongawilli Creek catchment – 2 sites • Donalds Castle Creek catchment – 2 sites • Lake Avon tributary – 1 site • Native Dog tributary – 1 site		relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Reduction in habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Reduction in habitat for > 2 years or complete loss of habitat following the active subsidence period	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

* These may be revised in consultation with DoPE and T&I and other key stakeholders following analysis of natural variability within the pre-mining baseline data. These TARPs relate to Dendrobium Area 3B and impacts resulting from mining in Areas 1, 2 and 3A were managed under previous TARPs.

** Water budgets during recessional, baseflow and small storm unit hydrograph periods would be determined by hydrologic modelling of pre- and post-mining hydrographic data using the Free University of Amsterdam RUNOFF2005 model and validation of model-determined ETs against those estimated by the independent CSIRO Land and Water Division (Zhang et al.) method. These TARPs would apply only to the whole of catchment water delivered to Lake Cordeaux, Lake Avon and Cordeaux River. Model reliability is maintained only for catchments in excess of 1 km^2 in area. Average annual precipitation is modelled using the most recent 5 years of local record.

*** Hydrologic modelling conducted in the manner described above for the baseline period routinely produces mean estimated water budgets lying within about ±6% of average annual precipitation at the one standard deviation level and within about ±12% at the two standard deviation level.

Office of Environment and Heritage (OEH)

Department of Planning and Environment (DoPE)

Trade and Investment: including Division of Resources and Energy, Office of Water, Fisheries (T&I)

Water NSW (formally SCA)