Dendrobium Colliery
Area 3A

WATERCOURSE IMPACT MONITORING, MANAGEMENT AND CONTINGENCY PLAN

PART OF THE SUBSIDENCE MANAGEMENT PLAN

April 2010

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resourcing the future

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Watercourse Impact Monitoring, Management and Contingency Plan

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1. INTRODUCTION

1.1 Purpose

The Watercourse Impact, Monitoring, Management and Contingency Plan has been prepared to comply with the Dendrobium Consent in respect to surface water management issues within Dendrobium Area 3. The Dendrobium Mine revised Consent requires a Watercourse Impact, Monitoring, Management and Contingency Plan under Schedule 3(4) of the consent. Specifically Schedule 3(1-4) of the consent is provided below.

Watercourse Impact Management

1. The Applicant shall ensure that, as a result of the development:
   (a) no rock fall occurs at Sandy Creek Waterfall or from its overhang;
   (b) the structural integrity of the waterfall, its overhang and its pool are not impacted;
   (c) cracking in Sandy Creek within 30 m of the waterfall is of negligible environmental and hydrological consequence; and
   (d) negligible diversion of water occurs from the lip of the waterfall
   to the satisfaction of the Director-General.

2. 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 Director-General.
   Note: In this condition, "minor impacts" are those defined as minor triggers in Table 23.2 of the draft SMP submitted by the Applicant for Dendrobium Area 3A.

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 Director-General.

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 Director-General. 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;
   (e) 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;
   (f) address third and higher order streams individually but address first and second order streams collectively;
   (g) be prepared in consultation with DECC, SCA and DPI;
   (h) incorporate means of updating the plan based on experience gained as mining progresses;
   (i) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and
   (j) be implemented to the satisfaction of the Director-General.

   Notes: Should review by the Department of reports by the Applicant under paragraph (b) indicate that subsidence impacts have exceeded or threaten to limits imposed in conditions 1-3, then under condition 4 of Schedule 2 the Director-General may instruct the Applicant to implement reasonable and feasible requirements, which may include to cease mining within the operative longwall, shorten the length of that longwall or shorten the length and/or width of future longwalls.

   - *Requirements under paragraphs (a) and (b) respecting Sandy Creek and Sandy Creek Waterfall relate only to the Watercourse Impact Monitoring, Management and Contingency Plan for Area 3*

2. MINIMISATION OF IMPACTS

2.1 Sandy Creek and Wongawilli Creek

In order to ensure that subsidence impacts at Sandy Creek and Wongawilli Creek due to mining are limited to minor fracturing, gas release, iron staining and minor impacts on water flows, quality and levels (see Schedule 3, condition of consent), the measures outlined below are being implemented. This information has been drawn from the Environmental Assessment document for Area 3 with additional information provided for this report.

2.1.1 Approval Conditions

Condition 2 of Schedule 3 of the modified Development Consent states:

> 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 Director-General. Note: In this condition, "minor impacts" are those defined as minor triggers in Table 23.2 of the draft SMP submitted by the Applicant for Dendrobium Area 3A.

2.1.2 Longwall Setbacks from Major Creeks

Longwalls in Area 3A will be set back at least 85 m from Sandy Creek and 110 m from Wongawilli Creek to achieve closure of <200 mm and tensiles strains of <0.5mm/m or compressive strains <2mm/m (see Attachment A - MESC, 2007; Section 2.4.3). These setbacks have been determined by detailed subsidence modelling, and while they necessitate sterilisation of coal resources that otherwise could have been extracted, the aim is to avoid cracking leading to surface water loss that may drain pools in these creeks. Due to the set back distance of Area 3A longwalls it is not expected that any significant fracturing and sub-bed flow diversions will occur in Sandy Creek or Wongawilli Creek or that there will be detectable losses of outflows from these catchments. If impacts are greater than those predicted, a range of mitigation and rehabilitation techniques may be applicable and will be implemented in consultation with relevant agencies. These techniques are described in Section 4.5.

2.1.3 Subsidence Induced Erosion Issues

Ground movements caused by mine subsidence may increase erosion and loss of soil materials through rock falls, or fissure opening in cohesive surface soils. Minor rock falls and surface soil cracking occurred as a result of mining Dendrobium Areas 1 and 2.

Monitoring and inspection by IC and its consultants for Elouera Mine shows there has been no evidence of sustained subsidence-induced erosion of the valley slopes of upper Wongawilli Creek and its tributaries during the past seven year monitoring period, even during periods of high rainfall..

Cliff lines associated with Wongawilli Creek are no larger than those that have been previously mined under in Dendrobium Areas 1 and 2. Slopes are no steeper or more extensive than those that have been previously mined under in Areas 1 and 2 and soil landscape types are similar to those previously encountered in the upper Wongawilli Creek catchment.

Based on that experience no significant erosive effects on water quality from the mining of Area 3 are expected.

2.1.4 Minimisation of 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 over many years in the Southern Coalfield indicate the principal effects are:

1. Compressive and tensile failure fracturing of bedrock leading to increased permeability and storage, possibly reduced surface flows over the mined under stretch of the watercourse, especially at the low end of the flow rate regime and more rapid draining of defined pools in no and low flow situations.
2. Diversion of stream flows through the fractured bedrock leading to loss of surface flows and potential loss of catchment yield if a connection to a deep storage was established.
3. Oxidative dissolution of accessory marcasite within freshly fractured bedrock water pathways, leading to release of sulfuric acid and iron, manganese, nickel and zinc and re-emergence of more acidic water of lower pH, lower redox potential, lower dissolved oxygen concentrations and high concentrations of the above metals from immediately downstream.
4. Leaching of aluminium from kaolinite by acidic water flowing through the fracture network.

It has been demonstrated that, subject to predictive modelling, if adequate set backs from the sides or ends of longwalls from major watercourses are provided, the above-described hydrologic and geochemical effects can be avoided or minimised.

Dendrobium Area 3A Longwalls 6 to 8 and Longwall 19 will not mine under Wongawilli or Sandy Creeks by a minimum distances of 110 m for Wongawilli Creek and 115 m for Sandy Creek. The rationale for this is described in detail in the report by Mine Subsidence Engineering Consultants (2010) entitled:

> *The Effects of the Proposed Modifications to the Longwalls in Area 3A at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. Report Number MSEC 437, Revision D.*

This report was submitted along with an application to amend the Dendrobium Area 3A mine plan in February 2009. Such was required as exploration activities had shown the extent of the Nepheline Syenite intrusion at the southern extremity of Dendrobium Area 3A to be greater than previously known. The new layout was proposed to replace that previously in the SMP and outlined in the document:

> *Dendrobium Mine Area 3, The Prediction Of Subsidence Parameters And The Assessment Of Mine Subsidence Impacts On Natural Features And Surface Infrastructure Resulting From The Extraction Of Proposed Longwalls 6 To 10 In Area 3a And Future Longwalls In Areas 3b And 3c At Dendrobium Mine*

This mine planning approach will also be used for future mining in Areas 3B and 3C. On this basis it was concluded that it is unlikely that the mining of Area 3 will lead to cracking within the main channel of Sandy Creek or Wongawilli Creek resulting in sub-bed diversion hydrologic and geochemical effects. .

MSEC (2007) indicate that maximum tensile strains greater than 0.5mm/m may be of sufficient magnitude to result in cracking in the beds of (say) tributary creeks. They also indicate that compressive strains greater than 2mm/m may be of sufficient magnitude to result in the topmost bedrock buckling and fracturing, which can induce surface cracking in the beds of the drainage lines.

There is some evidence that these predictions are relatively conservative. This is based on local experience over Longwalls 1 and 2 in Dendrobium Area 1 where, out of six main tributaries with maximum predicted systematic tilts, maximum predicted tensile strains and maximum predicted compressive strains along their channels of the order of 20, 4.0 and 9.0 mm/m respectively, only one (designated No. 22) exhibited surface fracturing. Geochemical studies also indicated the fracturing impact was minor and of limited duration. We infer from this that, while fracturing in the Sandy Creek

tributary SC10 possibly has higher probability; the probability of a similar effect in Creek WC17/17A may be no more than about 15%. Such is reduced further by the proposed mine plan applied for in February 2010, in which the length directly mined beneath is reduced from 1.3 km as per the SMP layout, to 0.5 km.

Most of the baseflow in the lower SC10 tributary of Sandy Creek derives from Swamps 15A and 15B, which lie along relatively weakly incised tributaries. Field studies show that baseflows in Sandy Creek derive from outflows from significant hillslope aquifers on both the western (Area 3A) and eastern (Area 2) sides of the Creek and a broad un-mined southern area in Upper Sandy Creek catchment. As the February 2010 proposed mine plan reduced the directly undermined section of SC10 to 0.5 km and no longer directly undermines SC7, it is expected only marginal changes in several water quality parameters for these tributaries are likely near their points of discharge into Lower Sandy Creek. Due to the broad scale sources of baseflow, downstream water quality impact is predicted to be insignificant.

Minor fracturing is also possible on the longer, more incised, high gradient tributaries of Wongawilli Creek in Area 3B e.g. creeks designated WC15, WC21 and DC1, and possibly in Area 3C in the well incised creeks designated LC6 and LC7 which drain to Lake Cordeaux and tributaries that drain to Wongawilli Creek. It is considered any such fracturing is unlikely to cause significant downstream water quality impacts due to its minor and discontinuous nature. If impacts are greater than those predicted, a range of mitigation and rehabilitation techniques may be applicable and will be implemented in consultation with relevant agencies. These techniques are described in Section 4.5.

2.1.5 Ferruginous Springs

Induction of ferruginous springs as a consequence of upland subsidence has been identified in the Southern Coalfield in subcatchments of the Nepean, Cataract and Georges River, most notably by being:

- The long-lived 'SW2 Spring' (Appin Area 3) in Cataract River just west of Back Gully Creek; and
- The long lived 'Pool 11 Spring' (West Cliff Area 5) in Georges River.

Mining-related subsidence can have the effect of delaminating erosion surfaces and bedding planes within and between strata. These effects are predicted to occur preferentially along the interfaces between materials with different elastic properties. Where broad scale upland subsidence occurs as a consequence of longwall mining, delamination, dilation and hence interfacial permeability enhancement is likely along the sub-horizontal interface between a sub-cropping Hawkesbury Sandstone and an outcropping Wianamatta Shale sequence. The effects of ferruginous springs will be mitigated by the placement of course limestone downstream of the spring to increase pH and increase the aeration coefficient of the stream to increase the localised precipitation of dissolved iron.

A substantial portion of Area 3B is mantled by Wianamatta Shale-based soils occupying several catchments at the 1 – 2 km^2 scale which drain via steep (10 – 20%) slopes with sandstone outcrops southwest to the Native Dog Creek Arm of Lake Avon. One or more ferruginous springs may be induced in the slopes of the southwest-draining catchments over Area 3B.

Such an effect, if it does occur, is likely to be largely aesthetic rather than posing any adverse impact on stream ecology due to the relatively short length and high gradients of the ephemeral creeks potentially involved and the substantial dilution and dispersion that would occur at the Lake Avon shoreline.

Notwithstanding, specific water quality monitoring sites would be located in this part of Area 3B to provide early detection and ongoing assessment of this potential effect. Drainage of the Wianamatta Shale-based soil uplands to the northwest to tributaries of Donald's Castle and Wongawilli Creeks occurs over much longer distances of far gentler slopes and there are numerous intervening swamps. It is considered unlikely that springs would be induced in this area and if they were, would be likely to occur around the margins of swamps or upslope of swamps and their effects be largely attenuated by those landscape features.

2.2 Sandy Creek Waterfall

Illawarra Coal included the below Commitment in the recently modified Development Consent for Dendrobium Mine.

Sandy Creek Waterfall

Prior to the commencement of mining within Dendrobium Area 3A, Illawarra Coal will:

- establish a "technical committee" that includes BHPB, DPI, MSEC, and independent subsidence and geotechnical experts to advise on Sandy Creek Waterfall,
- develop and implement detailed management outcomes such as a Trigger, Action, Response Plan (TARP) triggers and detailed monitoring where Longwalls 6-8 approach the Sandy Creek Waterfall.
- The TARP or other relevant management and/or mitigation plan will be finalised and agreed by the Technical Committee before the longwall retreat is within 700m of the Sandy Creek Waterfall, and address triggers to initiate early longwall take off at either of the pre-installed points, should ongoing monitoring indicate this action is necessary. A draft TARP is provided in Section 3.3, however this will be subject to further review by the Sandy Creek Waterfall Technical Committee.

2.2.1 Approval Conditions

Condition 1 of Schedule 3 of the modified Development Consent states:

The Applicant shall ensure that, as a result of the development:

(a) no rock fall occurs at Sandy Creek Waterfall or from its overhang;

(b) the structural integrity of the waterfall, its overhang and its pool are not impacted;

(c) cracking in Sandy Creek within 30 m of the waterfall is of negligible environmental and hydrological consequence; and

(d) negligible diversion of water occurs from the lip of the waterfall

to the satisfaction of the Director-General.

In addition, on the 24 December 2009 BHPB Illawarra Coal were issued with an interim approval, allowing extraction of Longwall 6 subject to a number of conditions. Condition 13 outlines further requirements for a Sandy Creek Waterfall Management Plan. Specifically:

Within six (6) months of the date of this approval the Leaseholder must submit to the Director Environmental Sustainability for approval a Sandy Creek Waterfall Management Plan.
The Leaseholder must not operate other than in accordance with an Environmental Management Plan (EMP) approved by the Director Environmental Sustainability. This plan must address subsidence impacts above and must include:

(a) detailed monitoring programme;
(b) trigger levels for subsidence impacts that require actions and responses;
(c) the procedures that would be followed in the event that the monitoring indicates an exceedance of trigger levels;
(d) measures to mitigate, remediate and/or compensate any identified impacts;
(e) a protocol for the notification of identified exceedences of the trigger levels; and
(f) a contingency plan.

2.2.2 Revised Mine Plan

In February 2010 an application was submitted to modify the mine plan for Dendrobium Area 3A. The new layout increased the minimum distance between the Longwalls and Sandy Creek Waterfall from the 250 m from the SMP layout, to 270 m (Longwall 8).

It is inferred from the sensitivity subsidence prediction provided in the SMP application that upsidence and valley closure from the revised longwall finishing point would be less that 75mm and 140mm, respectively. At this level of predicted closure, no or very minor cracking within the rock base of Sandy Creek above the waterfall is expected to occur. This will ensure the structural and hydrological integrity of the base of Sandy Creek within 30 m of the waterfall remain intact.

Two preinstalled longwall take off cut-throughs are located between the revised finishing end and a distance of 400 m from the Sandy Creek Waterfall. These cut throughs will enable stopping the longwall prior to the revised longwall finish line should monitoring data indicate that non compliance with condition 2.1 of the development consent may occur.

Previous experience in the Southern Coalfield indicates that:

- Very few rockfalls have occurred outside of extracted longwall goaf areas, and only in extremely rare cases have rockfalls occurred more than half the depth of cover from extracted longwall goaf edges.
- All rockfalls observed in Dendrobium Areas 1 and 2 have occurred directly above the extracted longwalls, and no rock falls have been observed outside of the extracted longwall goaf areas.
- Non-systematic subsidence movements are likely to contribute to significant impacts such as fracturing leading to pool water loss where substantial valley closure occurs (> 200m). Predicted non-systematic closure subsidence movements at the top of the waterfall are low (< 50 mm).

It is unlikely, therefore, that the extraction of the proposed and future longwalls in Area 3 would result in structural and hydrological impacts at the waterfall, as the site is located more than the equivalent depth of cover from the proposed and future longwalls.

Monitoring undertaken during the retreat of Longwall 5 demonstrated that differential horizontal subsidence movements are spatially limited to close (~100 m) proximity to the goaf. Surface strains at greater distances from the goaf have been within the limits of survey tolerance. In situ stresses measured within the Hawkesbury Sandstone strata were very small during the retreat of Longwall 5.

2.2.3 Technical Committee

Illawarra Coal has commenced all activities proposed in Commitment 6 of the modified development approval in respect of the management of Sandy Creek Waterfall. The technical committee first convened on 24 April 2009 and has recommended a course of monitoring and geotechnical modelling to further enable management decisions in regard to the Sandy Creek Waterfall.

These data will augment existing information which includes:

- spherical photography
- terrestrial laser scan
- subsidence predictions including valley related movement and strain calculations
- regional geological/stratigraphy data.

A summary of the recommended monitoring program is provided in Section 3.3.

2.3 Water Quality and Flows to Lake Cordeaux, Lake Avon & Cordeaux River

2.3.1 Approval Conditions

Condition 3 of Schedule 3 of the modified Development Consent states:

> 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 Director-General.

2.3.2 Water Quality Impacts on Water Supply Reservoirs and the Cordeaux River

Over five years of monitoring that 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 substantial creek bedrock fracturing. Similarly, monitoring undertaken at Dendrobium Areas 1 and 2 that there has been no significant effect in the short or long term on either bulk raw water quality or drinking water quality in Lake Cordeaux.

Any input of water-borne contaminants (to Lakes Avon and Cordeaux) from Dendrobium Area 3 will 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) and LC6, LC7 and LC8 (Lake Cordeaux) during mining of Areas 3B and 3C respectively. These creeks are all remote from their respective dam off-takes and outflows. Such zones would be localised to around the point of input to the Lakes and would be unlikely to have any significant impact on local freshwater ecology and would be undetectable in the bulk water supply quality.

Based on past experience from Wongawilli and Native Dog Creeks which were directly mined under by Elouera Colliery, and Dendrobium Areas 1 and 2, it is also considered highly unlikely that there will be any adverse effect on bulk drinking water supply quality in the Lake Cordeaux or Lake Avon systems. Hence, Area 3 development would be compatible with raw water supply quality standards for the Lake Cordeaux and Lake Avon systems.

It is unlikely that any measurable reduction in flow to Cordeaux or Avon Reservoirs or the Cordeaux River will occur. Due to the set back distance of Area 3A longwalls, it is not expected that any major fracturing and sub-bed flow diversions will occur in Sandy Creek or Wongawilli Creek, or that there will be measurable losses of outflow from these catchments. Sandy Creek flows into Cordeaux Reservoir. Wongawilli Creek flows into the Cordeaux River below the outflow of the Cordeaux Dam. Flow in the Cordeaux River is largely determined by discharge from the Cordeaux Dam. Flow monitoring of tributaries in Dendrobium Area 1 and Area 2 has not measured any decline in stream flow or inputs to the Cordeaux Reservoir. Both Cordeaux and Avon Reservoirs are the hydrological low points in their respective catchments. Any localised surface flow diversion that may occur in first or second order tributaries that will be directly undermined is expected to be shallow (~15m deep) and there will be no net loss of water from the hydrological catchment. 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.*

At the junction with Wongawilli Creek, any change in water quality in Cordeaux River is predicted to be negligible. This is on that basis that the majority of flow in the Cordeaux River results from dam release, environmental flows and/or overflow from Cordeaux Reserviour. As demonstrated above,

inflow and quality impacts to the reservoir from Dendrobium Mine are predicted to be negligible. Outflows from the reservoir will be representative of bulk water quality. Water quality impacts within Wongawilli Creek are predicted to be minor within the reach of the Creek adjacent to Dendrobium Area 3A extraction. For Dendrobium Area 3A, the reach of Wongawilli Creek extends a further ~4.5 km to the confluence of the Cordeaux River. Additional catchment inflows to Wongawill Creek occur in this reach and will dilute any minor water quality impacts that do occur. In combination, the dilution of any minor water quality impacts in Wongawilli Creek and the flows discharged from Cordeaux Dam to the Cordeaux River will give rise to negligible change in water quality or flow.

3. MONITORING AND REPORTING

3.1 Hydrology and Water Quality Monitoring plan

Details of the water monitoring plan 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 has been incorporated into this plan, the Area 3A SMP and the Statement of Commitments.

The water-related field work will concentrate in the first instance on regular monitoring of main channel water quality/flow sites in Sandy and Wongawilli Creeks and some associated tributaries. These sites will be monitored for key water quality and flow parameters on a monthly basis for 12 months prior to mining, during mining and for an appropriate time following mining. Shallow piezometers surrounding and within swamps will monitor groundwater level.

Additional water quality monitoring sites will be established for obtaining baseline data well prior to the mining of Areas 3B and 3C (in that order).

As all proposed longwalls are set back from the main channels of Sandy and Wongawilli Creeks, a key aspect of the monitoring plan deals with the early detection and subsequent investigation and assessment of any upsidence effects within tributaries.

If geochemical effects are detected just downstream of a confluence but not at the main channel upstream site, which are judged to be possibly a consequence of subsidence-related effects, assessment of the tributary sub-catchment's both water quality and hydrologic behaviour will be initiated.

The locations and numbers of routine water quality, hydrographic and piezometric monitoring sites are satisfactory for assessing the potential hydrologic and water quality effects of Dendrobium Area 3A and enabling rapid assessment of any sites or sub-catchments where impacts are suspected.

3.2 Monitoring

3.2.1 Baseline Studies and Initial Reconnaissance

Baseline studies are being undertaken in areas above longwall panels in order to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence and in reference areas. The baseline studies identify permanent monitoring sites in these areas.

Pre-mining surveys have been undertaken to catalogue the biophysical characteristics of the watercourses in Area 3A. The surveys established the location of permanent monitoring sites within the areas of impact, identified reference sites and developed suitable site-specific methodologies. Long-term water level data is sourced from the SCA for dam levels and water flow/quality monitoring data at Sandy Creek immediately upstream of the waterfall.

Baseline water quality is sampled in Area 3A from upstream and downstream sites. The sites in the potential impact zone will be compared to upstream and reference sites.

3.2.2 Surface Water Baseline Monitoring

Area 3A will be monitored using a number of existing and proposed (new) surface water and flow monitoring sites. Instrumented surface water flow monitoring sites will be downloaded on a monthly basis. Water samples are collected on either a monthly or bi-monthly basis and are dependant on water availability. The Area 3A surface water quality and flow monitoring sites are shown in **Figure 3.1**.

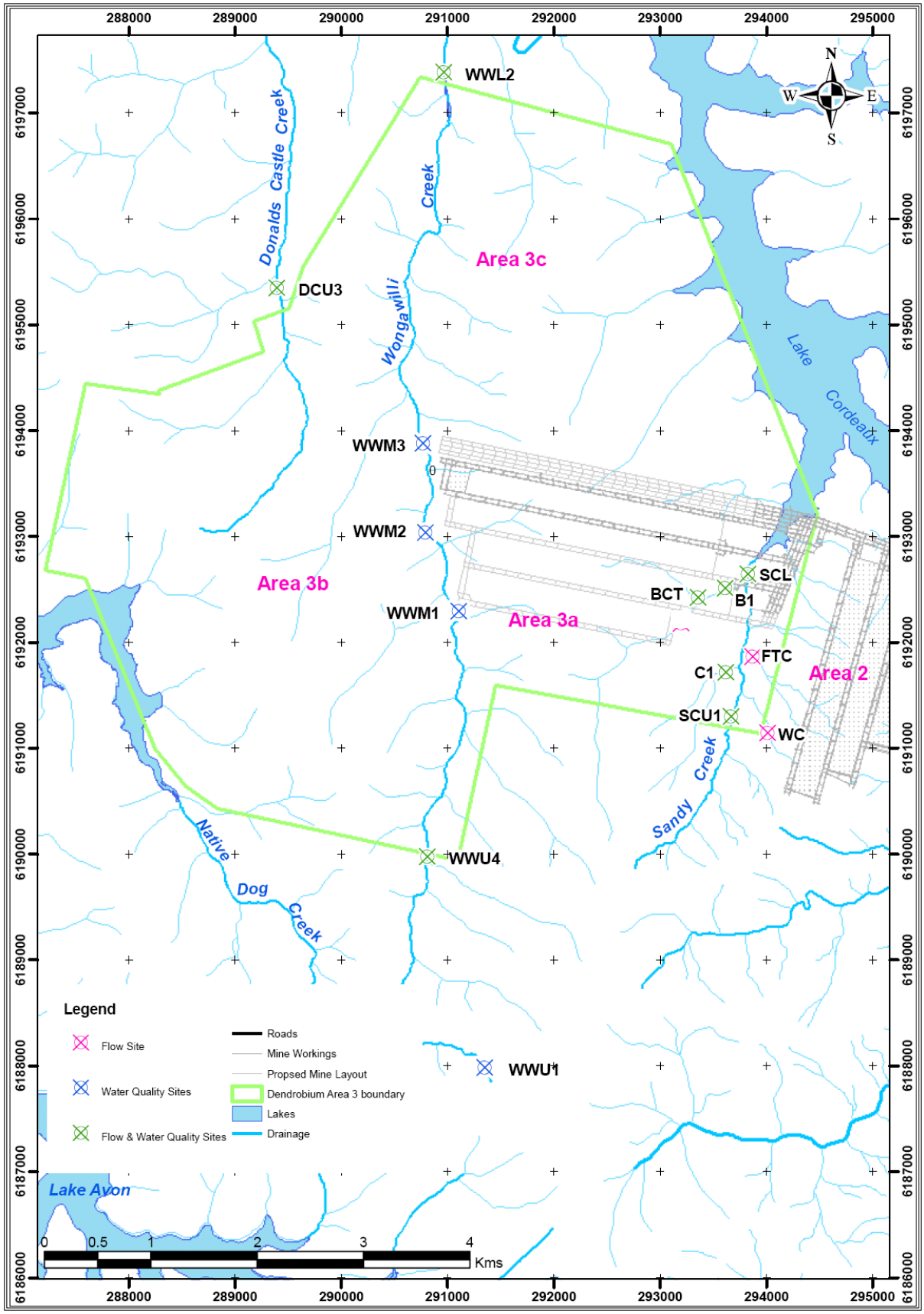

Figure 3.1 - Area 3A surface water quality and flow monitoring sites

The rationale behind the location of the monitoring sites is to establish the upstream (inflow) and downstream (outflow) monitoring at significant pools in the zone of potential subsidence. A rainfall gauge is installed and operating on the boundary between Wongawilli Creek and Lake Cordeaux catchments to the north of the study area.

The location and instrumentation details of the Area 3A sites are outlined in **Figure 3.1** and the field laboratory water quality parameters and monitoring frequency for the water quality sites are provided in **Table 3.2**. The surface water level and quality monitoring sites are described further in Ecoengineers (2007e, which is provided in **Attachment B** of the SMP).

Table 3.1 – Proposed Area 3A Surface Water Monitoring Sites

Monitoring Location	Site ID	Sub-catchment	Site Type
Upper Wongawilli 1	WWU1	Wongawilli	Water Quality
Upper Wongawilli 4	WWU4	Wongawilli	Water Quality / Flow
Mid-Wongawilli 1	WWM1	Wongawilli	Water Quality
Mid-Wongawilli 2	WWM2	Wongawilli	Water Quality
Mid-Wongawilli 3	WWM3	Wongawilli	Water Quality
Lower Wongawilli	WWL2	Wongawilli	Water Quality / Flow
Upper Sandy	SCU1	Sandy	Water Quality / Flow
Lower Sandy	SCL	Sandy	Water Quality / Flow
Lower SC10	BC1	Sandy	Water Quality / Flow
SC10C	BCC1	Sandy	Water Quality / Flow
SC8	FTC	Sandy	Flow
SC6	WC	Sandy	Flow
SC7	CC1	Sandy	Water Quality / Flow
Centroid Rainfall Station	CRS	Wongawilli / Lake Cordeaux (ridge)	Rainfall

Table 3.2 – Proposed Area 3A Field and Laboratory Water Quality Parameters and Monitoring Frequency

Site ID	Analytes	Sampling Frequency	Trigger Parameter
WWU1	Field pH, EC, DO. All lab. analytes	Monthly	Presence of water in pool
WWU4	Field pH, EC, ORP, DO. All lab. analytes	Monthly	Active flow
WWM1	Field pH, EC, ORP, DO, All lab. analytes	Monthly	Active flow
WWM2	Field pH, EC, ORP, DO, All lab. analytes	Monthly	Active flow
WWM3	Field pH, EC, ORP, DO, All lab. analytes	Monthly	Active flow
WWL2	Field pH, EC, ORP, DO, All lab analytes	Monthly	Presence of water in pool
SCU1	Field pH, EC, DO, All lab analytes	Monthly	Presence of water in pool
SCL	Field pH, EC, DO, All lab analytes	Monthly	Presence of water in pool
BC1	Field pH, EC, ORP, DO, All lab analytes	Monthly	Presence of water in pool
BCC1	Field pH, EC, ORP, DO, All lab analytes	Monthly	Presence of water in pool
CC1	Field pH EC, ORP, DO, All lab analytes	Monthly	Presence of water in pool

NOTE1: All lab. analytes = Lab check of pH, Lab. Check of EC, Na, K, Ca, Mg, Filt. SO_4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Ba, Sr, TKN, NH_3-N, NO_x-N, TP.

NOTE2: Limits of detection for major anions and cations is 0.5 mg/L, nutrients is 0.01mg/L, and 0.001 mg/L for metals.

The Area 3A hydrologic, shallow groundwater and water quality monitoring and assessment programs will provide ongoing water-related monitoring of the streams and subcatchments potentially affected by the mining of Dendrobium Area 3 and allow month-by-month assessment of the magnitude of any developing trends in overland and subsurface flow and water quality effects as a result of the mining.

3.2.3 Dam Water Baseline Monitoring

The water chemistry, algae and level of the water in Cordeaux and Upper Cordeaux No. 2 Reservoirs are monitored as a basis for comparison to the mine water. The locations of the samples and the testing procedure are detailed in the Dendrobium Underground Water Sampling and Analysis Procedure.

3.2.4 Site Surveying of Key Habitat Features

Surveys have been undertaken to identify physical attributes that influence flow regimes and provide a relationship of height of barriers and recorded water levels on fish movement. These surveys also provide input for the modelling component and assists in the selection of longer-term sampling sites. A stream morphology map for Sandy and Wongawilli Creeks are shown in **Figure 3.2** and **Figure 3.3**.

3.2.5 Rainfall

A rainfall gauge has been installed within Area 3, on the boundary between Lake Cordeaux and Wongawilli Creek catchments (refer **Figure 3.1**). For Areas 1 and 2 a station has been installed on the banks of the Kembla Creek arm of Lake Cordeaux.

Rainfall gauging is carried out to enable verification of discharge data through catchment runoff estimates derived from the rainfall. Hydrological modelling will be undertaken to estimate catchment runoff from the rainfall data.

3.2.6 Hydrologic Modelling

Using data (rainfall, water level, groundwater and derived flow) collected over relatively short periods spanning one or more storm events, systematic hydrologic model calibrations are made of selected headwater catchments in the Dendrobium mining areas. Water level/flow monitoring locations for Area 3A are shown in **Figure 3.1**.

This data will provide with the capability for quantitative hydrologic model simulations for the purpose of comparison and assessment of the possible hydrologic effects of the mining of Longwalls 1 to 10 in Areas 1, 2, and 3A.

The model structure adopted would focus primarily on assessment of the potential geohydrologic effects of stream bed upsidence and would provide a quantitative assessment of the significance of any upsidence-induced bedrock groundwater reservoir.

This would enable catchments that had potentially been affected by mining-related phenomena to be compared with other similar, unaffected catchments to determine any changes to the magnitudes of key hydrologic parameters over time. This analysis could also be used to measure changes associated with self-sealing or man-made remedial effects.

For Area 3A, it is planned that parametric outcomes of the RUNOFF modelling of SC10, SC7, Upper and Lower Sandy Creek, and Upper and Lower Wongawilli Creek will be able to be linked to the CSIRO Land and Water hillslope aquifer model FLOWTUBE to assess water level data obtained from

the networks of shallow piezometers distributed within in the Area 3A hillslope aquifers (and hence also of the swamps embedded in them).

Detail on the modelling for Area 3 is provided in Ecoengineers (2007e) (refer **Attachment B** of the SMP).

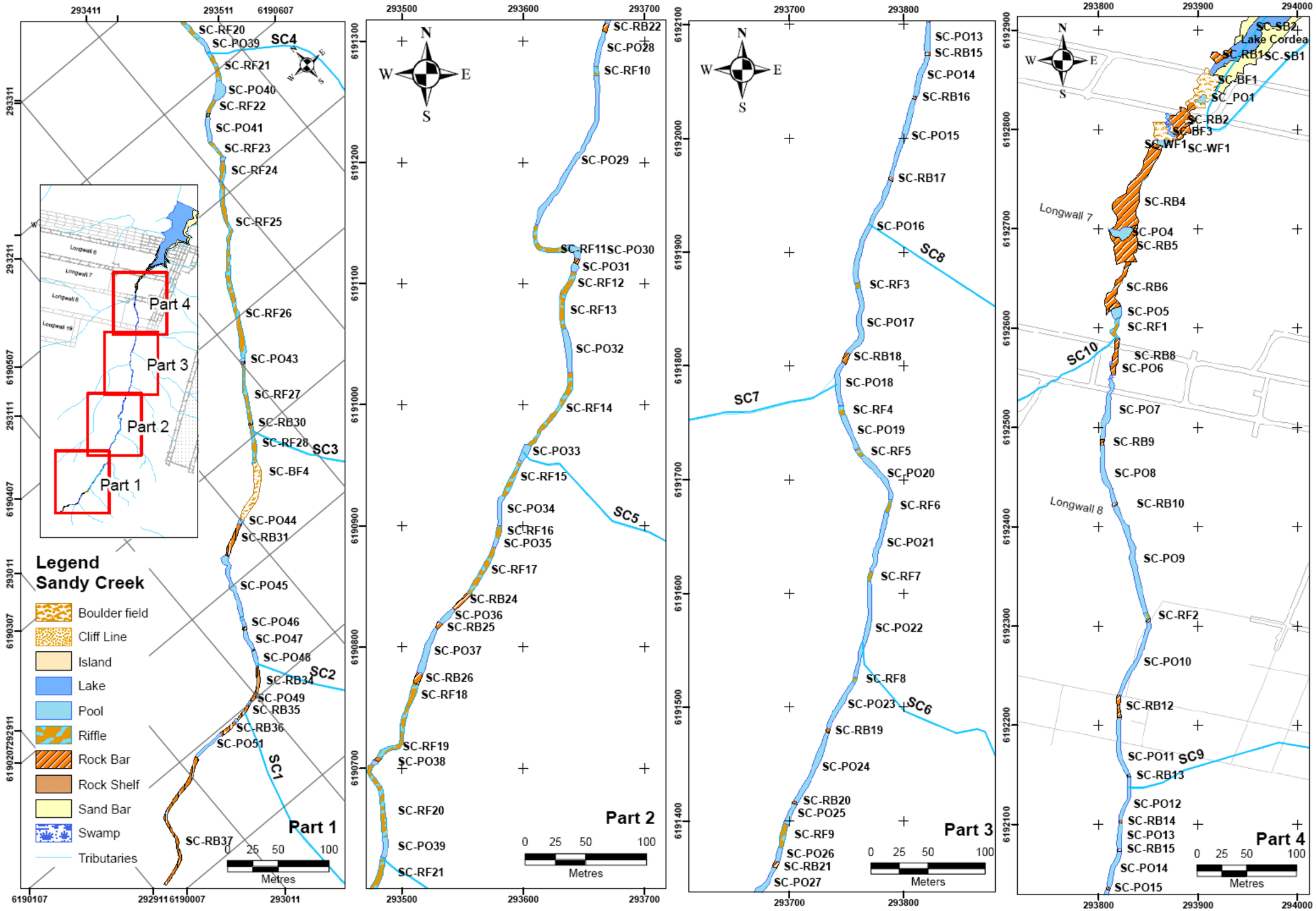

Figure 3.2 – Stream Morphology Map for Sandy Creek

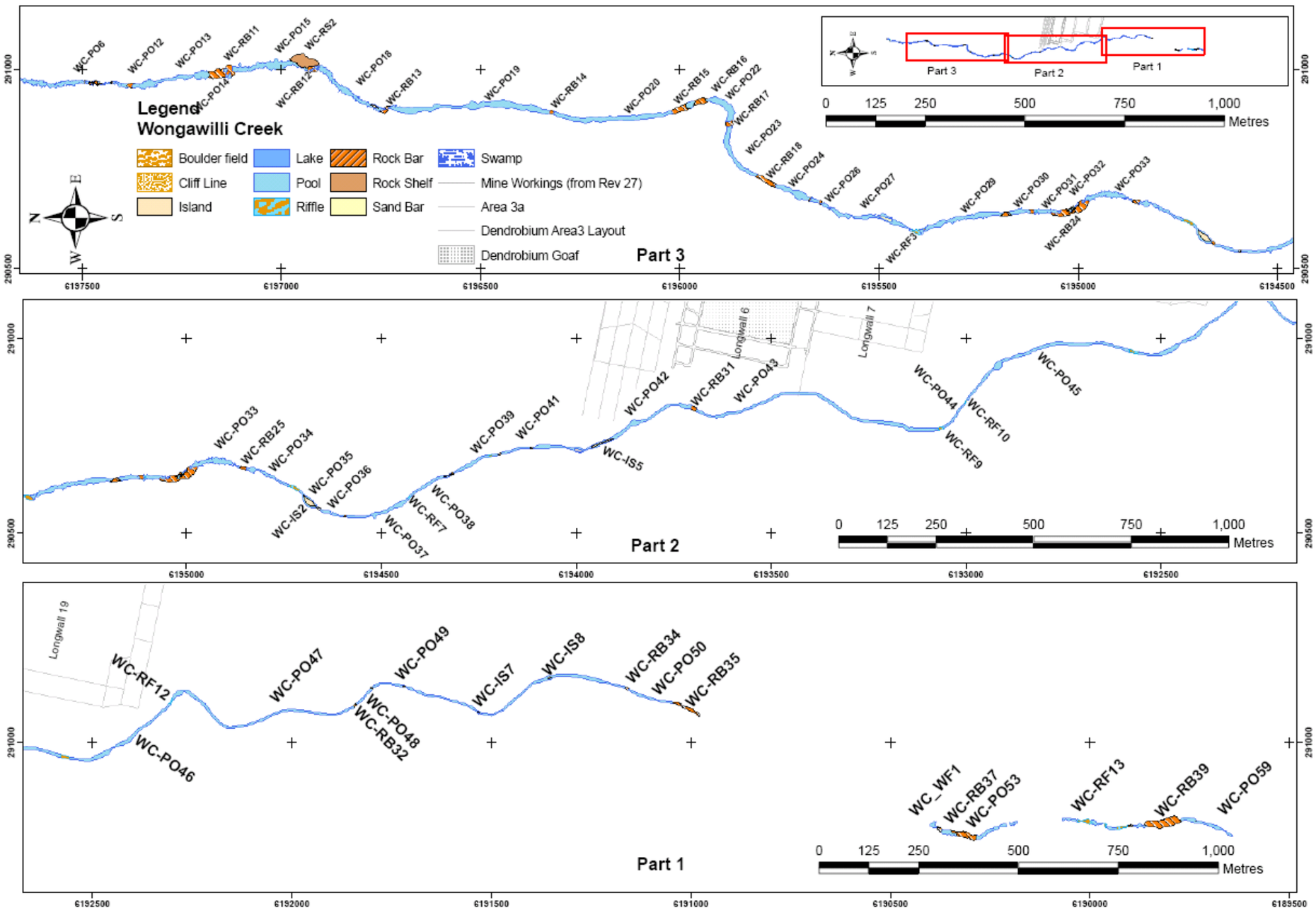

Figure 3.3 – Stream Morphology Map for Wongawilli Creek

3.2.7 Monthly Baseline Sampling Program

Surface Waters

Samples from monitoring sites are collected and analysed in a NATA registered laboratory on a monthly or bi-monthly basis. During the sampling run, water quality profiler instruments are deployed to collect physico-chemical parameters - temperature, pH, conductivity, salinity, DO and turbidity.

The baseline phase of the monitoring program is broad and can be more targeted during the impact monitoring phase based on the results obtained. Replicates of samples and blanks are used to ensure robustness of any statistical analyses. For the baseline phase of the program the following parameters are laboratory analysed:

- pH.
- EC (µS/cm).
- Total suspended solids (mg/L).
- Total dissolved solids (mg/L).
- Major cations, including Na, K, Ca and Mg (mg/L).
- Major anions, including Cl, SO_4 and Total Alkalinity (mg/L).
- Total metals including Fe, Mn and Al (mg/L).
- Dissolved metals including Fe, Mn, Si, Ba, Sr and Al (mg/L).
- Filterable elements including, Ni,and Zn (mg/L).
- Nutrients being at least Total Kjeldahl Nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate/nitrite nitrogen (NO_x-N) and Total Phosphorus.

This program continues to develop as additional information is obtained from Areas 1, 2 and 3A.

Baseline Reporting

In accordance with the consent, findings of the baseline assessment will be included in the AEMR. This report will include interpretation and presentation of data, re-assessment of the type and magnitude of predicted impacts, description of refinements to modelling, water budgets, water quality and geomorphological indicators.

Baseline Outcomes

The baseline studies are providing:

- A catalogue of the biophysical characteristics of Area 3A.
- Spatial and temporal data on water quality, flow, rainfall and other biophysical parameters prior to any effects of subsidence.
- The basis for the preparation of the ongoing monitoring program for Area 3A.

Summary of Baseline Data in Area 3A

Since 2001 IC commissioned Ecoengineers to carry out monthly water quality monitoring monthly campaigns at a significant number of sites in both Wongawilli Creek and Donald's Castle Creeks.

Area 3A Baseline Monitoring - Baseline surface water flow and quality monitoring has commenced and continues in Area 3A. Stream flow monitoring sites were established after approval from the SCA in mid 2007 and began to establish continuous flow monitoring from October 2007. Water quality baseline monitoring commenced in April 2008 and is continuing. Shallow groundwater monitoring commenced in 2003 and is continuing.

3.3 Sandy Creek Waterfall

In order to measure the influence of Longwall 5 as it moves toward the Sandy Creek Waterfall, the following monitoring was undertaken:

- Three dimensional GPS survey around the waterfall to determine magnitude of global movements associated with mining
- Three dimensional survey across survey lines above, at and below the waterfall to accurately measure any valley movements associated with mining
- Continuous measurement of linear displacement across bedding planes above the the waterfall to determine the magnitude of any localised strain in the waterfall rockmass;
- Construction of several boreholes adjacent to the waterfall to measure *in situ* geomechanical properties of the rock. The boreholes were then instrumented with stress cells to monitor any mining induced stresses within the rock mass associated with mining. Geophones were also incorporated into the boreholes.

The monitoring program was approved by the SCA and was implemented to measure any subsidence effects during the retreat of Longwall 5. There were no measured or observed changes at the Sandy Creek Waterfall due to the extraction of Longwall 5.

A geotechnical engineer has been commissioned to undertake simulation modelling of the waterfall rockmass. This modelling will assume a range of imposed stress boundary conditions to simulate the stress/displacement caused by mining. The model is calibrated against monitoring information described above.

The locations of the above Sandy Creek Waterfall monitoring program is shown in **Figure 3.4 (a) and (b)**.

Future action

The Sandy Creek Waterfall Technical Committee will meet as necessary to assess further information as it becomes available. It is envisaged that a Trigger Action Response Plan or other relevant management and/or mitigation plan will be submitted in accordance with Condition 13 of the DPI approval of the Sandy Creek Waterfall. This management approach will be endorsed by the Sandy Creek Waterfall Technical Committee.

A draft TARP for the Sandy Creek Waterfall is provided in Table 3.3. Note that the draft TARP is subject to further change pending ongoing monitoring and assessment works currently underway.

Table 3.3 –Draft TARP for Sandy Creek Waterfall

Monitoring Parameter	Units	Location	Possible Survey Method(s)	Survey Accuracy	Survey Frequency	Triggers	Responses to Triggers	Comments
Valley Closure	mm	Sandy Creek (downstream of waterfall)	2D or 3D ground survey	< 5 mm	Monthly during extraction of LWs 6-8 within 1500m of the waterfall Weekly within 1000m of waterfall Twice weekly during extraction of LWs 6-8 within 700 m of waterfall	> 90 mm (stage 1) > 125 mm (stage 2) >160 mm (stage 3) >215 (stage 4)	Stage 1: Increased monitoring to 2/week Stage 2: Consider slow longwall Stage 3: Consider stop longwall at next cut through Stage 4: Stop longwall at next cut through and review finish position of next longwall	Two point closure measurement at SCW A line as base of valley is flooded
		Sandy Creek (upstream of waterfall)	2D or 3D ground survey	< 5 mm		> 20 mm (stage 1) > 30 mm (stage 2) > 40 mm (stage 3)	Stage 1: Increased monitoring to 2/week Stage 2: Consider slow longwall Stage 3:	Survey line containing points at a nominal spacing of 20m Twice weekly survey will be implemented at 700m which is greater than twice depth of cover distance to

Table 3.3 –Draft TARP for Sandy Creek Waterfall

Monitoring Parameter	Units	Location	Possible Survey Method(s)	Survey Accuracy	Survey Frequency	Triggers	Responses to Triggers	Comments
						>50 mm (stage 4)	Consider stop longwall at next cut through Stage 4: Stop longwall at next cut through and review finish position of next longwall	the waterfall
Surface Strain	mm/m	Sandy Creek (upstream of waterfall)	2D or 3Dground survey (20 m bay lengths)	<0.25 mm/m	Monthly during extraction of LWs 6-8 within 1500m of the waterfall Weekly within 1000m of waterfall for LWs 6-8 Twice weekly within 700m of waterfall for LWs 6-	>1 mm/m (stage 1) >1.5 mm (stage 2)	Stage 1: Consider stop longwall at next cut through Stage 2: Stop longwall at next cut through and review finish position of next longwal	

Table 3.3 –Draft TARP for Sandy Creek Waterfall

Monitoring Parameter	Units	Location	Possible Survey Method(s)	Survey Accuracy	Survey Frequency	Triggers	Responses to Triggers	Comments
					8			
In situ strain in strata	uS	Borehole SCW Dend 10	In situ strain sensors bonded to strata		Continuous and weekly download	TBD	Stage 1: Increased monitoring to 2/week Stage 2: Consider slow longwall Stage 3: Consider stop longwall at next cut through Stage 4: Stop longwall at next cut through and review finish position of next longwall	
Movement along joint and bedding planes at waterfall	mm	Surface joint and bedding planes	Extensometers or strain gauges	<1 mm	Continuous and weekly download	None	None	Automated. Fine accuracy. Requires drilling of holes. Requires input from geotechnical consultant.
Subsidence		Whole of panel	Airborne laser scan	± 150 mm	Pre and post mining of each longwall	None	None	Provides additional information for consideration by technical committee

Table 3.3 –Draft TARP for Sandy Creek Waterfall

Monitoring Parameter	Units	Location	Possible Survey Method(s)	Survey Accuracy	Survey Frequency	Triggers	Responses to Triggers	Comments
Observation		All creek and cliff faces	Visual, photographic	-	Monthly during extraction of relevant longwall Weekly within 1000m of feature Twice weekly within 700m of feature	None	None	Requires safe access to some areas. Provides additional information for consideration by technical committee

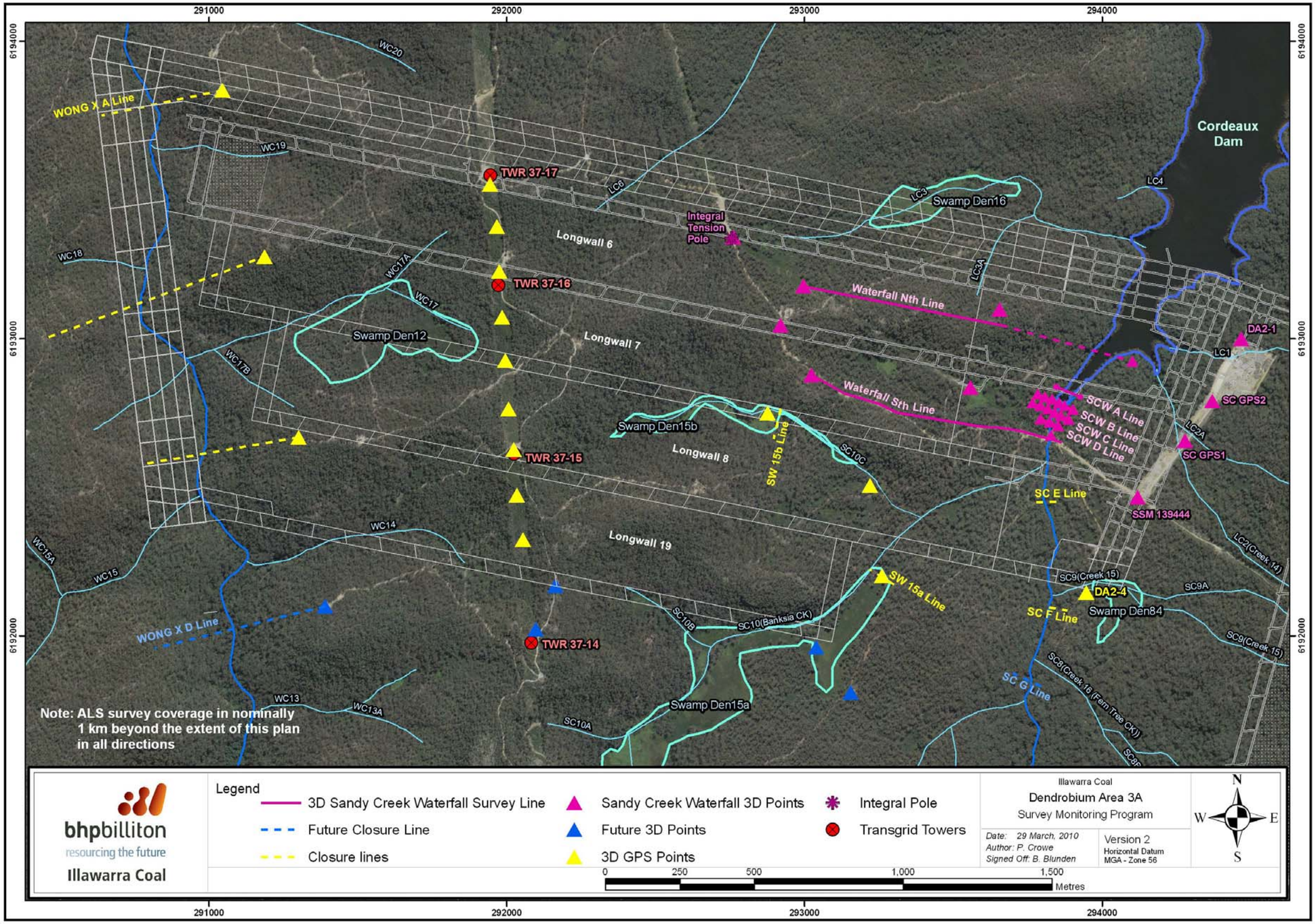

Figure 3.4(a) – Dendrobium Area 3A Subsidence Survey Monitoring

Figure 3.4(b) – Sandy Creek Existing Stress Change and Bedding Plane Shear Monitoring

4. CORRECTIVE MANAGEMENT ACTIONS

4.1 Objectives of Mitigation and Remediation Measures

The aims of the mitigation and remediation measures (BHPB, 2005a & 2005b) include:

- Carrying out remediation works in a manner that protects to the greatest practicable extent the ecological values of the area.
- Repairing the aesthetic values of the area where necessary.
- Reducing the interaction of surface and groundwater flow where it has been enhanced through mining.
- Having creeks and pools functioning in a similar manner to the pre-impact state.
- Having surface flows and pool water quality continue to provide suitable aquatic habitat.
- Re-establishing the ecological values of the area to a similar state to that existing before mining.
- Having creeks and catchments yielding similar water quantity and quality following mining.
- Monitoring and reporting effectiveness of the program.

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

4.2 Summary Of Impacts, Mitigation And Remediation Measures

Subsidence levels and potential impacts for key natural features in Area 3A are provided below, together with a summary of the avoidance, mitigation and contingent measures proposed to manage impacts where predicted impacts are exceeded. Specific details on contingent remediation measures are provided in Section 4.3.

Table 4.1 - Predicted Subsidence and Potential Impacts and Mitigation to Watercourse Features

Description of Item	Predicted Subsidence	Key Potential Impacts	Avoidance, Mitigation and Rehabilitation
Sandy and Wongawilli Creeks (Flow)	Sandy Creek: maximum subsidence 35 mm, maximum upsidence 125 mm, maximum closure 180 mm. Wongawilli Creek: maximum subsidence <20 mm, maximum upsidence 190 mm, maximum closure 195 mm.	**Predicted Impacts** Minor fracturing in the beds of Wongawilli and Sandy Creeks. **Impacts Exceeding Those Predicted** Major fracturing in the beds of Wongawilli and Sandy Creeks leading to significant surface water loss.	**Avoidance & Mitigation** Minimum set backs of 110 and 85 metres from Wongawilli & Sandy Creeks to avoid major fracturing and loss of surface flow. **Contingent Measure** Grouting and repair of significant surface water controlling features where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders.
Ephemeral watercourses ***(Flow)***	Area 3A: Maximum subsidence 2275 mm, maximum upsidence 520 mm. Maximum closure 450 mm.	**Predicted Impacts** Fracturing of the beds of some minor streams & diversion of flows.	**Avoidance & Mitigation** Not mining under Sandy or Wongawilli Creeks.

Table 4.1 - Predicted Subsidence and Potential Impacts and Mitigation to Watercourse Features

Description of Item	Predicted Subsidence	Key Potential Impacts	Avoidance, Mitigation and Rehabilitation
		Impacts Exceeding Those Predicted Major fracturing in the beds of streams leading to total surface water loss.	**Contingent Measure** Grouting and repair of significant surface water controlling features where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders.
Lakes	Negligible subsidence.	**Predicted Impacts** Negligible impacts. **Impacts Exceeding Those Predicted** Connectivity of the lake with the mining area.	**Avoidance & Mitigation** The layout has been modified to significantly reduce impacts on the lake. Potential impacts are considered negligible. **Contingent Measure** As per the DSC Contingency Plan.
Aquatic fauna and flora	Indirect effects from subsidence.	**Predicted Impacts** Impacts on fauna are possible due to 'loss' of water from pools. Impacts on vegetation expected to be very small. **Impacts Exceeding Those Predicted** Major reduction in pool water level or complete loss of pool water. Major reduction in aquatic habitat for an extended timeframe or complete loss of habitat. Identified mortality of fauna/flora in proximity to identified mining impact.	**Avoidance & Mitigation** Minimum set backs of 110 and 85 metres from Wongawilli & Sandy Creeks to avoid major fracturing and loss of surface flow. **Contingent Measure** Grouting and repair of significant surface water controlling features where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Active preservation of life such as relocation of stranded fish. Temporary ecosystem maintenance such as watering aquatic plants until final rehabilitation completed, where this is practical.
Wongawilli and Sandy Creeks*. *(Water quality)	Indirect effect from subsidence.	**Predicted Impacts** Impacts on water quality are possible due to reduced flow and/or increased interaction of ground and surface water. These impacts are likely to include reduced oxygen, higher dissolved ions and precipitates. There is also a possibility of lower pH and lower temperature variation as a result of	**Avoidance & Mitigation** Effects are expected to be much less as a result of the modified longwall layout that does not mine under Sandy or Wongawilli Creeks.

Table 4.1 - Predicted Subsidence and Potential Impacts and Mitigation to Watercourse Features

Description of Item	Predicted Subsidence	Key Potential Impacts	Avoidance, Mitigation and Rehabilitation
		groundwater inflows. **Impacts Exceeding Those Predicted** Major reduction in water quality when comparing baseline period to mining period, ie: • pH drop of >2 • EC increase >100 uS/cm • ORP* drop >200 mV A > 2 standard deviation reduction in water quality apparent at downstream monitoring site when comparing pre-mining to baseline data.	**Contingent Measure** Grouting and repair of surface water controlling features and the beds of streams where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Limestone emplacement to raise pH where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Emplacement of sandstone rocks in constricted stream flow areas to increase the aeration capacity where ORP drop is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders.
Ephemeral watercourses ***(water quality)***	Area 3A: Maximum subsidence 2275 mm, maximum upsidence 520 mm.	**Predicted Impacts** Some buckling and fracturing of creek beds & diversion of flows. Impacts on water quality are possible due to reduced flow and/or increased interaction of ground and surface water. These impacts are likely to include reduced oxygen, higher dissolved ions and precipitates. There is also a possibility of lower pH and lower temperature variation as a result of groundwater inflows. However, volumes of pooled water in ephemeral streams are small relative to the entire catchment. **Impacts Exceeding Those Predicted** Major reduction in water quality when comparing baseline period to mining period, ie:	**Avoidance & Mitigation** Monitoring and measurement **Contingent Measure** Grouting and repair of surface water controlling features and the beds of streams where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA,

Table 4.1 - Predicted Subsidence and Potential Impacts and Mitigation to Watercourse Features

Description of Item	Predicted Subsidence	Key Potential Impacts	Avoidance, Mitigation and Rehabilitation
		• pH drop of >2 • EC increase >100 uS/cm • ORP* drop >200 mV A > 2 standard deviation reduction in water quality apparent at downstream monitoring site when comparing pre-mining to baseline data.	DPIM, DECC and other stakeholders. Limestone emplacement to raise pH where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Emplacement of sandstone rocks in constricted stream flow areas to increase the aeration capacity where ORD drop is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders.

4.3 Principal Trigger- Action- Response- Plans (TARPs)

The Principal "Trigger- Action- Response Plans" (TARPs) relate to identifying, assessing and responding to abnormal conditions related to subsidence impact.

It should be noted that the Principal TARPs represent actions to be taken as each defined trigger level is reached. A **CMA** is a *corrective management action* developed in consultation with stakeholders in order to manage an observed impact in accordance with the relevant approvals. The management programme provides a basis for the design and implementation of any mitigation and remediation.

Monitoring of environmental aspects of the area will provide key data when determining any requirement for mitigation or rehabilitation. The triggers are based on comparison of baseline with monitoring results and the proposed triggers are presented in **Table 4.2**. Specific triggers will continue to develop as the impact monitoring phase of the SMP matures. Refinement of triggers will be in consultation with key stakeholders and subject to approval by DoP and DPIM.

Explanatory Notes for TARP's in Table 4.2

The TARP's should be read in conjunction with the Area 3A SMP Parts A & B.

1. The stated monitoring and triggers are likely to cater for most events related to subsidence within the SMP Area. Should additional monitoring or triggers be identified as appropriate they will be implemented in consultation with DoP and DPI.

2. Access to any monitoring site is subject to SCA authorisation to enter the catchment area which is normally only permitted in dry weather. Therefore proposed monitoring frequencies may be delayed due to wet weather.

3. Stated notification and investigation timeframes are from when triggers have been confirmed by the Manager Environment.

4. This TARP will be reviewed and any improvement opportunities will be proposed within each End of Panel report.

Specialist investigations and reports will include:

1. Scope of the study.
2. Consider any relevant aspect from this plan.

3. Analysis of trends.
4. Assessment of any impacts against prediction.
5. Root cause analysis of any change or impact.
6. Options for management and mitigation.
7. Assessment for the need for contingent measures.
8. Any recommended changes to this plan.
9. Appropriate consultation.

Site specific ***corrective management action*** (CMA) plans will include:

1. A description of the impact to be managed.
2. Results of the investigations.
3. Aims and objections for the plan.
4. Specific actions required to mitigate/manage.
5. Timeframes for implementation.
6. Roles and responsibilities.
7. Identification of and gaining appropriate approvals from landholders and government agencies.
8. Consultation and communication plan.

Example ***corrective management actions*** are provided in Table 4.2 and Sections 4.4 to 4.5.10.

4.4 Preventative Options

The management actions listed in **Table 4.1** will be implemented if subsidence impact exceeding the predictions has been identified. Some measures, such as grouting, would be implemented following the completion of the majority of subsidence movements in that area.

The most applicable pre-emptive measure for reduction of impact is through the reduction of subsidence. At this stage, the most appropriate method of reducing subsidence is by leaving barriers of coal to support the surface. This has been achieved through modifications to the mine layout to avoid significant impacts to Sandy and Wongwailli Creeks.

The mine layouts at Dendrobium have been modified to reduce the potential for impacts to surface features. Change to a mine layout has significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when assessing mine layout options.

During IC's longwall layout optimisation process for Area 3A, the proposed longwalls have been set back from major watercourses such that it is unlikely that significant impacts, such as major fracturing leading to draining of pools would occur in Sandy and Wongawilli Creeks. This process adopts the hierarchy of avoid/minimise/mitigate as requested by the DoP and DECC during consultation with IC.

IC will plan future longwalls using the methodology described above as outlined in the statement of commitments. It is therefore unlikely that significant impacts (sub-bed diversion of surface waters resulting in loss of flow or pools) will occur at major watercourses within the vicinity of future proposed longwalls.

A full description of preventative options are discussed in the Illawarra Coal Natural Features Subsidence Management Strategy (IC, 2005).

4.5 Mitigation Measures

Mitigation measures are outlined in detail within the Area 3A SMP. In relation to surface water diversion into sub-beds and geochemical effects, the major mitigation measure is the set back of longwalls from Wongawilli and Sandy Creeks, to avoid or minimise subsidence induced impacts to these creeks. Site specific contingency measures to address particular geochemical effects have also

been considered and could be deployed with the agreement of stakeholders if appropriate, and are outlined below. It is considered unlikely these measures would need to be implemented.

4.5.1 Natural Remediation

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 dynamics of a specific area will determine the rate of fracture sealing. In some circumstances, an area may be disturbed to such an extent that the natural processes of sealing may not result in an acceptable level of protection for the area's environmental values. In other cases, although there may be minimal impact, an area may have a particularly low ability to naturally seal. In these circumstances, a more interventionist approach or pro-active rehabilitation would be required. An area with high impact and low ability to self-heal will require the highest level of rehabilitation.

Cracks that occur in drainage paths are more likely to have the erosion and deposition processes acting to facilitate natural sealing. It is also possible that the erosion deposition equilibrium is disrupted and one process could dominate leading to additional surface impacts. Where a stream or water channel is ephemeral, it is important to note that the potential for natural sealing and or additional impacts may be temporally offset to the initial impact.

While sealing of surface fractures will occur naturally in some instances and over time, it is recognised that this may not provide sufficient mitigation in some situations and that active sealing of the streams may be required in some locations.

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
CREEKS AND DRAINAGE LINES								
Water Quality	**Area 1 Sites (2 total):** • KS1 (Kembla Ck Pool 3) • KS2 (trib. of Kembla Ck, Un-named Ck) **Area 2 Sites (9 total):** • MC (Middle Gully or Ck 13) • GFC (Green Fields Ck Waterfall Pool) • WC (Waratah Ck) • FTC (Fern Tree Ck • SC (Sandy Ck D/S) • P3 (Sandy Ck U/S trib. Pool 3) • LGU (Locked Gate Ck or Creek 10 U/S) • LGD (Locked Gate Ck or Creek 10 D/S) • C12 (Creek 12) **Area 3A (11 total):** **Wongawilli Creek** • WWU1 (headwaters of Wongawilli Ck) • WWU4 (U/S Wongawilli Ck) • WWM1 (mid Wongawilli Ck adjacent to LW 10) • WWM2 (mid Wongawilli Ck adjacent to LW 8) • WWM3 (mid Wongawilli Ck D/S of LW 6) • WWL2 (D/S Wongawilli Ck) **Sandy Creek** • SCU1 (U/S Sandy Ck) • SCL (D/S Sandy Ck adjacent to LW 7) **Ephemeral watercourses** • BC1 (Sandy Ck trib. SC10 over LW 8) • BCC1 (Sandy Ck trib. SC10C over LW 8) • CC1 (Sandy Ck trib. SC7 adjacent to LW10)	**Automatic Data Logging (Areas 2 only):** • Temperature • Dissolved oxygen • Conductivity • pH • Turbidity **Manual Field Testing:** • Field pH • Temp • EC • DO • ORP • Lab. analytes (incl. lab check of pH, lab. check of EC, Na, K, Ca, Mg, Cl, Total. Alk.) • Total Fe, Mn, Al, • Filt. Fe, Mn, Al, Ni, Zn SO4, Si, Ba, Sr • DOC • TKN, NH3-N, NOx-N, TP)	• Monthly Baseline monitoring 1 year prior to mining. • 5 minute logging intervals for automatic data loggers. (Areas 1 and 2 only) • Monthly manual monitoring during and post mining. (Excluding Area 1) • Monthly manual monitoring post mining for two years or longer if required. (Completed for Area 1) • Bi monthly manual post mining monitoring (Area 1 only)	• To provide pre-mining baseline water quality for comparison with post-mining. • To identify any water quality impact from mining. • To identify water quality impacts related to physical or chemical changes to the creeks and/or drainage lines during mining.	***Normal*** No change in water quality when comparing baseline to mining period and considering environmental conditions.	• Continue monitoring program. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).	Manager Environment – IC. Expert Water Consultants	Inform stakeholders of baseline assessment Report to key stakeholders in SMP Application and AEMR. Identify, investigate and report on impacts. To provide data for any investigation into impacts.
					Within Prediction (Level 1) Temporary reduction in water quality (observed for less than 2 months) at any site when comparing baseline period to mining period, ie: – pH drop of 1.5 units – EC increase of 50 uS/cm – ORP* drop 150 mV These may be revised in consultation with DoP and DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Continue monitoring program. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		
					Within Prediction (Level 2) Temporary reduction in water quality (observed for less than 2 months) at any site when comparing baseline period to mining period, ie: – pH drop of 2 units – EC increase of 100 uS/cm – ORP* drop 200 mV These may be revised in consultation with DoP and DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Continue monitoring program (review monitoring frequency). • Submit an Impact Report • Notify relevant technical specialists. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		
					Exceeding Predicted Impact	• Notification to DPIM, SCA and resource manager/s immediately.		

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
	Refer to Area 3A SMP **Figures 18.1, 18.2, and 18.4** for location of these sites.				***Criteria*** Major reduction in water quality (observed for more than 2 months) when comparing baseline period to mining period, ie: – pH drop of >2 – EC increase >100 uS/cm – ORP* drop >200 mV • A > 2 standard deviation reduction in water quality apparent at downstream monitoring site or within Lake Cordeaux when comparing pre-mining to baseline data. These may be revised in consultation with DoP and DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Notify Ecological Specialists and other relevant Specialists immediately. • Site visits with stakeholders within 1month. • Capture photographic record immediately. • Collect laboratory samples within 2 weeks and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al. – Analyse filterable suite of metals. • Review sampling program within 1 month and modify if necessary. • Notify other relevant specialists (IC). • Develop and implement site CMA in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals. These may include: Grouting and repair of surface water controlling features and the beds of streams where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Limestone emplacement to raise pH where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Emplacement of sandstone rocks in constricted stream flow areas to increase the aeration capacity where ORD drop is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. • Completion of works following approvals. • Additional follow up monitoring and reporting within 2 weeks if required. • Report in the End of Panel Report submitted annually with AEMR. • Summarise all actions and monitoring in AEMR by end of February (Annually).		
Water Level / Flow	**Area 1 Water Level Logger Sites (2 total):** • KS1 (Kembla Ck Pool 3) • KS2 (trib. of Kembla Ck, Un-named Ck) **Area 2 Water Level Logger Sites (3 total):** • GFC (Green Fields Ck) Waterfall Pool • FTC (Fern Tree Ck) • LGU- (Locked Gate Ck Creek 10) **Area 3A Water Level Logger Sites (7 total):** **Wongawilli Creek** • WWU4 (U/S Wongawilli Ck) • WWL2 (D/S	Water level / flow Automatic pool water level measurements (in various flows) which are converted to flows by calculation of rating curves using measured creek cross sections at the monitoring point. Monthly Manual Water level measurements using pre-established benchmarks (i.e. nails) in major pools. (Excluding Area 1)	• Monthly baseline monitoring 1 year prior to mining. Area 2 baseline monitoring was bi-monthly. • Continuous 1hr logging intervals for automatic data logger sites. • Monthly manual monitoring during mining. • Ongoing monthly monitoring post mining.	• To provide pre-mining baseline water levels/flows for comparison with post-mining. • To identify any water levels/flow impacts from mining. • To identify water levels/flow impacts related to physical changes to the creeks and/or drainage lines during mining.	***Normal*** No reduction in pool water levels when considering baseline data and environmental conditions	• Continue monitoring program • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).	• Manager Environment – IC. • Expert Water Consultants.	• Inform stakeholders of baseline assessment. • Report to key stakeholders in SMP Application and AEMR. • Identify, investigate and report on impacts (in SMP and AEMR). • To provide data for any investigation into impacts.
					Within Prediction • Temporary reduction in pool water levels (observed for less than 2 months) declining < 20% during mining in any of the pools being monitored when compared with similar flows before mining. These may be revised in	• Continue monitoring program • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
	Wongawilli Ck) **Pool level Benchmarks (i.e. nails)** • WWM1 (mid Wongawilli Ck adjacent to LW 10) • WWM2 (mid Wongawilli Ck adjacent to LW 8) • WWM3 (mid Wongawilli Ck D/S of LW 6) Multiple nails will be installed in all pools adjacent to Longwalls 6-10 to provide redundancy in case high flows damage sites. **Sandy Creek** • SCU1 (U/S Sandy Ck) • SCL (D/S Sandy Ck adjacent to LW 7) Multiple nails will be installed in all pools adjacent to Longwalls 6-10 to provide redundancy in case high flows damage sites.				consultation with DoP and DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.			
					Exceeding Predicted Impact Criteria • Permanent reduction (observed for more than 2 months) in pool water level (>20% decline in any pools monitored) or complete loss of pool water when compared with similar flows before mining. This may be revised in consultation with DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Notification to DoP, DPIM, SCA and resource manager/s immediately. • Notify Ecological Specialists and other relevant Specialists immediately. • Site visits with stakeholders. • Capture photographic record immediately. • Review monitoring program within 2 weeks and Implement additional monitoring or increase frequency if required. • Notify other relevant specialists (IC) immediately. • Develop and implement site CMA in consultation with key stakeholders within 2 months. These may include: Grouting and repair of surface water controlling features and the beds of streams where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. • Completion of works following approvals. • Conduct initial follow up and additional monitoring & reporting within 2 months of CMA completion if required. • Report in the End of Panel Report submitted annually with AEMR. • Summarise all actions and monitoring in AEMR by end of February (Annually).		
	Ephemeral watercourse • BC1 (Sandy Ck trib. SC10 over LW 8) • BCC1 (Sandy Ck trib. SC10C over LW 8) • CC1 (Sandy Ck trib. SC7 adjacent to LW10) 75% of the major pools in SC10and SC7 will also have Pool level nail benchmarks installed. Refer to Area 3A SMP **Figures 18.1, 18.2, and 18.4** for location of these sites.	Water level / flow Automatic pool water level measurements (in various flows) which are converted to flows by calculation of rating curves using measured creek cross sections at the monitoring point. Monthly Manual Water level measurements using pre-established benchmarks (i.e. nails) in major pools. (Excluding Area 1)	• Continuous 1hr logging intervals for automatic data logger sites. • Monthly manual monitoring during mining. • Ongoing monthly monitoring post mining.	• To provide pre-mining baseline water levels/flows for comparison with post-mining. • To identify any water levels/flow impacts from mining. • To identify water levels/flow impacts related to physical changes to the creeks and/or drainage lines during mining.	***Normal*** No observable drainage of pools when compared with baseline conditions and considering climatic conditions.	• Continue monitoring program • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		
					Within Prediction (Level 1) • Fracturing of bedrock in the ephemeral drainage lines that are directly mined beneath. • Minor fracturing causes short term (< 6 months) lowering of some mapped pool water levels under similar flows when comparing pre-mining and environmental conditions. This may be revised in consultation with DPI and other key stakeholders following analysis of natural variability within	• Continue monitoring program • Submit an Impact Report • Capture a photographic record as each impact is observed. • Notification to agencies within 24 hours upon confirmation that any pool has drained. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
					the pre-mining baseline data.			
					Within Prediction (Level 2) • Fracturing of bedrock in the ephemeral drainage lines that are directly mined beneath. • Minor fracturing causes ongoing (> 6 months) lowering of mapped pool water levels under similar flows when comparing pre-mining and environmental conditions. This may be revised in consultation with DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Continue monitoring program • Submit an Impact Report. • Notify relevant technical specialists. • Capture photographic record as each impact is observed. • Notification to agencies within 24 hours upon confirmation that any pool has drained. • Review need for CMA. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		
					Exceeding Predicted Impact Criteria • Fracturing of bedrock in the ephemeral drainage lines that are directly mined beneath. • Fracturing results in re-direction of surface flows fully draining all pools over the longwalls under similar flows when comparing baseline and environmental conditions. This may be revised in consultation with DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• .Notification to agencies within 24 hours upon confirmation that any pool has drained. Notify that all pools within an ephemeral waterway have drained. • Notify Ecological Specialists and other relevant Specialists immediately. • Site visits with stakeholders. • Capture photographic record immediately. • Review monitoring program within 2 weeks and Implement additional monitoring or increase frequency if required. • Notify other relevant specialists (IC) immediately. • Develop and implement site CMA in consultation with key stakeholders at the completion of subsidence movements in Area 3A or after subsidence movement from future extraction will not adversely affect the effectiveness of rehabilitation works. These may include: Grouting and repair of surface water controlling features and the beds of streams where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. • Completion of works following approvals. • Conduct initial follow up and additional monitoring & reporting within 2 months of CMA completion if required. • Report in the End of Panel Report submitted annually with AEMR. Summarise all actions and monitoring in AEMR by end of February (Annually).		
Appearance	All flow and quality monitoring sites as listed above. General observation of active mining areas for	Visual signs of impacts on creeks and drainage lines (i.e., cracking, vegetation changes, increased erosion, changes in water colour etc.) determined by	• Monthly Baseline monitoring 1 year prior to mining. • Monthly monitoring during mining. • 6 Monthly monitoring	• To provide pre-mining baseline creek bed, bank and water quality observations for comparison with post-mining. • To identify any creek	***Normal*** No visual signs of impacts when comparing baseline to mining period and considering environmental conditions.	• Continue monitoring program • Report in the End of Panel Report Summarise all actions and monitoring in AEMR by end of February (Annually)	• Manager Environment – IC. Expert water & Ecology Consultants.	• Inform stakeholders of baseline assessment • Report to key stakeholders in SMP Application and AEMR.

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
	SC10, SC7, WC17, Sandy and Wongawilli Creeks. Particular focus on rockbars in Swamps 15a and 15b	comparing baseline photos with photos during the mining period	for 2 yrs post mining	bed, bank and water quality impacts from mining. • To identify any creek bed, bank and water quality impacts related to physical or chemical changes to the creeks and/or drainage lines during mining.	***Within Prediction*** • Small crack/s with no observable loss of surface water flow. • Slight increase in turbidity, iron staining, algal growth, or other visible water quality parameters determined by comparing baseline photos with photos during the mining period.	• Continue monitoring program • Submit an Impact Report. • Notify relevant technical specialists. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually)		• Identify, investigate and report on impacts (in SMP and AEMR). • To provide data for any investigation into impacts.
					Exceeding Predicted Impact Criteria • Crack in a watercourse that is resulting in visible loss of surface water or erosion. • Major increase in turbidity, iron staining, algal growth, or other visible water quality parameters. • Vegetation changes. • Increased erosion.	• Notification to DPIM, SCA and resource manager/s immediately • Notify Ecological Specialists and other relevant Specialists immediately. • Site visits with stakeholders within one month. • Capture photographic record immediately. • Review sampling program and modify if necessary within 2 weeks. • Implement additional monitoring or increase frequency if required within 2 weeks. • Notify other relevant specialists (IC) immediately. • Develop site CMA in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals. These may include: Surface sealing of cracks, grouting and repair of surface water controlling features and the beds of streams where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. • Completion of works following approvals. • Conduct initial follow up monitoring & reporting within 2 months of CMA completion. • Issue CMA report within 1 month of works completion. • Report in the End of Panel Report submitted annually with AEMR. • Summarise all actions and monitoring in AEMR by end of February (Annually).		
LAKE CORDEAUX								
Water Quality	Sandy Creek arm of Lake Cordeaux nearest Areas 2 and 3A. •SC (Sandy Ck D/S)	Manual Field Testing: • Field pH • EC • DO • ORP* Lab. analytes (incl. lab	• 6 monthly Baseline monitoring 1 year prior to mining. • Monthly manual monitoring during and post mining. • Monthly manual monitoring post mining for two years or	• To provide pre-mining baseline water quality for comparison with post-mining. • To identify any water quality impact on Lake Cordeaux during mining.	***Normal*** No change in water quality when comparing with baseline period and considering environmental and operational factors.	• Continue monitoring program • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually)..	Manager Environment – IC. Expert Water Consultants.	Inform stakeholders of baseline assessment Report to key stakeholders in SMP Application and AEMR. Identify, investigate and report on impacts (in EoP and AEMR).

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
	Refer to Area 3A SMP Figure **18.2**.	check of pH, lab. check of EC, Na, K, Ca, Mg, Filt. SO_4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Ba, Sr, TKN, NH_3-N, NO_x-N, TP) Filterable metals (Mn, Ni, Zn).	otherwise required.		***Within Prediction*** • Regular samples of filterable metals (Mn, Ni, Zn) exceeding 95% ecosystem protection trigger level in the National Water Quality Guidelines. This may be revised in consultation with DoP and DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Continue monitoring program • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		To provide data for any investigation into impacts.
					Exceeding Predicted Impact Criteria • Statistical assessment shows mean value of key metals over 12 month period post initial detection, significantly (>1 SD) in excess of 95% ecosystem protection trigger level. This may be revised in consultation with DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Notify DoP, DPIM, SCA & resource manager/s immediately. • Nearest arms of lake monitored for As, Cu, Pb, Ni, Se, Zn, Al, Fe, Mn within 1 week. • Look for Mn, Ni, Zn (major stressors). • Consider mitigation measures in consultation with resource managers within 2 weeks. • Develop and implement site CMA if required in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals. These may include: Grouting and repair of surface water controlling features and the beds of streams that flow into lake Cordeaux where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Limestone emplacement to raise pH where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Emplacement of sandstone rocks in constricted stream flow areas to increase the aeration capacity where ORD drop is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. • Issue CMA report within 1 month of works completion. • Completion of works following approvals. • Conduct additional monitoring and reporting if required within 2 weeks. • Report in the End of Panel Report submitted annually with AEMR. • Summarise all actions and monitoring in AEMR by end of February (Annually).		

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
Catchment Yield	**Area 3A** Catchment yields for SC10, SC7, Upper and Lower Sandy Creek, and Upper and Lower Wongawilli Creek	Jd quick runoff coefficient from Runoff 2005 model Using input data from hydrological monitoring	• After each longwall during mining • For a period of two years post mining	• To provide pre-mining baseline water levels/flows and runoff yield parameters for comparison with post-mining. • To identify any surface water runoff yield impacts from mining. • To identify surface water runoff yield impacts related to physical changes to the creeks and/or drainage lines during mining.	***Normal*** No change in catchment yield when comparing with baseline period and considering environmental conditions.	• Implement analysis of Runoff 2005 for EoP • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).	• Manager Environment – IC. • Expert Water Consultants.	• Inform stakeholders of baseline assessment • Report to key stakeholders in SMP Application and AEMR. • Identify, investigate and report on impacts (in SMP and AEMR). • To provide data for any investigation into impacts.
					Within Prediction • Minor reduction (less than 1 standard deviation change from pre-mining) for < 6 months in observed catchment yield in any of the major creeks being monitored indicated by - Jd quick runoff coefficient from Runoff 2005 model. This may be revised in consultation with DoP, DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Implement analysis of Runoff 2005 for EoP • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		
					Exceeding Predicted Impact Criteria • ***Significant reduction (greater than 1 standard deviation change from pre-mining) for > 6 months in observed catchment yield in any of the major creeks being monitored indicated by - Jd quick runoff*** coefficient from Runoff 2005 model This may be revised in consultation with DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Implement analysis of Runoff 2005 for EoP • Develop site CMA in consultation with key stakeholders if required within 1 month (pending stakeholder availability) and seek approvals. • Implement CMA if required as agreed with stakeholders. • Conduct initial follow up and additional monitoring & reporting within 2 months of CMA completion if required. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		
Structure and Impoundment Integrity	Refer to DSC Management Plan for further details relating to structure and impoundment integrity							
SHALLOW GROUNDWATER								

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
Shallow Groundwater Level	**Area 2 (14 piezometers in total):** • D2-1, D2-2, D2-3, D2-4, and D2-5 (Swamp 1) • D4-1 and 89C (SC9 catchment, above LWs 4 and 5) • D3-1, D3-2, D3-3, D3-4, and D3-5 (Swamp 134) • D5-1 and D5-2 (approx. 200 m N of Swamp 134) **Area 3A (Approx. 60 piezometers in total):** • S15BH1, S15BH2, and S15BH3 (Swamp 15b above edge of LW 8) • Approximately 50 piezometers in hillslope aquifers around swamps in Area 3A. Refer to Area 3A SMP **Figures 18.1, and 18.2** and the Swamp Monitoring and Management Plan for the location of these sites.	• Shallow Groundwater level.	• Monthly Baseline monitoring 1 year prior to mining. • Monthly monitoring during and post mining. • Monthly manual monitoring post mining for two years or as otherwise required. • Automatic groundwater level monitoring, at least every 4 hours. • Groundwater level monitoring during mining and for two years post mining (to be reviewed annually).	• To provide pre-mining baseline shallow groundwater quality and levels for comparison with during and post-mining. • To identify any lowering of groundwater levels or increased interactions between surface and groundwater during or post mining (particularly around swamps). • To identify any significant changes in shallow groundwater quality during or post mining.	***Normal*** No signs of impact when comparing baseline to mining period and considering environmental conditions.	•Continue monitoring program. •Report in the End of Panel Report •Summarise all actions and monitoring in AEMR by end of February (Annually). •	Manager Environment – IC. Expert Groundwater Consultants.	Inform stakeholders of baseline assessment Report to key stakeholders in SMP Application and AEMR. Identify, investigate and report on impacts (in SMP and AEMR). To provide data for any investigation into impacts.
					Within Prediction • Temporary (i.e. effect not persisting after significant groundwater recharge rainfall events) reduction in groundwater level at more than one site (beyond variability determined in baseline monitoring due to rainfall). This may be revised in consultation with DoP & DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	•Continue monitoring program. •Report in the End of Panel Report •Summarise all actions and monitoring in AEMR by end of February (Annually). •		
					Exceeding Predicted Impact Criteria • Major reduction (monitoring bore dry where it has not been prior to mining or reference sites) in groundwater level at the majority of bores within any particular aquifer or swamp system or complete loss of groundwater. These may be revised in consultation with DoP & DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	•Notification to DoP & DPIM and resource manager/s immediately. •Site visits with stakeholders within one month. •Review monitoring program and modify if necessary within 1 month. •Develop and implement site CMA if required in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals. These may include: Grouting and repair of surface water controlling features and the beds of streams that flow where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Also see remedial actions described in Swamp Management Plan. •Completion of works following approvals. •Conduct initial follow up and additional monitoring and reporting within 2 months of CMA completion. •Notify other relevant specialists (IC) immediately. •Report in the End of Panel Report submitted annually with AEMR. •Summarise all actions and monitoring in AEMR by end of February (Annually).		
DEEP GROUNDWATER								
see Groundwater Monitoring Plan								
AQUATIC ECOLOGY - GENERAL								

Table 4.2 – Potential Impacts, Key Monitoring, Triggers, Response & Responsibilities

ASPECT	MONITORING				MANAGEMENT			
	SITES	PARAMETERS	FREQUENCY	PURPOSE	TRIGGER	ACTION	RESPONSIBILITY	PURPOSE
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat, fish kill, frog kill	**Area 2 (16 total):** • Sandy Ck - 4 sites • SC6 – 2 sites • SC7 – 2 sites • SC10 – 2 sites • SC8 – 2 sites • Middle Gully Ck (Creek 13) – 2 sites • Green Fields Ck (Creek 11) – 2 sites **Area 3A (15 total):** • Wongawilli Ck – 8 sites • WC15 – 1 site • WC21 – 1 site • Sandy Ck – 2 sites • SC10 – 1 site • SC7 – 1 site • Donalds Castle Ck – 1 site Refer to Area 3A SMP **Figures 20.1, 20.2, and 20.3** for the location of these sites. General observation of active mining areas.	Physical aspects of watercourses, including: – Wetted perimeter. – Pool depth and presence of large pools. – Riffle/run/pool sequences. – Heights of any barriers as well as their structure and composition. – Presence and position of gravel beds likely to be used for spawning by Macquarie Perch. Water flow characteristics, including: – Rainfall. – Surface and near surface water flows. Water Quality (refer above water quality section). Ecological Investigations, including: – Catalogue of aquatic habitats, flora and fauna of watercourses. –Photographic records. – Measurement of aquatic plants using transects. – Sampling of Macroinvertebrates. – Sampling fish and large invertebrates (e.g. yabbies).	• Two Baseline monitoring campaigns 1 year prior to mining during autumn and spring. • 6 monthly monitoring during mining in autumn and spring of each year. • 6 monthly monitoring post mining for two years or as otherwise required. • General observation of active mining areas during all other monitoring.	• To provide pre-mining baseline aquatic ecology survey for comparison with post-mining. • Identify any impacts on aquatic habitat and biota during mining.	***Normal*** No signs of impact when comparing baseline to mining period and considering environmental conditions.	• Continue monitoring program. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).	Manager Environment – IC. Expert Aquatic Consultants.	Inform stakeholders of baseline assessment Report to key stakeholders in SMP Application and AEMR. Identify, investigate and report on impacts (in SMP and AEMR). To provide data for any investigation into impacts.
					Within Prediction • Temporary pool water levels decline < 20% occurs during mining in any of the pools being monitored when compared with similar flows before mining. • Temporary (1-2 seasons) reduction in aquatic habitat. These may be revised in consultation with DoP, DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	• Continue monitoring program. • Report in the End of Panel Report • Summarise all actions and monitoring in AEMR by end of February (Annually).		
					Exceeding Predicted Impact Criteria • Major reduction in pool water level (>20% decline in any pools monitored) or complete loss of pool water during reduced surface flows. • Major reduction in aquatic habitat for an extended timeframe (> 2 seasons) or complete loss of habitat. These may be revised in consultation with DoP, DPI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.	•Notification to DoP, DPIM and resource manager/s immediately. •Notify Ecological Specialists and other relevant Specialists immediately. •Site visits with stakeholders within one month. •Capture photographic record immediately. •Review monitoring program and modify if necessary within 1 month. •Implement and conduct additional monitoring or increase frequency if required within 2 weeks. •Notify other relevant specialists (IC) immediately. •Develop and implement site CMA if required in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals. These may include: Grouting and repair of surface water controlling features and the beds of streams that flow where fracturing is evident where it is appropriate to do so in consultation with DoP, SCA, DPIM, DECC and other stakeholders. Also see remedial actions described in Swamp Management Plan. •Completion of works following approvals. •Issue CMA report within 1 month of works completion. •Report in the End of Panel Report •Summarise all actions and monitoring in AEMR by end of February (Annually).		

4.5.2 Hand Mortaring

Where water transfer is observed through well-defined joints or fractures, the joints and fractures will be sealed using a variety of products, some of which can be applied in wet conditions and under water. These materials are normally applied using small held-held equipment and in localised situations.

Should large fractures occur in the base of the pools they will be sealed over with hand placed cement grout and natural oxides. This technique was used in at Marhnyes Hole successfully, prior to pattern grouting.

4.5.3 Injection Grouting

Where creeks are fractured as a result of subsidence and there is limited ability for them to naturally seal it would be necessary to carry out remedial measures. Such remedial measures have been implemented at other locations in the region. These measures usually include some sort of grouting of mining induced fractures. This grouting returns surface water that has been diverted to underground flow back to the surface. Grout can be delivered by small handheld equipment or truck-mounted equipment for deeper holes. Angled and horizontal drilling techniques can be utilised to position grout remotely from the site. The engineering techniques on which this type of rehabilitation is based are well established and used in the mining and construction industries and are readily adapted to rehabilitation activities.

A number of grouts are available for use in such situations including cement, pulverised ash and chemical grouts, with or without fillers. The fillers can include sand and gravel or vegetable fibres. The choice of grout will be determined based on the nature and extent of the fracturing, the surface/ground water interaction and the objectives of the rehabilitation program.

These rehabilitation operations have the potential to cause adverse environmental impacts through the materials used and the disturbance associated with access and will be carefully planned to avoid contamination of watercourses. Cofferdams can be built to isolate the grouting operations to collect any spillage of materials for appropriate disposal off site. Bunds will be used to contain any spillage at mixing points. The materials used in these processes are non-toxic, environmentally inert and do not significantly impact upon the natural habitats of aquatic species.

4.5.4 Pattern Grouting

Large surfaces of a stream bed may be sealed using pattern grouting. This involves drilling holes in a grid pattern in areas that stream bed fracturing is identified. A number of passes of grouting are generally required to seal the subsurface layers. This involves injection into the voids of the fractured strata with grouts and filler materials. The intention of this grouting is to achieve a low permeability ‘layer’ below the riverbed over the impacted area to restore steam flow and pool water level to the affected waterway.

Grouting holes are drilled in a pattern, usually commencing at a grid spacing of 1 m x 1 m to 2 m x 2 m. The most efficient way to drill the holes taking into account potential environmental impact is by using small handheld drills. The drills are powered by compressed air which is distributed to the work area from a compressor.

Once mechanical packers have been installed at the surface, grout is injected sequentially into the holes at a low pressure using specially designed packers. Grout is pumped into the holes from a small tank.

The grout is mixed and pumped according to the preferred grout design. A grout of high viscosity will be used if vertical fracturing is believed to be present since it has a faster 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 harden the area may be in-filled with additional grouting holes that target areas of significant grout taken from the previous pass. The entire grouting exercise can be completed with hand held equipment.

Grouting volumes and locations are recorded and high volume areas identified. Once the grout take in the area is reduced and the material has cured, the grouted section of the pool is allowed to fill with water and monitored. The grouting process is iterative; relying on detailed monitoring of grout injection quantities, grout backpressure analysis and water holding capacity measurements. An area is targeted for the grouting and this area is completed to the agreed success criteria prior to moving to other sites.

The choice of grout is dependent upon the permeability of the rock from site to site. A range of specialist grouts and techniques can be used including cement, bentonite, mixes, micro fine cements and sodium silicate-based grouts. The selection of a particular grout includes an analysis of potential aquatic ecosystem toxicity.

4.5.5 Deep Angled Hole Grouting

Where access difficulties make pattern grouting inappropriate (for example where a pool has not totally drained), directionally drilled holes may be installed from some distance away to allow grouting to be delivered from a remote location.

The grout used is likely to be a standard 2% Bentonite and General Purpose Cement mix with a specific gravity of 1.57 delivered to the directionally drilled holes through a packer system. Pumping continues until the grout material returns to the top of the delivery holes. Regular inspections are undertaken throughout and following the operation to ensure that there are no significant releases of grout into the river.

4.5.6 Permeation Grouting

This involves the introduction of grouting and filling materials into an individual pool or a stream flow, in such a manner that the material will be drawn into cracks and thereby seals the voids in the bed of the creek.

4.5.7 Impermeable Blankets or Linings

This involves the installation of a waterproof lining to a pool to prevent loss of water into the voids below. A variety of materials are available with the choice dependent on site-specific circumstances.

4.5.8 Curtain grouting

This involved the installation of a curtain of grout to the depth of fracturing to create an impermeable barrier to bypass flow. A variety of materials are available with the choice dependent on site-specific circumstances.

4.5.9 Joint Sealing

Where water is leaking from a creek or riverbed through well-defined joints or fractures, the joints and fractures can be sealed using a variety of products, some of which can be applied in wet conditions and under water.

4.5.10 Surface Treatment

Surface impacts may display as cracks of varying depths and widths, erosion scares or deposition areas. The treatment of these areas will be planned taking into account specific site conditions and impacts.

Where cracking develops in significant areas and natural sealing is not progressing, the cracks may require forking over and compacting to prevent subsequent 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 local native plants. Such rehabilitation measures have the potential to cause impact through the materials used and the disturbance associated with access. Considerable care and relevant approvals will be obtained to ensure the protection of the environment as such works are implemented.

4.5.11 Water Quality impact Mitigation measures

In Appendix A of **Attachment B** (see SMP), Ecoengineers (2007e) outline mitigation measures that could be considered if unexpected water quality impacts were detected.

Any works on SCA land requires prior approval from the SCA and there is a requirement for compliance with the Sydney Catchment Authority Water Supply Catchment Special Areas Standard Conditions for Entry (SCA, 2001). These requirements ensure strict limits are placed on any impacts associated with undertaking rehabilitation works on SCA land.

4.5.12 Mitigation of Acid and Heavy Metals Generation

With respect to remediation of the effects of decreased pH and heavy metals generation through fracturing of stream bedrock and/or rock bars, liming of streams and rivers is generally the technique of first choice for aquatic ecosystem restoration under stress from acidification and heavy metals.

A logical contingency measure for this proposal is to use a granular agricultural grade limestone ($CaCO_3$) 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 250m of Lake Cordeaux.

Emplacement of limestone at any such location would provide a continual reactive surface for:

- The neutralisation of excessive acidity.
- Encourage the localized precipitation of Fe and Mn hydrous oxides with consequent adsorptive removal of potential eco-toxic trace metals.
- Increase the hardness of the water and encourage 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.

Water quality monitoring sites are carefully located to enable a means of isolating and assessing such occurrences to determine if remedial action is required.

4.5.13 Mitigation Measures for Ferruginous Springs

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 down slope to ameliorate the effects of the spring.

4.5.14 Land Stability

Landslips and slides are to be monitored and reported in the AEMR. Specific actions to address subsidence impacts on cliffs and steep slopes will be developed and implemented where adverse subsidence impacts occur.

Rock falls from clifflines and slope slippage could be precipitated by the levels of movement that have been predicted, particularly where rocks and slopes are marginally stable.

Remediation requirements for any mine related rock falls and slippage would be in accordance with DoP Guidelines and to the satisfaction of DoP and SCA. Measures considered are outlined in the SSCMMP and may include:

- Surface water management measures to minimise sediment mobilisation.
- Erosion and sedimentation control measures to minimise downstream effects.
- Revegetation of disturbed areas.
- Preventive measures such as removal or stabilisation of loose boulders and scaling of loose rocks from cliff faces.
- Filling and mulching over large cracks to prevent the development of erosion channels.

4.5.15 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 with groundwater flows to the surface. Grouting techniques discussed above can reduce these associated gas flows at specific sites. In all identified circumstances in the Southern Coalfields 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.

4.6 Environmental Compensatory Measures

4.6.1 Approval Conditions

Condition 14 of Schedule 3 of the Development Consent is as follows:

14. The Applicant shall provide suitable offsets for loss of water quality or loss of water flows to SCA 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 Director-General. These offsets must:
    (a) be submitted to the Director-General for approval by 30 April 2009;
    (b) be prepared in consultation with SCA;

(c) provide measures that result in a beneficial effect on water quality, water quantity, aquatic ecosystems and/or ecological integrity of SCA's special areas or water catchments.

4.6.2 Offsets

Longwalls within Dendrobium Area 3A, and the commitments proposed for the longwalls in Areas 3B & 3C, have been designed to avoid or minimise significant impacts to major creeks and the biota therein. Comprehensive management and monitoring programs have been proposed to rapidly evaluate and remediate any significant impact to the natural features within Area 3.

It has been predicted that any mining induced impacts will be of a minor nature and at a local scale. As outlined in the monitoring and management plans, considerable amounts of data, interpretation and analysis of many aspects of the environment will be generated and made available through this proposal. This will assist land and conservation managers better understand the nature and function of this landscape and the environmental values therein.

The specific measures included within this SMP and the various management programs attached have been developed to restore ecological and other values of the Special Areas. Condition 3(14) requires that a suitable offset for loss of water quality or loss of flow to SCA storages, clearing or other ground disturbance caused by mining activities be provided. Current negotiations are underway to transfer 33 ha of land adjacent to the Cataract River to the SCA to meet the above condition.

Additional compensatory measures have included:

- Assisting DPI Fisheries to conduct surveys to determine the status of the various populations of Macquarie Perch in eastern drainages.
- Assisting DPI Fisheries to conduct research to determine the genetic status and relationships of the various lake bound and riverine populations of Macquarie Perch.

4.7 Contingency Plan And Emergency Response

The monitoring programs outlined in the SMP will identify subsidence impacts. Predicted impacts will be managed as outlined in the SMP. Contingency and emergency response options are available and will be implemented if it is demonstrated that environmental and water harvesting values or public safety impacts are greater than predictions. The SMP details the actions that will be undertaken to respond to adverse subsidence impacts and this is summarised in **Table 4.1**. The following framework will be used to implement these actions.

The subsidence management framework involves the following components:

- Identifying features/values of significance and impact prediction – to determine the range of possible events and impacts.
- Risk assessment – in terms of determining the probability and consequence of an event occurring.
- Defining triggers and trigger levels for features/values affected and/or the identified events/impacts.
- Defining and implementing environmental monitoring.
- Identifying responses/actions to be taken when different triggers and trigger levels are reached. These include response measures and actions relating to avoidance, minimization, mitigation and compensation and contingency plans and emergency responses.

- Identifying roles and responsibilities of various stakeholders.

- Assessing measured with predicted impacts as mining progresses for features/values affected and implement responses/actions identified based on triggers and various pre-defined trigger levels being exceeded. Impacts need to be assessed based on the significance, extent, scale or longevity of impact and practical aspects of mitigation/rehabilitation.

4.7.1 Environment

The impacts resulting from subsidence occur gradually and affect a relatively small area of the surface above the longwall. It is possible that a longwall could affect only a small area and that the remainder, being unaffected, will continue to provide unaffected habitats for terrestrial and aquatic species immediately adjacent to impacted areas.

To minimise the impacts associated with subsidence and rehabilitation works a number of measures can be implemented. These include:

- Relocation of fauna and fish.
- Temporary maintenance of individual species such as watering aquatic plants.
- Provision of compensatory habitat.
- Timing of works.
- Staged work programs.
- Altering mining methods or modifying the mining area.

If pools are substantially drained, large aquatic fauna could be relocated to ensure that they are not significantly impacted prior to rehabilitation being completed. This work would be done in consultation with SCA, DPI Fisheries and other agencies as required.

If rehabilitation of aquatic habitats is required, a catalogue of the habitat will be developed and used in site preparation to assist with rehabilitation. Boulders and logs could be removed from the area during site preparation and returned to pre-disturbance positions. Stockpiling rocks and logs adjacent to the watercourse and marking pre-disturbance positions with a non-toxic marking paint would assist this process. Larger aquatic plants can be removed from watercourse during site preparation in a non-destructive manner (i.e. by shovel). This allows the macrophytes to be stored off-site and replanted on completion of works. Patches of aquatic vegetation that do not need to be removed, but are left stranded by a fall in water level could be watered until water levels are restored.

With the provision of contingency and emergency measures, there is the potential to cause secondary impacts through the introduction of materials to the area or any disturbance associated with the activity. Considerable care and relevant approvals will be obtained to ensure the protection of the environment as such works are executed. Contingency and emergency measures would be monitored to confirm maintenance of the ecological values of the area and to confirm that measures in place to manage secondary impacts are effective.

5. MEANS TO UPDATE THE PLAN ON EXPERIENCE

Illawarra Coal is significantly involved in the development of new techniques for monitoring and managing mining induced impacts on natural and man made features. New methodologies and techniques will be evaluated as they are developed and incorporated into this Plan where it is appropriate to do so.

Consideration will also be given to updating the Plan during the development of, or in response to feedback on:

- End of Panel Reports
- Annual Environmental Management Reports
- Independent Environmental Audits

- Recommendations from the Sandy Creek Waterfall Technical Committee
- Exceedance of the Minor and Predicted Trigger levels
- Variations to the Subsidence Management Plan attributed to changes in mine layout

Any modification to this Plan will be submitted to the DoP for approval prior to its implementation in accordance with Condition 2(8) of the Dendrobium Mine development consent.