Mining Impacts at Dendrobium Coal Mine Area 3B

Report to Government

December 2015

Cover photo: Wongawilli Creek tributary WC21, looking downstream

Published December 2015
NSW Planning and Environment
www.planning.nsw.gov.au

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EXECUTIVE SUMMARY

Background

Illawarra Coal Holdings Pty Limited (Illawarra Coal) owns and operates the Dendrobium Coal Mine, located in the Illawarra Region, approximately fifteen kilometres (km) west of Wollongong. The mine is an underground mine that has been operating since 2001.

In response to public concerns and media interest concerning potential environmental impacts within Dendrobium Mine's Area 3B, in late July 2015 the Minister for Planning, the Hon Rob Stokes MP asked for an inspection of mining impacts within Area 3B and publication of an investigation report. This report satisfies this commitment and has been prepared by the Department of Planning and Environment (DPE) in consultation with other affected agencies following a joint agency site inspection on 8 September 2015.

The key matters of interest during the inspection were:

- fractures and resultant water flow diversions (ie loss of surface flow from the creek bed) in WC21 for a length of approximately 600 m (see cover photo);
- apparent loss of soil moisture and changed hydrogeological conditions within the swamps;
- research stations and monitoring equipment within the swamps; and
- general condition of the vegetation within the swamps.

The agencies consulted by DPE, termed for the purposes of this report as the Dendrobium Mine Impacts Inter-Agency Committee (DMIIAC), comprised representatives of DPE, the Office of Environment & Heritage (OEH), the Division of Resources & Energy (DRE) of the Department of Industry, the Department of Primary Industries - Water (DPI-Water) and WaterNSW. The scope of the report is restricted to impacts associated with the longwalls in Area 3B; the impacts caused by longwall mining in previous Dendrobium mining domains have not been considered.

A total of 89 impacts have been recorded to date for mining undertaken in Longwalls 9 – 11. This number of recorded impacts is not in itself unusual. Recorded impacts have affected watercourses (52%), swamps (18%) and other features (30%). The scale and significance of most impacts fall within predictions included in Illawarra Coal's Area 3B SMP. However, the impacts to a tributary of Wongawilli Creek, known as WC21, are considered to be greater than predicted.

The majority of impacts have been in accordance with predictions and have not led to breaches of the mine's performance measures. Most mining-related impacts have not caused significant environmental harm. However, the impacts at WC21 are significant. The extent of the subsidence impacts at WC21 has exceeded the predictions of Illawarra Coal and its specialist advisers.

While the impacts on upland swamps have been in accordance with predictions and are not considered at this stage to be in breach of the mine's performance measures, it is more difficult to determine their long-term significance. This is because the timeframes for impacts to swamp vegetation communities and long-term soil stability are likely to be much longer than the less than three years since mining commenced in Area 3B.

Watercourse Impacts

The Area 3B SMP application predicted that surface fracturing to a depth of 15 – 20 metres (m) would occur over the length of WC21 directly above longwall extraction. It also predicted that it was possible that surface flow diversion into the new fracture network would cause temporary surface flow diversions. However, the SMP predicted that any diverted surface water flow would re-emerge in WC21 downstream of the fractured area.

Of the 16 Level 2[1] watercourse impacts recorded within the catchment of Wongawilli Creek, 10 have occurred within WC21. These impacts involved significant rock fracturing, reduction in water levels in pools and an absence of surface flows. Level 2 fracturing in rockbars has been observed in WC21. Since undermining of Longwalls 9 and 10, complete loss of flow has been observed in this watercourse in the area overlying the mined panels, this length being some 600 m. The bed of the stream is sufficiently cracked that it seems incapable of containing significant runoff flows for more than a few days.

DPE, WaterNSW and DRE carried out an inspection of the subsidence impacts at WC21 on 12 May 2015. The three agencies also met on 17 July 2015 to discuss the impacts. It was agreed that remediation action by Illawarra Coal is required at WC21.

On 28 August 2015, DPE wrote to Illawarra Coal, under its powers under the Dendrobium mine's development consent, requesting it to prepare a remediation program for the impacts to WC21 by 31 December 2015. The remediation program must be prepared in consultation with WaterNSW and include details of the proposed remediation works and the likely timing of implementation of the proposed works.

Whilst noting that the impacts at WC21 are greater than predicted, they are not considered by DPE to be a breach of the mine's performance measures. The performance measures specifically relate to Wongawilli Creek and Donalds Castle Creek, rather than their associated tributaries, including WC21. DPE assigned performance measures to Wongawilli Creek and Donalds Castle Creek in its conditional approval for the Area 3B SMP because they are the most significant watercourses within Area 3B. The Southern Coalfield Inquiry and also subsequent Planning Assessment Commission reviews of both the Bulli Seam Operations Project and the Metropolitan Coal Project all recommended protection of third and higher order streams, which is the nature of these two streams. WC21 is variously a first and second order stream.

DPE's conditional approval for Illawarra Coal's Area 3B SMP was only granted after all key agencies were satisfied that it was highly unlikely there would be unacceptable or material impacts on the quantity or quality of Sydney's and Wollongong's water supply. Based on all available information, DPE is satisfied that so far there have been no unacceptable or material impacts from mining in Area 3B on Sydney's and Wollongong's water supply.

DPE is satisfied that there have been no unacceptable impacts on Wongawilli Creek with no observed flow diversion associated with the observed fracturing and pools remaining full and flowing. The relevant performance measure of 'minor environmental consequences including, minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality' is therefore not considered to have been breached.

The impacts to Donalds Castle Creek and its associated swamps and tributaries also appear to be in line with predictions in the Area 3B SMP, including occurrences of rock fracturing, reduced pool water levels and flow diversions beneath the creek bed. There is no evidence that the relevant performance measure of '*minor environmental consequences'* has been breached. Key agencies will continue to monitor for impacts through the current reporting procedures and require remediation if necessary.

DPE generally considers that the performance measures relating to watercourses and water bodies have been met. However, methodologies for defining, measuring and assessing impacts, may need to be improved and expanded to determine the extent and significance, particularly in respect of baseflow losses and streamflow diversions to underlying aquifers. The impacts within WC21 remain a particular concern to WaterNSW and other agencies, given that the proposed Longwalls 12 – 15 are likely to extend these impacts. Close attention will be paid to the ongoing monitoring of flows and pool levels as additional longwalls are mined.

[1] Illawarra Coal's Trigger Action Response Plans (TARPs) for both watercourses and swamps contain four trigger levels – Levels 1, 2, 3 and 'exceeding prediction'. Responses to Level 2 and Level 3 triggers typically require investigations and reporting by specialists and may require the development of Corrective Management Actions, developed in consultation with relevant stakeholders to manage an observed impact.

Biodiversity Impacts

Based on the predicted subsidence movements, Illawarra Coal predicted in its Area 3B SMP application that bedrock below the upland swamps associated with the key watercourses in Area 3B was likely to be fractured following longwall mining. DPE and other agencies recognised during their assessment of the Area 3B SMP that there would be impacts on several upland swamps, particularly from the first three longwalls in Area 3B (Longwalls 9 – 11).

A number of impacts to upland swamps have indeed resulted following extraction of Longwalls 9 – 11. There have been impacts to the level of the shallow aquifers within swamp sediments (ie loss of the permanent perched aquifer) and increases in the rates of groundwater level recession in response to rainfall after undermining when compared to the rate of recession prior to undermining.

A total of 16 swamp impacts have been reported, including five Level 3 impacts and two Level 2 impacts in Swamp 5, one Level 1 impact in Swamp 8 and eight Level 2 impacts in Swamps 1a and 1b.[2] These impacts mostly relate to increases in groundwater recession rates and/or significant changes in the shallow groundwater regimes. All undermined piezometers within swamps have exhibited an increase in groundwater recession rates and/or water levels lower than before mining, suggesting that the hydrological characteristics have been temporarily or possibly permanently altered. The monitoring results show that mining of Longwalls 9 – 11 has impacted on every swamp that has been directly undermined or is immediately adjacent to mining.

However, DPE, which has responsibility for enforcing the conditions of the Area 3B SMP approval, does not consider that these impacts are breaches of the mine's performance measures relating to upland swamps. The performance measures specifically relate to erosion, swamp size, ecosystem functionality, composition or distribution of species and maintenance or restoration of the structural integrity of the bedrock base of permanent pools or rockbars. '*Ecosystem functionality*' is measured by the size of the groundwater dependent communities contributing to the swamps, specifically any changes in the proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex within the monitored swamps. Illawarra Coal's vegetation monitoring is focussed on monitoring the size of these communities and the species distribution within them.

To date, no triggers have been exceeded which relate to the performance measures for erosion, swamp size, ecosystem functionality, composition or distribution of species and maintenance or restoration of the structural integrity of the bedrock base of permanent pools or rockbars associated with the swamps. At this point, the possibility that some or all of these performance measures would eventually be breached as the swamps dry out as a consequence of the fractured basements cannot be ruled out.

The conditions of the Area 3B SMP approval require that Illawarra Coal provide significant offsets to compensate for the anticipated impacts to upland swamps, detailed monitoring of impacts, an extensive research program into remediating subsidence impacts on upland swamps ($3.5 million over 5 years), and remediation where feasible. A draft *Swamp Rehabilitation Research Program* and *Biodiversity Offset Strategy* have been submitted to DPE and are currently being considered in consultation with other affected agencies.

Further biodiversity impacts include those to threatened fauna species. Hydrological impacts are may pose significant environmental consequences for the persistence of populations of Giant Dragonfly within the swamps and Littlejohn's Tree Frog within drained watercourses in Area 3B. These impacts were acknowledged during the preparation and assessment of the Area 3B SMP. There is no indication that the observed impacts recorded to date have been beyond those predicted in the SMP. Further investigation is needed to understand the significance of these impacts to regional populations.

Remediation

Remediation of cracking within watercourses has been successfully undertaken at a number of sites within the Southern Coalfield but requires significant cost and resources and is potentially limited by access difficulties.

[2] See Note 1.

DPE has requested remediation of WC21 and will closely monitor other watercourses in order to determine if further remediation is required.

Remediation of swamps damaged by subsidence has not yet been proven to be viable. Remediation has typically been limited to the most accessible and obvious impact areas, such as repairing of rockbars and erosional scours. DPE has required Illawarra Coal to undertake a significant ($3.5 million) research program focusing on swamp rehabilitation. The results of the research program, once finalised, are likely to substantively inform the possibility and likelihood of success of swamp rehabilitation in the future.

Recommendations

Surface Water and Groundwater Modelling

DPE recommends engaging an independent expert to assess matters pertaining to this modelling. The proposed scope of works for this review should include:

- documenting the available investigation techniques and types of information/evidence used to examine post-longwall mining fracturing patterns and hydrogeological responses to fracturing with a particular focus on identifying the heights of connective cracking and desaturation above longwalls, as well as surface water flow diversions;
- undertaking a critical analysis of the investigative and evidentiary data types identified above and of the factors that affect their accuracy and/or uncertainty;
- reviewing and cataloguing all available (relevant to a NSW context) evidentiary data sources;
- reviewing all available data sources which inform an understanding of temporal changes in overlying aquifers following longwall extraction.
- providing comment on the post-mining temporal trends identified;
- categorising the data according to location, measured subsidence effects, time elapsed between nearest mining and measurement, quality or indicative uncertainty of data point, and any other relevant distinguishing traits identified;
- reviewing the evidentiary databases used by Ditton (2013) and Tammetta (2012 and 2015) and providing a critical review of the reliability of the data points used, potential sources of uncertainty and a summary of which data points have been included in each model;
- briefly analysing the statistical methods used in the two approaches, and providing comment on the potential strengths and weaknesses of each;
- providing comment on what constitutes an ideal and an adequate monitoring network to investigate geotechnical and hydrogeological behaviour over mined longwalls; and
- providing a summary of key trends and recommendations for further work required to clarify geotechnical and hydrogeological responses above longwall mining panels.

Watercourses

In August 2015, DPE requested that Illawarra Coal prepare a remediation program for the impacts to WC21. To inform the remediation program, DPE recommends that Illawarra Coal be required to undertake the following:

- installation of boreholes with piezometers targeted at suitable depths to measure groundwater levels in the WC21 valley (both pre-mining and post-existing mining), with the depth and key characteristics of bedrock fracturing being clearly identified by appropriate geotechnical, geophysical and lithological logging. In-hole water quality testing, water level monitoring, permeability testing and flow testing should be undertaken to clarify the extent, depth and magnitude of shallow cracking; and
- undertake a limited set of tracer tests to determine what proportions of diverted stream flows are returning to the stream further down-gradient as against being delivered to underlying aquifers.

DPE will consider the need for performance measures for key tributaries as part of its assessment for further approval of Longwalls 14 – 18. DPE also proposes to further consider Illawarra Coal's current Area 3B watercourse monitoring system, in consultation with other relevant agencies, as part of its assessment for further approval for Longwalls 14 – 18. If necessary, it will require expansion of this monitoring system.

Upland Swamps

As part of the assessment for SMP approval of Longwalls 14 – 18, DPE proposes to further consider Illawarra Coal's current Area 3B swamp monitoring system, in consultation with relevant agencies. This analysis will involve review of the number, location and purpose of swamp piezometers in impacted and control swamps to ensure a robust before-after-control-impact program design. If necessary, DPE will require a refinement to or expansion of this monitoring system. The performance measures relating to upland swamps in the Area 3B SMP approval and triggers in the approved TARPs will also be reviewed.

A draft offset strategy for Area 3B has been submitted by Illawarra Coal to DPE. DPE, in consultation with other agencies, would finalise the implementation of this strategy, including the transfer of Illawarra Coal's Maddens Plains land to OEH as a matter of priority.

A draft *Swamp Rehabilitation Research Program* has also been submitted by Illawarra Coal and is currently being considered by DPE in consultation with affected agencies. DPE proposes to finalise this program as a matter of priority in order for this vital research to be undertaken. Future decisions regarding swamp remediation will take into account the investigations and results of the *Swamp Rehabilitation Research Program*.

Threatened Species

The potential cumulative impacts to Littlejohn's Tree Frog as a result of watercourse impacts remain of concern to agencies. DPE recommends engaging an independent expert, in consultation with OEH and Water NSW, to assess the local and regional impacts to this species.

Further Approval of Longwalls 14 – 18

DPE has already informed Illawarra Coal that its key considerations in deciding whether to grant further approval will include:

- Illawarra Coal's performance under the SMP approval to date, including consideration of the impacts outlined in this report;
- Illawarra Coal's compliance with performance measures to date and whether there is a need for revision of the current performance measures; and
- the revised subsidence predictions and whether these are significantly different to those previously reported.

During DPE's assessment, the currently applied performance measures and the TARPs used to assess compliance with these measures will be reviewed. DPE will consult with the relevant agencies and the broader community regarding this further approval.

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1. INTRODUCTION AND BACKGROUND

1.1 Introduction

Illawarra Coal Holdings Pty Limited (Illawarra Coal) owns and operates the Dendrobium Coal Mine, located in the Illawarra Region, approximately fifteen kilometres (km) west of Wollongong. The mine is an underground mine that has been operating since 2001.

In response to public concerns and media interest concerning potential environmental impacts within Dendrobium Mine's Area 3B, in late July 2015 the Minister for Planning, the Hon Rob Stokes MP asked for an investigation of mining impacts within Area 3B and publication of the investigation report. This report satisfies this commitment and has been prepared by the Department of Planning and Environment (DPE) in consultation with other affected agencies following a joint agency site inspection on 8 September 2015.

The agencies consulted by DPE, termed for the purposes of this report as the Dendrobium Mine Impacts Inter-Agency Committee (DMIIAC), comprised representatives of DPE, the Office of Environment & Heritage (OEH), the Division of Resources & Energy (DRE) of the Department of Industry, the Department of Primary Industries - Water (DPI-Water) and WaterNSW.

As agreed by the DMIIAC, this report provides:

- background information on the catchment area in which the mine operates and WaterNSW's policy position on mining in this area;
- a summary of the existing operations at the mine and the current development consent and other approvals under which it operates;
- a clear, factual summary of the environmental impacts and environmental consequences of current mining operations;
- a detailed account of existing and proposed Illawarra Coal and agency responses to these impacts; and
- advice to Government on the scale and significance of the impacts, their predictability and avoidability, the potential for recurrences, compliance and offsetting, and public knowledge and future confidence in subsidence management processes.

1.2 Sydney's Drinking Water Catchment

About 4.5 million people in the Sydney, Illawarra, Southern Highlands, Shoalhaven and Blue Mountains areas rely on water harvested from surrounding water catchments. In the Greater Sydney region, WaterNSW manages a total of 21 storage dams (including 11 major dams) that together have the capacity to hold more than 2.6 million megalitres (ML) of water. Water for these dams is collected from five catchment areas covering a total of 16,000 square kilometres (km²) (see **Table 1**).

Under the provisions of the *Water NSW Act 2014*, Sydney's drinking water catchments are 'Declared Catchment Areas', managed by WaterNSW (previously the Sydney Catchment Authority or SCA). The Upper Nepean and Woronora catchments, located south of Sydney, comprise a 'Declared Catchment Area' which includes the catchments of the Cataract, Cordeaux, Avon, Nepean and Woronora rivers.

Table 1: *The five drinking water catchments of the greater Sydney region*

Catchment	Catchment area (km²)	Main Creeks and Rivers	Dams
Upper Nepean	683	Nepean, Avon, Cordeaux and Cataract	Nepean, Avon, Cordeaux and Cataract
Woronora	75	Woronora	Woronora
Warragamba	9,050	Wingecarribee, Wollondilly and Coxs	Warragamba and Wingecarribee
Shoalhaven	5,821	Shoalhaven	Fitzroy Falls and Tallowa
Blue Mountains	22	Cascade, Adams, Greaves, Woodford and Bulls	Cascade, Lakes Medlow Greaves and Woodford

The entire Upper Nepean catchment is also declared under this legislation as a 'Special Area', known as the Metropolitan Special Area. Special Areas are declared for the purposes of protecting the quality of stored drinking water and for maintaining the ecological integrity of the land in the general vicinity of stored drinking water. Special Areas in Sydney's drinking water catchment are jointly managed by WaterNSW and the National Parks and Wildlife Service, with management guided by the *Special Areas Strategic Plan of Management* (see **Appendix 1** for Water NSW's position regarding longwall mining near its water storages). The Metropolitan Special Area was originally proclaimed as a protected catchment in 1880 and includes all land that drains to Pheasants Nest Weir on the Nepean River and Broughtons Pass Weir on the Cataract River. Water from the Metropolitan Special Area is used to provide water supplies to Wollongong and the Illawarra Region, and also contributes to the water supply for the Sydney Metropolitan Area.

There is a long history of mining in the drinking water catchments to the south and southwest of Sydney. The catchments comprise part of an area known in NSW as the 'Southern Coalfield'. Coal mining has been a major part of the development of the Illawarra and Wollondilly regions for over 160 years. Coal was first mined in the Illawarra Region at Mt Keira in 1848.

Underground mining occurs or has occurred under a significant proportion of the Metropolitan Special Area. Mining occurs mainly under the Cataract, Cordeaux and Woronora catchments which form part of the Upper Nepean and Woronora water supply systems. Around 20% of water supplied by WaterNSW within the Greater Sydney Region is sourced from these catchments.

At present, three mining companies operate a total of four active longwall coal mining operations under either the Metropolitan Special Area that supplies the Cataract, Cordeaux, Avon and Nepean Dams or the Woronora Special Area that supplies Woronora Dam (see **Figure 1**).

1.3 Dendrobium Coal Mine and Illawarra Coal's Other Mining Operations

Illawarra Coal, a wholly owned subsidiary of South32 (previously BHP Billiton), owns and operates three underground metallurgical (ie coking) coal mines in the Southern Coalfield: Appin, West Cliff and Dendrobium Coal Mines. It also operates two coal preparation plants: West Cliff Coal Preparation Plant and Dendrobium Coal Preparation Plant.

Illawarra Coal also manages the Port Kembla Coal Terminal (PKCT) on behalf of a consortium of coal mining companies. The partners in the consortium are Centennial Coal Company Ltd; Illawarra Services Pty Ltd; Metropolitan Collieries Pty Ltd; Oakbridge Ltd; Tahmoor Coal Pty Ltd; and Wollongong Coal. The consortium leases the terminal from the NSW Government.

Illawarra Coal produces premium quality, hard coking coal for steelmaking, with small amounts of energy coal as a by-product, from the Bulli and Wongawilli coal seams. Coal is transported via road and rail to the company's preparation plants and thence to PKCT for distribution to domestic and international markets. The Illawarra Coal workforce consists of close to 2,500 full-time employees and contractors.

The Appin and West Cliff Coal Mines are now referred to as the company's Bulli Seam Operations. Underground mining activities have been carried out at West Cliff Mine since 1976. Underground mining activities in the Appin area commenced at Appin Mine (Appin East Pit Top) in 1962 and at the Appin West Pit Top (formerly Tower Colliery) in 1978.

The Dendrobium Mine, located approximately 15 km west of Wollongong, is a longwall mine which has been operating since 2001. The mine is located near Lake Cordeaux in the Wollongong and Wingecarribee local government areas. Coal is extracted from the Wongawilli Seam.

As noted above, the longwall mining activities at Dendrobium Mine are being undertaken in the Metropolitan Special Area, including the Cordeaux and Avon river catchments. The approved underground mining area covers approximately 4,100 hectares (ha) which is about 4.5% of the 90,000 ha Metropolitan Special Area (see **Figure 1**).

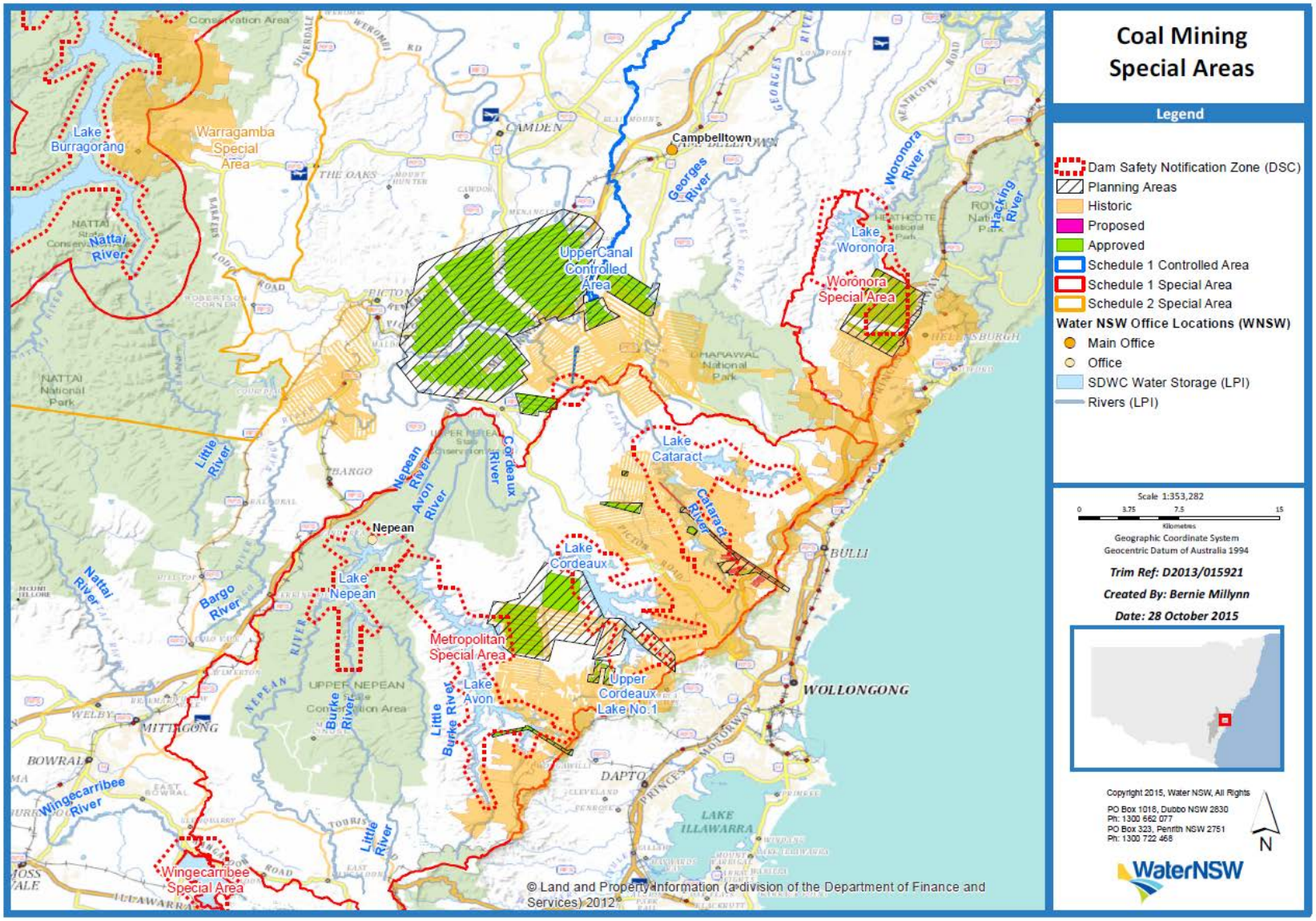

Figure 1: *Historic, approved and proposed coal mining in Sydney's drinking water catchment*

The majority of the surface land surrounding the underground mining domains is bushland within the Special Area. Mining operations at Dendrobium Mine have involved extraction of coal by longwall mining methods beneath the Cordeaux Dam Notification Area since 2005.

Mining at Dendrobium is divided into three mining domains (Areas 1, 2 and 3), with Area 3 divided into three zones (3A, 3B and 3C). Mining is complete in Areas 1, 2 and 3A, with mining currently occurring in Longwall 11 within Area 3B.

Coal from the Dendrobium Mine is critical to Illawarra Coal's operations as it is blended with other coal extracted in the region to produce a premium coking coal blend for steel production at both Port Kembla and Whyalla, and for export markets. Dendrobium Mine is a major and significant contributor to employment within the Illawarra region, with 330 full time employees and at least another 890 employees that are indirectly reliant on the mine's operations. Illawarra Coal is expected to provide some $787 million in State Government revenue over the 12 years of operations in Dendrobium Area 3B through royalties, levies and payroll tax.

1.4 Current Development Consent and Other Approvals

Illawarra Coal currently operates under a number of consents, approvals and licences issued by a variety of State agencies (see **Table 2**).

Development Consent

In November 2001, the then Minister for Urban Affairs and Planning approved the Dendrobium Coal Mine Project, following a Commission of Inquiry, under Part 4 of the *Environmental Assessment and Planning Act 1979* (EP&A Act). The development consent has since been modified a total of seven times and currently allows Illawarra Coal to:

- continue underground mining for a further 15 years using longwall and conventional mining methods;
- extract up to 5.2 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal;
- construct and use various existing surface infrastructure;
- transport ROM coal by rail to the Dendrobium Coal Preparation Plan at the Port Kembla Steelworks site for processing and transport; and
- emplace coal rejects at the West Cliff Wash Emplacement Area.

Table 2: *Dendrobium consents, approvals and licences*

Approval	Authority	Date of Approval
Development Consent for the Dendrobium Coal Mine Project (DA 60-03-2001)	DPE	20 November 2001
Area 3B Subsidence Management Plan, including: - SCA Asset Protection Plan; - Groundwater Management Plan; - Swamp Impact, Monitoring, Management and Contingency Plan; and - Watercourse Impact, Monitoring, Management and Contingency Plan.	DPE DRE	6 February 2013 5 February 2013
Mining leases (ML1510, ML1566 and CCL768)	DRE	24 April 2002 (ML1510) 7 September 2005 (ML1566) 29 October 1991 (CCL768)
Consent to enter and carry out activities permitted by statutory approvals	WaterNSW	13 March 2015
General subsidence management and monitoring activities licence	DSC	Various
Environment Protection Licence (EPL) 3241	EPA	1 August 2000
Groundwater Licence	10BL161946	Not known

Subsidence Management Plans

Under the development consent, Illawarra Coal is required to prepare and submit a Subsidence Management Plan (SMP) to manage the carrying out of any underground mining operations that could cause subsidence in either Area 3A, 3B or 3C (see condition 7 of Schedule 3).

The SMP must be approved by both the Director-General (now Secretary) of DPE and the Director-General of the Department of Trade and Investment, Regional Infrastructure and Services (NSW Trade and Investment, now the Department of Industry), prior to commencing such mining. The development consent enables an SMP to be approved subject to conditions.

DPE received a draft Area 3B SMP in October 2012. Whilst DPE does not ordinarily exhibit management plans required to be developed under conditions of development consent (including SMPs or Extraction Plans), DPE placed the draft Area 3B SMP and all relevant supporting documents on its website for public consideration. The community was also notified that the SMP was publicly available in both the *Illawarra Mercury* and *The Land* in November 2012.

Submissions were received from relevant State agencies and a range of community and special interest groups, including individual members of the Dendrobium Community Consultative Committee (CCC), three separate National Parks Association branches, Rivers SOS, the Georges River Environmental Alliance, the Northern Illawarra Sustainability Alliance and a small number of individual community members. In assessing the SMP application, DPE also held discussions with DRE, the Dendrobium CCC, OEH, the then SCA and Illawarra Coal.

DPE also required Illawarra Coal to address comments received in relation to the draft SMP, and prepare a revised document. DRE, OEH and the then SCA were provided with the opportunity to review the final conditions which were attached to the SMP approval and broadly agreed with the recommended framework of conditions and the reasons for their adoption.

In February 2013, the Director-General of the Department of Planning & Infrastructure (now DPE) and the Director-General of NSW Trade and Investment approved the final Dendrobium Area 3B SMP. The SMP incorporates a number of sub-plans, which require monitoring and management of subsidence impacts on water, biodiversity, land, heritage, built features and public safety. Extraction of Longwall 9 commenced in February 2013. Mining is currently being undertaken in Longwall 11 with over 1,500 metres (m) extracted to date (see **Figure 2**).

Mining Leases

Dendrobium Mine is covered by three mining leases granted under the under the *Mining Act 1992*:

1) Mining Lease (ML) 1510;
2) ML1566; and
3) Consolidated Coal Lease (CCL) 768 (first granted under the previous *Coal Mining Act 1973*).

All longwall panels are within CCL768. ML1566 covers the No. 2 and No. 3 shaft sites and ML1510 covers the Kemira Valley Coal loading facility site at Mt Kembla. Conditions of CCL768 stipulate that a SMP must be approved by the Director-General of the NSW Trade and Investment prior to commencing any underground mining operations which will potentially lead to subsidence of the surface.

Environment Protection Licence

Illawarra Coal holds Environment Protection Licence (EPL) 3241, granted under the *Protection of the Environment Operations Act 1997* (POEO Act) by the Environment Protection Authority (EPA). Under the POEO Act, 'mining for coal' and 'coal works' are scheduled activities that are required to be licensed and for which the 'appropriate regulatory authority' is the EPA. The EPL authorises Illawarra Coal's 'mining for coal' and 'coal works'. The EPL sets out a range of conditions relating to the operation of these activities at Dendrobium, and requires the monitoring of water and ambient air quality parameters. The EPL does not authorise or regulate rehabilitation or remediation activities, including the remediation of subsidence impacts.

Approval to Conduct Activities in the Catchment Area
All persons and other entities require consent from WaterNSW to enter and conduct activities in Special Areas. Illawarra Coal has been granted consent by WaterNSW to enter and conduct work activities associated with the Dendrobium Mine in the Metropolitan Special Areas.

DSC Approvals
Approval from the DSC is required for mining that takes place within dam notification areas declared by the DSC under the *Dams Safety Act 1978*. Approval is currently being sought from the DSC for Longwalls 13 – 18, all located partly within the Avon Dam Notification Area. DSC provided DRE with its recommendation for approving the extraction of Longwall 12 on 29 October 2015.

Water Licences
The extraction of water from rivers or aquifers to use for commercial purposes requires a water licence or other approval from DPI-Water under either the *Water Management Act 2000* or the *Water Act 1912*.

The current total mine inflows were reported to be about 6.2 ML/d (2263 ML/year) following the completion of Longwall 10. Illawarra Coal presently holds a groundwater entitlement of 1537 ML/year. Illawarra Coal has confirmed that in September 2014 it acquired the rights to an additional 2500 ML/year through a controlled allocations release. However, the entitlement has not been registered by Illawarra Coal with Land and Property Information and therefore to date a water access licence has not been issued.

Reporting by Illawarra Coal indicates that surface water may be being diverted (ie 'taken' under the water legislation) which is not being properly accounted for. This matter needs to be further examined as Illawarra Coal is required to hold a water access licence with sufficient allocation to account for this water take. These issues are to be resolved between Illawarra Coal and DPI-Water separately.

1.5 Site Inspection

On 8 September 2015, representatives from DPE, OEH, DRE, WaterNSW and DPI-Water undertook an inspection of recent mining impacts above Area 3B. The inspections could not be undertaken at an earlier date (ie closer to the Minister's request) due to significant rainfall events which caused the catchment to be closed.

Specific sites inspected include Swamp 14, a tributary of Wongawilli Creek (WC21) and its upper reaches and Swamp 1b over Longwalls 9 – 11. Access to these sites entailed walking along fire trails and in bushland. The group also passed close to Wongawilli Creek by vehicle. The key matters of interest during the inspection were:

- fractures and resultant water flow diversions (ie loss of surface flow from the creek bed) in WC21 for a length of approximately 600 m;
- apparent loss of soil moisture and changed hydrogeological conditions within the swamps;
- research stations and monitoring equipment within the swamps; and
- general condition of the vegetation within the swamps.

Since mining began in Area 3B, numerous other site inspections have been conducted by relevant agencies, including one in May 2015 with representatives from DPE, OEH, WaterNSW and DRE. The agencies, in particular WaterNSW and OEH, are familiar with the terrain over Area 3B and are aware of, and have familiarity with, the key matters of interest.

1.6 Dendrobium Mine Impacts Inter-Agency Committee

This report has been prepared by the Department of Planning and Environment (DPE) in consultation with other affected agencies. For the purposes of this report this consultation group is termed the Dendrobium Mine Impacts Inter-Agency Committee (DMIIAC). This group consists of DPE, OEH, WaterNSW, DPI-Water and DRE.

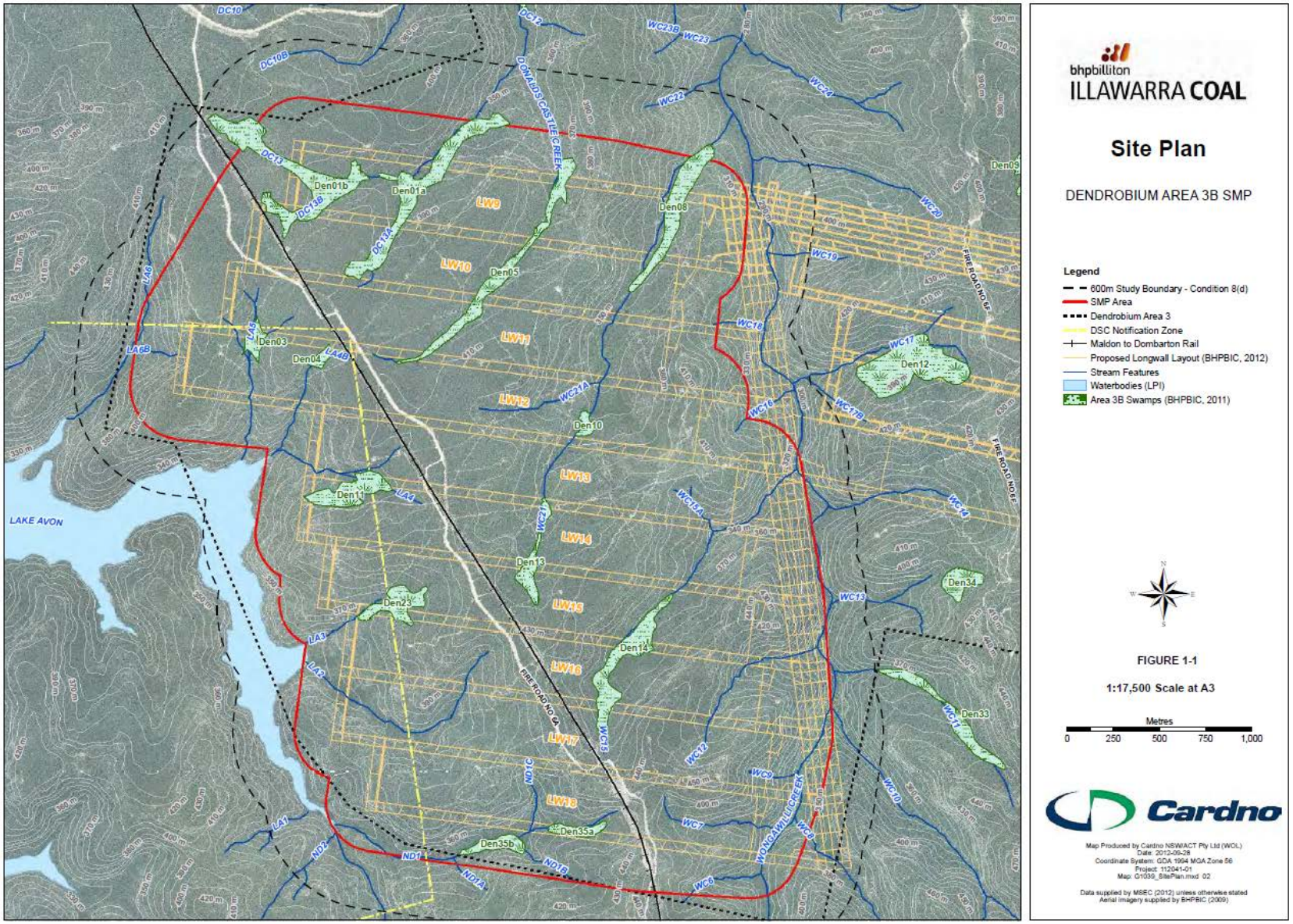

Figure 2: *Dendrobium Mine Area 3B*

2. MINING IMPACTS

2.1 Background

Underground coal mining by longwall mining methods unavoidably causes the extracted coal void to collapse, resulting in subsidence of the surface of the land. Mining-induced subsidence and resulting impacts are generally localised to the surface directly above the mined longwall panels and a surrounding margin within what is known as an 'angle of draw' (see **Figure 3**).

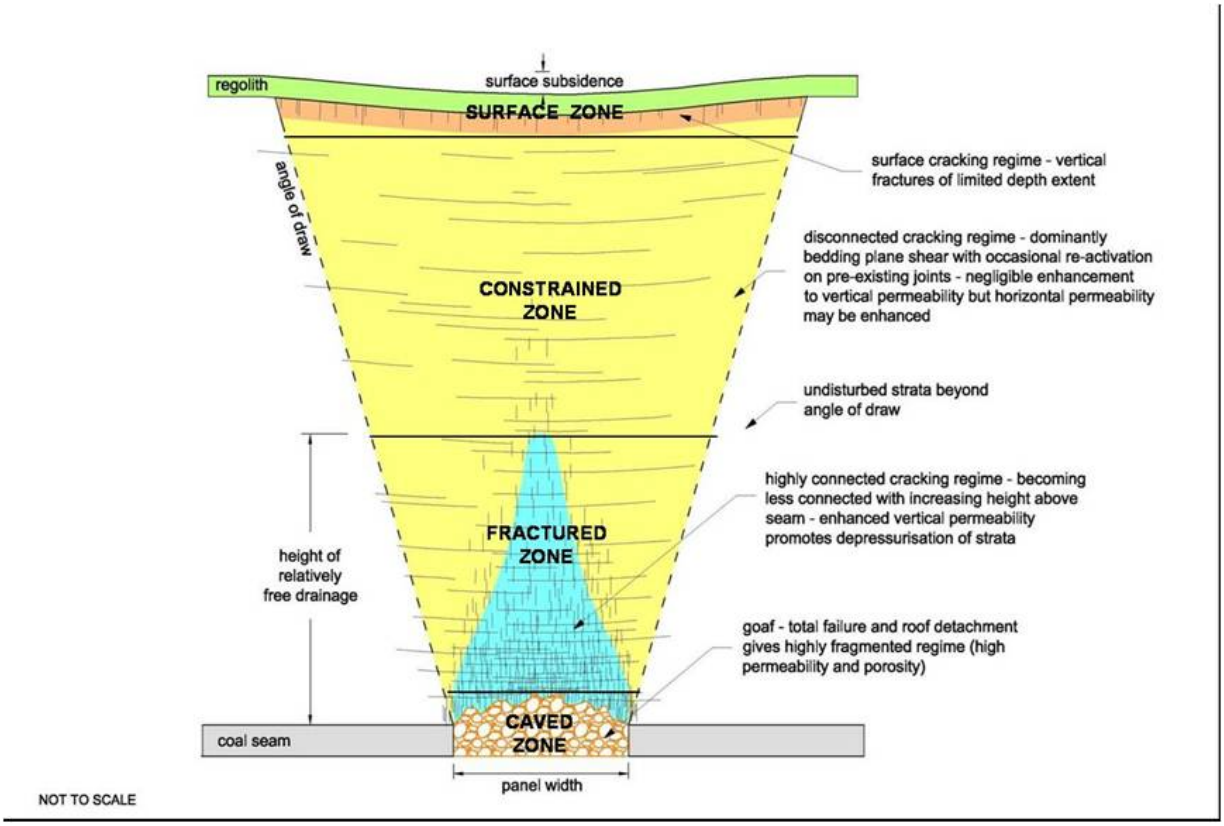

Figure 3: *Conceptual model of caving and the nature of fracturing above a mine excavation*

Surface subsidence associated with underground coal mining is generally relatively predictable in its manifestation, magnitude and extent. This is particularly the case for what are known as 'conventional' subsidence effects, such as vertical subsidence, tilts and strains. Conventional subsidence prediction and impact assessment is a well-established engineering discipline. However, so-called 'non-conventional' subsidence effects, such as valley closure and upsidence, have been recognised more recently and their prediction is considered to be a developing field of both science and engineering. NSW has a very substantial history of subsidence prediction and impact assessment, both in the mining industry and in government (particularly DRE), and is generally regarded as a world leader in predicting and managing all forms of surface subsidence associated with underground coal mining.

Following suggestions first made in the Southern Coalfield Inquiry (2008), it has become common practice in NSW to differentiate between subsidence effects, subsidence impacts and the resulting environmental consequences. 'Subsidence effects' are limited to the deformation of the ground mass, as measured by quantifiable parameters such as vertical subsidence, tilt, compressive strain and tensile strain. 'Subsidence impacts' describe the physical changes to the ground (ie cracking, buckling etc). 'Environmental consequences' are the results of the subsidence effects and impacts on the surrounding environment and could include loss of stream flow, loss of vegetation and faunal habitat, erosion, scouring, ponding and development of iron staining.

Where mine subsidence leads to significant stresses at the land surface, then surface cracks may result. These impacts may be increased if the land surface also involves steep slopes or valley sides. The extent and severity of these mining-induced ground deformations depend on a number of factors, including the longwall panel geometry (principally the width of the void left after extraction of a longwall panel and the height of the portion of the coal seam that is extracted), depth of cover, overburden geology, surface geomorphology, locations of natural jointing within the overlying strata and the presence of other geological structures such as faults and dykes.

2.2 Subsidence Impact Predictions and Performance Measures

The environmental impact statement (EIS) for the Dendrobium Coal Mine Project, subsequent environmental assessments (EAs) for modifications to the Dendrobium consent (in particular for Modification 6, which was approved in December 2008) and subsequent SMPs, all predicted that there would be subsidence impacts in the catchment area. The development consent (as modified) and other relevant approvals (ie SMP approvals) act to keep these within reasonable and appropriate limits. In regard to Area 3B, this includes a number of strict performance measures for a range of natural and built features near the underground mining operations (see **Table 3**). These performance measures include specific limits on impacts to upland swamps and significant water bodies and storages.

Table 3: *Subsidence impact performance measures (from Area 3B SMP approval)*

Swamps	
Swamps 1a, 1b, 5, 8, 11, 14 and 23	Minor environmental consequences including: • *negligible* erosion of the surface of the swamps; • *minor* changes in the size of the swamps; • *minor* changes in the ecosystem functionality of the swamp; • *no significant* change to the composition or distribution of species within the swamp; and • *maintenance or restoration* of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.
Swamps 3, 4, 10, 13, 35a and 35b	No significant environmental consequences beyond predictions in the Subsidence Management Plan.
Watercourses	
Waterfall WC-WF54	Negligible environmental consequences including: • *no* rock fall occurs at the waterfall or from its overhang; • *no* impacts on the structural integrity of the waterfall, its overhang and its pool; • *negligible* cracking in Wongawilli Creek within 30 m of the waterfall; and • *negligible* diversion of water from the lip of the waterfall.
Wongawilli Creek Donalds Castle Creek	Minor environmental consequences including: • *minor* fracturing, gas release and iron staining; and • *minor* impacts on water flows, water levels and water quality.
Water storages	
Avon Reservoir	Negligible environmental consequences including: • *negligible* reduction in the quality or quantity of surface water inflows to the reservoir; • *negligible* reduction in the quality or quantity of groundwater inflows to the reservoir; and • *negligible* leakage from the reservoir to underground mine workings.

Before approving the Area 3B SMP, both DPE and DRE examined all reasonable opportunities to avoid, reduce, minimise, remediate and offset the predicted impacts. The decision makers were satisfied that full avoidance or substantial reduction of the predicted swamp impacts in the early years of the mining was not economically feasible given that the layout for the initial longwall panels had already been established. In particular, the proposed width of the longwalls had already been established by first workings undertaken by Illawarra Coal to define the longwall layout.

The roadway development for Longwalls 9 and 10 had already established that these longwall panels would be 294 m in width, leading to an overall void width after longwall extraction (ie including the two associated roadways) of 305 m. The chain pillar between the longwalls was set at 45 m in width. However, the longwall layout had been set back by between 75 and 500 m from Wongawilli Creek and between 230 m and 310 m from Lake Avon. These setbacks reduced potential coal extraction, but also reduced subsidence movements at surface features close to Wongawilli Creek and Lake Avon, including the streams LA2, LA4, LA4, LA5, WC7, WC9, WC12, WC15, WC16, WC18 and Swamps 23 and 11.

Illawarra Coal's application for its Area 3B SMP sought approval for 11 longwalls (Longwalls 9 – 19). The first 10 of these are located in Area 3B. Longwall 19 is a proposed longwall in the southern portion of the previously approved Area 3A. The then-Directors-General of DPE and NSW Trade and Investment decided to only approve the first five of these longwalls (Longwalls 9 – 13). Approval was withheld for Longwalls 14 – 19. Conditions of the Area 3B approval require Illawarra Coal to apply again for approval for Longwalls 14 – 19. It was made clear by DPE that approval of Longwall 14 – 19 was contingent on Illawarra Coal's performance in regards to Longwalls 9 – 13.

Under the Area 3B approval, draft mine plans for both the second group of longwalls in Area 3B (ie Longwalls 14 – 19) and the next mining domain (Area 3C) must be submitted for approval *prior to* undertaking any gateroad development (ie first workings) to establish the layout of those longwall panels.

At the time of their approval of the Area 3B SMP, the then-Directors-General of DPE and NSW Trade and Investment determined that the economic and social costs and risks associated with substantially revising this pre-established mine layout were substantially greater than the associated environmental impacts. While some of these impacts will be able to be remediated, it was also accepted that some residual impacts would remain.

A second fundamental consideration in the decision by the two agencies to approve longwall mining for the first five longwalls in Area 3B was to ensure that there would be no unacceptable impacts on Sydney's and Wollongong's water supplies. There was consensus between the agencies that it was highly unlikely there would be damage to critical public infrastructure, such as the dam walls (which were a very considerable distance from the proposed mining). It was also considered that there were very limited risks to the stored waters of Avon Dam and Cordeaux Dam, which would, in any case be assessed in much greater detail by the DSC prior to mining taking place. Finally, it was considered that impacts on the overall supply of runoff to the water storages and the water quality of stored waters were likely to be negligible, if any.

However, it was noted that there would be impacts on several upland swamps and watercourses, particularly caused by mining the first three longwalls in Area 3B. Mining in Area 3B was predicted to result in damage to up to twelve upland swamps arising from mine subsidence. These upland swamps are listed as an Endangered Ecological Community (EEC) under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and also under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Consequently, the conditions of approval require the provision of significant offsets to suitably compensate for the anticipated impacts to upland swamps. The SMP and conditions also require detailed monitoring of impacts, an extensive research program into remediating subsidence impacts on upland swamps ($3.5 million over 5 years), and remediation where feasible.

A draft Biodiversity Offset Strategy has been submitted by Illawarra Coal to DPE and is currently being considered in consultation with other affected agencies. The Biodiversity Offset Strategy must incorporate a process whereby the actual impacts of the development on upland swamps are regularly reviewed against predicted impacts, and suitable offsets provided to compensate for residual impacts. The approval also contemplated additional offset obligations for upland swamps affected following any approval of subsequent longwalls in Area 3B (ie Longwalls 14 – 19). Water NSW considers that, wherever practicable, offsets should be identified within the same general catchments, or at least the same Special Area, as the location of the biodiversity impact.

The Area 3B longwalls are also predicted to impact on parts of Wongawilli Creek, Donalds Castle Creek and various tributaries of these creeks (including WC21), as well as creeks that drain directly to Lake Avon. The development consent (condition 14 of Schedule 3) requires suitable offsets for the loss of water quality and loss of water flows to WaterNSW's storages, vegetation clearing and any other ground disturbance (including cliff falls) that may occur as underground workings progress, and for impacts caused by surface activities within the mining area.

As required by the conditions of the SMP approval, Illawarra Coal has reviewed and updated its swamp and watercourse management plans. The Department considered the revised documents in consultation with OEH, DRE and WaterNSW. All agencies requested a significant number of further changes. DPE has since received and considered a number of revisions of the swamp and watercourse management plans from Illawarra Coal. The final plans were approved on 10 July 2015.

2.3 Trigger, Action, Response Plans (TARPs)

Trigger, Action, Response Plans, or TARPs, are a common management tool used to manage risk in many industries, including the underground coal mining industry in NSW. TARPs involve a set of clear and quantifiable 'triggers'. When any one monitoring trigger is met, it automatically leads to a pre-defined management 'action' and to any pre-agreed mitigatory or remedial 'response'. Illawarra Coal personnel undertaking site monitoring and inspections must assess impacts and react according to the TARP.

Illawarra Coal's Area 3B SMP classifies all subsidence impacts and environmental consequences into four clear trigger categories within the TARPs included in its *Watercourse Impact Monitoring Management and Contingency Plan* and *Swamp Impact Monitoring Management and Contingency Plan* (see **Appendix 3** for a summary of Illawarra Coal's swamp and watercourses TARPs and **Appendices 4** and **5** respectively for full copies of those plans). The TARPs relate to identifying, assessing and responding to the potential impacts to watercourses or swamps from subsidence in Area 3B and have been prepared using knowledge gained from previous mining in other areas at Dendrobium. Once a subsidence impact or environmental consequence is identified, it triggers a series of actions according to the level or significance of the impact.

The four trigger levels are Levels 1, 2, 3 and 'exceeding prediction'. Responses to Level 2 and Level 3 TARP triggers typically require investigations and reporting by specialists and may require the development of Corrective Management Actions (CMAs). CMAs are developed in consultation with relevant stakeholders in order to manage an observed impact in accordance with the relevant approvals and may include a requirement for remediation.

TARP triggers are typically sequential, ie subsidence impacts or environmental consequences within an upland swamp or watercourse may initially be reported as Level 1 and later progress to Level 2 and maybe Level 3 if successive triggers are exceeded. For this reason, this report focuses on the most recent and/or highest TARP trigger for each feature.

In August 2014, the Commonwealth Independent Expert Scientific Committee (IESC) stated in relation to longwall mining engineering design, that "the difficulty of quickly finding suitable parameters to indicate impacts on peat swamps makes TARPs ineffective for managing the impacts of longwall mining". DPE does not fully agree with this position. In particular, DPE considers that soil moisture measurements and the use of shallow piezometers and hydrographs to indicate changes in water table and increased rates of groundwater level recession can be coupled with appropriate TARP triggers to provide strong early indicators of impacts on upland swamps. OEH has also noted that TARPs can provide an effective management framework, but must have performance triggers that are effective within a timeframe meaningful to a regulatory response. Until a better alternative is provided, DPE considers that TARPs remain a useful monitoring and management tool.

2.4 Subsidence Impacts and Environmental Consequences

A number of surface subsidence impacts and resulting environmental consequences either have been identified following the extraction of Longwalls 9 – 11, or else have the potential to occur. These include:

- rock and creek bed fracturing and resultant draining of pools;
- reductions in surface water flows and/or loss of surface flows to the sub-surface leading to loss of aquatic ecology and/or changes in aquatic habitat;
- iron staining;
- fracturing beneath swamps leading to either falls in groundwater level or increased rate of groundwater recession after rainfall events;
- reduced periods of saturated conditions and reduced soil moisture within the swamp substrate;
- species composition change and/or changes in vegetation communities;
- water-borne inputs to Lake Avon and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates; and
- reduced inflows into Lake Avon and Cordeaux River.

A summary of identified subsidence impacts as reported by Illawarra Coal up to September 2015 in its Longwalls 9 and 10 End of Panel Reports and impact summary reports for Longwall 11 was compiled by DPE (see **Appendix 2**). A total of 89 impacts have been recorded for mining undertaken in Longwalls 9 – 11 to date (see **Figure 4**). Recorded impacts have affected watercourses (52%), swamps (18%) and other features (30%).

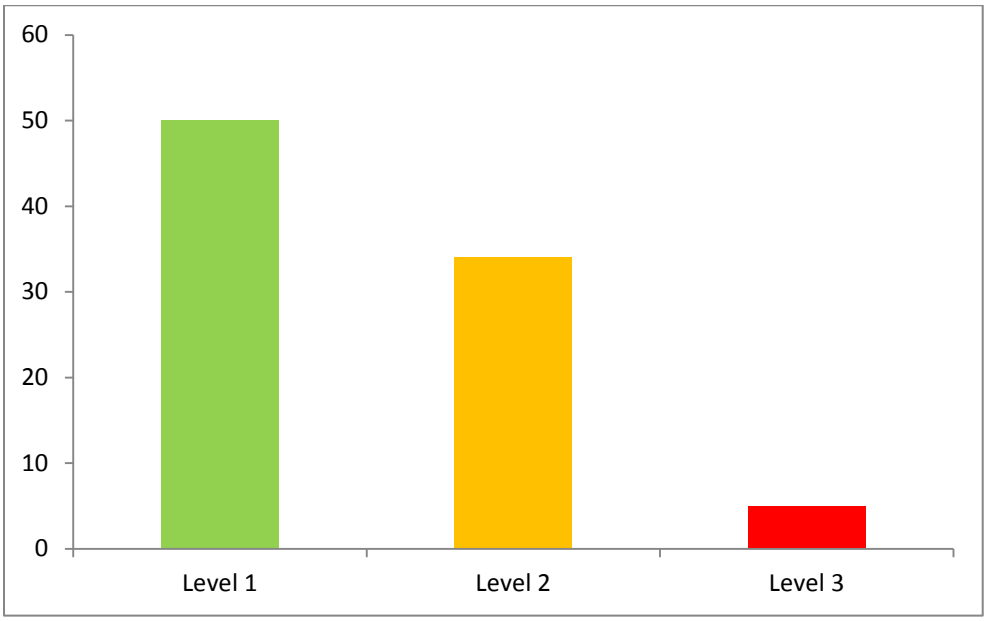

Figure 4: *Total number of triggers by trigger rating as reported by Illawarra Coal (Longwalls 9 – 11)*

The scale and significance of most impacts fall within predictions included in Illawarra Coal's Area 3B SMP. However, the impacts to a tributary of Wongawilli Creek, known as WC21, are considered to be greater than predicted.

The key subsidence impacts and environmental consequences are discussed in detail in **Sections 2.4.1** and **2.4.2** below.

2.4.1 Impacts on Watercourses

Significant Watercourses

Dendrobium Mine uses the Strahler stream classification, as was also used in the Southern Coalfield Inquiry (2008). Under this system, streams are classified according to the number of contributing tributaries, with headwater streams classed as first and second order streams and third and higher order streams being given the classification of 'streams of significance'.

The largest watercourse in the vicinity of Area 3B is Wongawilli Creek which is located between Areas 3A and 3B. Wongawilli Creek is classed as a third order stream and Donalds Castle Creek (within Area 3B) is classed as a second order stream. Wongawilli and Donalds Castle Creeks are permanent or perennial flowing streams with small base flows and increased flows for short periods of time during and after significant rainfall events (*Watercourse Impact, Monitoring, Management and Contingency Plan*). Other unnamed drainage lines within Area 3B are first or second order streams (see **Figure 2**).

Illawarra Coal deliberately set out its Area 3A and 3B mining domains in order to avoid undermining Wongawilli Creek and to minimise subsidence impacts on its stream bed and to maintain its water flow and water quality. Nonetheless, the Area 3B longwalls were predicted to impact on parts of Wongawilli Creek as well as Donalds Castle Creek, various tributaries of these creeks (including WC21) and a number of small creeks that drain directly to Lake Avon. **Table 4** lists the watercourses in or adjacent to Area 3B and the types of monitoring of subsidence impacts and environmental consequences undertaken by Illawarra Coal in each stream. The monitoring detailed in **Table 4** provides key data to assess compliance against the performance measures relevant to Wongawilli and Donalds Castle Creek as shown in **Table 3**.

Table 4: *Summary of watercourses in Dendrobium Area 3B, associated catchment and monitoring undertaken*

Watercourse	Catchment	Monitoring
Donalds Castle	Donalds Castle	Water quality, observations, photo, water level and flow
DC13	Donalds Castle	Water quality, observations, photo, water level and flow
Wongawilli	Wongawilli	Water quality, observations, photo, water level and flow
WC21	Wongawilli	Water quality, observations, photo, water level and flow
WC18	Wongawilli	Water quality, observations, photo and water level
WC16	Wongawilli	Water quality, observations, photo and water level
WC15	Wongawilli	Water quality, observations, photo and water level
WC12	Wongawilli	Water quality, observations, photo and water level
WC9	Wongawilli	Water quality, observations, photo and water level
WC8	Wongawilli	Water quality, observations, photo and water level
WC7	Wongawilli	Water quality, observations, photo and water level
WC6	Wongawilli	Water quality, observations, photo and water level
Native Dog	Native Dog	Water quality, observations, photo and water level
ND1	Native Dog	Water quality, observations, photo and water level
LA2	Lake Avon	Water quality, observations, photo and water level
LA3	Lake Avon	Water quality, observations, photo and water level
LA4	Lake Avon	Water quality, observations, photo, water level and flow
LA5	Lake Avon	Water quality, observations, photo and water level

Subsidence Predictions

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

1) the bedrock below the watercourse is fractured as a consequence of compressive or tensile strains and surface water then drains into this surface fractured zone (and potentially to lower strata); and/or
2) tilting, cracking, desiccation and/or changes in vegetation health result in changes in concentration of runoff and erosion which in turn alters water distribution (ie currents and flows) in the watercourse which in turn can lead to ponding or scouring.

In the Southern Coalfield, fracturing due to subsidence movements has generally not been observed where:

- valley closure is less than 200 mm; and
- conventional tensile and compressive strains are less than 0.5 mm/m and 2 mm/m respectively.

Surface cracking of streambeds is most commonly associated with valley closure and upsidence. These subsidence effects cause crushing and heaving of the rocks in the stream bed which leads to network of cross-cutting cracks beneath the floor of the valley. These cracks permit drainage of surface waters to a depth generally considered to be in the range of 10 – 20 m (unless these cracks directly connect with the underlying fractured zone, in which case drainage may continue to the collapsed zone and the goaf). This in turn leads to a loss of water holding capacity in the streambed which leads to partial or complete drainage of pools and/or overall loss of capacity of the stream bed to carry water (whether flowing or pooled) for extensive periods after rainfall events.

Based on the predicted subsidence movements for Area 3B, the bedrock below the watercourses is likely to fracture only where valley closure exceeds 200 mm (as shown in bold, in **Table 5** below). Illawarra Coal predicted that surface flows captured by the surface subsidence fracture network which do not connect to a deeper aquifer or the mine workings would re-emerge further downstream. It predicted that the depth of the surface fracture network in stream beds would be restricted to approximately 15 to 20 m below the surface.

Table 5: *Maximum predicted total subsidence, upsidence and closure at Wongawilli Creek, Donalds Castle Creek and the drainage lines resulting from extraction of longwalls in Dendrobium Area 3B*

Location	Longwall (LW)	Maximum predicted subsidence (mm)	Maximum predicted upsidence (mm)	Maximum predicted closure (mm)
Wongawilli Creek	After LW8 (Area 3A)	<20	110	140
	After LW9	<20	130	170
	After LW10	<20	130	190
	After LW11	<20	140	210
	After LW12	<20	140	210
	After LW13	<20	140	210
	After LW14	<20	140	210
	After LW15	<20	140	210
	After LW16	<20	140	210
	After LW17	<20	140	210
	After LW18	<20	160	210
Donalds Castle Creek	After LW9	1625	150	100
	After LW10	2025	280	190
	After LW11	2050	320	**230**
	After LW12	2050	340	**260**
	After LW13	2050	360	**270**
	After LW14-18	2050	370	**280**
Drainage Lines	DC13	1500	250	**225**
	ND1	2350	275	**425**
	WC15	2600	725	**700**
	WC21	2550	700	**700**

It was also considered possible that there could be localised areas along a number of drainage lines (including WC21, DC13 and DC15) which could experience small increases in the levels of ponding and flooding. This was predicted as most likely where maximum reverse tilts were predicted (ie upstream of the longwall chain pillars and goaf edges). It was also considered possible that there could be localised areas of increased bank scouring where maximum increased tilts were predicted (ie downstream of the longwall

chain pillars and goaf edges). Changes in the levels of ponding, flooding and scouring of the banks of the drainage lines were also possible where the existing natural gradients are relatively flat. The impacts resulting from these changes in surface water flows were expected to be small in comparison with those which occur during natural flooding conditions.

Overall subsidence effects in Wongawilli Creek and Avon Reservoir as a result of mining of Longwalls 9 and 10 have been less than predicted. However, subsidence effects at some locations along Donalds Castle Creek and WC21 have exceeded predictions. This is discussed in further detail below.

Wongawilli Creek and its Tributaries

There were 32 impacts recorded for Wongawilli Creek and its tributaries, of which 50% were rated as Level 2 (see **Figure 5**). The remaining 50% were rated as Level 1, and included impacts such as rock fracturing, minor uplift, changes in water appearance and minor rock falls. There was only one recorded impact in Wongawilli Creek itself, a Level 1 impact.

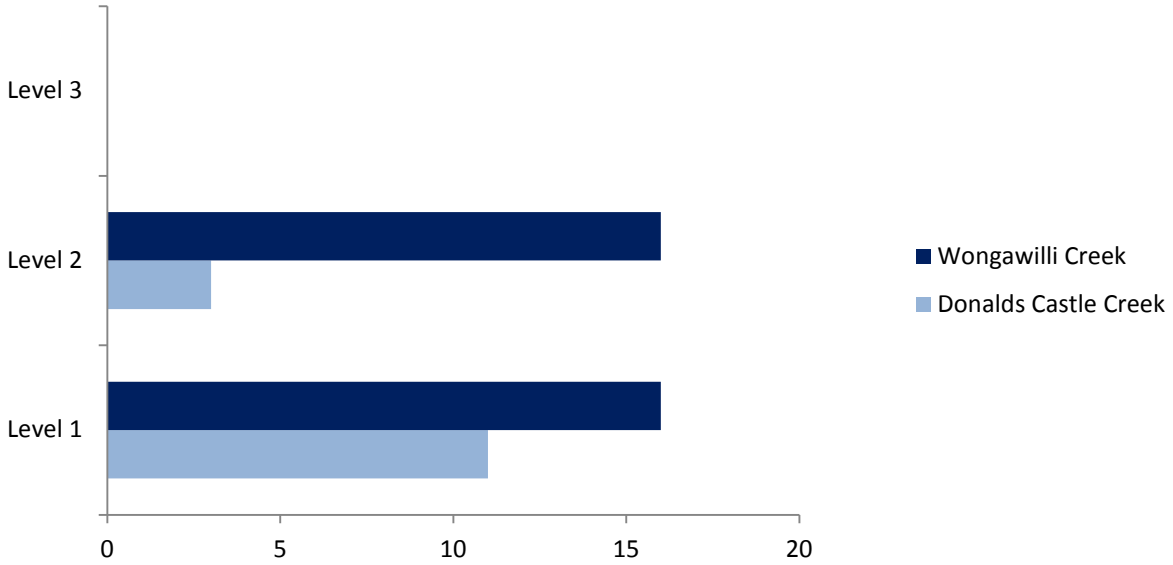

Figure 5: *Impact triggers associated with key streams and their tributaries (Longwalls 9 – 11)*

The longwalls in Dendrobium Areas 3A and 3B have been set back from Wongawilli Creek so that the maximum predicted valley closure at the mapped rockbars and riffles is 200 mm (see **Table 5**) and the maximum predicted conventional strains anywhere along the creek are 0.5 mm/m tensile and 2 mm/m compressive. The maximum predicted total conventional tensile and compressive strains at Wongawilli Creek, resulting from the extraction of the existing mining domains and Area 3B are both less than 0.3 mm/m. Illawarra Coal and its consultants concluded that it is unlikely that any significant fracturing or surface water flow diversions would occur along Wongawilli Creek. While minor fracturing could still occur in the bed of the creek it was expected to be isolated and of a minor nature and to not result in any significant surface water flow diversions.

After extraction of Longwalls 6 - 8 in Area 3A and the extraction of Longwall 9 in Area 3B, a fracture was identified in Wongawilli Creek. The rock fracture is in the base of WC_Pool 43a and has a length of approximately 2 m and a width of up to 0.02 m. There was no observed flow diversion associated with the fracture and the pool remains full and flowing. This Level 1 impact is consistent with predictions.

Nonetheless, WaterNSW considers that some loss of flows from Wongawilli Creek may be occurring, but that the sensitivity of Illawarra Coal's monitoring has not been able to identify such losses.

Based on the available information, DPE is satisfied that there have been no unacceptable impacts on Wongawilli Creek and that the relevant performance measure of 'minor environmental consequences including, minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality' has not been breached.

- *Impacts at Tributary WC21*

WC21 is a stream some 3 km in length, of which more than 2 km has been or will be undermined. The watercourse transects Longwalls 9 – 15 and is associated with Swamp 8, as well as Swamp 10 and Swamp 13. WC21 is a significant and previously perennial tributary of Wongawilli Creek with a large number of pools and rockbars. WC21 is a second order stream in the area where it is currently impacted. Upstream of its confluence with WC21A (see **Figure 2**), it is a first order stream. Because WC21 directly overlies the longwall panels, the Area 3B SMP application predicted that the full length of WC21 directly above longwall extraction would be subject to surface fracturing to a depth of 15 m – 20 m. It also predicted that it was possible that surface flow diversion into the new fracture network would cause temporary surface flow diversions. However, the SMP predicted that any diverted surface water flow would re-emerge downstream of this fractured area. The SMP also predicted reversals in grade along sections of WC21.

Of the 16 Level 2 watercourse impacts recorded within the catchment of Wongawilli Creek for Longwalls 9 - 11, 10 have occurred within WC21. These impacts involved significant rock fracturing, reduction in water levels in pools and an absence of surface flows (see cover photo). Level 2 fracturing in rockbars has been observed in WC21. Since undermining of Longwalls 9 and 10, complete loss of flow has been observed in this watercourse in the area overlying the mined panels, this length being some 600 m during wet periods and longer in dry periods. The bed of the stream is sufficiently cracked that it seems incapable of containing significant runoff flows for more than a few days.

Some iron-stained water has been observed to be returning to the stream downstream of Longwall 9, but the returned flow has been measured by WaterNSW as lower than would be expected relative to upstream flows (Water Research Laboratory, measurements made on 22/07/2015 and 11/09/2015).

Illawarra Coal's Statement of Commitments which was provided in conjunction with Modification 6 and attached to the revised consent (as a requirement which must be carried out by Illawarra Coal) contains the following commitment with respect to watercourses such as WC21:

> *In the case of impacts exceeding those predicted (ie **major fracturing in the beds of streams leading to total pool water loss or complete loss of surface flow through controlling rockbars**) the Contingent Measure is "grouting and repair of significant surface water controlling features where it is appropriate to do so in consultation with [WaterNSW, DRE, OEH] and other stakeholders*.

DPE, WaterNSW and DRE all consider that the trigger in Illawarra Coal's Statement of Commitments has been exceeded for the length of WC21 which can no longer hold water.

WC21 will be further undermined by Longwalls 11 – 13 and, potentially, by future Longwalls 14 and 15. WaterNSW is also concerned that this increasing scale of water losses may be exceeding predictions and considers that management control actions, including investigation into the scale and depth of surface water diversion, should be implemented. WaterNSW's recommendation for further investigations into the scale and depth of surface water diversion is considered further in **Section 3**.

DPE, WaterNSW and DRE carried out an inspection of the subsidence impacts at WC21 on 12 May 2015. The three agencies also met on 17 July 2015. It was agreed that remediation action at WC21 by Illawarra Coal is required. Illawarra Coal's Statement of Commitments (see Appendix 4 of the mine's development consent) includes a commitment to implement contingent measures in the event predicted impacts are exceeded.

On 28 August 2015, DPE wrote to Illawarra Coal requesting it to prepare a remediation program for the impacts to WC21 by 31 December 2015. This action was taken under DPE's powers under condition 4 of Schedule 2 of the Dendrobium mine's development consent. The remediation program must be prepared in consultation with WaterNSW and include details of the proposed remediation works and the likely timing of implementation of the proposed works. Water NSW wrote to DPE on 15 September 2015 to express its view that further investigations at WC21 are required in order to understand where surface flows have diverted to, and to clarify the need for and potential efficacy of any proposed remedial methods. DPE has recommended such investigations in **Section 3.6**.

Whilst noting that the impacts at WC21 are greater than predicted, they are not currently considered by DPE to be a breach of the mine's performance measures. The performance measures specifically relate to Wongawilli Creek and Donalds Castle Creek, rather than their associated tributaries, including WC21. DPE assigned performance measures to Wongawilli Creek and Donalds Castle Creek in its conditional approval for the Area 3B SMP because they are the most significant watercourses within Area 3B. The Southern Coalfield Inquiry and also subsequent Planning Assessment Commission reviews of both the Bulli Seam Operations Project and the Metropolitan Coal Project all recommended protection of third and higher order streams, which is the nature of these two streams.

Donalds Castle Creek and its Tributaries

The upper reaches of Donalds Castle Creek are located in the northern part of Area 3B with 1.5 km of the creek located directly above the existing and proposed longwalls. As shown in **Figure 2**, upper reaches of Donalds Castle Creek are associated with a number of swamps (Swamps 1a, 1b and 15). The length of the creek within the predicted limits of 20 mm total upsidence and 20 mm total closure is approximately 2.4 km. However, the identified rockbars along Donalds Castle Creek are all located outside the extent of the longwalls, with the closest being 25 m north of Longwall 9.

Nevertheless, cracking was predicted to occur in Donalds Castle Creek, and such cracking was predicted to lead to a diversion of surface water flows into dilated strata beneath the stream bed. However, Illawarra Coal considered it unlikely that there would be any net loss of water from the catchment, noting that the depth of dilation and fracturing is expected to be less than 15 m and diverted water would likely re-emerge further downstream. It was noted during the agencies' assessment of the SMP that remedial measures may be required after completion of mining if there had been greater than minor impacts on water flows and pool levels.

It was also predicted by Illawarra Coal that reversals in grade could also occur along Drainage Lines DC13 (see **Figure 2**) and DC15.

Donald's Castle Creek and its tributaries have suffered 14 recorded impacts, of which three were rated as Level 2 and the remaining 11 as Level 1 (see **Figure 5**). Similar to Wongawilli Creek, Level 2 impacts relate to rock fracturing, reduced pool water levels and flow diversions beneath the creek bed. Fracturing in rockbars has been observed in Donalds Castle Creek, at a maximum of Level 2 on Rockbar 33. In general, fracturing has been observed to be uncommon in Donalds Castle Creek.

It is noted that the sections of Donalds Castle Creek and its key tributaries undermined by Longwalls 9 and 10 do not have any surface pools or rockbars. However, Swamps 1a, 1b and 5 occupy a substantial portion of the length of Donalds Castle Creek and its key tributaries and these swamps have experienced significant lowering of groundwater levels in the majority of shallow groundwater monitoring sites. Therefore, it is likely that rock fracturing has occurred beneath the swamp sections of Donalds Castle Creek and its key tributaries, but it is not directly observable unless the rock is outcropping. On this basis, it is possible that environmental consequences in terms of loss of flows and catchment yield from the Donalds Castle Creek catchment may be occurring without having been recognised by field inspections or in downstream flow gauging results.

OEH estimates a loss of 0.3 – 0.4 ML/day at the basal end of Swamp 1b and proposes that this has led to an increase in the number of cease to flow periods in Donalds Castle Creek downstream of this swamp. This is contrasted to the two reference swamps where the drainage lines downstream of the swamps have continuously flowed.

Nonetheless, in general, the impacts to Donalds Castle Creek and its tributaries appear to be in line with predictions in the Area 3B SMP. Key agencies will continue to monitor for impacts through the current reporting procedures and require remediation if necessary.

2.4.2 Impacts on Water Storages

A key concern is that near-surface cracking in the stream bases and valley floors may lead to losses of baseflow and diversion of waters that would otherwise be captured within the existing Sydney drinking water storages.

The western ends of Longwalls 11 - 18 lie within the DSC's Avon Notification Area. As was the case for Areas 1, 2 and 3A, no longwall extraction in Area 3B is proposed to take place below the stored waters of Lake Avon. Longwalls 9 and 10 are completely outside the Avon Notification Area and only a small sliver of Longwall 11 is within the Area. Longwalls 12 - 18 are set back from the Avon Reservoir Full Storage Level (FSL) by 310 m, 250 m, 260 m, 270 m, 230 m, 240 m and 240 m respectively.

Due to these standoffs from Lake Avon, Illawarra Coal does not expect that there would be a reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Avon. In addition, due to the substantial size of the Lake Avon system, it was predicted that there would be no measurable reduction in the quality or quantity of water in Lake Avon resulting from surface water or groundwater inflows.

Illawarra Coal predicted that any water-borne inputs to Lake Avon would likely be restricted to possible erosive export of fine sands and clays and/or ferruginous precipitates near the mouths of minor creeks designated LA2, LA3, LA4 and LA5 (see **Figure 2**). Illawarra Coal predicted that these water-borne inputs would result in negligible environmental consequences. These creeks are all very remote from the respective dam off-takes and outflows. Any mixing zone affected by this limited erosion would be localised around the point of input to the Lake and would be unlikely to have any detrimental effect on local freshwater ecology and unable to affect bulk water supply quality.

DPE's conditional approval for Illawarra Coal's Area 3B SMP was only granted after all key agencies were satisfied that it was highly unlikely there would be unacceptable or material impacts on the quantity or quality of Sydney's and Wollongong's water supply. Based on all available information, DPE is satisfied that so far there have been no unacceptable or material impacts from mining in Area 3B on Sydney's and Wollongong's water supply.

2.4.3 Impacts on Groundwater Resources

Groundwater impacts are an inevitable consequence of longwall mining. Whilst it is clear that groundwater held in the rocks immediately overlying the mined coal seam (ie the collapsed zone, or goaf) would quickly drain into the mine-water collection system, current predictions suggest that groundwater levels in upper aquifers (ie the Hawkesbury Sandstone) would be maintained at or near pre-mining levels. Vertical groundwater flow is predicted to be very slow within the upper strata overlying Area 3B, and unless a rapid channel is formed through direct vertical or sub-vertical fracturing (which was not predicted), the SMP indicates that it may take decades or centuries for surface waters to reach the mine. These predictions are primarily based on observed phenomena over and around previously-mined areas.

The characterisation of subsidence impacts on groundwater resources is heavily dependent on groundwater modelling undertaken prior to mining. Modelled predictions are based on assumed hydrogeological behaviour, calibrated by observed phenomena (mainly measured groundwater levels) over

and around previously-mined areas. Modelling is also based on baseline data for porosity, permeability and hydraulic pressure in each layer of the geological strata between the surface and the seam. Post-mining monitoring of these parameters provides a measure of changes induced by mining. Analysis of the groundwater reporting to the mine (including chemical analysis) also provides information on the source of that water.

Parsons Brinckerhoff has recently completed an extensive set of tests for Illawarra Coal to characterise pre and post mining permeability above Longwall 9. The results of this testing are described in **Section 2.6**.

The volume of groundwater extracted from Dendrobium Mine, known as goaf water, is licensed by DPI-Water. Chemical analysis of goaf water at Dendrobium suggests that approximately 20% of the goaf water in previously mining in Areas 2 and 3A is 'modern' (ie sourced from surface water or near-surface aquifers) (Parsons Brinckerhoff 2012 and Ecoengineers 2014). Insufficient data is currently available to confirm whether or not there is any contribution of modern waters to Area 3B goaf inflows.

The only performance measure in the relevant approvals which refers to groundwater losses relates to losses from shallow aquifers supplying baseflow to reservoirs and streams. To date, no significant groundwater losses in these shallow aquifers have been reported. Nonetheless, WaterNSW recommends expanding the shallow groundwater monitoring system to provide additional confidence in this conclusion.

2.4.4 Conclusions Regarding Impacts on Water Resources

It is critical to assess whether Illawarra Coal's mining in Area 3B has been complying with the performance measures relevant to water resources set out in its development consent and conditional SMP approval. A summary of DPE's assessment of compliance with the performance measures in the development consent and the SMP is provided in **Tables 6 and 7** below.

Table 6: *Development consent (DA 60-03-2001) performance measures relating to watercourses and water storages*

Reference	Condition	Condition Status
Subsidence impacts to Sandy Creek & Wongawilli Creek	The Applicant shall ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than 'minor impacts' (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary. *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.*	Ongoing. No subsidence impacts in Wongawilli Creek which exceed this standard have been reported to date.
Quality and quantity reductions in Lake Cordeaux, Lake Avon & Wongawilli Creek	The Applicant shall ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.	Ongoing. No water quality or quantity reductions in Lake Avon or in Wongawilli Creek which exceed this standard have been reported to date.

Table 7: *Area 3B SMP performance measures relating to watercourses and water storages*

Reference	Condition	Condition Status
Waterfall WC-WF54	Negligible environmental consequences including: • *no* rock fall occurs at the waterfall or from its overhang; • *no* impacts on the structural integrity of the waterfall, its overhang and its pool; • *negligible* cracking in Wongawilli Creek within 30 m of the waterfall; and • *negligible* diversion of water from the lip of the waterfall.	Not yet applicable. Waterfall WC-WF54 is unlikely to be affected until around LW17.
Wongawilli Creek Donalds Castle Creek	Minor environmental consequences including: • *minor* fracturing, gas release and iron staining; and	Ongoing.

	• *minor* impacts on water flows, water levels and water quality.	Only minor impacts on Wongawilli and Donalds Castle Creek have been reported to date.
Avon Reservoir	Negligible environmental consequences including: • *negligible* reduction in the quality or quantity of surface water inflows to the reservoir; • *negligible* reduction in the quality or quantity of groundwater inflows to the reservoir; and • *negligible* leakage from the reservoir to underground mine workings.	Ongoing. No water quality or quantity reductions in Avon Reservoir have been reported to date.

DPE generally considers that the performance measures relating to watercourses and water bodies have been met. However, methodologies for defining, measuring and assessing impacts may need to be improved and expanded to determine their extent and significance, particularly in respect of baseflow reductions and streamflow diversions to underlying aquifers. An expanded monitoring network in the shallow bedrock aquifer would also provide additional confidence in determining the extent and significance of impacts, particularly in respect of baseflow losses.

The impacts within WC21 remain a particular concern to WaterNSW and other agencies, given that the proposed Longwalls 12 – 15 are likely to extend and exacerbate these impacts. Similar impacts may also occur on other creeks like WC15, WC11 and creeks draining to Lake Avon by the mining of Longwalls 12 – 18. Close attention will be paid to the ongoing monitoring of flows and pool levels as additional longwalls are mined.

2.4.5 Impacts on Upland Swamps

Upland Swamps

Upland swamps are vegetated freshwater wetlands occurring in shallow basins located in low hills or mountainous areas. They occur in either low-slope headwater tributary valleys (headwater or hillslope swamps) that are characteristically derived from colluvial sand eroded from the ridgelines or along the riparian zone of the creeks within headwater valleys (valley infill swamps). Large swamps can display attributes of both swamp types and can grade from one to the other.

Upland swamps occur as a result of either one or a combination of the following mechanisms – a perched aquifer maintained within valley-infill sediments, groundwater baseflow seeping from shallow bedrock and regular saturation by rainfall or runoff of a thin layer of sediment above bedrock. Swamps often form where shallow, low permeability bedrock restricts vertical migration of groundwater. Shallow groundwater is forced to flow laterally/horizontally, with any runoff then joining other surface water in drainage channels. Valley infill swamps form in drainage channels where a combination of low slope, low floodflows, regular baseflow, and possible stream blockages and/or rockbar retention leads to a build-up of peaty and sandy sediments, further slowing water migration through the swamp.

Valley infill swamps are generally fed by a combination of stream flow and runoff, baseflow from shallow groundwater aquifers and rainfall. Headwater swamps are generally dependent on baseflow from shallow groundwater aquifers, rainfall and runoff and have no significant input from streamflow.

The swamps contain between one and all four of the recognised swamp vegetation communities on the Woronora Plateau (Fringing Eucalypt Woodland, Banksia Thicket, Sedgeland-heath complex and Tea Tree Thicket). The latter three communities are recognised as being components of the *Coastal Upland Swamp* endangered ecological community. The Hawkesbury Sandstone is the predominant source of sediment for the swamps. A number of swamps (particularly the valley infill swamps) terminate in rocky outcrops, exposed bedrock platforms or small waterfalls.

Desiccation of valley infill swamps can lead to changes in species distributions, increased oxidation of iron and other metal ions, destabilisation and subsidence of peat deposits, increased potential for further drying out during droughts and a consequent increase in fire risk, changes in hydraulic conductivity and a loss of

recharge potential (ie the swamp peat becomes hydrophobic and loses some of its water absorption capacity), 'flashier' flooding during storm events and an increased tendency for the containing valley to dry out faster following rainfall, leading to an increase in the number of cease-to-flow days for the associated stream.

There are five headwater swamps (Swamps 1b, 3, 4, 11 and 13) and eight valley infill swamps (Swamps 1a, 5, 8, 10, 14, 23, 35a and 35b) within Area 3B (see **Figure 2**). These swamps have a total area of 54.1 ha, of which 36.6 ha are above Longwalls 9 – 13 and the remaining 17.5 ha are above Longwalls 14 – 18. So far, Longwalls 9 – 11 have undermined Swamps 1a, 1b, 3, 5 and 8.

Subsidence impacts on upland swamps at Area 3B are managed under an approved TARP (see **Section 2.3**). Illawarra Coal undertakes structured mapping and monitoring of upland swamps, focussed on the following attributes:

- *water:* location, volume and flow characteristics;
- *significant features:* rockbars, pools and flow channels;
- *vegetation:* location, species, height and observed health; and
- *sediment:* composition, depth and moisture.

This monitoring provides key data to assess Illawarra Coal's compliance with the relevant performance measures (see **Table 3**). Shallow piezometers are embedded in the swamps to identify changes to the shallow perched aquifers that are a fundamental component of many swamps (particularly valley infill swamps, which seldom, if ever, dry out naturally). Piezometric monitoring of shallow groundwater levels is supplemented with monitoring of soil moisture profiles using dielectric moisture probes.

Water NSW considers that monitoring of groundwater within the swamp substrate should be supplemented with groundwater level monitoring in the shallow bedrock aquifer to enable an understanding of the interaction between perched aquifers and any underlying aquifers.

Subsidence Predictions

There are two broad mechanisms by which subsidence could cause changes in swamp hydrology, being:

1) the bedrock below the swamp fractures as a consequence of strains and, as a result, shallow perched groundwater (whether permanent or ephemeral) drains more readily into the fractured zone; and/or
2) tilting, cracking, desiccation and/or changes in vegetation health result in concentration of runoff and erosion which alters water distribution in the swamp.

Based on the predicted subsidence movements, Illawarra Coal predicted in its Area 3B SMP application that the bedrock below the upland swamps associated with the key watercourses in Area 3B was likely to be fractured following longwall mining, primarily due to subsidence-induced strains, as expressed through upsidence and valley closure (see **Table 8**).

Based on the subsidence movements outlined in **Table 8** and other relevant data, Illawarra Coal made the following predictions in its Swamp Management Plan:

- fracturing in the bedrock is likely to occur and could develop at any location that is directly mined beneath or in proximity to the longwalls;
- the lower reaches of swamps located in close proximity to drainage lines are likely to experience valley and slope related movements which is likely to result in fracturing;
- fracturing may result in diversion of surface flow into the dilated strata leading to loss of surface flow however it is likely that this diversion of surface flow would be to a depth of no greater than 15 m and would re-emerge downstream;
- predicted changes in grade are generally smaller than natural surface gradients within the swamps, therefore there are no overall predicted reversals of grade within the swamps;
- predicted differential total subsidence and total tilt within the swamps located directly above the longwalls could result in increased ponding above the centrelines of the longwalls and decreased water levels above the chain pillars and longwall goaf edges; and

- predicted changes in water levels within the swamps could impact on the distribution of vegetation within the swamp; however as the surfaces of the swamps are free draining, it is not anticipated that significant changes in water levels would occur as a result of tilt.

Table 8: *Maximum predicted total subsidence, upsidence and closure at upland swamps resulting from the extraction of longwalls in Dendrobium Area 3B*

Location	Maximum predicted total upsidence (mm)	Maximum predicted closure (mm)	Maximum predicted cumulative subsidence (mm)	Maximum predicted cumulative or travelling tilt (mm/m)	Maximum predicted cumulative or travelling hogging curvature (km^{-1})	Maximum predicted cumulative or travelling sagging curvature (km^{-1})
Swamp 1a	250	200	2000	20	0.30	0.45
Swamp 1b	200	150	1500	16	0.25	0.35
Swamp 3	100	100	2250	17	0.25	0.30
Swamp 4	100	100	2150	16	0.20	0.30
Swamp 5	357	275	2050	25	0.35	0.45
Swamp 8	700	600	2250	25	0.55	0.65
Swamp 10	275	275	2450	30	0.55	0.70
Swamp 13	400	400	2200	25	0.45	0.55
Swamp 11	200	200	2200	25	0.40	0.40
Swamp 14	650	650	2500	30	0.55	0.65
Swamp 23	300	300	2400	30	0.50	0.65
Swamp 35a	200	350	1000	25	0.55	0.7
Swamp 35b	175	425	<20	<0.5	<0.01	<0.01

A number of subsidence impacts to upland swamps have indeed resulted following extraction of Longwalls 9 – 11 (see **Figure 6**). There have been impacts to the level of the shallow aquifers within swamp sediments (ie loss of the permanent perched aquifer) and increases in the rates of groundwater level recession in response to rainfall after undermining when compared to recessions prior to undermining.

Figure 6 shows a total of 16 impacts. There are five Level 3 impacts and two Level 2 impacts in Swamp 5, one Level 1 impact in Swamp 8 and eight Level 2 impacts in Swamps 1a and 1b. Impacts to the various upland swamps are discussed in further detail below.

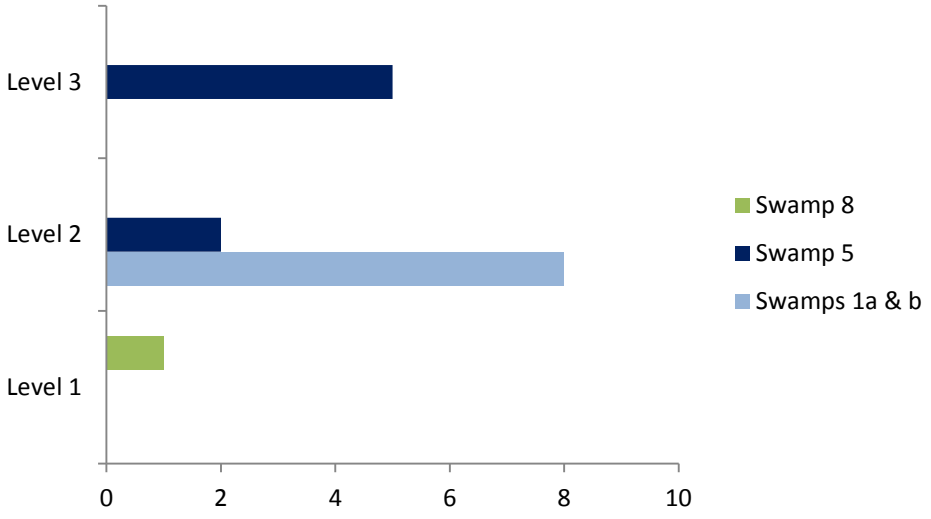

Figure 6: *Impact triggers associated with upland swamps as reported by Illawarra Coal (Longwalls 9 – 11)*

It is noted that OEH considers some of these trigger levels to be incorrectly reported. OEH has assessed the data presented for the boreholes in these swamps and concluded that greater than 80% of the swamp piezometers in each swamp either have groundwater levels below the lowest recorded baseline period and/or exceedance of the groundwater level recession rate recorded before mining. OEH equate such impacts to a Level 3 impact for each swamp. OEH also raised concerns regarding the availability of adequate baseline data.

DPE has noted OEH's assessment of the reported trigger levels. The impacts discussed below are based on impacts and trigger levels reported by Illawarra Coal up to September 2015 in its publicly available End of Panel Reports for Longwalls 9 and 10 and impact summary reports for Longwall 11 (see **Appendix 2**).

Figure 7 shows a representative hydrograph where the sediments in Swamp 5 are retaining very little water, even after heavy rainfall events. **Figure 8** shows a different part of Swamp 5 where the sediments do retain significant amounts of water, but the rate of water table recession (as shown by the steepness in the slope of the blue line) has increased. Shallow groundwater piezometers installed by Illawarra Coal and OEH have shown an increase in groundwater recession rates and/or significant changes in the shallow groundwater regime in the vast majority, if not all undermined piezometers in these swamps.

Swamps 1a, 1b and 5

The majority of the boreholes within Swamp 1a and 1b have recorded impacts. These impacts relate to shallow groundwater, including falls in groundwater levels below the lowest recorded baseline period, exceedance of the water level recession rate recorded before mining, dry boreholes and soil moisture levels which have dropped below baseline levels. Illawarra Coal has reported these impacts to Swamps 1a and 1b as Level 2 under the relevant TARP (Longwall 10 End of Panel Report). It is noted that many of these impacts have escalated from previously reported Level 1 impacts.

OEH Science Division also monitored Swamp 1b before and after the passage of Longwall 9 and found that longwall mining had impacted on:

- perched aquifer levels;
- soil moisture levels; and
- flow from Swamp 1b to the Donalds Castle Creek tributary.

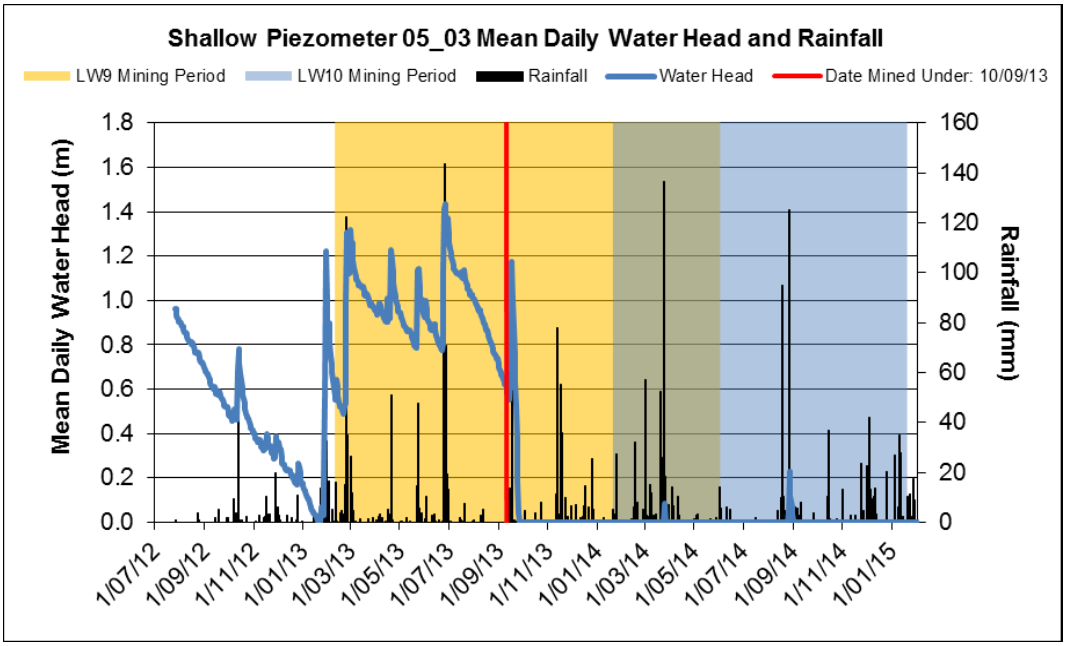

Figure 7: *Shallow groundwater levels in piezometer 05_03 in Swamp 5*

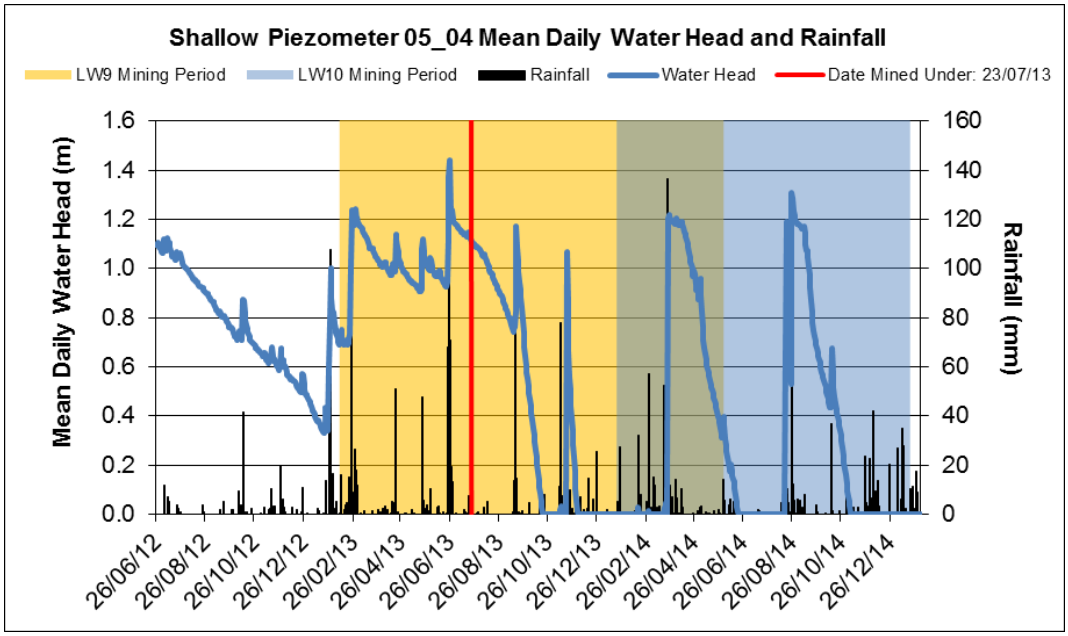

Figure 8: *Shallow groundwater levels in piezometer 05_04 in Swamp 5*

This contrasted strongly with aquifer levels and downstream flows for the two reference swamps also studied. OEH concluded that the overall effect of longwall mining was a loss of the consistent (ie perennial) perched aquifer within the undermined section of the swamp, a slower saturation of swamp sediments in response to rainfall and faster recession rates for soil moisture levels after rainfall events (together leading to increased desiccation or drying out of the swamp) and a reduced delivery of water to the downstream catchment. Using a preliminary water budget model, OEH calculated an unexplained shortfall of approximately 0.3 – 0.4 ML/day of flow for Swamp 1b, which are presumably a result of mining-induced subsidence impacts.

In regards to swamp vegetation, Biosis (2015) notes that data collected in Swamp 1a and 5 indicate a decline in species richness and diversity following mining of Longwalls 9 and 10, but that this does not currently represent a statistically significant reduction based on the three years of data that has been collected. Biosis also reported no evidence of trends over time for Swamp 1b, which has eight years of data collection. Biosis did report patches of dieback, changes in vegetation vigour and holes in the soil within Swamps 1a, 1b and 5, but states that similar effects have been observed in control swamps that have not been mined under.

The most recently-reported impact at Swamp 5 relates to shallow groundwater levels and was rated at Level 3. All recorded Level 3 groundwater-related impacts have progressed from lower trigger levels over time as mining of Longwalls 9 – 11 has progressed. The relevant Level 3 trigger is:

> ***Level 3:*** *Groundwater level lower than baseline level at* ***>80%*** *of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at* ***>80%*** *of monitoring sites (within 400 m of mining) within the swamp.*

An area of fracturing and flow diversion was observed at the basal step of Swamp 5, in the upper section of Donalds Castle Creek (Longwall 9 End of Panel Report). The fractures are up to 0.015 m wide and 2 m long and have a maximum uplift of 0.04 m. Flow was reported to have returned to the surface stream approximately 10 m downstream at the bottom of the basal step.

The shallow groundwater monitoring results indicate that the relatively impermeable bedrock base of each of these swamps has been fractured as a result of mine subsidence, causing a loss of structural integrity (ie the capacity to contain a perched aquifer). This has caused the perched aquifer to drain downwards into

the surficial fracture network, thereby altering natural groundwater levels and regimes within the swamp and leading to increased drying of the swamp.

Illawarra Coal has proposed investigations of subsidence impacts on the bedrock base and rockbars of Swamp 5 in its draft *Swamp Rehabilitation Research Program* (2015), as required under the Area 3B SMP approval. This document is still under assessment by DPE, DRE, OEH and WaterNSW.

Illawarra Coal proposes to continue monitoring of these swamps and associated reporting as required by the SMP. The latest results from this monitoring will be assessed to determine if there are any indications of changes to vegetation communities within Swamps 1a, 1b and 5, with the assessment to be made available to key stakeholders once complete.

Swamp 8

Swamp 8 is characterised by Banksia Thicket and Eucalypt Fringing Woodland and has been undermined by Longwalls 9 and 10. The proportion of the swamp which contains listed EEC vegetation (ie Banksia Thicket) is quite small when compared with the Eucalypt Fringing Woodland which is not included within the NSW Scientific Committee's EEC listing for upland swamps. Monitoring sites for Swamp 8 have shown an increase in groundwater recession rates and/or water level lower than the pre-mining baseline. This has been reported as a Level 1 impact.

Swamp 3

Swamp 3 is a relatively small (3.5 ha) swamp that sits above the pillar between Longwalls 11 and 12 at the western end of Area 3B. Longwall 11 undermined a piezometer in this swamp in March 2015.

Monitoring reports show that the post-mining rate of groundwater recession exceeded those recorded before mining. Nevertheless, the report does not categorise this impact under the Area 3B TARP, because there are no specific performance measures for this swamp under the SMP approval other than "*no significant environmental consequences beyond predictions in the Subsidence Management Plan*".

2.4.6 Conclusions Regarding Impacts on Upland Swamps

It is critical to assess whether Illawarra Coal's mining in Area 3B has been complying with the performance measures relevant to upland swamps as set out in its development consent and conditional SMP approval. A summary of DPE's assessment of strict compliance with the performance measures in the development consent and the SMP is provided in **Table 9** below.

Table 9: *Area 3B SMP performance measures relating to upland swamps*

Reference	Condition	Condition Status
Swamps 1a, 1b, 5, 8, 11, 14 and 23	Minor environmental consequences including: • *negligible* erosion of the surface of the swamps; • *minor* changes in the size of the swamps; • *minor* changes in the ecosystem functionality of the swamp; • *no significant* change to the composition or distribution of species within the swamp; and • *maintenance or restoration* of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.	Ongoing. No clear exceedance of the listed environmental consequences on Swamps 1a, 1b, 5 and 8 have been reported to date. However, see discussion below.
Swamps 3, 4, 10, 13, 35a and 35b	No significant environmental consequences beyond predictions in the Subsidence Management Plan.	Ongoing. No significant environmental consequences on Swamp 3 have been reported to date.

Nevertheless, it is clear that monitoring results identify that Longwalls 9 – 11 have impacted on every swamp that has been directly undermined or is located immediately adjacent to the longwall panel being mined. These impacts, as discussed above, mostly relate to increases in groundwater recession rates and/or significant changes in the shallow groundwater regimes. It is accepted by all agencies that all undermined piezometers within swamps have exhibited an increase in groundwater recession rates and/or water level lower that pre-mining baseline.

Nonetheless, DPE, which has responsibility for enforcing the conditions of the Area 3B SMP approval, does not consider that these impacts are breaches of the mine's performance measures relating to upland swamps. The performance measures in the approval do not directly consider shallow groundwater, but specifically relate to erosion, swamp size, ecosystem functionality, composition or distribution of species and maintenance or restoration of the structural integrity of the bedrock base of permanent pools or rockbars. Under the TARP within Illawarra Coal's approved *Swamp Impact, Monitoring, Management and Contingency Plan,* 'ecosystem functionality' is measured by changes in the extent of the groundwater dependent communities contributing to the swamps, specifically any changes in the proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex within the monitored swamps (see **Table 1** in **Appendix 3**). Illawarra Coal's vegetation monitoring is focussed on monitoring the extent of these communities and the species distribution within them. While groundwater is a key trigger within this TARP, is it not currently a component of the definition of 'ecosystem functionality'.

However, OEH and Water NSW both consider that the loss of structural integrity in the bedrock base of the swamps either already has or else will lead to greater than 'minor changes in the ecosystem functionality of the swamps' performance measures. OEH is of the view that shallow groundwater is fundamental to the ecological character and function of upland swamps and the definition of 'ecosystem functionality' should better reflect this. DPE will seek to better define this term when considering further approval of Longwalls 14 – 18.

To date, no TARP triggers have been exceeded which relate to the performance measures for erosion, swamp size, ecosystem functionality, composition or distribution of species and maintenance or restoration of the structural integrity of the bedrock base of permanent pools or rockbars associated with the swamps. DPE supports the use of adaptive management as the proposed Area 3B mine plan progresses to ensure that the relevant performance measures continue to be met.

Illawarra Coal has proposed that the longwalls in Area 3B which are not yet approved (ie Longwalls 14 – 18) would have the same void width and maximum mining height as Longwalls 9 – 13 (ie 305 m and 4.6 m, respectively). If the existing mining geometry is maintained, then all upland swamps that lie above Longwalls 14 – 18 (ie Swamps 3, 4, 10, 11, 13, 23, 14, 35a) will almost certainly be impacted in a manner similar to that described above for swamps 1a, 1b and 5 (ie loss of the permanently perched aquifer, loss of soil moisture levels and loss of flow to downstream tributaries).

It was noted during the assessment of the Area 3B SMP that there would be impacts on several upland swamps, particularly caused by mining the first three longwalls in Area 3B. Consequently, the conditions of approval require the provision of significant offsets to suitably compensate for the anticipated impacts to upland swamps, detailed monitoring of impacts, an extensive research program into remediating subsidence impacts on upland swamps ($3.5 million over 5 years) and remediation where feasible.

A draft *Swamp Rehabilitation Research Program* and Biodiversity Offset Strategy has been submitted to DPE and is currently being considered in consultation with other affected agencies (see **Sections 2.5.2** and **3.4** respectively).

2.4.7 Impacts on Aquatic Species and Threatened Fauna

Aquatic Species

Where there are large and persistent changes to watercourse hydrology, there is likely to be an aquatic ecology response. For example, aquatic species which do not have life-cycles adapted to temporary loss of aquatic habitat are likely to be relatively susceptible to changes in pool water level. However, where there are impacts to aquatic ecology caused by mine subsidence, they tend to be localised to the area of the watercourse physically subject to subsidence impacts.

The data collected prior to and following the extraction of Dendrobium Area 3A provides little evidence to suggest mining-related impacts have had any negative consequences on aquatic ecology. There was evidence at some potential impact sites of changes to aquatic ecology indicators that could have been related to mining; however Illawarra Coal's consultant (Cardno Ecology Lab) concluded that the impacts appeared transient and were only observable in some indicators.

In regards to Area 3B, iron staining, fracturing, flow diversions and elevated turbidity (in areas still flowing) has been observed at WC21 associated with the extraction of Longwalls 9 and 10. Area 3B aquatic ecology impact sites were not visited in 2014 as the biennial monitoring was not scheduled for this sampling period. However, there was no evidence in macroinvertebrate and fish data of any impacts to the aquatic ecology at Site 6 on WC21 or Site 14 on Donalds Castle Creek (Cardno 2015). Both these sites are downstream of the mining impacts observed in WC21 and Donalds Castle Creek. Cardno concludes that if any impacts to aquatic ecology did occur further upstream in these drainage lines they appear to have been localised to these affected areas.

WaterNSW and OEH considers this assessment and conclusion to be unsatisfactory as the affected sections of Donalds Castle Creek and its tributaries and WC21 all form part of Swamps 1a, 1b, 5 and 8, where the hydrology and moisture content in these swamps has been significantly affected.

Threatened Fauna

Illawarra Coal's fauna consultant, Biosis, has assessed the impacts of subsidence on threatened fauna species, being those that rely on groundwater or surface water, in the Longwall 10 End of Panel Report. Threatened species that are water-dependent and have been recorded in Area 3B include the Giant Dragonfly (Swamps 1a, 1b and 14) and Littlejohn's Tree Frog (suitable habitat identified along Donalds Castle Creek, DC13 and WC21).

- *Giant Dragonfly*

Mining in Area 3B was predicted to have a significant impact on the local population of Giant Dragonfly, which is listed as endangered under the TSC Act. The Giant Dragonfly has been recorded in Swamps 1a, 1b and 14, and suitable habitat exists for this species in all upland swamps within Area 3B. The Giant Dragonfly is an obligate, groundwater dependent, mire-dwelling species which relies on waterlogged sediments for burrowing (depositing of eggs) and the long larval stage (estimated between 10 and 30 years) where access to groundwater is required.

The Giant Dragonfly is a naturally rare species, which is very hard to monitor given its generally cryptic life cycle and limited knowledge concerning its preferred habitat and food requirements and the triggers for egg laying, larval hatching and metamorphosis. However, it seems apparent that changes to groundwater levels and the integrity of peat swamps could have an impact on local populations of this species, particularly permanent alterations to shallow groundwater regimes within upland swamps.

There are no performance measures in the Area 3B SMP approval specifically focussed on this species. Under the existing conditions of consent, Illawarra Coal is also required to implement a monitoring and reporting program which addresses threatened aquatic and terrestrial species and their habitats. Illawarra Coal does not undertake systematic monitoring of the Giant Dragonfly and instead undertakes monitoring

on an opportunistic basis (ie sightings are recorded), due to the difficulty of monitoring this species, particularly in its larval stage.

Despite the absence of systemic monitoring for the Giant Dragonfly, it is likely that the measured change to shallow groundwater regimes (discussed above) in undermined swamps has resulted in an impact on the known population in Swamps 1a and 1b. Given that the only other known population within Area 3B is in Swamp 14, which is proposed to be undermined, the loss of all known populations within Area 3B represents an impact on the local population. However, it is very difficult to know the exact extent of this impact and its significance. It can be noted that there are many other unaffected swamps in the catchment area that provide similar suitable habitat. Further work on the cumulative loss of habitat for this species is required to put this impact in context (see **Section 3.6**).

- *Littlejohn's Tree Frog*

Mining in Area 3B was predicted to impact on the local population of Littlejohn's Tree Frog, which is listed as a threatened species under both State and Commonwealth legislation.

There are no performance measures in the Area 3B SMP approval particularly focussed on this species. Under the existing conditions of consent, Illawarra Coal is required to implement a monitoring and reporting program which addresses threatened aquatic and terrestrial species and their habitats.

Monitoring of water flow, pool depth and numbers of Littlejohn's Tree Frog (tadpole and adult) has occurred over the past 2 – 4 years in Donalds Castle Creek, DC13 and WC21. There has been a recorded loss of breeding habitat due to cracking and fracturing of stream beds and subsequent sub-surface diversion of water. Biosis (2015) reports a total of 22 pools over 1.3 km of first and second order streams are now dry and no longer provide suitable breeding habitat. Frog monitoring reveals that adults and tadpoles are no longer present at DC13 and the populations of adults in both Donalds Castle Creek and WC21 are reduced.

Similar impacts were observed in Dendrobium Area 3A in watercourses SC10C and WC17. The cumulative impact on the regional viability of Littlejohn's Tree Frog from the loss of breeding streams above the Dendrobium Mine has not been assessed and warrants further investigation and reporting.

2.4.8 Conclusions Regarding Impacts on Aquatic Species and Threatened Fauna

The hydrological impacts as discussed throughout the report are likely to pose potentially significant environmental consequences in the short-medium term and potentially the long-term for the persistence of populations of Giant Dragonfly within the swamps and Littlejohn's Tree Frog within drained watercourses in Area 3B.

These impacts were acknowledged during the preparation and assessment of the Area 3B SMP. There is no indication that the impacts recorded to date have been beyond those predicted in the SMP.

OEH has recommended a quantifiable performance measure specifically relating to threatened species for any future approval of Longwalls 14 – 18.

2.5 Remediation

Remediation involves the repair or rehabilitation of impacts resulting from mine subsidence. Remediation opportunities, restrictions, techniques and impacts vary according to the feature being remediated. In the case of Area 3B, there is a need to particularly consider potential remediation of both watercourses and upland swamps.

2.5.1 Remediation of Watercourses

Subsidence impacts on watercourses include significant cracking of the streambed leading to partial or complete drainage of pools and/or loss of capacity of the stream bed to carry water (whether flowing or

pooled), superficial cracking, release of gas from cracks in rocks into pooled water and iron staining. These impacts and the potential for remediation are separately considered below.

Remediation of Drained Pools and Loss of Capacity to Carry Water due to Significant Cracking

Remediation of drained pools and watercourses typically involves drilling holes to a depth of 5 to 15 metres beneath the streambed and injecting the use of various fillers (either cement-based grout or polyurethane) under pressure to fill the network of cracks. A series of drillholes is constructed at appropriate intervals and filled with grout to form a sub-surface 'grout curtain', an impenetrable line of rock and grout material which prevents water passage. Water is trapped above this curtain, filling all remaining cracks and allowing surface flow to return.

Grouting techniques have improved over the past decade with major increases in knowledge and efficiencies resulting from remediation trials and successful remediation works. Sealing of cracks within watercourses and pools has been successfully undertaken at Metropolitan Colliery (in Waratah Rivulet) and West Cliff Colliery (in the Georges River).

In some instances, drainage of creeks and pools has occurred for a temporary period following mining but infill of the cracks has occurred naturally as a result of sediment deposition. The Bargo River was impacted by mining at Tahmoor Colliery resulting in significant reduction in surface flows for an 18 month period. However, following a major flow event the river has subsequently shown no obvious sign of subsidence impacts or water drainage.

It has been agreed between WaterNSW, DPE and DRE that remediation action at WC21 is required. It is highly unlikely that cracks in WC21 will infill naturally as a result of sediment deposition. On 28 August 2015, DPE wrote to Illawarra Coal and requested it to prepare a remediation program for the impacts to WC21 by 31 December 2015. The remediation program must be prepared in consultation with WaterNSW and include details of the proposed remediation works and the likely timing of their implementation.

It is highly likely that some degree of grouting will be required. However, limitations on access for personnel and equipment along WC21 may inhibit an effective and efficient grouting program or else lead to additional environmental impacts. Most equipment (including the drilling equipment) is able to be broken down into components which can be either hand-carried or else helicoptered in for on-site construction. Some clearing may be necessary for safe siting of equipment and to allow safe personnel access.

The recovery of flora and fauna within re-established pools and streams will depend to a large extent on connectivity with unaffected areas. In some instances full recovery of flora and fauna may take several years or decades. In other instances, re-establishment may occur relatively quickly. The consequences of this are further discussed in **Section 2.4.7** above.

Superficial Cracking within Creek Beds

This may include minor cracking on rock bars. Minor cracking would typically result in visual impacts only and would not require remediation. However, cracking can be associated with iron staining (see below).

Gas Releases

Cracked surface strata can result in the upwards migration and surface venting of methane gas from deeper strata. Visual impacts can occur where this gas is released in a waterbody, with gas bubbling through the water to the surface. These methane releases generally diminish to very low levels over a matter of months.

Methane gas is flammable and can be ignited, such as by a bushfire or lighter. There is some potential for safety concerns in the event that concentrated pockets of gas are released and ignited but typically the volumes are too small to sustain a flame for more than a few seconds. By reducing oxygen, gas releases can also be harmful to aquatic species and riparian vegetation.

Gas releases in Area 3B are not currently a concern.

Iron Staining

Iron staining of watercourses is associated with the release of groundwater (ie baseflow) which contains significant amounts of dissolved iron. Near-surface cracking of unweathered rock material (particularly beneath a watercourse) can lead to dissolution of iron from iron carbonates and similar minerals contained within the rocks. When water containing this dissolved iron returns to the surface (typically further down the affected watercourse), the dissolved iron undergoes an oxidation reaction, leading to the precipitation of iron oxides and hydroxides, which are reddish brown or black in colour.

These precipitates either bond to the surface of rocks in the stream, where they become effectively insoluble, or else feed iron-consuming bacteria and algae, leading to the production of orange-brown algal mats and films. A high level of growth of orange-brown algal mats and films can smother or be toxic to some flora and fauna within the creek or pool, leading to a change in species diversity and available habitat.

These impacts typically reduce over time as the reactivity of the recently-cracked rock mass is reduced. The impacts are primarily visual and remediation is generally not appropriate. Extensive iron staining is currently observed below Longwall 9 in WC21, but is not reported to be significant at the downstream confluence with Wongawilli Creek.

2.5.2 Remediation of Upland Swamps

Subsidence impacts on upland swamps include significant cracking of the rocky substrate leading to drainage of perched groundwater, cracking of rockbars and erosional scours. Significant vegetation changes may take place as a secondary result of these impacts. This may include invasion of exotic or other native species (such as wattles) when swamps are drained.

Drainage of Groundwater

Cracking of the bedrock underlying swamps can lead to drainage of perched shallow groundwater aquifers, resulting in the swamp sediments drying out, which in turn leads to long term changes in the vegetation structure. It may also lead to surface outflows from the swamp diminishing, thereby reducing downstream stream flows.

Potential grouting of the cracks within the retaining rockbar and/or the basal substrate of the swamps is the main method quoted by Illawarra Coal, and other mining companies, to try and reinstate groundwater levels within swamps. However, the use of a pattern of horizontal or angled drillholes to deliver grout to reinstate the previous impermeability of the underlying bedrock has only been proposed at the conceptual stage. Drilling programs are restricted by the presence of overlying swamp sediments and thick vegetation, making access extremely difficult.

Further, it remains uncertain whether the subsidence impacts on the perched aquifer are primarily restricted to the drainage line beneath valley infill swamps or if larger scale impacts are also occurring to aquifers feeding the swamp from the sides of the containing valley. If the aquifers feeding the swamp are also significantly drained, then it could make successful remediation of a swamp which is significantly groundwater-dependent extremely difficult.

This kind of remediation, while theoretically possible, has not been carried out by any mining company in NSW to date. Agencies are unaware of successful swamp remediation being completed within Australia which has resulted in reinstatement of the perched aquifer and groundwater inputs into the swamp.

Condition 15 of DPE's SMP approval for Area 3B requires the development of a Swamp Rehabilitation Research Program. A draft research program has been submitted by Illawarra Coal and considered by the relevant agencies in detail. Proposed actions identified in the draft research program include:

- continuation of a connective fracturing research project;
- trialling of rock fracture sealing within swamps including the use of injection grouting;
- use of 'knick point' controls, which involve the use of erosion control measures such a coir log dams in identified erosional flow paths to slow flow paths and reduce the potential for erosion; and
- assessment of monitoring data including installation of additional monitoring sites.

The Swamp Rehabilitation Research Program is still under assessment by DPE, DRE, OEH and WaterNSW. The four agencies have agreed to meet separately following the release of this report to finalise this program in order for the proposed research to be undertaken. The results of the research program, once finalised, are likely to substantively inform the possibility and likelihood of swamp rehabilitation in the future.

Surface Cracking and Surface Erosion

Surface cracking within the upland swamp sediments may result directly from subsidence movements or as a result of drying out due to drainage of water. Filling of cracks with soil or soil substitutes can be undertaken. However, soil cracking is typically minor in extent.

East Wolgan Swamp was impacted by Springvale Colliery and/or Angus Place Colliery operations in 1998. Piping and erosion occurred above the bedrock deep within the swamp sediments, which caused sections of the surface of the swamp to collapse into 'sinkholes'. The combination of cracking of underlying bedrock (ie groundwater loss) and the high mine water discharges being sent through the swamp at the time, possibly in conjunction with heaving of the bedrock surface caused by upsidence, is thought to be the cause of the unusual piping and erosional impacts within this swamp.

Remediation at East Wolgan Swamp is currently being undertaken by Centennial Coal using sandbags to fill the lower sections of the eroded swamp sediment with hay bales and brush matting placed on the surface to slow and spread the water flow within the swamp during rainfall events. The remediation has not focussed on the more significant loss of groundwater inputs but rather has primarily had an aesthetic focus in filling the erosional scours. The long term success of this remediation program has not yet been proven; however, the initial results are promising.

2.5.3 Conclusions Regarding Remediation

Remediation of cracking within watercourses has been successfully undertaken at a number of sites within the Southern Coalfield but requires significant cost and resources and is potentially limited by access.

Remediation of swamps damaged by subsidence has not yet been proven to be viable. Remediation has typically been limited to the most accessible and obvious impact areas, such as repairing of rockbars and erosional scours.

DPE has required Illawarra Coal to undertake a significant ($3.5 million) research program focusing on swamp rehabilitation. The results of the research program, once finalised, are likely to substantively inform the possibility and likelihood of success of swamp rehabilitation in the future.

2.6 Groundwater and Surface Water Modelling

2.6.1 Impacts of Longwall Extraction on the Overlying Rock Mass

When a longwall panel is extracted, the overlying unsupported rock strata break and collapse into the extracted void. This zone of broken, collapsed roof rock which fills the extracted void is known as the caved or 'collapsed zone' (commonly called the 'goaf') (refer to **Figure 3**).

Above the goaf, the rock strata largely remain in place, but strata sag downwards under their own weight towards the goaf and consequently suffer significant bending, fracturing, joint opening and bed separation. This zone is known as the 'fractured zone'. The fractured zone commonly comprises two sub-zones. The

lower zone is characterised by significant vertical or sub-vertical cracking and joint openings, which leads to large increases in vertical groundwater transmissivity.

The upper part of the fractured zone is characterised more by bed separation (or delamination). This increase in horizontal openings within the sagged rock mass may not lead to significant increases in vertical groundwater transmissivity. This upper part of the fractured zone is therefore commonly included in the overlying 'constrained zone', where the rock strata remain essentially intact. These three zones are in turn overlain by the surface zone, which may develop the kind if surface cracking described in **Section 2.4**.

Where the longwall panel width-to-depth ratio is high and the depth of cover is shallow, the fractured zone can extend all the way from the seam to the surface. Where the panel width-to-depth ratio is low, and where the depth of cover is high, the fractured zone does not normally extend from the seam to the surface. Because the longwall width in the first part of Area 3B is wide (leading to an overall extracted void width of 305 m), the fractured zone is also high. This makes the question of whether it is predicted to extend to the surface (or whether it does so in actuality) a critical consideration.

However, the height of the fractured zone cannot simply be predicted as a function of longwall panel geometry. In some circumstances, the stiff, competent nature of particular strata will lead to bridging across the panel. More commonly, the presence of aquitards (such as claystones and mudstones) within the strata inhibits vertical transmissivity of groundwater.

2.6.2 Groundwater Modelling

Appropriate groundwater modelling is an important feature for any major underground mine, and in particular for mines operating in a water catchment area. Groundwater modelling is required in order to predict and understand the impacts of longwall extraction on groundwater resources found in the rock mass overlying the extracted longwall panels.

A requirement of both the Dendrobium development consent and the Area 3B SMP approval is the development of a numerical groundwater model to predict groundwater impacts associated with longwall mining. The assessment of potential impacts of longwall mining in Area 3B on groundwater has been conducted principally by numerical groundwater modelling. These models have been developed based on hydrogeological conceptualisations of the region, multiple data sets which supply information on groundwater behaviour within each of the region's aquifers, the region's geology, its surface elevation, climate and streams, and characterisation of aquifer properties from field investigations at Dendrobium Mine and other mines in the Southern Coalfield.

The prediction of impacts is based on ground deformation models developed by geotechnical engineers based on observations of subsidence caused from the extraction of longwalls. Geotechnical and hydrogeological measurements over numerous longwalls at Dendrobium Mine and other locations have been used by various authors to predict the height of connective cracking or the associated groundwater depressurisation over mined longwalls. A summary of the key hydrogeological modelling reports prepared since 2012 relating to Area 3B is shown in **Table 10**.

Table 10: *Key hydrogeological modelling reports*

Key Hydrogeological Modelling Reports	Associated Documentation
Coffey, 2012a *Groundwater Study Area 3B Dendrobium Coal Mine Numerical Modelling*. Prepared for Illawarra Coal, dated October 2012	Provided as Attachment C to Illawarra Coal's SMP Application documents in October, 2012
Coffey, 2012b *Groundwater Study Area 3B Dendrobium Coal Mine Data Analysis* (2nd edition). Prepared for Illawarra Coal	This report was prepared for Illawarra Coal. It has not been publicly released. It is the basis for further modelling completed by HydroSimulations
HydroSimulations, 2013 *Dendrobium Area 3b Groundwater Model: Swamps, Stream Flows and Shallow Groundwater Data*. For Illawarra Coal, October 2013	Prepared to provide background to comply with condition 13 of the Area 3B SMP approval, but not publicly released
HydroSimulations, 2014a	Provided as part of the documentation supporting

Dendrobium Area 3b Groundwater Model Revision: Swamps, Stream Flows and Shallow Groundwater Data, March 2014	Illawarra Coal's application to DSC to mine Longwalls 12 to 18 in the Avon Dam Notification Area
HydroSimulations, 2014b *End of Panel Groundwater Assessment for Dendrobium Longwall 9 (Area 3B)*, August, 2014.	Provided as Attachment F to Illawarra Coal's Longwall 9 End-of-Panel Report, provided on 26 September, 2014
HydroSimulations, 2014c *Hydrogeological analysis regarding DSC's requirements for mining within the Avon Notification Area*, 15 November 2014	Attachment supporting Illawarra Coal's application to DSC to mine Longwalls 12 to 18 in the Avon Dam Notification Area
HydroSimulations, 2015a *End of Panel Groundwater Assessment: Longwall 10 (Area 3B)*, May 2015	Report provided as an attachment to Illawarra Coal's Longwall 10 End-of-Panel report on 15 May 2015
HydroSimulations, 2015b *Estimated Height of Connected Fracturing above Dendrobium Longwalls*, August 2015	Submitted as part of the documentation supporting Illawarra Coal's application to mine Longwalls 12 to 18 within Avon Dam Notification Area. The report has not been publicly released

A sub-regional groundwater model for the Area 3B longwalls was originally prepared by Coffey Geotechnics Pty Ltd to support the Area 3B SMP application (Coffey 2012a). The Area 3B SMP was approved by the Directors-General of DPE and NSW Trade & Investment with a full awareness of the predictions of the modelling presented in Coffey (2012a).

The predicted ground deformations in the Coffey (2012a) model for Longwalls 9 – 18 were based on an empirical formula developed by Coffey's Mr Paul Tammetta. Following the release of this report, Mr Tammetta published his methodology in the paper *'Estimation of height of complete groundwater drainage above mined longwall panels'* in a peer-reviewed journal.

The stated purpose of the groundwater model in Coffey (2012a) was to estimate:

- impacts of mining in Area 3B on Lakes Avon and Cordeaux;
- groundwater inflows into the Area 3B workings; and
- impacts of extending some of the longwalls closer to Lake Avon.

Coffey then modified this model to conduct sensitivity analysis of the impact of extending the length and height of the Longwalls 9 to 18 in Area 3B. This subsequent report was titled '*Groundwater Study Area 3B Dendrobium Coal Mine Data Analysis* (2nd edition)' (Coffey's 2012b). This report was presented to Illawarra Coal, but was not made available to DPE or other agencies.

Illawarra Coal contends that Coffey's groundwater model is very conservative and could be equated to a worst case situation. This is due to the height of groundwater desaturation in the rock strata above the goaf allowed for by Coffey. The desaturation zone adopted for the model was based on a literature review by Mr Tammetta.

DPE's view was that the differences between Illawarra Coal's and Mr Tammetta's views on the height of desaturation could not be fully resolved prior to approval of the SMP. Consequently, DPE addressed this uncertainty by including in the SMP approval firm requirements for Illawarra Coal to conduct:

- revised groundwater modelling;
- detailed groundwater monitoring; and
- a report which includes a model describing both measured and predicted height of cracking above existing and proposed longwalls.

The revised groundwater model was required to:

- include detailed consideration of surficial aquifers, swamps and watercourses;
- include all available data on groundwater levels; and
- model baseflow contributions for all sub-catchments from baseline (i.e. prior to the extraction of Longwall 9) until 30 years post-mining, using 5-yearly increments.

HydroSimulations was engaged by Illawarra Coal to address these requirements and was provided with components of the modelling used in the two Coffey reports, but not the actual model itself.

The numerical groundwater model developed by HydroSimulations uses a 'finite difference' model (MODFLOW), applied to a grid of rectangular model cells. HydroSimulations rebuilt and modified the Coffey (2012b) model by adding a thin (2 m thick) surficial layer to represent the swamp deposits (where they exist) and weathered soil and rock (ie the 'regolith'). To model stream interactions with groundwater it used the Stream Flow Routing boundary condition in place of the method used by Coffey.

A number of further modifications to the Coffey model were made by HydroSimulations (see HydroSimulations (2014a)). The most significant of these were:

- the estimated height of connective fracturing was modified using the unpublished method of Ditton (2012), rather than Tammetta (2013) which was used in Coffey (2012a & 2012b);
- time-variable material properties for the fractured zone. Coffey used stacked MODFLOW Drain boundary conditions. This was replaced with drain boundaries in the mined seam and time-variable material properties in the continuous fractured zone above the longwall, as suggested by Ditton (2012);
- use of the Richards' equation, as opposed to pseudo soil functions or traditional MODFLOW saturated-only groundwater flow simulation, to enable modelling of flow in the unsaturated fractured zone;
- a revised land surface based on Airborne Laser Survey elevation data and the Tahmoor Colliery's 50 m digital elevation model;
- the predictive model was extended to simulate a 30-year post-Dendrobium mining period (30/03/2053, rather than 05/06/2040); and
- the verification period was rebuilt and extended due to it not being supplied by Coffey, and a requirement from DPE to extend the model simulation from 05/11/2009 to 31/12/2013.

The numerical model reported in HydroSimulations (2014a) was then used to compare observed groundwater levels following completion of Longwalls 9 and 10, as reported in the relevant End of Panel reports. These reports present mine inflows, groundwater salinity ranges and measured drawdowns compared to those predicted by HydroSimulations.

The regional groundwater models developed by HydroSimulations and now used at Dendrobium Mine use site specific data to determine the height of desaturation, including data from a network in excess of 1,000 piezometers in approximately 100 boreholes at Dendrobium.

The HydroSimulations Longwall 9 End-of-Panel report found that drawdowns were higher than expected in the upper and lower Hawkesbury Sandstone and impacts on swamp water levels were generally greater than predicted. This was due to the influence of surface cracking not being included in the numerical model. This was an area recommended for further enhancement of the model. The groundwater level impacts on underlying formations were generally consistent with predictions.

The HydroSimulations End-of-Panel Longwall 10 report found that mine inflows and drawdowns were generally within expectations.

In 2012, Illawarra Coal engaged Parsons Brinckerhoff to peer review the results of water analysis and the interpretation of the height of connective fracturing as reported by Heritage Computing (now HydroSimulations). The peer review states that "the use of standard hydro-geochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux". However, the report also acknowledged limitations in the available dataset, notwithstanding that this review is based on one of the most comprehensive datasets available for the Southern Coalfield.

Most of the change in aquifer properties occurs within the collapsed zone (or goaf). Changes in aquifer properties above the collapsed zone are less severe and largely restricted to increases in storativity (which are primarily associated with horizontal bed separations). However, groundwater drawdown due to sudden storativity increases at lower depths will ultimately impact the surface, either directly (as seepage from watercourses or lakes to satisfy the drawdown), or by intercepting baseflow. Estimating the length of time involved in re-establishing post-mining hydrogeological equilibrium, and the level at which deep and

shallow piezometric levels will re-establish in this regime, is a key uncertainty for modellers, regulators and resource managers.

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

Predictions of fractured zone dimensions at Area 3B refer to geotechnical fracturing behaviour, and are not necessarily directly related to a groundwater responses resulting from increased vertical permeability. Evidence from piezometer monitoring can provide useful data points to ascertain whether there is direct connectivity to the collapsed zone or not. Post-mining equilibrium conditions may not stabilise until some decades or even centuries after mining ceases

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

Parsons Brinckerhoff and Illawarra Coal have completed testing to characterise the pre and post mining permeability above Longwall 9. The investigation key site for this testing was a group of nine vertical boreholes on a ridgeline near the centreline of Longwall 9, eight of which included some casing near the surface or at other horizons and all of which were subject to a suite of instrument and other testing, including core and downhole logging, packer and borehole interference permeability testing, extensometer and tracer testing. Both before and after Longwall 9 mined beneath the test site, instruments were used to quantify the changes to vertical and horizontal permeability in the strata overlying the longwall panel, including the Bulgo Sandstone, Hawkesbury Sandstone and the Bald Hill Claystone (which is located between these two sandstone strata).

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

Most post-mining test bores showed decreases in groundwater levels and strong downward hydraulic gradients, particularly in the lower Bulgo Sandstone. However, the testing indicated that post-mining groundwater levels in the upper parts of the Hawkesbury Sandstone had not been lowered, implying that perched conditions were maintained in the upper Hawkesbury Sandstone after mining.

Increases in hydraulic conductivity were observed in every geological unit, but were not evenly distributed. The greatest increases were in the lower Bulgo Sandstone and around the Bald Hill Claystone, and the lowest were within the upper Bulgo Sandstone.

The study suggests that the increased bulk porosity in the strata overlying a single longwall panel is in the order of 2.7 gigalitres. Most of this increased porosity would occur in the goaf and the fractured zone. However, some of it would reflect bed separation and delamination in the constrained zone which would be expected to lead to (at least) a temporary reduction in baseflows at the surface.

In contrast to pre-mining testing in which no breakthrough was observed, horizontal tracer testing after the passage of Longwall 9 resulted in breakthrough in about 40 minutes. No breakthrough in tracer was observed in either the pre-mining or the post-mining tests of the Bald Hill Claystone and this indicates that the vertical conductance was below the detection limit of the test.

Activated carbon samplers deployed in streams upstream of the research site detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths either existing or induced between the research site and adjacent streams. Sampling of water from the underground mine suggests there is no connection established between the tested bores and the goaf.

Although current observations do not allow a precise measurement of the height of intense fracturing using any criteria (and the boundaries are gradational in any case), most evidence suggests that the zone of most intense and vertically connected fracturing extends into the base or bottom half of the Bulgo Sandstone. The Hawkesbury Sandstone, particularly the mid to upper levels are considered to be part of the 'constrained zone', where ground deformation is characterised by sagging and some horizontal bed separation or delamination, but no significant increase in vertical transmissivity of groundwater.

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

On the basis of the available data and the Parsons Brinckerhoff review, Illawarra Coal considers that the height of desaturation used in the HydroSimulations model is conservative and likely to be appropriate. There is a requirement for this model to be to the satisfaction of the Secretary of DPE. To date no such formal 'satisfaction' has been sought by Illawarra Coal or expressed by DPE.

Agencies recognise the work Illawarra Coal and its consultants are undertaking in relation to connective cracking and consider that it is utilising leading technology and is providing worthwhile, important and useful information. Nevertheless, while more information regarding the predicted height of fracturing is becoming available, there are a still a number of questions and concerns that remain unanswered or are unclear.

Recent Stakeholder Group and Media Concerns in Relation to the Groundwater Modelling

On 14 July 2015, the National Parks Association (NPA) circulated a letter titled *Concerns arising from flawed groundwater impact assessments in NSW,* to various Ministers, Members of Parliament, senior executives of various Departments and the media. The NPA letter raised a number of concerns with the groundwater assessments for longwall mining in Area 3B and also those included in the Environmental Impact Statement for the Springvale Mine Expansion Project which was under assessment at the time.

The Sydney Morning Herald subsequently published an article titled *BHP's coal mine approved in Sydney's catchment without groundwater assessment* (31 July 2015), which questioned the adequacy of the model and reiterated NPA's concerns.

NPA's concerns were primarily in relation to the:

- assumed height of extraction within the coal seam, as used in the groundwater model ;
- predicted height of cracking above the extracted coal seam;
- Illawarra Coal's decision to employ a second groundwater consultant (ie HydroSimulations); and
- predicted impacts to streams, groundwater and upland swamps.

DPE considers that, while the water modelling work done at Area 3B is significant and its predictions are important, the critical matters associated with the SMP approval are whether its performance measures are robust and whether they are being complied with.

Notwithstanding this, DPE are proposing to engage an independent expert to review and evaluate the databases and interpretations of monitoring data on which the empirical models have been based. See **Section 3** for further details.

2.6.3 Surface Water Flow Modelling

Since 1999, Illawarra Coal has engaged Ecoengineers Pty Ltd (Ecoengineers) to model, predict and assess mining impacts on surface water resources and near-surface aquifer resources above Dendrobium Mine. Modelling by Ecoengineers is undertaken using RUNOFF2005.

The two End-of-Panel reports for Longwalls 9 and 10 include appendices by Ecoengineers which report mining-related impacts on these water resources, as measured by water quality and stream flow. In general, no significant impacts have been detected by Ecoengineers for either water quality or quantity.

However, WaterNSW does not support the flow modelling methodology used by Ecoengineers to undertake its water flow prediction and impact assessments. Two external peer reviews of Ecoengineers' reports have been commissioned (one by WaterNSW and the other by the Dendrobium Community Consultative Committee). Each of these have identified a number of deficiencies and made recommendations for improved modelling.

DPI-Water has undertaken a review of documentation provided by WaterNSW which included the two external peer reviews of the Ecoengineers' reports and an assessment of the flow modelling based on the peer views. DPI-Water's review agreed with the findings of the two peer views that there are concerns with the modelling methodology and that these should be addressed.

DPI-Water has also advised that Illawarra Coal has not reported how much water is being taken from the surface water and groundwater sources under the relevant Water Sharing Plans as the current surface and groundwater models do not provide this information. As noted above, Illawarra Coal is currently revising its surface water and groundwater modelling. Once it is determined how much water is coming from each water source, DPI-Water can ensure that water take by the mine is appropriately licensed.

It should also be noted that WaterNSW has questioned the TARP triggers included in Illawarra Coal's Area 3B *Watercourse Impact, Monitoring, Management and Contingency Plan* for 'Modelled periods of recessional, baseflow and small storm unity hydrograph periods'. In the view of both WaterNSW and DPI-Water, the current TARP definition used by Ecoengineers (2015) allows for substantially higher levels of percentage impact to catchment runoff yields than notionally implied by the 6%, 12% and 18% TARP trigger values.

3 CONCLUSION

3.1 Significance of the Impacts

It is important to assess the overall scale and significance of the environmental impacts which have taken place at Area 3B. The majority of impacts have been in accordance with predictions and have not led to breaches of the mine's performance measures. Most mining-related impacts have not caused significant environmental harm.

However, all agencies consider that the impacts at WC21 are significant. The extent of the subsidence impacts at WC21 has exceeded the predictions of Illawarra Coal and its specialist advisers. Nonetheless, while 600 m of the watercourse is affected, this is not a very large area in terms of the total catchment. The overall area directly affected is less than 1 ha, which is a very small proportion of the Metropolitan Special Area's overall total of 90,000 ha.

While the impacts on upland swamps have been in accordance with predictions and are unlikely to be in breach of the mine's performance measures, it is more difficult to determine their long-term significance. This is because the timeframes for impacts to swamp vegetation communities and long-term soil stability are likely to be much longer than the less than three years since mining commenced in Area 3B.

3.2 Predictability and Avoidability of the Impacts

Surface subsidence associated with underground coal mining is relatively predictable in its manifestation, magnitude and extent. When subsidence impacts such as those outlined above are reported, it is important to examine what the subsidence predictions were and whether the observed effects are in line with those predicted. DPE has reviewed the subsidence predictions set out in the EA for Modification 6 (ie the modification covering Area 3B), and more specifically the subsidence predictions made in the Area 3B SMP. A comparison of predicted versus measured maximum total subsidence and maximum total closure for Wongawilli Creek, Donalds Castle Creek, WC21 and Swamps 1a, 1b and 5 is provided in **Table 11**.

Table 11: *Comparison of predicted versus measured maximum total subsidence and maximum total closure for Wongawilli Creek, Donalds Castle Creek, WC21 and Swamps 1a, 1b and 5 due to Longwalls 9 and 10*

Location	Monitoring Line	Observed/ Predicted	Maximum Total Subsidence (mm)	Maximum Total Closure (mm)
Wongawilli Creek	Wong X A-Line	Observed	Not reported	126
		Predicted	Not reported	175
	Wong X B-Line	Observed	Not reported	117
		Predicted	Not reported	175
	Wong X C-Line	Observed	Not reported	25
		Predicted	Not reported	50
WC21	WC21XA-Line	Observed	174	103
		Predicted	325	400
	WC21XB-Line	Observed	1,748	308
		Predicted	2,825	400
	WC21XC-Line	Observed	515	157
		Predicted	1,275	450
	WC21XD-Line	Observed	1,892	***820***
		Predicted	2,650	775
	WC21XE-Line	Observed	190	202
		Predicted	250	375
	WC21XF-Line	Observed	***41***	46
		Predicted	<20	125
	WC21XG-Line	Observed	872	163
		Predicted	1,550	175
Donalds Castle Creek	DCCXA-Line	Observed	1,333	81
		Predicted	1,750	175
	DCCXB-Line	Observed	714	1
		Predicted	975	200
	DCCXC-Line	Observed	2,008	***550***
		Predicted	2,250	325
	DCCXD-Line	Observed	***363***	26
		Predicted	275	125
	DCCXE-Line	Observed	***122***	6
		Predicted	<20	50
Swamp 1a	SW1A-Line	Observed	1,956	30
		Predicted	2,275	250
Swamp 1b	SW1B-Line	Observed	***1,911***	311
		Predicted	1,825	350
Swamp 5	SW5-Line	Observed	***122***	50
		Predicted	50	150

It can be seen from **Table 11** that observed subsidence in Area 3B has generally been similar to, or in many cases significantly less than, predicted subsidence. There are a few localised exceptions to this (shown in bold italics), although these are not considered to be significant in either number or degree, with only two exceedances of valley closure predictions. Valley closure of > 200 mm is a key predictor for impacts on watercourses, and most valley closure predictions have been shown to be conservative. Even in WC21, observed subsidence values have generally been less than predicted.

Given the close relationship between observed and predicted subsidence effects, agencies are satisfied that an appropriate subsidence prediction model is in place at Dendrobium and notes that the model is calibrated using local geological information and monitoring results from completed longwalls. Agencies accept that Illawarra Coal's subsidence predictions have been suitably conservative.

Subsidence impacts are an inevitable consequence of longwall mining. The degree to which impacts can be avoided is a key consideration in the mine planning, mine design and environmental assessment processes. Importantly, Area 3B was designed to avoid impacts to critical public infrastructure, such as the dam walls and stored waters of Avon Dam or Cordeaux.

If impacts cannot be avoided, mining companies must demonstrate that all reasonable and feasible measures have been taken to minimise the predicted impacts, followed by a program of appropriate and

adequate monitoring and management of the predicted impacts. If impacts are still predicted to be significant, offsets are generally required (see **Section 3.5**).

As described in **Section 2.2**, the agencies' ability to further restrict the impacts of mining in Area 3B was substantially limited by Illawarra Coal's decision to submit the Area 3B SMP well after roadway development for the first two longwall blocks had been initiated. The Area 3B SMP was approved based on the acceptance that there will be impacts on several swamps, particularly by the first three longwalls, which are now almost completed.

Overall, the economic and social costs and risks associated with a substantially revised mine layout were considered to be substantially greater than the associated environmental impacts. While some of the impacts discussed above will be able to be remediated, it is likely that some residual impacts will remain.

3.3 Potential for Further Impacts

Conditions of the Area 3B approval require Illawarra Coal to apply again for approval for Longwalls 14 – 19. It was made clear by DPE that approval of Longwall 14 – 19 was contingent on Illawarra Coal's performance in regards to Longwalls 9 – 13.

Under the Area 3B approval, draft mine plans for both the second group of longwalls in Area 3B (ie Longwalls 14 – 19) and the next mining domain (Area 3C) must be submitted for approval prior to undertaking any gateroad development (ie first workings) to establish the layout of those longwall panels.

Illawarra Coal has previously undertaken an analysis into options for having no impacts on swamps in Area 3B, including options for not mining under swamps. The analysis demonstrated that the reduction in coal resource recovery necessary to achieve this outcome was approximately 45% of the total resource available within Area 3B.

Detailed analysis was also conducted into options for reducing impacts to swamps, including reducing the widths of the longwalls to a maximum of 180 m (*Swamp Impact, Monitoring, Management and Contingency Plan*). The reduction in subsidence effects achieved through reducing longwall width is significant in respect of vertical subsidence. However, because the critical subsidence effects (ie valley closure and compressive strains) are not greatly reduced, there would be no significant reduction in potential subsidence impacts to swamps (see **Table 12**).

Table 12: *Comparison of predicted subsidence parameters at swamps for 180 m and 305 m longwalls*

	Maximum predicted cumulative subsidence (mm)	**Maximum predicted cumulative closure (mm)**	**Maximum predicted cumulative closure strain (mm/m)**
Maximum for 180 m longwalls	1150	600	>20
Maximum for 305 m longwalls	2550	700	>20

On this basis, Illawarra Coal is proposing that the future Area 3B longwalls (ie Longwalls 14 – 18) maintain the same void width (305 m), with a mining height of up to 4.6 m. It is noted that while the maximum mining height of 4.6 m is used for subsidence predictions, the actual mining height employed to date has generally been much lower (see **Table 13**). Only a single 100 m length of Longwall 10 was extracted at 4.5 m height (in order to manage poor roof conditions). The great majority of Longwall 9 was extracted at 3.4 m in height and most of Longwall 10 was extracted at 3.9 m in height.

In October 2015, Illawarra Coal requested the Secretary's further approval to extract Longwalls 14 – 19. In support of its request, Illawarra Coal provided a review of impacts observed to date, an assessment of the height of connective fracturing, a revised subsidence model and revised *Swamp and Watercourse Impact, Monitoring, Management and Contingency Plans*.

DPE has informed Illawarra Coal that its key considerations in deciding whether to grant further approval will include:

- Illawarra Coal's performance under the SMP approval to date, including consideration of the impacts outlined in this report;
- Illawarra Coal's compliance with performance measures to date and whether there is a need for revision of the current performance measures;
- the revised subsidence predictions and whether these are significantly different to those previously reported; and
- any revised predicted impacts resulting from the revision of the subsidence model.

***Table 13**: Actual mining heights for Longwalls 9 – 11*

Longwall	Start Location (m)	End Location (m)	Mining Height (m)
Longwall 9	2,180	1,740	3.4
	1,740	1,400	3.7
	1,400	0	3.4
Longwall 10	2,200	1,140	3.9
	1,140	1,040	4.5
	1,040	910	3.9
	910	460	3.7
	460	0	3.9
Longwall 11	2,290	Ongoing	3.95

DPE expects all mining companies to consult effectively with Government and the community at an early stage of mine development to ensure acceptable outcomes for all parties, the community and the environment. DPE will seek comments from the relevant agencies and the broader community on Illawarra Coal's request for further approval and the supporting documentation. It is expected that the documents will be made available shortly.

3.4 Offsetting and Compliance

3.4.1 Offsetting

Under condition 6 of the Area 3B SMP approval, Illawarra Coal must prepare, to the satisfaction of the Secretary of DPE, a Biodiversity Offset Strategy that compensates for the impacts of Longwalls 9 – 13 on upland swamps, with a priority for like-for-like physical environmental offsets.

Illawarra Coal has purchased 599 ha of land at Maddens Plains near Helensburgh to offset the impacts on upland swamps from the mining of Longwalls 9 – 13, and also future Longwalls 14 – 19. Illawarra Coal has proposed that it transfer this land to OEH for inclusion in the national parks system. Water NSW considers that, wherever practicable, offsets should be identified within the same general catchments, or at least the same Special Area, as the location of the biodiversity impact.

OEH and DPE are working together to develop and finalise an offset policy framework for upland swamps impacted by longwall mining subsidence. In May 2015, OEH released the draft *Policy Framework for Biodiversity Offsets for Upland Swamps and Associated Threatened Species Impacted by Longwall Mine Subsidence* (draft Swamp Offset Policy) for public consultation. Extensive consultation has since taken place between DPE and OEH and public and stakeholder comments have been taken into account. The new policy is expected to be finalised in the near future and become an addendum to OEH's *Biodiversity Offsets Policy for Major Projects*.

The draft Swamp Offset Policy outlines a clear and consistent approach to identifying subsidence related impacts to upland swamps and calculating and securing offsets for swamps impacted by longwall mining subsidence. It is anticipated that the new policy will be taken into account in DPE's consideration of Illawarra Coal's application for approval of Longwalls 14 – 18.

OEH considers that the Maddens Plains property is likely to contain sufficient upland swamps to reasonably offset (at least) the impacts of mining Longwalls 9 – 13. OEH has advised that until such time as the draft Swamp Offset Policy is finalised, it is not in a position to assess whether there is sufficient

excess credit available at the Maddens Plains property for offsetting the future swamp impacts predicted for the mining of Longwalls 14 – 18.

In April 2015, DPE approved modifications to Illawarra Coal's Bulli Seam Operations project approval and Dendrobium development consent that permit Illawarra Coal to offer land in excess of existing offset requirements. Depending on the method used in calculating offset requirements, the land at Maddens Plains needs to be assessed to see if it can meet both existing and future consent and SMP requirements.

DPE currently has draft Biodiversity Offset Strategies for both Bulli Seam Operations and Dendrobium and will continue to assess the documents in close consultation with OEH and other relevant agencies. The transfer of this land to the NSW Government is subject to DPE's approval of these Biodiversity Offset Strategies, and negotiation with OEH of any relevant management cost contribution.

3.4.2 Compliance

On 28 August 2015, DPE wrote to Illawarra Coal and requested it to prepare a remediation program for the impacts to WC21 under condition 4 of Schedule 2 of the mine's development consent. The remediation program must be prepared in consultation with WaterNSW and include details of the proposed remediation works and the likely timing of implementation of the proposed works.

3.5 Public Awareness

All agencies have worked effectively and co-operatively together while investigating and managing the subsidence impacts and environmental consequences caused by mining of Area 3B.

Illawarra Coal regularly provides detailed reports of its monitoring programs at Dendrobium and its other coal mines in the Southern Coalfield to all key agencies. Government agencies always review these reports and take appropriate steps to investigate impacts, including inspections. The TARPs within the key management plans offer a ready mechanism to classify the significance of impacts and to identify next steeps for both Illawarra Coal and the regulatory agencies. However, these individual impact reports are not made publicly available until they are aggregated into End of Panel reports prepared after the completion of each longwall.

Illawarra Coal also provides the Dendrobium Community Consultative Committee (CCC) with regular reports regarding both its mining operations and environmental impacts. The CCC meets regularly, throughout the year. Extraordinary meetings are also able to be called by the community members of the CCC.

3.6 Recommendations

Surface Water and Groundwater Modelling

Given the complex technical nature of the groundwater and surface water modelling for Area 3B and other domains within the NSW Coalfields, and particularly of the estimation of the height above the longwalls where (and when) full desaturation of the regional aquifer will occur, DPE recommends engaging an independent expert to assess the data and empirical relationships on which these estimates are made. The proposed scope of works for this review should include:

- documenting the available investigation techniques and types of information/evidence used to examine post-longwall mining fracturing patterns (including extensometer, micro-seismic, core-logging, down-hole camera and geophysical methods) and hydrogeological responses to fracturing (including piezometer responses, pump testing, flow testing, temperature and geochemical logging, tracer tests, and drilling-fluid losses), with a particular focus on identifying the heights of connective cracking and desaturation above longwalls, as well as surface water flow diversions;
- undertaking a critical analysis of the investigative and evidentiary data types identified above and of the factors that affect their accuracy and/or uncertainty including, the position of instrument or

observation relative to longwall centre, availability of pre-mined or unmined observations for comparison, instrument precision etc;

- reviewing and cataloguing all available (relevant to a NSW context) evidentiary data sources, eg local and international published investigation papers and unpublished reports held by DPE and DRE on post-mining geotechnical and hydrogeological investigations in NSW and End-of-Panel reports;
- reviewing all available data sources (eg piezometer measurements over or adjacent to longwalls) which inform an understanding of temporal changes in overlying aquifers following longwall extraction.
- providing comment on the post-mining temporal trends identified (ie static, recovering or falling piezometric heads in deep and shallow aquifers over time);
- categorising the data according to location, measured subsidence effects, time elapsed between nearest mining and measurement, quality or indicative uncertainty of data point, and any other relevant distinguishing traits identified;
- reviewing the evidentiary databases used by Ditton (2013) and Tammetta (2012 and 2015) and providing a critical review of the reliability of the data points used, potential sources of uncertainty and a summary of which data points have been included in each model;
- briefly analysing the statistical methods used in the two approaches, and providing comment on the potential strengths and weaknesses of each;
- based on the analyses performed above, providing comment on what constitutes an ideal and an adequate monitoring network to investigate geotechnical and hydrogeological behaviour over mined longwalls; and
- based on a review of the evidentiary data presented, providing a summary of key trends and recommendations for further work required to clarify geotechnical and hydrogeological responses above longwall mining panels.

Watercourses

On 28 August 2015, DPE requested that Illawarra Coal prepare a remediation program for the impacts to WC21. The remediation program must be prepared in consultation with WaterNSW and include details of the proposed remediation works and the likely timing of implementation of the proposed works.

The proposed remediation method should be derived by first determining where the water diverted from WC21 is going. DPE therefore recommends that Illawarra Coal be required to undertake the following:

- installation of boreholes with piezometers targeted at suitable depths to measure groundwater levels in the WC21 valley (both pre-mining and post-existing mining), with the depth and key characteristics of bedrock fracturing being clearly identified by appropriate geotechnical, geophysical and lithological logging. In-hole water quality testing, water level monitoring, permeability testing and flow testing should be undertaken to clarify the extent, depth and magnitude of shallow cracking; and
- undertake a limited set of tracer tests to determine what proportions of diverted stream flows are returning to the stream further down-gradient as against being delivered to underlying aquifers.

WaterNSW considers that the Area 3B SMP approval's performance measures are less specific or absent for impacts on the key tributaries which contribute significant flow to the major creeks, which are addressed by the current performance measures. DPE will consider the need for performance measures for key tributaries as part of its assessment for further approval of Longwalls 14 – 18. DPE also proposes to further consider Illawarra Coal's current Area 3B watercourse monitoring system, in consultation with other relevant agencies, as part of its assessment for further approval for Longwalls 14 – 18. If necessary, it will require expansion of this monitoring system.

Upland Swamps

As part of the assessment for further approval of Longwalls 14 – 18, DPE proposes to further consider Illawarra Coal's current Area 3B swamp monitoring system, in consultation with other relevant agencies. This analysis will also involve review of the number, location and purpose of swamp piezometers in impacted and control swamps to ensure a robust before-after-control-impact program design. If necessary,

it will require a refinement to or expansion of this monitoring system. The performance measures relating to upland swamps in the Area 3B SMP approval and triggers in the approved TARPs will also be reviewed.

DPE would also consider the appropriateness of applying the Swamp Offsets Policy to any further approval of Longwalls 14 – 18, providing that the policy is finalised before any approval is granted. In line with the current draft Swamp Offset Policy, in cases where potential impacts to swamps are uncertain, Illawarra Coal would be required to provide up-front offsets for the predicted impacts. Recently applied swamp offset conditions (ie Springvale Mine Extension Project) require that the potential swamp offset liability under any Extraction Plan (formerly an SMP) is assessed as a potential maximum (ie worst case scenario). On this basis, Illawarra Coal would be required to demonstrate that it can satisfy the maximum predicted offset liability for the total area of swamp(s) predicted to be impacted under any particular SMP.

If monitoring of previous longwalls demonstrates that greater than 'negligible environmental consequences' (under the draft offset policy) have resulted from mining, then Illawarra Coal would be required to meet the full calculated value of the offset. Illawarra Coal would then need to make a decision about potential impacts and liabilities associated with future longwalls. It would be at the discretion of the company to either accept the swamp offset liability or modify (ie adaptively manage) its mine plan to reduce swamp impacts and the associated liabilities. At present, Illawarra Coal's is bound by a performance measure of 'minor environmental consequences'. Careful consideration would be required by DPE in its decision to apply the draft offset policy or amend the performance measures.

DPE supports adaptive management in relation to swamps. DPE would look to strengthen conditions to facilitate this approach as part of the further approval for Longwalls 14 – 18.

A draft offset strategy for Area 3B has been submitted by Illawarra Coal to DPE. DPE, in consultation with other agencies, would finalise the implementation of this strategy, including the transfer of Illawarra Coal's Maddens Plains land to OEH as a matter of priority.

A draft *Swamp Rehabilitation Research Program* has also been submitted and is currently being considered by DPE in consultation with k affected agencies. DPE proposes to finalise this program as a matter of priority in order for this vital research to be undertaken. Future decisions regarding remediation will take into account the investigations and results of the *Swamp Rehabilitation Research Program*.

Threatened Species

OEH commented that performance measures for impacts are absent for specific threatened species which inhabit the watercourses and swamps within Area 3B. The potential cumulative impacts to Giant Dragonfly as a result of swamp impacts and Littlejohn's Tree Frog as a result of watercourse impacts remain of concern to agencies. DPE recommends engaging an independent expert, in consultation with OEH and Water NSW, to assess the local and regional impacts to this species.

Further Approval of Longwalls 14 – 18

DPE has already informed Illawarra Coal that its key considerations in deciding whether to grant further approval will include:

- Illawarra Coal's performance under the SMP approval to date, including consideration of the impacts outlined in this report;
- Illawarra Coal's compliance with performance measures to date and whether there is a need for revision of the current performance measures; and
- the revised subsidence predictions and whether these are significantly different to those previously reported.

During this review, the currently applied performance measures and the TARPs used to assess compliance with these measures will be reviewed. DPE will consult with the relevant agencies and the broader community regarding this further approval.

APPENDIX 1. WATERNSW BOARD'S POSITION REGARDING LONGWALL MINING NEAR WATER STORAGES

In March 2014, following recommendations from Stage 1 of the Bulk Water Delivery Review, the NSW Government agreed to integrate the former Sydney Catchment Authority (SCA) with the State Water Corporation to form WaterNSW.

A principal objective of WaterNSW is to ensure that the Sydney catchment area is managed and protected so as to promote water quality, the protection of public health and public safety, and the protection of the environment. A function of WaterNSW is to protect and enhance the quality and quantity of water in this catchment.

In early 2012, the former SCA developed a set of principles to guide its assessment and provision of advice to the Department of Planning and Environment (DPE) for managing mining and coal seam gas impacts. The principles can be summarised as:

- mining and coal seam gas activities must not result in a reduction in the quantity of surface and groundwater inflows to storages or loss of water from storages or their catchments;
- mining and coal seam gas activities must not result in a reduction in the quality of surface and ground water inflows to storages;
- mining and coal seam gas activities must not pose increased risks to human health as a result of using water from the drinking water catchments;
- the integrity of the (then) SCA's water supply infrastructure must not be compromised;
- the ecological integrity of the Special Areas must be maintained and protected; and
- information provided by proponents, including environmental impact assessments for proposed mining and coal seam gas activities, must be detailed, thorough, scientifically robust and holistic. The potential cumulative impacts must be comprehensively addressed.

In 2013, the independent Board of the former SCA took a position against any longwall mining within 'dam notification areas'. The new Board of WaterNSW reaffirmed this position in 2015. The Board considers that such mining is "inconsistent with the role, objectives and functions as defined in the *Sydney Water Catchment Management Act 1998*".

APPENDIX 2. DPE'S DENDROBIUM AREA 3B IMPACT SUMMARY FOR LONGWALLS 9 - 11

Table 1: *Longwall 9 impact summary derived from the Longwall 9 End of Panel Report (prepared by DPE)*

Location	ID	Report Date	Impact	Trigger
Donalds Castle Creek & DC13	DA3B_LW9_001	08-May-13	Appearance	Level 1
	DA3B_LW9_002	08-May-13	Fracturing	Level 2
		23-May-13		
	DA3B_LW9_003	09-May-13	Fracturing	Level 2
	DA3B_LW9_004	23-May-13	Fracturing	Level 1
	DA3B_LW9_005	23-May-13	Soil Surface Cracking	Level 1
	DA3B_LW9_006	27-Sep-13	Fracturing	Level 2
		14-Oct-13		
	DA3B_LW9_007	14-Oct-13	Water Appearance	Level 1
	DC_Pool_34	25-Nov-13	Pool Water Level	Level 1
	DC13_Pool20	09-May-13	Pool Water Level	Level 1
	DC13_RB21	09-May-13	Pool Water Level	Level 1
	DC13_Pool19	15-May-13	Pool Water Level	Level 1
	DC13_Pool16B	15-May-13	Pool Water Level	Level 1
	DC13_Pool16A	20-May-13	Pool Water Level	Level 1
	DC13_Pool21	15-Apr-13	Pool Water Level	Level 1
Access Track 6000	DA3B_LW9_008	06-Nov-13	Soil Cracking	Level 1
	DA3B_LW9_009	06-Nov-13	Soil Cracking	Level 2
	DA3B_LW9_010	06-Nov-13	Soil Cracking	Level 1
	DA3B_LW9_025	09-Jan-14	Fracturing	Level 1
	DA3B_LW9_026	09-Jan-14	Fracturing	Level 1
	DA3B_LW9_030	12-Sep-14	Fracturing	Level 1

	DA3B_LW9_031	12-Sep-14	Fracturing	Level 1
	DA3B_LW9_032	09-Feb-15	Rock Fall	Level 1
SLMMP - SS2 point 1	DA3B_LW9_012	09-Dec-13	Fracturing	Level 1
	DA3B_LW9_013	09-Dec-13	Fracturing	Level 1
		03-Jan-14		Level 1
WC21 & Wongawilli Creek	DA3B_LW9_014	11-Dec-13	Fracturing	Level 1
		29-Jan-14		
	DA3B_LW9_015	11-Dec-13	Fracturing	Level 2
		19-Dec-13		
	DA3B_LW9_016	19-Dec-13	Fracturing	Level 2
	DA3B_LW9_017	19-Dec-13	Fracturing	Level 1
		24-Dec-14	Fracturing	Level 1
	WC21_Pool16	19-Dec-13	Pool Water Level	Level 2
	WC21_Pool17	19-Dec-13	Pool Water Level	Level 2
	WC21_Pool18	19-Dec-13	Pool Water Level	Level 2
	DA3B_LW9_018	27-Dec-13	Fracturing	Level 1
	DA3B_LW9_019	27-Dec-13	Subsurface outflow and Iron staining	Level 1
		03-Jan-14		
		21-May-14		
		24-Dec-14		
	DA3B_LW9_020	03-Jan-14	Fracturing	Level 1
	WC21_Pool 19	03-Jan-14	Pool Water Level	Not specified
	DA3B_LW9_021	03-Jan-14	Fracturing	Level 1
	DA3B_LW9_022	03-Jan-14	Fracturing	Level 1
	DA3B_LW9_023	03-Jan-14	Fracturing	Level 1
	DA3B_LW9_024	03-Jan-14	Fracturing	Level 2
	DA3B_LW9_027	29-Jan-14	Fracturing	Level 1

	DA3B_LW9_028	24-Mar-14	Rock Fall	Level 1
Swamp 1a & 1b	Borehole 01b_02	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
	Borehole 01b_02ii	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
	Borehole 01b_02iv	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
	Borehole 01a_04	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
	Borehole 01a_04i	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
	Borehole 01a_04ii	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
	Borehole 01a_04iii	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
	Borehole 01a_04iv	08-May-13	Shallow Groundwater	Level 2
		09-May-13		
Swamp 5	Borehole 05_03	27-Sep-13	Shallow Groundwater	Level 3
		14-Oct-13		
		06-Nov-13		
		25-Nov-13		
		19-Aug-15		
	Borehole 05_03i	27-Sep-13	Shallow Groundwater	Level 2
		14-Oct-13		
		06-Nov-13		

		25-Nov-13		
	Borehole 05_03ii	06-Nov-13	Shallow Groundwater	Level 3
		25-Nov-13		
		19-Aug-15		
	Borehole 05_03iii	14-Oct-13	Shallow Groundwater	Level 2
		06-Nov-13		
		25-Nov-13		
	Borehole 05_04	27-Sep-13	Shallow Groundwater	Level 3
		14-Oct-13		
		06-Nov-13		
		25-Nov-13		
		19-Aug-15		
Swamp 8	Borehole 08_04	27-Dec-13	Shallow Groundwater	Level 1
N/A	DA3B_LW9_011	09-Dec-13	Fracturing	Level 1
N/A	DA3B_LW9_029		Fracturing	Level 1

Table 2: *Longwall 10 impact summary derived from the Longwall 10 End of Panel Report (prepared by DPE)*

Location	ID	Date	Impact	Trigger
Access track 6000	DA3B_LW10_001	24-Mar-14	Fracturing	Level 1

	DA3B_LW10_002	08-Oct-14	Soil cracks	Level 1
	DA3B_LW10_003	08-Oct-14	Soil cracks	Level 1
	DA3B_LW10_004	27-Oct-14	Rock fall / Fracturing	Level 1
	DA3B_LW10_005	07-Nov-14	Soil cracks	Level 1
	DA3B_LW10_006	07-Nov-14	Soil cracks	Level 1
	DA3B_LW10_021	09-Feb-15	Fracturing	Level 1
	DA3B_LW10_024	19-Feb-15	Soil cracks	Level 2
	DA3B_LW10_025	26-Feb-15	Soil cracks	Level 2
WC21	DA3B_LW10_007	19-Nov-14	Fracturing	Level 2
		25-Nov-14		
		24-Dec-14		
	DA3B_LW10_008	19-Nov-14	Fracturing	Level 2
	DA3B_LW10_009	19-Nov-14	Fracturing	Level 2
		03-Mar-15		
	DA3B_LW10_010	25-Nov-14	Dialation	Level 1
	DA3B_LW10_011	25-Nov-14	Fracturing	Level 1
	DA3B_LW10_012	05-Dec-14	Soil cracks	Level 1
	DA3B_LW10_013	05-Dec-14	Fracturing	Level 1
	DA3B_LW10_014	05-Dec-14	Fracturing	Level 2
		02-Feb-14		
	DA3B_LW10_015	05-Dec-14	Fracturing	Level 2
	DA3B_LW10_016	05-Dec-14	Fracturing	Level 2
	DA3B_LW10_018	24-Dec-14	Fracturing	Level 2

	DA3B_LW10_019	24-Dec-14	Fracturing	Level 2
		02-Feb-15		
	DA3B_LW10_020	02-Feb-15	Fracturing	Level 1
	DA3B_LW10_023	19-Feb-15	Fracturing	Level 2
	DA3B_LW10_026	03-Mar-15	Fracturing	Level 2
Swamp 5	Borehole 05_02	02-Feb-15	Shallow Groundwater	Level 3
		19-Aug-15		
Monitoring site A3B-SS2-SLMMP-Pnt 2	DA3B_LW10_022	09-Feb-15	Fracturing	Level 1

Table 3: *Longwall 11 impact summary derived from impact reports submitted to September 2015 (prepared by DPE)*

Location	ID	Date	Impact	Trigger
Swamp 3	Piezometer 03_01	28-May-15	Shallow Groundwater	N/A
Fire Road 6A	DA3B_LW11_001	02-Jun-15	Soil Crack	Level 2
	DA3B_LW11_002	02-Jun-15	Soil Crack	Level 2
	DA3B_LW11_003	25-Jun-15	Soil Crack	Level 1
Swamp 5	Borehole 05_01	19-Aug-15	Shallow Groundwater	Level 3
Access Track 6000	DA3B_LW11_004	24-Aug-15	Soil Crack	Level 1

APPENDIX 3. SUMMARY OF ILLAWARRA COAL'S SWAMP AND WATERCOURSE TARPS

Table 1: *Summary of Illawarra Coal's TARP adapted from its approved Swamp Impact, Monitoring, Management and Contingency Plan*

Swamp Performance Measure	Swamp Impact Performance Trigger
Negligible erosion of the surface of the swamp	*Level 1:* The increase in length of erosion within a swamp (compared to its pre-mining length) is 2% of the swamp length or area; and/or Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without corrective management actions and within a period of monitoring. *Level 2:* The increase in length of erosion within a swamp (compared to its pre-mining length) is 3% of the swamp length or area; and/or Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention. *Level 3:* The increase in length of erosion within a swamp (compared to its pre-mining length) is 4% of the swamp length or area; and/or Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention. *Exceeding Prediction:* Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase >5% of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (ie increase in length or area of erosion in an impact swamps less any increase in length or area in erosion in a reference swamp is >5%).
Minor changes in the size of the swamps	*Level 1:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for two consecutive monitoring periods, greater than observed in the control group, and exceeding the standard area of the control group *Level 2:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for three consecutive monitoring periods, greater than observed in the control group, and exceeding the standard area of the control group *Level 3:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for four consecutive monitoring periods, greater than observed in the control group, and exceeding the standard area of the control group *Exceeding Prediction:* Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for five consecutive monitoring periods, greater than observed in the control group, and exceeding the standard error of the control group.
Minor changes in the ecosystem functionality of the swamps	*Level 1:* A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than observed in the control group, and exceeding the standard error of the control group. *Level 2:* A trending decline in the extent of any groundwater dependent community within a swamp for three consecutive monitoring periods, greater than observed in the control group, and exceeding the standard error of the control group. *Level 3:* A trending decline in the extent of any groundwater dependent community within a swamp for four consecutive monitoring periods, greater than observed in the control group, and exceeding the standard error of the control group.

	Exceeding Prediction: Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring periods, greater than observed in the control group, and exceeding the standard error of the control group.
No significant change to the composition or distribution of species within the swamp	*Level 1:* A 2**%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for two consecutive years; and/or *Level 2:* A 5**%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for three consecutive years. *Level 3:* An 8% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for four consecutive years. *Exceeding Prediction:* Mining results in a >10% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for five consecutive years.
Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps	*Level 1:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of 10% compared to baseline for the pool (in addition to any decrease in reference pools). *Level 2:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of 20% compared to baseline for the pool (in addition to any decrease in reference pools). *Level 3:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of 20% compared to baseline for the pool for >20% of the time over a period of 1 year (in addition to any decrease in reference pools). *Exceeding Prediction* Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, ie pool water level within the swamp after corrective management actions continues to be >20% lower than baseline for >20% of the time over a period of 1 year.
Groundwater levels (not specifically linked to a performance measure)	*Level 1:* Groundwater level lower than baseline level at any monitoring site within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/day during the recession curve). *Level 2:* Groundwater level lower than baseline level at 50% of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at a 50% of monitoring sites (within 400m of mining) within the swamp. *Level 3:* Groundwater level lower than baseline level at >80% of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at >80% of monitoring sites (within 400 m of mining) within the swamp.
Soil moisture (not specifically linked to a	*Level 1:* Soil moisture level lower than baseline level at any monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps).

performance measure)	<u>*Level 2:*</u> Soil moisture level lower than baseline level at 50% of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps). <u>*Level 3:*</u> Soil moisture level lower than baseline level at >80% of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps).

Table 2: *Summary of Illawarra Coal's TARP adapted from its approved Watercourse Impact, Monitoring, Management and Contingency Plan*

Watercourse Performance Measure	**Watercourse Performance Trigger**
Observational, photo point and watercourse monitoring	
Wongawilli Creek – **minor** environmental consequences Donalds Castle Creek – **minor** environmental consequences Waterfall WC-WF54 – **negligible** environmental consequences	<u>*Level 1:*</u> • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion; • Crack or fracture up to 10m length with no observable loss of surface water or erosion; • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without corrective management actions and within the period of monitoring; • Observable release of strata gas at the surface; or • Observable increase in iron staining within the mining area. <u>*Level 2:*</u> • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion; • Crack or fracture between 10 and 50m length; • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention; or • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall. <u>*Level 3:*</u> • Crack or fracture over 300mm width at its widest point; • Crack or fracture over 50m length; • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water; • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention; • Gas release results in vegetation dieback, mortality or loss of aquatic habitat; or • Observable increase in iron staining within the mining area continues more than 600m from the longwall. <u>*Exceeding Prediction:*</u> • Structural integrity of the bedrock base of any significant pool or controlling rockbar cannot be restored i.e. pool water level within the pool after corrective management actions continues to be lower than baseline period; • Gas release results in vegetation dieback that does not revegetate; • Gas release results in mortality of threatened species or ongoing loss of aquatic habitat; • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Creek (FR6); • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Creek (FR6); • Rock fall at WC-WF54 or its overhang; or

	• Impacts on the structural integrity of WC-WF54, its overhang or its pool
Water quality	
Wongawilli Creek – **minor** environmental consequences	*Level 1:* One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 µS/cm – DO 50.5% *Level 2:* Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 µS/cm – DO 50.5% *Level 3:* Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 µS/cm – DO 50.5% *Exceeding Prediction:* Mining results in two consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 µS/cm – DO 50.5%
Donalds Castle Creek – **minor** environmental consequences	*Level 1:* One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 µS/cm – DO 40.1% *Level 2:* Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 µS/cm – DO 40.1% *Level 3:* Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 µS/cm – DO 40.1%

	Exceeding Prediction: Mining results in two consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 µS/cm – DO 40.1%
Lake Avon - **negligible** reduction in the quality of surface water inflows to Lake Avon	*Level 1:* One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 µS/cm – DO 69.5% *Level 2:* Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 µS/cm – DO 69.5% *Level 3:* Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 µS/cm – DO 69.5% *Exceeding Prediction:* Mining results in two consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 µS/cm – DO 69.5%
Pool water level	
Wongawilli Creek – **minor** environmental consequences Donalds Castle Creek – **minor** environmental consequences	*Level 1:* Fracturing not resulting in diversion of flow. *Level 2:* Fracturing resulting in diversion of flow. *Level 3:* Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period. *Exceeding Prediction* Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period.
Waterfall WC-WF54 – **negligible** environmental consequences	*Exceeding Prediction* • Fracturing in Wongawilli Creek within 30 m of the waterfall which results in observable flow diversion; and/or • Fracturing in Wongawilli Creek which results in observable flow diversion from the lip of the waterfall.

Modelled periods of recessional, baseflow and small storm unit hydrograph periods	
Lake Avon - **negligible** reduction in the quality of surface water inflows to Lake Avon Cordeaux River – **negligible** reduction in the quantity of surface water flows from Wongawilli Creek to Cordeaux River	*Level 1:* Change 6-12% less than average annual precipitation. *Level 2:* Change 12-18% less than average annual precipitation. *Level 3:* Change >18% less than average annual precipitation. *Exceeding Prediction* • Measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River that is greater than predicted by the groundwater model that cannot be attributed to natural variation. • Surface water flow reduction into Lake Avon is greater than predicted by the groundwater model that cannot be attributed to natural variation.
Aquatic Ecology	
Not specifically linked to a performance measure	*Level 1:* Reduction in aquatic habitat for 1 year. *Level 2:* Reduction in aquatic habitat for 2 years following the active subsidence period. *Level 3:* Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period.
Terrestrial fauna – threatened frog species	
Not specifically linked to a performance measure	*Level 1:* Reduction in habitat for 1 year. *Level 2:* Reduction in habitat for 2 years following the active subsidence period. *Level 3:* Reduction in habitat for >2 years or complete loss of habitat following the active subsidence period.

APPENDIX 4: WATERCOURSE IMPACT MONITORING MANAGEMENT AND CONTINGENCY PLAN

Please see: https://www.south32.net/our-operations/australia/illawarra-coal/regulatory-document

APPENDIX 5. SWAMP IMPACT MONITORING MANAGEMENT AND CONTINGENCY PLAN

Please see: https://www.south32.net/our-operations/australia/illawarra-coal/regulatory-document

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