

Attachment A – Aquatic Flora and Fauna Review

Aquatic Flora and Fauna Assessment

Longwalls 22 and 23 Subsidence
Management Plan

59919104



Prepared for
South32 – Illawarra Metallurgical Coal

26 August 2021

Contact Information

Cardno (NSW/ACT) Pty Ltd

ABN 95 001 145 035

Level 9 - The Forum
 203 Pacific Highway
 St Leonards NSW 2065
 Australia

www.cardno.com

Phone +61 2 9496 7700

Fax +61 2 9439 5170

Document Information

Prepared for	South32 – Illawarra Metallurgical Coal
Project Name	Longwalls 22 and 23 Subsidence Management Plan
File Reference	59919104_R008_Longwalls2 223SMP_AFFA_Rev1.docx
Job Reference	59919104
Date	26 August 2021
Version Number	1
Effective Date	26/08/2021

Author(s):



Dan Pygas
 Principal – Aquatic Ecology

Approved By:



Dr Brendan Alderson
 Senior Environmental Scientist

Date Approved 26/08/2021

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
A	21/06/2021	Draft	Dan Pygas	Dr Brendan Alderson Cody Brady (South32)
0	30/06/2021	Final	Dan Pygas	Cody Brady (South32)
1	26/08/2021	Revised Final	Dan Pygas	Cody Brady (South32)

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Executive Summary

Introduction

South32 – Illawarra Metallurgical Coal (South32) plans to extract coal from Longwalls 22 and 23 in Dendrobium Area 3C (Area 3C) of the Dendrobium Mine Area (the Project). Longwalls 22 and 23 are located between Wongawilli Creek and Lake Cordeaux and to the north the approved Longwall 21. This Aquatic Flora and Fauna Assessment (AFFA) has been prepared to support the Subsidence Management Plan (SMP) for Longwalls 22 and 23. The AFFA focuses on the sections of Wongawilli Creek, Lake Cordeaux and drainage lines that may be affected by mining induced ground movements due to longwall extraction. Potential impacts to aquatic flora and fauna are associated with subsidence and fracturing of bedrock resulting in water diversion, groundwater depressurisation and consequent loss of aquatic habitat and biota in watercourses. Sandy Creek and Lake Avon are located some distance away from the longwall and would not be affected by extraction. The AFFA includes:

- > A review and synthesis of existing information on the aquatic flora and fauna of the Wongawilli Creek and Lake Cordeaux catchments in the Study Area (area within 600 metres (m) of Longwalls 22 and 23);
- > Assessment of the potential impacts on aquatic flora and fauna (including threatened species) arising directly and indirectly from the proposed mining; and
- > Recommendations on impact mitigation measures and monitoring for inclusion within the SMP.

Existing Environment

Wongawilli Creek is a third order and greater watercourse partly located in the Study Area. It provides substantial aquatic habitat including Type 1 – Highly Sensitive Key Fish Habitat (KFH) (Type 1 - KFH) and permanent pools. It has previously experienced impacts (loss of pool water and reduction in availability of aquatic habitat) associated with extraction of previous Area 3A and Area 3B longwalls, resulting groundwater depressurisation and reduced surface flows. During a drought period in May 2018 to November 2019, some sections of the watercourse upstream of the current Study Area were dry. During the most recent investigations in 2021, there was no observable impact to pool water levels and flow. Lake Cordeaux also provides Type 1 – KFH, as it provides habitat for the threatened Macquarie perch.

Aquatic habitat in first and second order drainage lines within the Study Area are largely undisturbed though some have been impacted by previous mining in Area 3B. Aquatic habitat in drainage lines include small, disconnected and largely ephemeral pools with limited habitat potential for aquatic flora and fauna, though some towards the downstream reach of drainage lines LC5 and LC6 of Lake Cordeaux include apparent semi-permanent pools that should provide aquatic habitat for some time following rainfall. . These drainage lines are not KFH.

Although some of the biotic indices derived from AUSRIVAS aquatic macroinvertebrate sampling in Wongawilli Creek are indicative of degraded habitat or water quality, these more likely reflect natural conditions and the naturally low pH of stream water within the catchment. Suitable habitat for three threatened species, Adams emerald dragonfly (*Archaeophya adamsi*), Sydney hawk dragonfly (*Austrocordulia leonardi*) and Macquarie perch (*Macquaria australasica*) occurs in the Study Area. Macquarie perch are likely to occur in Lake Cordeaux but are considered unable to access Wongawilli Creek in the Study Area due to the presence of natural barriers to fish passage downstream.

Impact Assessment

Given that Lake Cordeaux is not expected to experience adverse subsidence related impacts due to extraction of Longwalls 22 and 23, impacts to aquatic habitat and biota, including Macquarie perch in Lake Cordeaux are not expected.

Twenty-one flow controlling rockbars are located in Wongawilli Creek within 600 m of Longwalls 22 and 23. Based on the predicted rate of fracture of 6 % (or 1 in 17) it is probable that one of these rockbars would fracture. Resulting flow diversions could result in the drainage of the upstream pool with associated loss of aquatic habitat. These pools range in length from 15 m to 200 m. The loss of water and aquatic habitat from one of these pools would represent a severe impact at the scale of individual pools, with the probable loss of most aquatic fauna, a reduction in longitudinal connectivity between remaining pools, and a reduction in the population size of aquatic biota. In isolation, such impacts at the scale of the watercourse (total length 12 km) would be more minor. Extraction of Longwalls 22 and 23 is not predicted to contribute to reduced surface flows in Wongawilli Creek associated with groundwater depressurisation (no more than 1 % and 2 % reduction, respectively). Thus associated impacts to aquatic habitat and biota associated with extraction of these longwalls in isolation are likely to be minor and probably indistinguishable from natural variability. The cumulative impact on surface water flows due to groundwater depressurisation following extraction of Area

3A, Area 3B and Area 3C, however, is likely to continue. During periods of extended drought, this will likely result in reduced flows and draining of some pools in Wongawilli Creek adjacent to these mine areas. Flow and pool water levels would recover following the return of substantial rainfall. Macquarie perch has not been identified in these areas, and so should not be affected. There would, however, be temporary (likely up to several months) reductions in aquatic habitat availability, including Type 1 – KFH, and connectivity.

Based on predictions of subsidence, it is expected that a reduction in the amount and connectivity of ephemeral aquatic habitat in drainage lines in the Study Area would occur due to fracturing of bedrock. Approximately 1.7 km of first and second order drainage lines occur directly above Longwalls 22 and 23 and a further 5.2 km is within 400 m of the longwalls. Fracturing and flow diversion is very likely to occur in drainage lines above the longwalls, and could occur up to 400 m away. This is expected to impact aquatic biota via reduction in the amount of available habitat and habitat fragmentation. Although impacts to aquatic habitat and biota would be significant at the scale of individual pools and drainage lines, in isolation, impacts associated with extraction of Longwalls 22 and 23 would be minimal in the context of the upper Avon River and Cordeaux River catchments. The aquatic habitat provided by these watercourses is very limited (in terms of permanence and quality) and also abundant in the Study Area and Dendrobium Mine Area. Again, the cumulative impact of the loss of drainage line habitat in the Dendrobium Mine should be considered.

Recommendations and Management

Potential impacts on aquatic habitat and biota within the Study Area would be managed by:

- > Impact minimisation, including the significant distance of the longwall from Wongawilli Creek and identification of triggers that would prompt surveys to assess any impacts on aquatic habitats and their biota identified during and after extraction of the longwalls;
- > Monitoring of aquatic habitat and biota during and after mining to determine the nature and extent of any subsidence-induced impacts on aquatic ecology and responses of aquatic ecosystems to any remediation or management works implemented;
- > Undertaking additional aquatic ecology studies in response to specific impacts on water quality and availability of aquatic habitats within the watercourses; and
- > Implementation of contingent measures such as review of mine layout and appropriate future offset distances from creeks, watercourse remediation measures, appropriate control measures to limit deposition of any eroded sediment into the watercourses, and appropriate offset and compensatory measures.

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1 Introduction

1.1 Background

South32 – Illawarra Metallurgical Coal (South32) is using longwall mining to extract coal from the Dendrobium Coal Mine, situated near Cordeaux approximately 20 kilometres (km) west of Wollongong. Consent for the mine, granted in November 2001, allows extraction from three longwall domains, known as Dendrobium Areas (DA) DA1, DA2 and DA3. DA3, situated to the west of Lake Cordeaux, is currently being mined. A modification to the mine layout of DA3 approved in December 2008 allowed the mine to be expanded and Area 3 to be sub-divided into three smaller domains; Dendrobium Area 3A (Area 3A), Dendrobium Area 3B (Area 3B) and Dendrobium Area 3C (Area 3C). Area 3A currently comprises Longwalls 6, 7, 8 and 19, which are situated between Wongawilli and Sandy Creeks. Mining of Area 3B Longwalls 9 to 16 was undertaken between February 2013 to November 2020. Extraction of Longwall 17 commenced in December 2020 and is currently underway. Extraction of remaining Area 3B Longwalls 18, Area 3A Longwall 19 and Area 3C Longwalls 20 and 21 is to follow.

The Dendrobium Mine Consent conditions require that prior to carrying out any underground mining operations that could cause subsidence, a Subsidence Management Plan (SMP) should be prepared and approved by the Department of Planning, Industry and Environment (DPIE). The overall objective of the SMP is to manage any impacts to watercourses, other natural features and built features associated with mine-induced subsidence. The SMP for Area 3B was submitted in 2012 (BHPBIC 2012). Approval for Longwalls 9 to 13 was granted in 2013 and approval of Longwalls 14 and 15 was granted in 2016. Approval for Longwalls 14 and 15 also required that further individual assessment be undertaken for subsequent Area 3B longwalls. The requisite SMPs for Longwalls 16 (South32 2017), 17 (South32 2019), Longwall 18 (South32 2020) were approved in 2018, 2019 and 2020, respectively. The aquatic ecology assessment to support the SMP for Longwalls 20 and 21 in Area 3C was completed in 2019 (Cardno 2019a) and extraction of these longwalls will follow completion of mining in Area 3B.

South32 are proposing to extract coal from Longwalls 22 and 23 in Area 3B (the Project) and invited Cardno (formerly trading as Cardno Ecology Lab and The Ecology Lab Pty Ltd) to prepare a proposal to undertake the Aquatic Ecology Assessment (AEAs) to support the SMP for these longwalls.

Longwall mining is the most common form of coal mining in the Illawarra Region. Longwall mining contrasts with open-cut mining, with the former being undertaken by extracting coal accessed via tunnels. The coal seams are progressively accessed and extracted by longwalls. Longwall mining can affect the surface, principally by the effects of subsidence. Physical impacts such as subsidence induced fracturing of creek beds can cause diversions of surface and sub-surface flows, drainage of pools and increases in groundwater inflows.

1.2 Scope of Works

The work undertaken for the AFFA by Cardno consisted of the following:

- > Desktop review and compilation of existing information on aquatic habitat, vegetation and macroinvertebrates, fish, and any listed threatened species and populations, in the third or greater Strahler stream order (order) Wongawilli Creek catchment and Lake Cordeaux adjacent to the proposed location of Longwalls 22 and 23. This information was obtained from investigations that have been underway for several years, as part of existing mining operations in the Dendrobium Mine area.
- > Assessment of the potential impacts of the Project on aquatic ecology, including threatened species, and any cumulative impacts, in Wongawilli Creek and Lake Cordeaux and their tributaries that may experience impacts associated with potential mining subsidence.
- > Provide recommendations on measures to avoid and mitigate potential impacts on aquatic ecology and the form and content of the requisite aquatic ecology monitoring plan for these longwalls. This would be implemented to determine the nature and extent of any subsidence induced impacts on aquatic ecology and assess the response of aquatic ecology to any subsequent remediation and management works.

2 Relevant Management, Policies and Guidelines

2.1 Dendrobium Mine Development Consent

Schedule 3 of the Dendrobium Mine Consent includes several conditions concerning management of potential environmental impacts associated with mine subsidence. These include preparation of a SMP that integrates monitoring and management of potential impacts to natural (e.g. watercourses, swamps), built (e.g. electrical, communications and other infrastructure) and cultural (e.g. aboriginal heritage) features of the environment. With relevance to aquatic ecology, the SMP should:

- > Identify and assess the significance of all-natural features located within 600 m of the edge of secondary extraction;
- > Include a minimum of two years of baseline data, collected at appropriate frequency and scale, for all significant natural features;
- > Address third and higher order streams individually and address first and second order streams collectively;
- > Include a detailed subsidence impact assessment, clearly setting out all predicted subsidence effects, subsidence impacts and environmental consequences;
- > Describe a monitoring and reporting program addressing aquatic flora and fauna including any threatened aquatic species and their habitats and ecosystem function; and
- > Provide a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses, including a contingency plan focusing on measures for remediating both predicted and unpredicted impacts.

Several conditions also relate specifically to swamps, these are considered by other specialists.

Appendix 4 of the Dendrobium Mine Consent also provides a statement of commitments relating to longwall layouts, impact monitoring, avoidance, mitigation and any rehabilitation in DA3. These include a commitment to avoid significant impact to major natural features such as creeks, and a commitment to avoid mining under Wongawilli Creek and Sandy Creek to minimise the potential for major fracturing and loss of surface flow and any associated impacts to aquatic ecology. Pre, during and post mining subsidence impact monitoring of aquatic flora and fauna will also be undertaken in accordance with the approved SMP.

NSW Resources Regulator (formerly NSW Resources and Energy) has prepared guidelines for SMP (now known as Extraction Plan (EP)) applications (DRE 2003). A key component of the application is characterisation of each of the identified surface and sub-surface features that may be affected by the proposed mining. Results of a minimum of one-year pre-mining base-line monitoring of relevant environmental values in areas of environmental sensitivity that may be affected by the proposed mining with reference to applicable guidelines published by the NSW Government should also be included. The applicant should provide the results of a risk assessment, where appropriate, with an emphasis on identifying those subsidence impacts with high-risk levels and/or potentially severe consequences. Areas requiring attention by the applicant when conducting risk assessments include potential subsidence impacts on:

- > Wetlands, swamps and water related ecosystems;
- > Significant watercourses including surface flows, water quantity and quality and ecological integrity; and
- > Threatened and protected species.

2.2 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) contains provisions for the conservation of fish stocks, key fish habitat (KFH), biodiversity, threatened species, populations and ecological communities. The FM Act regulates the conservation of fish, marine vegetation and some aquatic macroinvertebrates and the development and sharing of the fishery resources of NSW for present and future generations. The FM Act lists threatened species, populations and ecological communities under Schedules 4, 4A and 5. Schedule 6 lists key threatening processes (KTPs) for species, populations and ecological communities in NSW waters and declared critical habitat are listed in a register kept by the Minister of Primary Industries. Impacts to these species, populations, communities, processes and habitats due to the Project need to be considered.

Assessment guidelines to determine whether a significant impact is expected are detailed in Section 220ZZ and 220ZZA of the FM Act.

Another objective of the FM Act is to conserve KFH. These are defined as aquatic habitats that are important to the sustainability of recreational and commercial fishing industries, the maintenance of fish populations generally and the survival and recovery of threatened aquatic species. In freshwater systems, most permanent and semi-permanent rivers, creeks, lakes, lagoons, billabongs, weir impoundments and impoundments up to the top of the bank are considered KFH. Small headwater creeks and gullies that flow for a short period after rain and farm dams on such systems are excluded, as are artificial water bodies except for those that support populations of threatened fish or invertebrates. At a broad scale, KFH relevant to the Project includes the following:

- > Permanently flowing rivers and creeks including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified;
- > Intermittently flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases including those where the flow is modified by upstream dam(s), up to the top of the natural bank regardless of whether the channel has been physically modified; and
- > Any waterbody if it is known to support or could be confidently expected (based on predictive modelling) to support threatened species, threatened populations or threatened communities listed under the provisions of FM Act.

2.3 NSW DPI (Fisheries) Policy and Guidelines for Fish Habitat Conservation and Management

The NSW Department of Primary Industries (DPI) Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013) (NSW DPI 2013a) replaces the Policy and Guidelines for Aquatic Habitat Management and Fish Conservation (NSW DPI 1999) and the former Fisheries NSW Policy and Guidelines for Fish Friendly Waterway Crossings (Fairfull and Witheridge 2003). These updated policies and guidelines are applicable to all planning and development proposals and various activities that affect freshwater, estuarine and marine ecosystems. The aims of the updated policies and guidelines are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species, in marine, estuarine and freshwater environments. The updated document assists developers, their consultants and government and non-government organisations to ensure their actions comply with legislation, policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes, and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed or offset. The policies and guidelines outlined in this document are taken into account when NSW DPI assesses proposals for developments and other activities that affect fish habitats. The document contains:

- > Background information on aquatic habitats and fisheries resources of NSW;
- > An outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitats in NSW;
- > General policies and classification schemes for the protection and management of fish habitats and an outline of the information that NSW DPI requires to be included in development proposals that affect fish habitat;
- > Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish through instream structures and barriers;
- > Specific policies and guidelines for foreshore works and waterfront developments; and
- > Specific policies and guidelines for the management of other activities that affect waterways.

NSW DPI considers the 'sensitivity' of any KFH that would be affected by the Proposal (NSW DPI 2013a). The term 'sensitivity' refers to the importance of the habitat to the survival of fish and its ability to withstand disturbance. In freshwater ecosystems, instream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 m in length, native aquatic plants, and areas known or expected to contain threatened and protected species are considered highly sensitive KFH. Other freshwater habitats plus weir pools and dams across natural waterways are considered to be moderately sensitive KFH. Ephemeral aquatic habitat that does not support native aquatic or wetland vegetation is considered to be of

minimal sensitivity. It is important to note that aquatic habitats within first and second order gaining streams, sections of stream that have been concrete-lined or piped (excluding waterway crossings) and artificial ponds are not regarded as KFH unless they support a listed threatened species, population or ecological community or 'critical habitat'. NSW DPI may in addition assess development proposals in relation to waterway class (i.e. their ability to provide habitat that is suitable for fish), which in turn determines the appropriate type of any waterway crossings.

2.4 Key Threatening Processes

A Key Threatening Process (KTP) is a process that threatens, or may have the capability to threaten, the survival or evolutionary development of species, population or ecological community. KTPs are listed under the FM Act, *Biodiversity Conservation Act 2016* (BC Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). There are eight listed KTPs under the FM Act, 38 listed under the BC Act and 21 listed under the EPBC Act. Broadly, the KTPs include threats to threatened species, population and ecological communities as well as cause species, population or ecological communities to become threatened.

One KTP listed under the BC Act is directly applicable to the Project: *Alteration of habitat following subsidence due to longwall mining*.

In the final determination for this KTP, the NSW Scientific Committee found that:

- > Mining subsidence following longwall mining is frequently associated with cracking of valley floors and creek lines and with subsequent effects on surface and groundwater hydrology.
- > Subsidence-induced cracks occurring beneath a stream or other surface water body may result in the loss of water to near-surface groundwater flows. If the water body is located in an area where the coal seam is less than approximately 100 to 120 m below the surface, longwall mining can cause the water body to lose flow permanently. If the coal seam is deeper than approximately 150 m, the water loss may be temporary unless the area is affected by severe geological disturbances such as strong faulting.
- > In the majority of cases, surface waters lost to the sub-surface re-emerge downstream. The ability of the water body to recover is dependent on the width of the crack, the surface gradient, the substrate composition and the presence of organic matter. An already-reduced flow rate due to drought conditions or an upstream dam or weir will increase the impact of water loss through cracking.
- > Subsidence can cause decreased stability of slopes and escarpments, contamination of groundwater by acid drainage, increased sedimentation, bank instability and loss, creation or alteration of riffle and pool sequences, changes to flood behaviour, increased rates of erosion with associated turbidity impacts, and deterioration of water quality due to a reduction in dissolved oxygen (DO) and to increased salinity, iron oxides, manganese, and electrical conductivity (EC).
- > Loss of native plants and animals may occur directly via iron toxicity, or indirectly via smothering. Long-term studies in the United States indicate that reductions in diversity and abundance of aquatic invertebrates occur in streams in the vicinity of longwall mining and these effects may still be evident 12 years after mining.
- > In the Southern Coalfield, substantial surface cracking has occurred in watercourses within the Upper Nepean, Avon, Cordeaux, Cataract, Bargo, Georges and Woronora catchments, including Flying Fox Creek, Wongawilli Creek, Native Dog Creek and Waratah Rivulet. The usual sequence of events has been subsidence-induced cracking within the streambed, followed by significant dewatering of permanent pools and in some cases complete absence of surface flow.
- > Subsidence associated with longwall mining has contributed to adverse effects on upland swamps. The conversion of perched water table flows into subsurface flows through voids, as a result of mining-induced subsidence may affect the water balance of upland swamps. The timeframe of these changes is likely to be long-term. While subsidence may be detected and monitored within months of a mining operation, displacement of susceptible species by those suited to altered conditions is likely to extend over years to decades as the vegetation equilibrates to the new hydrological regime.

The Department of Environment and Conservation (now the DPIE) has identified several priority actions to promote the abatement of this KTP, including:

- > Examine the effects of subsidence from longwall mining on priority ecosystems including streams, wetlands and threatened species, populations and ecological communities.
- > Prepare guidelines outlining key factors that should be considered when assessing impacts of new longwall mines on biodiversity.
- > Develop recommendations for monitoring impacts of new longwall mines on biodiversity and mitigation methods.
- > Ensure rigorous assessment of new mines continues through existing approval processes including the preparation of SMPs.

Consideration of the effect of exacerbation of any KTP on a listed threatened species, population or ecological community must be taken into consideration during any assessment.

3 Existing Environment

3.1 Study Area

The proposed Longwalls 22 and 23 are located within the Metropolitan Catchment Area, which is a special declared area controlled by Water NSW (previously the Sydney Catchment Authority (SCA)) (**Figure 3-1**). The Study Area for the aquatic ecology assessment is the surface environment directly above and within 600 m of the footprint of the longwalls. This is consistent with Condition 8d of Schedule 3 of the Dendrobium Mine Consent, which requires the identification and assessment of the significance of all natural features located within 600 m of longwalls. The main watercourse within the vicinity of Longwalls 22 and 23 is Wongawilli Creek, which flows in a northerly direction west of the longwalls. Wongawilli Creek is a third order creek that is 12 km long from its confluence with the Cordeaux River to its headwater, with 1.8 km within the Study Area.

The eastern shore of Lake Cordeaux is also within the Study Area but not within the 35 degree angle of draw. There are also several other first and second order drainage lines and upland swamps within the Study Area that flow into Wongawilli Creek and into Lake Cordeaux to the east. Physical impacts are not expected to occur in Lake Avon due to extraction of Longwalls 22 and 23 as it is located at least 3 km from the longwalls. Avon River and Cordeaux River are also located over 3 km from the longwalls and are not expected to be impacted by longwall extraction. Thus, Lake Avon, Avon River and Cordeaux River have not been considered further. Swamps and associated flora and fauna in the Study Area were assessed by other specialists.

Figure 3-1 also includes the 400 m boundary and the area within the 35° angle of draw. The 35° angle of draw indicates where conventional longwall mine subsidence impacts would be expected to occur. In the Southern Coalfield, subsidence induced fracturing has been observed up to 400 m from longwall extraction. Therefore the 400 m boundary has been used as a reference to make predictions about the extent of impacts to watercourses in MSEC (2021) and in this AFFA.

3.2 Overview of Previous Studies and Field Surveys

Numerous studies of aquatic habitat, flora and fauna in the Dendrobium Mine area have been undertaken by Cardno (formerly Cardno Ecology Lab and The Ecology Lab). These studies assessed impacts of predicted mine subsidence on aquatic ecology, including threatened species, in DA3, and undertook monitoring before, during and after mining. These included studies in:

- > DA1: AEA studies (The Ecology Lab 2001a, b and 2003) and monitoring study (The Ecology Lab 2005).
- > DA2: AEA studies (The Ecology Lab 2006) and monitoring studies (Cardno Ecology Lab 2009); and
- > DA3: AEA studies (The Ecology Lab 2007), including the Area 3B AEA (Cardno Ecology Lab 2012a), baseline studies (Cardno Ecology Lab 2011) and ongoing monitoring studies (Cardno Ecology Lab 2012; 2013; 2014; 2015 and 2016 and Cardno 2018a) and most recently (in 2019) (Cardno 2020a). Assessments were also undertaken for Longwalls 20 and 21 in Area 3C (Cardno 2019), Longwall 19 in Area 3A (Cardno 2020b) and Longwall 18 in Area 3B (Cardno 2020c).

In these studies, the primary watercourses considered were in the Wongawilli Creek, Sandy Creek and Donalds Castle Creek catchments. Sandy Creek and Donalds Castle Creek, and their drainage lines, are located outside the Study Area for Longwalls 22 and 23 and would not be affected by extraction, thus they are not considered in this assessment. Information on aquatic habitat, water quality, aquatic macroinvertebrates and fish in the Study Area available from these previous studies is reviewed in **Section 3.3 to 3.11**. This review of existing information included the findings of surveys undertaken at Sites 5, 19 and 20 on Wongawilli Creek. These are the closest sites to Longwalls 22 and 23 and would be those most likely to experience any impacts associated with extraction. Information from sites farther upstream on Wongawilli Creek has also been reviewed for comparative purposes. These are Sites 1 to 4 and X4 to X8. Sites 19 and 20 were visited in June 2017 as part of the AFFA for Longwalls 20 & 21 (Cardno 2019) and Sites 1 to 5 and X4 to X8 in autumn and spring of 2019 as part of the ongoing monitoring of aquatic ecology in Area 3B (Cardno 2020a). Details of the methods used in these studies and the GPS coordinates of monitoring sites are provided in **Appendix A**.

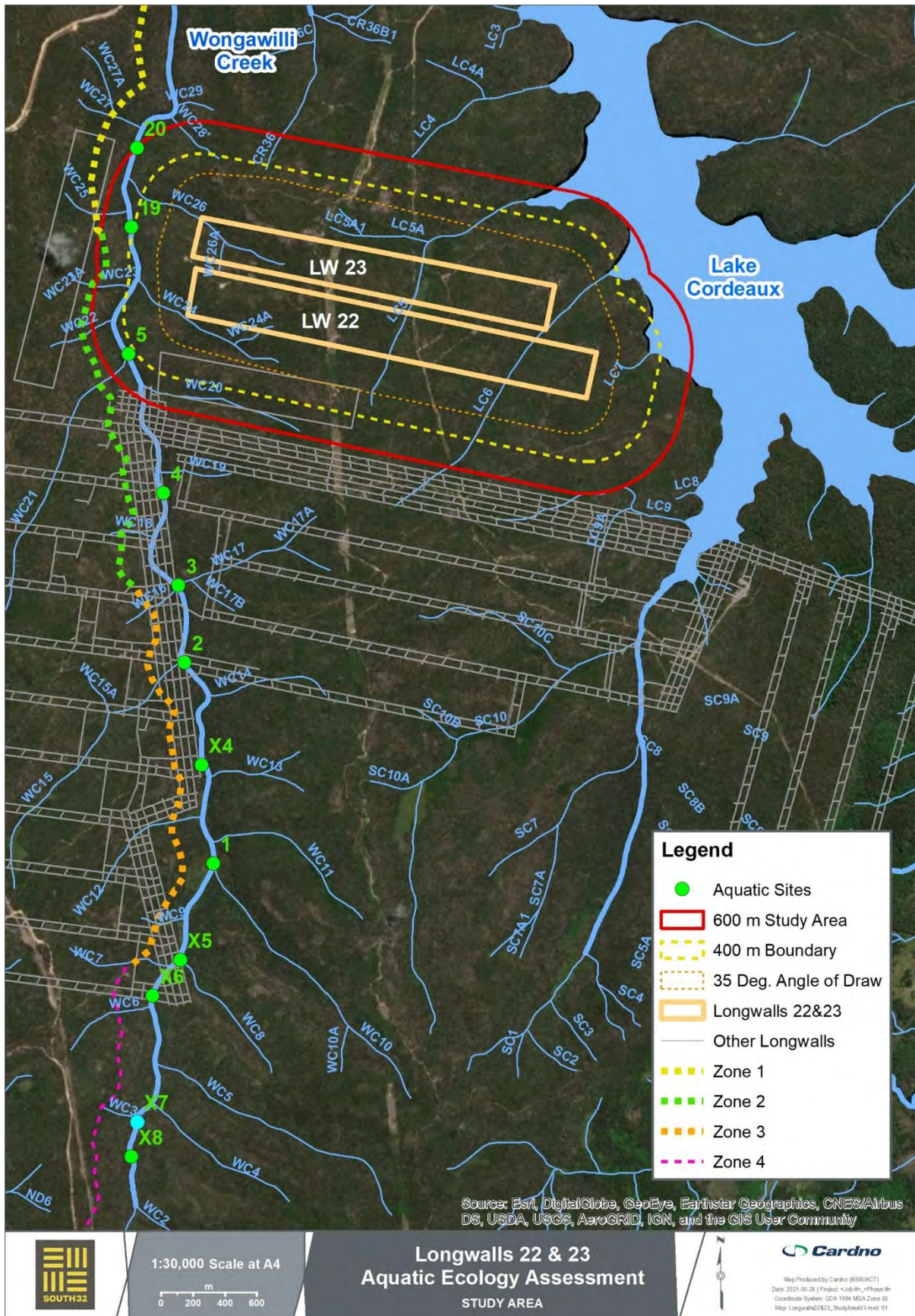


Figure 3-1 Aerial image overlaid with longwall layouts, watercourses and aquatic ecology sites within and adjacent to the Longwalls 22 and 23 Study Area (600 m boundary). The 400 m boundary is presented to provide context for the subsidence predictions (Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield (MSEC 2021).

3.3 Aquatic Habitat and Vegetation

3.3.1 Wongawilli Creek

Detailed investigations of Wongawilli Creek were undertaken as part of the initial investigations for DA3 in July 2007 (The Ecology Lab 2007). Four zones each with different habitat characteristics were identified within Wongawilli Creek. The Study Area for Longwalls 22 and 23 is located within Zones 1 and 2. Zone 1 is located from the confluence with the Cordeaux River to approximately 3 km upstream (approximately at the current Site 19 location) and Zone 2 extends from here upstream to the inflow of drainage line WC16 between Sites 4 and 5 upstream of the Study Area. The aquatic habitat within Zones 1 and 2 is characterised as follows:

- > Riparian vegetation consisting primarily of sawgrass (*Gahnia* sp.), wattle (*Acacia* sp.), tea-tree (*Leptospermum* sp.) and ferns along the creek banks, surrounded by dry eucalypt forest. There is extensive overhanging vegetation along the stream margin. Stream banks composed of well vegetated sandy soil with little erosion or undercutting. The channel within Zone 2 is far more incised and steep than that in Zone 1 and with sections of exposed sandy soil with signs of erosion including undercutting and scouring.
- > A main channel providing substantial aquatic habitat including a series of large deep pools, some of which are over 100 m in length, over 10 m wide and up to 4 m deep. In the large pools, the dominant substratum is sand, with significant areas of bedrock, and boulders. Small gravel beds are present in the upstream sections of some of the pools. The pools also have accumulation of detritus, including leaf litter and woody debris. In Zone 1 the pools are separated by sandstone rock bars ranging in height from 1 to 15 m and up to 50 m in length. The largest of the rock bars (WC-RB 1) is situated just upstream of the confluence with the Cordeaux River. There are numerous in-stream habitat features, including large snags, tree roots, sandstone rock walls, caves, boulders and aquatic macrophytes. In Zone 2 the pools are shallower and interspersed by small sandstone rock bars, sandbars, debris dams and small boulder fields. The substratum consists of large areas of sand deposit and small amounts of boulders, cobbles, pebbles and gravel. The pools contain leaf litter and woody debris. Large snags and tree roots are also present.
- > There are three significant barriers to fish passage in Zone 1. The largest being a rockbar-waterfall (WC RB 1) located just upstream of the confluence with Cordeaux River. This waterfall has a series of sandstone steps up to 2 m high and a total fall in elevation of approximately 15 m and would therefore pose a hindrance to the upstream passage of species such as Macquarie perch, but less so freshwater eels and galaxiids which are more adapted passing such barriers. The other barriers are the rockbars (WC-RB 11 & 12) located upstream of Fire Road 6. During periods of low to moderate flow, the shallow flow and vertical fall of these rockbars would create a major barrier to the upstream passage of Macquarie perch. During large floods, these rockbars are likely to be submerged for short periods, so it is possible that Macquarie perch and other fish are able to move further upstream at these times.
- > The distribution of aquatic plants is patchy throughout Zones 1 and 2, with green and brown algae present. The only other submerged plant found was Watermilfoil (*Myriophyllum* sp.) at Site 5. Three emergent plants were recorded in Wongawilli Creek, rush (*Juncus* sp.) at Sites 1 and 3, sedge (*Cyperus* sp.) and *Lomandra* sp. at Site 3. The baseline monitoring (Cardno Ecology Lab 2011) indicated that aquatic macrophytes were relatively scarce covering $\leq 5\%$ of the surface area at the majority of monitoring sites, except for Site 5, where the percentage cover varied from 10% to 40% in spring and 15% to 80% in autumn. The percentage cover of aquatic macrophytes at the other sites exceeded 5% on only two occasions in September 2011 and April 2009 at Sites X6 and 3, respectively. Algae were more common, covering $\geq 20\%$ of the area on occasion at all of the sites. Mosses were present on bedrock, boulders and large woody debris and appeared to be more prevalent in spring. The Ecology Lab (2001a) also noted small beds of *Myriophyllum* sp. in most pools and extensive algal growth on hard surfaces.

Based on description of the four habitat types adapted from Fairfull and Witheridge 2003 (**Appendix A**), Wongawilli Creek through Zone 1 and in Zone 2 (i.e. within the Study Area) provides significant aquatic habitat (i.e. watercourses that contain numerous large, permanent pools and generally have flow connectivity except during prolonged drought) (**Plate 1**).



Plate 1. Wongawilli Creek at i to ii) Sites 19 and 20 in Zone 1 and at iii and iv) Site 5 and Site 3 in Zone 2.

Mapping undertaken by IMCEFT has identified 21 flow-controlling rockbars and 22 pools in Wongawilli Creek within the 600 m boundary (**Figure 3-2**). These pools develop behind the rockbars as water flow is restricted by shallow sections and sediment and debris accumulations. The pools range between 15 m and 200 m long and between 5 m and 25 m wide.

3.3.2 Drainage Lines

3.3.2.1 Wongawilli Creek

Ten drainage lines of Wongawilli Creek are located in the Study Area (WC20, WC21, WC22, WC23 and WC24, WC24A, WC25, WC26, WC26A and WC28).

WC21 (**Plate 2**) is the largest tributary within the Study Area and contains “moderate” aquatic habitat. However, it has experienced impacts including loss of flow and reductions in pool water levels due to previous mining in Area 3A and Area 3B. It is characterised by a permanent pool at the base of a large sandstone cascade/waterfall. This pool is approximately 15 m in diameter and has sandy substratum with large sandstone boulders and bedrock throughout. This pool would provide habitat for fish and invertebrates throughout prolonged dry periods. The cascade on WC21 consists of a series of sandstone steps up to 4 m high with a total change in elevation of approximately 20 m over a horizontal distance of approximately 70 m and would thus prevent upstream passage of Macquarie perch. It is noted that only the downstream most 100 m is located within the 600 m boundary, with none within the 400 m boundary.

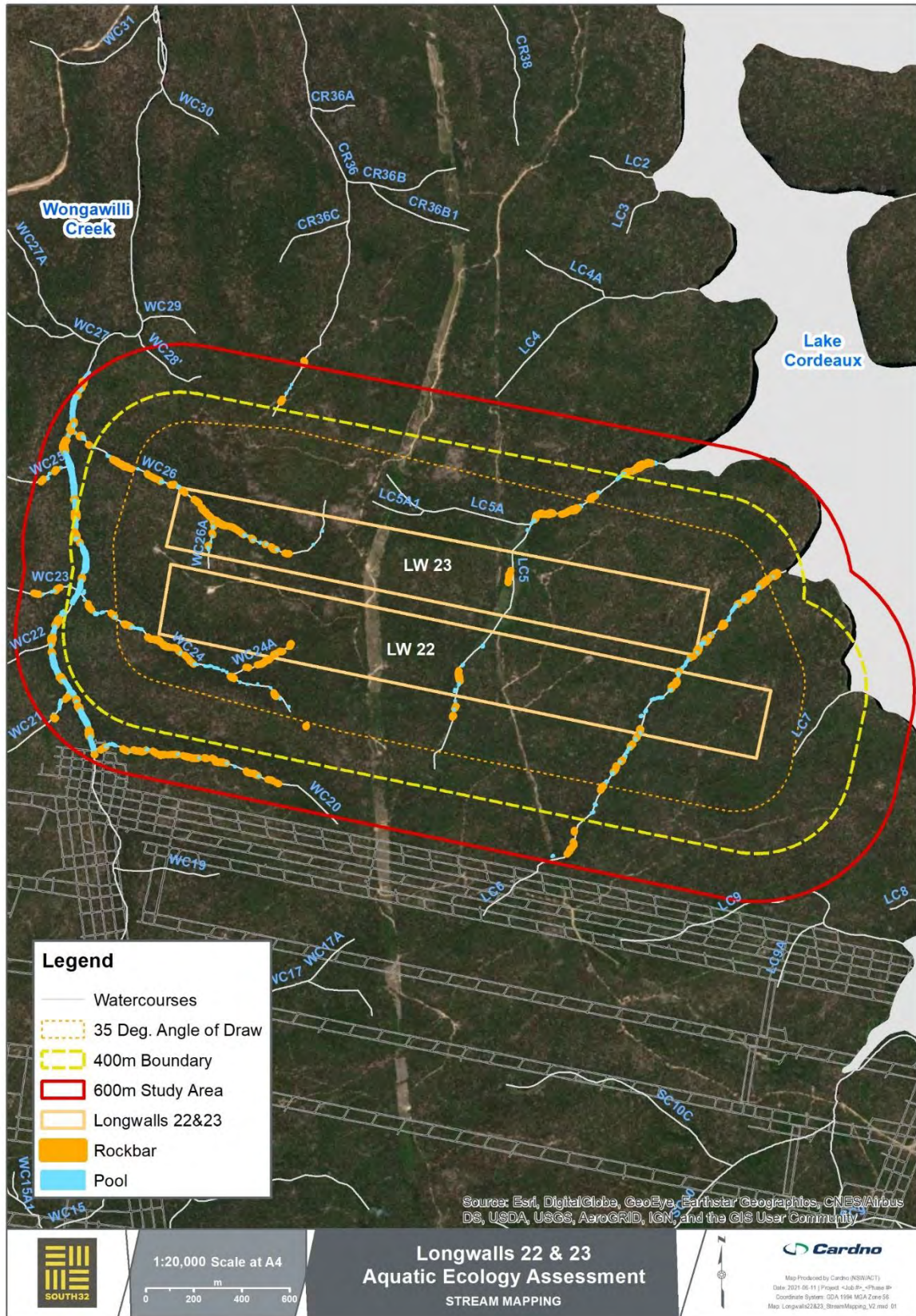


Figure 3-2 Location of pools and flow controlling rockbars mapped within Wongawilli Creek and drainage lines within the Study Area

WC20, WC23, WC24, WC25 and WC26 contain “minimal” aquatic habitat. The extreme upper reaches of some of these and all of WC22, WC24A and WC26A contain ‘unlikely’ aquatic habitat. WC26 is one the largest of these drainage lines and contains some small pools likely to provide some aquatic habitat for aquatic macroinvertebrates, including freshwater crayfish. These findings were used to inform the detailed KFH mapping using the updated classifications in NSW DPI (2013a) during the current assessment (**Section 3.4**).



Plate 2. Drainage line WC21 within the 600 m boundary

3.3.2.2 Lake Cordeaux

Five drainage lines of Lake Cordeaux (LC5, LC5A, LC5A1, LC6 and LC7) and one drainage line of Cordeaux River (CR36) are located within the Study Area. The lower reaches of LC5 (**Plate 3i**) and LC6 (**Plate 3ii**) contain ‘moderate’ aquatic habitat and the upper reaches of these drainage lines contain ‘minimal’ and ‘unlikely’ aquatic habitat, respectively. LC5A, LC5A1 and LC7 contain unlikely aquatic habitat.



Plate 3. Drainage lines i) LC5 and ii) LC6 in September / November 2020

As part of initial investigations for the Dendrobium Coal Project The Ecology Lab (2001a) assessed aquatic habitats in Lake Cordeaux and in its major tributaries along its eastern and southern shore, including LC6 and LC5, with particular consideration given to habitat for Macquarie perch. In general, shoreline riparian vegetation consisted of large stands of undisturbed native eucalypts, casuarinas and cabbage tree palms. LC6 and LC5 had similar stream morphologies, flow rates and riparian vegetation. A notable feature of these drainage lines was the presence of a waterfall at their mouths, forming permanent fish barriers to and from Lake Cordeaux. The stream substratum above the waterfalls comprised of sandstone bedrock, forming long shallow pools and alternating short riffles. These pools provided habitat for invertebrates and amphibians and most probably reflect the absence of predatory fish above the water falls. Accumulated wood, bark and leaves characterised the stream detritus, and native eucalypts and bottlebrush characterised the riparian

vegetation. At the base of the waterfalls, the habitat was characterised by coarse sand and large sandstone boulders. Riparian vegetation was dominated by a continuous stand of native casuarinas and eucalypts, though no instream vegetation was observed. The RCE score for both drainage lines was 40, indicating limited physical disruption, excellent aquatic habitat yet limited fish passage. LC7 was not assessed, but would be unlikely to provide habitat for Macquarie perch due to its small length.

3.3.3 RCE Inventory

Results of the RCE assessment at sites on Wongawilli Creek are provided in **Appendix B**. Total scores ranged from 46 to 50. These are relatively high and indicative of largely undisturbed systems. All sites scored high (i.e. 4, no evidence of disturbance) in categories associated with the condition of riparian vegetation and channel morphology. While there was some evidence of sediment accumulation, this appears to be a natural occurrence given the undisturbed nature of the surrounding environment.

3.4 Key Fish Habitat

The broad scale KFH map for Wollongong available on the NSW DPI website indicates that Lake Cordeaux and the third order sections of Wongawilli Creek are KFH (NSW DPI 2020) (**Figure 3-3**). The first and second order drainage lines that traverse the Study Area are not identified as KFH by this map. Wongawilli Creek provides Type 1 – Highly sensitive KFH, and contains areas of aquatic plants, large rocks and large wood debris. First and second order streams, including the first and second order drainage lines of Wongawilli Creek, Lake Cordeaux and Cordeaux River (**Section 3.3.2**) within the Study Area, are not KFH (NSW DPI 2013a). Nevertheless, lower sections of these drainage lines are likely to provide somewhat permanent aquatic habitat in the form of larger pools connected by flow. Further upstream in drainage lines, aquatic habitat becomes increasingly limited as baseflow reduces due to the smaller sub-catchment areas. While these areas may contain some rocks and wood debris, they would have intermittent flow, with disconnected pools that would provide sporadic refuges for aquatic fauna such as fish and freshwater crayfish, if present. Furthermore, several substantial natural barriers to fish passage (such as waterfalls, cascades, and low flow over rock bars) were present on these drainage lines which generally have much steeper grades than the larger creeks. This would limit the number and type of fish species present to those capable of passing such barriers, such as climbing galaxias.

Lake Cordeaux provides habitat for the listed threatened Macquarie perch (**Section 3.8**). As such, it provides Type 1 – Highly Sensitive KFH.

3.5 Water Quality

The limited *in-situ* water quality measurements taken in Wongawilli Creek during the baseline aquatic ecology monitoring showed:

- > EC levels were generally within the ANZECC/ARMCANZ (2000) guideline default trigger values (DTVs) (30 to 350 ($\mu\text{S}/\text{cm}$) for upland rivers in south-east Australia (Cardno Ecology Lab 2009 and 2011). EC measurements below the lower DTV were recorded at Sites X5, X4 and 4, but only on one occasion.
- > pH of the water at all sites was generally below the DTVs (pH 6.5 to 8.0). It should be noted that this is typical for watercourses that flow through Hawkesbury sandstone environments.
- > DO levels at all the sites on the creek fell below the lower DTV (90 % saturation) during some surveys. This more commonly occurred at the sites downstream (1, 2, 3, 4, 5 and X4) than at sites within (X6 and X5), the Study Area. DO levels in excess of the upper DTV (110 % saturation) were recorded at Sites X6, 3 and 4 in September 2010 and at Sites 1, 2, 3 and 4 in April 2009.
- > In spring, the turbidity measurements taken at Sites X6, X5 and 5 were frequently below the lower DTV (2 ntu), as were the measurements taken at Sites 1 and X4 in autumn. Turbidity readings in excess of the upper DTV (25 ntu) were recorded at Sites 3 and 4, but only in October/November 2011.

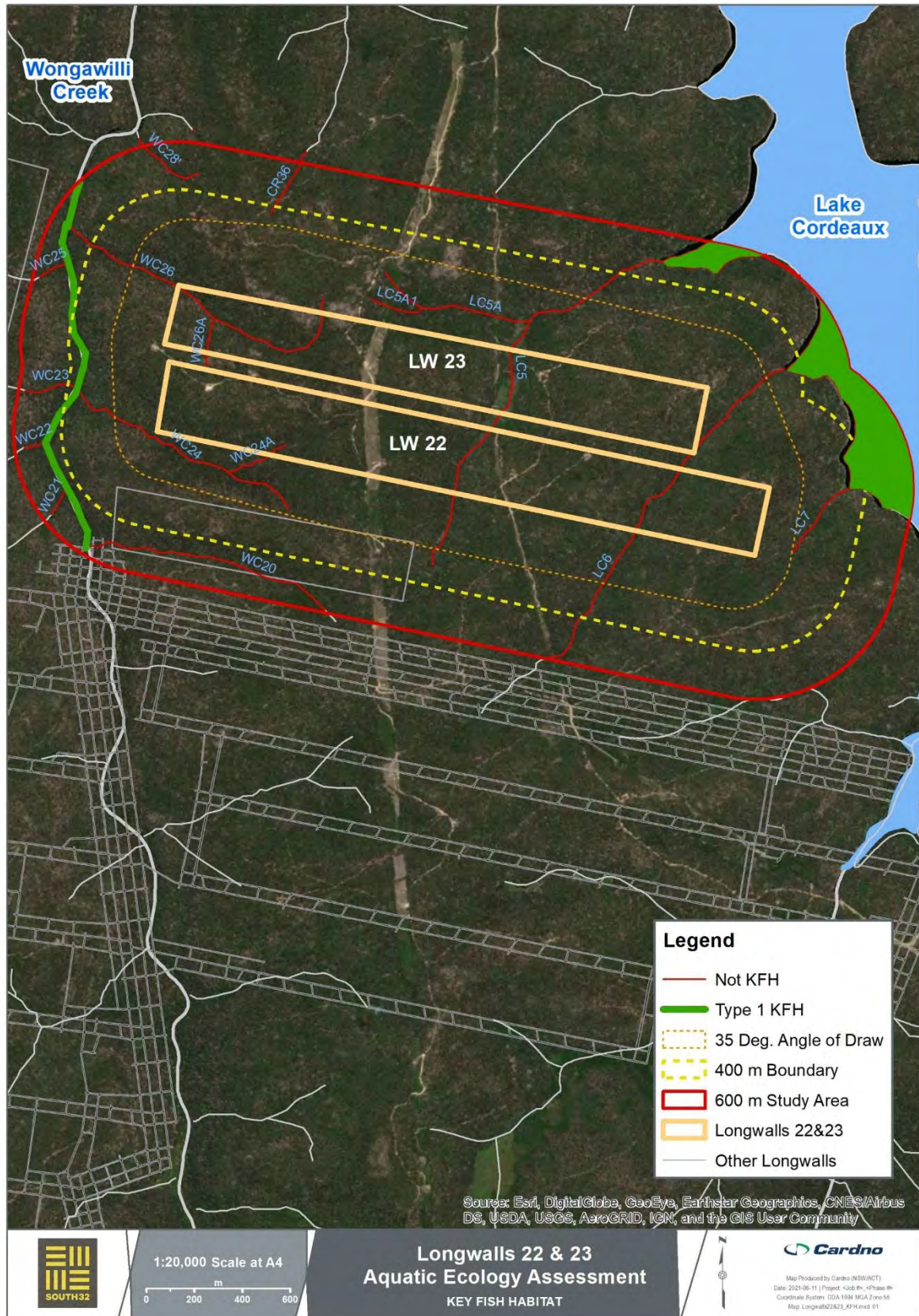


Figure 3-3 Key fish habitat mapped within the Study Area

While water quality measures have often been found outside DTVs, the relatively remote and undisturbed catchment area does not suggest influence by any anthropogenic disturbance. Turbidity values below 2 ntu are not cause for concern, and most likely reflect the relatively low organic content of the water. Also, low pH levels have been recorded generally across the Dendrobium Mine area. They appear to occur naturally, most likely associated with local geology and its influence on water chemistry. The natural water quality of these creeks should be taken in to consideration when interpreting the results of macroinvertebrate sampling.

Water quality is regularly (at least monthly) monitored by IMCEFT at sites on Wongawilli Creek. A review of 11 years of baseline data undertaken for the surface water assessment (HGeo 2020) for the previous Longwall 18 SMP indicates these (and other watercourses draining the Dendrobium Mine Area) are relatively fresh and within ANZECC (2000) water quality guidelines (EC generally <150 µS/cm) though contain sodium and chloride ions, reflecting mostly direct rainfall runoff. pH is generally mildly acidic (pH 4.9 to 6.5) and below guidelines, likely due to drainage from swamps and organic-rich soils. Dissolved trace metals are present in very low concentrations, mostly below the ANZECC guidelines for protection of 95% of freshwater species (where available). An exception is dissolved aluminium and zinc in some locations. The slightly elevated aluminium concentrations are to be expected since aluminium (and most metals) are more soluble in waters of low pH. DO levels are variable and typically between 80 % saturation and 95% saturation and within or slightly below guidelines.

3.6 Macroinvertebrates

The several AUSRIVAS surveys undertaken in Wongawilli Creek have indicated a relatively large amount of variability in biotic indices. During sampling as part of the Area 3A and Area 3B monitoring and surveys for the Longwalls 20 & 21 AFFA, assemblages on Wongawilli Creek ranged from more diverse than AUSRIVAS reference condition (AUSRIVAS Band X) to severely impaired (Band C) (**Appendix C**). AUSRIVAS Band scores are derived from the OE50 Taxa Score, which is a biotic index of habitat and water quality (**Appendix A**). The Stream Invertebrate Grade Number Average Level (SIGNAL2 Scores), a biotic index of water pollution, suggested severe to mild water pollution. However, while these results suggest potential anthropogenic disturbance to habitat and / or water quality, there is no other evidence to support this. It is possible that the naturally low pH levels in this watercourse, and others that traverse the Dendrobium Mine area may be influencing the type of macroinvertebrates that are present. Other measures of water quality, such as naturally occurring levels of some heavy metals, may also influence the type of macroinvertebrates, and other organisms, present (Cardno Ecology Lab 2012a; b; Ecoengineers 2006). Overall, there was little difference in biotic indices between sites in Wongawilli Creek within and outside of the Study Area (**Table 3-1**).

Table 3-1 Mean AUSRIVAS data from sites in Wongawilli Creek within (Sites 5, 19 and 20) and outside (Sites 1 to 4 and X4 to X5) the Study Area in each of Wongawilli Creek and Sandy Creek from 2008 to 2017. Note not all sites sampled on each occasion, see **Appendix B** for further detail. SE = standard error.

Site	Number of Taxa		OE50 Taxa		SIGNAL2 Score	
	Mean	SE	Mean	SE	Mean	SE
Within Study Area						
Site 5	22.0	0.7	0.85	0.03	4.7	0.1
Site 19	15		0.78		5.1	
Site 20	16		0.97		5.0	
Outside (Upstream) of the Study Area						
Site 1	15.5	0.7	0.72	0.03	4.8	0.1
Site 2	17.2	0.7	0.80	0.03	4.8	0.1
Site 3	17.7	0.5	0.83	0.03	4.6	0.1
Site 4	18.6	0.7	0.88	0.03	4.6	0.1
Site X4	13.0	0.6	0.71	0.03	4.5	0.1
Site X5	14.7	1.0	0.73	0.05	4.7	0.2
Site X6	16.3	1.1	0.76	0.06	4.5	0.1
Site X7	14.5	1.4	0.63	0.05	4.1	0.1
Site X8	17.5	2.6	0.71	0.15	4.5	0.2

The one exception was that the number of taxa tended to be greater at Site 5 (within Study Area) than at other sites on the creek. However, differences between sites inside and outside the Study Area were otherwise marginal, and do not suggest substantial differences in aquatic habitat and water quality inside

and outside of the Study Area. Neither Adams emerald dragonfly or Sydney hawk dragonfly have been identified in any of the AUSRIVAS samples collected by Cardno in the Dendrobium Mine Area.

3.7 Fish

Numerous fish surveys have been undertaken in Wongawilli Creek previously. In particular, in autumn 2008 and summer 2009, targeted backpack electrofishing surveys were undertaken in the reaches of Wongawilli Creek identified as containing potential habitat for Macquarie perch (Cardno Ecology Lab 2009), including that within the Study Area. Climbing galaxias (*Galaxias brevipinnis*), Australian smelt (*Retropinna semoni*) and freshwater crayfish (*Euastacus* sp.) were caught in the reach of the creek immediately downstream of Fire Road 6, just downstream of the Study Area. The deeper pool sections immediately upstream of this road and within the Study Area contained Australian smelt and longfinned eel (*Anguilla reinhardtii*). Further upstream, large numbers of climbing galaxias and freshwater crayfish were caught. In 2001, fish occurring in pools and riffles from the upstream limit of boat passage back down to the road crossing were sampled using an electrofisher (The Ecology Lab 2001a, b). Australian smelt, freshwater eels (*Anguilla* sp.), mountain galaxias and climbing galaxias were caught upstream of the major barriers. No Macquarie perch were caught during these surveys, although this species has been recorded in Wongawilli Creek in pools just upstream and downstream of Fire trail 6A (NSW DPI (Fisheries), pers. com.; The Ecology Lab, 2001a, b; MPR 2006a; b). On 31 October 2011, eight individuals of this species were observed in the pool immediately upstream of fire trail 6A (Matt Richardson, Niche pers. comm.). This species has not, however, been caught any farther upstream in Wongawilli Creek despite extensive subsequent sampling for the ongoing Area 3A and Area 3B investigations (Cardno 2012 and 2016).

There are three significant barriers to fish passage on Wongawilli Creek downstream of the Study Area. The largest being rockbar-waterfall (WC-RB 1) located just upstream of the confluence with Cordeaux River. This waterfall has a series of sandstone steps up to 2 m high and a total fall in elevation of approximately 15 m and would therefore pose a hindrance to the upstream passage of species such as Macquarie perch, but less so for freshwater eels and galaxiids which are more adept at passing such barriers. The other barriers are the rockbars (WC-RB 11 & 12) located upstream of Fire Road 6. During periods of low to moderate flow, the shallow flow and vertical fall of these rockbars would create a major barrier to the upstream passage of Macquarie perch. During large floods, these rockbars are likely to be submerged for short periods, so it is possible that Macquarie perch and other fish are able to move further upstream at these times. However, the apparent absence of Macquarie perch upstream of these rockbars suggests it is possible that this species is unable to pass this natural barrier and access the section of Wongawilli Creek within the Study Area, at least not in any appreciable numbers.

A survey of Lake Cordeaux, undertaken in 1994 using gill nets and electro-fishing, indicated that three native fish species, longfinned eel, Australian smelt and Macquarie perch, and goldfish (*Carassius auratus*), an invasive species, were present (Gehrke and Harris 1996). During subsequent surveys, Australian smelt, numbers of goldfish, longfinned eels, mountain galaxias and shortfinned eels and a single Macquarie perch were caught (Gowns and Gehrke 2001). Freshwater crayfish (*Euastacus* sp.) were also caught in Lake Cordeaux (Gowns and Gehrke 2001). During the third survey, undertaken when Macquarie perch are known to migrate from reservoirs to spawning habitats in creeks, four specimens were caught in Lake Cordeaux, but none were found in the creeks entering the lake. This was despite the presence of habitats suitable for spawning in Goondarrin and Kembla Creeks (Creese and Hartley 2003). It is possible that a low storage level in the dam at the time of sampling may have prevented Macquarie perch from accessing these spawning areas. In Lake Avon, Macquarie perch, longfinned eel, and Brown trout (*Salmo trutta*) have been recorded, and it is thought that a further 12 species may be present (Cardno Ecology Lab 2012a).

Fish surveys undertaken at Sites 5, 19 and 20 as part of the assessment for Longwalls 20 and 21 identified galaxiids, Australian smelt and freshwater crayfish. Macquarie perch were not caught. Most recently in 2019, galaxiids were caught at Sites 1, 3, 5 and X4 on Wongawilli Creek and freshwater crayfish observed at Sites 2, 4 and 5 on Wongawilli Creek. Numbers were comparable with those caught in this watercourse previously (Cardno 2020a).

Aside from the listed threatened Macquarie perch, all species of fish identified from the Study Area are widespread and abundant, and currently have no cause for conservation concern.

3.8 Listed Threatened Species, Populations and Ecological Communities

3.8.1 Information Sources

A search for information on records and distributions of threatened species, populations and ecological communities listed under the FM Act, EPBC Act and BC Act in the Wongawilli Creek catchments was

undertaken to update searches completed for previous assessments for DA3 (The Ecology Lab 2007; Cardno Ecology Lab 2011). The search used the following resources:

- > The Department of the Environment and Energy (DEE) Protected Matters Search Tool (DEE 2020) was used to determine whether any Matters of National Environmental Significance (MNES) listed under schedules of the EPBC Act occurred in a 10 km radius from the centre of the Study Area;
- > The DPIE managed BioNet searched for records of BC Act listed flora and fauna within the Sydney – Cataract sub-region held in the Atlas of NSW Wildlife. The Atlas of Living Australia (ALA 2021) was also searched for records of species of fish (including invertebrates and vertebrates) listed under the FM Act occurring in the catchments of Lake Cordeaux and Wongawilli Creek; and
- > Species distribution maps contained in the NSW DPI Fish Communities and Threatened Species Distributions of NSW (NSW DPI 2016a) were examined for the occurrence of threatened species listed under the FM Act in the upper catchments of Cordeaux River and Avon River.

The desktop search indicated several species that occur, or have potential to occur, in the Study Area. Amphibians, aquatic mammals, reptiles and Giant dragonfly (*Petalura gigantea*) are being considered by other specialists and were excluded from the search.

3.8.2 Macquarie Perch

Macquarie perch is listed as endangered under the EPBC Act and the FM Act. In addition to reaches of Wongawilli Creek downstream of the Study Area (**Section 3.7**) it has been recorded also in Lake Avon and Lake Cordeaux (ALA 2020) and suitable habitat exists in the upper reaches of Cordeaux and Avon Rivers and in Lake Avon (NSW DPI 2016a) (see **Section 3.7** for a description of more recent records in Lake Cordeaux). Outside of these areas, Macquarie perch are found in the Murray-Darling Basin, particularly the upstream reaches of the Lachlan, Murrumbidgee and Murray rivers, and parts of south-eastern coastal NSW, including the Hawkesbury and Shoalhaven catchments.

Macquarie perch prefer clear water and deep, rocky holes with extensive cover in the form of aquatic vegetation, large boulders, debris and overhanging banks (NSW DPI 2016b). They spawn in spring or summer and lay their eggs over stones and gravel in shallow, fast-flowing upland streams or flowing parts of rivers. Macquarie perch is an active predator of macroinvertebrates. While other large-bodied percichthyids are generally higher-order ambush predators that may have limited range, the Macquarie perch tends to have a relatively larger linear (along shore) diel range (Ebner *et al.* 2010). A study in a Canberra reservoir found that Macquarie perch have a mean linear diel range of 516 m (± 89 S.E.) which suggests that discontinuous and small pools would not provide suitable habitat for this species (Ebner *et al.* 2010).

The National Recovery Plan for Macquarie perch (DEE 2018). This contains background information on the biology, ecology, distribution and populations, decline and threats and recovery objectives and strategies and associated actions for this species. Identified threats include:

- > Habitat degradation;
- > Alien (non-native) fish;
- > Barriers to fish movement;
- > Altered flow and thermal regimes;
- > Disease;
- > Illegal / incidental capture;
- > Chemical water pollution; and
- > Climate change.

Recovery Strategies are:

- > Conserve existing Macquarie perch populations;
- > Protect and restore Macquarie perch habitat;
- > Investigate threats to Macquarie perch populations and habitats;

- > Establish additional Macquarie perch populations;
- > Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance; and
- > Increase participation by community groups in Macquarie perch conservation.

Actions directly applicable to the Project include the provision of advice on the distribution of Macquarie perch to determining authorities to ensure appropriate consideration during development assessment processes, and the undertaking of targeted surveys to determine the current distribution and abundance of Macquarie perch.

3.8.3 Australian Grayling

Australian grayling is listed as a vulnerable species under the EPBC Act and is a protected species under the FM Act. It occurs in coastal streams and rivers on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria, and Tasmania (NSW DPI 2006). Australian grayling has been recorded in the Grose River, but there are no records of this species from the upper Nepean Catchment. They have also been recorded in estuarine areas. The life cycle of Australian grayling is dependent upon migration to and from the sea (McDowall 1996). Spawning occurs in late summer or autumn and larvae are swept downstream to the sea (NSW DPI 2006). Juvenile fish return to freshwater when they are about six months old and remain in rivers and streams for the rest of their life. Australian Grayling has undergone a considerable decline in its distribution and abundance and, although it was historically present in the Hawkesbury-Nepean, it is now restricted to the coastal rivers of southern New South Wales (Morris *et al.* 2001; NSW DPI 2016a). The decline of this species has been attributed to dams, weirs and culverts preventing it from migrating to and from the sea and completing its life cycle. As Australian grayling is highly unlikely to occur within the Study Area, further consideration of this species is not considered necessary.

3.8.4 Sydney Hawk Dragonfly

The Sydney hawk dragonfly (*Austrocordulia leonardi*) is listed as endangered under the FM Act. It is extremely rare, having been collected in small numbers at only a few locations in a small area to the south of Sydney, between Audley and Picton (NSW FSC 2004). The species is also known from the Hawkesbury-Nepean, Georges River and Port Hacking drainages. It was discovered in 1968 from Woronora River and Kangaroo Creek, south of Sydney, and has subsequently been found in the Nepean River at Maldon Bridge near Picton and further upstream at Nepean Dam (ALA 2020). There are no records for this species within the Study Area or the Cordeaux and Lake Avon catchments. Extensive sampling has failed to discover further specimens in other areas suggesting that it has a highly restricted distribution within the catchment of the Nepean River (NSW DPI 2007).

Most of the lifecycle of this species is spent as an aquatic larva, with adults living for only a few weeks. The larvae appear to have specific habitat requirements, being found under rocks in deep, cool, shady pools (NSW DPI 2007). Relative environmental stability appears to be an important habitat feature, with rapid variation in water level and flow rate likely to have a negative effect on the suitability of habitat for larvae.

No recovery and threat abatement plans exist for this species. Several conservation and recovery actions for Sydney hawk dragonfly are included in NSW DPI (2007):

- > Allocate and manage environmental water through water sharing planning processes, to lessen the impacts of altered flows;
- > Prevent sedimentation and poor water quality by using conservation farming and grazing practices, conserve and restore riparian (river bank) vegetation and use effective erosion and sediment control measures;
- > Rehabilitate degraded habitats. Protect riparian vegetation and encourage the use of effective sediment control measures in catchments where the dragonfly may occur;
- > Protect the few remaining sites with the potential to support the species, and address key threats such as habitat degradation and water quality decline;
- > Conduct further research into the species' biology, ecology and distribution; and

- > Implement the Protected, Threatened and Pest Species Sighting Program and report any sightings to NSW DPI.

3.8.5 Adams Emerald Dragonfly

Adams emerald dragonfly (*Archaeophya adamsi*) is listed as endangered under the FM Act. It is extremely rare, having been collected only in small numbers at a few locations in the greater Sydney region (NSW DPI 2013b). Specimens have been collected at five localities: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford; Berowra Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park. There are no records for this species within the Study Area or the Cordeaux and Lake Avon catchments (ALA 2020). There are no records of Adam's emerald dragonfly occurring south of Sydney, despite active collecting in the Hawkesbury-Nepean River catchment (NSW FSC 2008). This species was not collected by Cardno during the baseline surveys of aquatic macroinvertebrates in Wongawilli, Sandy, Donalds Castle or Native Dog Creeks as part of the Dendrobium Mine area studies, but aquatic habitat that appears suitable for this species does occur within these watercourses (Cardno Ecology Lab 2011).

The larvae of Adam's emerald dragonfly inhabit small creeks with gravel or sandy bottoms in narrow, shaded riffle zones with moss and abundant riparian vegetation (NSW DPI 2013b). The larvae live for approximately seven years before metamorphosing into adults that probably live for only a few months. They are thought to have a low natural rate of recruitment and limited dispersal abilities.

No recovery and threat abatement plans exist for this species. Conservation and recovery actions (NSW NSW DPI 2013b) for Adams emerald dragonfly are:

- > Rehabilitate degraded habitats. Protect riparian vegetation and encourage the use of effective erosion and sediment control measures in catchments where the dragonfly may occur;
- > Protect the few remaining sites that still support the species, and address key threats such as habitat degradation and water quality decline from expanding development;
- > Conduct further research into the biology and distribution of the species; and
- > Report any sightings to NSW DPI.

3.8.6 Likelihood of Occurrence

Table 3-2 assesses the likelihood of occurrence of Listed Threatened Species in the Study Area.

Table 3-2 Likelihood of Occurrence of Listed Threatened Species in the Study Area

Species and Listing	Likelihood of Occurrence
Macquarie perch (endangered under FM Act and EPBC Act)	Occurs in Lake Cordeaux, Cordeaux River and the reach of Wongawilli Creek just upstream of Fire Road 6 and downstream of the Study Area. Suitable pool habitat exists within Wongawilli Creek upstream but it has not been caught during numerous surveys in Wongawilli Creek upstream of Fire Road 6, possibly due to the presence of natural barriers to fish movement further downstream. Very unlikely to occur in drainage lines in the Study Area due to the limited aquatic habitat provided by these watercourses.
Adams emerald dragonfly (endangered under FM Act)	Unlikely to occur within the Study Area. No records within, or adjacent to the Study Area despite extensive sampling, though suitable microhabitat appears to exist in creeks and drainage lines.
Sydney hawk dragonfly (endangered under FM Act)	Unlikely to occur within the Study Area. Records from the adjacent Nepean Catchment though no records within the catchments of Wongawilli Creek and Sandy Creek despite extensive sampling, though suitable microhabitat appears to exist in creeks and drainage lines.
Australian grayling (endangered under FM Act and vulnerable under EPBC Act)	Does not occur in the Study Area. Present in coastal rivers of southern NSW outside of the Study Area.

3.9 Critical Habitat

The Study Area does not contain any critical habitats listed under the FM Act, BC Act or EPBC Act.

3.10 Existing Mining Impacts to Watercourses

Cardno (2018b) undertook a review of existing mining impacts that have occurred due to previous and existing mining in the upper Avon and Cordeaux River catchments. These include the following mining in the Metropolitan Special Area:

- > Longwall mines: Dendrobium Areas 1, 2, Area 3A, Area 3B Longwalls 9 to 13, Elouera Mine, Cordeaux Mine, Kemira Mine; and
- > Bord and pillar mines: Nebo Mine and Wongawilli Mine.

Subsidence induced impacts (fracturing, flow diversions and/or reductions in pool water levels) have been observed in watercourses overlying each of the previous mine areas. To provide an indication of the cumulative impact of these mines on aquatic ecology in these and the upper Avon and Cordeaux River catchments, the length of watercourse known or expected to experience subsidence related impacts was calculated by the Illawarra Metallurgical Coal Environmental Field Team (IMCEFT). As of May 2018, of the 716 km of watercourses (first order and above) mapped within the upper Avon and Cordeaux River catchments, direct mining impacts (fracturing, flow diversions and/or pool water loss) had or were highly likely to have occurred in approximately 36 km of watercourses located directly above longwall mining. This included first, second and higher order streams within the Wongawilli, Sandy and Donalds Castle Creek Catchments.

The most recent impacts observed (associated with mining in DA3) include fracturing, flow diversions and reductions in pool water levels in SC10C (a tributary of Sandy Creek) and WC17 (a tributary of Wongawilli Creek) in Area 3A. Fracturing of bedrock and flow diversions have also been experienced in WC15, which is also within the current Study Area. Impacts have not been experienced in WC13, WC14, WC16, SC10, SC10A or SC10B, which are within the current Study Area but are not located directly above and have not been impacted by previous Area 3A and Area 3B longwalls. Outside of the Study Area, such impacts have also been observed and in WC21 (a second order tributary of Wongawilli Creek) and in upper Donalds Castle Creek in Area 3B. In each case there was an associated loss of aquatic habitat and likely also biota.

Impacts occurring in SC10C were assessed in detail in Cardno Ecology Lab (2015). Fracturing of bedrock and reductions in pool water levels and flow occurred here in December 2011, and in early 2013 low pool water levels were evident throughout SC10C. These changes were attributed to the extraction of Longwalls 7 and 8 which took place below SC10C and the adjacent area between May 2011 and December 2012. During the 2013 and 2014 aquatic ecology surveys, the only water present in SC10C was a small, shallow pool at Site 13. The complete drainage of all but one pool in SC10C resulted in a direct loss of aquatic habitat and likely some biota. Other impacts to aquatic ecology associated with the physical impacts include the loss of longitudinal connectivity. The impact to aquatic ecology due to desiccation of aquatic macrophytes was considered minimal, as very little in-stream aquatic vegetation has been identified in SC10C. A reduction in abundance of Leptoplebiidae (a pollution sensitive Family of mayfly in the Order Odonata) and an increase in abundance of Chironomidae (consisting of three pollution tolerant Subfamilies: Chironominae, Orthocladiinae and Tanypodinae) was also detected, indicating associated impacts to aquatic biota. The impacts to aquatic ecology observed in SC10C were localised to the areas directly affected by physical mining impacts and were considered relatively minor in the context of the Sydney Catchment Area. This watercourse was visited last in 2014.

Approximately 77 km of watercourse is located above previous bord and pillar mining. Based on observations of impacts due to longwall mining there is potential for these to have also experienced direct subsidence related impacts similar to that experienced above longwall mining. The most severe watercourse impacts described above (fracturing and flow diversions resulting in part or complete drainage of pools and loss of surface water) tend to occur when watercourses are directly mined under. However, such impacts may also occur in watercourses that are not directly mined under. A further 18 km of watercourse located directly downstream of longwall mining is expected to have experienced indirect impacts (including reductions in pool water levels and flow). Fracturing of rockbars was observed in Donalds Castle Creek, LA4 (tributary of Lake Avon) and WC15 100 m to 300 m from Area 3B longwalls. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield (MSEC 2021).

Collectively, the length of watercourse that has experienced indirect and direct mining impacts is estimated to be 16% of that present in the upper Avon and Cordeaux River catchments. The majority of this would be first and second order drainage lines. However, impacts of groundwater depressurisation have recently been

observed in Wongawilli Creek. During inspections in May 2018, a reduction in flow and a series of disconnected pools were observed within an approximate 1,400 m section of Wongawilli Creek and representing about 10% of the total 12 km length of Wongawilli Creek. This section included Pool 44 to Pool 53. Surface flow was observed just downstream of the confluence with Wongawilli Creek tributary WC21. Although fracturing in one rockbar at Pool 43a in Wongawilli Creek was observed during extraction of Longwall 9 in December 2012, this is not considered to be the cause of the reduced flow and reduction in pool water levels here. Rather, assessment of flow and water level data with rainfall and rates of pool water recession from before and after commencement of mining and the timing of fracturing suggest mining induced groundwater depression coinciding with low rainfall explain the low flow and water levels observed in Wongawilli Creek (HGeo2018). Low pool water levels were not restricted to Pool 43a but were also observed in Pool 49. Pool water levels also begun to decline 2 years before the fracture was observed. The pool recession rate, calculated as the decline in pool level between consecutive observations averaged over the number of days, was not greater after the observation of the fracture. Mining is considered to be the primary cause of reductions in groundwater levels in the lower Hawksbury Sandstone and upper Bulgo Sandstone. This has contributed to a reduction in baseflow in Wongawilli Creek, which was most noticeable during periods of low rainfall and greater evapotranspiration that occurred in 2018. Extraction of each individual longwall would be expected to contribute to reductions in groundwater levels. HGeo (2018) estimated baseflow capture of approximately 0.3 ML/d in Wongawilli Creek, this would be a significant fraction of flow under conditions of very low rainfall such as those that have occurred during 2018 with typical surface flow below 1 ML/day (HGeo 2018). It is noted that a significant mining effect on surface flow in Wongawilli Creek was not apparent approximately 3 km downstream at gauge WWL.

Pool water levels and flow are also restored following rainfall events, thus impacts to the availability and connectivity of aquatic habitat is temporary. During aquatic ecology surveys throughout 2019, water and flow was present in the sections of Wongawilli Creek previously affected by reductions in water levels and flow, albeit water levels appeared reduced slightly during the current survey in November 2019. Nevertheless, temporary reductions in flow and pool water levels would be expected to affect aquatic biota. Such as the changes observed in SC10C in the Sandy Creek catchment. Changes in the abundance of several macroinvertebrate taxa have also been observed in WC21 and Donalds Castle Creek and have been attributed to reductions in pool water levels observed here (Cardno 2018a). Temporary reductions in longitudinal connectivity would also be expected to affect fish and aquatic macroinvertebrates by limiting movement in search of food and refuge. It may also result in reduction in genetic transfer, particular if it coincides with migration as part of reproduction. Species of freshwater eel (*Anguilla* sp.), for example, undertake long distance reproductive migration that could be hindered during times of low flow and pool water level. As well as direct habitat loss, associated reductions in water quality could also affect the type and number of macroinvertebrates and other aquatic biota (fish, large mobile invertebrates and aquatic macrophytes) in watercourses. However, the changes in water quality observed that are associated with mining (reduced DO and elevated EC) have been relatively minor. Changes in macroinvertebrates appear to be localised to the areas of watercourse directly affected by physical mining impacts and habitat loss. They do not appear to persist downstream once water reappears (Cardno 2018a).

3.11 Summary

The findings of the current and previous investigations indicated that aquatic habitat in drainage lines within the Study Area is relatively limited. This habitat comprises relatively small (in terms of length, catchment size and area of aquatic habitat) first and second order drainage lines of Wongawilli Creek and Lake Cordeaux. These drainage lines support semi-permanent pools that would retain water for some time after rainfall and provide habitat for aquatic biota and have been largely unaffected by mining. The current and previous investigations indicate that the aquatic ecology in sections of these watercourses in the Study Area are comparable with that present throughout the larger catchment area.

Though some of the biotic indices derived from AUSRIVAS aquatic macroinvertebrate sampling in Wongawilli are indicative of degraded habitat or water quality, these more likely reflect natural conditions and the naturally low pH of stream water within the catchment, rather than any anthropogenic disturbance. Wongawilli Creek provides the most substantial habitat for native fish, aquatic plants and macroinvertebrates in DA3. The listed threatened Macquarie perch is likely to be present in Wongawilli Creek downstream of the Study Area, though the presence of natural barriers and its apparent absence in this and previous targeted surveys upstream of here suggests it is very unlikely to occur in watercourses in the Study Area. Other threatened species (Australian grayling, Adams emerald dragonfly and Sydney hawk dragonfly) do not, or are highly unlikely to, occur in the Study Area. There is very little evidence of invasive plant species instream or within the riparian zone.

4 Assessment of Impacts

4.1 Subsidence Predictions

Wongawilli Creek is located at minimum distances of 345 m and 320 m from the western ends of Longwall 22 and Longwall 23, respectively. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield (MSEC 2021). The extraction of coal from the proposed longwalls will result in vertical and horizontal movements of the rock and soil mass directly above and immediately adjacent to the extracted coal seam (i.e. subsidence). Subsidence that occurs under surface watercourses is likely to result in fracturing of the streambed and banks, movements of joints and bedding plates in the streambed, uplift and buckling of rock strata in the streambed. Fracturing of bedrock and diversion of surface flows in watercourses depends on the magnitude of subsidence movements, valley-related upsidence and closure movements. Ground movements can also lead to tilting of streambeds that can, in turn, lead to erosion of the streambed and banks and increased instream sediment load, changes in flow rates and migration of stream channels. Where mining induced tilts oppose and are greater than the natural drainage line gradients that exist before mining, subsidence can potentially result in increased levels of ponding. The potential for changes to the level of ponding, flooding and scouring of banks along watercourses depends on whether the net vertical movements brought about by longwall mining alters the gradients of the watercourses. Mining can also potentially result in an increased likelihood of scouring of the banks in the locations where tilts considerably increase natural gradients. Mining induced tension and compression can also result in dilation and bed separation in the topmost bedrock. Subsidence may also allow the release of gas from sub-surface strata that could affect water quality and, in some cases, lead to dieback of riparian vegetation.

MSEC (2021) assess physical impacts that may occur in watercourses and in Lake Cordeaux within 600 m of the longwalls. The impacts predicted to occur by MSEC (2021) are summarised as follows:

- > Lake Cordeaux is predicted to experience less than 20 mm vertical subsidence and although it could experience low level vertical subsidence, it is not expected to experience measurable tilts, curvature or conventional strains. It is possible that fracturing could occur in the bedrock beneath the Lake Cordeaux where it is located within approximately 400 m of the proposed longwalls. However, it is unlikely that fracturing would be visible in the bed of the reservoir due to the alluvial deposits.
- > The section of Wongawilli Creek located within the Study Area is predicted to experience less than 20 mm vertical subsidence. Based on predicted compressive strains in Wongawilli Creek of 8 mm / m, it is possible fracturing could occur in Wongawilli Creek (fracturing has been observed where compressive strains are greater than 2 mm / m). Based on observed rates of fracture and total closure measurements in the Southern Coalfield, the potential for Type 3 fracturing related impacts (i.e. fracturing in rockbar or upstream pool resulting in a reduction in standing water level based on current rainfall and surface water flow) is considered low (6 %) (MSEC 2021). Minor fracturing (not resulting in flow diversions) could still occur elsewhere along the creek, at distances up to approximately 400 m from the proposed longwalls. While the creek could experience very low levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains. The predicted changes in grade due to the mining of Longwalls 22 and 23 are considerably less than the average natural grade. Thus, ponding, flooding or scouring of the banks along the creek due to any mining-induced tilt are unlikely. It is possible, however, that there could be some localised changes in the levels of ponding or flooding where the maximum changes in grade coincide with existing pools, steps or cascades along Wongawilli Creek. It is not anticipated that these changes would result in adverse impacts on the creek, since the predicted changes in grade are less than 0.05 %.
- > A total of 16 drainage lines are located across the Study Area, with six (WC24, WC24A, WC26, WC26A, LC5 and LC6) located at least partly above Longwalls 22 and / or 23. Drainage lines within the Study Area could experience subsidence of up to 3,000 mm. It is expected that fracturing of the bedrock would occur along the sections of the drainage lines that are located directly above the proposed longwall. Fracturing could also occur outside the extents of the longwall, with minor and isolated fracturing expected at distances up to approximately 400 m. Surface water flow diversions are likely to occur along the sections of drainage lines that are located directly above and adjacent to the longwall. The maximum predicted incremental (i.e. due solely to Longwalls 22 and 23) change in grade is 4.0% or 1 in 25. The natural gradients of the drainage lines vary from 5% to 20%. The potential for fracturing of drainage lines within the Study Area is expected to be similar to that observed above and adjacent to the existing longwalls in Area 3B. It is possible that minor and localised increased ponding could develop, though

impacts resulting from the changes in surface water flows due to the mining-induced tilt are expected to be small in comparison with those which occur during natural flooding conditions.

The assessment of potential impacts on aquatic ecology arising from the extraction of Longwall 22 and 23 was based on the maximum predicted movements for the sections of creeks and drainage lines that flow through and adjacent to the Study Area and their predicted physical impacts (MSEC 2021) and associated impacts on surface water (HGeo 2020a) and groundwater (HGeo 2021b).

4.2 Impacts on Aquatic Habitat and Biota

The assessment of impacts to aquatic habitat was undertaken with consideration of amount (linear length) of watercourse that would be affected by physical mining impacts, the relative value of this habitat, the severity of predicted impacts, and the amount of comparable watercourse present in the wider catchment that would remain unaffected by the mining. Physical impacts such as creek bed fracturing may cause diversion of surface and sub-surface flows, drainage of pools and increases in groundwater inflows. These changes, in turn, may have adverse effects on aquatic flora and fauna via reductions in the amount of aquatic habitat, desiccation of fringing vegetation and reductions in longitudinal connectivity. The impact of changes in surface and sub-surface water availability on aquatic habitats is likely to be greater if it coincides with periods of low or no flow. The duration of these impacts on aquatic habitats depends on the characteristics of the watercourses, such as substratum type, and subsequent flow events. In some cases, cracks in bedrock may be filled partially or completely by alluvial deposits during subsequent flow events.

4.2.1 Lake Cordeaux

Less than 100 m² of the full supply area of Lake Cordeaux is located within the 400 m boundary (i.e. where fracturing could occur). Assessment of associated impacts to surface water storage by HGeo (2021a and b) indicates that Longwalls 22 and 23 may result in an incremental seepage loss from Lake Cordeaux of approximately 0.08 and 0.05 ML/day, respectively. The cumulative impact due to extraction of all longwalls in the Dendrobium Mine would be up to 0.36 ML/d (HGeo 2021b). Water quality effects in Lake Cordeaux are expected to be negligible and undetectable (HGeo 2021a). Thus, any impacts to the availability of aquatic habitat and to aquatic biota in Lake Cordeaux are not expected.

4.2.2 Wongawilli Creek

4.2.2.1 Loss of Aquatic Habitat

Impacts to aquatic habitat and biota in Wongawilli Creek could arise due to loss of aquatic habitat following fracturing of rockbars and resulting diversion of flows. It could also occur following reduced groundwater recharge following mining induced groundwater depressurisation. Twenty-one flow controlling rockbars have been identified in Wongawilli Creek within 600 m of longwalls 22 and 23. Based on the predicted rate of fracture of 6 % (or 1 in 17) it is probable that one of these rockbars would fracture. Resulting flow diversions could result in the drainage of the upstream pool with associated loss of aquatic habitat. These pools range in length from 15 m to 200 m. The loss of water and aquatic habitat from one of these pools would represent a significant impact at the scale of individual pools, with the probable loss of most aquatic fauna (at least that less mobile and unable to relocate to nearby pools). Pool drainage would also reduce longitudinal connectivity between remaining pools. The loss of aquatic habitat and reduction in connectivity of remaining habitat would be expected to result in a reduction in the population size of aquatic biota, including native fish, large mobile macroinvertebrates and smaller macroinvertebrates. Such impacts would be significant at the scale of the individual pool, and would be expected to result in a reduction in the population size of aquatic biota in the creek. Such impacts represent a relatively minor impact at the scale of the entire creek. It is expected that any affected pool(s) would experience flow during and soon after rain events, which would limit impacts associated with reduced habitat connectivity. Some biota would be able to use the pool as habitat during this time also. The rate of pool recession (how long it takes to drain following refilling) will depend on the extent and exact location of fractures.

Groundwater modelling (HGeo, 2021b) indicates that the incremental reduction in flow along Wongawilli Creek adjacent to Area 3C due to extraction of Longwall 22 would be 0.02 ML/day to 0.06 ML/day and for Longwall 23 it would be 0.007 ML/day to 0.026 ML/day. As a result, it is expected that Longwall 22 would cause a negligible (1%) increase in the duration and length over which cease-to-flow conditions can occur in Wongawilli Creek during drought periods (HGeo 2021a). The effect of Longwall 23 is predicted to be up to a 2% increase (from approximately 6% of the time to 8%). Flow effects would likely not be discernible from natural variability or from other historical, approved and proposed longwalls (HGeo 2021a). Therefore, associated impacts to aquatic habitat and biota due to groundwater depressurisation and reductions in

surface water availability associated with Longwalls 22 and 23, in isolation, are likely also to be negligible and not detectable.

The cumulative effect on flows due to the extraction Area 3A, 3B and 3C (Longwalls 6 to 23) would be approximately 0.13 ML/day to 0.46 ML/day. The cumulative effects are likely to increase the number of cease-to-flow days in the middle to lower reach of Wongawilli Creek (adjacent to Areas 3A, 3B and 3C) from 6% (background rate) of the time to 17%, on average (i.e. from 22 days per year to 62 days per year). This would be most obvious during extended periods of low rainfall and limited surface run-off and surface recharge. Such an increase, however, is considered highly unlikely based on analysis of historical field data (HGeo 2021a). Such impacts would be expected to occur during future comparable drought conditions, and become more noticeable as further longwalls in Area 3C are extracted (**Section 4.2.6**).

Localised changes in availability of aquatic habitat due to ponding, flooding and scouring of stream banks as a result of subsidence induced tilt in drainage lines are not expected to result in adverse physical impacts in Wongawilli Creek (**Section 4.1**), and thus adverse impacts to habitat and biota are not expected either.

4.2.2.2 Changes to Water Quality

Based on previous observations, it is expected that water quality influence due to the extraction of Longwalls 22 and 23 would be minor or undetectable in stream reaches within most subsidence affected areas and water quality impacts have not been detected in watercourses that are not directly mined under (HGeo 2021a). Thus, no associated impacts to aquatic habitat and biota area expected in Wongawilli Creek.

4.2.3 Drainage Lines

4.2.3.1 Loss of Aquatic Habitat

Drainage lines directly above Longwall 22 and 23 would be most at risk of flow diversions and reductions in aquatic habitat area and quality due to a greater potential for subsidence and fracturing to occur here. It is expected that fracturing of the bedrock would occur along the sections of the drainage lines that are located directly above Longwalls 22 and 23, with a total of approximately 1,700 m of first / second order drainage lines directly above the longwalls. Fracturing can also occur outside the extents of the proposed longwalls, with minor and isolated fracturing previously observed at distances up to approximately 400 m. An additional ~ 5,200 m of first / second order drainage line habitat is located within 400 m of the longwalls.

These drainage lines generally support limited aquatic ecology (i.e. consist generally disconnected pools) and would dry during periods of prolonged drought. The lower sections of LC5 and LC6, however, appear to support some relatively permanent pools that could provide habitat for large mobile macroinvertebrates (*Euastacus* sp.) and fish including galaxiids. Fracturing induced flow diversions would reduce the volume and duration of ephemeral flows, though there would also not be any fundamental change in habitat type (i.e. it would still be ephemeral watercourse). In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows can be diverted into the dilated strata below the beds and there would be a reduction in the availability of aquatic habitat in these drainage lines.

Drainage of pools and loss of aquatic habitat following fracturing leading to flow diversion in drainage lines is likely to have localised, significant impact on aquatic biota, particularly on aquatic plants and sessile animals. The survival of mobile organisms is difficult to predict, it will depend on individual taxon tolerance and response to desiccation and changing water levels, their ability to migrate to nearby unaffected areas, weather conditions, the underlying substratum and duration of exposure. Due to the generally limited aquatic habitat supported by these drainage lines and the abundance of ephemeral drainage line habitat in the wider catchment, potential consequences to aquatic ecology whilst significant at the scale of individual pools and drainage lines, would be minor at the wider catchment scale. It is noted that the lower sections of LC5 and LC6 that provide the most substantial aquatic habitat in these drainage lines are not located directly above the longwalls and so should not experience the most severe fracturing and loss of flow. While the loss of associated aquatic biota represents a severe impact to aquatic biota at the scale of individual pools, at the scale of the upper Avon and Cordeaux River catchments, impacts to the population size of affected aquatic biota associated with drainage lines associated with extraction of Longwalls 22 and 23 would be minor. Although complete drainage of a pool or section of pool would reduce longitudinal connectivity in the drainage lines and impact the ability of aquatic biota to move in search of food and refuge, natural connectivity within these ephemeral drainage lines would be limited. Nevertheless, these impacts would further contribute to the cumulative reduction in the availability of this habitat in the Cordeaux Catchment associated with the Dendrobium Mine.

Potential ponding and scouring of the drainage lines are expected to be minor and localised. Significant associated impacts to aquatic habitat and biota are therefore not expected. In any case, localised and minor changes in habitat availability and connectivity would also be difficult to detect due to the large variability in grade and natural flows within these ephemeral systems.

Loss of baseflow due to groundwater depressurisation is also predicted in LC5, LC6, WC26 and WC24, as well as a very minor loss of baseflow at CR36 (located almost entirely outside the 400 m boundary) (HGeo 2021a). The availability of gauging flow data from CR36 allowed a prediction of the likely increase in zero flow days, with an increase from 11 % of the time (natural conditions) to between 18 % and 24 % of the time expected. Such an increase in the number of zero flow days in a natural ephemeral drainage line are not expected to have significant impacts to aquatic habitat and biota.

4.2.3.2 Changes to Water Quality

Based on previous observations, it is expected that water quality impacts, including transient increases in EC, pH, some dissolved metals, and localised iron staining, may be observed in drainage lines that cross the longwall footprints (WC24, WC26, LC5 and LC6), and possibly in LC7 (HGeo 2021a). Such transient changes are not expected to result in significant impact to aquatic biota in drainage lines. In any case, the aquatic habitat they provide is relatively limited.

4.2.4 Key Fish Habitat

Impacts to KFH in Lake Cordeaux are not expected. Type 1 KFH habitat is present in Lake Cordeaux, though no significant impacts to the availability of this habitat would occur as no significant fracturing or reductions in water levels are predicted.

Impacts to Type 1 KFH in Wongawilli Creek could occur if fracturing resulting in the drainage of any pool occurs following extraction. Although impacts to Type 1 KFH at the scale of watercourse would be relatively minor, they would be significant at the scale of individual pool(s).

KFH is not present in the first and second order drainage lines and its availability and quality would not be affected by the impacts that occur in these watercourses.

4.2.5 Threatened Species

Sydney hawk dragonfly and Adams emerald dragonfly were not found in the AUSRIVAS samples collected from Wongawilli Creek as part of several previous studies within, and adjacent to, the Study Area. While suitable microhabitat for this species occurs in the Study Area, the absence of this species in the numerous collected samples, and its known distribution outside of the Study Area, provides sufficient evidence that it does not currently occur here. Australian grayling also does not occur in the Study Area, thus, assessments of significance for these species were not considered necessary.

Macquarie perch have previously been recorded in the lower reach of Wongawilli Creek downstream of the Study Area. Though habitat (larger pools) suitable for this species does occur in Wongawilli Creek within the Study Area, none have been found during the several fish surveys here and farther upstream. Lake Cordeaux provides habitat for Macquarie perch, however, impacts associated with extraction of Longwalls 22 and 23 would be negligible. Nevertheless, as a precautionary measure an assessment of significance was undertaken for this species in accordance with the Threatened Species Assessment Guidelines (DECC 2007) (**Appendix D**).

The guidelines specify the important factors that must be taken into considered when assessing potential impacts on threatened species, populations, or ecological communities. The factors requiring consideration are:

- > How is the Project likely to affect the lifecycle of a threatened species and/or population?
- > How is the Project likely to affect the extent and composition of a threatened ecological community?
- > How is the Project likely to affect the habitat of a threatened species, population or ecological community?
- > Will the Project affect any critical habitat?
- > Is the Project consistent with the objectives or actions of a recovery plan or threat abatement plan?
- > Is the Project part of a KTP or is it likely to exacerbate a KTP?

The potential for adverse effects on the lifecycle of threatened fish species depends on whether the works are likely to cause loss or degradation of habitat, reduction in water quality, limit their foraging activities and

disrupt their reproduction and recruitment. The assessment presented in **Appendix F** indicated the risk of Macquarie perch being impacted by the Project as unlikely.

4.2.6 Cumulative Impacts

Although extraction of Longwall 22 and 23 would result in a negligible contribution to the predicted cumulative reductions to baseflow in Wongawilli Creek, groundwater depressurisation due to extraction of Area 3A, Area 3B and Area 3C longwalls would result in an increase in zero flow days in Wongawilli Creek. Zero flow or 'cease-to-flow' conditions are estimated to occur in Wongawilli Creek up to 6 % of the time under natural conditions (HGeo 2021a). The cumulative effect of all Dendrobium Mine longwalls could increase the number of zero flow days from 6 % of the time to 17 % of the time in the reach of Wongawilli Creek near Area 3C. Such reductions in baseflow due to groundwater drawdown, while small in absolute magnitude, can be a significant portion or all of the flow down the reach of Wongawilli Creek adjacent to Area 3B longwalls in extreme drought periods, as was experienced 2017 into early 2020. Following completion of extraction of Longwall 16 on 4 November 2020, changes to stream flow characteristics were not evident at the downstream gauge (WWL) on Wongawilli Creek Lower (HGeo 2021c).

5 Recommendations

Four approaches would be used to manage potential impacts on aquatic ecology within the Study Area from Longwalls 22 and 23:

- > Impact minimisation;
- > Aquatic ecology monitoring;
- > Additional aquatic ecology studies that would be triggered by specific impacts on physical and water quality characteristics of the watercourses;
- > Contingent measures should impacts exceed predictions; and
- > Compensatory measures, if required.

5.1 Impact Minimisation

Temporary erosion and sediment control measures such as sediment fences, sandbag weirs, temporary drains, and temporary silt traps should be installed prior to any minor surface works (e.g. road construction and clearing of vegetation) in the vicinity of watercourses and swamps to prevent the input of sediment into watercourses and perched aquifer systems during rainfall events.

5.2 Monitoring

5.2.1 Background

An aquatic ecology monitoring program would be implemented to:

- > Determine the nature and extent of any subsidence-induced impacts on aquatic ecology due to extraction of Longwalls 22 and 23; and
- > Assess the response of aquatic ecosystems to any stream remediation and management works implemented.

A comprehensive monitoring plan designed to assess the potential impacts of mine subsidence on aquatic habitat and biota within watercourses of Area 3 was outlined in The Ecology Lab (2007). This monitoring plan was prepared in accordance with the Dendrobium Consent, the Director General's Requirements (DoP) to modify the Area 3 mine area and in support of the SMP application for Area 3A and Area 3B. The monitoring plan indicated that baseline sampling would be conducted in impact and control locations four times within a 12 month period prior to the commencement of longwall mining and that during-extraction and post-extraction monitoring would be undertaken at the same seasonal periods to determine the extent and nature of any impacts and recovery. The plan also advocated a temporally staged monitoring approach be adopted and that impact and control locations relevant to each of Areas 3A, 3B and 3C be monitored over a 12-month period prior to that area's development. The strategic review of the impacts of underground mining in the Southern Coalfield, recommends that baseline studies be conducted at sufficient intensity over a minimum period of 18 to 24 months to gain a better understanding of the variability and seasonality in distribution of flora and fauna, prior to any mining activity (NSW DoP 2008). The review also recommended that replicate surveys be undertaken at sites directly above the mine and at comparable control sites outside the direct impact zone, so that changes and fluctuations due to mining can be distinguished from those due to natural variability.

The Independent Expert Panel for Mining in the Catchment was established in late February 2018 to provide informed expert advice to the (then) Department of Planning and Environment, now the Department of Planning, Industry and Environment) on the impact of mining activities in the Greater Sydney Water Catchment Special Areas, with a focus on risks to the quantity of water and swamps. Part 1 (IEPMC 2019a) reviewed specific mining activities at the Metropolitan and Dendrobium coal mines and Part 2 (IEMPC 2019b) focused on the impacts of mining on water quantity and swamps, including cumulative impacts, and includes a review and update of relevant findings of the strategic review (NSW DoP 2008).

Recommendations specific to monitoring of aquatic ecology were not included, though several recommendations relevant to monitoring of groundwater and surface water and the development of associated TARPs will assist in the future assessment and identification of causes of any impacts to aquatic ecology. These suggestions have been adopted by South32 and are reported in End of Panel reports following extraction of each longwall.

5.2.2 Sites and Timing

Two types of monitoring sites have been incorporated into the plan: 'impact' sites that may be subject to mine subsidence impacts during and after longwall extraction and 'control' sites that will provide a measure of the background environmental variability within the catchments as distinct from any mine subsidence impacts. Monitoring sites have been established previously for Area 3B on Wongawilli Creek. One of these (Site 5) is located within the Study Area for Longwalls 22 and 23 and would provide control data for these longwalls. Two additional impact sites applicable to monitoring potential impacts associated with Longwalls 22 and 23 on Wongawilli Creek would be established (provisionally Sites 19 and 20, though their exact location will be finalised according to available access to the watercourse). Two control sites would be established on Wongawilli Creek near Fire Road 6, downstream of Longwalls 22 and 23 and future Longwalls 24 to 28. These would provide control data for Longwalls 22 to 28. Sites X7 and X8 on Wongawilli Creek upstream of Area 3B Longwalls would also provide control data. However, the aquatic habitat at Sites X7 and X8 is at the upstream extent of the catchment and differs from that further downstream with less flow and more disconnected pool habitat.

Ideally, baseline surveys at impact and control sites would be undertaken over a 24-month period prior to the commencement of longwall mining and during and post-extraction monitoring to determine the extent and nature of any impacts and recovery. This would provide a better measure of background temporal variability and provide more confidence regarding potential changes occurring several years into the future. Baseline monitoring specific to these longwalls commenced in autumn 2021 and will be undertaken next in spring 2021 in conjunction with the biennial Area 3B monitoring also being undertaken in 2021. Ongoing monitoring for Longwalls 22 and 23 begins could be incorporated into the ongoing biennial monitoring for Area 3B.

5.2.3 Indicators and Methods

The following indicators of aquatic ecology would be monitored at each site:

- > Aquatic habitat;
- > *In situ* water quality;
- > Aquatic macrophytes;
- > Aquatic macroinvertebrates; and
- > Fish.

5.2.3.1 Aquatic Habitat

During the first baseline survey, the condition of the aquatic habitat at each site was assessed using a modified version of RCE (Chessman *et al.* 1997). This assessment involved evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. Any changes in the condition of the aquatic habitat would be recorded during the subsequent surveys.

During each survey, a comprehensive photo record of each site would be taken to gain an understanding of environmental variation within the watercourses. This would be done by taking standardised photos, using a 2 m tall x 1 m wide T-bar, from the top of the site looking downstream, the middle of the site looking upstream, the middle of the site looking downstream, and the bottom of the site looking upstream.

Ongoing monitoring of physical attributes (such flow and depth of water in larger pools) of Wongawilli Creek and larger drainage lines would be undertaken by IMCEFT. These data would be examined alongside aquatic ecology data during the aquatic ecology reporting. These observations may also trigger additional surveys of aquatic ecology (**Section 5.3**).

5.2.3.2 Water Quality

At each site, two replicate measurements of DO, EC, ORP, pH, temperature and turbidity of the water would be taken from just below the surface of the water. The measurements taken would be used to help interpret differences in biotic assemblages. The EC, DO, pH and turbidity measures would also be compared with the ANZECC (2000) DVTs for slightly disturbed upland rivers in south-east Australia. Specific guidelines are not available for temperature and ORP measures.

A more comprehensive assessment of changes in surface water quality at selected sites would be undertaken by IMCEFT and other specialist consultants.

5.2.3.3 Aquatic Macrophytes

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

5.2.3.4 Aquatic Macroinvertebrates

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

5.2.3.4.1 AUSRIVAS

At each site, samples of aquatic macroinvertebrates associated with the pool edge habitat would be collected by using dip nets (250 µm mesh) to agitate and scoop up material from vegetated areas of the river bank. Samples would be collected over a period of 3 to 5 minutes from a 10 m length of habitat along the river, in accordance with the AUSRIVAS Rapid Assessment Method (RAM) (Turak *et al.* 2004). If the required habitat was discontinuous, patches of habitats with a total length of 10 m would be sampled. Each RAM sample would be rinsed from the net onto a white sorting tray from which animals are picked using forceps and pipettes. Each tray would be picked for a minimum period of forty minutes, after which they would be picked at 10-minute intervals for either a total of one hour or until no new specimens are found. These samples would be preserved in alcohol and transported to the laboratory for identification.

In accordance with the AUSRIVAS protocol, RAM samples would be sorted under a binocular microscope (at 40 X magnification), macroinvertebrates identified to family level and up to ten animals of any one taxon counted (Turak *et al.* 2004). A randomly chosen 10% of the RAM sample identifications would be checked by a second experienced scientist to validate macroinvertebrate identifications.

Data would be analysed using the spring AUSRIVAS predictive models for the edge habitat (Coysh *et al.* 2000). The AUSRIVAS methodology and predictive model requires that sampling be done in autumn (15 March to 15 June) and/or spring (15 September to 15 December).

AUSRIVAS models generate the following indices:

- > OE50Taxa Score - This is the ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence. OE50 taxa values range from 0 to 1 and provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams.
- > Overall Bands - These indicate the level of impairment of the assemblage and are derived from OE50Taxa scores. These bands are graded as follows:
 - Band X = Richer invertebrate assemblage than reference condition.
 - Band A = Equivalent to reference condition.
 - Band B = Sites below reference condition (i.e. significantly impaired).
 - Band C = Sites well below reference condition (i.e. severely impaired).
 - Band D = Impoverished.

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) would also be used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers to each macroinvertebrate family or taxa found, based largely on their responses to chemical pollutants. The sum of all grade numbers for that habitat is then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values greater than 6, between 5 and 6, 4 and 5 and less than 4 indicate that the quality of the water is clean, doubtful, mildly, moderately or severely degraded, respectively.

5.2.3.4.2 Artificial Macroinvertebrate Collectors

Eight replicate artificial collector units, consisting of 24 cm long x 3 cm diameter bundles of 18 wooden chopsticks held together with plastic cable ties, would be deployed at each monitoring site. The collectors would be attached to vegetation with nylon twine and submerged at least 1 meter apart at the edge of pools in 30 to 60 cm of water. The collectors would be retrieved six weeks after being deployed. During retrieval the collectors would be carefully cut away from their anchors, placed into plastic bags, labeled and preserved in 70% ethanol for subsequent laboratory identification and analysis.

The aquatic macroinvertebrates that colonise each bundle of chopsticks would be rinsed onto a 0.5 mm mesh sieve and examined in the laboratory using a binocular microscope. The samples would be sorted and macroinvertebrates identified to family (most invertebrate taxa), sub-family (chironomids) or class (flatworms and leeches) level and counted. Mayflies, damselflies and stoneflies would be identified to genus, where possible. Genus level taxonomic resolution may be more appropriate when attempting to detect an environmental impact on aquatic ecology, as some taxa within the same family may respond differently to disturbance. SIGNAL2 scores would also be calculated for the macroinvertebrate assemblages that developed on the artificial collectors.

5.2.3.5 Threatened Species

As there is a possibility, albeit unlikely, that two threatened aquatic macroinvertebrate species (Adams emerald dragonfly and Sydney hawk dragonfly) occur in watercourses within the Study Area, all the dragonfly larvae collected would be identified to family level. Any individuals of the genera Austrocorduliidae and Gomphomacromiidae found would be identified to species level, if possible. If there is any uncertainty as to their identification, specimens will be referred to a specialist taxonomist. The presence of either one or both of these threatened species would trigger further investigations into the species and its habitats in relation to potential subsidence impacts.

5.2.3.6 Fish

Fish would be sampled using baited traps. At each site, eight baited traps would be deployed for 30 to 45 minutes in a variety of habitats, such as amongst aquatic plants and snags, in deep holes and over bare substratum. Fish caught would be collected in a scoop net, identified and measured. Native species would be released unharmed. Non-native species, if any, would not be returned to the water in accordance with Cardno's Scientific Research Permit. Previous monitoring in Area 3B has indicated that baited traps capture a greater or comparable number of species of fish at each of the monitoring sites compared with backpack electrofishing.

5.2.3.7 Statistical Analysis

The aim of the statistical analyses would be to identify differences in the selected indicators of aquatic ecology at the Impact sites that are in a different direction, or of a different magnitude, to those at the Controls. Statistically significant differences provide evidence that an impact may have occurred. Evidence would be assessed by examining data from before with those collected after commencement of longwall extraction. Spatial and temporal changes in macroinvertebrate abundance data from artificial collectors would be examined using Generalised Linear Mixed Modelling (GLMM). This technique is more appropriate than distance-based methods (e.g. permutational analysis of variance - PERMANOVA) for analysis of univariate data. Spatial differences and temporal changes, and their interaction, in macroinvertebrate assemblages sampled using artificial collectors would be examined (PERMANOVA+). Multivariate patterns in the data would also be examined using the unconstrained ordination technique Principal Coordinates Analysis (PCO). This will provide a graphical representation of assemblages based on their similarity within and among places or times sampled. In these plots, samples which have similar sets of organisms are grouped closer together than ones containing different sets of organisms.

5.3 Additional Aquatic Ecology Studies

The aquatic ecology monitoring program outlined in **Section 5.2** has been designed to detect and determine the extent and nature of impacts on aquatic habitat and biota resulting from mining induced subsidence impacts within watercourses. It incorporates monitoring events throughout the duration of mining regardless of observed physical and chemical impacts within watercourses. Physical-chemical impacts detected within watercourses by routine surface monitoring by IMCEFT that may require further investigation into potential impacts on the aquatic ecology include:

- > Reductions in flow in Wongawilli Creek that exceed expected increases in the number of zero flow days (HGeo 2021); and

- > Greater than minor change in water chemistry (particularly pH, dissolved oxygen, turbidity, or metal concentration) in Wongawilli Creek.

Other observations made during routine surface monitoring that may require further investigation of the aquatic ecology would include:

- > Fish/crayfish kills; and
- > Die-off of macrophyte beds (if present).

Trigger values for aquatic ecology monitoring parameters are contained in the Area 3C Watercourse Impact Monitoring Management and Contingency Plan (South32 2021). These are based on the duration of reductions in aquatic habitat that may occur in watercourses due to mining impacts.

5.4 Contingent Measures

In the event that the impacts due to the extraction Longwalls 22 and 23 on aquatic habitats and biota in Wongawilli Creek are greater than predicted, the following contingent measures could be implemented:

- > Implementing watercourse remediation measures, such as backfilling or grouting, in areas where fracturing of controlling rock bars and/or the creek bed leads to diversion of creek flow and drainage of pools; and
- > Implementing appropriate control measures, such as installation of sediment fences down slope of areas where subsidence has led to erosion and stabilisation of areas prone to erosion and soil slumping using rock, brush matting or vegetation, to limit the potential for deposition of eroded sediment into the watercourses.

If these management strategies prove ineffectual, appropriate offset and compensatory measures would be implemented.

6 Conclusion

The greatest risk to Wongawilli Creek associated with extraction of Longwalls 22 and 23 is the potential for fracturing of one of the twenty-one flow controlling rockbars within 600 m of the longwalls. Although the predicted rate of rockbar fracturing is low (6 %) (MSEC, 2021), it is possible that one of these rockbars could fracture resulting in flow diversion and drainage of the associated pool, with pools ranging in size from 15 m to 200 m. The associated loss of aquatic habitat and reduction in population size of aquatic biota would be severe at the scale of individual pool. It would, however, be more minor at the scale of entire watercourse. If such impacts occur, potential rehabilitation could be considered, and, if required, compensatory measures.

Impacts to aquatic habitat, vegetation, macroinvertebrates or fish in drainage lines in, and adjacent to, Longwalls 22 and 23 may occur following predicted mine subsidence and associated fracturing. Fracturing and flow diversions have potential to occur in these sections of watercourse and may result in reductions in the availability of aquatic habitat. However, the aquatic habitat provided by these ephemeral drainage lines is relatively limited. While impacts to aquatic biota at the local scale (e.g. individual pools and drainage lines) would be significant, due to the abundance of this habitat in the Cordeaux River catchments, impacts to aquatic biota at this wider scale would be minor.

No significant impacts to the threatened Macquarie perch, Sydney hawk dragonfly or Adams emerald dragonfly are expected as these species are unlikely to occur in drainage lines that traverse the Study Area that would be most susceptible to mining related subsidence impacts. Macquarie perch are also unlikely to occur in Wongawilli Creek within the Study Area for Longwalls 22 and 23. Although this species is considered present in Lake Cordeaux, no adverse impacts associated with mining are expected to occur here.

Ongoing monitoring associated with Area 3B longwalls will incorporate monitoring of impacts to aquatic ecology that may occur due to extraction of Longwalls 22 and 23. This will also consider the results of monitoring of physical and water quality impacts undertaken by IMCEFT. The detection of physical impacts, such as rockbar fractures resulting in water loss in a pool within Wongawilli Creek or more than minor changes in water chemistry, would trigger investigations into potential impacts on aquatic ecology. Observations of fish/crayfish kills or die-off of any macrophyte beds would also trigger further monitoring to determine the nature and extent of secondary impacts on aquatic ecology. The level of impact would determine the type of response. The implementation of such management measures would reduce impacts on aquatic ecology.

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APPENDIX

A

SURVEY METHODOLOGY

Site Coordinates

Table A-i. Site Coordinates

Site	Watercourse	Easting	Northing
1	Wongawilli Creek	291156	6191184
2	Wongawilli Creek	290977	6192444
3	Wongawilli Creek	290939	6192926
4	Wongawilli Creek	290844	6193506
5	Wongawilli Creek	290625	6194378
19	Wongawilli Creek	290645	6195106
20	Wongawilli Creek	290671	6195676
21	Wongawilli Creek	290643	6195176
22	Wongawilli Creek	290670	6194989
X4	Wongawilli Creek	291083	6191801
X5	Wongawilli Creek	290950	6190581
X6	Wongawilli Creek	290775	6190356
X7	Wongawilli Creek	290810	6190022
X8	Wongawilli Creek	290800	6189817

Datum: GDA 94 Zone 56H

Aquatic Habitat and Vegetation

Habitat Types

The July 2007 investigations (The Ecology Lab 2007) mapped four habitat types (adapted from Fairfull and Witheridge 2003) within Wongawilli Creek and drainage lines:

- > Unlikely habitat: Ephemeral drainage lines that only contain flow during and immediately after significant rainfall. Permanent or semi-permanent pools that could provide refuge for aquatic biota during prolonged dry weather are absent.
- > Minimal habitat: Watercourses that contain some small semi-permanent refuge pools which are unlikely to persist through prolonged drought. Flow connectivity would only occur during and following significant rainfall. These pools may provide habitat for some aquatic species including aquatic macroinvertebrates and freshwater crayfish.
- > Moderate habitat: Watercourses that contain some larger permanent and semi-permanent refuge pools, which would persist through prolonged drought, although become greatly reduced in extent. These watercourses should support a relatively diverse array of aquatic biota including some fish, freshwater crayfish and aquatic macroinvertebrates. There may also be some aquatic plant species present.
- > Significant habitat: Watercourses that contain numerous large, permanent pools and generally have flow connectivity except during prolonged drought. They provide extensive and diverse aquatic habitat for aquatic flora and fauna.

REC Inventory

The condition of the aquatic habitat at each site was assessed using a modified version of the Riparian, Channel and Environmental Inventory method (RCE) (Chessman *et al.* 1997) (**Table A-ii**). This assessment involves evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. The occurrence of key aquatic habitat (e.g. gravel beds, pools, macrophytes, riffles, and woody debris) in these watercourses was also identified along with surrounding land uses.

Notes were also taken on the presence of the following features:

- > Surrounding vegetation and riparian vegetation;
- > Barriers to fish passage;

- > The species and percent cover (in an approximate 100 m reach) of in-stream aquatic vegetation present at each site; and
- > The presence of algae or flocculent on the surface of macrophytes was also be noted, if present.

Table A-ii. River, Channel and Environmental (RCE) Criteria

Descriptor and category	Score	Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone		8. Riffle / pool sequence	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequence	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2. Width of riparian strip of woody vegetation		9. Retention devices in stream	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effect	3
Less than 5 m	2	Rocks / logs present, but unstable, no damming	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3. Completeness of riparian strip of woody vegetation		10. Channel sediment accumulations	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sediments	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4. Vegetation of riparian zone within 10 m of channel		11. Stream bottom	
Native tree and shrub species	4	Mainly clean stones with obvious interstices	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / silt	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5. Stream bank structure		12. Stream detritus	
Banks fully stabilised by trees, shrubs etc.	4	Mainly un-silted wood, bark, leaves	4
Banks firm but held mainly by grass and herbs	3	Some wood, leaves etc. with much fine detritus	3
Banks loose, partly held by sparse grass etc.	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1
6. Bank undercutting		13. Aquatic vegetation	
None, or restricted by tree roots	4	Little or no macrophyte or algal growth	4
Only on curves and at constrictions	3	Substantial algal growth; few macrophytes	3
Frequent along all parts of stream	2	Substantial macrophyte growth; little algae	2
Severe, bank collapses common	1	Substantial macrophyte and algal growth	1
7. Channel form			
Deep: width / depth ratio < 7:1	4		
Medium: width / depth ratio 8:1 to 15:1	3		
Shallow: width / depth ratio > 15:1	2		
Artificial: concrete or excavated channel	1		

Key Fish Habitat

The occurrence of sensitive fish habitat in the Study Area was assessed using the criteria in NSW DPI (2013a) relevant to freshwater habitat (**Table A-iii**).

Mapping was done initially as a desktop exercise with the aid of existing information from previous surveys including information on habitat types (Fairfull and Witheridge 2003). Findings were used to inform the detailed KFH mapping using the updated classifications in NSW DPI (2013a). Where sections of drainage lines could not be accessed, KFH type was inferred based on the findings from other drainage lines in the Study Area.

Table A-iii. Classification of KFH according to sensitivity (NSW DPI 2013a)

Classification	Habitat Type
Type 1 – highly sensitive KFH	Instream gravel beds, rocks greater than five hundred millimeters in two dimensions, snags (wood debris) greater than three hundred millimeters in diameter or three meters in length, native aquatic plants, and areas known or expected to contain threatened and protected species
Type 2 – Moderately sensitive KFH:	Freshwater habitats other than those defined in Type 1
Type 3 – Minimally sensitive KFH	Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation
Not considered KFH	First and second order streams on gaining (those where streams are coming together and becoming progressively larger) streams (based on the Strahler method of stream ordering)

In-situ Water Quality

At each site, two replicate measurements of DO, EC, oxidation-reduction potential (ORP), pH, temperature and turbidity of the water were taken from just below the surface of the water using a YSI multiprobe. The measurements taken would be used to assist in interpretation of the results of biotic sampling. The EC, DO, pH and turbidity measures were also compared with the ANZECC (2000) DTVs for slightly disturbed upland rivers in south-east Australia. Specific guidelines are not available for temperature and ORP measures.

AUSRIVAS Macroinvertebrates

Field and Laboratory Methods

At each site, samples of aquatic macroinvertebrates associated with the pool edge habitat were collected by using dip nets (250 µm mesh) to agitate and scoop up material from vegetated areas of the river bank. Samples were collected over a period of 3 to 5 minutes from a 10 m length of habitat along the river, in accordance with the AUSRIVAS Rapid Assessment Method (RAM) (Turak *et al.* 2004). If the required habitat was discontinuous, patches of habitats with a total length of 10 m were sampled. Each RAM sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten-minute intervals for either a total of one hour or until no new specimens were found. Samples were preserved in alcohol and transported to the laboratory for identification and subsequent derivation of biotic indices and assessment of habitat and water quality using the AUSRIVAS modelling software.

AUSRIVAS samples were sorted under a binocular microscope (at 40 X magnification) and identified to family level with the exception of Oligochaeta and Polychaeta (to class), Ostracoda (to subclass), Nematoda and Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). Up to ten animals of each family were counted, in accordance with the latest AUSRIVAS protocol (Turak *et al.* 2004). There is a possibility, albeit unlikely, that two threatened aquatic macroinvertebrate species (Adams emerald dragonfly and Sydney hawk dragonfly) occur in the Study Area. Therefore, if any individuals of the family Austrocorduliidae and Gomphomacromiidae were found these would have been identified to species level. However, no specimens from these families have been found in the Dendrobium Mine Area (**Cardno 2020a**).

AUSRIVAS Model

The AUSRIVAS protocol uses an internet-based software package to determine the environmental condition of a waterway based on predictive models of the distribution of aquatic macroinvertebrates at reference sites (Coysh *et al.* 2000). The ecological health of the creek is assessed by comparing the macroinvertebrate

assemblages collected in the field (i.e. 'observed') with macroinvertebrate assemblages expected to occur in reference waterways with similar environmental characteristics. The data from this study were analysed using the NSW models for pool edge habitat sampled in spring. The AUSRIVAS predictive model generates the following indices:

- > OE50Taxa Score – The ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence. OE50 taxa scores provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams.
- > Overall Bands derived from OE50Taxa scores that indicate the level of impairment of the assemblage. These bands are graded as described in **Table A-iv**.

Table A-iv. AUSRIVAS Bands and corresponding OE50 Taxa Scores for AUSRIVAS edge habitat.

Band	Description	Autumn OE50 Score	Spring OE50 Score
X	Richer invertebrate assemblage than reference condition	> 1.17	>1.16
A	Equivalent to reference condition	0.82 to 1.17	0.84 to 1.16
B	Sites below reference condition (i.e. significantly impaired)	0.47 to 0.81	0.52 to 0.83
C	Sites well below reference condition (i.e. severely impaired)	0.12 to 0.46	0.20 to 0.51
D	Impoverished (i.e. extremely impaired)	≤0.11	≤0.19

The SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between 1 and 10 to each macroinvertebrate family, based largely on their responses to chemical pollutants. The sum of all grade numbers for that site was then divided by the total number of families recorded in each site to obtain an average SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

- > SIGNAL > 6 = Healthy habitat;
- > SIGNAL 5 – 6 = Mild pollution;
- > SIGNAL 4 – 5 = Moderate pollution; and
- > SIGNAL < 4 = Severe pollution.

Fish

Fish were sampled using a backpack electrofisher (model LR-24 Smith-Root) and baited traps. At each site, four baited traps were set for approximately one hour in a variety of habitats, such as amongst aquatic plants and snags, in deep holes and over bare substratum. Bait traps were approximately 30 cm x 30 cm x 40 cm with 0.3 cm aperture mesh and a 3 cm opening and were unbaited. The backpack electrofisher was operated around the edge of pools and in riffles (if present), with four two minute shots being performed at each site. Fish stunned by the current were collected in a scoop net, identified and measured. All captured fish would be handled with care to minimise stress and be released as soon as possible.

APPENDIX

B

RCE RESULTS

RCE Category	1	2	3	4	5	X4	X5	X6	X7	X8	Site 19	Site 20
Land use pattern beyond the immediate riparian zone	4	4	4	4	4	4	4	4	4	4	4	4
Width of riparian strip of woody vegetation	4	4	4	4	4	4	4	4	4	4	4	4
Completeness of riparian strip of woody vegetation	4	4	4	4	4	4	4	4	4	4	4	4
Vegetation of riparian zone within 10 m of channel	4	4	4	4	4	4	4	4	4	4	4	4
Stream bank structure	4	4	4	4	4	4	4	4	4	4	4	4
Bank undercutting	3	3	3	3	3	4	4	4	3	3	4	4
Channel form	3	3	3	3	3	3	3	3	3	3	3	3
Riffle/pool sequence	4	3	3	3	3	3	4	4	3	4	3	3
Retention devices in stream	4	4	4	4	3	4	4	4	4	4	3	3
Channel sediment accumulations	3	3	3	3	4	4	4	4	2	2	3	3
Stream bottom	4	2	2	2	4	4	4	4	3	3	4	4
Stream detritus	4	4	4	4	4	4	4	4	4	4	4	4
Aquatic vegetation	3	4	4	4	3	4	3	4	4	4	3	3
Total	48	46	46	46	47	50	50	51	46	47	47	47

APPENDIX

C

COMPILED AUSRIVAS DATA

Date	Spring No. of Taxa	OE50 Taxa	SIGNAL2 Score	Autumn Date	No. of Taxa	OE50 Taxa	SIGNAL2 Score
Site 1							
Sep-08	20	0.84	4.5	Mar-09	21	0.93	4.6
Nov-08	23	0.99	4.6	May-09	24	0.93	4.8
Sep-10	19	0.83	4.6	Mar-10	18	1.15	4.1
Nov-10	16	0.72	5.4	May-10	16	0.92	4.7
Sep-11	11	0.35	5.5	Apr-11	16	0.63	4.2
Oct-11	19	0.90	4.2	Jun-11	12	0.65	5.2
Sep-12	21	0.67	4.1	May-12	17	0.87	5.1
Nov-12	13	0.66	4.6	Jun-12	20	0.93	5.5
Sep-13	12	0.41	5.5	Apr-13	18	0.97	5.0
Nov-13	15	0.67	4.9	Jun-13	13	0.80	4.4
Sep-14	13	0.67	5.1	Mar-14	14	0.83	4.6
Nov-14	17	0.72	4.9	Apr-14	12	0.80	4.3
Oct-15	14	0.66	4.8	May-15	12	0.58	5.4
Nov-15	19	0.65	4.9	Jun-15	9	0.62	5.8
Sep-17	19	0.70	4.2	Apr-17	6	0.28	6.0
Nov-17	16	0.91	4.6	Jun-17	14	0.28	4.4
Oct-19	17	0.87	5.8	May-19	8	0.53	4.4
Nov-19	11	0.47	3.7	Jun-19	13	0.62	4.4
Site 2							
Sep-08				Mar-09			
Nov-08				May-09			
Sep-10	15	0.71	4.8	Mar-10	19	1.06	3.9
Nov-10	16	0.81	4.2	May-10	15	0.77	4.1
Sep-11	18	0.52	4.5	Apr-11	20	1.16	4.4
Oct-11	18	0.89	4.5	Jun-11	19	0.97	4.4
Sep-12				May-12			
Nov-12				Jun-12			
Sep-13	15	0.70	5.4	Apr-13	24	0.77	4.7
Nov-13	20	0.82	5.4	Jun-13	14	0.82	5.3
Sep-14				Mar-14			
Nov-14				Apr-14			
Sep-15	15	0.70	5.4	May-15	24	0.77	4.7
Nov-15	20	0.82	5.4	Jun-15	14	0.82	5.3
Sep-17	17	0.89	4.6	Apr-17	12	0.74	4.9
Nov-17	21	0.57	4.7	Jun-17	19	0.74	5.0
Oct-19	15	0.67	4.7	May-19	14	0.79	5.3
Nov-19	15	0.65	4.5	Jun-19	13	0.97	3.9
Site 3							
Sep-08	20	0.85	4.4	Mar-09	22	1.02	4.8
Nov-08	20	0.89	4.7	May-09	19	1.02	4.6
Sep-10	21	0.92	4.6	Mar-10	20	1.25	4.4
Nov-10	23	0.68	4.8	May-10	16	1.05	4.1
Sep-11	14	0.59	4.8	Apr-11	14	0.82	4.1
Oct-11	23	0.91	5.0	Jun-11	20	0.95	4.6
Sep-12	17	0.81	4.5	May-12	14	0.87	3.8
Nov-12	18	0.71	5.1	Jun-12	15	0.86	4.8
Sep-13	15	0.70	4.4	Apr-13	17	0.70	4.4
Nov-13	20	0.86	4.7	Jun-13	14	0.77	4.3
Sep-14	15	0.69	4.0	Mar-14	20	1.08	4.5
Nov-14	20	0.95	4.9	Apr-14	19	1.07	4.8
Oct-15	17	0.66	4.7	May-15	16	0.69	5.2
Nov-15	18	0.70	4.8	Jun-15	17	0.85	4.9
Sep-17	15	0.52	4.8	Apr-17	18	0.90	4.1
Nov-17	17	0.77	4.8	Jun-17	16	0.90	4.3
Oct-19	20	1.00	4.6	May-19	17	0.58	5.1
Nov-19	19	0.81	4.7	Jun-19	12	0.55	4.8
Site 4							
Sep-08	19	0.87	4.9	Mar-09	17	1.03	5.2

Date	Spring			Autumn			
	No. of Taxa	OE50 Taxa	SIGNAL2 Score	Date	No. of Taxa	OE50 Taxa	SIGNAL2 Score
Nov-08	23	0.98	4.6	May-09	22	1.03	4.9
Sep-10	19	0.73	4.4	Mar-10	18	1.03	4.2
Nov-10	25	1.06	4.8	May-10	13	0.82	3.8
Sep-11	14	0.60	4.9	Apr-11	23	0.98	4.5
Oct-11	22	0.80	4.5	Jun-11	17	0.77	4.9
Sep-12	19	0.82	4.0	May-12	20	0.77	5.0
Nov-12	19	0.93	4.7	Jun-12	23	0.97	5.0
Sep-13	16	0.64	4.9	Apr-13	21	1.09	4.8
Nov-13	18	0.81	4.8	Jun-13	18	0.87	4.4
Sep-14	21	0.85	5.2	Mar-14	22	1.22	4.3
Nov-14	20	0.81	4.7	Apr-14	16	0.77	4.1
Oct-15	16	0.77	5.6	May-15	14	0.67	4.5
Nov-15	24	0.87	5.1	Jun-15	14	0.97	4.4
Sep-17	21	0.93	4.4	Apr-17	16	0.97	4.1
Nov-17	15	0.62	4.9	Jun-17	10	0.97	4.2
Oct-19	25	1.09	4.4	May-19	17	0.72	4.4
Nov-19	24	1.14	4.7	Jun-19	10	0.62	5.1
Site 5							
Sep-08	25	0.81	4.5	Mar-09	29	0.87	4.6
Nov-08	25	1.12	5.0	May-09	23	0.87	4.2
Sep-10	21	0.82	4.1	Mar-10	24	1.30	4.4
Nov-10	24	0.94	4.5	May-10	22	1.08	4.5
Sep-11	22	0.78	5.0	Apr-11	20	0.60	4.8
Oct-11	14	0.71	4.2	Jun-11	16	0.93	4.5
Sep-12	20	0.78	5.7	May-12	22	0.86	4.5
Nov-12	17	0.43	4.5	Jun-12	19	0.96	4.6
Sep-13	24	0.92	4.6	Apr-13	23	1.15	4.8
Nov-13	21	0.82	4.8	Jun-13	16	0.98	4.4
Sep-14	31	0.96	4.5	Mar-14	28	0.98	5.0
Nov-14	30	0.89	5.3	Apr-14	25	0.77	4.8
Oct-15	18	0.71	5.2	May-15	23	0.80	5.3
Nov-15	25	0.81	5.3	Jun-15	17	0.92	5.1
Sep-17	17	0.64	4.7	Apr-17	18	0.70	4.9
Nov-17	21	0.57	5.2	Jun-17	23	0.70	4.5
Oct-19	14	0.59	4.8	May-19	22	1.03	3.7
Nov-19	30	0.85	4.3	Jun-19	22	0.79	4.7
Site X4							
Sep-08							
Nov-08							
Sep-10	10	0.75	4.4		18	1.12	3.9
Nov-10	9	0.58	3.9		17	1.02	4.4
Sep-11	18	0.67	4.8		17	0.65	4.6
Oct-11	15	0.48	4.7		15	0.65	3.9
Sep-12							
Nov-12							
Sep-13	11	0.69	4.9		11	0.82	4.0
Nov-13	11	0.49	4.9		11	0.72	4.1
Sep-14							
Nov-14							
Oct-15	11	0.49	5.7		12	0.77	3.8
Nov-15	11	0.61	4.9		10	0.72	4.9
Sep-17	13	0.69	4.3		9	0.65	4.0
Nov-17	16	0.75	4.7		13	0.68	4.8
Oct-19	17	0.73	4.5	May-19	9	0.62	4.2
Nov-19	16	0.87	4.7	Jun-19	11	0.92	4.3
Site X5							
Sep-08							
Nov-08							
Sep-10	19	1.09	5.2				

Date	Spring			Autumn			
	No. of Taxa	OE50 Taxa	SIGNAL2 Score	Date	No. of Taxa	OE50 Taxa	SIGNAL2 Score
Nov-10	19	0.70	5.0				
Sep-11							
Oct-11							
Sep-12							
Nov-12							
Sep-13							
Nov-13							
Sep-14							
Nov-14							
Oct-15							
Nov-15							
Sep-17	16	0.75	5.1	Apr-17	10	0.55	5.0
Nov-17	16	0.67	4.8	Jun-17	12	0.74	4.5
Oct-19	16	0.77	4.7	May-19	12	0.71	3.8
Nov-19	15	0.75	5.5	Jun-19	12	0.55	3.8
Site X6							
Sep-08							
Nov-08							
Sep-10	18	0.96	4.6				
Nov-10	25	1.14	4.7				
Sep-11							
Oct-11							
Sep-12							
Nov-12							
Sep-13							
Nov-13							
Sep-14							
Nov-14							
Oct-15							
Nov-15							
Sep-17	14	0.50	4.8	Apr-17	15	0.64	4.4
Nov-17	19	0.88	4.3	Jun-17	14	0.74	4.6
Oct-19	14	0.70	4.4	May-19	14	0.65	4.0
Nov-19	15	0.75	4.2	Jun-19	15	0.65	4.8
Site X7							
Oct-19	18	0.67	4.0	May-19	11	0.53	4.0
Nov-19	14	0.59	4.5	Jun-19	15	0.74	4.0
Site X8							
Oct-19	20	0.46	4.2	May-19	10	0.53	4.8
Nov-19	22	0.75	4.7	Jun-19	18	1.11	4.2
Site 19							
				Jun-17	15	0.78	5.1
Site 20							
				Jun-17	16	0.97	5.0

APPENDIX

D

AOS M. AUSTRALASICA

1) Assessment of Significance (FM Act) – Macquarie perch

a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction

Macquarie perch has been recorded in the Dendrobium Mine area in the mid to lower reaches of Wongawilli Creek, including pools just upstream and downstream of Fire trail 6A (NSW DPI (Fisheries), pers. com.; The Ecology Lab, 2001 and pers. obs. 2005; MPR 2006b; Niche, pers. obs. 2011). However, this species was not caught further upstream in Wongawilli Creek despite extensive sampling (Cardno 2012 and 2016). It has been recorded also in Lake Avon and Lake Cordeaux and previously recorded, or potentially present, in the upper reaches of Cordeaux and Avon Rivers (NSW DPI 2016a). The steep bedrock cascade features directly upstream of the crossing at Fire Road No. 6 would pose a substantial barrier to the upstream passage of the Macquarie perch populations from the lower to mid reaches of Wongawilli Creek to the reach within the Study Area. The presence of a natural barriers to passage at the mouths of Lake Cordeaux drainage lines would also likely prevent this species utilising these drainage lines. Regardless, drainage lines in the Study Area do not provide suitable habitat for Macquarie perch. Thus, within the Study Area the only area where Macquarie perch is likely to occur is in Lake Cordeaux.

Life history studies of Macquarie perch have been largely carried out on western drainage populations. These populations are known to spawn just above riffles in shallow upland streams in October to January when water temperatures rise to around 16 C. Eastern populations, however, inhabit rivers with very different hydrological conditions to the inland populations and very little is known of their life cycle. The eggs are adhesive and stick to gravel. Hatching commences 13 days after fertilisation and is completed by 18 days after fertilisation at water temperatures of 11 to 18°C. Newly-hatched larvae shelter amongst pebbles. In impounded waters, hatched fish move back downstream to the lake habitat from their upstream spawning sites.

The lifecycle of Macquarie perch could be adversely affected if mining results in changes in levels of ponding, flooding or scouring of river banks, fracturing of rock bars and diversion of surface flows and these, in turn, lead to drainage of pools, loss of habitat, and reductions in habitat connectivity and/or water quality. The subsidence predictions indicate that extraction of the proposed longwall is not expected to result in major fracturing in Lake Cordeaux that could otherwise result in adverse impacts. Due to the presence of natural barriers to fish movement, Macquarie perch are not expected to be able to use sections of Wongawilli Creek or drainage lines that may be affect by major fracturing resulting in flow diversions.

Given the extensive amount of potential habitat available for this species further downstream and in Avon and Cordeaux rivers, it is highly unlikely that mining would have any adverse effects on the life cycle of Macquarie perch in the Avon / Cordeaux River Catchment or place a viable local population at risk of extinction. Likewise, impacts to water quality in Lake Cordeaux are not expected.

b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

No endangered populations of Macquarie perch have been listed on the Schedules of the FM Act.

c) In the case of an endangered ecological community or critically endangered ecological community, whether the proposed action is likely to:

i) Have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

ii) Substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.

Macquarie perch is not part of a listed endangered ecological community.

d) In relation to the habitat of a threatened species, population or ecological community:

i) The extent to which habitat is likely to be removed or modified as a result of the action proposed;

ii) Whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action;

iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.

Subsidence predictions indicate fracturing and flow diversions could occur in Wongawilli Creek, however, the section that would be affected does not appear accessible to Macquarie perch. Where it does occur in Lake Cordeaux, changes to water availability and quality due to longwall extraction are expected to be negligible. Thus, there are unlikely to be any reduction in Macquarie perch habitat availability, quality or connectivity here due to fracturing. Although fracturing and flow diversions are likely to result in more severe impacts to habitat in drainage lines, these are very unlikely to provide habitat for Macquarie perch. Thus, it is highly unlikely that mining would lead to removal, fragmentation or isolation of a Macquarie perch population.

e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

There is no listed critical habitat for Macquarie perch listed on the NSW Register of Critical Habitat.

f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

The National Recovery Plan for Macquarie perch (DEE 218) contains background information on the biology, ecology, distribution and populations, decline and threats and recovery objectives and strategies and associated actions for this species. The objectives are:

- > Conserve existing Macquarie perch populations;
- > Protect and restore Macquarie perch habitat;
- > Investigate threats to Macquarie perch populations and habitats;
- > Establish additional Macquarie perch populations;
- > Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance; and
- > Increase participation by community groups in Macquarie perch conservation.

Identified threats include:

- > Habitat degradation;
- > Invasive fish;
- > Barriers to fish movement;
- > Altered flow and thermal regimes;
- > Disease;
- > Illegal and incidental capture;
- > Chemical water pollution;
- > Climate change.

Potential impacts to Macquarie perch associated with the Project (primarily loss of habitat following significant fracturing leading to flow diversions and reductions in pool water levels) are not expected. The Project would not interfere with these objectives and the recovery of the species.

g) Whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

One KTP listed under the BC Act is directly applicable to the Project: *Alteration of habitat following subsidence due to longwall mining.*

While the Project is expected to exacerbate this KTP, associated impacts to Macquarie perch due to subsidence are unlikely. Macquarie perch is very unlikely to be found in the Study Area where major fracturing and flow diversions could occur.

2) Assessment of Significance Based on Significant Impact Criteria for Endangered Species (EPBC Act) – Macquarie perch

An action is likely to have a significant impact on an endangered species if there is a real chance or possibility that it will:

a) Lead to a long-term decrease in the size of a population

Macquarie perch has been recorded in the Dendrobium Mine area in the mid to lower reaches of Wongawilli Creek, including pools just upstream and downstream of Fire trail 6A (NSW DPI (Fisheries), pers. com.; The Ecology Lab, 2001 and pers. obs. 2005; MPR 2006b; Niche, pers. obs. 2011). However, this species was not caught further upstream in Wongawilli Creek despite extensive sampling (Cardno 2012 and 2016). It has been recorded also in Lake Avon and Lake Cordeaux and previously recorded, or potentially present, in the upper reaches of Cordeaux and Avon Rivers (NSW DPI 2016a). The steep bedrock cascade features directly upstream of the crossing at Fire Road No. 6 would pose a substantial barrier to the upstream passage of the Macquarie perch populations from the lower to mid reaches of Wongawilli Creek to the reach within the Study Area. The presence of a natural barriers to passage at the mouths of Lake Cordeaux drainage lines would also likely prevent this species utilising these drainage lines. Regardless, drainage lines in the Study Area do not provide suitable habitat for Macquarie perch. Thus, within the Study Area the only area where Macquarie perch is likely to occur is in Lake Cordeaux.

Life history studies of Macquarie perch have been largely carried out on western drainage populations. These populations are known to spawn just above riffles in shallow upland streams in October to January when water temperatures rise to around 16 C. Eastern populations, however, inhabit rivers with very different hydrological conditions to the inland populations and very little is known of their life cycle. The eggs are adhesive and stick to gravel. Hatching commences 13 days after fertilisation and is completed by 18 days after fertilisation at water temperatures of 11 to 18°C. Newly-hatched larvae shelter amongst pebbles. In impounded waters, hatched fish move back downstream to the lake habitat from their upstream spawning sites.

The subsidence predictions indicate that extraction of the proposed longwall is not expected to result in major fracturing in Lake Cordeaux that could otherwise result in adverse impacts. Macquarie perch are not expected to be able to use sections of Wongawilli Creek or drainage lines that may be affected by major fracturing due to the presence of natural barriers to fish movement that would prevent the species from accessing these sections of watercourse.

Also given the extensive amount of potential habitat available for this species further downstream and in Avon and Cordeaux rivers, it is highly unlikely that mining would have any adverse effects on the life cycle of Macquarie perch in the Avon / Cordeaux River Catchment or place a viable local population at risk of extinction. Likewise, impacts to water quality in Lake Cordeaux are not expected.

b) Reduce the area of occupancy of the species

As described above, reductions in availability of aquatic habitat due to fracturing is not expected in Lake Cordeaux. Macquarie perch are not expected to occur in sections of these Wongawilli Creek and drainage lines within the Study Area. The Project would also not require any crossings over Avon River and Cordeaux River that could hinder fish passage and any impacts to water quality are expected to be localised and minor. Thus, reductions in the occupancy of this species due to the Project are not expected.

c) Fragment an existing population into two or more populations

As described in a) and b), potential impacts to Macquarie perch due to the Project are not expected. No structures that may hinder fish passage would be installed. Macquarie perch is not expected to occur within Wongawilli Creek and drainage lines in Study Area where fracturing and flow diversions could occur.

d) Adversely affect habitat critical to the survival of a species

As described in a), potential impacts to Macquarie perch habitat are not expected. Critical breeding habitat (shallow flowing sections of rivers) is likely present throughout Avon River, Cordeaux River and the lower section of Wongawilli Creek, though the Project would not result in any impacts here.

e) Disrupt the breeding cycle of a population

It is highly unlikely that mining would have any adverse effects on the life cycle of any Macquarie perch in Lake Cordeaux or place a viable local population at risk of extinction. Macquarie perch are considered very unlikely to occur in drainage lines in the Study Area, and, thus, would not be affected by any mining induced impacts here. The population in Wongawilli Creek is located downstream of the proposed mining where no fracturing could occur and is not expected to be affected by the Project.

f) Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

As described in (a) – (d) potential impacts to Macquarie perch and their habitat due to the Project are not expected and not expect to affect its forage, resting or spawning habitat to the extent that the species is likely to decline.

g) Result in invasive species that are harmful to an endangered species becoming established in the endangered species' habitat

Invasive species that may predate on Macquarie perch eggs or young fish and/or potentially compete with Macquarie perch for food and habitat include redfin perch (*Perca fluviatilis*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), wild goldfish (*Carassius auratus*), eastern gambusia (*Gambusia holbrooki*) and carp (*Cyprinus carpio*). The Project does not include any vectors that may introduce/further introduce these species to Macquarie perch habitat within the Study Area.

h) Introduce disease that may cause the species to decline

The invasive species listed in g) may carry disease or parasites that could infect Macquarie perch. However, the Project would not result in the introduction or further introduction of these species to the Study Area.

i) Interfere substantially with the recovery of the species

The National Recovery Plan for Macquarie perch (DEE 218) contains background information on the biology, ecology, distribution and populations, decline and threats and recovery objectives and strategies and associated actions for this species. The objectives are:

- > Conserve existing Macquarie perch populations;
- > Protect and restore Macquarie perch habitat;
- > Investigate threats to Macquarie perch populations and habitats;
- > Establish additional Macquarie perch populations;
- > Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance; and
- > Increase participation by community groups in Macquarie perch conservation.

Identified threats include:

- > Habitat degradation;
- > Invasive fish;
- > Barriers to fish movement;
- > Altered flow and thermal regimes;
- > Disease;
- > Illegal and incidental capture;
- > Chemical water pollution;
- > Climate change.

Potential impacts to Macquarie perch associated with the Project (primarily loss of habitat following significant fracturing leading to flow diversions and reductions in pool water levels) are not expected. The Project would not interfere with these objectives and the recovery of the species.

APPENDIX

E

LC5 AND LC6 SUPPLEMENTARY SURVEY

Introduction

Following submission of the SMP Application for Longwalls 22 and 23, South32 was provided comments on the Longwall 22 and 23 SMP Application from the Biodiversity and Conservation Division (BCD) of NSW DPIE (Environment, Energy and Science). This included a request for further baseline data on aquatic ecology to support the AFFA. This request focussed on first and second order drainage lines LC5 and LC6 of Lake Cordeaux, which partially overlay Longwalls 22 and 23.

Following review of the comments from BCD, Cardno proposed and undertook further baseline surveys in LC5 and LC6. The aim was to confirm the aquatic habitat and biota supported by these drainage lines, particularly that relating to Macquarie perch, update the impact assessment, if required, and support a response to comments from BCD.

Methodology

Surveys of aquatic habitat and biota was undertaken in LC5 and LC6 between 12 and 13 August 2021 (**Figure E-1**). The survey focused on the lower sections of the drainage lines that would be expected to provide more permanent and substantial aquatic habitat (primarily larger pools) suitable for Macquarie perch. The recommended survey period for Macquarie perch is March to September (DEE 2018). This timing is recommended to avoid disturbance to the species during upstream reproduction related migrations that occur for during October to January. The following survey methods were undertaken:

- > Aquatic habitat assessment using the RCE method and per the criteria for the four habitat types used by The Ecology Lab (2007).
- > AUSRIVAS sampling at two sites in each of LC5 and LC6 (total of 4) (**Figure E-1**). This included identification of any threatened dragonfly species (Adam's emerald dragonfly and Sydney hawk dragonfly). Giant dragonfly (*Petalura gigantea*) larvae occur in burrows in swamp habitat would not be expected to be found in watercourses. The AUSRIVAS model was run using the spring (September 15 to December 15), although the survey was undertaken three weeks prior to this.
- > General fish survey using backpack electrofishing and 8 baited traps. The electrofisher was operated throughout the survey extent of each drainage line. This included a minimum of 8 x 150 s shots per drainage line.
- > Confirmation of the KFH provided by LC5 and LC6 and as per the classification criteria in Policy and guidelines for fish habitat conservation and management (NSW DPI 2013).
- > Assessment of the potential for LC5 and LC6 to support Macquarie perch, via:
 - Identification of habitat suitable for Macquarie perch.
 - Targeted electrofishing survey for Macquarie perch focussed on larger pools where fish would most likely be present.
 - Assessment of natural barriers to fish movement at the confluence with Lake Cordeaux and in LC5 and LC6 that could hinder or prevent utilisation of LC5 and LC6 by Macquarie perch.

Further detail on the AUSRIVAS surveys, aquatic habitat assessment, backpack electrofishing and bait trapping undertaken is provided in **Appendix A**.

Results

Aquatic Habitat

Aquatic habitat within LC5 (**Plate E-1a to f**) and LC6 (**Plate E-2a to f**) consisted of a series of pools connected by shallow flow over rockbars. Channel width ranged from approximately 1 m up to 8 m (at some wider pool sections) with a mode of approximately 2 m. Pools were generally 1 to 2 m deep. Flow was present in both drainage lines during the survey. Large rocks (greater than 500 mm in two dimensions) and large wood debris (greater than 300 mm in diameter or 3 metres in length) were observed in some sections of each drainage line. Each drainage line scored high (51 out of 52) in the RCE criteria (**Table E-1**). This reflected the undisturbed condition of the sections of drainage lines visited and surrounding bushland. A species of *Myriophyllum*, an aquatic plant, was observed in 2 m x 1 m patch in LC5. This genus includes non-native and native species, though due to the absence of flowers and emergent leaves used as key diagnostic features it was not identified to species. The sections of drainage lines visited were classified as containing 'Moderate' habitat based on the criteria adapted from Fairfull and Witheridge (2003) (**Appendix A**). This was based primarily on the presence of some larger permanent / semi-permanent pools that would be expected to

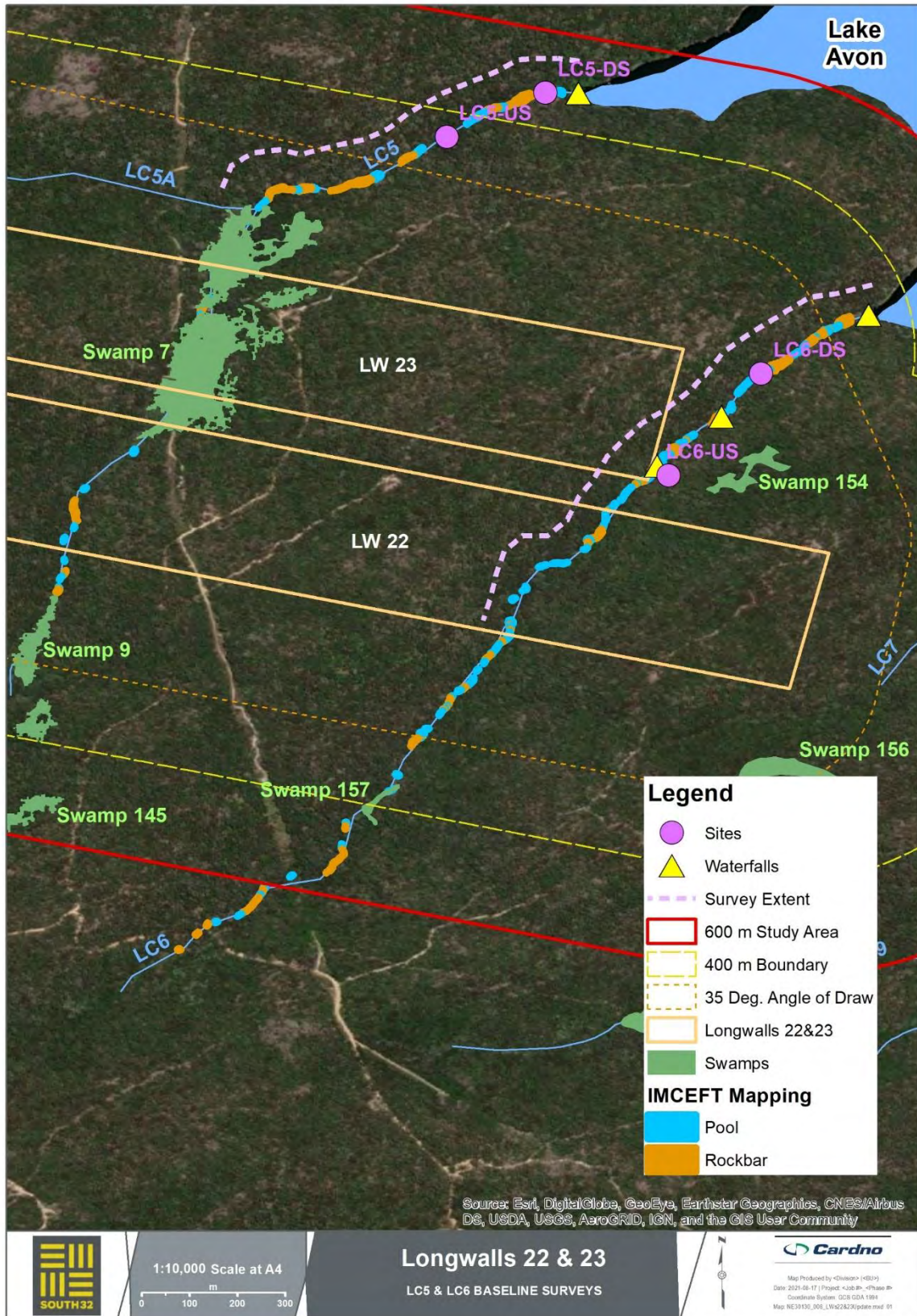


Figure E-1. Surveys undertaken in LC5 and LC6 between 12 and 13 August 2021

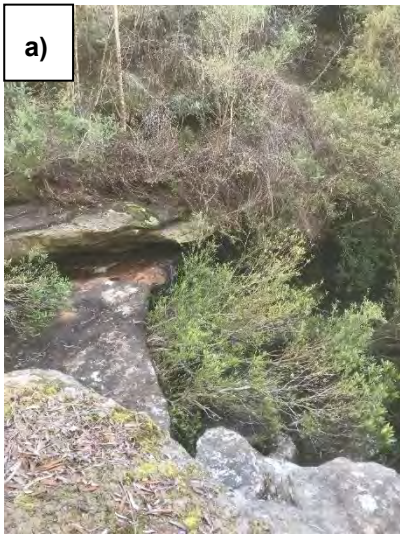


Plate E-1: LC5, including a) the waterfall at the confluence with Lake Cordeaux, b) larger pools, c) a patch of aquatic plants, d) large wood debris, e) large rocks and f) disconnected flow between pools



Plate E-2: LC6, including a) the waterfall/cascade at the confluence with Lake Cordeaux, b) 2 m wide channel, c) large rocks and wood debris, d) small (1 m to 2 m high) waterfall approximately 400 m upstream of Lake Cordeaux, e) larger pool with a second (2 m to 3 m) high waterfall f) 500 m upstream of Lake Cordeaux and f) narrower channel upstream of e).

persist through drought. This is consistent with the mapping undertaken by The Ecology Lab (2007). Pools in LC5 and LC6 have been mapped up to 40 m and 30 m in length, respectively, by IMCEFT. Waterfalls / cascades of at least 10 m in height were present at the confluence of LC5 (**Plate E-1a**) and LC6 (**Plate E-2a**) with Lake Cordeaux. These would almost certainly be complete barriers to fish passage even during high flow events. Two smaller waterfalls of 1 m to 3 m in height were also present in LC6 (**Plate E-2d** and **e**). These would also prevent passage of most fish during low to moderate and possibly also high flow events. Areas of shallow (a few centimetres) flow over rockbars and areas of channel with no observable surface flow were also observed in each drainage line. Fish passage through these areas would also be hindered and in some cases prevented.

Table E-1: RCE results for LC5 and LC6

RCE Category	LC5	LC6
Land use pattern beyond the immediate riparian zone	4	4
Width of riparian strip of woody vegetation	4	4
Completeness of riparian strip of woody vegetation	4	4
Vegetation of riparian zone within 10 m of channel	4	4
Stream bank structure	4	4
Bank undercutting	3	3
Channel form	4	4
Riffle/pool sequence	4	4
Retention devices in stream	4	4
Channel sediment accumulations	4	4
Stream bottom	4	4
Stream detritus	4	4
Aquatic vegetation	4	4
Total	51	51

Key Fish Habitat

First and second order gaining streams, such as LC5 and LC6, are not considered KFH according to *Section 3.2.1* and *Table 1* in NSW DPI (2013a). It is noted that LC5 and LC6 contained aquatic habitat (large rocks, large wood debris, and in the case of LC5, native aquatic plants) that is diagnostic of Type 1 – Highly Sensitive KFH in third and greater order streams.

AUSRIVAS

AUSRIVAS data is provided in **Table E-2** and **Table E-3**. Number of taxa range from 11 to 16, OE50 Taxa

Table E-2: AUSRIVAS data from LC5 and LC6

Site	Number of Taxa	OE50 Taxa Score	Band Scores	SIGNAL2 Score
LC5-DS	16	0.77	B	3.6
LC5-US	12	0.73	B	4.6
LC6-DS	11	0.67	B	4.3
LC6-US	12	0.61	B	4.3

Score 0.61 to 0.77 (Band B – significantly impaired relevant to reference condition) and SIGNAL2 Score 3.6 (indicative of severe pollution) to 4.6 (indicative of moderate pollution). Examination of the raw AUSRIVAS data indicated that the tolerance of individual taxa to pollution ranged from pollution sensitive (Leptophlebiidae, SIGNAL2 Score: 8) to pollution tolerant (several taxa with SIGNAL2 Score < 4). Although the biotic indices suggest impairment of aquatic habitat and water quality, there is no evidence of this in the drainage lines. Rather, it is possible that the naturally low pH levels in watercourses in the Dendrobium Mine area may be influencing the type of macroinvertebrates that are present. Other measures of water quality, such as naturally occurring levels of some heavy metals, may also influence the type of macroinvertebrates, and other organisms present in these watercourses. These findings are comparable AUSRIVAS data collected across the Dendrobium Mine Area (**Section 3.6**).

Fish

No fish were caught whilst electrofishing or in the bait traps. Freshwater crayfish (*Euastacus* sp.) up to approximately 4 cm length was caught and observed throughout each section of drainage line visited. One adult frog was caught inadvertently in the AUSRIVAS dip net at LC5-DS and several frog egg masses were

observed attached to trailing vegetation in the water throughout LC6. Assessment of frogs and frog habitat in LC5 and LC6 has been undertaken in the terrestrial ecology assessment.

Table E-3: AUSRIAVS data from LC5 and LC6

Taxon	LC5-DS	LC5-US	LC6-DS	LC6-US	SIGNAL2 Score
DugesIIDae		1			2
Nemertea	1				3
Nematoda	1		1	1	3
Oligochaeta			1		2
Copepoda	10	2	7	1	
Hydracarina	6	3	5	5	6
Leptophlebiidae	10	9	10	10	8
Synthemistidae	1				2
Hydrometridae		1			3
Veliidae		2		1	3
Nepidae	1				3
Notonectidae	1		2	1	1
Haliplidae	4				2
Dytiscidae	1				2
Gyrinidae	3	3	2		4
Hydrochidae				3	4
Scirtidae		1			6
Chironominae	4	2	6	3	3
Tanypodinae	8	2	5	1	4
Ceratopogonidae	6	3			4

Hydrology

IMCEFT has been undertaking monitoring of flow in LC5 since April 2019 (Figure E-2). Eighty-two days of zero flow days were recorded over the total 821 days to 1 July 2021, including 51 consecutive zero flow days between 28 November 2019 and 17 January 2021. While LC5 and LC6 provide larger pools that would persist during dry periods, it is probable that they could dry during severe drought. During the recent drought period in 2018/2019, several pools in LC5 downstream of Swamp 7 were dry (IMCEFT pers. Comm. Aug 2021). Based on the catchment area of LC5 (186 ha) and LC6 (118 ha) it is possible also that several pools in LC6 dried during this time.

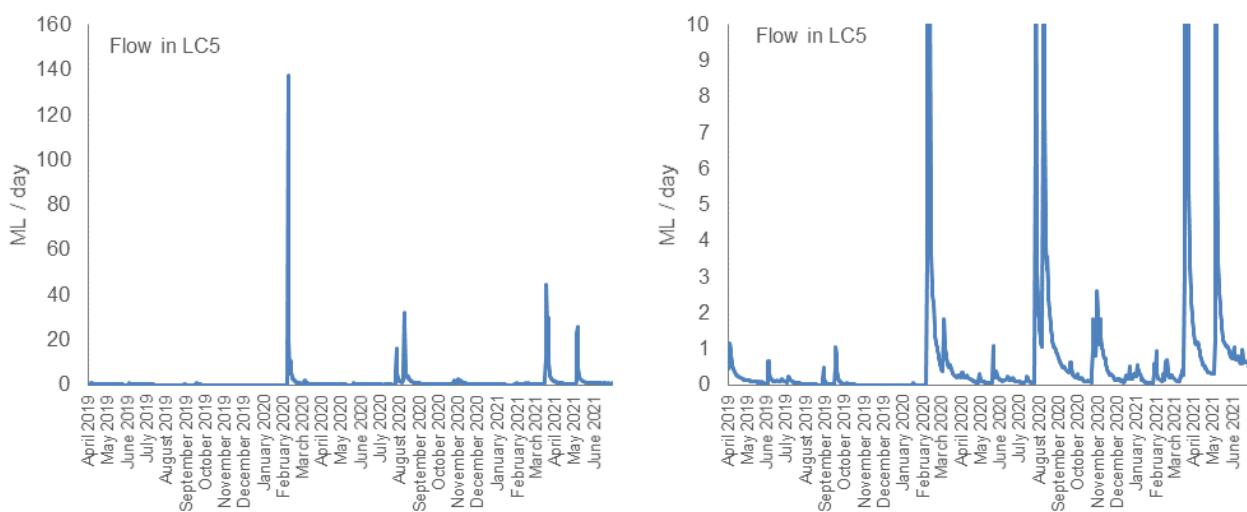


Figure E-2. Flow in LC5 downstream of Swamp 7 during April 2019 to July 2021.

Response to Comments

- *The aquatic flora and fauna assessment (Cardno 2021) identifies that there has been very limited aquatic flora and fauna survey in the area and streams that are most likely to be impacted by*

longwalls 22 & 23; and much of this is based on decade old survey information. The report largely concentrates on impacts to Wongawilli Ck and Cordeaux Reservoir, ignoring impacts to LC5 and LC6. Both streams are likely to be permanent streams due to the swamps located in their headwaters (including the 4.8 ha Swamp 7 EEC). If the current configuration of LW 22 & 23 is adopted, all surface water will be lost and likely move directly into the mine due to connective fracturing. This will likely leave LC5 & LC6 without any aquatic habitat. This has not been appropriately considered in the aquatic flora and fauna assessment. There is also no identified offsetting of stream and aquatic fauna/flora impacts.

The assessment for LC5 and LC6 was undertaken in **Section 4.2.3.1** based on recent survey, mapping and photographs of these water courses provided by IMCEFT as well as previous inspection and mapping of these drainage lines by The Ecology Lab (2007). This previous survey was of physical characteristics of the watercourses and the presence of barriers to fish passage from Lake Cordeaux in to LC5 and LC6. The presence of significant barriers to fish passage at the confluence of these drainage lines and Lake Cordeaux was confirmed following surveys undertaken in August 2021.

LC5 and LC6 flow directly over Longwalls 22 and 23 and are located almost entirely within 400 m of each longwall. Subsidence predictions (MSEC 2021) indicate that subsidence and fracturing is expected to occur in sections of watercourse directly above the longwalls, and that fracturing is likely to occur in watercourses up to approximately 400 m away. It was predicted that a localised significant impact to aquatic habitat and biota would occur in these watercourses and that a localised reduction in the population size of aquatic biota would occur. At a catchment scale, such impacts would be more minor. This assessment is consistent with that provided in **Section 4.2.3.1** of the AFFA. Given available hydrological data, field observations during drought conditions, and the relatively small catchment sizes of LC5 and LC6, these drainage lines appear likely to stop flowing and several pools would become dry during severe drought. Larger pools would, however, provide refuge for aquatic biota for several months following low rainfall.

- *The only impact sites monitored are in Wongawilli Creek. LC6 and LC5 are likely to contain significant aquatic habitat and pools for which baseline data has not been collected. Pools in the lower reaches of LC5 and LC6 may experience reduced inflows and fracturing, and this could impact suitable habitat and food resources for Macquarie Perch in connected areas of Lake Cordeaux.*
- *There needs to be surveys for threatened Macquarie Perch in the study area, especially within the tributaries to Lake Cordeaux LC5 and LC6;*
- *The assessment that Macquarie Perch are not present in LC5 and LC6 due to barriers for dispersal in the lower reaches of these tributaries should be reviewed.*

LC5 and LC6 were assessed as providing 'moderate' aquatic habitat based on criteria based on in Fairfull and Witheridge (2003). This classification was due primarily on the presence of some large permanent to semi-permanent pools. LC5 and LC6 provide habitat for aquatic macroinvertebrates and frogs. No fish were caught in LC5 or LC6 (albeit this was only a single sample event) and these watercourses appear to provide limited habitat for fish. This presence of significant barriers to fish passage at their confluences with Lake Cordeaux likely prevents access for all species except those adapted to moving over waterfalls such as climbing galaxias (*Galaxias brevipinnis*). Even if some fish were able to access these watercourses, the apparent periodic (every few years) drying of pools in these watercourses would also hinder the establishment of local populations of fish. "Significant" aquatic habitat contain numerous large, permanent pools and generally have flow connectivity except during prolonged drought. Nearby Wongawilli Creek has been classified as 'Significant' aquatic habitat.

The significant barriers to fish passage at the confluence of LC5 and LC6 and Lake Cordeaux represent a near certain barrier to passage of Macquarie perch from Lake Cordeaux to these drainage lines. Within the drainage lines, several other barriers to fish passage were present including smaller waterfalls and shallow flow over waterfalls. The few larger pools that are present are also far smaller than the reported diel range of Macquarie perch of 516 m (± 89 S.E.) (Ebner *et al.* 2010) (**Section 3.8.2**). Macquarie perch spawn in spring or summer and lay their eggs over stones and gravel in shallow, fast-flowing upland streams or flowing parts of rivers. LC5 and LC6 do not provide such habitat. No fish were caught in LC5 or LC6 during the field survey. LC5 and LC6 do not provide suitable habitat for Macquarie perch and it is considered almost certain that Macquarie perch would not be able to access these drainage lines, or persist if present.

- *The assessment of LC5 and LC6 as not containing KFH should be reviewed.*

The presence of KFH in LC5 and LC6 is consistent with criteria in the Policy and guidelines for fish habitat conservation and management (NSW DPI 2013a). This indicates first and second order gaining streams such as LC5 and LC6 do not provide KFH. The exception is when they are confirmed to provide habitat for

threatened species or in the case of losing streams. In any case, the apparent unsuitability of these watercourses for fish including the threatened Macquarie perch, due to the presence of significant natural barriers and their potential to dry during extended drought, would indicate they provide limited habitat for fish.

- TARPS for Aquatic Ecology: Insufficient monitoring sites for Area 3C are listed. Please include monitoring in LC5, LC6 and LC7

Two additional sites (Sites 21 and 22) have been established in Wongawilli Creek to monitor potential impacts associated with extraction of Longwalls 22 and 23. Baseline monitoring at these sites commenced at the start of 2021 and is currently underway. This includes surveys of macroinvertebrates using AUSRIVAS and quantitative methods, fish, *in-situ* water quality and aquatic plants. Wongawilli Creek contains 'significant' aquatic habitat and, along with Donalds Castle Creek and Sandy Creek, is the focus of aquatic ecology monitoring in Areas 3A, 3B and 3C. Aquatic ecology sites have been established in all of these watercourses. Monitoring for Area 3C and across the Dendrobium Mine also includes the numerous drainage lines of these watercourses and of Lake Cordeaux with a focus towards the physical attributes and particularly water availability in pools. Based on previous observations in the Dendrobium Mine area, aquatic habitat and biota in pools is relatively unaffected unless a substantial amount of water is lost. Monitoring is undertaken by IMCEFT and includes surveys of physical attributes including pool size, water depth in pools, water flow and any evidence of subsidence related impacts such as fracturing and flow diversions that may occur following longwall extraction. Water quality data is also collected from sites within these watercourses. The findings are reviewed as part of the aquatic ecology and assessment reporting during and following completion of each longwall. This includes an assessment of related changes to aquatic ecology that may have occurred following any observed subsidence related impacts such as reductions in flow and water levels and changes in water quality. This is undertaken for each creek and drainage line where mining related impacts have been observed and includes an assessment of whether impacts to aquatic ecology are within or exceed predictions made in the EIS and AFFAs. These findings are reported as part of End of Panel Reporting following the completion of extraction of each longwall.

Summary

LC5 and LC6 are first and second order drainage lines that flow directly above the proposed Longwalls 22 and 23. They provide several semi-permanent pools that provide habitat for macroinvertebrates, aquatic plants and frogs. Some pools may persist for some time following low rainfall, but would be reduced in extent and size. They provide very limited habitat for fish. This is due primarily to the presence of significant barriers to fish passage at their confluence with Lake Cordeaux and observations that these watercourses dry during drought periods. These drainage lines do not contain Key Fish Habitat under the definitions of NSW DPI (2013a), though large rocks, wood debris and aquatic plants are present and these drainage lines and they do provide aquatic habitat of value. Macquarie perch almost certainly do not occur in these drainage lines. Macquarie perch and their habitat would not be impacted by extraction of Longwalls 22 and 23. No other threatened species have been identified as likely to occur in LC5 and LC6. Based on subsidence predictions, it is likely that these drainage lines would be impacted by subsidence, resulting in flow diversions, pool drainage and loss of aquatic habitat. Such impacts would be severe at the scale of individual watercourses and would result in a localised reduction in the population sizes of aquatic macroinvertebrates. At the wider Cordeaux Catchment scale, these impacts would be relatively minor. The loss of aquatic habitat in these drainage lines would contribute to the cumulative loss of this aquatic habitat in the Dendrobium Mine Area. These findings are consistent with the impacts assessment undertaken in **Section 4** of the AFFA for Longwalls 22 and 23.