# Aquatic Flora and Fauna Assessment

Longwall 19A Subsidence Management Plan

NE30130

Prepared for

South32 – Illawarra Metallurgical Coal

30 September 2022

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# Executive Summary


**Introduction**

South32 – Illawarra Metallurgical Coal (South32) plans to extract coal from Longwall 19A in Dendrobium Area 3A (Area 3A) of the Dendrobium Mine Area (the Project). Longwall 19A is located between Wongawilli Creek and Sandy Creek and to the south of the approved Longwall 19. This Aquatic Ecology Assessment (AEA) has been prepared to support the Subsidence Management Plan (SMP) for Longwall 19A. The AEA focuses on the sections of Wongawilli Creek, drainage lines of Wongawilli Creek and drainage lines of Sandy Creek 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, Lake Cordeaux and Lake Avon are located some distance away from the longwall and would not be affected by extraction. The AEA includes:

> A review and synthesis of existing information on the aquatic flora and fauna of the Wongawilli Creek and drainage lines in the Study Area (area within 600 metres (m) of Longwall 19A;

> 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.

Aquatic habitat in first and second order drainage lines within the Study Area is largely undisturbed. Aquatic habitat in drainage lines include small, disconnected and largely ephemeral pools with limited habitat potential for aquatic flora and fauna, though semi-permanent pools would 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 and drainage lines of Sandy 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. Although suitable micro-habitat for Adams emerald dragonfly (*Archaeophya adamsi*) and Sydney hawk dragonfly (*Austrocordulia leonardi*) appears to occur in the Study Area, none have been caught despite extensive sampling and the Study Areas appears located outside their restricted range. Macquarie perch (*Macquaria australasica*) occurs downstream of the Study Area, but is considered unable to access Wongawilli Creek and drainage lines in the Study Area due to the presence of natural barriers to fish passage outside the Study Area.

**Impact Assessment**

There are no flow controlling rockbars in Wongawilli Creek within 400 m of Longwall 19A that would otherwise be at risk of fracturing following subsidence due to extraction of Longwall 19A. Thus, significant impacts to Wongawilli Creek are not expected. The contribution to groundwater depressurisation and baseflow reduction in Wongawilli Creek due to extraction of Longwall 19A are predicted to result in negligible (< 1%) increase in the duration and length over which cease-to-flow conditions can occur in Wongawilli Creek during drought periods. Impacts to water quality in Wongawilli Creek are also predicted to be undetectable. Thus, associated impacts to aquatic habitat and biota associated with extraction of Longwall 19A in isolation are likely to be minor and probably indistinguishable from natural variability.

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 50 m of first and second order drainage lines occur directly above Longwall 19A and a further 3.3 km is within 400 m of the longwall. 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 Longwall 19A 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.

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.

**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 DA3 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 18 was undertaken between February 2013 to December 2021. Extraction of Area 3A Longwall 19 is currently underway.

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 and Environment (DPE). 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 Longwalls 22 and 23 in Area 3C in 2021 (Cardno 2021). Extraction of these longwalls will follow completion of mining in Area 3A.

South32 are proposing to extract coal from Longwall 19A in Area 3A (the Project) and invited Cardno now Stantec (Cardno) (formerly trading as Cardno Ecology Lab and The Ecology Lab Pty Ltd) to prepare a proposal to undertake the Aquatic Ecology Assessment to support the SMP for this longwall.

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 AEA 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, Sandy Creek catchment and Lake Cordeaux adjacent to the proposed location of Longwall 19A. 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 entities, and any cumulative impacts, in Wongawilli Creek, Sandy 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 DPE) 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 Longwall 19A is 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 AEA 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 Study Area for Longwall 19A 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 1,050 m within the Study Area. There are also several first and second order drainage lines and upland swamps within the Study Area that flow into Wongawilli Creek to the west and into Sandy Creek and Lake Cordeaux to the east.

Lake Cordeaux and Sandy Creek are located at least 1.2 km from the Study Area and are unlikely to experience physical impacts due to extraction of Longwall 19A (MSEC 2022). Physical impacts are also not expected to occur in Lake Avon due to extraction of Longwall 19A 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, Lake Cordeaux, Avon River, Cordeaux River and the main channel of Sandy Creek have not been considered in detail. 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 (2022) and in this AEA.

## 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, 2018a, 2020a) and most recently (in 2021) (Cardno 2022). Assessments were also undertaken for Longwalls 20 and 21 in Area 3C (Cardno 2019), Longwall 19 in Area 3A (Cardno 2020b), Longwall 18 in Area 3B (Cardno 2020c) and Longwalls 22 and 23 in Area 3C (Cardno 2021).

In these studies, the primary watercourses considered were in the Wongawilli Creek, Sandy Creek and Donalds Castle Creek catchments. Donalds Castle Creek and the main channel of Sandy Creek are located outside the Study Area for Longwall 19A 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**. This review of existing information included the findings of surveys undertaken at Sites 2 and X4 on Wongawilli Creek. These are the closest sites to, and are located within the Study Area for, Longwall 19A 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, 3 and X5 to X8 and were visited most recently in 2021. Data from sites 11 and 12 on SC10 and Site 13 on SC10C (tributaries of Sandy Creek) have also been reviewed as these sites may experience subsidence related impacts associated with extraction of Longwall 19A. Details of the methods used in these studies and the GPS coordinates of monitoring sites are provided in **Appendix A**.

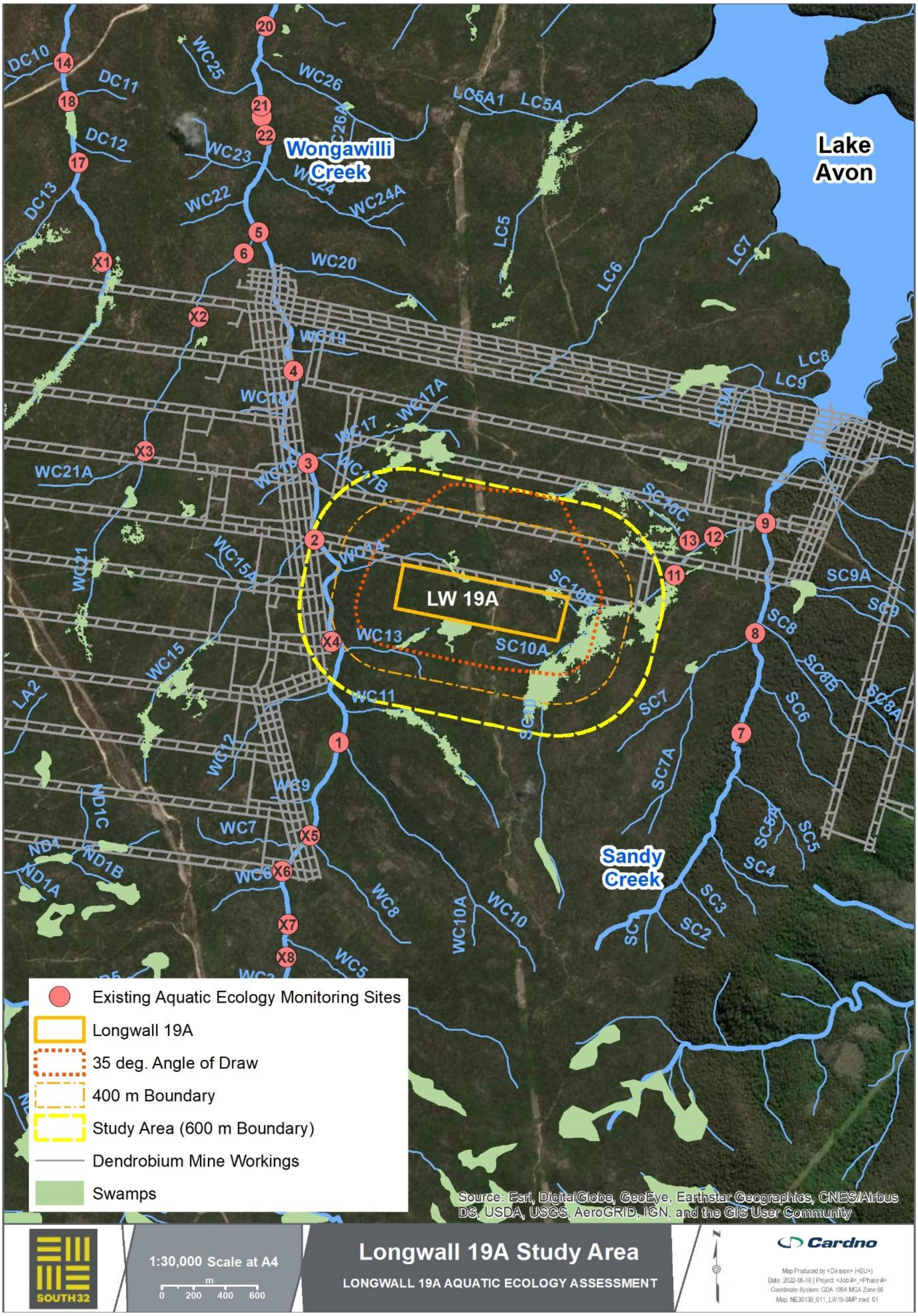


Figure 3-1 Aerial image overlaid with longwall layouts, watercourses and aquatic ecology sites within and adjacent to the Longwall 19A Study Area (600 m boundary). The 400 m boundary is presented to provide context for the subsidence predictions (Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield (MSEC 2022).

## 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 Longwall 19A is located within Zone 3. Zone 3 (**Plate 1i-iii**) includes Sites 2 and X4 and is located from the confluence with WC15 upstream to the large waterfall on Wongawilli Creek at Rockbar 36.

The aquatic habitat within Zone 3 was characterised as follows:

- Riparian vegetation is dominated by dry Eucalypt native forest within an increasingly steep and narrow (moving upstream) valley. This forest vegetation extends to the banks of the creek and almost fully shades the channel in Zone 3 and partially shades the channel in Zone 4. Riparian vegetation along the banks includes numerous native grasses, shrubs and trees including saw grass (*Gahnia* sp.), mat rush (*Lomandra* sp.), wattles (*Acacia* sp.), and tea-tree (*Leptospermum* sp.). There is also a variety of native ferns present along the banks of the main drainage and tributaries of these zones, including coral ferns (*Gleichenia* sp.).
- The channel morphology of Wongawilli Creek in Zone 3 is characterised by extensive reaches of relatively long, narrow, shallow pools with few sections deeper than 1 metre, and rarely wider than 3 m. These pools are separated by short riffle sections which consist of boulder fields, and gravel-pebble beds. There were also sandbars and some small areas of bedrock along this reach. Within the pools there was some accumulation of detritus including leaf litter and woody debris.
- The distribution of aquatic plants was patchy, with green and brown algae present within Zones 3. 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 ≤ 5% of the surface area at the majority of monitoring sites in Wongawilli Creek. The percentage cover of aquatic macrophytes at the other sites exceeded 5% on one occasion (April 2009 at Site 3). Algae were more common, covering ≥ 20% of the area on occasion at all of the sites in Zone 3. Mosses were present on bedrock, boulders and large woody debris and appeared to be more prevalent in spring.

Based on description of the four habitat types adapted from Fairfull and Witheridge 2003 (**Appendix A**), Wongawilli Creek through Zone 3 (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).

Mapping undertaken by IMCEFT has identified 13 pools in Wongawilli Creek within the 600 m boundary (**Figure 3-2**). These pools develop as water flow is restricted by shallow sections and sediment and debris accumulations. The pools are up to 10 m wide and 160 m long. Importantly, these pools do not form behind flow controlling rockbars but rather wood debris and / or sand. Rockbars are otherwise susceptible to subsidence induced fracturing and flow diversions that can result in the draining of pools upstream.

### 3.3.2 Drainage Lines

Four drainage lines of Wongawilli Creek (WC13, WC13A, WC14 and WC17B) and three drainage lines of Sandy Creek (SC10, SC10A and SC10B) are located in the Study Area. Of these, only WC17B is not located within the 400 m boundary.

WC13 (**Plate iv**) and WC14 (**Plate v**) contain “minimal” aquatic habitat. WC13A, WC17B (**Plate vi**), SC10A, SC10B and the upper reaches of WC13 and SC10 contain ‘unlikely’ aquatic habitat. The lower reaches of SC10 contain ‘moderate’ aquatic habitat and includes some semi-permanent 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**).

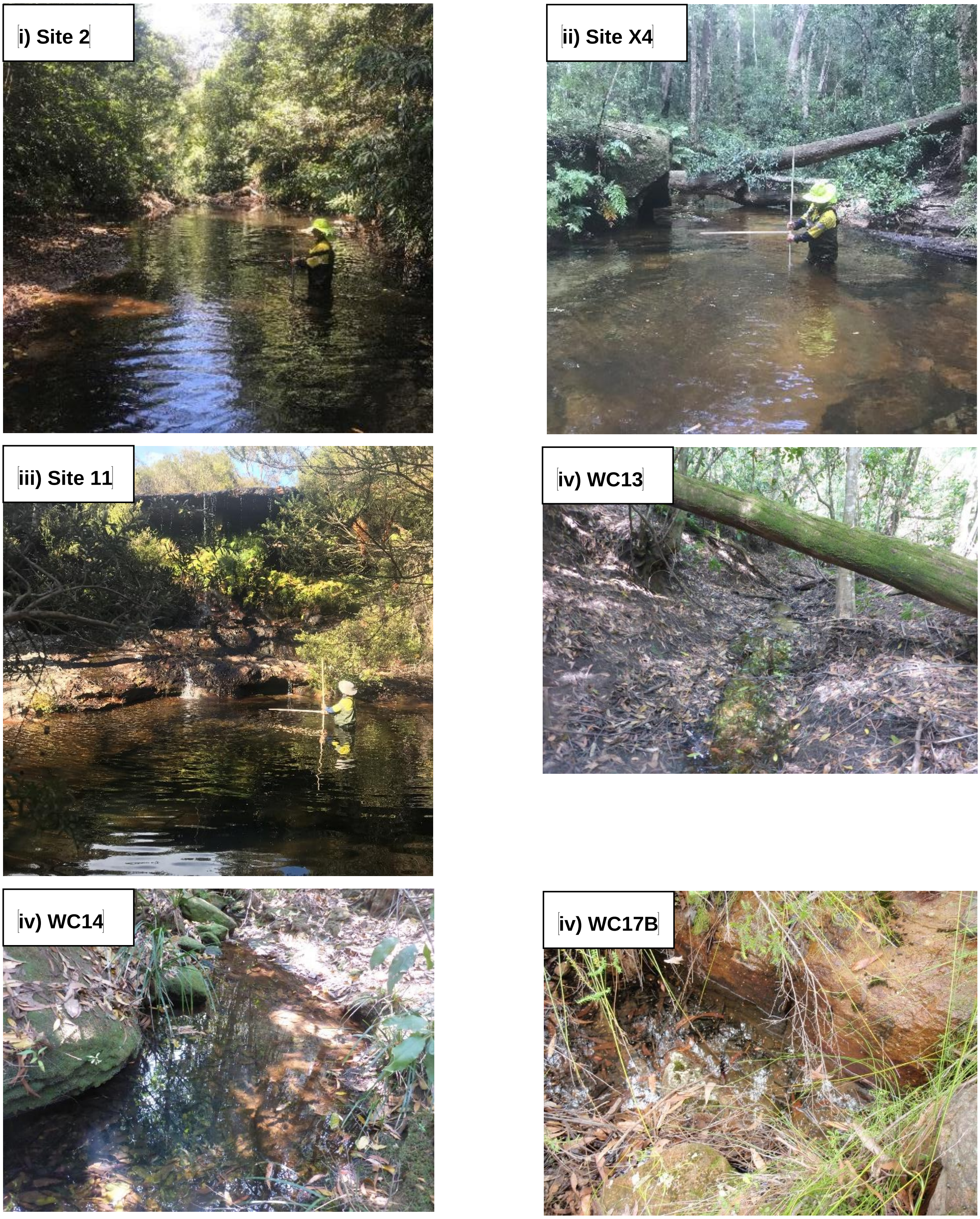


**Plate 1. Wongawilli Creek at i) Site 2 and ii) Site X4, iii) SC10 at Site 11, iv) WC13, v) WC14 and vi) WC17B.**

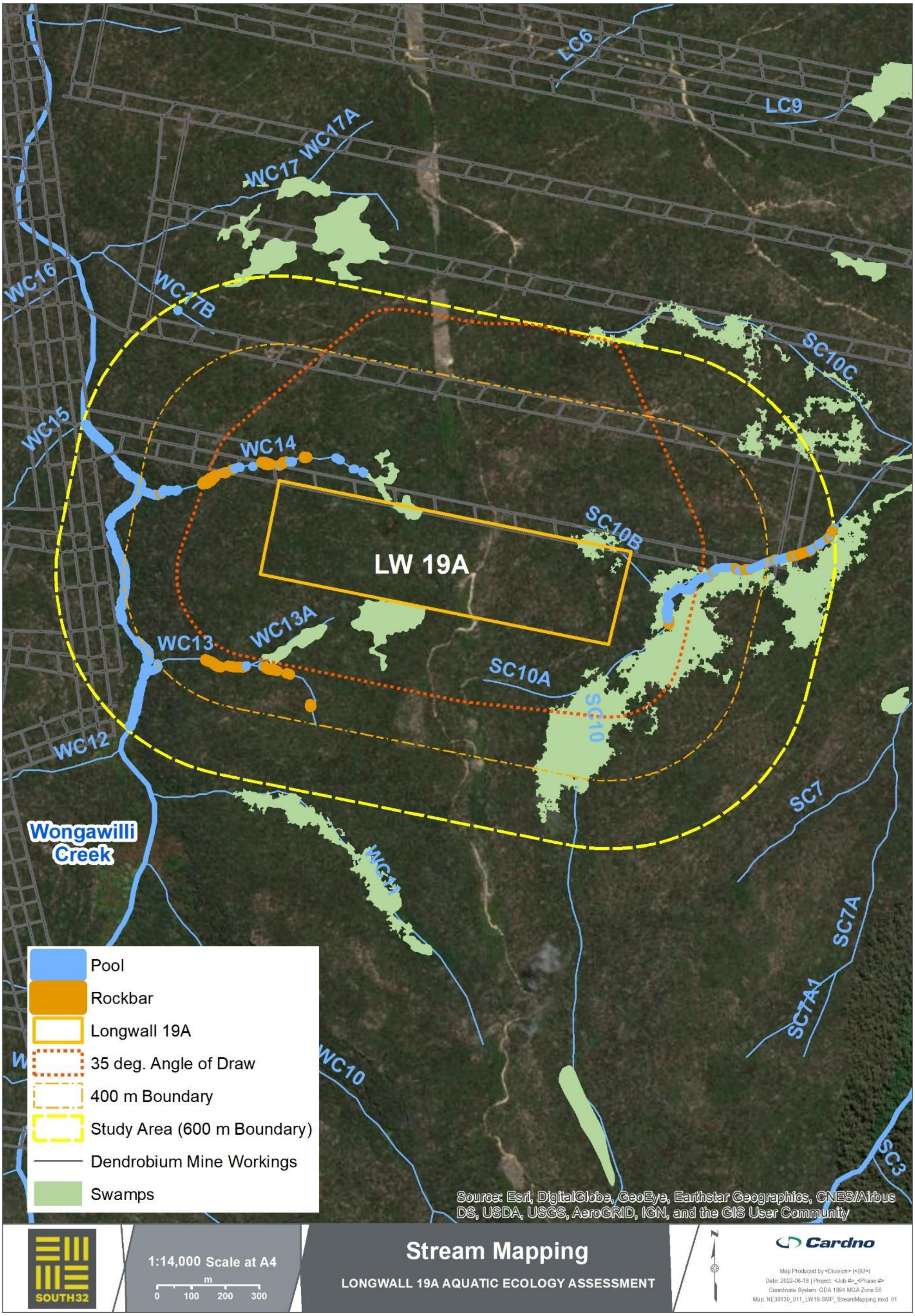


Figure 3-2 Location of pools and flow controlling rockbars mapped within Wongawilli Creek and drainage lines within the Study Area

### 3.3.3 RCE Inventory

Results of the RCE assessment at sites on Wongawilli Creek, SC10 and SC10C 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. Previous mining impacts (pool drainage, reduction in flow and iron staining) associated with extraction of previous Area 3A Longwalls 6 to 8 have been observed in SC10C. However, SC10C over 600 m from Longwall 19A and is not expected to experience impacts associated with extraction of this longwall

## 3.4 Key Fish Habitat

The broad scale KFH map for Wollongong available on the NSW DPI website indicates that 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 drainage lines of Wongawilli Creek and Sandy Creek (**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. Isolated pools would be substantial natural barriers to fish passages, as would such as waterfalls, cascades, and low flow over rock bars, which are also 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.

## 3.5 Water Quality

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

> EC levels were generally within the ANZECC/ARMCANZ (2000) guideline default trigger values (DTVs) (30 to 350 (µS/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, 4 and 13, 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 fell below the lower DTV (90 % saturation) during some surveys. On Wongawilli Creek this more commonly occurred at the sites downstream (1, 2, 3, 4, 5 and X4) than at upstream 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. On Sandy Creek DO levels tended to be lower at sites 7 and 9.

> In spring, the turbidity measurements taken at Wongawilli Creek 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. Turbidity levels in the Sandy Creek catchment were within DTVs on each occasion.

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 into consideration when interpreting the results of macroinvertebrate sampling.

Water quality is regularly (at least monthly) monitored by IMCEFT at sites on Wongawilli Creek and in drainage lines of Wongawilli Creek and Sandy 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.

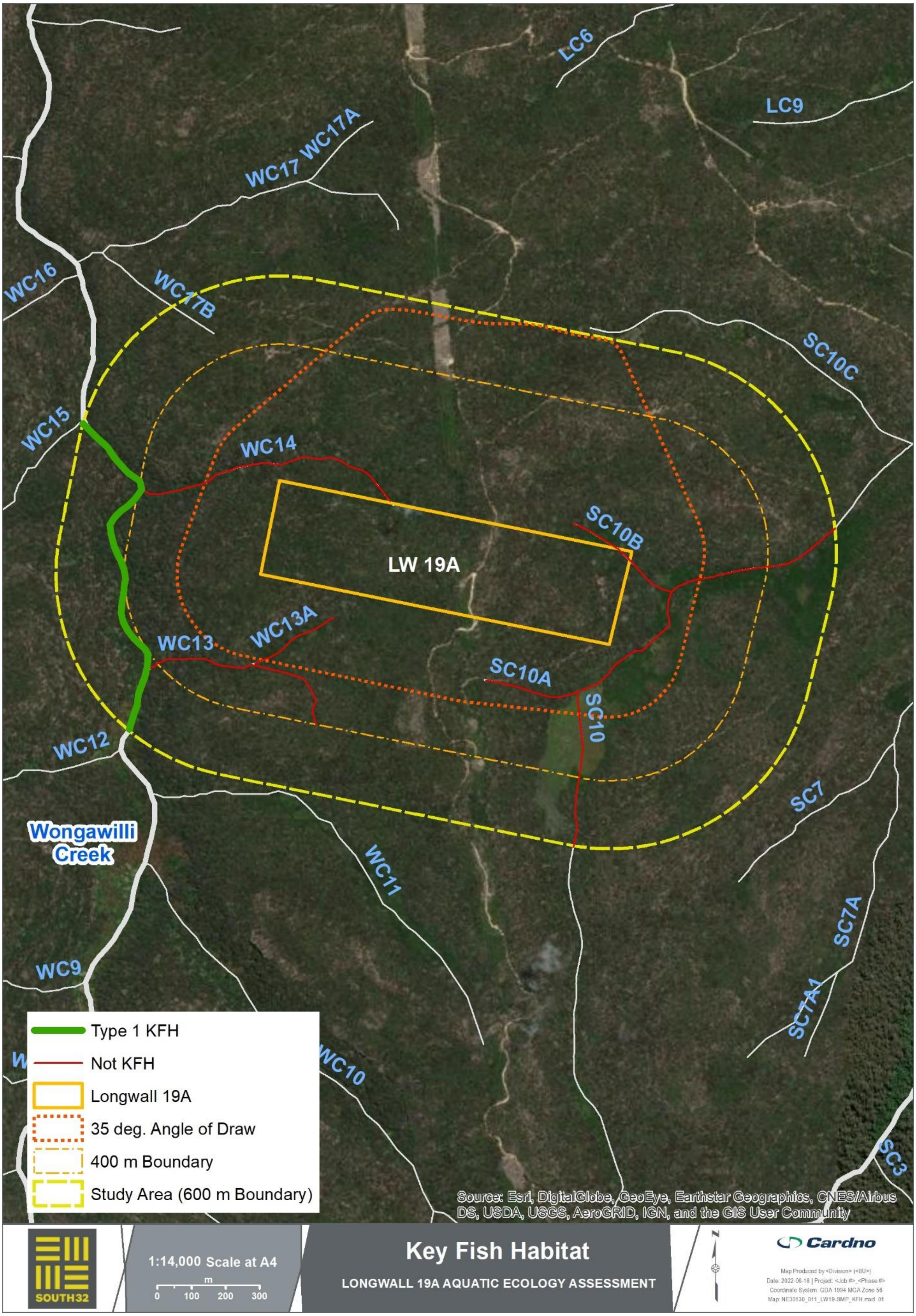


Figure 3-3 Key fish habitat mapped within the Study Area

## 3.6 Macroinvertebrates

The several AUSRIVAS surveys undertaken in Dendrobium Area 3 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 AEA, assemblages at each site on Wongawilli Creek have ranged from an average of 0.63 (BAND B – significantly impaired relative to reference condition) to 0.88 (Band A – equivalent to reference condition) (**Table 3-1**). On Sandy Creek catchment sites OE50 Scores have averaged slightly higher, ranging from 0.79 (Band B) to 0.97 (Band A). On occasion, OE50 Taxa Scores at these sites have ranged from Band C (severely impaired) to Band X (richer assemblage than reference condition) 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 moderate water pollution (SIGNAL Scores 4 to 5) in Wongawilli Creek and Sandy Creek drainage lines. 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 these watercourses, 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 within and outside of the Study Area (**Table 3-1**). The one exception was that the number of taxa tended to be lower at Site X4 (within Study Area) than at other sites on Wongawilli 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.

Table 3-1 Mean AUSRIVAS data from sites in Wongawilli Creek and on Sandy Creek drainage lines 2008 to 2017. Note not all sites sampled on each occasion.

| Site | Number of Taxa | | OE50 Taxa | | SIGNAL2 Score | |
|---|---|---|---|---|---|---|
| | Mean | SE | Mean | SE | Mean | SE |
| **Sandy Creek Catchment** | | | | | | |
| Site 11 | 16.3 | 0.7 | 0.80 | 0.04 | 4.4 | 0.1 |
| Site 12 | 16.6 | 0.7 | 0.79 | 0.04 | 4.5 | 0.1 |
| Site 13 | 16.3 | 0.6 | 0.97 | 0.04 | 4.3 | 0.1 |
| **Wongawilli Creek** | | | | | | |
| 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 |

## 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.

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 and 2021, 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).

Galaxiids and freshwater crayfish have also been sampled in Sandy Creek drainage lines (Cardno Ecology Lab 2014; 2014; 2016). Although Macquarie perch have previously been caught in Lake Cordeaux (Growns and Gehrke 2001; Creese and Hartley 2003), this species is not expected to be able to move upstream into Sandy Creek and its tributaries due to the significant natural barrier present in Sandy Creek just upstream of its confluence with Lake Cordeaux. Macquarie perch has not been caught in Sandy Creek during the several surveys undertaken by Cardno during in the Dendrobium Mine.

All species of fish identified from the Study Area are widespread and abundant, and currently have no cause for conservation concern.

## 3.8 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 DPE 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<br>(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 farther upstream and within the Study Area, but it has not been caught here during numerous surveys in Wongawilli Creek upstream of Fire Road 6, possibly due to the presence of natural barriers to fish movement further downstream.<br>Very unlikely to occur in drainage lines in the Study Area due to the limited aquatic habitat provided by these watercourses. The natural waterfall where Sandy Creek meets Lake Cordeaux would almost certainly also prevent this species from accessing the Sandy Creek catchment. |
| Adams emerald dragonfly<br>(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<br>(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<br>(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, 3A, 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 underground mining 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 IMC. As of January 2022, 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 38.6 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.

Some of the most recent impacts observed (associated with mining in Area 3) 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. 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 Leptophlebiidae (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 Cordeaux River catchment. More recently in November 2019 as part of investigations for the Longwall 19 impact assessment, observations of SC10C by Cardno suggested some recovery in flow and pool water levels.

Approximately 86 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 23 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 longwalls in Area 3B. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield (MSEC 2022).

Collectively, the length of watercourse that has experienced indirect and direct mining impacts (147.6 km) is estimated to be 21 % of that present in the upper Avon and Cordeaux River catchments (717 km). The majority of this would be first and second order drainage lines. However, impacts of groundwater depressurisation have 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 (HGeo 2018). 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 megalitres per day (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 no significant mining effect on surface flow in Wongawilli Creek was apparent approximately 3 km downstream at the Wongawilli Creek gauge.

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 Sandy Creek. 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 Creek and drainage lines of Sandy 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, 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 distance of 390 m from the western end of Longwall 19A. 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 (2022) assessed physical impacts that may occur in watercourses within 600 m of Longwall 19A. The impacts predicted to occur by MSEC (2022) are summarised as follows:

> The section of Wongawilli Creek located within the Study Area is predicted to experience less than 20 mm vertical subsidence. 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 (7 %). 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 Longwall 19A 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 %.

> Localised ponding could develop along some sections of the drainage lines, upstream of the chain pillars and the edges of the mining area, and where the natural stream gradients are relatively low. It is expected that fracturing would occur along the sections of the drainage lines that are located directly above the proposed Longwall 19A. Fracturing can also occur outside the extents of the proposed longwall at distances up to approximately 400 m. Surface water flow diversions are also likely to occur along the sections of drainage lines that are located directly above and adjacent to the mining area. The maximum predicted incremental (i.e. due solely to Longwall 19A) change in grade is 3.0% or 1 in 33. 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 19A 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 2022) and associated impacts on surface water (HGeo 2022) and groundwater (WHG 2022).

## 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 Wongawilli Creek

#### *4.2.1.1 Loss of Aquatic Habitat*

Impacts to aquatic habitat in creeks can 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. No flow controlling rockbars in Wongawilli Creek are located within 400 m of Longwall 19A. This would substantially limit the potential for flow diversions and loss of aquatic habitat to occur in Wongawilli Creek due to extraction of Longwall 19A. Pooling of water does occur in the section of Wongawilli Creek within 400 m of Longwall 19A, however, these pools form behind wood debris and / or sand and rather than flow controlling rockbars. Thus, they would not be susceptible to any mining induced fracturing and associated flow diversions.

Surface and Groundwater modelling (HGeo 2022; WHG 2022) indicates that the short term (up to 6 years) and long term (> 40 years) incremental reduction in flow along Wongawilli Creek adjacent to Area 3C due to extraction of Longwall 19A would be up to 0.02 ML/day (maximum reduction in the short-term). Thus, it is expected that Longwall 19A would cause a negligible (< 0.1 %) increase in the duration and length over which cease-to-flow conditions can occur in Wongawilli Creek during drought periods (HGeo 2022). Flow effects would likely not be discernible from natural variability or from other historical, approved and proposed longwalls (HGeo 2022). Changes in flow in Sandy Creek would also be negligible (HGeo 2022). Therefore, associated impacts to aquatic habitat and biota due to groundwater depressurisation and reductions in surface water availability associated with Longwall, in isolation, are likely also to be negligible and not detectable. The estimated incremental leakage losses from both reservoirs as a result of extraction of Longwall 19A is estimated to be negligible.

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.

#### *4.2.1.2 Changes to Water Quality*

Based on previous observations, it is expected that water quality influence due to the extraction of Longwall 19A 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 2022). Thus, no associated impacts to aquatic habitat and biota area expected in Wongawilli Creek.

### 4.2.2 Drainage Lines

#### *4.2.2.1 Loss of Aquatic Habitat*

Drainage lines directly above Longwall 19A 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 Longwall 19A, with a total of approximately 50 m of first order drainage lines directly above the longwall. 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 ~3,300 m of first / second order drainage line habitat is located within 400 m of the longwalls. This represents a very small proportion of the total watercourse length in the upper Avon and Cordeaux River catchments (< 0.5 %) (**Section 3.10**).

These drainage lines generally support limited aquatic ecology (i.e. consist of generally disconnected pools) and would dry during periods of prolonged drought. 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. 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 Longwall 19A 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. Loss of baseflow due to groundwater depressurisation would likely also occur in WC13, WC13A, WC14, WC17B, SC10, SC10A and SC10B. However, related increases in the number of zero flow days in a natural ephemeral drainage would not be expected to have significant impacts to aquatic habitat and biota.

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.

##### *4.2.2.2 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 the drainage line that crosses the longwall footprint (SC10B) (HGeo 2022). 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. Transient changes could also occur in drainage lines within the 400 boundary, though also would not be expected to result in significant impact to aquatic biota.

### 4.2.3 Key Fish Habitat

Impacts to Type 1 KFH in Wongawilli Creek are not expected as there are no flow controlling rockbars within 400 m that would otherwise be susceptible to fracturing and associated flow diversions.

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.

### 4.2.4 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 Longwall 19A 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 C**).

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 is unlikely.

#### 4.2.5 Cumulative Impacts

Combined baseflow reductions in Wongawilli Creek as a result of mining in the Dendrobium Mine are predicted to be up to 1.4 ML/day (maximum reduction in the short-term) and 0.9 ML/day after 8 years. The cumulative effects on flow 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 44 days (background rate) to 97 days in the short-term. In the long-term, the number of cease-to-flow days would return to the background rate (HGeo 2022). 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 2022). Such impacts would be expected to occur during future comparable drought conditions, and become more noticeable as further longwalls in Area 3C are extracted.

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 3A and 3B longwalls in extreme drought periods, as was experienced from 2018 into early 2020.

# 5 Recommendations

Four approaches would be used to manage potential impacts on aquatic ecology within the Study Area from Longwall 19A:

> 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 Longwall 19A; 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 Trigger Action Response Plans (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 3A on Wongawilli Creek. Two of these (Sites 2 and X4) are located within the Study Area for Longwall 19A and would provide impact data for Longwall 19A. Sites X7 and X8 on Wongawilli Creek upstream of Area 3A and 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. Sites 15 and 16 on Kentish Creek outside the Dendrobium Mine area also provide control data for Area 3A and Area 3B longwalls.

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 Longwall 19A commenced in 2021 and will be undertaken next in 2023 in conjunction with the biennial Area 3B monitoring also being undertaken in 2023. Ongoing monitoring for Longwall 19A would be incorporated into the ongoing monitoring for Area 3A and 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 response 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). Spatial differences and temporal changes, and their interaction, in macroinvertebrate assemblages (multivariate data) sampled using artificial collectors would be examined using PERMANOVA+) and 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 2022); 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 Longwall 19 and 19A Watercourse Impact Monitoring Management and Contingency Plan (South32 2022). 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 of Longwall 19A 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

There are no flow controlling rockbars within 400 m of Longwall 19A that would otherwise be at risk of fracturing following subsidence due to extraction of Longwall 19A. Thus, there is a small risk to Wongawilli Creek associated with extraction of Longwall 19A.

Impacts to aquatic habitat, vegetation, macroinvertebrates or fish in drainage lines in, and adjacent to, Longwall 19A 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 Longwall 19A.

Ongoing monitoring associated with Area 3 longwalls will incorporate monitoring of impacts to aquatic ecology that may occur due to extraction of Longwall 19A. 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 |
| 11 | SC10 | 293240 | 6192222 |
| 12 | SC10 | 293489 | 6192462 |
| 13 | SC10C | 293335 | 6192439 |
| 19 | Wongawilli Creek | 290645 | 6195106 |
| 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 |
|---|---|
| 1. Land use pattern beyond the immediate riparian zone | |
| Undisturbed native vegetation | 4 |
| Mixed native vegetation and pasture/exotics | 3 |
| Mainly pasture, crops or pine plantation | 2 |
| Urban | 1 |
| 2. Width of riparian strip of woody vegetation | |
| More than 30 m | 4 |
| Between 5 and 30 m | 3 |
| Less than 5 m | 2 |
| No woody vegetation | 1 |
| 3. Completeness of riparian strip of woody vegetation | |
| Riparian strip without breaks in vegetation | 4 |
| Breaks at intervals of more than 50 m | 3 |
| Breaks at intervals of 10 - 50 m | 2 |
| Breaks at intervals of less than 10 m | 1 |
| 4. Vegetation of riparian zone within 10 m of channel | |
| Native tree and shrub species | 4 |
| Mixed native and exotic trees and shrubs | 3 |
| Exotic trees and shrubs | 2 |
| Exotic grasses / weeds only | 1 |
| 5. Stream bank structure | |
| Banks fully stabilised by trees, shrubs etc. | 4 |
| Banks firm but held mainly by grass and herbs | 3 |
| Banks loose, partly held by sparse grass etc. | 2 |
| Banks unstable, mainly loose sand or soil | 1 |
| 6. Bank undercutting | |
| None, or restricted by tree roots | 4 |
| Only on curves and at constrictions | 3 |
| Frequent along all parts of stream | 2 |
| Severe, bank collapses common | 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 |

| Descriptor and category | Score |
|---|---|
| 8. Riffle / pool sequence | |
| Frequent alternation of riffles and pools | 4 |
| Long pools with infrequent short riffles | 3 |
| Natural channel without riffle / pool sequence | 2 |
| Artificial channel; no riffle / pool sequence | 1 |
| 9. Retention devices in stream | |
| Many large boulders and/or debris dams | 4 |
| Rocks / logs present; limited damming effect | 3 |
| Rocks / logs present, but unstable, no damming | 2 |
| Stream with few or no rocks / logs | 1 |
| 10. Channel sediment accumulations | |
| Little or no accumulation of loose sediments | 4 |
| Some gravel bars but little sand or silt | 3 |
| Bars of sand and silt common | 2 |
| Braiding by loose sediment | 1 |
| 11. Stream bottom | |
| Mainly clean stones with obvious interstices | 4 |
| Mainly stones with some cover of algae / silt | 3 |
| Bottom heavily silted but stable | 2 |
| Bottom mainly loose and mobile sediment | 1 |
| 12. Stream detritus | |
| Mainly un-silted wood, bark, leaves | 4 |
| Some wood, leaves etc. with much fine detritus | 3 |
| Mainly fine detritus mixed with sediment | 2 |
| Little or no organic detritus | 1 |
| 13. Aquatic vegetation | |
| Little or no macrophyte or algal growth | 4 |
| Substantial algal growth; few macrophytes | 3 |
| Substantial macrophyte growth; little algae | 2 |
| Substantial macrophyte and algal growth | 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

| Catchment: | Wongawilli Creek | | | | | | | | | Sandy Creek | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site: | 1 | 2 | 3 | 4 | 5 | X4 | X5 | X6 | X7 | X8 | 11 | 12 | 13 |
| **RCE Category** | | | | | | | | | | | | | |
| Land use pattern beyond the immediate riparian zone | 4 | 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 | 4 |
| Completeness of riparian strip of woody vegetation | 4 | 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 | 4 |
| Stream bank structure | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Bank undercutting | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 4 |
| Channel form | 3 | 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 | 4 | 4 | 2 |
| Retention devices in stream | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Channel sediment accumulations | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 2 | 2 | 3 | 3 | 4 |
| Stream bottom | 4 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 |
| Stream detritus | 4 | 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 | 3 |
| Total | 48 | 46 | 46 | 46 | 47 | 50 | 50 | 51 | 46 | 47 | 48 | 48 | 48 |

## Assessments of Significance

# APPENDIX

# C

## ASSESSMENTS OF SIGNIFICANCE FOR *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.

***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 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 of flow controlling rockbars resulting in flow diversion is not expected in Wongawilli Creek. Regardless, the section that would be affected does not appear accessible to Macquarie perch. 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.

Macquarie perch are not expected to be able to use sections of Wongawilli Creek or drainage lines within the Study Area 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 or place a viable local population at risk of extinction.

**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 Wongawilli Creek and drainage lines within the Study Area, nor is Macquarie perch expected to occur here. 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 miner. Thus, reductions in the occupancy of this species die 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.

**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 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 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.

**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.