Report to:

BHP Billiton - Illawarra Coal

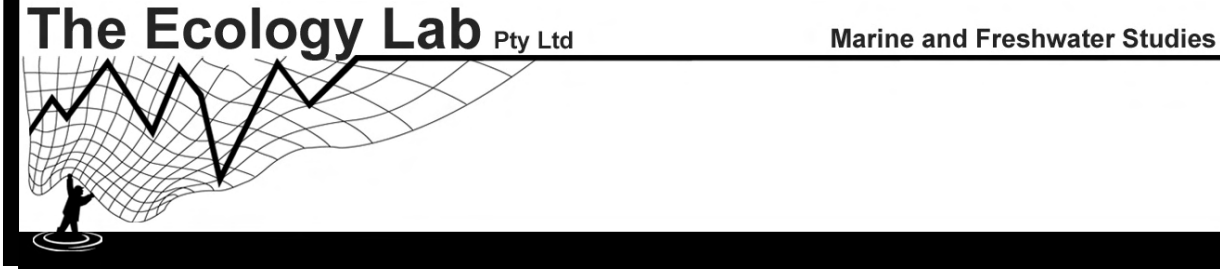
Dendrobium Area 3
Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota

FINAL

October 2007

Report prepared by:

The Ecology Lab Pty Ltd



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Report Prepared for:

BHP Billiton

Illawarra Coal

Environment and Sustainable Development

CRM Administration Building

Old Port Road, Port Kembla

Report Prepared by:

The Ecology Lab Pty Ltd

4 Green Street

Brookvale, NSW, 2100

Phone: (02) 9907 4440

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SUMMARY

Introduction

BHP Billiton Illawarra Coal (BHPBIC) proposes to extend its longwall coal mining operations at Dendrobium Colliery in the Southern Coalfield of New South Wales by extracting coal from the Wongawilli Seam in Area 3. BHPBIC is currently preparing an assessment of potential impacts in Area 3 for;

(a) submission to the Department of Planning to modify the footprint of Dendrobium Mining Area 3, and

(b) submission to the Department of Primary Industries - Mineral Resources for a Subsidence Management Plan approval (SMP) for Longwalls 6 – 10 in Area 3A.

BHPBIC commissioned The Ecology Lab Pty Ltd to undertake literature and field-based investigations of aquatic ecology in Dendrobium Area 3 and assess the potential impacts on aquatic ecology resulting from mine subsidence.

Existing Information

Aquatic ecological studies in watercourses of the Cordeaux and Avon Dam catchments have been undertaken previously in relation to the Dendrobium coal project and mining of longwalls at the nearby Elouera Colliery. The aquatic habitats in Sandy Creek, streams LC6 and LC7 to the east of Dendrobium Area 3, and the Upper Wongawilli Catchment to the south of Dendrobium Area 3 have been described (The Ecology Lab 2005, 2006a, 2006b). A qualitative assessment of aquatic habitats that Macquarie Perch may use for spawning has also been conducted in numerous waterways that flow into Lake Cordeaux (The Ecology Lab 2001a). Water quality data is available for sites in the Sandy, Wongawilli, Native Dog and Donalds Castle Creek catchments. Native Dog and Wongawilli Creeks both have quantitative data to describe the geochemical effects resulting from past mining by the Elouera Colliery. This data shows that water quality impacts have improved over time (Ecoengineers 2007).

No information was identified in relation to aquatic plants in the creek systems flowing into Lake Cordeaux and Lake Avon. Aquatic macroinvertebrate surveys have been conducted in Wongawilli, Native Dog, Donalds Castle, Sandy, Banksia and Cascade Creeks and in several un-named creeks draining into the Cordeaux River. The macroinvertebrate fauna at the sites within Dendrobium Area 3 was generally similar to the AUSRIVAS reference condition, but on some occasions was found to be either significantly impaired or richer than reference condition. The fauna at sites above or in the vicinity of Elouera Colliery was generally in a poorer condition. Fish surveys have been undertaken in Wongawilli, Native Dog, Donalds Castle, Sandy Creeks and Lake Cordeaux and some of its other tributaries. Long-and short-finned eels, Australian smelt, Macquarie Perch, mountain galaxias and goldfish have been caught in Lake Cordeaux and some of its tributaries. Climbing galaxias has also been identified within the mid reaches of Wongawilli Creek.

Four threatened species, Sydney Hawk Dragonfly (*Austrocordulia leonardi*), Adams Emerald Dragonfly *(Archaephya adamsi),* Macquarie Perch (*Macquaria australasica*) and Australian grayling (*Prototroctes maraena*) could potentially occur in the study area. Macquarie Perch is the only threatened species that has been recorded in the area, having been identified in Wongawilli Creek, the lower arm of Sandy Creek and Lake Cordeaux. The only tributaries draining to Lake Cordeaux from the proposed

Dendrobium Area 3 maximum footprint that contain "moderate" or "significant" aquatic habitat suitable for Macquarie Perch also have large waterfalls and rock-bar cascades which are potential barriers to the upstream passage of this species. Recent observations indicate that Macquarie Perch may be able to migrate upstream of these barriers under extreme high-flow conditions. There is consequently a possibility that this species may be able to access the entire reach of Wongawilli Creek that overlies all three sub areas of Dendrobium Area 3. Suitable spawning areas for this species have also been identified within Wongawilli Creek, including within the General SMP Area of Area 3A. Potential habitat for the Sydney Hawk and Adams Emerald dragonflies exists within Wongawilli and Sandy Creeks. The Australian grayling is a migratory species and is unlikely to occur in the study area, because of the lack of provision for fish passage in the upper Nepean System.

Assessment of Aquatic Habitats

A qualitative assessment of the aquatic habitats within the Wongawilli, Donalds Castle and Native Dog Creek catchments overlying Dendrobium Area 3 was undertaken between 16 and 20 July 2007. For the purposes of this assessment, Wongawilli Creek, the major watercourse, was sub-divided into 4 zones (Figure 1). The assessment of aquatic habitats in Sandy Creek is based on the ongoing monitoring undertaken in relation to Dendrobium Area 2.

Zone 1, which is located within and downstream of the maximum footprint for mining area 3C, includes the main channel of Wongawilli Creek between its confluence with the Cordeaux River and the rock bar (WC-RB 23) at Site No. 30 and tributaries WC25 – WC31. The main creek channel is characterized by large deep pools separated by sandstone rock bars and a substratum composed of either sandstone bedrock or a mixture of sand, with significant areas of bedrock and boulders. There are also some small areas of gravel beds in the upstream sections of some pools. The channel contains numerous instream habitat features and a diverse range of aquatic habitats and is therefore considered to be significant aquatic habitat. The main channel contains three significant barriers to fish passage: a 15 m high rockbar-waterfall (WC-RB 1) just upstream of its confluence with the Cordeaux River and two smaller rockbars upstream of Fire Road 6 (WC-RB 11 & 12). The lower reaches of tributaries WC25-WC27 and WC31 contain "minimal" aquatic habitat, but the other tributaries are considered "unlikely" aquatic habitat.

Zone 2 is located within the maximum footprint for mining areas 3A, 3B and 3C and includes the reach of Wongawilli Creek extending from the rock bar (WC RB 23)at Site No. 30 upstream to the inflow of tributary WC15. The main creek channel is characterised by a series of long pools separated by small sandstone rock bars, sandbars, debris accumulations and small boulder fields. The substratum consisted of large areas of sand deposits, with a smaller proportion of boulders, cobbles, pebbles and gravel. The channel contains numerous instream habitat features and a diverse range of aquatic habitats and is therefore considered to be significant aquatic habitat. There are no significant barriers to fish passage present within the main channel, hence this reach may provide potential habitat for Macquarie Perch if they can negotiate the barriers downstream in Zone 1. Tributary WC21 is characterised by a moderate-sized, permanent pool at the base of a large sandstone cascade and is considered "moderate" aquatic habitat. The cascade consists of a series of sandstone steps up to 4 m high and has a total change in elevation of 20 m over a horizontal distance of 70 m making it an effective barrier to passage of Macquarie Perch upstream within this tributary. The lower reaches of tributaries WC17, WC20, WC23 and WC24

contain "minimal" aquatic habitat, while the remaining tributaries are considered "unlikely" aquatic habitat.

Zone 3 is located within the maximum footprint for mining areas 3A and 3B and includes the reach of Wongawilli Creek extending from its confluence with tributary WC15 upstream to a large waterfall at Site No. 4 (WC RB 36). The main channel of the creek is characterised by extensive reaches of relatively long, narrow, shallow pools separated by riffle sections, consisting of boulder fields and gravel-pebble beds, sandbars and small areas of bedrock. The channel contains numerous instream habitat features and a diverse range of aquatic habitats and is therefore considered to be significant aquatic habitat. There are no significant barriers to fish passage within the main channel, hence this reach may provide potential habitat for Macquarie Perch if they can negotiate the barriers downstream in Zone 1. The waterfall at Site No. 4 is 25 m high and has a single vertical drop that would prevent passage of Macquarie Perch upstream into Zone 4, but may be negotiable by galaxid fish and freshwater eels. Tributaries WC15 and WC10 contain "moderate" aquatic habitat. WC15 flows out of Swamp 14 and is characterised by a series of permanent pools amongst sandstone boulders and small waterfalls, which would be an effective barrier to upstream passage of Macquarie Perch. WC10 has a well defined channel with a substratum of gravel, pebbles and cobbles and there are likely to be permanent pools upstream that would provide habitat for some fish and aquatic invertebrates. The lower reaches of WC8, WC11, WC12, WC13 and WC14 contain "minimal" aquatic habitat. The other tributaries in this zone are considered as "unlikely" aquatic habitat.

Zone 4 includes the main channel of Wongawilli Creek extending upstream from the waterfall at Site No. 4 (WC RB 36) to the upper reaches of Wongawilli Creek and tributaries WC1-WC6. Only the most downstream 400 m reach of the creek and tributary WC6 falls within the maximum footprint for the mining area. The main channel of the creek is characterised by relatively small, shallow pools separated by retaining sandstone rockbars containing small steps. The substratum of the creek is composed of sandstone bedrock in areas where water flowed over the retaining rock bars, but in the pools is dominated by sand, but with significant areas of bedrock and boulder. The main channel of the creek between the waterfall and its confluence with WC2 contain "significant" aquatic habitat, whereas that further upstream is considered to be "moderate" aquatic habitat. The steps associated with the sandstone rockbars could be potential barriers to fish passage for some species; but not for freshwater eels or galaxids. Tributaries WC4 and WC5 contained small permanent pools in their lower reaches and are therefore categorized as "moderate" aquatic habitat. Tributaries WC6 and WC3, were inspected, and are considered to be "unlikely" aquatic habitat.

Sandy Creek is located on the south-eastern corner of the proposed maximum footprint for Dendrobium Area 3A. The mid to lower reach of this creek (upstream of the waterfall) and its tributaries, Banksia Creek and Cascade Creek, lie within the General SMP Area for Dendrobium Area 3A. The reach of Sandy Creek near the Fire Road 6C crossing is characterised by a series of long shallow pools, short deep pools and alternating short riffles. Approximately 100 m below the crossing there is a 25 m high waterfall which constitutes a substantial barrier to fish passage into Sandy Creek from Lake Cordeaux and an absolute barrier to the passage of Macquarie Perch into the General SMP Area of Area 3A. The creek bed below the waterfall is characterised by a moderate slope with large boulders and sandbars to the high water mark of the dam. The reach of Sandy Creek between its confluences with Banksia and Cascade Creeks is characterised by alternating riffles with sand and gravel bars and moderate size pools. Sandy Creek has extensive and diverse

aquatic habitat in the mid to lower reaches and is therefore considered as "significant" aquatic habitat. The flow further upstream in the main channel of Sandy Creek is greatly reduced and while there are still some small permanent pools, this reach contains only "moderate" aquatic habitat.

The entire catchment of Banksia Creek, which joins Sandy Creek approximately 50 metres upstream of the Fire Road 6C, lies within the General SMP Area for Area 3A. The reach of the creek downstream of Swamp15A is characterised by long, permanent pools separated by small sandstone rockbars with short drops (< 2 m) and is considered to be "moderate" aquatic habitat. The creek bed consists of a mixture of bedrock, boulder, sand and detritus. The catchment of Cascade Creek, which joins Sandy Creek approximately 700 m upstream of the Fire Road 6C crossing, is located partially within the General SMP Area for Area 3A. The substratum of the creek consists of sandstone bedrock with some sand and gravel bars. Approximately 200 m upstream of its confluence with Sandy Creek there is a series of cascades over bedrock with a boulder filled pool at the base. The reach of Cascade Creek within the General SMP Area is considered to be "moderate" aquatic habitat.

The upper catchment of Donalds Castle Creek lies within the north-western section of the Dendrobium Area 3 proposed maximum footprint. Tributaries DC1 and DC2 also lie within the proposed footprint, as does approximately 2.25 km of the upper reach of Donalds Castle Creek. The main channel of this reach of Donalds Castle Creek consists of a series of relatively small, permanent pools with a mainly sand substratum that are connected by narrow channels with a mainly sand substratum , small sections of gravel riffles and sandstone rockbars with small cascades (≤ 1m high). The reach of Donalds Castle Creek upstream as far as Swamp 5 is considered "moderate" aquatic habitat.

Native Dog Creek lies to the south-west of the maximum proposed footprint for Dendrobium Area 3, but a small tributary, ND9, lies within the footprint. This watercourse contains very limited aquatic habitat apart from some small, semi-permanent pools and is thus considered to be "minimal" aquatic habitat.

Tributaries CR1 and CR2 flow into the Cordeaux River downstream of the dam wall from within the northern section of the maximum proposed footprint of Dendrobium Area 3. The reach of CR1 to the north of the footprint contains "minimal" aquatic habitat, whereas CR2 just downstream of the footprint contains "moderate" aquatic habitat in its lower reach.

Ten small to moderate size watercourses, LC1-LC10, that flow into Lake Cordeaux lie within the north-east of the maximum proposed footprint for Dendrobium Area 3. The two largest (LC6 and LC7) contain small pools in their lower reaches that may persist through extended dry periods and hence are considered to contain limited "moderate" aquatic habitat. The other watercourses have small steep drainage lines and are therefore likely to contain either "minimal" or "unlikely" aquatic habitat.

Five small watercourses (LA2 – LA6) that flow to the Native Dog Creek arm of Lake Avon lie within the south-west of the maximum proposed footprint for Dendrobium Area 3. These watercourses also have small steep drainage lines and are therefore unlikely to have aquatic habitat.

Assessment of Subsidence-Induced Impacts

The assessment of potential impacts of longwall mining on aquatic habitat and biota is based on predictions of mine subsidence provided by Mine Subsidence Engineering Consultants (MSEC 2007) and of impacts on water quality within surface watercourses provided by Ecoengineers (2007).

Ground movements associated with longwall mining can impact on availability of aquatic habitats by changing levels of ponding, flooding and scouring of banks along watercourses and altering surface water flows through fracturing of river and streams beds.

The subsidence predictions indicate that significant increases in the levels of ponding, flooding or scouring of banks are unlikely to occur in the reaches of Wongawilli Creek and Sandy Creek within the Study Area. Localised increases in ponding or flooding may occur in areas where maximum predicted changes in slope of the ground coincide with existing pools, steps or cascades along these watercourses. Changes of this type could lead to localised increases in the availability of aquatic habitat. The predictions also indicate that there is unlikely to be any significant fracturing of sandstone bedrock or surface water diversions within these creeks. The extraction of longwalls could, however, cause localised, minor fracturing of bedrock within Wongawilli and Sandy Creeks which may extend up to 400 m away from the longwalls. This fracturing is not expected to cause any significant diversion of surface flows, but could cause minor, localised reductions in the availability of aquatic habitat. Predictions about potential impacts in the reaches of Donalds Castle Creek which flow through Areas 3B and 3C are likely to be similar to those for Area 3A (MSEC 2007).

The ephemeral drainage lines located across the Study Area are expected to experience a variety of systematic subsidence and valley-related movements when the longwalls are extracted. Levels of ponding, flooding and scouring are not expected to change significantly along tributary WC 17 (Drainage Line 1), but there may be increased ponding and flooding adjacent to longwall tailgates and increased scouring adjacent to longwall maingates along Banksia Creek (Drainage Line 2). These changes would lead to a temporary increase in the availability of aquatic habitat adjacent to the longwall tailgates and a transient reduction in quality of aquatic habitat in the vicinity of the longwall maingates due to increased turbidity. Cracking of bedrock is also expected to occur along the drainage lines, with that along the lower reaches resulting in some diversion of surface flows into underlying strata and drainage of pools. Changes of this type will cause a localised reduction in the availability of aquatic habitats, which are already ephemeral in nature.

The extraction of the proposed and future longwalls is not expected to have any significant systematic subsidence impacts in Lakes Avon or Cordeaux, however, there is a possibility that it will cause localised, minor cracking in the lake bed. This is unlikely to result in any loss of water or changes in the availability of aquatic habitat.

The fracturing of bedrock and diversion of sub-surface flows into pools can lead to weathering and leaching of minerals which, in turn, can have a localised impact on the quality of water in rivers and creeks, particularly during low flow conditions. The deposition of sediments mobilised by subsidence-induced erosion events may cause a short-term increase in turbidity levels within watercourses. Ecoengineers have concluded that mining of Area 3 is unlikely to have significant geochemical effects on Wongawilli, Sandy or Donalds Castle Creeks. Minor fracturing could lead to changes in water quality in Banksia Creek in the vicinity of Longwall maingate 10 and tailgate 9, in the longer, incised, high gradient tributaries of Wongawilli Creek in Areas 3B and 3C and in creeks LC6 and LC7 in Area 3C. Mining could also lead to the development of ferruginous springs on the slopes of the south-west draining catchments over Area 3B. Minor erosion may occur on the steep slopes along the main channel and tributaries of Wongawilli Creek in Area 3A, on the steep slopes draining the western side of Area 3B to the Native Dog Creek Arm of Lake Avon and on the eastern side of Area 3C draining to Lake Cordeaux. These events are expected to

have only minor, localised, short-term impacts on the lower sections of creeks and shorelines of Lakes Cordeaux and Avon.

Any sudden drainage of pools and rapid drops in surface flow due to subsidence are likely to have localised impacts on aquatic biota, particularly if they are left stranded in air or unable to move to areas that are damp or submerged. The survival of mobile organisms is difficult to predict, because it depends on their tolerance and response to desiccation and rapid changes in water level, ability to move, weather conditions, the underlying substratum and duration of exposure. The specific assessments of impacts undertaken for Macquarie Perch, Sydney Hawk Dragonfly and Adams Emerald Dragonfly indicate that the proposed longwall mining does not pose a significant threat, provided that the future longwall layouts for Areas 3B and 3C are offset from the main channel of Wongawilli Creek in a similar manner to that proposed in Area 3A.

Aquatic Monitoring Plan

A comprehensive, phased monitoring plan has been designed to assess the potential impacts of mine subsidence on aquatic habitat and biota within the watercourses overlying Dendrobium Area 3. The plan recommends that baseline sampling be undertaken in impact and control locations four times within the 12 month period prior to the commencement of mining within each Area and be repeated during and after extraction to determine the extent and nature of any impacts and recovery should these occur. It is recommended that monitoring be limited to watercourses rated as containing "significant" and "moderate" aquatic habitats. Potential sampling locations have been identified within Zones 1-4 Wongawilli Creek, Donalds Castle Creek, tributaries LC 4 and LC7 of Lake Cordeaux and tributary CR3 of the Cordeaux River. Monitoring should also be continued at the locations within the main channel of Sandy Creek, Banksia Creek and Cascade Creek that are currently being used to assess impacts in Dendrobium Area 2. Potential control locations have been identified within the catchments of Loddon Creek (Cataract River Catchment) and O'Hares Creek (Georges River Catchment). At each location, habitat features and water quality should be assessed, the abundance and distribution of aquatic macrophytes should be recorded and samples of fish and macroinvertebrates should be collected using standardized procedures. Larvae of the dragonfly genera *Austrocorduliidae* or *Gomphomacromiidae* should be identified to genus and species level to determine whether the threatened Adams Emerald Dragonfly and Sydney Hawk Dragonfly occur within the study area.

It is also recommended that an intensive fish survey be undertaken along the full reach of Wongawilli Creek from the confluence of the Cordeaux River upstream to the large waterfall during spring 2007. The aim of this survey is to determine whether Macquarie Perch are able to access and utilise aquatic habitat within the proposed Area 3 footprint for spawning.

Management Measures

The detection of primary impacts, such as rockbar fractures resulting in water loss in a pool within an area of 'significant' or 'moderate' aquatic habitat or significant changes in water chemistry within such areas, would trigger investigations into potential impacts on aquatic ecology. Observations of fish/crayfish kills or die-off of macrophyte beds would trigger a rapid response aquatic monitoring plan to determine the nature and extent of secondary impacts on aquatic ecology. The level of impact found would determine the type of response. It could, for example, include rehabilitation of aquatic habitat being undertaken in conjunction with mitigative works, such as grouting, followed by monitoring to assess

recovery. Significant changes in aquatic biota detected 'during mining' monitoring events would also provide triggers for further investigation.

Conclusions

There is "significant" aquatic habitat along the main channel of Wongawilli Creek and in the mid to lower reaches of Sandy Creek and "moderate" aquatic habitat in some of the tributaries of Wongawilli Creek, the upper reaches of Sandy Creek, some of the reaches of Banksia, Cascade and Donalds Castle Creek and lower reach of tributary CR2. The other tributaries generally have either "minimal" or "unlikely" aquatic habitat. Minor fracturing is expected to occur along the reaches of Wongawilli and Sandy Creeks within Area 3 but it is unlikely that there would be significant diversion of flow or pool water loss. Some fracturing is likely to occur along the ephemeral drainage lines overlying Area 3 (i.e. WC 17 and Banksia Creek) and there may be some surface water flow diversion associated with this fracturing within these ephemeral streams.

Where this fracturing leads to sudden drainage of pools and rapid drops in surface water flow it is likely that there will be a localised impact on aquatic habitats and their biota. Fracturing of bedrock and diversion of surface flows can also lead to geochemical changes in water quality, due to the weathering and leaching of minerals. There are unlikely to be significant geochemical changes within Wongawilli, Sandy or Donalds Castle Creeks, but changes may occur in Banksia Creek, some of the tributaries of Wongawilli Creek and in creeks LC6 and LC7. These changes could have a minor, localised impact on the biota, but these will not persist during normal flow periods associated with rainfall within the catchment. Subsidence may cause minor erosion on the steep slopes along the main channel of Wongawilli Creek and some of the other tributaries. These erosion events may result in minor, localised, short-term increases in turbidity within some watercourses, which, in turn, may have a localised, short-term impact on aquatic biota. The specific assessments of impacts undertaken for Macquarie Perch, Sydney hawk dragonfly and Adams emerald dragonfly indicate that the proposed longwall mining does not pose a significant threat to these species, provided that longwall layouts are offset from the main channel of Wongawilli Creek.

1.0 INTRODUCTION

BHP Billiton Illawarra Coal (BHPBIC) proposes to extend its underground coal mining operations at Dendrobium Colliery in the Southern Coalfield of New South Wales by extracting coal from the Wongawilli Seam in Area 3 using longwall mining techniques.

BHPBIC is currently preparing an assessment of potential impacts for submission to the Department of Planning, NSW (DoP) for all of Area 3 and a Subsidence Management Plan (SMP) for Longwalls 6 – 10 in Area 3A for submission to the NSW Department of Primary Industries - Mineral Resources (DPI), as part of the approval processes required prior to the commencement of mining. BHPBIC commissioned The Ecology Lab Pty Ltd to undertake preliminary investigations of aquatic ecology in Dendrobium Area 3, so that potential impacts on aquatic ecology resulting from mine subsidence could be assessed. The specific aims of these investigations were to provide:

- An overview of aquatic ecological features within the proposed "Maximum Footprint" of the mining area;
- Descriptions of sensitive aquatic features within the Maximum Footprint;
- An investigation of the range and habitat of the listed threatened species "Macquarie Perch" within Wongawilli Creek and other watercourses;
- A comprehensive map of aquatic habitat within Wongawilli Creek and Sandy Creek;
- A comprehensive aquatic monitoring plan for Dendrobium Area 3 and the results of initial investigations.
- An assessment of potential impacts on the aquatic ecology for submission to DoP and specific detailed assessment of impacts and management plan for Area 3A suitable for incorporation into a SMP.
- A comprehensive monitoring plan suitable for the assessment of potential mine subsidence impacts, including: Selection of sampling sites for ongoing monitoring within the Maximum Footprint and preliminary consideration of monitoring reference locations.

2.0 EXISTING INFORMATION ON AQUATIC ECOLOGY

Studies of aquatic habitats, water quality and/or biota in surface watercourses of the Cordeaux and/or Avon Dam catchments have been undertaken in relation to the Dendrobium coal project (The Ecology Lab 2001) and mining of longwalls at Elouera Colliery (Ecoengineers 2003, 2004a and b, 2006a and b, 2007; MPR 2002, 2003a and b, 2004, 2005, 2006a, b and c; The Ecology Lab 2005; 2006a and b). The components examined and the various locations at which these studies were conducted are summarised in Table 1.

2.1 Physical Setting

Dendrobium Area 3 is situated to the west of Lake Cordeaux and to the east of Lake Avon and encompasses part of the Sydney Catchment Authority's Special Area (Cardno Forbes Rigby 2007). There are a number of water courses on the surface of the application area, with Wongawilli Creek flowing from north to south through the centre and several smaller creeks, including Sandy Creek and Donalds Castle Creek, flowing across the area. Several unnamed tributaries also feed into Wongawilli Creek from both sides of the creek valley. Wongawilli Creek and Donalds Castle Creek both drain into the Cordeaux River, whereas Sandy Creek flows directly into Lake Cordeaux. Drainage to the west of the western ridge line flows into Lake Avon, while the eastern ridge line flows into Lake Cordeaux.

2.2 Aquatic Habitats

Studies on aquatic habitats have focused on Sandy Creek and streams 12 (now called LC6) and 13 (LC7) to the east of Dendrobium Area 3, the waterways that flow into Arms 1, 2 and 3 of Lake Cordeaux and watercourses in the vicinity of Longwalls 14 and 17 of Delta Colliery in the Upper Wongawilli Catchment to the south of Dendrobium Area 3 (Table 1).

Sandy Creek and streams LC6 and LC7 have similar morphologies, flow rates, riparian vegetation and waterfalls at their mouths which form a barrier to the passage of fish to and from Lake Cordeaux (The Ecology Lab 2001a). The aquatic habitat above the waterfalls consists of long shallow pools and alternating short riffles over a sandstone bedrock, whereas that at the base of the waterfalls comprises coarse sand and large sandstone boulders, with rock pools also being present in Sandy Creek and LC7. The streams contain detritus in the form of accumulations of wood, bark and leaves, but no instream vegetation. The riparian vegetation consists of eucalypts and callistemon above the waterfalls and a continuous stand of casuarinas and eucalypts below the falls. Qualitative assessments based on the Riparian, Channel and Environmental Inventory (RCE) (Chessman *et al.* 1997) indicated limited physical disruption, excellent aquatic habitat, but limited fish passage.

Qualitative assessments of aquatic habitats that Macquarie Perch may use for spawning have been undertaken in 47 waterways that flow into Arms 1, 2 and 3 of Lake Cordeaux in order to assess the use of the Cordeaux catchment by Macquarie Perch from a regional perspective (The Ecology Lab 2001b). The presence of riffles, runs and pools, gravel beds and barriers to fish passage, steepness and permanence of the watercourse, size and setting of the surrounding catchment and size fraction of material within the stream bed of each waterway were noted. Suitable spawning habitats were identified in the headwaters of Cordeaux Creek and in Little Wattle Tree and Wattle Tree Creeks in Arms 1 and 2 and in Kembla, Kentish and Wattalli Creeks and the headwaters of Goondarrin Creek in Arm 3.

The Ecology Lab (2005) found only one watercourse in the vicinity of Longwall 14, an upper reach of the Cordeaux River located in a gully directly above the southern-most corner of the longwall. The aquatic habitat consisted of a small creek with small pools of clear water up to about one metre wide. The pools within the creek were separated by rocky barriers that would probably prevent the passage of fishes, other than possibly climbing galaxids, between the study area and Cordeaux Reservoir. There were no riffles or any other observable creek flow. The small size of the pools suggests that the study area is unlikely to be occupied by any fish species, but may be suitable as habitat for freshwater crayfish (*Euastacus* sp.), although no individuals or burrows were observed. The creek was surrounded by a dense understorey of native plant species, including king ferns (*Todea barbara*) and saw-sedge (*Gahnia* sp.) Above the gully there were areas of heathland containing a few small puddles, but insufficient aquatic habitat for species other than freshwater crayfish (*Euastacus* sp.).

The Ecology Lab (2006a) did not find any aquatic habitat directly above Longwall 17, but observed a pool of clear water about 20 m long, 1-4 m wide and up to 1.5 m deep at the bottom of the area of heathland or upland swamp which extended about 100 m west of the southern corner of the longwall. The substratum of the pool was composed of sand and silt and the banks were well vegetated with native plant species. Below this there was a creek with small pools linked by riffle sections that flowed over a bedrock base until coming to a waterfall about 300 m downstream. There was another pool about 400 m downstream of the waterfall and approximately 250 m southwest of the western corner of Longwall 17. The slope between the creek immediately below the waterfall and the land above the proposed longwall was relatively steep. The substratum of the downstream section of the creek was composed of bedrock, boulders, cobble stones and sand. There was also a heathland or upland swamp directly above the northwest end of Longwall 17.

2.3 Water Quality

Studies on water quality have focused on sites in the Wongawilli, Native Dog and Donalds Castle Creek catchments (Table 1).

Routine *in situ* measurements of dissolved oxygen (DO), electrical conductivity (EC), oxidation reduction potential (ORP) and pH have been taken at sites in Native Dog Creek and Lake Avon and of pH and EC at sites in Wongawilli Creek and Donalds Castle Creek. A wide range of additional chemical parameters, including calcium, magnesium, sodium, potassium, total alkalinity, sulphate, chloride and fluoride ions, heavy metals (e.g. iron, aluminium , manganese, arsenic, copper, etc.), and various nitrogenous compounds (e.g. ammonia, nitrate and nitrite, total oxidized nitrogen), dissolved organic carbon and chemical oxygen demand have also been measured in the laboratory (Ecoengineers 2003, 2004 a and b, 2006 and 2007).

The quality of water at sites in Native Dog Creek affected by the mining of Longwalls 5-7 has improved since the upsidence-related geochemical event in autumn 2003. There is no evidence of any geochemical effects resulting from the mining of Longwalls 9 and 10 or that the upsidence in Native Dog Creek has affected the quality of water in the nearest arm of the Avon Dam (Ecoengineers 2007). During significant rainfall and stream flow, natural amelioration of sites geochemically affected by longwall mining occurs over a time-scale of less than ten and possibly less than five years (Ecoengineers 2007).

The quality of water in drainages flowing from swamps in the vicinity of Longwalls 14 and 17 (e.g. DAQ30 and DAQ40) has also been compared with that at sites in Wongawilli Creek

downstream of the longwalls (e.g. WWU3, WWU4 and WWL2) (Ecoengineers 2007). The mining of Longwall 14 had no detectable effects on any of the water quality parameters measured. During the extraction of Longwall 17, a reduction in pH and increases in filterable metals were recorded at site WWU3 and minor reductions in pH and small increases in some filterable metals were noted at DAQ30 and the downstream Wongawilli Creek site WWU4. These potentially ecotoxic changes in water quality may be a result of mine subsidence. There were no notable changes in water quality at Site DAQ40. The water quality parameters at the site furthest downstream in Wongawilli Creek (WWL2) were comparable with those at baseline sites. This suggests that the mining of Longwall 17 did not have any adverse effects on downstream water quality for aquatic biota or raw water harvesting within the catchment.

Ecoengineers (2006a) also noted that the water at most of the upstream and reference sites had relatively low pH levels and high dissolved aluminium levels. These attributes are potentially ecotoxic to a wide range of aquatic species, particularly benthic macroinvertebrates, juvenile amphibians and fish which have not evolved adaptations to such conditions. This implies that the diversity and abundance of aquatic species at these sites may be limited by the prevailing natural water chemistry.

2.4 Aquatic Plants

No literature could be located in relation to aquatic plants in the creek systems flowing into Lake Cordeaux and Lake Avon.

2.5 Aquatic Macroinvertebrates

Surveys of aquatic macroinvertebrates associated with the edge habitat have been conducted in Wongawilli, Native Dog, Donalds Castle, Sandy, Banksia and Cascade Creeks and several un-named creeks draining into the Cordeaux River (Table 1). Notes on the occurrence of conspicuous invertebrates, such as water striders, freshwater shrimp and crayfish, have also been made during assessments of aquatic habitats (The Ecology Lab 2005 and 2006a) and fish surveys (Growns and Gehrke 2001).

Biannual surveys of aquatic macroinvertebrates in Wongawilli, Native Dog and Donalds Castle Creeks and several un-named creeks draining into the Cordeaux River were undertaken between spring 2002 and autumn 2006 as part of the Integrated Environmental Monitoring Program for Elouera Colliery (MPR 2002, 2003a and b, 2004, 2005, 2006a, b and c). These studies indicate that the fauna consisted primarily of insect taxa, but also included crustaceans, molluscs, worms, arachnids and sponges. Total number of taxa collected per survey at the study sites varied from 5 to 37. Three sites in the upper section of Wongawilli Creek above Elouera Mine, two sites in Native Dog Creek and at on a tributary thereof had the least diverse fauna. Two sites situated at a relatively low elevation in Wongawilli Creek above Dendrobium Area 3 had the most diverse assemblages. Ecowise Environmental (2005)'s study of aquatic macroinvertebrates at 75 sites within the SCA's 27 sub-catchments indicated that a site in Wongawilli Creek near Fire Trail 6A had one of the most diverse assemblages, with 33 taxa being collected.

The data collected by MPR has recently been re-analysed using the AUSRIVAS predictive modelling software (The Ecology Lab 2007). The condition of the fauna at a site on Wongawilli Creek near Fire Trail 6A (Ecowise Environmental 2005) and at sites in the upper and lower part of Sandy Creek and two of its tributaries, Banksia and Cascade Creeks, has

also been assessed using these models (The Ecology Lab 2006b). The condition of the macroinvertebrate fauna at sites in Wongawilli and Native Dog Creeks situated above or close to the Elouera Colliery varied, with some being generally classed as either equivalent to reference condition, significantly impaired or severely impaired, whereas others varied between equivalent to reference condition and severely impaired (Table 2). The condition of the fauna at the sites within Dendrobium Area 3 and in Wongawilli Creek near Fire Trail 6A, in contrast, was generally similar to the AUSRIVAS reference condition (The Ecology Lab 2007). The fauna at the sites in Banksia Creek was classified as significantly impaired on both sampling occasions, whereas the sites in its tributaries were either equivalent to reference condition or significantly impaired (The Ecology Lab 2006b)..

Freshwater crayfish(*Euastacus* sp.) have been caught in Cordeaux Dam (Growns and Gehrke 2001) and the upper and lower part of Sandy Creek (i.e. below and above its confluence with Waratah Creek) (The Ecology Lab 2006b). Freshwater crayfish have also been observed in a pool downstream of the waterfall near the western corner of Longwall 17, Elouera Colliery (The Ecology Lab 2006a). Suitable habitat for these animals has been found above the southern-most corner of Longwall 14 (The Ecology Lab 2005) and to the west of the southern corner of Longwall 17 (The Ecology Lab 2006a). Freshwater shrimp have also been caught in Cordeaux Dam (Growns and Gehrke 2001).

2.6 Fish

General fish surveys have been conducted in Lake Cordeaux and its tributary creeks, the upper, mid and lower reaches of Wongawilli Creek and in Donalds Castle and Native Dog Creeks (Table 1). The species that have been recorded in each of these systems are listed in Table 3.

The initial survey of Lake Cordeaux, undertaken in 1994 using gill nets and electro-fishing, indicated that three native fish species, long-finned eel (*Anguilla reinhardtii*), Australian smelt (*Retropinna semoni*) and Macquarie Perch (*Macquaria australasica*) and one alien species, the goldfish (*Carassius auratus*) were present (Gehrke and Harris 1996). During the second survey, numerous smelt, modest numbers of goldfish, long-finned eels, mountain galaxids (*Galaxias olidus*) and short-finned eels (*Anguilla australis*) and a single Macquarie Perch were caught (Growns & Gehrke 2001). During the third survey, undertaken when Macquarie Perch are known to migrate from reservoirs to spawning habitats in creeks, four specimens were caught in Lake Cordeaux, but none were found in the creeks entering the lake, despite the presence of habitats suitable for spawning in Goondarrin and Kembla Creeks (Creese and Hartley 2003). NSW Fisheries (2002) suggested that the low storage level of the dam at the time of sampling may have prevented Macquarie Perch from accessing these spawning areas.

A subsequent targeted survey of Goondarrin and Kembla Creek indicated that long and short-finned eel, mountain galaxias, Australian smelt and goldfish were present, but no Macquarie Perch (The Ecology Lab 2004). A similar survey undertaken in October 2006 as part of the Dendrobium Area 1 and Area 2 investigations, revealed two Macquarie perch in the Cordeaux River arm and eight individuals in the Sandy Creek arm of Lake Cordeaux, all of which appeared to be displaying spawning behaviour. Macquarie Perch have also been positively identified on a number of occasions within Wongawilli Creek, in pools just upstream and downstream of Firetrail 6A (Andrew Bruce (NSW DPI fisheries), pers. com. The Ecology Lab, 2001; MPR, 2006b; The Ecology Lab, pers. obs. 2005). Suitable habitat for Macquarie Perch has also been identified upstream of two large barriers on Wongawilli

Creek, but no specimens have been found despite extensive sampling efforts (The Ecology Lab, 2001). A qualitative assessment of potential spawning habitat for this species has also been made of 47 waterways flowing into Arms 1, 2 and 3 of Lake Cordeaux (The Ecology Lab 2001b).

Bi-annual surveys undertaken for Elouera Colliery Longwalls 7-10 between 2002 and 2006 indicated that Australian smelt, long-finned eel, Macquarie Perch and another native species mountain galaxias (*Galaxias olidus*) were present in the mid to lower reaches of Wongawilli Creek (MPR 2002, 2003a and b, 2004, 2005, 2006a, b and c). Australian smelt and mountain galaxias were also caught in Donalds Castle Creek, but no fish were found in the upper reaches of Wongawilli Creek, any section of Native Dog Creek or at sites within the mine area. Mountain galaxias have also been caught in the upper and lower section of Sandy Creek (The Ecology Lab 2006b). Another native species, climbing galaxias (*Galaxias brevipinna*), has also been identified within the mid reaches of Wongawilli Creek (The Ecology Lab 2001).

2.7 Threatened Species/Populations and Ecological Communities

Threatened native fish and aquatic invertebrate species, populations and ecological communities are protected by the NSW Threatened Species Conservation Act 1995 (TSC Act), NSW Fisheries Management Act 1994 (FM Act) and Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Threatened aquatic species, populations and ecological communities that occur or could potentially occur within the Study Area were identified by reviewing the current listings on the appropriate websites (NSW DPI/Fisheries 2007) and searching the BIONET and EPBC databases. These searches indicated that four listed aquatic species: Macquarie Perch (*Macquaria australasica*), Sydney Hawk Dragonfly (*Austrocordulia leonardi*), Adams Emerald Dragonfly *(Archaephya adamsi)*, and Australian grayling (*Prototroctes maraena*) could potentially occur in the study area. Existing information on the occurrence and ecology of each of these species is summarized and conclusions about their likely occurrence in the study area are provided below. No threatened populations or ecological communities are known to occur within the Study Area.

2.7.1 Macquarie Perch

Macquarie Perch is listed as a vulnerable species under both the FM Act and TSC Act and as an endangered species under the EPBC Act. This species occurs in both lake and river habitats, particularly the upper reaches of rivers and their tributaries (NSW DPI 2005). It is endemic to the southern tributaries of the Murray-Darling River System, and is also found in the Hawkesbury-Nepean and Shoalhaven River systems in the eastern coastal drainages of New South Wales (NSW DPI Fisheries Scientific Committee 2006). There are also some records of the Murray-Darling variety having been stocked in some of the impoundments of the Neapean River system. Genetic research currently underway at Macquarie University indicates that individual Macquarie Perch sampled from Lake Cordeaux and Wongawilli Creek are of the eastern variety, and are not the Murray-Darling variety generally associated with stocking in the eastern impoundments (Leanne Faulks pers comm.).

Macquarie Perch are known to occur within Lake Cordeaux (Gehrke and Harris 1996; Grown and Gehrke 2001; Creese and Hartley 2003; The Ecology Lab 2006b). Sandy Creek, LC6 and LC7 are the only tributaries draining to Lake Cordeaux from the proposed maximum footprint that contain "moderate" or "significant" aquatic habitat (Section 3.1.1)

that could be potential habitat for Macquarie Perch. As these creeks have impenetrable barriers to fish passage in the form of large waterfalls, the watercourses draining to Lake Cordeaux from Dendrobium Area 3 (Sandy Creek, LC1 – LC8) are not accessible to Macquarie Perch. Eight Macquarie Perch were found at the extent of the current supply level within the Sandy Creek arm of Lake Cordeaux. It is likely that these individuals were utilizing the stream habitat of Sandy Creek (downstream of the waterfall) for spawning (The Ecology Lab 2006b).

This species is present in the most downstream reach of Wongawilli Creek, at the northern margin of the proposed maximum footprint near the Fire Road 6 crossing (The Ecology Lab 2001 and 2004). This area consists of large, deep, permanent pools and provides extensive aquatic habitat (Section 3.1). It is located upstream of a relatively large waterfall-cascade at the confluence with the Cordeaux River (downstream of the Cordeaux dam wall) which is considered to be a major barrier to Macquarie Perch movement upstream in almost all conditions. The occurrence of a population upstream of this barrier raises the question of how these fish came to be established here. Three possibilities are considered here:

1. Macquarie Perch are able to access Wongawilli Creek from the Cordeaux River via this barrier in extreme flood events with the raising of the water level within the Cordeaux River and Wongawilli Creek greatly reducing the height of this barrier. If this is the case, it is unlikely that such a flood event has occurred since the construction of Cordeaux Dam.
2. This population has existed in isolation of known populations within the Cordeaux and Nepean River system as a result of geological changes in the landscape which have created this barrier.
3. This population was established in Wongawilli Creek artificially. It is known that Macquarie Perch have been stocked in watercourses of the Nepean River system, however stocked species are generally of the Murray-Darling variety and genetic analysis of fin clips shows that these are the eastern variety.

It is possible that Macquarie Perch have been able to negotiate this substantial barrier at the confluence of the Cordeaux River.

Two substantial barriers to Macquarie Perch passage upstream in Wongawilli Creek from the location of the known population have been identified (The Ecology Lab 2001). These are the rockbar-cascade features discussed in Section 3.1.1. and are considered to be impenetrable barriers under most, if not all, conditions (The Ecology Lab, 2001a). An extensive survey, using a back-pack electrofisher, of the reach of Wongawilli Creek upstream of these barriers into the proposed mine footprint did not reveal any further individuals and it was considered highly unlikely that this species would be present. In consideration of the possibility that Macquarie Perch may have been able to negotiate the substantially larger barrier at the confluence with the Cordeaux River, and that recently deposited flood debris indicates water levels in excess of 2 metres above base flow levels (Section 3.1), it is necessary, as a precautionary interpretation, to consider that this species may be able to migrate upstream of these barriers under extreme high-flow conditions.

Using this conservative assessment, the entire reach of Wongawilli Creek from the confluence with the Cordeaux River, upstream to the large waterfall at field inspection site 4 (Section 3.1) is considered potentially accessible habitat for Macquarie Perch. This reach of Wongawilli Creek incorporates areas 3A, B and C of the proposed mine footprint, and part of the General SMP Area for Area 3A.

No records exist for this species for any other watercourses within the proposed maximum footprint of Area 3 despite fish sampling having been undertaken in Donalds Castle Creek and Sandy Creek (upstream of the waterfall).

Macquarie Perch spawn in spring in shallow upland streams and flowing sections of rivers (NSW DPI 2005). Females deposit the adhesive eggs among stones and gravel in riffle areas (NSW DPI Fisheries Scientific Committee 2006). Such suitable spawning areas are available within Wongawilli Creek, including within the General SMP Area of Area 3A (Section 3.1).

2.7.2 Sydney Hawk Dragonfly

The Sydney Hawk Dragonfly is listed as an endangered species under the FM Act 1994. This species 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 Fisheries, 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 Wilton (NSW Fisheries Scientific Committee 2004). There are no records for this species within the Study Area or the Cordeaux and Avon Dam catchments.

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, 2007b). 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 (G. Theischinger, pers. comm.). These habitat features are found within Wongawilli and Sandy Creeks within the proposed mine footprint. However, this species was not in Sandy Creek during the baseline studies for Dendrobium Area 2 (The Ecology Lab 2006b), nor was it recorded at the sites in Wongawilli Creek and other watercourses in the vicinity of Area 3 sampled by MPR (2002-2006). As a precautionary approach these watercourses are considered as potential habitat for this species.

2.7.3 Adam's Emerald Dragonfly

Adam's Emerald Dragonfly is listed as a vulnerable species under both the FM Act and TSC Act. It is extremely rare, having been collected only in small numbers at a few locations in the greater Sydney region (NSW Fisheries, 2002). 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 (NSW Fisheries Scientific Committee 2006). There are no records for this species within the Study Area or the Cordeaux and Avon Dam catchments.

The larvae of Adam's Emerald Dragonfly inhabit small creeks with gravel or sandy bottoms in narrow, shaded riffle zones with moss and lush riparian vegetation (NSW Fisheries 2002). The larvae live for approximately 7 years before metamorphosing into adults which probably live for only a few months. They are thought to have a low natural rate of recruitment and limited dispersal abilities. There are areas of suitable habitat for this species within Wongawilli Creek and Sandy Creek. However, this species was not found at any of

the sites sampled by MPR (2002-2006) or The Ecology Lab (2006b). As a precautionary approach these watercourses are considered as potential habitat for this species.

2.7.4 Australian Grayling

The Australian Grayling is listed as a vulnerable species under the EPBC Act and is a protected species under the FM Act. This species 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 have been recorded in the Grose River, but there are no records of this species from the upper Nepean Catchment (Bionet Web Reference 1). They have also been recorded in estuarine areas. The life cycle of the 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. The construction of dams and weirs in some river systems has had a major impact on this species. It is not expected to occur in the upper Nepean System above barriers such as the Pheasants Nest Weir and Cordeaux Dam which contain no provision for fish passage. As Australian grayling is highly unlikely to occur within the study area, further investigation of this species is not considered necessary.

3.0 FIELD INVESTIGATIONS

Watercourses within the Study Area of Dendrobium Area 3 were inspected by The Ecology Lab from 16th to 20th of July 2007. The description of habitats in watercourses within the Sandy Creek catchment is based on that undertaken by The Ecology Lab as part of Dendrobium Area 2 studies. Where specific stream features are referred to such as pools or rock bars within Wongawilli and Sandy Creek, the stream feature code as used by the BHPBIC surface monitoring program has been included as well as The Ecology Lab's site reference.

The 1:25 000 topographical map series (Wollongong, Bargo, Bulli, Avon River) and aerial photos with GIS drainage layers supplied by BHPBIC were used to identify watercourses within the study area that may experience direct or indirect mine subsidence impacts.

Aquatic habitat assessment was undertaken by walking along watercourses within the study area and using GPS to record the positions of specific observations. These observation points are shown in Figure 1 and the GPS positions are presented in Table 4. Water quality (pH, conductivity, temperature, dissolved oxygen, turbidity and oxidation-reduction potential) was recorded using a hand-held probe (Yeokal 611) at each observation point. Water quality data is presented in Table 5. It should be noted that Ecoengineers are undertaking detailed investigation of water quality within the study area and that The Ecology Lab's water quality readings are designed to provide context for ecological observations and sampling at the time of field investigations.

During the week that field investigations were undertaken the weather was mainly fine with no significant rainfall. There had been substantial rainfall within the Cordeaux catchment throughout June and July of 2007. As a consequence, numerous ephemeral watercourses that could be expected to dry out completely or be reduced to series of disconnected pools were flowing. Furthermore flood debris was evident well above current water levels indicating recent large flows throughout the catchment (Plate 7a).

Watercourses were described qualitatively using the following features:

- Surrounding vegetation and riparian vegetation
- Stream morphology (pools, riffles, rock bars, channel and bank form)
- Flow
- Stream substratum
- Presence of aquatic macrophytes
- Indication of recent flood levels
- Shading
- Observed-Expected biota (fish, yabbies)
- Barriers to fish passage
- Other observed features

The aquatic habitat within each watercourse was described in terms of four habitat types (adapted from Fairfull and Witheridge, 2003):

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.

Within each watercourse, habitat type was mapped according to the above classifications and represented on an aerial photo of the area (Figure 1).

3.1 Wongawilli Creek Catchment

Wongawilli Creek is the largest stream within the Dendrobium Area 3 study area. It flows north through the middle of the proposed Area 3 footprint and into the Cordeaux River downstream of the Lake Cordeaux dam wall. Wongawilli Creek and its numerous unnamed tributaries contain extensive and diverse aquatic habitat. There is very little disturbance to the natural environment of the Wongawilli Creek catchment. The crossing of Fire Road 6 is the only major construction along the Wongawilli Creek line. There is very little evidence of invasive plant species instream or within the riparian zone. The geology of the Wongawilli Creek catchment is dominated by sandstone, and this is evident in the geology of the stream substratum which consists of sandstone bedrock, boulders, pebble-gravel beds and sand bars.

For the purposes of habitat description, Wongawilli Creek has been considered in terms of four major habitat zones. These have been designated on the basis of stream morphology (length, width and depth of pools, retaining rock bars, substratum, channel form, flow characteristics) and surrounding landscape (vegetation, topography, geology). There is not necessarily a clearly defined demarkation point between each of these zones, but rather a gradual transition along a length of the watercourse. These habitat zones described below.

3.1.1 Zone 1: Cordeaux River Confluence to Site No. 30

Zone 1 is located within, and downstream of the maximum footprint for Area 3C. It extends from the confluence of Wongawilli Creek and the Cordeaux River upstream to rock bar (WC-RB 23) at Site No. 30 (Figure 1) which is the most upstream of the major rock bars in the lower reaches of the creek. Vegetation surrounding this reach of Wongawilli Creek is dominated by dry Eucalypt forest which extends to the banks of the creek. Along the banks there are numerous native grasses, shrubs and trees including saw grass (*Gahnia* sp.), mat rush (*Lomandra* sp.), wattles (*Acacia* sp.), and tea-tree (*Leptospermum* sp.).

The main channel of Wongawilli Creek within Zone 1 is characterised by a series of large deep pools some of which are over 100 metres in length, over 10 metres wide and up to 4 metres deep. These pools are separated by sandstone rock bars which vary in length and height with some being up to 50 metres long and changes in elevation varying between 1 and 15 metres (Plates 1a – 5b). The largest of these rock bars (WC RB 1) is just upstream of the confluence with the Cordeaux River (Plate 1a). There were numerous in-stream habitat features including large snags, tree roots, sandstone rock walls, caves and boulders. Within the stream channel, aquatic macrophytes including the spike rush; *Eleocharis* sp. and the water milfoil *Myriophyllum* sp. were present. An unidentified brown filamentous algae was observed on aquatic macrophytes and in-stream features such as snags and tree roots throughout Zone 1. Stream banks consisted mainly of well vegetated sandy soil with little erosion or undercutting evident and extensive overhanging vegetation along the stream margin.

Two dominant types of substratum were present. In areas where water flowed over retaining rock bars, the stream substratum was composed entirely of sandstone bedrock. In the large pools, the dominant substratum was sand, with significant areas of bedrock, and boulders. There were some small areas of gravel beds associated with the upstream sections of some of the pools. Within the pools there was also some accumulation of detritus, including leaf litter and woody debris.

During the field investigations of zone 1, Australian smelt (*Retropinna semoni*) was the only fish species observed. The freshwater crayfish (*Euastacus* sp.) was also observed, as were numerous crayfish burrows.

Three significant barriers to fish passage were identified. The largest of these was the rockbar-waterfall (WC RB 1) just upstream of the confluence with the Cordeaux River (Plate 1a). This rockbar consists of a series of sandstone steps of up to 2 metres in height. The total fall in elevation at this site is approximately 15 metres. This feature is considered a major barrier to the upstream passage of species such as Macquarie Perch, although fish such as freshwater eels and galaxids would not be restricted by this barrier. It should be noted that fish surveys and observations have revealed the presence of Macquarie Perch upstream of this barrier. The two other barriers to fish passage identified within Zone 1 are the rockbars (WC-RB 11 & 12) located upstream of Fire Road 6 (Plate 2b, Site No. 40). 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. However, it was noted that flood debris deposited following the recent large rainfall event was over 2 metres above the current stream level and that these rockbars would be submerged for short periods during large floods. It is therefore considered possible that reaches of Wongawilli Creek upstream of these rockbars may be accessible to Macquarie Perch for brief periods, and therefore it is considered as potential habitat for this species, despite these fish not having been found in surveys undertaken by The Ecology Lab (2001) and MPR (2002-2006).

The entire main channel of Wongawilli Creek within Zone 1 has been classified as "significant" aquatic habitat, because of the extensive and diverse range of aquatic habitats present.

Within zone 1 there are seven tributaries (WC25 – WC31). On the basis of field inspection of these tributaries the lower reaches of WC25, WC26, WC27 and WC31 have been determined to provide only "minimal" aquatic habitat while the remaining tributaries are considered as "unlikely" to provide aquatic habitat. The largest of these tributaries,WC26 (Plate 5b)

contained some small pools and would be expected to provide some aquatic habitat for aquatic macroinvertebrates including freshwater crayfish.

The water within the main channel and tributaries of Zone 1 appeared very clear and there was no sign of contamination such as odour, emulsion or discolouration. A small reach of the river (Site Nos. 34 and 37) contained a red iron precipitate which is a relatively common occurrence in areas of Hawkesbury sandstone.

3.1.2 Zone 2: Site No. 30 to WC16

Zone 2 extends from rock bar WC-RB 23 at Site No. 30 upstream to the inflow of tributary WC16. It is located within the maximum footprint for mining Areas 3A, 3B and 3C including the General SMP Area for 3A.

The vegetation surrounding this reach of Wongawilli Creek is dominated by dry Eucalypt forest within an increasingly steep and narrow (moving upstream) valley. This native vegetation extends to the banks of the creek and partially shades the channel along much of this reach. Along the banks there are numerous native grasses, shrubs and trees including saw grass (*Gahnia* sp.), mat rush (*Lomandra* sp.), wattles (*Acacia* sp.), and tea-tree (*Leptospermum* sp.). There are also a variety of native ferns present along the banks of the main drainage and tributaries of this zone.

The main channel of Wongawilli Creek within Zone 2 is characterised by a series of long pools some of which are over 100 metres in length, up to 10 metres wide and up to 2 metres deep (Plates 6a – 8a). These pools are separated by small sandstone rock bars, many of which were largely submerged under the relatively high flow conditions. There are also sandbars, debris dams and small boulder fields between these long pools. Stream banks consisted of sections of well vegetated sandy soil with overhanging vegetation along the edge, and sections of exposed sandy soil with signs of recent erosion including undercutting and scouring (Plate 6b). There were numerous in-stream habitat features, including large snags and tree roots. Within the stream channel, the only species of aquatic macrophyte observed was water milfoil *Myriophyllum* sp. The brown filamentous algae noted in Zone 1 was also present on aquatic macrophytes and other in-stream features. The substratum consisted of large areas of sand deposits, with a smaller proportion of boulders, cobbles, pebbles and gravel. Sandstone rockbars were a much less dominant feature than in Zone 1. Within the pools there were also accumulations of detritus, including leaf litter and woody debris.

During the field investigations of Zone 2, numerous crayfish burrows were observed in the main channel and tributaries however no fish or crayfish were sighted.

There were no significant barriers to fish passage within Zone 2 of the main channel of Wongawilli Creek and it is therefore considered possible that this reach of Wongawilli Creek provides potential habitat for Macquarie Perch if they are able to negotiate barriers downstream in Zone 1. The main channel of Wongawilli Creek within Zone 2 was classified as "significant" aquatic habitat, because of the extensive and diverse aquatic habitat present.

Within Zone 2 there are nine tributaries (WC18 – WC24). On the basis of field inspection of these tributaries; WC21 is considered to provide "moderate" aquatic habitat, the lower reaches of WC17, WC20, WC23 and WC24 to provide only "minimal" aquatic habitat while the remaining tributaries are considered as "unlikely" to provide aquatic habitat. WC21, the largest of the tributaries within Zone 2 flows out of Swamp 8. WC21 is characterised by a permanent pool at the base of a large sandstone cascade/waterfall. This pool is

approximately 15 metres in diameter and has sandy substratum with large sandstone boulders and bedrock throughout (Plate 7b). This pool would provide habitat for fish and invertebrates throughout prolonged dry periods. The cascade consists of a series of sandstone steps of up to 4 metres with a total change in elevation of approximately 20 metres over a horizontal distance of approximately 70 metres (Plate 8a). This cascade is an effective barrier to passage of Macquarie Perch upstream within this tributary.

The water within the main channel and tributaries of Zone 2 appeared very clear and there was no sign of contamination such as odour, emulsion, or discolouration.

3.1.3 Zone 3: WC16 to Waterfall (Site No. 4)

Zone 3 extends from the confluence of tributary WC16 upstream to the large waterfall (DA3-RB 36) at Site No. 4. It is located within the maximum footprint for Areas 3A and 3B including the General SMP Area for 3A.

This reach of Wongawilli Creek is located within a steep and narrow gorge with very distinctive rainforest vegetation. Towards the downstream reach of Zone 3 there are patches of dry eucalypt forest amongst the dominant rainforest species. The rainforest canopy is almost unbroken above the creek and thus the creek is in almost permanent shade. Native ferns dominate the stream bank vegetation with the mat rush (*Lomandra* sp.) also present. In the lower reaches of Zone 3, where the rainforest canopy is sparse there are, wattles (*Acacia* sp.), and tea-tree (*Leptospermum* sp.) shrubs amongst the stream bank vegetation.

The main channel of Wongawilli Creek within Zone 3 is characterised by extensive reaches of relatively long, narrow, shallow pools with few holes deeper than 1 metre, and rarely wider than 3 metres (Plates 8b – 11a). These pools are separated by riffle sections which consist of boulder fields, and gravel-pebble beds. There are also sandbars and some small areas of bedrock along this reach. Stream banks consisted of sandy soil with varying degrees of vegetative cover. In some sections of the banks, the sandy soil showed signs of recent erosion (scouring and undercutting) and deposition (sandbars). There were numerous in-stream habitat features including large snags and tree roots. No instream aquatic macrophytes were observed within Zone 3. The filamentous brown algae seen in Zones 1 and 2 was also absent. A variety of mosses were common on bedrock, boulders and large woody debris along the channel. Within the pools there was some accumulation of detritus including leaf litter and woody debris.

During the field investigations of Zone 3, numerous crayfish burrows were observed in the main channel and tributaries, however, no fish or crayfish were sighted.

There were no significant barriers to fish passage within Zone 3 of the main channel of Wongawilli Creek and it is therefore considered possible that this reach of Wongawilli Creek provides potential habitat for Macquarie Perch if they are able to negotiate barriers downstream in Zone 1. The entire main channel of Wongawilli Creek within Zone 3 was classified as "significant" aquatic habitat, because of the extensive and diverse aquatic habitat present. The upstream limit of Zone 3 is a large waterfall (DA3-RB 36) approximately 25 metres high with a single vertical drop (Plate 11a). As such, this is considered an absolute barrier to passage of Macquarie Perch upstream into Zone 4, however, it may be possible for some fish species such as galaxids and freshwater eels to negotiate this barrier.

Within Zone 3 there are nine tributaries (WC7 – WC15). On the basis of field inspection of these tributaries; WC15 and WC10 are considered to provide "moderate" aquatic habitat, the

lower reaches of WC8, WC11, WC12, WC13 and WC14 to provide only "minimal" aquatic habitat, while the remaining tributaries are considered as "unlikely" to provide aquatic habitat. WC15 flows out of Swamp 14 and is characterised by a series of permanent pools amongst sandstone boulders and small waterfalls (Plate 10a). These pools would provide habitat for some fish and invertebrates throughout prolonged dry periods. This series of waterfalls is an effective barrier to passage of Macquarie Perch upstream within this tributary.

WC10 has a well defined channel through the sandy soil banks with a substratum of gravel, pebbles and cobbles (Plate 10b). It is expected that there would be permanent pools upstream in this tributary that would provide habitat for some fish and aquatic invertebrates. Freshwater crayfish burrows were observed in the banks of this tributary.

The water within the main channel and tributaries of Zone 2 appeared very clear and there was no sign of contamination such as odour, emulsion, or discolouration.

3.1.4 Zone 4: Upstream of Waterfall (Site No. 4)

Zone 4 extends upstream from the waterfall (DA3-RB 36) (Site No. 4) to the upper reaches of Wongawilli Creek. Approximately 400 metres (most downstream) of this reach is located within the mining area maximum footprint. The rest of the Wongawilli catchment is upstream of the proposed maximum footprint for Dendrobium Area 3. Field inspections of Zone 4 were conducted upstream as far as the rockbar (Site No. 2) just upstream of tributary WC3 (Figure 1).

This reach of Wongawilli Creek is located within a steep and narrow sandstone valley (gorge in places) with vegetation dominated by dry eucalypt forest. This native vegetation extends to the edge of the watercourse and creates some patchy shading of the creek. The stream bank vegetation comprises numerous native grasses, shrubs and trees including saw grass (*Gahnia* sp), mat rush (*Lomandra* sp.), wattles (*Acacia* sp.), banksia (*Banksia* sp.) and tea-tree (*Leptospermum* sp.). Coral ferns (*Gleichenia* sp.) were also present along the banks.

The main channel of Wongawilli Creek within Zone 4 is characterised by relatively small, shallow pools with few holes deeper than 1.5 metres, and rarely wider than 3 metres (Plates 11a – 13b). These pools are separated by retaining sandstone rockbars which often contain small (up to 1 metre) steps. Stream banks consisted mainly of well vegetated sandy soil with little erosion or undercutting evident and extensive overhanging vegetation along the stream margin. There were numerous in-stream habitat features including snags and tree roots. No aquatic macrophytes were observed within the stream channel.

Two dominant substratum types were present in the reach of Wongawilli Creek within Zone 4. In areas where water flowed over the retaining rock bars, the substratum was composed entirely of sandstone bedrock (Plate 11b). In the pools, the substratum was dominated by sand, but with significant areas of bedrock, and boulder also present. Within the pools there was also some accumulations of detritus, including leaf litter and woody debris.

No fish or crayfish were observed within Zone 4 during the field investigations, however, numerous freshwater crayfish burrows were noted in the stream banks of the main channel and tributaries.

The steps associated with the sandstone rockbars in Zone 4 could be considered as potential barriers to fish passage for some species; however, it is unlikely that these small vertical

drops would pose a significant impediment to upstream migrations of species potentially present upstream of the large waterfall (Site No. 4), such as freshwater eels and galaxids.

The main channel of Wongawilli Creek within Zone 4 upstream as far as the confluence with WC2 was classed as "significant" aquatic habitat on the basis of field observations and study of high resolution aerial photographs. Further upstream, Wongawilli Creek is considered to consist of "moderate" aquatic habitat.

Within Zone 4 there are six tributaries (WC1 – WC6). WC6 is located within the proposed maximum footprint and is considered to be "unlikely" aquatic habitat. WC 3, WC4 and WC5 were also inspected. WC4 and WC5 contained small permanent pools in their lower reaches that would provide habitat for some fish and macroinvertebrates and were therefore categorized as "moderate" aquatic habitat (Plate 13b). WC3 was classed as "unlikely" aquatic habitat.

The water within the main channel and tributaries of Zone 4 appeared very clear and there was no sign of contamination such as odour, emulsion, or discolouration. It was noted that there were areas of freshly exposed sandstone in the rockbar (Plate 13a).

3.2 Sandy Creek Catchment

Sandy Creek is located on the south-eastern corner of the proposed maximum footprint for Dendrobium Area 3A. The mid to lower reach of Sandy Creek (upstream of the waterfall) and two of its tributaries (Banksia Creek and Cascade Creek lie within the General SMP Area for Dendrobium Area 3A (Figure 1). The Sandy Creek catchment was not visited as part of the July 2007 field investigations, because it is well known to TEL due to monitoring of aquatic habitat and biota for Dendrobium Area 2. The following habitat assessment draws upon numerous site visits to the area made since 2004. The crossing of Fire Road 6C is the only major construction along Sandy Creek. There is very little evidence of invasive plant species instream or within the riparian zone. The geology of the Sandy Creek catchment is dominated by sandstone, and this is evident in the geology of the stream substratum which consists of sandstone bedrock, boulders, pebble-gravel beds and sand bars.

Near the Fire Road 6C crossing, Sandy Creek flows over sandstone rockbars forming a series of long shallow pools, short deep pools and alternating short riffles (Plate 14b). Approximately 100 m below the crossing is a large waterfall approximately 25 metres high (Plate 14a). Below the waterfall the creek bed is characterised by a moderate slope with large boulders and sandbars to the high water mark of the dam (Plate 14a). This waterfall is downstream of the General SMP area for Area 3A.

The reach of Sandy Creek upstream of the confluence with Banksia Creek as far as the confluence with Cascade Creek is characterised by alternating riffles with sand and gravel bars and moderate size pools (Plate 15a). No in-stream aquatic macrophytes have been observed, but bank vegetation was extensive and dominated by saw grass (*Gahnia* sp.) and mat rush (*Lomandra* sp.) (Plate 5 Upper). Large woody debris and overhanging banks provided extensive aquatic habitat features. Surrounding riparian vegetation was predominantly eucalypt forest. Sandy Creek has extensive and diverse aquatic habitat in the mid to lower reaches and is therefore considered as "significant" aquatic habitat.

Further upstream in the main channel of Sandy Creek flow is greatly reduced and while there are still some small permanent pools, this reach of the watercourse is considered as "moderate" aquatic habitat (Plate 15b).

The waterfall on Sandy Creek is a substantial barrier to fish passage into Sandy Creek from Lake Cordeaux. This waterfall is considered an absolute barrier to the passage of Macquarie Perch into the General SMP Area of Area 3A. Fish sampling undertaken during Area 2 investigations has revealed healthy populations of Galaxids and Freshwater Crayfish within the Sandy Creek Catchment upstream of the waterfall. Macquarie Perch have been observed in the Sandy Creek arm of Lake Cordeaux during Area 2 investigations.

Banksia Creek joins Sandy Creek approximately 50 metres upstream of the Fire Road 6C crossing. The entire catchment of Banksia Creek lies within the General SMP Area for Area 3A. The reach of Banksia Creek downstream of Swamp15A has a relatively level gradient, with long pools separated by small sandstone rockbars with falls of less than two metres (Plate 16). The creek bed consisted of a mixture of bedrock, boulder, sand and detritus. The bank vegetation was dominated by native shrubs and grasses with some ferns. Surrounding vegetation consisted of sparse eucalypt woodland with a dense under-story of native shrubs and grasses. The relatively deep pools (up to 2 metres) provide permanent refuge and Banksia Creek is considered as "Moderate" aquatic habitat downstream of Swamp 15a.

Cascade Creek joins Sandy Creek approximately 700 metres upstream of the Fire Road 6C crossing. The catchment of Cascade Creek is partially within the General SMP Area for Area 3A. Cascade Creek flows mainly over sandstone bedrock with some sand and gravel bars. The creek banks are well vegetated with overhanging native ferns, shrubs and grasses and contain large amounts of woody debris (Plate 17a). Large stands of saw grass (*Gahnia* sp.) dominate the creek vegetation in the lower reaches near the confluence with Sandy Creek. Dry eucalypt forest is the dominant terrestrial vegetation in the area. Approximately 200 metres upstream of the confluence with Sandy Creek is a waterfall consisting of a series of cascades over bedrock with a boulder filled pool at the base. It is expected that aquatic habitat would be restricted to a few permanent pools during periods of extended dry weather and that these would provide refuge for some fish and invertebrate species. Cascade Creek was considered "moderate" aquatic habitat within the General SMP Area.

3.3 Donalds Castle Creek Catchment

The upper catchment of Donalds Castle Creek lies within the north-western section of the Dendrobium Area 3 proposed maximum footprint. There are two tributaries (DC1 and DC2) of Donalds Castle Creek that lie within the proposed footprint and there is approximately 2.25 km of the upper reach of the Creek within the proposed footprint. Donalds Castle Creek was inspected at two points (Figure 1) as part of the July 2007 field investigations. The most downstream of these is just outside the proposed maximum footprint near the Fire Road 6 crossing and confluence of tributary DC4 (Plate 18a). This crossing is the only significant modification of the channel of the creek (Plate 18b). The second site was located at the outflow of Swamp 5 (Plate 19a). The surrounding vegetation in this reach of Donalds Castle Creek is dominated by dry Eucalypt forest which extends to the banks of the creek. Along the banks there are numerous native grasses, shrubs and trees including saw grass (*Gahnia* sp.), mat rush (*Lomandra* sp.), wattles (*Acacia* sp.), and tea-tree (*Leptospermum* sp.). Stream banks consisted mainly of well vegetated sandy soil with little erosion or undercutting evident and extensive overhanging vegetation along the stream margin. There were numerous in-stream habitat features, including snags and tree roots. No instream aquatic macrophytes were observed within this reach of the creek. The main channel of this reach of Donalds Castle Creek consisted of a series of relatively small permanent pools with a maximum depth of 1.5 metres, width of 6 metres and length of 25 metres. These pools had a mainly sand substratum with some areas of bedrock, boulder and

gravel. These pools were connected by narrow channels with a mainly sand substratum with small sections of gravel riffles and some sandstone rockbars with small cascades up to 1 metre in height. It is expected that this connectivity between pools would not persist through extended dry periods. No fish were observed during the site visit, however, freshwater crayfish burrows were present in the creek banks. This reach of Donalds Castle Creek is considered as "moderate" aquatic habitat upstream as far as Swamp 5.

The water within Donalds Castle Creek appeared very clear and there was no sign of contamination such as odour, emulsion, or discolouration.

3.4 Native Dog Creek Catchment

Native Dog Creek lies to the south-west of the maximum proposed footprint for Dendrobium Area 3. There is one small tributary (ND9) within the proposed footprint (Figure 1). This tributary was inspected as part of the July 2007 field investigations. There was very limited aquatic habitat within this watercourse, apart from some small semi-permanent pools (Plate 19b) that may support some aquatic invertebrate species including freshwater crayfish. As these pools are not expected to persist through prolonged dry periods, Tributary ND9 has been classified as "minimal" aquatic habitat.

Cordeaux River Tributaries

There are two watercourses (CR1 and CR2) that flow to the Cordeaux River downstream of the dam wall from within the northern section of the maximum proposed footprint of Dendrobium Area 3 (Figure 1). These watercourses were inspected as part of the July 2007 field investigations.

CR1 was assessed from the Fire Road 6F crossing (Plate 20a) which lies to the north of the proposed mine footprint. This watercourse was classified as "minimal" aquatic habitat, because it was considered unlikely that any of the pools observed would persist through prolonged dry periods.

CR2 was assessed from the Fire Road 6 crossing (Plate 20b) which is approximately 400 metres downstream of the maximum proposed footprint. Within this reach of the watercourse there were numerous small pools, some of which may persist during prolonged dry periods. These pools were connected by shallow flow over rockbars and channels through the sandy soil substratum. This watercourse was categorized as containing "moderate" aquatic habitat in its lower reach.

Lake Cordeaux Tributaries

Eight small to moderate size watercourses (LC1-LC8) that flow to Lake Cordeaux lie within the north-east of the maximum proposed footprint for Dendrobium Area 3 (Figure 1). Of these watercourses only the two largest (LC6 and LC7) were visited during the July 2007 field investigations (Plate 21). Both of these watercourses contained some small pools in their lower reaches that could be expected to persist through extended dry periods providing limited "moderate" aquatic habitat that could be utilised by freshwater crayfish and possibly some fish.

Aquatic habitat has been assessed for all other small Lake Cordeaux tributaries on the basis of catchment size using topographical maps and high resolution aerial photography. These small steep drainage lines have all been determined to be either "minimal" or "unlikely" aquatic habitat.

Lake Avon Tributaries

There are five small watercourses (LA2 – LA6) that flow to the Native Dog Creek arm of Lake Avon that lie within the south-west of the maximum proposed footprint for Dendrobium Area 3 (Figure 1). None of these watercourses were visited during the July 2007 field investigations. Assessments of aquatic habitats were made on the basis of catchment size using topographical maps and high resolution aerial photography. Based on this assessment it is considered likely that these small steep drainage lines are unlikely to have aquatic habitat.

4.0 ASSESSMENT OF IMPACTS

4.1 Description of the Proposal & General Impacts Associated with Mining Subsidence

BHP Billiton Illawarra Coal (BHPBIC) proposes to begin extracting coal from the Wongawilli Seam below Dendrobium Area 3 in January 2010 using longwall mining techniques. The application area has been divided into three Areas, A, B and C. It is understood that mining will commence in Area 3A which is located in the south-eastern part of the application area and includes Longwalls 6-10. The layout of longwalls in Areas 3B and 3C, located to the west and north of Area 3A, has not yet been determined. The proposed Longwalls 6 – 10 in Area 3A and future longwall layouts in Areas 3B and 3C will be set back from Wongawilli Creek so as to reduce the potential for subsidence impacts to the stream (MSEC, 2007). It is also understood that the longwalls in Areas 3B and 3C will be setback from Lake Avon and Lake Cordeaux so that there will be no significant direct impacts on the lakes (MSEC 2007).

The surface area that is likely to be affected by the mining of proposed Longwalls 6 to 10 in Area 3A and by the mining of the future longwalls in Areas 3B and 3C is referred to hereafter as the "Study Area". The term "SMP Area" refers to the surface area that is likely to be affected by the mining of proposed Longwalls 6 to 10 in Area 3A only. The SMP Area 3A lies within the Metropolitan Special Area. The proposed longwalls 6-10 are located within the Dams Safety Committee Notification Area for Lake Cordeaux. The closest dams, the Upper Cordeaux No.1 and No. 2 Dams, are located approximately 4 km south-east and 2.5 km south-east of the proposed longwalls, respectively. Two permanent streams flow through the SMP Area. The largest of these, Wongawilli Creek, is located 110 m to the west of the proposed longwalls, at its closest point (MSEC 2007). Sandy Creek crosses the eastern part of the SMP Area and is located 85 m away from the proposed longwalls, at its closest point. A 25 m high waterfall (A3-C11) located at the point where Sandy Creek flows into Lake Cordeaux has been included as part of the SMP Area due to valley-related upsidence and closure movements predicted to occur.

Longwall mining related ground movement can impact landscape features in a number of ways, including subsidence of uplands, plateaus and ridge tops, bulging of incised valleys and gorge walls and upward strain of creek and river beds. Valley closure and down slope movements associated with incised valley and gorge walls can in turn result in the erosion of slopes, mobilisation of sediment and its deposition in watercourses. The upsidence and closure caused by valley bulging can also lead to the fracturing of the substratum of creeks and rivers and result in changes to the stream morphology, such as the draining of pools, increased or decreased ponding, scouring and subsurface flow diversion (MSEC 2007). These changes in turn, can impact upon the aquatic ecology of a watercourse through loss of habitat, desiccation, sedimentation in pools, stream discontinuity, and deterioration in water quality due to leaching of minerals through fractured bedrock or groundwater inflows.

4.2 Aquatic Habitat

The ground movements associated with longwall mining can impact on the availability of aquatic habitats by changing the levels of ponding, flooding and scouring of banks along watercourses and altering surface water flows through the fracturing of river and streams beds. 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. Fracturing of bedrock and diversion of surface flows depends on subsidence, valley-related upsidence and closure movements (MSEC 2007). The impact of changes in surface and sub-surface flows on the availability of 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 river bed and subsequent flow events. In some cases, cracks in bedrock are filled partially or completely by alluvial deposits during subsequent flow events. In some cases, remediation work may be necessary to restore flows. Aquatic habitat can also be adversely affected by changes in water quality resulting from mine subsidence impacts. Changes in aquatic habitat of this nature are considered in Sections 4.3 and 4.4.

MSEC (2007) has assessed the impacts of subsidence resulting from the proposed extraction of coal on the watercourses and drainage lines flowing through the Study Area and on water bodies beyond the Study Area that are expected to experience either far-field movements, or valley related upsidence and closure movements. The latter waterbodies include creeks within the predicted limit of 20 mm total upsidence, Lake Cordeaux and Lake Avon, Cordeaux and Upper Cordeaux No. 2 dams. Their predictions indicate that there will be very small ($\leq$ 0.3%) changes in the gradients of the reaches of Wongawilli Creek and Sandy Creek within the Study Area. Changes of this magnitude are unlikely to cause significant increases in the levels of ponding, flooding or scouring of banks along these creeks. There is, however, a possibility of localised increases in ponding or flooding in areas where maximum predicted changes in slope of the ground coincide with existing pools, steps or cascades along these watercourses. These could result in localised increases in the availability of aquatic habitat. The predictions with respect to the potential for fracturing of bedrock and diversion of surface flows combined with the fact that Longwalls 6-10 in Area 3A will be set back at least 110 m and 85 m from Wongawilli Creek and Sandy Creek, respectively indicate that significant fracturing or surface water flow diversions are unlikely to occur along Wongawilli Creek and Sandy Creek. There is also unlikely to be any significant fracturing of the sandstone bedrock or surface water diversions along the section of Wongawilli Creek flowing through Areas 3B and 3C, provided that future longwalls are also set back from the creek (MSEC 2007). Extraction of the longwalls could result in localised, minor fracturing of bedrock within Wongawilli and Sandy Creeks which may extend up to 400 m away from the longwalls. Whilst this fracturing is not expected to cause any significant diversion of surface flows, it could cause localised reductions in the availability of aquatic habitat.

The upper reaches of Donalds Castle Creek are located in the northern part of Area 3B and in the western part of Area 3C. This creek is unlikely to experience significant systematic, valley-related or far-field horizontal movements as a result of the extraction of Longwalls 6-10 in the SMP Area. Predictions about movements resulting from mining of longwalls in Areas 3B and 3C are limited, however, it is unlikely that significant impacts will occur where proposed longwalls induce similar systematic, valley-related or far-field horizontal movements as for Area 3A.

The ephemeral drainage lines located across Areas 3A, 3B and 3C are expected to experience a variety of systematic subsidence and valley-related movements during the extraction of the longwalls. The predictions provided by MSEC (2007) indicate that the levels of ponding, flooding and scouring are unlikely to change significantly along Drainage Line 1 (Tributary WC17), but will change along Drainage Line 2 (Banksia Creek) with ponding and flooding increasing adjacent to the longwall tailgates and scouring increasing adjacent to the longwall

maingates. These changes are likely to have little impact on the availability of aquatic habitat, because of flow. Any changes to the level and extent of increased ponding is expected to decrease through time in areas with alluvial beds as these areas would be eroded by high flows during significant rainfall events. Cracking of bedrock is also likely to occur along the drainage lines. Cracks within alluvial reaches of the drainage lines are expected to fill with sediment during subsequent flow events. Along bedrock controlled reaches of the drainage lines, cracking may result in some diversion of surface flows into the underlying strata and drainage of pools. This will result in a localised reduction in the availability of ephemeral aquatic habitats. The diverted water is likely to re-appear further downstream, so there is unlikely to be any net loss of water from the catchment.

Lake Avon is situated 3 km to the west of the proposed longwalls in Area 3A and is therefore unlikely to experience any significant systematic, valley-related or far-field horizontal movements as a result of the extraction of Longwalls 6-10. The MSEC (2007) predictions indicate that the extraction of Longwalls 6-10 is unlikely to have any significant systematic subsidence impacts in Lake Cordeaux (MSEC 2007). The relatively short (250m) distance between the perimeter of Lake Cordeaux and Longwall 7 at its closest point, suggests that extraction of the longwalls in Area 3A may cause localised, minor cracking in the lake bed. The extraction of the future longwalls in Areas 3B and 3C may also lead to minor, isolated cracking in the beds of Lake Avon and Lake Cordeaux. As this cracking is unlikely to result in any loss of water, changes in the availability of aquatic habitat are also unlikely.

4.3 Effects on Water Quality

The fracturing of bedrock and diversion of surface flows into the dilated strata can lead to weathering and leaching of minerals which, in turn, can have a localised impact on the quality of water in rivers and creeks, particularly during low flow conditions. In addition, subsidence movements can increase the flow of groundwater into streams. This groundwater typically has lower dissolved oxygen, increased conductivity and increased levels of metals such as iron. Ecoengineers (2006b and 2007) assessment of impacts on surface water quality in Dendrobium Area 3 indicates that the following impacts can arise:

- Reduction in pH levels due to the release of sulphuric acid during the oxidative dissolution of marcasite;
- Decrease in dissolved oxygen levels resulting from oxidation of ferrous and manganese ions;
- Release of dissolved heavy metals, such as iron, manganese, nickel and zinc, during the weathering of marcasite (a form of iron sulphide);
- Smothering of hard surfaces (e.g. bedrock, boulders, cobbles and snags) due to the precipitation of iron and manganese hydrous oxides;
- Dispersion of small amounts of kaolinite from newly-fractured, unweathered sandstone in the bedrock; and
- Increase in concentration of aluminium in water emerging downstream from upsidence-affected areas due to its dissolution from kaolinite and formation of ferruginous springs (Ecoengineers 2006b). The dispersion of kaolinite results in an increase in turbidity downstream, but this is a much smaller effect than that caused by natural rainfall/runoff events and is short-lived (Ecoengineers 2006b). Ecoengineers (2007) have concluded that

mining of Area 3 is unlikely to have significant geochemical effects on Wongawilli, Sandy or Donalds Castle Creeks. There is, however, a possibility that minor fracturing could lead to changes in water quality in Banksia Creek in the vicinity of Longwall maingate 10 and tailgate 9, in the longer, incised, high gradient tributaries of Wongawilli Creek in Areas 3B and 3C and creeks LC6 and LC7 in Area 3C which feed into Lake Cordeaux. Ecoengineers (20007) also predict that mining could lead to the development of ferruginous springs on the slopes of the south-west draining catchments over Area 3B.

Rock falls and cracking of the surface induced by mine subsidence can lead to erosion. The sediments mobilised by this process can be deposited in watercourses resulting in smothering of aquatic habitat and result in short-term increase in turbidity levels. The suspended sediment is also likely to be transferred downstream into other watercourses. Ecoengineers (2007) indicate that minor erosion may occur on the steep slopes along the main channel and tributaries of Wongawilli Creek in Area 3A, on the steep slopes draining the western side of Area 3B to the Native Dog Creek Arm of Lake Avon and on the eastern side of Area 3C draining to Lake Cordeaux. These erosion events are expected to be relatively small compared with those occurring during natural storm events and bushfires. Ecoengineers (2007) conclude that mining-induced erosion events will have only minor, localised impacts on the lower sections of creeks and shorelines of Lakes Cordeaux and Avon. The impacts will take the form of minor, localised, but short-lived increase in turbidity.

4.4 Aquatic Biota

The ground movements induced by longwall mining can have indirect impacts on aquatic biota through the diversion of surface water flows to the dilated substrata and changes in water quality.

4.4.1 Diversion of Surface and Sub-surface Flows

The sudden drainage of pools or rapid drop in stream flow due to subsidence are likely to have localised, significant impact on aquatic biota, particularly on organisms that are left stranded in air or unable to move to areas that are damp or submerged.

Aquatic plants and sessile animals are particularly vulnerable to desiccation, because of their inability to move elsewhereto other available habitat. The survival of mobile organisms is difficult to predict, because it depends on their tolerance and response to desiccation, and rapid changes in water level, ability to move, weather conditions, the underlying substratum and duration of exposure. Simple experimental observations indicate that net-spinning caddis-fly larvae (Hydropsychid) respond to aerial exposure by commencing crawling before stones dried out, but cased caddis-fly larvae (Conoesucidae) do not move until stones are dry and then they simply drop off (Bergey 2000). This suggests that net-spinning caddis fly larvae may attempt to follow receding water by crawling, whereas cased caddis fly larvae are more likely to fall into crevices among stones. Gastropod molluscs also differ in their responses to aerial exposure with physids crawling off stones, but potamopyrgids crawling onto the underside and remaining in place. Streams with soft sediment banks are likely to contain moisture within interstices and this may prolong the survivorship of stranded animals. In streams with a bedrock substrate where there are few natural refugia, except cracks and cavities, few organisms may survive complete pool drainage. The survival times of mobile animals are likely to be longer on cool and rainy days than on hot

days. More hardy species, such as freshwater crayfish and yabbies, may be able to relocate to other areas of aquatic habitat. These species can also withstand prolonged periods of drought by retreating into their burrows (NSW DPI 2006). Species of fish, such as freshwater eels and climbing galaxids, may also be able to relocate provided sufficient damp surfaces are available (McDowall 1996). Other species of fish asphyxiate when exposed to air.

The predictions about the impact of subsidence on aquatic habitat outlined in Section 4.2 indicate that impacts of this type are likely to be localised. These impacts will not persist once flow is restored.

4.4.2 Changes in Water Quality

Increases in the sediment load in the water due to mine-induced erosion, reductions in dissolved oxygen levels, and increases in acidity and metal concentrations, resulting from the diversion of sub-surface flows and weathering or leaching of minerals may impact on aquatic biota.

Water with a high suspended sediment load could cause a localised reduction in the penetration of light which could, in turn, lead to a decline in primary production and be followed by a decrease in the availability of food for primary consumers. A reduction in the penetration of light could also lead to changes in temperature and chemistry of the water. Aquatic macroinvertebrates can also be adversely affected by high sediment loads. This is particularly the case if their respiratory and/or feeding appendages get clogged by clay particles or their habitat is smothered when the clay particles settle. The significance of such impacts is dependent on:

- the organisms capacity to seek out more favourable conditions elsewhere;
- the amount of sediment suspended in the water column; and
- the size of the suspended particles founding relation to those naturally occurring in the water column.

As mining-induced erosion is predicted to result in localised and short-term increases in sediment load in the lower sections of creeks and shorelines of Lakes Cordeaux and Avon, impacts on the fauna are likely to also be minor, localised and short-term, particularly if flow is relatively high and constant.

Low concentrations of dissolved oxygen are known to have adverse effects on many aquatic organisms, particularly fish and invertebrates that depend upon oxygen for their functioning (ANZECC, 2000). It is important to note that dissolved oxygen content decreases with increasing water temperature, and that it is difficult to recommend acceptable levels, because some organisms exhibit special adaptations to low concentrations (Rahel and Nutzman, 1994; Williamson, 1991). A laboratory-based study on the effects of low levels of dissolved oxygen on New Zealand native species, such as galaxiids, gudgeons, smelt, eels and shrimp, and juvenile rainbow trout showed that eels were the only species that could survive exposure to 1 mg/L for 48 hours at 15 °C and that only trout suffered mortalities at 3 mg/L. (Dean and Richardson, 1999). It was also noted that most fish moved towards the surface within the first few hours of exposure to 1 mg/L and that one of the galaxid species responded by leaving the water completely. Changes in oxygen level due to mining are likely to be minor, localised and short-term and are therefore likely to have only a low impact on aquatic biota.

Acidic waters with high aluminium concentrations are known to be ecotoxic to a wide range of aquatic species, including benthic macroinvertebrates, juvenile amphibians and fish (Tessier and Turner 1995; Poleo et al. 1997; Herrmann 2001). Acidic waters typically have fewer taxa and reduced abundance of macroinvertebrates than neutral or slightly alkaline waterbodies (Collier and Winterbourn 1987). This suggests that the sudden occurrence of such conditions within parts of Dendrobium Area 3 could have a significant, localised downstream impact on the diversity and abundance of aquatic species. The increase in acidity may also affect the physiological functioning of aquatic biota (ANZECC, 2000). Acidification from strata diversion may cause minor, localised and short-term impacts

4.5 Threatened Species

Habitat for three listed threatened species; Macquarie Perch, Sydney Hawk Dragonfly, and Adams Emerald Dragonfly, has been identified as potentially occurring within the proposed maximum footprint for Dendrobium Area 3. As such, a specific assessment of impacts for these species has been undertaken including Seven-Part tests as required by the FM Act under which they are listed. Macquarie Perch is also listed under the Commonwealth EPBC Act, and as such requires an assessment of significance to be made under EPBC Act guidelines. This assessment and a subsequent referral were undertaken in 2001 as part of the original EIS for the Dendrobium Project.

The following Seven–Part tests and EPBC assessment of significance have been prepared using specific mine subsidence predictions for Dendrobium Area 3A and an understanding of likely mine subsidence impacts for Areas 3B and 3C in relation to distance from watercourses as described by MSEC (2007) and summarised in section 2.1 above. In the case of Macquarie Perch, only the population within Wongawilli Creek has been considered as there are no significant impacts predicted within Lake Cordeaux as a result of mine subsidence (MSEC, 2007) or water quality (Ecoengineers, 2007). There are impenetrable barriers preventing passage of this species into the watercourses of the mine area from the Lake Cordeaux population. The Dendrobium Area 2 monitoring program for Macquarie Perch includes the Sandy Creek arm of Lake Cordeaux, and this monitoring is to continue during and after the development of Area 3A. As a precautionary approach, the reach of Wongawilli Creek from the Cordeaux River confluence upstream to the large waterfall has been considered as habitat for Macquarie Perch. As discussed in section 3.1 however, there are no records for this species upstream of the major barriers at the northern margin of the proposed mine footprint.

4.5.1 Seven-Part Test for Macquarie Perch

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.

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 and November when water temperatures rise to around 16^0C (McDowall, 1996). Eastern populations, however, inhabit rivers with very different hydrological conditions to the inland populations and very little is known of their life cycle.

Deep, permanent pools within the lower reach of Wongawilli Creek are likely to be important habitat areas for Macquarie Perch within various stages of the life cycle of the

species. All records of this species in the study area are restricted to a small number of pools at the most downstream reach of Wongawilli Creek. In this area Wongawilli Creek consists of large pool habitats (The Ecology Lab 2001c). Mine subsidence predictions for Area 3A and expected levels of impacts for Areas 3B and 3C indicate that major subsidence-induced fracturing of sandstone substratum of retaining rockbars which would lead to pool draining and habitat loss is unlikely in this area or the upstream reaches of Wongawilli Creek.

Other habitat areas within Wongawilli Creek that may be of importance in the life cycle of Macquarie Perch are gravel beds and riffles which could provide suitable substratum for spawning. Such habitat types could be affected by increased levels of ponding, flooding or scouring within the creek caused by subsidence-induced changes in gradient of the creek bed. There is a possibility that there may be some minor localised increases in the level of ponding, flooding and scouring within Wongawilli Creek (MSEC 2007). Considering the extensive availability of such habitat within Wongawilli Creek, minor localised changes in this habitat type are highly unlikely to have any significant impact on the reproductive success and hence the viability of the local population of Macquarie Perch.

Potential impacts on water quality such as increased acidity, reduced dissolved oxygen and increased heavy metal concentration which may impact on the habitat quality and hence the population viability of this species are not expected to occur as a result of mine subsidence because no significant fracturing is likely to occur in the substratum of Wongawilli Creek (Ecoengineers, 2007).

It is considered that mine subsidence resulting from Dendrobium Area 3 will not have any adverse effect on the local population of Macquarie Perch within Wongawilli Creek that would be likely to place it at risk of extinction.

In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the lifecycle of the species that constitutes the endangered population such that a viable 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.

In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

1. *is likely to have an adverse effect on the extent of the ecological community such that it local occurrence is likely to be placed at risk of extinction, or*
2. *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*

The eastern form of the Macquarie Perch is not part of a listed endangered ecological community.

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

1. *the extent to which habitat is likely to be removed or modified as a result of the action proposed*

Mine subsidence predictions for Dendrobium Area 3 (MSEC 2007) indicate that the large deep pool habitats that are known to support Macquarie Perch are unlikely to be removed or modified as a result of the limited localised fracturing that may occur within the main channel of Wongawilli Creek. Minor localised increases in flooding, ponding and scouring that may occur within areas identified as potential spawning habitat are highly unlikely to

constitute a significant proportion of the available habitat if it is utilised at all. Similarly, Ecoengineers (2007) do not predict that significant changes in water quality will occur in Wongawilli Creek as a result of mine subsidence impacts.

2. *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*

The known habitat of Macquarie Perch within Wongawilli Creek is bounded at the northern margin of the proposed maximum footprint for Dendrobium Area 3 by two significant barriers to passage upstream. As such, if Macquarie Perch are able to access the majority of the habitat within the direct area of potential mine subsidence effects, there must be certain flow conditions (large floods) that allow this barrier to be negotiated. Any minor fracturing of rockbars, or increased levels of ponding or scouring that result in the temporary isolation of some areas of habitat during periods of low flow are likely to be insignificant in the context of a large flood event. As such, it is considered highly unlikely that any area of habitat could become fragmented or isolated as a result of the mine subsidence impacts.

3. *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*

It is not expected that any habitat will be significantly removed, modified, fragmented or isolated within Wongawilli Creek as a consequence of mine subsidence.

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

There is no listed critical habitat for Macquarie Perch within the study area.

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

Recovery objectives for Macquarie Perch relative to this region include the prevention of siltation and erosion, the preservation of natural flows and the removal of existing barriers to fish passage (Morris *et al.* 2001). Some short-term minor siltation and erosion may occur as a result of mine subsidence -induced mobilisation of sediments that ultimately are transported into Wongawilli Creek. These inputs are likely to be relatively minor compared with those occurring during normal storm events and bushfires (Ecoengineers, 2007). The minor fracturing that may occur within Wongawilli Creek is not expected to result in any significant diversion of surface water which would affect the natural flow regime of Wongawilli Creek (MSEC 2007).

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

The proposed action is not classed as a Key Threatening Process under the *FM* Act 1994, under which Macquarie Perch are listed. However under the TSC Act, 1995, longwall mining resulting in the alteration of habitat has recently been listed as a Key Threatening Process. This does not define the action as a threatening process as described under the required assessment (seven-part test) for threatened species under the *FM* Act.

Conclusion

The proposed longwall mining of Dendrobium Area 3 does not pose a significant threat to the local viable population of Macquarie Perch provided final longwall layouts for Areas 3B and 3C maintain similar subsidence predictions for the main channel of Wongawilli Creek as subsidence predictions for Area 3A. As such, the

preparation of a Species Impact Statement as prescribed under the EP&A Act is not required. Further monitoring of the Macquarie Perch population has been incorporated into the monitoring plan for Dendrobium Area 3 (Section 5.0) as a precautionary measure.

4.3.2 Assessment of significance (EPBC Act) for Macquarie Perch

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

Possible causes of a decline in a population of Macquarie Perch relevant to the proposed development of Dendrobium Area 3 include: barriers to spawning migrations, and habitat reduction, degradation and fragmentation. Each of these possible causes is considered in further detail in relation to specific questions outlined below.

Will the action reduce the area of occupancy of an important population?

The known extent of Macquarie Perch in Wongawilli Creek to date is from the confluence of the Cordeaux River, upstream to the northern margin of the proposed Dendrobium Area 3 maximum footprint. A population has been found here in surveys undertaken by NSW DPI Fisheries (2001) and The Ecology Lab (2001). Further observations have been made by The Ecology Lab in 2004. Mine subsidence predictions (MSEC 2007) indicate that fracturing of retaining rockbars or substratum leading to the draining of pools is unlikely and will not result in any reduction of the known area of occupancy of this species. As a precautionary approach, the reach of Wongawilli Creek upstream to a large waterfall well within the proposed mine footprint is considered as potential habitat for Macquarie Perch despite some large existing barriers to upsteam migration that may be negotiable in extreme flood events. Some minor subsidence impacts may occur within this reach of Wongawilli Creek including minor rock fractures and some increased levels of ponding, flooding and scouring of banks (MSEC 2007). None of these effects is considered likely to reduce the available habitat of this species.

Will the action fragment an existing important population into two or more populations?

If the existing population of Macquarie Perch within Wongawilli Creek extends upstream into the proposed maximum footprint of the mining area beyond two significant barriers (discussed in section 3.1) it is expected that these barriers would naturally fragment the existing population for the majority of the time. Only in extreme flood events would these barriers be negotiable, and in such an event any minor barrier to fish passage resulting from mine subsidence impacts such as rock fracture, ponding or sediment deposition would be insignificant in comparison. As such it is considered highly unlikely that the development of Dendrobium Area 3 would fragment the existing population within Wongawilli Creek.

Will the action adversely affect habitat critical to the survival of the species?

The area of known occupancy of the population of Macquarie Perch within Wongawilli Creek is not expected to experience any significant mine subsidence impacts which could adversely affect this habitat. Potential important spawning habitat exists upstream in gravel beds and riffles. While some mine subsidence impacts may occur in these areas including; increased ponding, flooding and scouring, this is expected to be minor and localised (MSEC 2007). Increased sedimentation of the stream bed and spawning habitat may also occur at a very minor level resulting from mobilisation of sediment following mine subsidence and resultant transport into the creek. This is expected to be relatively small in comparison with normal storm and bushfire events (Ecoengineers, 2007). Habitat can also be adversely

affected by changes in water quality resulting from mine subsidence impacts. These can include increases in acidity, reduction of dissolved oxygen and increased heavy metal concentration. Ecoengineers (2007) assessment of potential impacts on water quality based on mine subsidence predictions does not predict any significant changes in water quality within Wongawilli Creek. As such, if critical habitat for this species does exist within the maximum proposed mine footprint, any impacts on this habitat are expected to be minor in the context of the total habitat available.

Will the action disrupt the breeding cycle of an important population?

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 and November when water temperatures rise to around 16^0C. Their eggs are carried downstream and lodge among pebbles and gravel in riffles (McDowall, 1996). Eastern populations, however, inhabit rivers with very different hydrological conditions to the inland populations and very little is known of their life cycle. It is however expected that similar upstream migrations may be necessary for spawning in the population within Wongawilli Creek. The breeding cycle could be interrupted by the creation of barriers to migration to breeding habitat, or the loss or degradation of spawning habitat. These possibilities have been considered above and it is concluded that the breeding cycle will not be interrupted as a consequence of mine subsidence impacts.

Will the action modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

Mine subsidence impacts that could result in the creation of barriers to upstream migration, draining of pools, degradation of spawning habitat and degradation of water quality have been considered in relation to the above questions. It is considered highly unlikely that the development of Dendrobium Area 3 will have any adverse impacts on Macquarie Perch habitat within Wongawilli Creek to the extent that the species is likely to decline.

Will the action result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat?

There are no processes associated with the mining of Dendrobium Area 3 that could be considered to potentially facilitate the introduction of invasive species into Wongawilli Creek which may be harmful to Macquarie Perch.

Will the action introduce disease that may cause the species to decline?

There are no processes associated with the mining of Dendrobium Area 3 that could be considered to potentially facilitate the introduction of disease into Wongawilli Creek which may be harmful to Macquarie Perch.

Will the action interfere substantially with the recovery of the species?

In consideration of all of the above points, it is highly unlikely that the development of Dendrobium Area 3 and subsequent potential mine subsidence impacts will have any significant impact on the Macquarie Perch population within Wongawilli Creek. Investigations into this species have been undertaken in conjunction with conservation researchers including the provision of genetic material that will advance the understanding of this species and possibly aid in its recovery.

Conclusion

The proposed longwall mining of Dendrobium Area 3 does not pose a significant threat to the local viable population of Macquarie Perch provided future longwall layouts for Areas 3B and 3C maintain subsidence predictions for the main channel of Wongawilli Creek as those proposed for Area 3A. As such, referral of this development in relation to Macquarie Perch to the Department of Environment and Water (DEW) as prescribed by the EPBC Act is not required. Further monitoring of the Macquarie Perch population has been incorporated into the monitoring plan for Dendrobium Area 3 (Section 5.2) as a precautionary measure.

4.3.3 Seven-Part Test for Sydney Hawk Dragonfly

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.

Sydney Hawk Dragonfly is extremely rare, having been collected only in small numbers at a few locations. Specimens (adults or larvae) have been collected from three locations in a small area south of Sydney, from Audley to Picton (NSW Fisheries, 2004). There are no records for this species within Wongawilli Creek or the Cordeaux River system.

Most of the lifecycle of this species is spent as an aquatic larva, while adults are present for only a few weeks. The larvae of Sydney Hawk Dragonfly appear to have specific habitat requirements, including deep, cool, slow-flowing water in rocky rivers with steep sides (NSW Fisheries, 2004). Relative environmental stability appears to be an important habitat feature, with rapid variation in water level and flow rate likely to have a negative affect on the suitability of habitat for larvae (G. Theischinger, pers. comm.).

Large permanent pools of Wongawilli Creek within the study area appear to provide suitable habitat for the larva of Sydney Hawk Dragonfly. However, the sampling done by MPR (2002-2006) in this area, along with historical survey records for the Sydney area suggest the waterways of the study area do not support an established population of Sydney Hawk Dragonfly. Therefore the lifecycle of this species is unlikely to be disrupted. In the unlikely case that a population of Sydney Hawk Dragonfly does exist within the large permanent pools of Wongawilli Creek, they are unlikely to be negatively impacted by the development of Dendrobium Area 3. This conclusion is based on the predictions of mine subsidence effects on watercourses (MSEC 2007) and water quality (Ecoengineers 2007) which do not include any significant impacts within large pools within Wongawilli Creek resulting from possible effects such as rock fracture, increased flooding, ponding and scouring, or degraded water quality.

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

To date, there are no threatened populations of Sydney Hawk Dragonfly listed on the Schedules of the FM Act 1994. Thus, the proposal will not affect a threatened population as currently listed.

In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

1. *is likely to have an adverse effect on the extent of the ecological community such that it local occurrence is likely to be placed at risk of extinction, or*

2. *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*

The Sydney Hawk Dragonfly is not part of a listed endangered ecological community.

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

1. *the extent to which habitat is likely to be removed or modified as a result of the action proposed*

Historical survey records for the region indicate there is no viable population of Sydney Hawk Dragonfly occurring in the study area. However, there is potential habitat in large pools. In the unlikely case that a population of Sydney Hawk Dragonfly does exist within the large permanent pools of Wongawilli Creek, it is unlikely that this habitat will be removed or modified by the development of Dendrobium Area 3. This conclusion is based on the predictions of mine subsidence effects on watercourses (MSEC 2007) and water quality (Ecoengineers 2007) which include that there will be no significant impacts within large pools within Wongawilli Creek resulting from possible effects such as rock fracturing, increased flooding, ponding and scouring, or reduced water quality.

2. *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*

The Sydney Hawk Dragonfly has an adult life stage in which it is capable of flying. As such it is not impacted by the effects of habitat fragmentation or isolation within a localised area such as Dendrobium Area 3. Furthermore, mine subsidence impacts are not predicted to result in flow diversion or pool draining that would lead to fragmentation of Wongawilli Creek which is thethis potential habitat for this species (MSEC 2007).

3. *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*

It is not expected that any habitat will be significantly removed, modified, fragmented or isolated within Wongawilli Creek as a consequence of mine subsidence.

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

No areas of critical habitat in relation to Sydney Hawk Dragonfly have yet been listed on the Threatened Species Schedules of the *FM* Act 1994.

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

There is no recovery or threat abatement plan for the Sydney Hawk Dragonfly.

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

The proposed action is not classed as a Key Threatening Process under the *FM* Act 1994, under which Sydney Hawk Dragonfly is listed. However under the TSC Act, 1995, longwall mining resulting in the alteration of habitat has recently been listed as a Key Threatening Process. This does not define the action as a threatening process as described under the required assessment (seven-part test) for threatened species under the *FM* Act.

Conclusion

It is unlikely that a viable population of Sydney Hawk Dragonfly exists within the study area. However, because of the presence of suitable habitat, this species has been

considered. The proposed longwall mining of Dendrobium Area 3 does not pose a significant threat to a potential population provided future longwall layouts for Areas 3B and 3C maintain similar subsidence predictions for the main channel of Wongawilli Creek as those proposed for Area 3A. As such, the preparation of a Species Impact Statement as prescribed under the EP&A Act is not required. Aquatic macroinvertebrate monitoring has incorporated a procedure for the identification to family, genus and species of dragonfly larvae (Section 5.3.4) as a precautionary measure.

4.3.4 Seven-Part Test for Adams Emerald Dragonfly

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.

Adam's Emerald Dragonfly is extremely rare, having been collected only in small numbers at a few locations despite widespread and consistent efforts since the 1960's (NSW Fisheries, 2002). In NSW, specimens (adults or larvae) have been collected from five localities: Somersby Falls, Floods Creek in Brisbane Waters National Park near Gosford; Tunks and Berowra Creeks near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park. There are no records for Adams Emerald Dragonfly south of Sydney despite active collecting in the Georges and Nepean River catchments (NSW Fisheries, 2002).

The larvae of Adam's Emerald Dragonfly inhabit small to moderate sized creeks within a well vegetated catchment. They are typically found in riffle and/or cascade habitat, or nearby pools. For example, in Tunks Creek they were found in narrow riffles with medium to large boulders and cobbles, gravel and some sand. Similarly, the Bedford Creek site in the Blue Mountains was relatively pristine riffle habitat with cobbles and sandy banks (NSW Fisheries, undated).

There does appear to be habitat features within the Dendrobium Area 3 study area particularly within Wongawilli Creek Zone 3 (section 3.1.) that would be suited to this species. However, macroinvertebrate sampling within Sandy Creek and its tributaries as part of the Dendrobium Area 2 baseline study (The Ecology Lab 2006b) has not identified this species. Nor has the macroinvertebrate sampling done by MPR (2002-2006) in Wongawilli Creek, Donalds Castle Creek, Native Dog Creek and other watercourses of the study area. Survey records for the Sydney area suggest the waterways of the study area do not support an established population of Adam's Emerald Dragonfly. Based on existing information, it is considered that this species is unlikely to occur within the study area. However, if a population of this species were to exist within the study area, it is unlikely that there would be any disruption to its lifecycle due to habitat degradation resulting from mine subsidence impacts. This conclusion is based on the prediction that any impacts such as sedimentation in riffles, water loss due to flow diversion into fractures, increased levels of ponding, flooding or scouring or degradation of water quality will be minor and localised in nature and will be unlikely to have a significant impact in the context of the available habitat within the study area (MSEC 2007 & Ecoengineers 2007).

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

To date, there are no threatened populations of Adams Emerald Dragonfly listed on the Schedules of the FM Act 1994. Thus, the proposal will not affect a threatened population as currently listed.

In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

1. *is likely to have an adverse effect on the extent of the ecological community such that it local occurrence is likely to be placed at risk of extinction, or*
2. *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction*

The Adams Emerald Dragonfly is not part of a listed endangered ecological community.

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

1. *the extent to which habitat is likely to be removed or modified as a result of the action proposed*

Survey records for the region indicate there is no viable population of Adams Emerald Dragonfly occurring in the study area. However, there is potential habitat in the area, particularly in Zone 3 of Wongawilli Creek. In the unlikely case that a population of this species does exist within the shaded riffle habitat of Wongawilli Creek, it is unlikely that this habitat will be removed or significantly modified by the development of Dendrobium Area 3 as predictions of mine subsidence effects on watercourses (MSEC 2007) and water quality (Ecoengineers 2007) indicate only local, minor impacts resulting from possible effects such as rock fracture, increased flooding, ponding and scouring, or degraded water quality.

2. *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*

The Adams Emerald Dragonfly has an adult life stage in which it is capable of flying. As such, it is not impacted by the effects of habitat fragmentation or isolation within a localised area such as Dendrobium Area 3. Furthermore, mine subsidence impacts are not predicted to result in flow diversion or pool draining within Wongawilli Creek that would lead to fragmentation of this potential habitat (MSEC 2007).

3. *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*

It is not expected that any habitat will be significantly removed, modified, fragmented or isolated within Wongawilli Creek as a consequence of mine subsidence.

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

No areas of critical habitat in relation to Adams Emerald Dragonfly have yet been listed on the Threatened Species Schedules of the *FM* Act 1994.

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

There is no recovery or threat abatement plan for the Adams Emerald Dragonfly.

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

The proposed action is not classed as a Key Threatening Process under the *FM* Act 1994, under which Adams Emerald Dragonfly is listed. However under the TSC Act,

1995, longwall mining resulting in the alteration of habitat has recently been listed as a Key Threatening Process. This does not define the action as a threatening process as described under the required assessment (seven-part test) for threatened species under the *FM* Act.

Conclusion

It is unlikely that a viable population of Adams Emerald Dragonfly exists within the study area. However, because of the presence of suitable habitat, this species has been considered. The proposed longwall mining of Dendrobium Area 3 does not pose a significant threat to a potential population provided future longwall layouts for Areas 3B and 3C maintain subsidence predictions for the main channel of Wongawilli Creek as those proposed for Area 3A. As such, the preparation of a Species Impact Statement as prescribed under the EP&A Act is not required. Aquatic macroinvertebrate monitoring has incorporated a procedure for the identification to family, genus and species of dragonfly larvae (Section 5.3.4) as a precautionary measure.

5.0 MONITORING PLAN

A comprehensive monitoring plan designed to assess the potential impacts of mine subsidence on aquatic habitat and biota within watercourses of the Dendrobium Area 3 mine area is outlined below. This monitoring plan complies with the Dendrobium Consent, the Director General's Requirements (DoP) to modify the Dendrobium Area 3 mine area and supports an application to the Department of Primary Industries for SMP approval for mining within Area 3A. It assesses and measures potential impacts on habitats, biodiversity and threatened species from the mining and associated activities.

This monitoring plan incorporates baseline sampling to be conducted in impact and control locations four times within a 12 months period, prior to the commencement of longwall mining. 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. A temporally staged approach to monitoring would be adopted such that impact and control locations relevant to each of Areas A, B and C are monitored over a 12 month period prior to that area's development.

There is also a specific fish survey program for Wongawilli Creek designed to target the threatened species Macquarie Perch.

5.1 Monitoring Within Each Watercourse

On the basis of habitat assessment of the watercourses within the proposed maximum footprint of Dendrobium Mine Area 3, it is considered appropriate and practical to undertake monitoring in watercourses rated as "significant" and "moderate" aquatic habitat. On the basis of recent and previous field investigations the following potential sampling locations distributed across the relevant watercourses have been identified and are illustrated in Figure 2. At each location all of the sampling methodologies indicated in Section 5.3 will be undertaken, with the exception of the mapping of aquatic plants which will only be done if instream plants are present. All watercourses considered below are suitable for AusRivAS assessment which requires 100 metres of watercourse. However, it is possible that some of these sites may be sufficiently reduced in extent due to prolonged dry weather that AusRivAS sampling may not be possible at these times. Proposed location names and corresponding water feature reference codes as determined by BHPIC are given for each proposed location.

5.1.1 Wongawilli Creek Catchment

The Wongawilli Creek catchment contains the greatest proportion of "significant" and "moderate" aquatic habitat within the study area. As such the greatest monitoring effort will be directed toward this watercourse. Appropriate monitoring methods are outlined below in terms of the four zones of Wongawilli Creek as defined in Section 3.1.

Wongawilli Zone 1

Three locations (AQ 8-11, Figure 2) will be established within the main drainage of Zone 1 of Wongawilli Creek. The most downstream of these would be on the edge of the maximum proposed footprint, close to Fire Road 6 (WC-PO 13). The other locations would be within the proposed footprint (WC-PO-21 & 27). As Zone 1 lies entirely within Area 3C baseline

sampling is not expected to commence for several years. The exact positions of sampling sites within Zone 1 will be finalised when the longwall layouts for 3C are known.

Wongawilli Zone 2

Two locations will be established within Zone 2 of Wongawilli Creek and a third location will be established within tributary WC21 (AQ 5-7, Figure 2). Zone 2 incorporates Areas 3A, B and C, and as such, baseline monitoring of the most downstream location (WC-PO 37) will commence 12 months prior to the commencement of mining in Area 3C. The most upstream location (WC-PO 43) is to be within the General SMP area for Area 3A, and this will also be relevant for Area 3B. Final site selection and baseline monitoring for this location is scheduled to commence in Spring of 2007 or Autumn of 2008. The location within tributary WC21 is downstream of Area 3B. Baseline monitoring for this location commence in late 2008 or early 2009.

Wongawilli Zone 3

Two locations will be established within Zone 3 of Wongawilli Creek and a third will be established within tributary WC15 (AQ 2-4), Figure 2).

The most downstream location (WC-PO 45) is within the General SMP area for Area 3A, and this will also be relevant for Area 3B. Final site selection and baseline monitoring is scheduled to commence in Spring of 2007 or Autumn of 2008. The upstream location (WC-PO 50) and tributary WC15 location are relevant to Area 3B. Baseline monitoring for these locations are scheduled to commence in late 2008 or early 2009.

Wongawilli Zone 4

One locations will be established within Zone 4 of Wongawilli Creek (AQ1, Figure 2). This location (WC-PO 55) is relevant to Area 3B only and baseline monitoring is scheduled to commence in late 2008 or early 2009.

5.1.2 Sandy Creek Catchment

The Sandy Creek catchment contains limited "significant" and "moderate" aquatic habitat within the study area. Existing monitoring sites used for the assessment of Dendrobium Area 2 are also appropriate for this monitoring plan and will be continued for the mining in Area 3. Four locatations are to be established within Sandy Creek catchment (AQ 12 – 14, Figure 2). Two are to be located within the main channel of Sandy Creek (SC-PO 5 -10 and SC-PO 14 -15) and one in each of the relevant tributaries (Banksia Creek and Cascade Creek). All of these sites are within the General SMP Area for Area 3A. Baseline monitoring for some these locations has already commenced as part of Dendrobium Area 2 studies and are scheduled to continue in Spring of 2007 or Autumn of 2008 in accordance with sampling in other control and impacted watercourses.

5.1.3 Donalds Castle Creek, Lake Cordeaux and Cordeaux River Tributaries

One monitoring location will be established within each of Donalds Castle Creek (AQ11, Figure 2), tributaries LC6 and LC7 of Lake Cordeaux, and tributary CR3 of the Cordeaux River. Donalds Castle Creek lies partially within Area 3B, and the location of the monitoring location will be finalised once the mine layouts are confirmed for Area 3B. Baseline sampling in this creek will be undertaken prior to the commencement of the mining in this

area. All of the above watercourses lie within Area 3C and the positions of the monitoring locations in this area will be finalised when the longwall layouts for Area 3C is developed.

5.1.4 Selection of Control Locations

Potential control locations have been identified within the catchments of Loddon Creek (Cataract River Catchment) and O'Hares Creek (Georges River Catchment). These watercourses have similar sized catchments, geology and surrounding landuse as Wongawilli Creek, and have numerous tributaries that would provide appropriate control locations for the tributaries being monitored. Further investigation of appropriate control locations is to be undertaken.

5.2 Spring 2007 Fish Survey of Wongawilli Creek

An intensive fish survey of the full reach of Wongawilli Creek from the confluence of the Cordeaux River upstream to the large waterfall (Site 4 – Figure 1) is planned to be undertaken during spring 2007 to coincide with possible spawning activity of Macquarie Perch. The aim of this survey is to determine if Macquarie Perch are able to access and utilise aquatic habitat within the proposed Area 3 footprint. This survey is to be undertaken using backpack electrofishing equipment and visual observations.

The survey is specifically designed to determine the distribution of Macquarie Perch within Wongawilli Creek. It will complement the ongoing monitoring of fish proposed at selected sites within Area 3 and at control locations

5.3 Sampling Methods

The sampling methods outlined in this section are recommended for assessment of aquatic impacts within Area 3. This approach has been developed for and used in Dendrobium Areas 1 and 2 and represents current best practice in ecological monitoring. Specific methods used in each watercourse have been selected on the basis of the assessment of aquatic habitat (Section 3). Where sampling locations are selected, they will consist of two replicate sites, each consisting of 100 metres of watercourse and separated by at least 100 metres.

5.3.1 Habitat Assessment

Habitat features recorded will include:

- Instream features such as sequence of pools, runs and riffles,
- Stream substratum and bank structure,

A photographic record will also be made of the habitat within each site.

5.3.2 Water Quality

Water quality will be measured at each site using a Yeo-Kal 611 probe. Variables to be measured include; pH, dissolved oxygen, oxidation-reduction potential, temperature, turbidity and conductivity. Two replicate measures will be taken from the surface and the bottom of pools within each site. Where applicable, the results will be compared to

ANZECC (2000) water quality guidelines for the protection of aquatic ecosystems. It should be noted that extensive water quality sampling and analysis is being undertaken by Ecoengineers. The water quality sampling undertaken by The Ecology Lab is used to assist with the interpretation of differences in biotic assemblages.

5.3.3 Fish

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

5.3.4 Macroinvertebrates

Quantatative Sampling

Macroinvertebrates from a three metre section of stream edge habitat will be sampled using a dip net. Three replicate samples will be collected from each site. The samples will be preserved in alcohol in the field and transported to the laboratory for sorting and identification.

Macroinvertebrate Collector Sampling

The Ecology Lab is currently developing a quantitative method to sample macroinvertebrates within stream habitats using collectors composed of a standardized artificial substratum deployed for a specified period of time. Upon retrieval the collectors and contents are stored in alcohol and transported to the laboratory for sorting and identification. This method may be used in preference to quantitative dip net sampling depending upon forthcoming results from trials of this method.

AusRivAS

At each site macroinvertebrates will also be sampled using the AusRivAS protocol developed under the National River Health Program. Where available, riffle and edge habitats will be sampled using a dip net along a 10m stretch of habitat. These samples will be sorted in the field, preserved in alcohol and transported to the lab for identification.

The AusRivAS methodology and predictive model requires that sampling be done in Autumn (April 15 to June 15) and/or Spring (Oct 15 to Dec 15).

Threatened Species

In consideration of the possible but unlikely presence of two threatened macroinvertebrate species (Adams Emerald Dragonfly and Sydney Hawk Dragonfly) within the study area (Section 2.7). All dragonfly larvae collected in invertebrate sampling will be identified to the taxanomic level of family. Any individuals of the genus *Austrocorduliidae* or *Gomphomacromiidae* will be further identified to genus and species level if possible, and if there is any confusion, specimens will be referred to a specialist taxonomist. The confirmed presence of a threatened species will trigger further investigation into this species and its habitats in relation to potential subsidence impacts.

5.3.5 Aquatic Macrophytes

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

6.0 MANAGEMENT MEASURES

The aquatic ecology monitoring program outlined in Section 5 has been designed to detect and determine the extent and nature of impacts on aquatic habitat and biota resulting from mine subsidence impacts within watercourses. Impacts on aquatic ecology are considered as 'secondary' impacts, as they are flow-on effects of 'primary' physical and chemical impacts directly resulting from mine subsidence. Changes in aquatic habitat and biota detected through the aquatic monitoring program therefore need to be considered within the context of primary physical and chemical impacts. Monitoring undertaken for Dendrobium Areas 1 and 2 has successfully incorporated integrated management measures for aquatic habitat and biota involving triggers and appropriate response actions if primary impacts within watercourses are detected. Primary impacts detected within watercourses by routine surface monitoring that would constitute a trigger for further investigation into potential impacts on the aquatic ecology include:

- Rockbar fracture resulting in water loss in a pool within an area of 'significant' or 'moderate' aquatic habitat; and
- Significant change in water chemistry (particulary pH, dissolved oxygen, turbidity, or metal concentration) within an area of 'significant' or 'moderate' aquatic habitat.

Other observations made during routine surface monitoring that would constitute a trigger for further investigation of the aquatic ecology include:

- fish/crayfish kills,
- die-off of macrophyte beds,

These triggers would initiate a rapid response aquatic monitoring plan. This would neccessitate a sampling event (as described in Section 5) being undertaken as soon as possible to determine the nature and extent (if any) of secondary impacts on aquatic ecology flowing on from primary impact triggers. Analysis of the level of impact would then determine appropriate response which may include rehabilitation of aquatic habitat as appropriate. This would be undertaken in conjunction with any mitigative works (e.g. grouting) which may be required. Such restorative actions would be subject to further monitoring to determine the success of recovery in comparison to baseline data.

The aquatic monitoring program incorporates monitoring events throughout the duration of mine working regardless of observed primary impacts within watercourses. Analysis of data from these 'during mining' sampling times can also provide triggers for further investigation. However these need to be considered with caution and in the context of primary mine subsidence impacts. These triggers include:

- Statistically significant changes in aquatic macroinvertebrate assemblages associated with observed mine subsidence impacts.
- Reduction in stream health as determined using the AusRivAS model for sites associated with observed mine subsidence impacts.
- Statistically significant change in the coverage of aquatic macrophytes associated with observed mine subsidence impacts.
- Detectable change in fish and crayfish diversity and/or abundance associated with mine subsidence impacts.

Response actions to such triggers would vary depending on the nature of the impact, and may range from continued monitoring to determine the nature, timing and extent of recovery, to active rehabilitation in conjunction with other mitigative works such as grouting of rock bar fractures.

7.0 CONCLUSIONS

This study has established that there is "significant" aquatic habitat along the main channel of Wongawilli Creek and in the mid to lower reaches of Sandy Creek. Some of the tributaries of Wongawilli Creek (WC 21, WC 15, WC10, WC4 and WC5), the upper reaches of Sandy Creek, Banksia Creek downstream of Swamp 15 A, a reach of Cascade Creek within the General SMP Area, a reach of Donalds Castle Creek upstream to Swamp 5, and the lower reach of tributary CR2 which feeds into the Cordeaux River have been categorized as having "moderate" aquatic habitat. The other tributaries generally have either "minimal" or "unlikely" aquatic habitat.

The assessment of subsidence-induced impacts provided by MSEC (2007) indicates that only minor fracturing will occur along the reaches of Wongawilli and Sandy Creeks overlying Dendrobium Area 3 and that significant diversion of surface flow is unlikely. Some fracturing is also expected to occur along the ephemeral drainage lines overlying Area 3A (i.e. WC 17 and Banksia Creek). This fracturing could lead to sudden drainage of pools and rapid drops in surface water flow. This could have a substantial local impact on aquatic habitats and their biota, particularly on organisms left stranded in air or unable to move to areas that are damp or submerged. Fracturing of bedrock and diversion of surface flows can also result in geochemical changes in water quality due to the weathering and leaching of minerals. Increased groundwater contributions to these streams can also impact on surface water flow quality. Ecoengineers (2007) have concluded that there are unlikely to be significant geochemical changes in water quality within Wongawilli, Sandy or Donalds Castle Creeks, but that changes may occur in some of the tributaries streams in the area. The latter changes could have a minor, localised impact on the biota, but are unlikely to persist if flows are relatively high and constant. Subsidence may cause minor erosion, particularly on steep slopes such as those along the main channel and tributaries of Wongawilli Creek in Area 3A, draining the western side of Area 3B to the Native Dog Creek Arm of Lake Avon and on the eastern side of Area 3C draining to Lake Cordeaux. These erosion events may result in minor, localised, and short-lived increases in turbidity within some watercourses.

It has been established that four threatened species, Sydney hawk dragonfly, Adams emerald dragonfly, Macquarie Perch and Australian grayling, could potentially occur in Dendrobium Area 3. Only Macquarie Perch have been recorded within the study area. Suitable habitat does, however, exist for the two dragonfly species. Assessments of impact undertaken for these species indicate that the proposed longwall mining does not pose a significant threat, provided that the future longwall layouts for Areas 3B and 3C maintain similar subsidence predictions for the main channel of Wongawilli Creek as those proposed in Area 3A.

The detection of primary impacts, such as rockbar fractures resulting in water loss in a pool within an area of 'significant' or 'moderate' aquatic habitat or significant changes in water chemistry within such areas, would trigger investigations into potential impacts on aquatic ecology. Observations of fish/crayfish kills or die-off of macrophyte beds would trigger a rapid response aquatic monitoring plan to determine the nature and extent of secondary impacts on aquatic ecology. The level of impact found would determine the type of response. Significant changes in aquatic biota detected 'during mining' monitoring events would also provide triggers for further investigation. The implementation of such management measures would help reduce impacts on aquatic ecology.

8.0 ACKNOWLEDGEMENTS

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TABLES

Table 1: Summary of existing information on aquatic ecology in the vicinity of Dendrobium Area 3

Component Studied	Location	Source
Aquatic Habitats	Sandy Creek, Streams LC4 and LC5 and Wongawilli Creek downstream of Dendrobium Area 3	The Ecology Lab (2001a)
	Waterways flowing into Arms 1, 2 and 3, Lake Cordeaux	The Ecology Lab (2001b)
	Upper reach of Cordeaux River above Longwall 14, Delta Colliery	The Ecology Lab (2005)
	Vicinity of Longwall 17, Delta Colliery	The Ecology Lab (2006a)
Water Quality	Wongawilli, Native Dog and Donalds Castle Creek catchments	Ecoengineers (2003, 2004a and b, 2006, 2007)
	Wongawilli Creek downstream of Longwalls 14 and 17, Delta Colliery and drainages from swamps in vicinity of the longwalls	Ecoengineers (2007)
Macroinvertebrates	Wongawilli, Native Dog, Donalds Castle and several un-named creeks in vicinity of Elouera Colliery draining into Cordeaux River	MPR (2002, 2003 a and b, 2004, 2005, 2006a, b and c)
	Wongawilli Creek near Fire Trail 6A	Ecowise Environmental (2005)
	Sandy, Banksia and Cascade Creeks	The Ecology Lab (2006b)
	Vicinity of Longwall 17, Delta Colliery	The Ecology Lab (2006a)
Fish	Lake Cordeaux	Gehrke and Harris (1996), Growns and Gehrke (2001), Creese and Hartley (2003)
	Goondarrin and Kembla Creeks	The Ecology Lab (2004)
	Sandy Creek and Cordeaux River arms of Lake Cordeaux	The Ecology Lab (2006b)
	Wongawilli Creek	The Ecology Lab (2001), MPR (2002, 2003a and b, 2004, 2005, 2006a, b and c)

Table 2: Assessments of the condition of aquatic macroinvertebrate fauna in the vicinity of Dendrobium Area 3 derived from AUSRIVAS predictive models.

Location	General Condition of Fauna
Sites within Dendrobium Area 3	Similar to AUSRIVAS reference condition, but classed as richer than reference condition or significantly impaired on some occasions.
Sites within Wongawilli Creek above or close to Elouera Colliery	Significantly impaired at the two most upstream sites, but similar to AUSRIVAS reference condition at the third site and varying from equivalent to reference condition to severely impaired at the fourth site.
Wongawilli Creek near Fire Trail 6A	Similar to AUSRIVAS reference condition.
Banksia Creek	Significantly impaired
Sandy and Cascade Creeks	Varied from similar to AUSRIVAS reference condition to significantly impaired.

Table 3: Species of fish recorded in watercourses in the vicinity of Dendrobium Area 3

Watercourse	Fish Species						
	Long-finned eel *Anguilla reinhardtii*	Short-finned eel *Anguilla australis*	Australian smelt *Retropinna semoni*	Macquarie Perch *Macquaria australasica*	Goldfish *Carassius auratus*	Mountain galaxids *Galaxias olidus*	Climbing galaxias *Galaxias brevipinna*
Lake Cordeaux	X	X	X	X	X	X	
Goondarrin and Kembla Creeks	X	X	X		X	X	
Sandy Creek				X		X	
Cordeaux River Arm of Lake Cordeaux				X			
Wongawilli Creek (mid to lower reaches)	X		X	X		X	X
Donalds Castle Creek			X			X	

Table 4. GPS locations for Dendrobium Area 3 habitat inspection sites in July 2007

TEL Site Name	Watercourse	WGS 84		TEL Site Name	Watercourse	WGS 84	
		Eastings	Northings			Eastings	Northings
1	WC5	290805	6189926	33	WC26	290644	6195464
2	Wongawilli Creek	290682	6189528	34	Wongawilli Creek	290678	6195681
3	Wongawilli Creek	290763	6190279	35	WC28	290888	6195834
4	Wongawilli Creek	290785	6190394	36	WC27	290720	6195846
5	WC8	291000	6190550	37	Wongawilli Creek	290913	6195918
6	WC7	290890	6190560	38	WC29	290954	6195952
7	Wongawilli Creek	290953	6190592	39	Wongawilli Creek	290907	6196574
8	WC9	290956	6190822	40	Wongawilli Creek/WC30	291010	6196935
9	WC10	291141	6191135	41	Wongawilli Creek	291010	6197122
10	WC11	291199	6191377	42	WC31	290988	6197203
11	WC12	291037	6191476	43	Wongawilli Creek	290962	6197400
12	WC13	291153	6191704	44	Wongawilli Creek	290992	6197710
13	WC14	291137	6192246	45	Wongawilli Creek	291040	6197915
14	Wongawilli Creek	290957	6192449	46	Wongawilli Creek/CR2/C	291081	6197975
15	WC15	290900	6192451	47	Sandy Creek	293677	6191265
16	WC16	290900	6192880	48	Sandy Creek	293730	6191463
17	WC17	290970	6192950	49	Cascade Creek	293543	6191740
18	Wongawilli Creek	290867	6192994	50	Cascade Creek	293705	6191793
19	Wongawilli Creek	290775	6193025	51	Sandy Creek	293848	6192330
20	WC18	290750	6193223	52	Banksia Creek	293531	6192476
21	WC19	290865	6193640	53	Banksia Creek	293686	6192524
22	Wongawilli Creek	290841	6193709	54	Sandy Creek	293811	6192551
23	Wongawilli Creek	290697	6193991	55	Donalds Castle Creek	289558	6193764
24	WC20	290742	6194132	56	Donalds Castle Creek	289676	6194137
25	WC21	290451	6194206	57	Donalds Castle Creek	289394	6195355
26	WC21	290555	6194282	58	Donalds Castle Creek	289394	6195472
27	WC22	290531	6194553	59	ND9C	289117	6190349
28	WC23	290624	6194816	60	LC5	292658	6195136
29	WC24	290710	6194820	61	CR3	291500	6197520
30	Wongawilli Creek	290643	6195126	62	CR1	292204	6197538
31	WC25	290563	6195307				
32	Wongawilli Creek	290581	6195421				

Table 5: Mean and standard error (SE) values for water quality variables measured at Dendrobium Area 3 inspection sites (July 2007). Recommended ANZECC guidelines (2000) values for upland rivers are included after some variables.Values highlighted in bold are those which were outside the recommended guidelines.

	Site 1		**Site 2**		**Site 3**		**Site 4**		**Site 5**	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	6.16	0.02	13.38	0.00	no data		no data		no data	
pH (6.5 - 7.5)	**5.84**	0.02	**5.26**	0.00						
Salinity (ppt)	0.05	0.00	0.07	0.00						
Conductivity (µS/cm) (30-350)	55.00	0.00	79.00	0.00						
Conductivity (mS/cm)	0.10	0.00	0.10	0.00						
Turbidity (ntu) (2 - 25)	**35.67**	2.18	**-0.30**	0.00						
DO (mg/L)	12.10	0.20	10.15	0.05						
DO (%saturation) (90 - 110)	97.00	1.20	97.15	0.25						
ORP (mV)	323.50	0.50	369.00	0.00						

	Site 6		**Site 7**		**Site 8**		**Site 9**		**Site 10**	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	no data		no data		no data		7.18	0.01	no data	
pH (6.5 - 7.5)							**5.94**	0.01		
Salinity (ppt)							0.05	0.00		
Conductivity (µS/cm) (30-350)							73.00	0.00		
Conductivity (mS/cm)							0.10	0.00		
Turbidity (ntu) (2 - 25)							**29.33**	0.06		
DO (mg/L)							11.70	0.10		
DO (%saturation) (90 - 110)							96.70	0.80		
ORP (mV)							360.00	1.00		

	Site 11		**Site 12**		**Site 13**		**Site 14**		**Site 15**	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	no data		no data		no data		6.46	0.01	no data	
pH (6.5 - 7.5)							**5.72**	0.01		
Salinity (ppt)							0.05	0.00		
Conductivity (µS/cm) (30-350)							74.00	0.00		
Conductivity (mS/cm)							0.10	0.00		
Turbidity (ntu) (2 - 25)							**28.65**	0.63		
DO (mg/L)							11.90	0.14		
DO (%saturation) (90 - 110)							96.25	1.061		
ORP (mV)							376.00	1.414		

	Site 16		Site 17		Site 18		Site 19		Site 20	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	no data		no data		6.32	0.02	no data		no data	
pH (6.5 - 7.5)					**5.89**	0.02				
Salinity (ppt)					0.05	0.00				
Conductivity (µS/cm) (30-350)					65.00	0.00				
Conductivity (mS/cm)					0.10	0.00				
Turbidity (ntu) (2 - 25)					**31.97**	0.54				
DO (mg/L)					11.45	0.15				
DO (%saturation) (90 - 110)					92.35	0.85				
ORP (mV)					299.50	3.50				

	Site 21		Site 22		Site 23		Site 24		Site 25	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	no data		no data		6.21	0.02	no data		no data	
pH (6.5 - 7.5)					**6.13**	0.01				
Salinity (ppt)					0.05	0.00				
Conductivity (µS/cm) (30-350)					67.50	2.50				
Conductivity (mS/cm)					0.10	0.00				
Turbidity (ntu) (2 - 25)					**32.00**	0.05				
DO (mg/L)					11.15	0.05				
DO (%saturation) (90 - 110)					**89.80**	0.70				
ORP (mV)					220.00	5.00				

	Site 26		Site 27		Site 28		Site 29		Site 30	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	6.43	0.01	no data		6.97	0.00	no data		no data	
pH (6.5 - 7.5)	**5.78**	0.01			**5.76**	0.01				
Salinity (ppt)	0.08	0.00			0.08	0.00				
Conductivity (µS/cm) (30-350)	89.00	0.00			123.00	0.00				
Conductivity (mS/cm)	0.11	0.09			0.20	0.00				
Turbidity (ntu) (2 - 25)	23.23	0.06			20.37	0.90				
DO (mg/L)	11.45	0.05			10.05	0.05				
DO (%saturation) (90 - 110)	92.85	0.45			**82.55**	0.35				
ORP (mV)	348.00	1.00			336.00	1.00				

	Site 31		Site 32		Site 33		Site 34		Site 35	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	6.90	0.01	no data		no data		6.57	0.06	no data	
pH (6.5 - 7.5)	**6.43**	0.46					**6.16**	0.00		
Salinity (ppt)	0.11	0.00					0.05	0.00		
Conductivity (µS/cm) (30-350)	157.00	0.00					74.00	0.00		
Conductivity (mS/cm)	0.20	0.00					0.10	0.00		
Turbidity (ntu) (2 - 25)	2.95	0.18					**0.92**	0.02		
DO (mg/L)	10.90	0.00					10.80	0.00		
DO (%saturation) (90 - 110)	**89.45**	0.25					**87.90**	0.30		
ORP (mV)	303.50	0.50					254.00	1.00		

	Site 36		Site 37		Site 38		Site 39		Site 40	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	6.33	0.02	6.32	0.02	no data		no data		no data	
pH (6.5 - 7.5)	**5.97**	0.01	**6.12**	0.00						
Salinity (ppt)	0.11	0.00	0.05	0.00						
Conductivity (µS/cm) (30-350)	180.00	0.00	75.00	0.00						
Conductivity (mS/cm)	0.20	0.00	0.10	0.00						
Turbidity (ntu) (2 - 25)	**0.67**	0.05	**0.30**	0.00						
DO (mg/L)	10.05	0.05	10.25	0.05						
DO (%saturation) (90 - 110)	**81.20**	0.20	**82.60**	0.50						
ORP (mV)	296.00	2.00	258.00	0.00						

	Site 41		Site 42		Site 43		Site 44		Site 45	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	6.93	0.01	no data		8.39	0.02	8.34	0.02	8.72	0.07
pH (6.5 - 7.5)	**6.18**	0.01			**6.19**	0.01	**6.23**	0.03	**6.41**	0.01
Salinity (ppt)	0.05	0.00			0.07	0.02	0.08	0.00	0.08	0.00
Conductivity (µS/cm) (30-350)	73.00	0.00			75.00	0.00	75.50	0.50	74.50	0.50
Conductivity (mS/cm)	0.10	0.00			0.15	0.05	0.20	0.00	0.20	0.00
Turbidity (ntu) (2 - 25)	**0.08**	0.00			**29.10**	0.35	**47.12**	2.13	14.80	0.06
DO (mg/L)	10.85	0.07			11.05	0.05	11.75	0.05	11.65	0.05
DO (%saturation) (90 - 110)	**89.10**	0.42			93.80	0.70	99.60	0.80	99.85	0.35
ORP (mV)	290.00	1.41			253.00	1.00	215.50	0.50	192.50	0.50

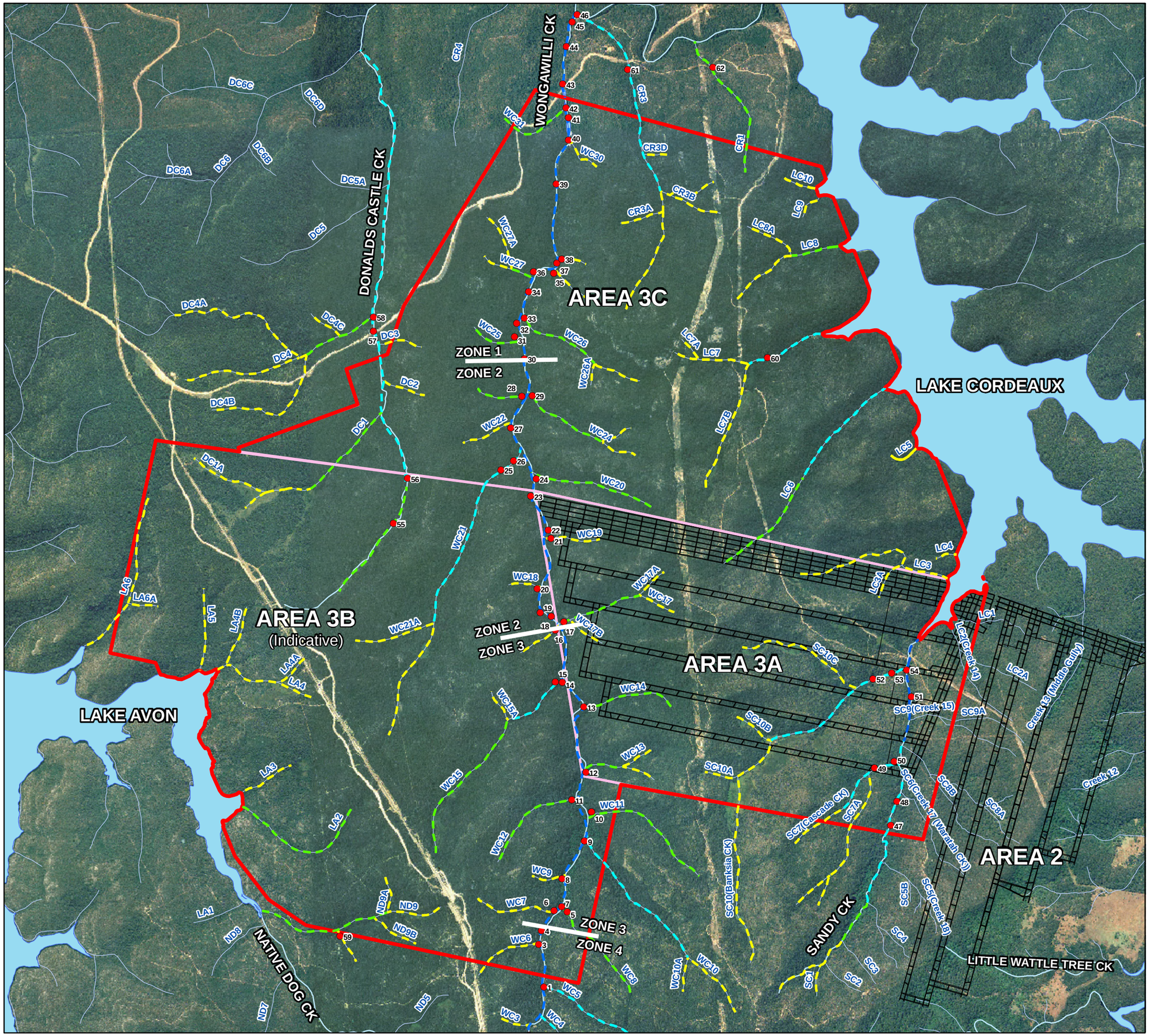
	Site 46		Site 47		Site 48		Site 49		Site 50	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	7.53	0.02	no data		no data		no data		no data	
pH (6.5 - 7.5)	6.87	0.01								
Salinity (ppt)	0.08	0.00								
Conductivity (µS/cm) (30-350)	82.00	0.00								
Conductivity (mS/cm)	0.20	0.00								
Turbidity (ntu) (2 - 25)	**61.78**	2.67								
DO (mg/L)	11.75	0.15								
DO (%saturation) (90 - 110)	97.40	1.30								
ORP (mV)	152.50	7.50								

	Site 51		Site 52		Site 53		Site 54		Site 55	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	no data		no data		no data		no data		7.30	0.04
pH (6.5 - 7.5)									**5.69**	0.05
Salinity (ppt)									0.05	0.00
Conductivity (µS/cm) (30-350)									73.00	0.00
Conductivity (mS/cm)									0.10	0.00
Turbidity (ntu) (2 - 25)									19.15	0.11
DO (mg/L)									9.95	0.15
DO (%saturation) (90 - 110)									**82.35**	1.05
ORP (mV)									377.00	1.00

	Site 56		Site 57		Site 58		Site 59		Site 60	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Temperature (^{0}C)	9.16	0.00	8.34	0.26	no data		10.65	0.01	8.70	0.01
pH (6.5 - 7.5)	**5.28**	0.00	**5.57**	0.00			**5.28**	0.00	**5.73**	0.01
Salinity (ppt)	0.05	0.00	0.08	0.00			0.07	0.00	0.08	0.00
Conductivity (µS/cm) (30-350)	74.00	0.00	90.00	0.00			94.00	0.00	94.00	0.00
Conductivity (mS/cm)	0.10	0.00	0.20	0.00			0.10	0.00	0.20	0.00
Turbidity (ntu) (2 - 25)	25.00	0.34	**28.65**	0.08			**1.18**	0.13	19.95	0.16
DO (mg/L)	10.85	0.05	10.35	0.05			7.40	0.00	10.75	0.05
DO (%saturation) (90 - 110)	93.80	0.20	**87.45**	0.35			**66.45**	0.25	92.00	0.50
ORP (mV)	394.50	0.50	333.00	1.00			380.00	3.00	353.50	0.50

	Site 61		Site 62	
Variable	Mean	SE	Mean	SE
Temperature (^{0}C)	8.43	0.02	10.98	0.00
pH (6.5 - 7.5)	**6.30**	0.01	**6.02**	0.00
Salinity (ppt)	0.08	0.00	0.07	0.00
Conductivity (µS/cm) (30-350)	90.00	0.00	77.50	2.50
Conductivity (mS/cm)	0.20	0.00	0.10	0.00
Turbidity (ntu) (2 - 25)	**34.85**	0.08	2.40	0.15
DO (mg/L)	10.65	0.05	10.90	0.00
DO (%saturation) (90 - 110)	90.35	0.45	98.85	0.15
ORP (mV)	230.50	1.50	295.50	1.50

FIGURES



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Aquatic Habitat and Field Survey Points Within Watercourses

DENDROBIUM AREA 3

Legend

- Field Survey Point
- Unlikely Habitat
- Minimal Habitat
- Moderate Habitat
- Significant Habitat
- Mine Layout
- Rivers & Creeks
- Lakes
- SMP Area
- Study Area

N
W E
S

FIGURE 1

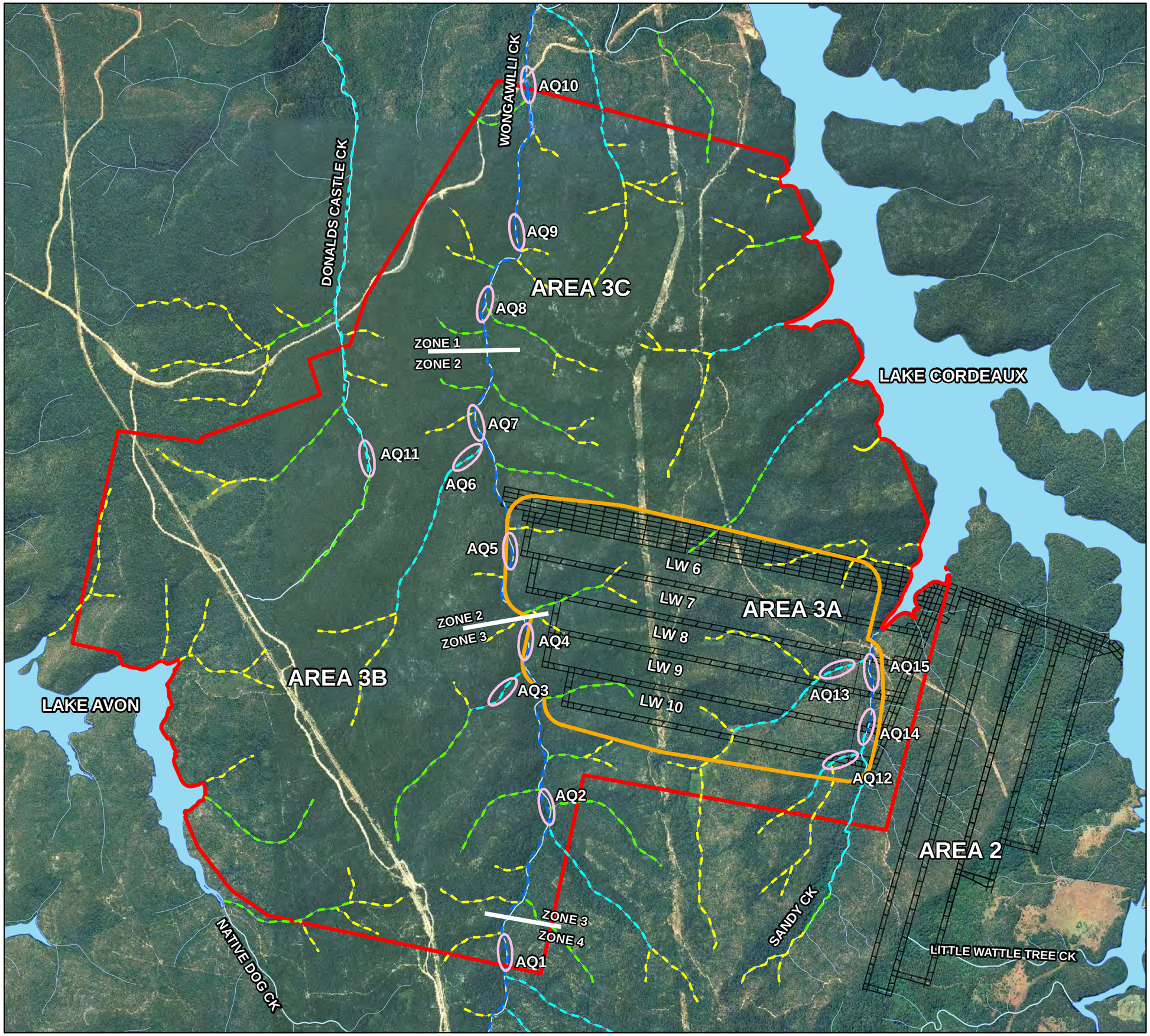
Scale 1:30,000 (at A3)

Metres

0 250 500 1,000 1,500

The Ecology Lab Pty Ltd

Map Produced by Cardno Forbes Rigby
Date: 11 October 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055_01_1821_aquatic_habitat_plan.mxd



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Proposed Aquatic Monitoring Locations

DENDROBIUM AREA 3

Legend

- Unlikely Habitat
- Minimal Habitat
- Moderate Habitat
- Significant Habitat
- Mine Layout
- Rivers & Creeks
- Lakes
- Proposed Aquatic Monitoring Locations
- Area 3A SMP Area
- Study Area

N
W E
S

FIGURE 2

Scale 1:30,000 (at A3)

Metres

0 250 500 1,000 1,500 2,000

The Ecology Lab Pty Ltd

Map Produced by Cardno Forbes Rigby
Date: 27 September 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055_01_1824_EIA_ecolab_aquatic_habitat_plan.mxd

PLATES

Plate 1a: Waterfall-rockbar in Wongawilli Creek (zone 1) at the confluence with the Cordeaux River.

Plate 1b: Large, deep pool (Site No. 44) in Wongawilli Creek (zone 1) downstream of Fire Road 6 – upstream view. Macquarie Perch sampled in this pool by NSW Fisheries in 2001.

Plate 2a: Large deep pool(Site No. 43) in Wongawilli Creek (zone 1) upstream of Fire Road 6 – upstream view. Macquarie Perch sampled in this pool by The Ecology Lab in 2001 and observed in 2004.

Plate 2b: Large rockbar (Site No. 40) on Wongawilli Creek (zone 1) upstream of Fire Road 6 – upstream view. Macquarie Perch have not been reported upstream of this rockbar in any published surveys to date.

Plate 3a: Small rockbar and pool (Site No. 39) in Wongawilli Creek (zone 1) – downstream view.

Plate 3b: Large deep pool (Site No. 37) in Wongawilli Creek (zone 1) – upstream view.

Plate 4a: Large deep pool and rockbar (Site No. 34) in Wongawilli Creek (zone 1) – upstream view.

Plate 4b: Rockbar and pool (Site No. 32) in Wongawilli Creek (zone 1) –upstream view.

Plate 5a: Pool and rockbar (Site No. 30) in Wongawilli Creek (upstream limit of zone 1). Upstream view.

Plate 5b: Tributary WC 26 of Wongawilli Creek (zone 1) – upstream view. This tributary has the largest sub-catchment within zone 1 and has been classified as minimal aquatic habitat.

Plate 6a: Pool (Site No. 23) in Wongawilli Creek (zone 2) – downstream view.

Plate 6b: Pool (Site No. 22) in Wongawilli Creek (zone 2) – upstream view.

Plate 7a: Flood debris within Wongawilli Creek (zone 2) deposited in large rainfall events of June 2007.

Plate 7b: Pool at base of waterfall in tributary WC21 of Wongawilli Creek (zone 2) – upstream view. This tributary contains the largest sub-catchment within zone 2 and has been classified as moderate aquatic habitat.

Plate 8a: Waterfall within tributary WC21 of Wongawilli Creek (zone 2) – upstream view. This waterfall is considered a major barrier to Macquarie Perch passage upstream.

Plate 8b: Wongawilli Creek at the downstream extent of zone 3 – upstream view. Note sand-gravel-pebble stream substratum.

Plate 9a: Stream channel within Wongawilli Creek (zone 3) – upstream view. Note extensive shading of the channel from rainforest canopy.

Plate 9b: Sand bar within Wongawilli Creek (zone 3) – upstream view.

Plate 10a: Tributary WC15 of Wongawilli Creek (zone 3) – upstream view. Waterfall is a major barrier to upstream migration of Macquarie Perch.

Plate 10b: Tributary WC 10 of Wongawilli Creek (zone 3) – upstream view.

Plate 11a: Large waterfall on Wongawilli Creek which is the demarkation between zone 3 and zone 4. This waterfall is considered an absolute barrier to Macquarie Perch passage upstream.

Plate 11b: Rockbar and pool (Site No. 3) in Wongawilli Creek (zone 4) – upstream view.

Plate 12a: Pool in Wongawilli Creek (zone 4) – upstream view.

Plate 12b: Rockbar and Pool (Site No. 2) in Wongawilli Creek (zone 4) – upstream view.

Plate 13a: Sandtone bedrock bar in Wongawilli Creek (zone 4), note the freshly exposed sandstone.

Plate 13b: Tributary WC5 of Wongawilli Creek (zone 4) – upstream view. This tributary and its catchment is upstream of the proposed mine footprint.

Plate 14a: Sandy Creek waterfall. This waterfall is considered an absolute barrier to Macquarie Perch migration upstream.

Plate 14b: Pool in Sandy Creek upstream of Fire Road 6C crossing – view upstream.

Plate 15a: Sandy Creek (mid-reach) – view downstream. Note the gravel-pebble substratum of the riffle.

Plate 15b: Sandy Creek (upper reach) – view upstream. Photo taken during baseline sampling for Dendrobium Area 2.

Plate 16a: Pool on Banksia Creek near confluence with Sandy Creek – view upstream.

Plate 16b: Pool and rockbar on Banksia Creek – view upstream.

Plate 17a: Cascade Creek near the confluence with Sandy Creek – view upstream.

Plate 17b: Pool in upstream Cascade Creek – view upstream.

Plate 18a: Donalds Castle Creek at the confluence of tributary DC4 – view downstream.

Plate 18b: Donalds Castle Creek at the Fire Road 6 crossing – view upstream.

Plate 19a: Donalds Castle Creek at the outflow of swamp 5 – view upstream.

Plate 19b: Tributary ND9 of Native Dog Creek – view downstream.

Plate 20a: Tributary CR1 of the Cordeaux River (downstream of dam) – view upstream.

Plate 20b: Tributary CR3 of the Cordeaux River (downstream of dam) – view upstream.

Plate 21a: Tributary LC6 of Lake Cordeaux – view downstream.

Plate 21b: Tributary LC7 of Lake Cordeaux – view upstream.

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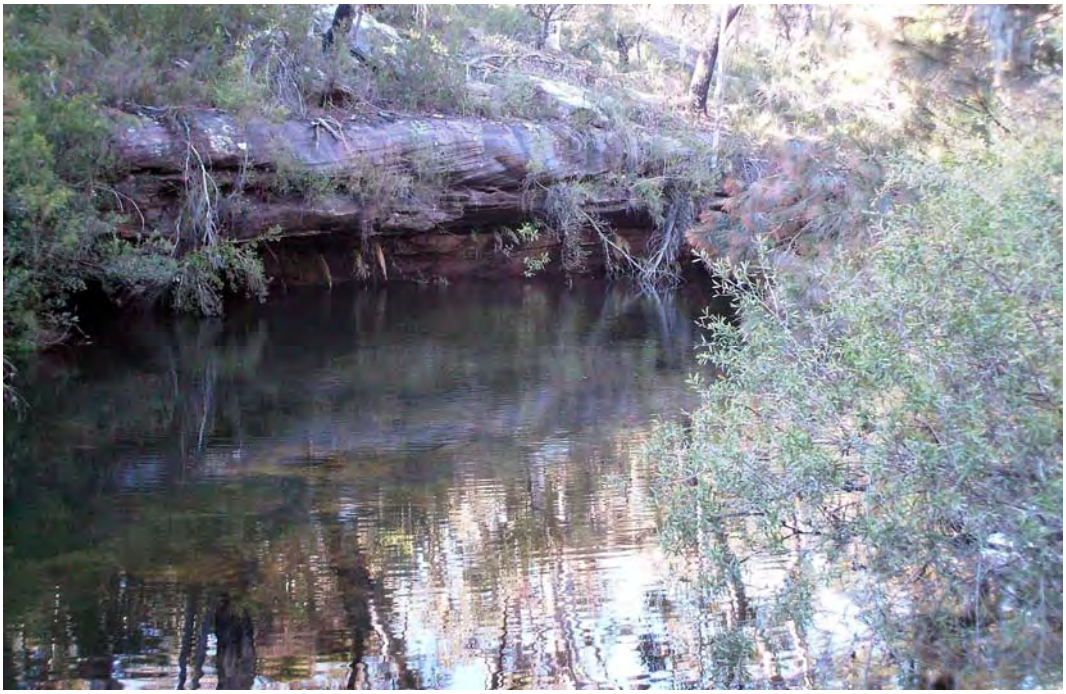

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