Report to:

BHP Billiton

Illawarra Coal

Appin Longwalls 705-710

Effects of Mine Subsidence on Aquatic Habitat and Biota

FINAL

June 2008

The Ecology Lab Pty Ltd

Marine and Freshwater Studies

Appin Longwalls 705-710

Effects of Mine Subsidence on Aquatic Habitat and Biota

June 2008

Report Prepared for:

BHP Billiton Illawarra Coal
Environment and Sustainability
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

Report Number – 55/0708A
Report Status – Final 23 June 2008

TABLE OF CONTENTS

SUMMARY

BHP Billiton Illawarra Coal (BHPB) proposes to extend its underground coal mining operations at Appin Colliery in the Southern Coalfield of New South Wales. The current proposal includes Longwalls 705 to 710 in an area of the Appin Mine referred to as the Appin Area 7. The Ecology Lab Pty Ltd has been commissioned by BHPB to describe the existing aquatic habitats and biota potentially subject to impacts from the proposed mining and to provide an assessment of the likelihood and significance of these impacts, with recommendations for ongoing monitoring prior to, during and after mining. This assessment will be included in the Subsidence Management Plan (SMP) currently being prepared by Cardno Forbes Rigby Pty Ltd (CFR), on behalf of BHPB, for submission to the Department of Primary Industries Mineral Resources (DPIM), as part of the approval process required to extend the mine.

For this assessment, the potential impact area is referred to as the 'SMP Area'. It is defined by Mine Subsidence Engineering Consultants (MSEC), as: "the surface area that is likely to be affected by the proposed mining of Longwalls 705 to 710 in the Bulli Seam at Appin Colliery". The SMP Area has been determined using 20 mm subsidence prediction limits, 35^0 angle of draw lines and includes features sensitive to far field movements.

All watercourses within the SMP Area are part of the Upper Nepean Catchment and drain to the Nepean River downstream of Douglas Park Weir. The main water body (and largest proportion of aquatic habitat) within the SMP Area is the Nepean River. A reach of approximately 7.8 kilometres of the river, downstream of Douglas Park Weir and the Cataract River confluence, and upstream of Menangle Weir is located within the SMP Area.

There are also a number of smaller surface watercourses within the SMP Area, including; Foot Onslow Creek, Navigation Creek, Harris Creek, Ousedale Creek, Leafs Gully and small unnamed drainages.

The proposed mine operation has the potential to impact aquatic habitats and biota within watercourses located within, and downstream of, the SMP Area. Potential impacts of mining on aquatic ecology considered in this report include:

1. The loss and/or alteration of aquatic habitat,
2. Impacts on fish passage (connectivity between up and downstream habitat),
3. Changes in water quality, and
4. Impacts on species of conservation significance.

This report, (i) considers existing aspects of the aquatic ecology as they relate to the proposed mining, (ii) assesses the potential impacts of the proposed mining on the aquatic ecology, and, (iii) provides recommendations for monitoring and management of potential impacts.

The Nepean River is the largest watercourse in the SMP Area and is considered as significant aquatic habitat. The river is set in a deep gorge, with steep banks and discontinuous sandstone cliffs up to 25 m high. Further downstream, the gorge opens up and becomes shallower and less steep. Weirs at Menangle, Douglas Park, Broughtons Pass and Maldon together with several other weirs along the Nepean River have significantly reduced the flow in the upper Nepean River (Williams 1994). These weirs have transformed the river from a free-flowing watercourse into a series of long, slow flowing pools. Menangle Weir pool extends upstream beyond the SMP Area to Douglas Park Weir. The

Nepean River between Menangle Weir and Douglas Park Weir (incorporating the SMP Area) can be considered as a single long, deep, slow flowing pool. In general, the river becomes deeper and wider further downstream. The riverbanks generally support a combination of native and exotic trees, shrubs and grasses. Various aquatic habitats including macrophyte beds, sand bars, overhanging banks, snags and boulders are present throughout the river. The river provides extensive and diverse habitat for freshwater fish and macroinvertebrates. There are no barriers to fish passage within the Nepean River within the SMP Area, however both Menangle and Douglas Park weirs would create significant barriers to upstream fish movement. There does not appear to be any stock access to the river within the SMP Area. There is no public access to this section of river via the adjacent land, however recreational fishers, canoeists and other members of the public do access this area by boat from either Douglas Park Weir or Menangle Weir. The river banks are used for recreational activities including fishing, camping and picnicking.

Smaller surface watercourses within the SMP Area, including; Foot Onslow Creek, Navigation Creek, Harris Creek, Ousedale Creek, Leafs Gully and small unnamed drainages are all ephemeral, being reduced to isolated pools during dry periods and only having continuous flow following significant rainfall. These watercourses provide minimal to moderate aquatic habitat and are generally highly disturbed with extensive stock access, degraded riparian vegetation, high levels of erosion, and extensive flow interruption from the construction of farm dams.

A review of the literature on the distribution of threatened aquatic species listed under state and federal legislation indicates that there are four scheduled species whose potential range may include the SMP Area:

1. Sydney Hawk Dragonfly (*Austrocordulia leonardi*), listed as endangered under the *FM Act*,
2. Adams Emerald Dragonfly (*Archaephya adamsi*), listed as vulnerable under the *FM Act*,
3. Macquarie Perch (*Macquaria australasica*), listed as vulnerable under the *FM Act* and listed as endangered under the *EPBC Act*,
4. Australian Grayling (*Prototroctes maraena*), listed as vulnerable under the *EPBC Act*.

Of these species Macquarie Perch and the Sydney Hawk Dragonfly were considered as potentially being impacted by mining operations and seven-part tests were conducted for these species.

Mine subsidence predictions (MSEC, 2008) suggest that reaches of the Nepean River within the SMP Area may experience a combination of subsidence, upsidence and closure affects that could result in a maximum net vertical uplift of the river bed of between 255 and 345 mm. These subsidence impacts are likely to affect 'relative' water level in sections of the river, resulting in the exposure of wetted substrata in some limited shallow areas of the river. Minor fracturing of the river bed is also predicted to occur, however, this is not expected to result in significant water loss or reduced flow due to the flooded nature of this reach of the river. Some releases of gas and minor iron staining may occur within the river as a result of mine subsidence.

Within small ephemeral surface watercourses within the SMP Area some increased flooding and ponding, as well as some surface fracturing resulting in the draining of pools may occur as a result of mine subsidence.

Subsidence impacts are unlikely to have a significant effect on important components of aquatic ecology including flow characteristics, and habitat connectivity, which influence aquatic habitat and biota. A potential impact on Dissloved Oxygen (DO) levels in the Nepean River has been identified by Ecoengineers (2008) as a result of microbiological consumption of dissolved methane from gas emission under low flow conditions. Further monitoring is required to validate this phenomena. If such a low DO level occurrence was widespread and prolonged it could have potential impacts on aquatic biota including fish and macroinvertebrates. Baseline monitoring has shown that low DO conditions arise in the Nepean River at low river flows. Changes in the relative depth of the river bed resulting from upsidence following longwall extraction, could, have an impact on the extent and composition of macrophytes beds within the Nepean River. Such an effect would be localised to a very small proportion of the river bed and would be unlikely to have a significant impact on the overall habitat within the river.

The potential temporary draining of pools within small ephemeral surface watercourses may result in the localised loss of habitat for some invertebrate and fish species, with any resident biota unable to relocate to nearby habitat, and possibly perishing as a result of desiccation and/or predation. This impact is considered to be very minor considering the highly degraded nature of such habitat and the limited aquatic biota present. These watercourses are not considered as providing potential habitat for any listed threatened species.

The known range and habitat requirements of the Sydney Hawk Dragonfly indicate that a viable population of this listed endangered species could occur within the reach of the Nepean River incorporated in the SMP Area. The seven-part test undertaken for this species has concluded that the predicted impacts resulting from extraction of Longwalls 705 to 710 are unlikely to have a significant impact on this species.

Viable populations of Macquarie Perch are known to be present upstream of the SMP Area in the Cataract and Nepean Rivers. It is possible that individuals could move downstream from these existing populations into the SMP Area. As a precautionary approach, a seven-part test was undertaken for this species assuming that a viable population could exist within the application area. Consideration of this species in the seven-part test has concluded that the predicted impacts resulting from extraction of Longwalls 705 to 710 are unlikely to have a significant impact on this species.

Other threatened species whose range could incorporate the SMP Area include the Adam's Emerald Dragonfly and Australian Grayling. After consideration of the ecology of these species it was concluded that a viable population of any of these species were unlikely to occur within the SMP Area.

Ongoing monitoring of the aquatic ecology, during and after extraction of longwalls is recommended. For the Nepean River and small surface watercourses within the SMP Area, it is recommended that aquatic macrophyte bed mapping, fish sampling, macroinvertebrate sampling and habitat assessment be used to monitor the effects of mine subsidence. This monitoring plan is a continuation and augmentation of the existing monitoring program approved for Appin Longwalls 701 to 704.

1.0 INTRODUCTION

1.1 Study Context

BHP Billiton Illawarra Coal (BHPB) proposes to extend its underground coal mining operations at Appin Colliery in the Southern Coalfield of New South Wales. The current proposal includes Longwalls 705 to 710 in an area of the Appin Mine referred to as the Appin Area 7. The Ecology Lab Pty Ltd has been commissioned by BHPB to describe the existing aquatic habitats and biota potentially subject to impacts from the proposed mining and to provide an assessment of the likelihood and significance of these impacts, with recommendations for ongoing monitoring prior to, during and after mining. This assessment will be included in the Subsidence Management Plan (SMP) currently being prepared by Cardno Forbes Rigby Pty Ltd (CFR), on behalf of BHPB, for submission to the Department of Primary Industries Mineral Resources (DPIM), as part of the approval process required to extend the mine.

The descriptions of existing aquatic ecology, assessments of potential mine subsidence impacts, and recommendations for ongoing monitoring presented in this report are based upon, and are an extension of, methods established in two previous studies undertaken in this area. These studies were:

- Assessment of aquatic ecological issues for Appin Workings (Longwalls 701-715) (The Ecology Lab, 2004). This report was part of the Review of Environmental Factors (REF) for the original proposal to extract coal from Longwalls 701 to 715 of Appin Area 7.
- Investigation of the effects of mine subsidence on aquatic habitat and biota for Douglas Area 7 (Longwalls 701-704) (The Ecology Lab, 2006). This report was produced for the incorporation into the SMP for Longwalls 701-704 of the area then referred as Douglas Area 7.

For this assessment, the impact area is referred to as the 'SMP Area'. It is defined by Mine Subsidence Engineering Consultants (MSEC), as: "the surface area that is likely to be affected by the proposed mining of Longwalls 705 to 710 in the Bulli Seam at Appin Colliery". The SMP Area has been determined using 20 mm subsidence prediction limits, 35^0 angle of draw lines and includes features sensitive to far field movements. These areas are outlined in MSEC (2008). A line has been drawn defining the 'general SMP Area', based upon the 35 degree angle of draw line and the predicted 20 mm subsidence contour (Figure 1). Of particular relevance to aquatic systems is the inclusion of reaches of the Nepean River and other watercourses that are outside the general SMP Area but within the predicted limits of 20 mm upsidence and 20 mm closure resulting from the extraction of Longwalls 705 to 710 (MSEC, 2008).

All watercourses within the SMP Area are part of the Upper Nepean Catchment and drain to the Nepean River downstream of Douglas Park Weir. The main water body (and largest proportion of aquatic habitat) within the SMP Area is the Nepean River. A reach of approximately 7.8 kilometres of the river, downstream of Douglas Park Weir and the Cataract River confluence, and upstream of Menangle Weir is located within the SMP Area, with 3.8 kilometres of this river lying within the general SMP Area (MSEC, 2008).

There are also a number of smaller surface water courses within the SMP Area including:

1. Foot Onslow Creek, Navigation Creek and their unnamed tributaries which flow from the north of the SMP Area into the Nepean River downstream of Menangle Weir.
2. Harris Creek, and a number of small unnamed drainages flowing from the SMP Area into the Nepean River between Douglas Park Weir and Menangle Weir from the western side of the river.
3. Ousedale Creek and Leafs Gully which flow from the eastern edge of the SMP Area into the Nepean River between Douglas Park Weir and Menangle Weir.

The proposed mine operation has the potential to impact aquatic habitats and biota within watercourses located within, and downstream of, the SMP Area. Potential impacts of mining on aquatic ecology considered in this report include:

- Loss and/or alteration of aquatic habitat,
- Impacts on fish passage (connectivity between up and downstream habitat),
- Changes in water quality, and
- Impacts on species of conservation significance.

This report, (i) considers existing aspects of the aquatic ecology as they relate to the proposed mining, (ii) assesses the potential impacts of the proposed mining on the aquatic ecology, and, (iii) provides recommendations for monitoring and management of potential impacts.

1.2 Legislative Context

1.2.1 Mining Act 1992

Primary regulatory control of mining is exercised by the DPIM through the provisions of the *Mining Act* 1992 and the conditions attached to mining leases granted under the provisions of that Act. The preparation of an SMP is required where underground mining is likely to lead to subsidence. BHPB is preparing an SMP as part of the application for approval to mine Appin Area 7 Longwalls 705 to 710.

1.2.2 Fisheries Management Act 1994

The *Fisheries Management Act* 1994 *(FM Act)* provides for the declaration and listing of threatened species of fish and marine vegetation, endangered populations and ecological communities and key threatening processes. One of the major features of this legislation is the integration of threatened aquatic species into the development control processes under the *Environmental Planning and Assessment Act* 1979 (*EP&A Act*).

1.2.3 Environmental Planning and Assessment Act 1979 (EP&A Act).

The *EP&A Act* sets out the factors to be considered in a preliminary assessment of whether a development is likely to have significant effects on threatened species. Seven factors are considered in a process referred to as the seven-part test. The test is a series of questions, the answers to which assist in determining whether a planned action will significantly affect threatened species, populations, ecological communities or their habitats. The seven-part test is only relevant if there is a likelihood of one or more threatened species occurring in the

area affected by the proposal. If the Approval Agency, on the basis of the seven-part test, determines that the proposal is likely to significantly affect threatened species, populations, ecological communities or their habitats, a Species Impact Statement (SIS) must be prepared as part of the environmental assessment process for SMP approval of the proposal under Part 5 of the *EP&A Act*.

1.2.4 Environmental Protection and Biodiversity Conservation Act 1999

The Commonwealth Government's instrument for national environmental protection is the *Environmental Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). Under the *EPBC Act*, any action which has, will have, or is likely to have a significant impact on a matter of national environmental significance, or is undertaken on Commonwealth land is defined as a controlled action and as such requires approval by the Minister for the Environment. Like the State legislation, the *EPBC Act* has provisions for the listing of threatened species and threatened ecological communities and requires proponents to consider impacts on threatened species.

2.0 AQUATIC HABITAT AND BIOTA OF THE SMP AREA

Watercourses within the SMP Area have been assessed as part of ongoing investigations for the Appin Area 7 (Longwalls 701 to 715) mine area. This description of aquatic habitat draws upon a review of existing information, investigations from previous field surveys (The Ecology Lab 2004; 2006) as well as investigations undertaken for the current SMP application for Longwalls 705 to 710.

2.1 Review of Existing Information

2.1.1 Water Quality

Geoterra (2006) conducted an assessment of surface water quality in relation to the proposed Appin Area 7 Longwalls 701 to 704 extraction. A distinctive thermal and oxygen stratification between surface and deeper waters of the Nepean River was identified, with deeper sections showing low to very low DO levels, particularly during summer months and low flow periods. A review of the water quality data from the study area collected by BHPB since 2002 shows average pH, salinity, phosphorus and nitrogen levels be outside ANZECC (2000) guidelines for the protection of aquatic ecosystems in South-Eastern Australia, and for concentrations of zinc and aluminium to be in excess of the recommendations for 95% species conservation level in some reaches of the Nepean River between Douglas Park Weir and Menangle Weir (Geoterra, 2006).

Gas releases associated with the extraction of Longwall 701 have been observed since January 2008 within the Nepean River closest to the eastern ends of the longwall (BHPB, 2008). Ecoengineers' (2008) analysis of water quality data from the BHPB monitoring program in the Nepean River indicates that this gas emission into the river may be having a influence on surface water DO levels under low flow conditions. There is considerable uncertainty about the nature of this process and further investigation is warranted.

Minor iron staining has been reported within Elladale Creek near the Nepean River confluence near the end of Longwall 701 (BHPB, 2008). A thin zone (<1m wide) of iron staining was identified along the northern edge of the river bank which extended for approximately 150 m and ceased just upstream of the water quality monitoring site NR7. No change in water quality parameters in respect of the pre-mining baseline data has been determined in the Nepean River since extraction to Longwall 701.

2.1.2 Fish

A search of NSW government records of fish fauna was undertaken using the internet based BioNet database (Web Reference 1) for the Nepean River and tributaries in the general surrounds of the SMP area. This search revealed a total of 14 species (Table 1), including 11 native species and 3 introduced species present within the catchment area. BioNet indicates that the listed threatened species, Macquarie Perch (*Macquaria australasica*), was recorded by the Australian Museum in this section of the upper Nepean River from 1894 to 1905.

Winstanley (2000) sampled fish once, at seven sites in the Cataract River downstream of Broughtons Pass Weir (continuous with the Nepean River within the SMP Area). The study was one component of a three-month program to determine the flow requirements to maintain a 'healthy' Cataract River. Three native fish, Australian Smelt (*Retropinna semoni*), Firetailed Gudgeon (*Hypseleotris galii*) and Cox's Gudgeon (*Gobiomorphus coxii*), and one

introduced species Gambusia (*Gambusia holbrooki*) were recorded, mostly from the lower reaches of the river.

The reach of the Nepean River between Douglas Park Weir and Menangle Weir is regularly used by recreational fishers, who mainly target Australian Bass (*Maccquaria novemaculeata*), but also make occasional and incidental catches of Freshwater Eels (*Anguilla sp*.), Carp (*Cyprinus carpio*) and Eel-tailed catfish (*Tandanus tandanus*) (Paul Frank, NSW DPI Fisheries, pers. comm.). Commercial fishing activity is not permitted within the reach of the Nepean River between Douglas Park Weir and Menangle Weir.

2.1.3 Aquatic Invertebrates

Williams (1994) used data on macroinvertebrate communities in six habitats and the SIGNAL index (Chessman, 1995) to examine the health of the Hawkesbury-Nepean River and some of its tributaries. Twenty-seven sites were sampled, including Douglas Park which is in close proximity to the SMP Area. He described the ecosystem as "widely impaired" and suggested that the disposal of treated sewage effluent, habitat destruction, river regulation and poor management practices were the major factors impacting the health of the river. It was also suggested that the construction of water storages, including a number of small compensation weirs between Pheasants Nest and Penrith, had favoured taxa that prefer low velocity environments and discouraged those that prefer higher velocities. These structures had also encouraged algal growth on the river bed and proliferation of organisms that graze on the attached algae.

2.1.4 Aquatic Macrophytes

In 1994, NSW EPA (now DECC) mapped the submerged macrophytes within the Hawkesbury-Nepean River to ascertain their large-scale distribution (Roberts *et al*., 1999). Vegetation was mapped using a combination of a hand-held GPS, a depth sounder and 1:8000 scale air photographs. The size, species composition and depth of each macrophyte bed were recorded. Seventeen submerged species, including the introduced invasive plant Egeria (*Egeria densa),* were recorded below the major storages. When part of this exercise was repeated in 1996, Egeria was found to have almost doubled its estimated distribution and biomass in some sections of river. In the lower sections of river, this species displaced beds of native *Vallisneria americana* (included in the species *Vallisneria gigantea*). No published information is available for the watercourses in the SMP Area.

2.2 Previous Investigations of Aquatic Ecology for the Appin Mine Area 7

A summary of the findings of field investigations of aquatic ecology in Appin Area 7 by The Ecology Lab (2004; 2006) is presented below:

- Aquatic habitat within the Nepean River is essentially a continuous, deep, slow flowing pool, created by the damming effect of Menangle Weir. The substratum is varied and includes sections of bedrock, boulder, sand and silt. The riparian vegetation consists of a mixture of native and exotic species, with some areas being dominated by grasses and others having overhanging trees. There are numerous beds of submerged aquatic macrophytes within the shallower sections of the river.
- Aquatic habitat within ephemeral tributaries of the Nepean River within the study area is generally highly disturbed by historical and current land use practices. These

watercourses are considered as providing only minimal to moderate habitat for aquatic species.

- Four species of aquatic macrophytes, Hydrilla (*Hydrilla verticillate*), Pondweed (*Potamogeton sulcatus* and *P. ochretus*) and Egeria, occur within the Nepean River within the study area. These species occur in dense, mixed beds and are considered to be in good health. Some changes in extent and composition were detected in the beds of aquatic macrophytes between surveys conducted in 2003 and 2005. This indicates a degree of variability prior to any mine subsidence impacts.
- Four species of native fish (Fire Tail Gudgeons, Flathead Gudgeons, Dwarf Flathead Gudgeons and Australian Smelt) were identified in the Nepean River using bait-trapping and seine netting methods. No listed threatened species of fish were found.
- Macroinvertebrate species sampled within the proposed mine area indicated the health of the Nepean River was poorer than the AusRivAS reference conditions, implying a moderately polluted system. No listed threatened species of invertebrates were found.

2.3 Current Field Investigation

2.3.1 General Habitat Assessment

Watercourses within the SMP Area were inspected by The Ecology Lab from 31st of March to 4th of April 2008. The description of habitats in watercourses within SMP Area is based on current investigations and previous investigations undertaken by The Ecology Lab as part of the REF for Appin Mine Area 7 (The Ecology Lab, 2004). The 1:25 000 topographical map series (Picton, Camden, Campbelltown and Appin) and aerial photos with GIS drainage layers supplied by BHPB and CFR were used to identify named and unnamed watercourses within the SMP Area that may experience direct or indirect mine subsidence impacts.

Watercourses were accessed at public access points (such as road crossings) and via private land where permission could be obtained from land owners. Aquatic habitat assessment was undertaken using a GPS to record the positions of specific observations. These observation points are shown in Figure 1 and the GPS positions are presented in Table 2. Water quality (pH, conductivity, temperature, DO, turbidity and oxidation-reduction potential) at each observation point was recorded using a hand-held probe (Yeokal 611). Water quality data is presented in Table 2. It should be noted that Ecoengineers (2008) present a 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, however, been substantial rainfall within the Upper Nepean catchment throughout February and March of 2008. As a consequence, some ephemeral watercourses that may 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.

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
- 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).

2.3.1.1 Nepean River

A reach of the Nepean River approximately 3.8 km long, downstream of Douglas Park Weir and upstream of Menangle Weir, is located within the general SMP Area. The river is set in a deep gorge, with steep banks and discontinuous sandstone cliffs up to 25 m high. Further downstream, the gorge opens up and becomes shallower and less steep. This is the largest watercourse in the SMP Area and is categorised Class 1 –significant aquatic habitat.

Weirs at Menangle, Douglas Park, Broughtons Pass and Maldon together with several other weirs along the Nepean River have significantly reduced the flow in the upper Nepean River (Williams, 1994). These weirs have transformed the river from a free-flowing watercourse into a series of long, slow flowing pools. Menangle Weir pool extends upstream beyond the SMP Area to Douglas Park Weir. The minimum water level downstream of the weir at Douglas Park is essentially the same at Menangle Weir (Geoterra, 2006). The Nepean River between Menangle Weir and Douglas Park Weir (incorporating the SMP Area) can therefore be considered as a single long, deep, slow flowing pool. In general, the river becomes deeper and wider further downstream. Flood debris was noted at levels up to 2 m above the current water level indicating a relatively recent large flood/high flow event.

The riverbanks generally support a combination of native and exotic trees, shrubs and grasses. Various aquatic habitats including macrophyte beds, sand bars, overhanging banks, snags and boulders are present throughout the river. Expansive beds of submerged macrophytes grow on the shallower riverbed reaches (confined to a maximum river depth of about 3.5 m). Species include Hydrilla, Pondweed, Egeria and Ribbonweed (*Vallisneria gigantea*). In general, Ribbonweed became the more dominant species with distance downstream.

The river provides extensive and diverse habitat for freshwater fish and macroinvertebrates. There are no barriers to fish passage within the Nepean River within the SMP Area, however both Menangle and Douglas Park weirs would create significant barriers to upstream fish movement. It is possible that these barriers could be negotiated by some species such as Freshwater Eels at all times, and that during high flows, other species including Australian Bass would be able to find passage upstream.

There does not appear to be any stock access to the river within the SMP Area. There is no public access to this section of river via the adjacent land, however recreational fishers, canoeists and other members of the public do access this area by boat from either Douglas Park Weir or Menangle Weir. The river banks are used for recreational activities including fishing, camping and picnicking.

2.3.1.2 Foot Onslow Creek

A two kilometre reach of Foot Onslow Creek is located in the middle of the northern section of the SMP Area above Longwalls 707 to 710. Access to this section of the creek was not possible, because the landholder refused access. Habitat inspections, however, were undertaken above Longwall 708 (Plate 1 upper) and Longwall 710 (Plate 1 lower), where access was obtained.

The reach of Foot Onslow Creek within the SMP Area was classified as Class 2 (moderate) aquatic habitat. It contains a number of relatively large, deep pools that would be expected to persist well into prolonged dry periods. At the time of inspection, there was no flow connectivity and standing pools were separated by sections of dry creek bed. Riparian vegetation is sparse and consists of some native eucalypt, tea tree and melaleuca trees. There are also numerous exotic tree, shrub and grass species amongst the riparian vegetation. No instream aquatic macrophytes were present in the reach of the watercourse inspected. The substratum of the watercourse is dominated by soft silt and clay sediments, with some sand and gravel bars. The banks of the watercourse are heavily eroded, probably as a result of removal of riparian vegetation and extensive stock access. At the time of inspection, there was a significant amount of garbage and abandoned equipment within the channel and along the banks of the watercourse. The water was generally very turbid, with some surface scum present.

There are a number of small unnamed tributaries of Foot Onslow Creek within the SMP Area. These are all classed as minimal or unlikely aquatic habitat, contain no natural pools and are generally within cleared pasture. There is some highly modified, albeit artificial, aquatic habitat within the numerous farm dams along these watercourses.

2.3.1.3 Navigation Creek

A one kilometre reach of the main channel of Navigation Creek lies within the western edge of the SMP Area, upstream of Cummins Road (Figure 1). This reach was classified as Class 2 (moderate) aquatic habitat. It contained some semi-permanent pools within the natural

watercourse, as well as a large pool formed by a now derelict farm dam (Plate 2 upper). Just upstream of the general SMP Area was a larger intact farm dam. At the time of inspection the watercourse was almost continuous with sections of low, shallow flow linking pools. This continuity is not expected to persist for long during dry periods. Riparian vegetation was generally sparse, however, there are some patches of continuous riparian vegetation dominated by mature eucalypt and melaleuca trees. Exotic shrubs and grasses are common along the banks. Instream aquatic macrophytes were noted within the natural channel and the farm dams along the watercourse and included *Typha* sp., *Ludwigia* sp., *Ottelia* sp., *Cyperus* sp. and *Juncus* sp. The substratum of the watercourse is dominated by soft silt and clay sediments, with some sections of shale bedrock, gravel and sand bars. Sections of the channel showed heavy erosion of the soft sediment banks.

Two unnamed tributaries of Navigation Creek (Figure 1) are located within the SMP Area east of the main channel of Navigation Creek and west of Foot Onslow Creek. These watercourses appear to provide very little aquatic habitat, apart from several farm dams along or adjacent to these channels, and pools formed where road culverts have had a dam effect (Plate 2 lower, Plates 3 upper, Plate 3 lower). These watercourses were classified as Class 3 (minimal) aquatic habitat. The numerous small drainage gullys that flow to these watercourses were considered as Class 4 (unlikely) aquatic habitat. It was noted that the introduced fish species, Gambusia, was present in both of these watercourses at the Carrols Road and Finns Road Culverts, and is likely to be present throughout the drainage.

2.3.1.4 Harris Creek

Harris Creek was classified as a Class 2/3 watercourse (i.e. moderate to minimal fish habitat) during the study. Harris Creek was visited at the Mountbatten Road crossing (Plate 4 upper). The creek originates about 3 km north of Nepean River in urban and semi-rural properties and joins the Nepean River immediately downstream of Douglas Park Weir. The channel is 3-5 m wide in its lower reaches and is clearly defined by bedrock and scattered boulders and a continuous band of riparian vegetation. There are a few scattered permanent pools providing habitat in these lower sections, and there was some flow connectivity at the time of inspection, however it is expected that connectivity would not be maintained during extended dry periods. The upper reaches meander through pasture, forming a gully with limited aquatic habitat. Stock has access to these upper reaches and there is extensive stock induced erosion of the banks and channel. Several farm dams are scattered along the channel interrupting downstream flow. The steep lower reach of Harris Creek in the Nepean River gorge creates a significant barrier to many fish species, however it is likely that some species including Freshwater Eels and Gudgeons are present within this watercourse.

2.3.1.5 Unnamed Creeks

Two unnamed creeks flow north from the eastern side of the SMP Area into the Nepean River. These are both classified as Class 3 watercourses (minimal aquatic habitat), and contain only small semi-permanent pools. There are some pockets of native riparian vegetation along these creeklines (Plate 4 lower). There are farm dams along these watercourses and the land use is predominantly grazing.

2.3.1.6 Ousedale Creek and Leafs Gully

Ousedale Creek and Leafs Gully flow into the reach of the Nepean River within the SMP Area from the eastern side. The catchment of these watercourses includes pasture, chicken farms, and some semi-urban development. The watercourses become steep gullies with a

mixture of native and exotic riparian vegetation as they approach the Nepean River. Only the very most downstream reaches of these watercourses lie within the SMP Area, and the steep grade of the watercourses creates a substantial barrier to passage of most fish upstream. The sections of these watercourses that are within the SMP Area are essentially backwaters of the Nepean River, and are as such, are considered as part of the Nepean River within this assessment.

2.3.2 Macroinvertebrate Sampling

Within the ephemeral surface watercourses of the SMP Area, three sites were selected to undertake macroinvertebrate sampling. One site was located within Navigation Creek adjacent to Quirkes Road (Site N1), and two sites were located within Foot Onslow Creek (Sites F1 and F2), both upstream of the Menangle Road bridge (Figure 1). These sites were selected, because they contained sufficient aquatic habitat to allow use of the AusRivAS protocol and contained pools that appeared likely to persist into drier periods and would therefore be suitable for ongoing monitoring. Macroinvertebrate sampling has been undertaken in the Nepean River in earlier investigations (The Ecology Lab 2004, 2006) and will be incorporated into ongoing monitoring for Longwalls 705 to 710.

2.3.4.1 AusRivAS Methods

Macroinvertebrates living in the edge habitat of pools were sampled using the AusRivAS protocol (Turak and Waddell, 2001); which is briefly described below. A dip net (400 x 200 mm triangular opening, 600 mm deep with 0.25 mm mesh size) was agitated along the pool edge working over a bank length of about 10 m. The contents of the dip net were then transferred to an enamel tray and sorted for 1 hour. The taxa collected were then placed in labelled containers, preserved with 70% alcohol and transported to the laboratory for identification. Macroinvertebrates were identified and counted in the laboratory under a binocular microscope at 40X magnification. Identifications were resolved to the taxonomic level of family. The exceptions were chironomids (sub-family); oligochaetes, ostracods and hydracarinas which were identified to Class/Order and odonates, which were identified to their lowest possible taxonomic resolution due to the listing of a dragonfly in the *FM Act*.

The autumn season AusRivAS model was used to generate the following indices:

- OE50Taxa Score - the ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50 % probability of occurrence. These values range from 0 to 1 and provide a measure of the impairment of macroinvertebrate assemblages at each site.
- Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. These bands are graded as follows:

  Band X = Richer invertebrate assemblage than reference condition.

  Band A = Equivalent to reference condition.

  Band B = Sites below reference condition (i.e. significantly impaired).

  Band C = Sites well below reference condition (i.e. severely impaired).

  Band D = Impoverished.

- OE50Signal index - the ratio of the observed to expected SIGNAL (Stream Invertebrate Grade Number Average Level) score per site for taxa that have a probability of occurrence of more than 50%. This biotic index was developed by Chessman (1995 and 2003) as a means of determining environmental quality of sites based on the presence or absence of macroinvertebrate families. Grade values assigned to each macroinvertebrate family or taxa range from 1 to 10, with a value of 1 indicating a family tolerant to chemical pollution and a value of 10 indicating a sensitive family.

2.3.4.2 AusRivAS Results

Seventeen macroinvertebrate taxa were collected from the upstream site (F1) and 15 taxa from the downstream site (F2) in Foot Onslow Creek. The total number of macroinvertebrate taxa collected across the two sites combined, was 23, compared with 26 taxa found in Navigation Creek (N1). Eight of the taxa were collected at all three sites (Table 3).

SIGNAL scores

The Baetidae family has a signal value of 5 and was found at all sites. Lestidae, Notonectidae, Dytiscidae and Corixidae families all have low SIGNAL values; 1, 1, 2 and 2 respectively, and were found at all 3 sites. Leptophlebiidae, the family with the highest SIGNAL value (8) of all taxa collected, was found at the Foot Onslow Creek downstream site (F2). Synlestidae with a SIGNAL value of 7 was found at Navigation Creek (N1).

AusRivAS model results

AusRivAS allocated band B to all three sites as they had fewer families than expected compared with reference streams. The Foot Onslow Creek U/S site had the greatest O/E50 value (0.73). The O/E50 values for the D/S site (0.66) was similar to that in Navigation Creek (0.65) (Table 4). O/E0 SIGNAL scores for the Foot Onslow Creek Upstream and Downstream sites were 0.83 and 0.80 respectively. The Navigation Creek site had and O/E0 signal value of 0.81.

The AusRivAS bands for these three sites indicate that at the time of assessment they were all significantly impaired in comparison to the AusRivAS reference condition. These AusRivAS results highlight a potential impact either on water quality or habitat quality or both resulting in loss of taxa, in both Foot Onslow and Navigation creeks. The O/E SIGNAL results showed that all the sites had poor water quality as they were not equal to or close to the value 1. The O/E0 SIGNAL values were all approximately 80% of the optimum SIGNAL value which implies that not all the sensitive taxa predicted to occur at these sites were present.

2.3.3 Fish Sampling

Fish were sampled in two ephemeral surface watercourses within the SMP Area at the sites where macroinvertebrate sampling was conducted (N1, F1 and F2). Fish were also sampled in the Nepean River at selected sites within the SMP Area and upstream.

2.3.5.1 Fish Sampling Methods

Within Navigation Creek and Foot Onslow Creek, fish and large invertebrates (yabbies) were sampled using baited traps and a backpack electrofisher. Within the Nepean River, only baited traps were used, because this habitat is not suitable for backpack electrofishing. Eight baited traps were deployed at each sampling site in a variety of available habitats (snags, macrophyte beds, overhanging banks, gravel beds). The traps were 350 mm long, 200 mm wide with an entrance that tapered in to 45 mm, with 3 mm mesh size throughout. The traps were baited with 70 ml of a mixture of chicken pellets and sardines and allowed to fish for 1.5 h. Backpack electrofishing was conducted along the entire reach of sites within Foot Onslow and Navigation Creek using a Smith Root LR24 model. Electrofishing was conducted in all available habitats, using sets of four, two minute shots. Fish were sampled in two unnamed tributaries of Navigation Creek at the Carrols Road and Finns Road causeways using a dip net. All fish and mobile invertebrates collected using baited traps, dip nets and electrofishing were identified and released in accordance with The Ecology Lab's scientific research permit issued by DPI Fisheries (permit number F86/670).

2.3.4.2 Fish Sampling Results

Results of fish sampling are presented in Table 5. Within Foot Onslow Creek and the main channel of Navigation Creek, no fish were caught although the freshwater yabby (*Cherax destructor*) was present in Foot Onslow Creek. The exotic fish species Gambusia was present in large numbers within the two tributaries of Navigation Creek. In the Nepean River, Fire Tail Gudgeon and Flat head Gudgeon were present at all sampling sites. Australian Smelt and Gambusia were both present at the most upstream site sampled.

2.4 Threatened Species

A review of the literature on the distribution of threatened aquatic species listed under state and federal legislation indicates that there are four scheduled species whose potential range may include the SMP Area:

5. Sydney Hawk Dragonfly (*Austrocordulia leonardi*), listed as endangered under the *FM Act*,
6. Adams Emerald Dragonfly (*Archaephya adamsi*), listed as vulnerable under the *FM Act*,
7. Macquarie Perch (*Macquaria australasica*), listed as vulnerable under the *FM Act* and listed as endangered under the *EPBC Act*,
8. Australian Grayling (*Prototroctes maraena*), listed as vulnerable under the *EPBC Act*.

Potential impacts on these listed threatened species are considered in Section 3.3 of this report.

3.0 ASSESSMENT OF IMPACTS

3.1 Description of the Proposal & General Impacts Associated with Mine Subsidence

The proposed mining of Appin Area 7 Longwalls 705 to 710 involves extraction of coal from six longwalls on the north-western side of the Nepean River. The longwalls have been offset from the river such that they are located at a minimum distance of 180 m from the river edge. As the proposal involves continuation of existing longwall operations, no additional surface facilities will be constructed as part of the mining proposal.

3.1.1 Nepean River

Mine subsidence predictions for the SMP Area (MSEC, 2008) indicate the reach of the Nepean River at the eastern ends of Longwalls 705 to 710 will be exposed to mine induced subsidence. Predicted impacts include a combination of subsidence, upsidence and closure that typically result in a net vertical uplift of the river bed. The maximum uplift is predicted to be between 255 and 345 mm in the Nepean River (MSEC, 2008).

The predicted subsidence impacts could affect the level of the river bed and banks in sections of the Nepean River. The level of water in the river is controlled by Menangle Weir and will not change due to subsidence (MSEC, 2008). The overall effect will be that some sections of the river will have a minor reduction in water depth (up to a maximum of 345 mm) compared to pre-mining. Sections of the Nepean River are likely to appear to have experienced a minor fall in water level due to the net uplift impacts following mining. This could potentially expose wetted substrata in some shallow areas of the river. Maximum uplift is predicted to occur in the base of the river bed (MSEC, 2008) and therefore, predicted uplift of the banks of the river will be less than the maximum prediction for the river bed at any point along the river.

Minor fracturing of the river bed is also predicted to occur (MSEC, 2008), however, this is not expected to result in any change in water level or reduced flow, as this reach of the Nepean River is a flooded system with continuous groundwater and surface water input. Any fracture within the river bed resulting from mining is likely to be filled immediately by water and/or sediment. The volume of water that fills such a fracture is extremely small relative to the volume of water in this reach of the river, and rapidly replenished by inputs to the system. Thus, no significant or long term change in water level (draining) is expected as a result of water flow into fractures of the river bed.

Fracturing of the strata above the extracted area is likely to result in the emission of methane within the river valley. These emissions are noticeable in the form of bubbles in the water and have been seen in the Nepean River following the extraction of Longwall 701 (BHPB, 2008). It is likely that some mining-induced gas emissions will be observed during the extraction of the proposed Longwalls 705 to 710 (MSEC, 2008). It may be possible that these emissions may have an impact on water quality at low flows within the river, including surface DO. However, further verification of such an influence is required. This is considered by Ecoengineers (2008) and discussed in terms of potential impacts on aquatic ecology in section 3.2.3 below.

3.1.2 Small Surface Watercourses

Small surface watercourses within the SMP Area, including Foot Onslow Creek, Navigation Creek, Harris Creek and small unnamed drainages are all ephemeral, being reduced to isolated pools during dry periods and having only continuous flow following significant rainfall. These watercourses provide minimal to moderate aquatic habitat and are generally highly disturbed with extensive stock access, degraded riparian vegetation, high levels of erosion and extensive flow interruption from the construction of farm dams.

MSEC (2008) predict that localised areas along drainage lines could experience increases in the levels of ponding and flooding, where predicted maximum tilts occur at locations with small natural gradients. These, however, are expected to be minor and would not have a significant impact on the drainage lines. Where bedrock substratum of watercourses is present within the SMP Area it is possible that surface fractures will occur (MSEC, 2008). These may result in surface water diversion into the dilated strata beneath with the potential resultant draining of pools. It is likely that such fractures will be filled with alluvial deposits during subsequent flow events.

3.2 Aquatic Habitat

3.2.1 Alterations to Flow

Changes in the dimensions of streams can alter the flow of water in rivers (Erskine, 1997; IEPEF, 2002). Subsidence predictions suggest the Nepean River is likely to become shallower by a maximum of about 345 mm in the most impacted section of the river bed (MSEC, 2008). These changes are relatively small when compared with the existing relief (pool depth of up to 8 m) of the riverbed and will only occur in small sections of the river.

Furthermore, as a flooded system, the flow rates within this reach of the river are regulated and do not experience the same variation as an unregulated or ephemeral watercourse. Changes in stream dimensions will therefore have a much smaller impact on flow regime. It is predicted that there will be no changes in flow characteristics in the SMP Area as a result of mine subsidence and that there will not be any significant impact on the aquatic habitat and biota present.

Within small surface watercourses, predicted increases in ponding and flooding and potential water loss through surface fractures are not predicted to have a significant impact on the ephemeral nature of the flow of these watercourses.

3.2.2 Connectivity

Continuity of a watercourse is ecologically important in maintaining connectivity between habitats (IEPEF 2002). The minimum pool depths of approximately 1-1.5 m (along the deepest section of river) measured by The Ecology Lab within the SMP Area, suggest that these pools are sufficiently deep to ensure the entire length of river remains inundated following longwall extraction. The shallower river margins may, however, become exposed, thus marginally reducing the wetted perimeter of the river (MSEC, 2008). Due to the relatively small area that may be exposed, no impact on aquatic biota resulting from fragmentation of habitat is expected as a result of mine subsidence within the Nepean River within the SMP Area.

Small ephemeral surface watercourses within the SMP Area are generally discontinuous, except during periods of high rainfall. Impacts including possible increased ponding and flooding and possible draining of pools are not considered likely to effect this connectivity.

3.2.3 Water Quality

Ecoengineers' (2008) comprehensive assessment of surface water quality effects in relation to the proposed Longwalls 705 to 710 has identified potential mechanisms which may have adverse impacts on surface water quality as a result of mine subsidence. These have been briefly summarised below and are considered with relevance to aquatic biota in sections 3.2.4 to 3.2.6 below.

Gas Emissions into the River

It is likely that zones of gas emission will occur within the Nepean River as a consequence of mining Longwalls 705 to 710. These emissions may result in low DO levels as a consequence of microbiological consumption of DO by bacterial biomass feeding on dissolved methane. It should be noted that this process is complicated by other factors including; low DO water entering from the Cataract River upstream, oxygen production of numerous aquatic plant beds and input of high levels of nutrients from surrounding land use and potential resultant algal blooms. Further investigations is warranted to validate the influence of gas emissions on the level of DO in the river.

Ecoengineers (2008) propose that, under low flow conditions, with gas emission occurring, if DO levels fall significantly (one or two standard deviations) below the long term mean levels established during baseline sampling, management responses such as increased monitoring, stakeholder notification and the development of remedial action(s) be triggered. The range of DO levels that may trigger such a response are approximately 60% (level 1 trigger) and 30% (level 2 trigger). The Ecology Lab has used these general levels as a guide for potential impacts on aquatic biota in Sections 3.4 to 3.6 below.

Ferruginous Springs

Ecoengineers (2008) consider it unlikely, but possible that mining induced ferruginous springs will be created close to the Nepean River following longwall extraction. Water from such springs can contain elevated salinity, and high concentrations of dissolved iron, manganese, nickel and zinc as a result of the geochemical properties of the local geology. These springs can result in; the production of highly visible iron staining within watercourses and reduction in pH and reduction in DO in receiving waters. Ecoengineers (2008) consider that reduction in pH within the receiving waters of the Nepean River is highly unlikely because of the significant bicarbonate alkalinity in the river which neutralises acidity. Furthermore, absence of acidification does not provide appropriate conditions for production of ecotoxic species of metals such as nickel and zinc. Reduction of DO is likely to be confined to the point of mixing if it occurs at all, and is not expected to have a broad scale effect.

Within the tributaries to be directly mined beneath by proposed Longwalls 705 to 710, ferruginous springs may be more likely to be induced, or if pre-existing, exhibit increased flow rates. These streams are ephemeral in nature and located in areas that are heavily disturbed by current land use. Ecoengineers (2008) therefore consider that it is highly unlikely that there would be a significant impact on water quality resulting from the formation of these springs over current anthropogenic effects.

3.2.4 Aquatic Macroinvertebrates

The occurrence of vertical movement in the bed and bank of the river resulting from subsidence could re-position the pool edge (MSEC, 2008). Loss of edge habitat would occur where there is a relative fall in water level due to upsidence as predicted by MSEC (2008). The maximum predicted net upsidence of the river bed is between 255 and 345 mm. It should be noted that where the banks are generally steep and the river is relatively deep, upsidence impacts occurring at the stream edge are likely to be of a much smaller magnitude than at the river bed (MSEC, 2008), so extensive loss of edge habitat is not predicted. Areas likely to experience the greatest loss of edge habitat are those where upsidence of the riverbed coincides with shallow edge habitat. The potential loss of macroinvertebrate edge habitat, however, is predicted to be relatively small in the context of the available habitat within the reach of the Nepean River within the SMP Area. No significant impact on macroinvertebrate assemblages is therefore predicted to occur as a result of mine subsidence.

Where bedrock substratum of small surface watercourses is present within the SMP Area it is possible that surface fractures will occur (MSEC, 2008). These may result in surface water diversion into the dilated strata beneath with the potential resultant draining of pools. It is likely that such fractures will be quickly filled with alluvial deposits during subsequent flow events. The draining of pools may result in temporary loss of small areas of minimal to moderate aquatic habitat. Aquatic biota dependent upon this habitat (including aquatic macroinvetebrates) that are unable to relocate to other areas of habitat are likely to perish as a result of desiccation and/or predation as these pools drain. This impact is considered as being of low significance because of the highly degraded nature of existing aquatic habitat, and the temporary and limited nature of such impacts. This habitat is not considered as potential habitat for any listed threatened aquatic macroinvertebrate species.

The production of increased levels of iron precipitate (iron floc) as a result of the induction of ferruginous springs by mine subsidence may have an impact upon some aquatic macroinvertebrate species. The ecological effects of these flocs on aquatic biota are largely unknown, but may include reduction of interstitial benthic habitat through smothering.

Dissolved oxygen is necessary to maintain aerobic conditions in surface waters and is considered a primary indicator when assessing the suitability of surface waters to support aquatic macroinvertebrate life. Fluctuations in DO levels occur in natural stream ecosystems throughout 24 hour periods as a result of temperature fluctuations and biological activity. Sustained reductions in DO levels can have profound effects on the inhabitants. Much of the data that has been published focuses on the effects of oxygen levels on fish, but they conclude that as long as DO requirements are satisfactory to the fish communities, their will be no material impairment on the macroinvertebrate populations on which they feed (Doudoroff and Shumway, 1970; Davis, 1975). Because minimal research has been done on Australian macroinvertebrates with regard to DO concentrations, general comparisons can only be made at the family and order level of classification to account for spatial variation among taxa.

ANZECC (2000) guidelines for lowland rivers recommend healthy DO percent saturation levels between 85-110%. The stream macroinvertebrates sampled in the Nepean River by The Ecology Lab (2006) represent an aquatic community characteristic of a lentic environment and these populations would perform very well in conditions such as these. Most of these macroinvertebrates are extremely hardy and mesocosm experiments using entire assemblages of Australian, tropical lowland streams found that even 25-35% oxygen saturation did not cause any mortality over 5-day experiments (Connolly *et al.*, 2004).

Dissolved oxygen levels below 85% and into the 60% saturation range should have very little impact on the aquatic community present in the Nepean River. Highly sensitive taxa, such as mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) may display slight reductions in metabolism (Nebeker, 1972; Williams *et al.*, 1987). Reduced metabolism would likely compromise fitness in the long term by reducing feeding, growth, emergence, and fecundity.

When DO levels decline towards 30% saturation there are more significant effects on freshwater macroinvertebrates, including distinct changes in the communities of these lowland streams (Jacobsen, 2007). Mayflies, stoneflies, and caddisflies generally begin to exhibit significant mortality in these ranges (Nebeker, 1972; Chambers *et al.*, 2000). Many organisms adapted to lentic environments will still perform well and their populations may thrive in the absence of some of these other competitors (eg. Diptera, Oligochaeta, Coleoptera). It is important to note that in addition to the direct effects of low DO levels as we see in this range, the acute toxicity of most contaminants is elevated under conditions of low DO (Sprague, 1985). Negative effects on macroinvertebrate communities observed at DO levels of approximately 30% and below could be compounded by such changes in toxicity. Additionally, many macroinvertebrates that are stressed by environmental factors will drift downstream in search of better conditions. This would significantly reduce levels of macroinvertebrate densities directly below the source of a DO sag even at levels below 60% saturation.

If freshwater conditions in the Nepean River fall below 30% DO, the ecosystem could be considered as degraded and the macroinvertebrate populations that persist in these situations become increasingly more tolerant of poor habitat. Significant mortality and reduction in respiration has been demonstrated in populations of freshwater mussels (Unionidae), Copepoda, Isopoda, Amphipoda, freshwater shrimp (Decapoda), and Diptera when levels of DO approach anaerobic conditions (Berg *et al*,. 1962; Sprague, 1963; Homer and Waller, 1983; Dean and Richardson, 1999; Chen *et al.*, 2001). Even the most tolerant Diptera species will not be able to inhabit DO conditions much below 5% saturation. Some of the macroinvertebrates found in the Nepean River have the ability to breathe atmospheric oxygen (Beetles – Scirtidae, Gyrinidae, Elmidae, Dytiscidae, Hydrophilidae, and the true bug – Corixidae) and their success would be independent of DO concentrations.

Any impacts upon aquatic macroinvertebrates as a result of low DO in the Nepean River as a result of gas emissions would need to be assessed in the context of the actual DO concentration, spatial extent and duration of the DO sag, and the total available habitat within the Nepean River between Douglas Park Weir and Menangle Weir.

3.2.5 Aquatic Macrophytes

The distribution of submerged (attached) macrophytes within the SMP Area may change in response to the vertical movement of the riverbed. A reduction of macrophyte coverage could occur as a result of desiccation. This could occur if macrophyte beds are located in any shallow areas of riverbed subject to net upsidence which exceeds the water depth. As the maximum predicted net upsidence following extraction within the Nepean River is 345 mm (MSEC, 2008), and this is predicted to occur in the middle of the channel, the reduction of macrophyte beds resulting from desiccation is likely to be confined to a very small proportion of any shallow margins of existing beds.

An increase in the coverage of macrophyte beds is also possible as a result of mine induced upsidence. A reduction in water level due to upsidence could increase the substrata available for macrophyte colonisation along the margin of macrophyte beds defined by

available sunlight penetration. This effect is also likely to be proportionally very small compared with existing macrophyte coverage.

Variability in the spatial extent and species composition of macrophyte beds in the Nepean River has been observed between surveys conducted in 2003 and 2005, prior to the commencement of mine operations. It is expected that any change in macrophyte beds resulting from mine subsidence induced impacts will be minor and indistinguishable from the natural variability within the river. No significant impact on macrophyte composition or coverage is therefore predicted to occur as a result of mine subsidence.

3.2.6 Fish

The response of fish to the effects of mine subsidence impacts is dependent on changes in fish habitat resulting from changes in flow, connectivity, water quality, and aquatic macrophyte beds. As discussed above, changes in most of these habitat components are not expected to be of sufficient magnitude to have a significant impact on the overall aquatic habitat within the Nepean River. The potential for gas emission induced DO sags within the river however, does require consideration in terms of potential impacts of fish.

Low concentrations of DO can result in adverse effects on many aquatic organisms including fish and invertebrates, which depend upon oxygen for their functioning (ANZECC, 2000). The recommended minimal acceptable concentrations of DO in freshwater range from 5.8 mg/L (82.9%) at 36 °C to 6.8 mg/L (56.7%) at 7.7 °C (Hart, 1974). It is important to note here that DO content decreases with increasing water temperature, and that it is difficult to assign values, as some organisms exhibit special adaptations to low DO levels.

The effects of low levels of DO on fish species, including galaxiids, gudgeons, smelt, eels and shrimp, in addition to juvenile Rainbow Trout has been investigated under laboratory conditions in New Zealand (Dean and Richardson, 1999). Fish were held in tanks at DO levels of 1, 3 or 5 mg/L for 48 hours at 15 °C (approximately 10%, 30% and 50% saturation). Most fish were dead after exposure to 1 mg/L, except for eels, all of which survived. Only trout suffered mortalities at 3 mg/L, and no deaths occurred at 5 mg/L. Most fish moved towards the surface within the first few hours of exposure to 1 mg/L, and one of the galaxiid species responded by leaving the water completely. Dean and Richardson (1999) concluded that most of the species tested were surprisingly tolerant to low levels of DO under lab conditions. They also recommended that until DO standards specific to New Zealand were developed, U.S. Environmental Protection Agency (USEPA) guidelines for salmonid waters be applied. These guidelines indicate that if the exposure period was limited to less than 3.5 days, and temperatures were between 10 and 20 °C, DO concentrations of at least 3 mg/L should not produce any direct mortality.

Any impacts upon fish as a result of low DO in the Nepean River due to gas emissions would need to be assessed in the context of the actual DO concentration, spatial extent and duration of the DO sag, and the total available habitat within the Nepean River between Douglas Park Weir and Menangle Weir. As fish are highly mobile organisms, and there are no barriers to fish passage in the reach of the river between Douglas Park Weir and Menangle Weir, it would require prolonged, very low DO concentrations of this entire reach of the river to result in impacts such as a fish kill.

Fish that utilise pool habitat within small ephemeral surface watercourses may be impacted by the draining of pools as a result of surface fractures. Some fish species (such as freshwater eels) may be able to relocate to nearby areas of aquatic habitat, however most

species would perish as a result of desiccation and/or predation. This impact is considered as being of low significance because of the highly degraded existing aquatic habitat, and the temporary and limited nature of such impacts. This habitat is not considered as potential habitat for any listed threatened fish species.

3.3 Threatened Species

3.3.1 Sydney Hawk Dragonfly

Sydney Hawk Dragonfly is extremely rare, having been collected in small numbers at only 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 the SMP Area, however, it has been recorded upstream in the Nepean River, at the Maldon Bridge near Wilton (NSW Fisheries, 2004).

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 effect on the suitability of habitat for larvae (G. Theischinger, pers. comm.). Large, deep, permanent pools of the Nepean River within the SMP Area appear to provide suitable habitat for the larva of Sydney Hawk Dragonfly. The relative stability in water level and flow rate within these pools resulting from flow regulation from Menangle Weir also suggest that this is appropriate habitat. Although the Sydney Hawk Dragonfly has not been found in the SMP Area, it is possible that a viable local population does exist. A seven-part test is therefore presented below.

The seven-part test for the Sydney Hawk Dragonfly

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

Aquatic larvae of the Sydney Hawk Dragonfly (the majority of its life cycle) appear to have specific habitat requirements, including deep, cool, slow-flowing water in rocky rivers with steep sides, such as are found in the SMP Area. The significant alteration of such habitat could potentially have an adverse effect on the life cycle of the Sydney Hawk Dragonfly. Mine subsidence induced impacts resulting from the Appin Area 7 proposal are not predicted to have a significant effect on the temperature, flow or general morphology of the river (MSEC, 2008). Some small sections of river substratum are in shallow depths and may become exposed as a result of upsidence, however, this is unlikely to have a significant impact on the overall deep, cool, slow-flowing nature of the river in the SMP Area. All dragonfly larvae are dependent upon the presence of DO for respiration. While no specific lower limits of DO for the survival of this species could be found, widespread, prolonged very low levels of DO in the Nepean River are likely to be detrimental to this species if present.

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

There are no threatened populations of Sydney Hawk Dragonfly listed on the Threatened

Species Schedules of the *FM Act*. Thus, the proposal will not affect a threatened population as currently listed.

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

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

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

Within the SMP Area, there are no endangered ecological communities listed on the Threatened Species Schedules of the *FM Act*. Thus, the proposal will not affect a threatened population as currently listed.

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

(i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and

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

Longwall extraction induced subsidence impacts within the Nepean River are likely to result in the exposure of some shallow river bed (MSEC, 2008) that may be considered as habitat for Sydney Hawk Dragonfly larva. This could be considered as removal of aquatic habitat if upsidence causes the river bed to be raised above the normal water level.

The extent to which such habitat removal is likely to occur within the SMP Area is not significant, as the Nepean River within the SMP Area is generally greater than two meters deep (maximum upsidence effects predicted to be approximately 255 to 345 mm). Impacts at the shallow river margins are predicted to be substantially less than in the river bed (MSEC, 2008).

The reach of Nepean River between Douglas Park Weir and Menangle Weir is a continuous pool as a result of the damming effect of Menangle Weir. Upsidence resulting from longwall extraction is not predicted to be of a magnitude that could result in complete exposure of any sections of the river bed with resultant fragmentation of Sydney Hawk Dragonfly habitat.

Shallow sections of the Nepean River that may experience exposure as a result of upsidence, may contribute to Sydney Hawk Dragonfly habitat, however they do not constitute "critical" habitat, in that dragonfly larva are mobile, and individuals would not be adversely impacted by the loss of small areas of shallow habitat.

e. whether the action proposed 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*.

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

At present there is no recovery or threat abatement plan for the Sydney Hawk Dragonfly.

Conclusion

The Nepean River within the SMP Area appears to contain extensive suitable habitat for the Sydney Hawk Dragonfly. Predicted impacts on this habitat resulting from mine subsidence are likely, if they occur at all, to affect a very small percentage of the total available habitat. The possible occurrence of a widespread, prolonged DO sag in the river under low flow condition could have a negative impact upon this species. Low DO conditions in the Nepean River can be caused from numerous natural and anthropogenic factors. These impacts are not likely to have a significant impact upon any local population of this species within the SMP Area or the greater regional setting. A species impact statement is therefore not recommended for the Sydney Hawk Dragonfly.

3.3.2 Adam's Emerald Dragonfly

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, undated). In NSW, specimens (adults or larvae) have been collected from four 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, undated).

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, at the Bedford Creek site in the Blue Mountains they were found in relatively pristine riffle habitat with cobbles and sandy banks (NSW Fisheries, undated).

There does not appear to be suitable habitat within the SMP Area to support the Adam's Emerald Dragonfly, as the Nepean River does not contain appropriate riffle or cascade habitat. Foot Onslow Creek, Navigation Creek , Harris Creek and the small unnamed creeks do not have well defined riffle and pool habitat, and are likely to almost completely dry out during extended dry periods. These creeks are also highly altered in their upper reaches as a result of historical land clearing, farming and grazing. Furthermore, the sampling for this study and previous studies (The Ecology Lab, 2004; 2006), along with historical survey records for the Sydney area suggest the waterways in the SMP Area do not support an established population of Adam's Emerald Dragonfly, and therefore no further investigation is considered necessary.

4.3.3 Australian Grayling

The Australian Grayling is listed under the *EPBC Act* as a vulnerable species, and is protected from fishing under NSW legislation. It has been recorded within the Hawkesbury-Nepean catchment in the Grose River, however no records exist within the upper Nepean Catchment (Web Reference 1). The life cycle of the Australian Grayling is dependent upon migration to and from the sea (McDowall, 1996), and as such it would not be expected to occur in the upper Nepean System above barriers such as Menangle Weir which has no provision for fish passage. Given that it is highly unlikely that the Australian Grayling occurs within the study area further investigation of this species is not considered necessary.

3.3.4 Macquarie Perch

The historical distribution of Macquarie Perch included the freshwater reaches of the Hawkesbury-Nepean River system, including the SMP Area. Australian Museum records from 1894 to 1905 show the presence of Macquarie Perch downstream of the SMP Area at Menangle, Camden and Cobbitty on the Nepean River (Bionet Web Reference 1). These records predate the construction of a series of 'compensation weirs' along the river as part of the Upper Nepean Scheme between 1900 and 1920 (Matthews, 2002). The regulation of the Nepean River resulting from the construction of these weirs transformed the river from a sequence of alternating pool and riffle habitat into a series of long, deep, pools with low flow rates.

Macquarie Perch require riffle habitat to spawn (McDowell, 1996), and the absence of such habitat and the presence of barriers to upstream migration for about a century would suggest that populations of Macquarie Perch within the reach of the river incorporating the SMP Area are likely to have been heavily reduced, if still present at all. This opinion is supported by sampling conducted by NSW Fisheries (Gerhke and Harris, 1996) in the reach of the Nepean River downstream of Douglas Park Weir which failed to find Macquarie Perch. Macquarie Perch were also not found during fish surveys conducted in 2003 in the vicinity of the SMP Area as part of this assessment. The nearest recent records of Macquarie Perch are from upstream of Broughton's Pass Weir in the Cataract River, and upstream and downstream of Pheasants Nest Weir in the Nepean River (Gerhke and Harris, 1996). These watercourses contain important riffle habitat required by Macquarie Perch for spawning, and are separated from the SMP Area by significant barriers to fish passage. It is possible that Macquarie Perch may be transported downstream of these existing known populations during flood events which overtop the weirs. It is also possible that individuals transported from known viable populations upstream may be transported further downstream into areas with access to suitable spawning habitat, or may integrate with other populations such as those in the Gross and Colo Rivers. Bass are known to be able to negotiate substantial barriers to upstream migration such as the system of weirs along the Nepean River during flood events. The possibility that Macquarie Perch can also do this can not be discounted.

A precautionary consideration of a possible Macquarie Perch population within the SMP Area is recommended because of the potential presence of individuals having been transported from upstream populations. As such, a seven-part test for this species is presented below.

The seven-part test for Macquarie Perch

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

Macquarie Perch require riffle habitat to spawn (McDowell, 1996). As a result of regulation of the Nepean River through the construction of numerous weirs, the habitat has been transformed from what would have been a natural series of riffle and pool habitats, to a series of very long, deep, slow flowing pools, separated by weirs. As such, within the SMP Area, the natural riffle habitat required for Macquarie Perch to spawn no longer exists. The nearest known riffle habitats occur in the Cataract River and the upper Nepean River. If a

viable population of Macquarie Perch does exist within the SMP Area, individuals are likely to be able to migrate over existing barriers (during flood events) to access this habitat. Mine subsidence impacts resulting from the extraction of Longwalls 705 to 710 are not predicted to create any new barriers to fish passage (Section 3.2). As such, no adverse effect of the lifecycle of Macquarie Perch present within the Nepean River within the SMP Area is likely to result from longwall extraction associated with this proposal.

Changes in the physical and chemical properties of the water in which a fish lives can have adverse affects on physiology. Changes in water quality resulting from mine subsidence-induced effects are predicted to be localised and within the existing water quality variability (Section 3.2). Thus, if Macquarie Perch are present within the SMP Area, they are not expected to suffer any adverse impact as a result of changes in water quality due to mine subsidence impacts providing the proper management and mitigation programs are in place.

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

There are no threatened populations of Macquarie Perch listed on the Threatened Species Schedules of the *FM Act*. Thus, the proposal will not affect a threatened population as currently listed.

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

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

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

Within the SMP Area there are no endangered ecological communities listed on the Threatened Species Schedules of the *FM Act*. Thus, the proposal will not affect a threatened population as currently listed.

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

   (i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

   (ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and

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

Longwall extraction-induced subsidence impacts within the Nepean River could possibly result in the exposure of some shallow river bed (MSEC, 2008) that may be considered as fringe habitat for Macquarie Perch. This could be considered as removal of aquatic habitat if upsidence causes the river bed to be raised above the normal water level.

The extent to which such habitat removal is likely to occur within the SMP Area is negligible, as the Nepean River within the SMP Area is generally greater than two metres deep (upsidence effects predicted to have a maximum of approximately 255 to 345 mm) and impacts at the shallow river margins are predicted to be substantially less than in the river bed (MSEC, 2008).

The reach of Nepean River between Douglas Park Weir and Menangle Weir is a continuous pool as a result of the damming effect of Menangle Weir. Upsidence resulting from longwall extraction is not predicted to be of a magnitude that could result in complete exposure of any sections of the river bed with resultant fragmentation of Macquarie Perch habitat.

Shallow sections of the Nepean River that may experience exposure as a result of upsidence, may contribute to Macquarie Perch habitat, however do not constitute "critical" habitat, in that fish are mobile, and individuals would not be adversely impacted by the loss of relatively small areas of habitat.

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

No areas of critical habitat in relation to Macquarie Perch have yet been listed on the Threatened Species Schedules of the *FM Act*.

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

At present there is no recovery or threat abatement plan for Macquarie Perch.

Conclusion

The Nepean River within the SMP Area is unlikely to support a viable population of Macquarie Perch due to the absence of suitable spawning habitat and existing barriers to upstream migration. However, individuals may move into this area from viable populations upstream in the Cataract and Nepean Rivers. Even if Macquarie Perch were present and did constitute a viable population, the predicted impacts on this habitat resulting from mine subsidence are likely, if they occur at all, to affect a very small proportion of the total available habitat. Changes in water quality resulting from mine subsidence-induced effects are predicted to be localised and within the existing water quality variability. Thus, these impacts are not likely to have a significant impact upon any local population of this species within the SMP Area or the greater regional setting. A species impact statement is therefore not recommended for Macquarie Perch for this proposal.

4.0 RECOMMENDATIONS FOR MONITORING

The Ecology Lab established a baseline monitoring program for the REF for Longwalls 701 to 715 which commenced with field sampling in September 2003 (The Ecology Lab, 2004). As part of the SMP for Longwalls 701 to 704, this field sampling was repeated in September 2005 (prior to the commencement of Longwall 701), with some modifications (additional sites in the Nepean River) incorporated into the monitoring plan to accommodate the revised longwall layout (The Ecology Lab, 2006). The next round of field sampling planned for this monitoring program is to be undertaken in September 2008; after the completion of Longwall 701 and during the extraction of Longwall 702. It is recommended that monitoring for Longwalls 705 to 710 be established as a continuation of the existing monitoring program, with the inclusion of some additional sites to accommodate the final longwall layout. These additional sites were selected as part of the field work undertaken for this study. General habitat descriptions and some preliminary baseline monitoring undertaken at some of these sites has been presented in Section 2.3.

A detailed description of monitoring methods and statistical analysis of results is described in The Ecology Lab (2006). These methods will be used for the extended monitoring program for Longwalls 705 to 710 and are briefly outlined below.

1. **Mapping of aquatic macrophytes**: Beds of aquatic macrophytes were identified at sites within reaches of the Nepean River potentially subject to mine subsidence impacts. Control sites upstream and downstream of the predicted mine subsidence area with comparable beds of macrophytes were also selected. Within these sites, species composition and geographical distribution was mapped using DGPS (Differential Global Positioning System) for each macrophyte bed. This allows for statistical comparison of macrophyte bed composition and extent before, during and after mine extraction with reference to control sites subject to similar environmental conditions including flow, water quality and climate.
2. **Fish sampling**: Fish were sampled at each of the sites within the Nepean River using baited traps and seine nets.
3. **Macroinvertebrate sampling**: Macroinvertebrates were sampled within pool edge habitats of the Nepean River using the AusRivAS protocol.
4. **Water Quality**: Water quality was measured using a hand-held probe at each of the sites within the Nepean River at the time of fish sampling, macroinvertebrate sampling and macrophyte mapping to give an indication of the conditions at the time of sampling.

Surface watercourses potentially impacted by the extraction of Longwalls 705 to 710 (Foot Onslow Creek, Harris Creek and Navigation Creek) are not expected to experience significant impacts as a result of mining (Section 3). Limited monitoring of macroinvertebrates using the AusRivAS protocol employed in this study (Section 2.3.2) at sites within these watercourses is recommended during September of 2008, in addition to during and after longwall extraction. No fish were found in these sites, and further fish monitoring is not recommended.

Existing and newly selected sites for the monitoring of aquatic habitat and biota for Longwalls 701 to 704 and Longwalls 705 to 710 are shown in Figure 1. The table below describes the monitoring undertaken in each site to date, proposed future monitoring and the relevance to Longwall extraction timing.

Aquatic Monitoring For Appin Area 7 Longwalls 701 to 710

Watercourse	Site	Longwall Reference	Monitoring to Date	Future Monitoring	Components of Monitoring
Nepean River	1 & 2	Upstream control sites for LW 701-704 and LW 705-710	Sept 03 (pre-mining) and Sept 05 (pre-mining)	During mining (Sept 08) and future during and post mining monitoring	• Macrophyte mapping • WQ • Fish sampling • AusRivAS macroinvertebrate
Nepean River	3 & 4	Impact sites for LW 701-702	Sept 03 (pre-mining) and Sept 05 (pre-mining)	During mining (Sept 08) and future during and post mining monitoring	• Macrophyte mapping • WQ • Fish sampling • AusRivAS macroinvertebrate
Nepean River	X1 & X2	Impact sites for LW 702-704	Sept 05 (pre-mining)	During mining (Sept 08) and future during and post mining monitoring	• Macrophyte mapping • WQ • Fish sampling • AusRivAS macroinvertebrate
Nepean River	5 & 6	Downstream control sites for LW 701-704 Impact sites for LW 705-710	Sept 05 (pre-mining)	Pre/during mining (Sept 08) and future during and post mining monitoring	• Macrophyte mapping • WQ • Fish sampling • AusRivAS macroinvertebrate
Nepean River	7 & 8	Downstream control sites for LW 705-710		Pre mining (Sept 08) and future during and post mining monitoring	• Macrophyte mapping • WQ • Fish sampling • AusRivAS macroinvertebrate
Foot Onslow Creek	F1 & F2	Impact sites for small watercourses above LW 705-710	April 08 (pre-mining)	Future during and post mining monitoring (if physical /chemical impacts detected)	• AusRivAS macroinvertebrate • WQ
Navigation Creek	N1	Impact site for small watercourse above LW 705-710	April 08 (pre-mining)	Future during and post mining monitoring (if physical /chemical impacts detected)	• AusRivAS macroinvertebrate • WQ

Regular water quality monitoring is to be undertaken by BHPB before, during and after the extraction of Longwalls 705 to 710, in the Nepean River and tributaries, as a continuation of the current monitoring program for Longwalls 701 to 704. This data is made available for

the purpose of aquatic ecological interpretation to The Ecology Lab in the form of regular monitoring reports. This will allow assessment of mining related water quality impacts that may have a negative impact upon aquatic habitat and biota, and for the initiation of appropriate management strategies. Such strategies may include targeted fish and/or aquatic macroinvertebrate sampling at existing sites, or at specific locations where impacts have been detected.

6.0 ACKNOWLEDGEMENTS

This report was written by Doug Hazell, Matthew Harper and Belinda Parkes and reviewed by Dr Theresa Dye. Doug Hazell and Dan Aveling conducted the field work. Belinda Parkes supervised the macroinvertebrate identifications and ran the AusRivAS model.

7.0 REFERENCES

ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Berg, K., Jonasson, P.M., and Ockelman, K.W. (1962). The respiration of some animals from the profundal zone of a lake. *Hydrobiologia*. **19**, pp. 1-39.

BHPB (2008). Appin Mine Longwall 701 – Nepean River Update Report , 9th May, 2008.

Chambers, P.A., Brown, S., Culp, J.M., Lowell, R.B., and Pietroniro, A. (2000). DO decline in ice-covered rivers of northern Alberta and its effects on aquatic biota. *Journal of Aquatic Ecosystem Stress and Recovery*. **8**, pp. 27-38.

Chen, L., Heath, A.G., and Neves, R.J. (2001). Comparison of oxygen consumption in freshwater mussels (Unionidae) from different habitats during declining DO concentration. *Hydrobiologia*. **450**, pp. 209-214.

Chessman, B.C. (1995). Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat-specific sampling, family level identification and a biotic index. *Australian Journal of Ecology*, **20**, pp. 122-129.

Connolly, N.M., Crossland, M.R., and Pearson, R.G. (2004). Effect of low oxygen on survival, emergence, and drift of tropical stream macroinvertebrates. *Journal of the North American Benthological Society.* **23**, pp. 251-270.

Davis, J.C. (1975). Minimal DO requirements for aquatic life with emphasis on Canadian species: a review. *Journal of the Fisheries Research Board of Canada.* **32**, pp. 2295-2310.

Dean, T.L. and Richardson, J. (1999). Responses of seven species of native freshwater fish and a shrimp to low levels of DO. *New Zealand Journal of Marine and Freshwater Research* **33**, pp. 99-106.

Doudoroff, P. and Shumway, D.L. (1970). *DO Requirements of Freshwater Fishes*. Food and Agriculture Organization of the United Nations. FAO Fisheries Technical Paper No. 86, Rome.

Ecoengineers (2008). Assessment of Surface Water Flow and Quality Effects, Appin Colliery Longwalls 705 to 710 for BHP Billiton Illawarra Coal, June 2008.

Erskine, W. (1997). The Real Environmental Costs of Sand and Soil Mining on Nepean River, NSW. Proceedings Science & Technology in the Environmental Management of the Hawkesbury-Nepean Catchment, pp 29-35.

Fairfull, S. and Witheridge, G. (2003). Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings. NSW Fisheries, Cronulla.

Geoterra (2006). Douglas Colliery Area 7 Longwalls 701 to 704 Surface Water Assessment, Douglas Park, NSW. Geoterra, Pty Ltd

Gehrke, P.C. and Harris, J.H. (1996). Fish and Fisheries of the Hawkesbury-Nepean River system. Final Report to the Sysdney Water Corporation. NSW Fisheries Research Institute, Cronulla

Hart, B.T. (1974). *A Compilation of Australian Water Quality Criteria: Australian Water Resources Research Council Technical Paper No. 7*. Australian Government Printing Service, Canberra.

Homer, D.H. and Waller, W.T. (1983). Chronic effects of reduced DO on *Daphnia magna*. *Water, Air, and Soil Pollution.* **20**, pp. 23-28.

Independent Expert Panel On Environmental Flows for the Hawkesbury Nepean, Shoalhaven and Woronora Catchments (IEPEF) (2002). Protection of Environmental Flows. Discussion Paper.

Jacobsen, D. (2007). Low oxygen pressure as a driving factor for the altitudinal decline in taxon richness of stream macroinvertebrates. *Oecologia.* **154**, pp. 795-807.

McDowell, R. (1996). Freshwater Fishes of South-Eastern Australia. Reed Books, Australia.

Matthews, L. (2002). History, Construction and Significance of the Bergins, Sharpes, Thurns and Brownlow Weirs. Independent Expert Panel on Environmental Flows for the Hawkesbury-Nepean, Shoalhaven and Woronora Catchments.

MSEC (2008). The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Longwalls 705 to 710 at Appin Colliery in Support of the SMP Application. Report No. MSEC342, Revision A. Mine Subsidence Engineering Consultants Pty Ltd.

Nebeker, A.V. (1972). Effect of low oxygen concentration on survival. and emergence of aquatic insects. *Transactions of the American Fisheries Society.* **4**, pp. 675-679.

NSW Fisheries (2004) Final Recommendation to List *Austrocordulia leonardi* – Sydney Hawk Dragonfly as an Endangered Species in Schedule 4 of the *Fisheries Management Act*, 1994. NSW Fisheries Scientific Committee. Ref. No. FR28, File No. FSC04/02.

NSW Fisheries (Undated) Fishfacts. Threatened Species in NSW. Adam's emerald dragonfly, *Archaephya adamsi*. 6 pp.

Roberts, D.E., Church, A.G. and Cummins, S.P. (1999). Invasion of *Egeria* into Hawkesbury-Nepean River, Australia. *J. Aquat. Plant Management* **37**, pp. 31-34.

Sprague, J.B. (1963). Resistance to four fresh water crustaceans to high temperatures and low oxygen. *Journal of the Fisheries Research Board of Canada*. **20**, pp. 387-415.

Sprague, J.B. (1985). Factors that modify toxicity. In: G. Rand and S.R. Petrocelli (eds), *Fundamentals of Aquatic Toxicology: Methods and Application*, Hemisphere Publishing Corporation, New York, NY, USA, pp. 124-163.

The Ecology Lab (2004). Appin Workings (Longwalls 701-715) Effects of Mine Subsidence on Aquatic Ecology in the Nepean River System between Douglas Park and Menangle. Report No. 08/0304A.

The Ecology Lab (2006). Douglas Area 7 (Longwalls 701-704) Effects of Mine Subsidence on Aquatic Habitat and Biota. Report No. 11/0506

Turak, E. and Waddell, N. (2001) New South Wales (NSW) Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual. Environmental Protection

Authority. pp. 45.

Web Reference 1: http://www.bionet.nsw.gov.au NSW Government Bionet System website. Accessed 5th May, 2008.

Williams, S. (1994). Macroinvertebrates of the Hawkesbury-Nepean River and Tributaries, January 1994. Prepared for Sydney Water Board (now Sydney Water). pp 92.

Williams, D.D., Tavares, A.F., and Bryant, E. (1987). Respiratory device or camouflage? A case for the caddisfly. *Oikos.* **50**, pp. 42-52.

Winstanley, R.K. (2000). Cataract River Fish Survey. Report Prepared for Department of Land and Water Conservation.

TABLES

Table 1. Records of fish species within the Campbelltown local government area of the Nepean River, from the NSW government BioNet data base (Web Reference 1). * indicates an exotic species, # indicates a listed threatened species.

Family Name	**Species name**	**Common name**
Anguillidae	*Anguilla reinhardtii*	Longfinned eel
Clupeidae	*Potamalosa richmondia*	Freshwater herring
Retropinnidae	*Retropinna semoni*	Australian smelt
Cyprinidae	*Cyprinus carpio**	Carp
	*Carassius auratus**	Goldfish
Plotosidae	*Tandanus tandanus*	Freshwater catfish
Poeciliidae	*Gambusia holbrooki**	Gambusia/mosquitofish
Percichthyidae	*Macquaria australasica#*	Macquarie perch
	Macquaria novemaculata	Australian bass
Eleotrididae	*Gobiomorphus coxii*	Cox's gudgeon
	Hypseleotris galii	Firetailed gudgeon
	Gobiomorphus australis	Striped gudgeon
	Philypnodon grandiceps	Flathead gudgeon
Mugilidae	*Mugil cephalus*	flathead Mullet

Table 2. Water quality measures collected from small watercourses within the study area and the Nepean River from 31 March to 3 April, 2008.

Site, Position (WGS84), Date and Time	Rep	Temp (^{O}C)	Cond. (µS/cm)	pH	ORP (mv)	DO (%)	Turbidity (ntu)
Navigation Creek							
Downstream (AusRivAS site)	1	15.5	1946.0	7.8	449.0	58.2	21.0
E 288045 N 6217952 31/03/2008 10:10	2	15.5	1940.0	7.8	450.0	57.6	21.2
Upstream	1	14.5	1679.0	7.6	459.0	82.4	2.7
E 287554 N 6217848 31/03/2008 11:00	2	14.5	1684.0	7.6	447.0	81.4	5.2
Tributary 1 (cnr Carols and Hawkey Rds)	1	17.8	173.0	8.0	447.0	134.0	129.7
E 288786 N 6217821 31/03/2008 12:00	2	18.2	158.0	8.3	441.0	132.0	130.7
Tributary 1 (Carols Rd Culvert)	1	15.7	318.0	8.0	447.0	108.9	227.0
E 289014 N 6219302 31/03/2008 12:20	2	15.6	319.0	8.0	450.0	105.7	241.0
Tributary 2 (Finns Rd Cuvert)	1	21.4	3140.0	8.1	463.0	106.4	12.0
E 289590 N 6219526 31/03/2008 12:30	2	19.1	3197.0	8.0	462.0	103.6	11.4
Foot Onslow Creek							
Downstream (AusRivAS site)	1	16.5	2446.0	7.4	446.0	84.7	11.7
E 290558 N 6219001 31/03/2008 13:50	2	16.7	2426.0	7.4	444.0	82.7	7.8
Upstream (AusRivAS site)	1	14.0	1781.0	8.3	497.0	75.1	60.2
E 290708 N 6218085 01/04/2008 10:00	2	13.9	1791.0	8.3	496.0	74.3	59.3
Harris Creek							
Mountbatten	1	15.7	891.0	7.6	443.0	91.9	11.6
E 289416 N 6215578 31/03/2008 15:20	2	15.7	890.0	7.6	444.0	75.1	11.7
Nepean River							
Site 1	1	18.6	338.0	8.1	491.0	107.2	3.4
E 288497 N 6214116 03/04/2008 17:40	2	18.5	340.0	8.1	489.0	108.2	3.4
Site 2	1	18.4	341.0	8.1	488.0	108.7	3.7
E 289010 N 6214204 03/04/2008 17:30	2	18.5	341.0	8.1	488.0	108.1	3.5
Site 3	1	20.1	280.0	7.8	480.0	90.0	3.8
E 291649 N 6215374 03/04/2008 16:45	2	20.0	276.0	7.8	480.0	88.0	3.6
Site 4	1	20.1	275.0	7.8	476.0	91.1	3.6
E 292205 N 6215263 03/04/2008 16:40	2	20.1	275.0	7.8	477.0	90.0	3.5
Site X1	1	20.7	299.0	7.7	475.0	86.0	4.0
E 292374 N 6216490 03/04/2008 16:35	2	20.6	299.0	7.7	476.0	85.8	3.9
Site X2	1	20.4	306.0	7.7	472.0	81.3	4.4
E 292374 N 6216890 03/04/2008 16:30	2	20.3	306.0	7.6	473.0	80.3	4.2
Site 5	1	22.5	339.0	8.0	461.0	101.1	3.6
E 292805 N 6218042 03/04/2008 16:20	2	22.3	341.0	7.9	464.0	90.1	3.6
Site 6	1	20.4	353.0	7.6	474.0	76.8	5.9
E 292659 N 6218541 03/04/2008 16:15	2	20.5	350.0	7.6	476.0	78.0	6.1
Site 7	1	21.1	295.0	7.4	466.0	64.8	4.1
E 292577 N 6220847 03/04/2008 15:55	2	21.2	295.0	7.4	467.0	62.8	3.9
Site 8	1	21.9	280.0	7.3	457.0	84.6	3.3
E 293101 N 6221980 03/04/2008 15:45	2	21.6	275.0	7.3	459.0	78.4	3.3

Table 3. Macroinvertebrates collected using a dip net (AusRivAS methods) at each site in April 2008. A ✓ denotes a taxa has been collected at that site. (*) no ausrivas code for these taxa.

Site	1	2	3
Creek	Foot Onslow creek	Foot Onslow creek	Navigation Creek
Position	Upstream	Downstream	n/a
Habitat	Edge	Edge	Edge
Order or Family			
Aeshnidae			✓
Atyidae	✓	✓	
Baetidae	✓	✓	✓
Belostomatidae			✓
Caenidae		✓	
Ceratopogonidae			✓
Chironomidae/Chironominae	✓		✓
Chironomidae/Orthocladiinae			✓
Chironomidae/Tanypodinae	✓		✓
Cladocera (*)	✓	✓	✓
Coenagrionidae		✓	✓
Copepoda (*)	✓	✓	
Corixidae	✓	✓	✓
Culicidae			✓
Dytiscidae	✓	✓	✓
Gerridae		✓	
Gyrinidae	✓		✓
Hydracarina			✓
Leptoceridae	✓		✓
Leptophlebiidae		✓	
Lestidae	✓	✓	✓
Libellulidae (ausrivas= Corduliidae)			✓
Megapodagrionidae			✓
Naucoridae			✓
Nematoda	✓		✓
Nepidae	✓		✓
Notonectidae	✓	✓	✓
Oligochaeta	✓		✓
Ostracoda	✓	✓	✓
Parastacidae	✓	✓	✓
Physidae		✓	✓
Scirtidae (= Helodidae, Cyphonidae)	✓	✓	
Synlestidae			✓
Tipulidae	✓		
Veliidae		✓	
total no. of ausrivas taxa collected	17	15	26

Table 4. AusRivAS results for macroinvertebrate assemblages collected in edge habitats. BAND grades: X = Richer than reference; A = Similar to reference; B = Poorer than reference; C = Much poorer than reference. SIGNAL grades: > 6 = healthy habitat, 5 - 6 = mild pollution, 4 - 5 = moderate pollution, <4 = severe pollution. Section 2.3 contains a detailed explanation of how BAND and SIGNAL scores are calculated.

	Foot Onslow Creek		Navigation Creek
	Upstream	Downstream	
Expected no of taxa (E50)	9.63	9.19	9.16
Observed/expected no. of taxa (O/E50)	73%	66%	65%
Expected SIGNAL (E/O0)	4.27	4.25	4.29
Observed/Expected SIGNAL scores (O/E0)	83%	80%	81%
Band	B	B	B

Table 5. Fish and crayfish sampled from small watercourses within the study area and the Nepean River from 31 March to 3 April, 2008. Methods used included: Baited Traps (BT), Backpack Electrofisher (EF), Dip Net (DN). * indicates exotic species (introduced from outside Australia), ** indicates native species outside of its natural range.

Site and method	Flathead Gudgeon (*Philypnodon grandiceps*)	Fire Tail Gudgeon (*Hypseleotris galii*)	Australian Smelt (*Retropinna semoni*)	Mosquito Fish (*Gambusia holbrooki*)	Yabby (*Cherax destructor*)
Navigation Creek					
(AusRivAS site) EF & BT	-	-	-	-	-
Tributary 1 (Carols Rd Culvert) DN	-	-	-	>1000	-
Tributary 2 (Finns Rd Cuvert) DN	-	-	-	>1000	-
Foot Onslow Creek					
Downstream (AusRivAS site) EF & BT	-	-	-	-	6
Upstream (AusRivAS site) EF & BT	-	-	-	-	18
Nepean River					
Sites 3 - 4	3	2	2	16	-
Sites X1 - X2	3	12	-	-	-
Sites 5 - 6	1	5	-	-	-

FIGURES

Figure 1. Aquatic habitat and monitoring sites for the proposed Appin Longwalls 705 to 710.

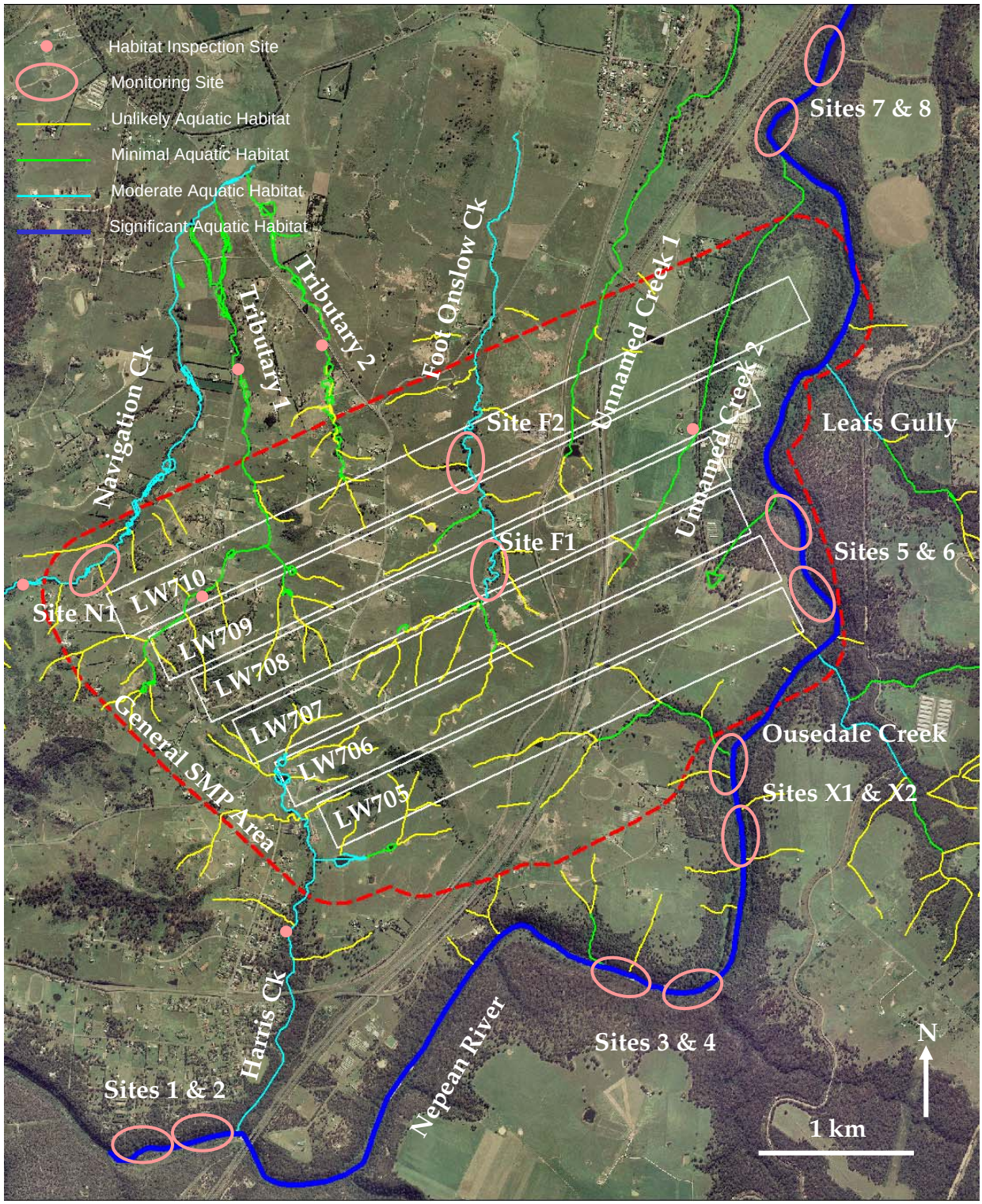

Figure 1. Aquatic habitat and monitoring sites for the proposed Appin Longwalls 705 to 710.

PLATES

Plate 1 upper. Site F1, Foot Onslow Creek (upstream AusRivAS site)

Plate 1 lower. Site F2, Foot Onslow Creek (downstream AusRivAS site)

Plate 2 upper. Site N1, Navigation Creek (AusRivAS site)

Plate 2 lower. Tributary 1 of Navigation Creek at Hawkey Road – Carols road intersection.

Plate 3 upper. Tributary 1 of Navigation Creek at Carols Road causeway.

Plate 3 lower. Tributary 2 of Navigation Creek at Finns Road causeway.

Plate 4 upper. Harris Creek at Mountbatten Road causeway.

Plate 4 lower. Un-named Creek 2 from Morton Park Road.

Plate 1 upper: Site F1, Foot Onslow Creek (upstream AusRivAS site)

Plate 1 lower: Site F2, Foot Onslow Creek (downstream AusRivAS site)

Plate 2 upper: Site N1, Navigation Creek (AusRivAS site)

Plate 2 lower: Tributary 1 of Navigation Creek at Hawkey Road – Carols road intersection.

Plate 3 upper: Tributary 1 of Navigation Creek at Carols Road causeway.

Plate 3 lower: Tributary 2 of Navigation Creek at Finns Road causeway.

Plate 4 upper: Harris Creek at Mountbatten Road causeway.

Plate 4 lower: Un-named Creek 2 from Morton Park Road.