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Marine and Freshwater Studies

Aquatic Ecology Environmental Assessment for Pipeline and Weir Construction at Penrith Lakes

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Cover Image: Nepean River, adjacent to Penrith Lakes, 18 February 2010. Photographer Bob Hunt, Cardno Ecology Lab

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Executive Summary

Cardno (NSW/ACT) Pty Ltd has been commissioned by the Penrith Lakes Development Corporation (PLDC) to prepare an Environmental Assessment (EA) for the proposed pipeline and weir construction works at Penrith Lakes.

The proposed works will allow the draw-down of flood levels within the Penrith Lakes to normal operating conditions, and would include:

- the construction of two sets of pipelines to allow for the discharge of stored floodwaters from the proposed Main Lake and Wildlife Lake; and
- the construction of a weir across Hunts Gully to inhibit the backing up of floodwaters from the Nepean River.

Penrith Lakes are located within the Cumberland sub-region of the Hawkesbury - Nepean catchment, approximately 60km west of Sydney and 2km north-west of Penrith. The EA study area includes the proposed construction sites and adjacent reaches of the Nepean River and Hunts Gully.

Field investigations of aquatic habitat, biota and water quality were made by Cardno (NSW/ACT) from 17 to 18 February 2010. Sites were established at each of the four possible pipeline locations; Main Lake South, Main Lake North, Wildlife South, Wildlife North, as well as two reference sites and the site of the proposed weir on Hunts Gully.

Aquatic Ecology and Water Quality in the Study Area

The Penrith Lakes are a series of artificially constructed water bodies, formed as a result of rehabilitation works at a large quarry located on the Nepean River floodplain. The major sources of recharge are surface flow from the local catchment, rainfall discharge from onsite quarry pits and groundwater flow.

The adjacent reach of the Nepean River has been extensively modified by mining, flood mitigation and surrounding agricultural/urban land use practices. The natural channel and alternating sequence of riffles and pools has been transformed into a straight long pool, ranging from 0 – 8 m in depth. The Nepean River is heavily regulated by water extraction and 12 major weirs.

The riparian habitat separating the eastern shore of the Nepean River and the Penrith Lakes has been heavily disturbed. Whilst the dominant native tree species was river oak (*Casuarina cunninghamiana*) the majority of riparian vegetation consisted of invasive weed species, such as willow, lantana, privet and balloon vine.

The Nepean River is major fish habitat (Class 1 waterway). It contains deep pools, large overhanging rock platforms, cobble riffles, gravel beds, overhanging branches and submerged woody debris ('snags'). Where the overhanging willows are absent the river banks are fringed by the emergent macrophyte stands of cumbungi (*Typha orientalis*), common reed (*Phragmites australis*) and dense mats of the introduced Alligator weed (*Alternanthera philoxeroides*). Further into the channel, the pool reaches are dominated by submerged beds of the introduced dense waterweed (*Egeria densa*) and to a lesser extent the native ribbonweed (*Vallisneria nana*) and hydrilla (*Hydrilla verticillata*). The DECCW Geographic Region Search tool used for the 'desktop' review indicated that tall knotweed (*Persicaria elatior*) – listed as vulnerable under both the *Environmental Protection and Biodiversity Conservation Act (EPBC Act) 1999* and the *Threatened Species Conservation Act (TSC Act) 1995* – had been recorded from the Cumberland sub-region of the Hawkesbury – Nepean system, but at much higher elevations within the catchment. The species is unlikely to inhabit the study area due to the history of disturbance, and neither tall knotweed, nor its commonly associated plant species, were identified by targeted surveys during the present study.

The macroinvertebrate assemblages sampled within the Nepean River were dominated by pollution-tolerant taxa, such as Chironomidae (true flies), Coenagrionidae (damselfly), Atyidae (freshwater shrimp) and the introduced Physidae (water snail), indicating that the aquatic habitat is severely polluted and/or degraded. Two endangered dragonfly species - Sydney hawk dragonfly (*Austrocordulia leonardi*) and Adam's emerald dragonfly (*Archaeophya adamsi*) – have previously been recorded from the Hawkesbury Nepean drainage but at much higher elevations than are present within the study area. Neither species were recorded during the survey, nor are they believed to inhabit the study area, given its history of disturbance and / or the lack of suitable habitat.

Twenty two species of fish inhabit the Nepean River in the study area. Of these, 16 species are endemic, three species are exotic (carp, goldfish and mosquitofish) and three are species native to NSW but have been translocated outside of their natural range (freshwater catfish, olive perchlet and western carp gudgeon). Of the 16 endemic species, at least ten are diadromous, meaning that they migrate between fresh and salt water at some stage in their life history. The Environmental Reporting Tool linked to a DEWHA database indicated that the threatened Macquarie Perch (*Macquaria australasica*) and Australian grayling (*Prototroctes maraena*) may either occur or suitable habitat for them may occur in the area. Both species have historically been recorded in the Hawkesbury – Nepean catchment but neither is believed to currently inhabit the study area, nor were they recorded during this survey. Macquarie perch typically inhabit higher altitude reaches than those present in the study area and are negatively associated with Australian bass, which are locally common. The downstream limit of Macquarie perch in the Nepean River (and upper limit of Australian bass), is just below Pheasants Nest, approximately 60 km to the south and upstream of the study area. It is also extremely unlikely that Australian grayling are present in the study area. The Hawkesbury – Nepean drainage represented the northern extent of the grayling's historical distribution, but despite considerable sampling within the region, the species has not been recorded in the catchment since the 1950s. It is likely that river regulation and habitat degradation are responsible for its local disappearance.

Surveys within Penrith Lakes found that the reservoirs have relatively healthy, functioning aquatic ecosystems and provide good fish habitat. There was an abundance of macroinvertebrate forage for the 11 fish species present, the species composition of the fish assemblages has remained relatively stable over the last 10 years and all populations of non-stocked species are self sustaining. Five of the eleven species are endemic to the area and the Lakes share the same three introduced species and three translocated species as the adjacent Nepean River reach. The shortfinned eel and the longfinned eel are the only diadromous species naturally recruiting into the 'closed system' of the Penrith Lakes, as they are able to climb banks and weirs and traverse short distances over moist ground to bypass barriers. The Australian bass population within Penrith Lakes has only been maintained by a stocking program and restrictions to downstream migrations by adult bass.

Environmental Constraints Associated with the Proposed Works

The reach of Hunts Gully that will be lost following the weir construction is ephemeral and highly degraded. A large portion of the lost section currently flows through a 170 m twin-pipe culvert. The diversion will not have a significant effect on aquatic ecology upstream in Hunts Gully catchment or downstream in the Nepean River and will be more than adequately offset by the creation of lacustrine aquatic habitat within the Penrith Lakes scheme.

Although thermal stratification has previously been observed within Penrith Lakes, the proposed drop pit inlets will draw-down water inflows from lake operating levels, avoiding potential cold water pollution.

There are currently no invasive or translocated aquatic species within Penrith Lakes that do not already have self sustaining populations within the adjacent reach of the Nepean River. As such, movement of these species from Penrith Lakes into the Nepean River via the draw-down pipelines would not constitute an introduction of a species to new waters outside of its range.

Modelling has indicated that the proposed weir and Penrith Lakes floodwater drawn down would not significantly change the hydrological profile of the Nepean River. Hunts Gully is ephemeral and makes an insignificant contribution to the Nepean River environmental flows. The major source of discharged water from the Penrith Lakes during rare large flood events would be the Nepean River itself when waters either back up Hunts Gully or overtop Weir 1 into Quarantine Lake. Water levels in the Nepean River would be close to "normal" levels several days after the discharge peak.

There are however a number of aspects of the proposed pipeline and weir construction which have the potential to cause a loss of aquatic biological diversity and ecological function and/or lead to a shift to a more pollution and disturbance tolerant biotic community. The major environmental constraints associated with the proposed works relate to:

- mobilisation of sediment;
- pollution;
- water quality;
- bank stability;
- degradation of riparian vegetation;
- removal of large woody debris.

Conclusions and Recommendations

To minimise potential impacts arising from the proposed works it is recommended that PLDCs Construction and Environment Management Plan (CEMP) for the proposed works addresses the following issues. Providing that these mitigation measures are adhered to, it is unlikely that the works will have a significant impact on the aquatic ecology of the study area.

It is recommended that regular monitoring be maintained within the Lakes System that will enable PLDC to identify and respond to potential water quality problems that may arise within the reservoirs (e.g. algal blooms, low dissolved oxygen) prior to discharge into the Nepean River. However, it should be noted that during large flood events the Nepean River itself would be a major source of floodwater in the Penrith Lakes, and as such Penrith Lakes would not be entirely responsible for the potential poor quality of the discharged water (e.g. elevated turbidity).

The mobilisation of sediment into aquatic habitats within the construction zone and further downstream would be minimised through the implementation of an Erosion and Sediment Control Plan (ESCP). Similarly, plans to maintain and/or strengthen riverbank stability in the proposed works area need to be included within the ESCP and Riverbank Plan of Management (RPOM).

Potential impacts from pollution would be minimised by ensuring the proper handling, storage, transport and disposal of hazardous materials onsite.

Removal of native riparian vegetation, where present, should be minimised and appropriate consideration given to the presence of threatened species or communities. Degraded riparian habitat and realigned channel banks should be rehabilitated by the removal of exotic species and regeneration and/or revegetation of native riparian species. Any large woody debris removed during works should be replaced back in the river following completion of construction works.

Given the similarity of aquatic biota and habitat between sites, the abundance of similar habitat and biota elsewhere in the reach and the absence of threatened or protected species, the two sites under consideration for the Main Lake and Wildlife Lake draw-down pipelines are equivalent with respect to potential impacts on aquatic ecology.

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1 Background

Cardno (NSW/ACT) Pty Ltd has been commissioned by the Penrith Lakes Development Corporation (PLDC) to prepare an Environmental Assessment (EA) for the proposed pipeline and weir construction works at Penrith Lakes. Penrith Lakes is identified under Schedule 2 of SEPP (Major Development) 2005 as a Part 3a Project. Therefore the potential environmental impacts of any works proposed on the site must be assessed under Part 3a of the Environmental Planning and Assessment (EP&A) Act 1979.

1.1 Aims

This aquatic ecology assessment comprises:

- Desktop review of information on the aquatic habitats and biota in the region of the study area, including threatened and protected species, populations and ecological communities that may be present;
- Description of the nature and condition of aquatic habitats and biotic communities within the study area based on field assessments;
- Identification of environmental constraints associated with the proposed works; and
- Recommendations to minimise or mitigate potential impacts.

1.2 Project Description

1.2.1 Study Area

Penrith Lakes are located within the Nepean River sub-catchment of the Hawkesbury - Nepean catchment, approximately 60km west of Sydney and 2km north-west of Penrith. It is bound to the north by Smith Road, to the east by The Cranebrook Terrace, to the west by the Nepean River and to the south by Castlereagh Road.

More specifically, the study area for this environmental assessment comprises the regions of disturbance associated with the pipeline and weir works, including adjacent and downstream reaches of the Nepean River (Figure 1).

1.2.2 Proposed Works

The project can be divided into two sections:

1. The construction of two sets of pipelines which have been proposed to allow for the discharge of stored floodwaters from the proposed lakes (Main Lake and Wildlife Lake) after a flood event into the Nepean River; and

2. The construction of a weir across Hunts Gully at the northern end of the Wildlife Lake to control the entry of floodwaters from the Nepean River.

The proposed works would allow the draw-down of post flood levels within the Penrith Lakes to normal operating conditions (10 m AHD for Wildlife Lake and 14 m AHD for Main Lake).

Two possible locations were identified for each set of pipes (Figure 1). The construction works would involve excavation of the creek bank (excavated material to be removed from the site), laying of the pipes, covering of the pipes with clean fill and revegetation. The pipelines would comprise of 2 x 1050 mm diameter pipes discharging from the Wildlife Lake into the Nepean River and 6 x 1350 mm diameter pipes discharging from the Main Lake into the Nepean River. Drop pit inlets, with an opening at the lake operating level, would convey water above the lake operating level to the outlet pipes. USBR Type VI energy dissipaters and sandstone boulder scour mats would be constructed at each pipe outlet to reduce the scour of the flood discharge. The scour mats and dissipaters would be positioned on low gradient sections of the river bank, primarily above the waterline.

The proposed weir is required to ensure that flood events of 10 - 25 year ARI (annual recurrence interval) do not result in flood waters ‘backing up’ through Hunts Gully and causing major erosion to the existing creek line and conservation zone. The weir would be located at the northern end of the Wildlife Lake and would be approximately 140 m wide. The weir would consist of a small concrete structure and earth mounding to tie in with the existing ground levels to the east and west. The weir will transverse Hunts Gully and divert flows into Wildlife Lake.

2 Study Methods

2.1 Review of Existing Information

Existing information on aquatic habitats and associated biota within the project area was obtained by searching Cardno Ecology Lab's extensive specialist library and undertaking searches for relevant literature using the internet.

This assessment has included reference to threatened species and threatening processes listed on the *Threatened Species Conservation Act (TSC Act) 1995*, *Fisheries Management Act (FM Act) 1994* and *Environmental Protection and Biodiversity Conservation Act (EPBC Act) 1999*. Threatened species, populations and ecological communities that occur or could potentially occur within the study area were identified by reviewing the current listings on databases maintained by NSW Government (BioNet), Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA), NSW Department of Environment, Climate Change and Water (DECCW) and Industry & Investment NSW (I&I NSW).

The NSW Government BioNet database indicates species that are threatened on the schedules of the TSC Act 1995 and species that are threatened or protected under the FM Act 1994 and *Fisheries Management Amendment Act (FMA Act) 1997*.

The DEWHA Environmental Reporting Tool was used to determine whether any species listed as threatened or protected under the schedules of the EPBC Act 1999 occurred in the Study Area. The search area for the Environmental Reporting Tool centred on the Nepean River from Victoria Bridge (Great Western Highway, Penrith) to the confluence with the Grose River (Hawkesbury Road Bridge) and included adjacent aquatic habitat.

The DECCW Geographic Region Search was used to determine whether any threatened species and communities listed under the TSC Act 1995 were present in the Study Area. The search was performed on the Cumberland sub-region of the Hawkesbury - Nepean Catchment Management Authority (HNCMA) area.

Searches were also done for the presence of significant or critical aquatic habitat present within the region of the study area, such as SEPP 14 and RAMSAR wetlands.

2.2 Field Sampling Methodology

Field investigations of aquatic habitat, biota and water quality were made by Cardno Ecology Lab from 17 to 18 February 2010. Sites were established at each of the four possible pipeline locations; Main Lake South, Main Lake North, Wildlife South, Wildlife North, as well as two reference sites, one upstream of the proposed pipeline locations (Southern Reference) and one downstream of the proposed pipeline locations (Northern Reference) (Figure 1).

At each site the aquatic habitat, surface water quality, macrophyte, aquatic macroinvertebrate and fish assemblages were recorded.

2.2.1 Habitat Characteristics

At each site, a standardised description of adjacent land and condition of riverbanks, channel and bed was recorded using the 'Riparian, Channel and Environmental Inventory' (RCE). RCE is used to rank the environmental state of particular locations for use in management decisions. The RCE score for each site is calculated by summing the scores for each descriptor noted (Appendix 1). The highest score (52) would be assigned to a stream with little or no obvious physical disruption. The lowest score (13) would be assigned to a heavily disturbed stream without any riparian vegetation. This methodology was developed by Chessman *et al*. (1997) by combining some of the descriptors, modifying some of the associated categories and simplifying the classifications from 1 to 4. Habitat descriptors included:

- Geomorphological characteristics of the waterways;
- Types of land use along the waterway (e.g. industries associated with the river, recreational uses);
- Riparian vegetation and instream vegetation (e.g. presence/absence, native or exotic, condition);
- Substratum type (e.g. rock, sand, gravel, alluvial substrata).

The waterway at each site was classified for fish habitat. The classification of waterways was done according to NSW Policy and Guidelines: Aquatic Habitat Management and Fish Conservation (Smith and Pollard 1999) and guidelines and policies for fish friendly road crossings (Fairfull and Witheridge 2003). The criteria for the fish habitat classifications are reproduced in Appendix 2.

2.2.2 Water Quality

Water quality was measured using a Yeo-Kal 611 probe. Physical-chemical properties measured included: electrical conductivity (ms/cm and µs/cm); salinity (ppt); temperature (^{0}C); turbidity (ntu); dissolved oxygen (mg Litre^{-1} and % saturation); pH; and ORP (oxidation reduction potential: mV). Alkalinity (mg $CaCO_3$ Litre^{-1}) was measured in situ using hand-held titration cells from CHEMetrics.

Two replicate measures of each variable were taken from just below the water surface at each site, except for alkalinity, where only one measure was taken.

2.2.3 Macrophytes

The presence of instream macrophyte taxa was recorded at each site.

2.2.4 Macroinvertebrates

Aquatic macroinvertebrates were sampled from edge habitat at each site. Edge habitat is defined as areas along creek banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation (Turak *et al*. 2004). Samples were collected over a total length of 10 m of edge habitat usually in 1-2 m sections, ensuring that all significant sub-habitats within each site were sampled (Turak *et al*. 2004).

Dip nets with a mesh size of 250µm were used to collect invertebrates. The dip net was first used to disturb animals by agitating bottom sediments and suspending invertebrates into the water column. The net was then swept through this cloud of material to collect suspended invertebrates and surface dwelling animals. Each sample was rinsed in the net with local water to minimise fine particles and placed inside a plastic bag containing 70 % ethanol for laboratory identification.

2.2.5 Fish

Electrofishing and bait traps were used to sample fish and large mobile macroinvertebrates at each site. These techniques are non-destructive, and all but introduced pest species such as the mosquito fish (*Gambusia holbrooki*) and carp (*Cyprinus carpio*), were returned unharmed to the water. Introduced species were euthanized humanely with clove oil.

Electrofishing is a commonly used and effective technique for sampling fish in freshwater habitats such as creeks, drainage ditches and streams. The technique involves discharging an electric pulse into the water which stuns fish, allowing them to be easily netted, counted, identified and released. Electrofishing was done in edge habitat beneath overhanging banks and vegetation and within macrophyte beds located away from the bank. One staff member used the electrofisher, whilst a second handled a dip net and was primarily responsible for capture of stunned fish. Captured fish were placed into a fish box filled with stream water for identification and subsequent release.

Fishing power (amps) was standardised across sites by adjusting voltage output according to the electrical conductivity of the water.

Five bait traps were deployed at each site. The traps used were rectangular in shape and approximately 350 mm long and 200 mm wide with an entrance tapering to 45 mm, with 3 mm mesh size throughout. Traps were deployed in shallow water habitats such as bare substratum and amongst macrophytes. Traps were baited with approximately 70 ml of a mixture of chicken pellets and sardines and were left overnight for approximately 18 hours.

Surveys of fish were undertaken only once (February 2010) and should reveal a range of fish present at each site. This survey provides no information on potential variation in fish populations through time; rather it presents an appropriate "snapshot" of fish communities.

2.3 Laboratory Methods

Animals in the macroinvertebrate samples were removed, identified using a binocular microscope, and counted. Taxa were identified to family level except for Araneae, Cladocera, Copepoda, Hydracarina, Nematoda, Nemertea, Oligochaeta and Ostracoda. Chironomidae were identified to sub-family. Some families of Anisoptera (dragonfly larvae) were identified to lower taxonomic resolution (species), because they could potentially include threatened aquatic species. Identification of animals was validated by a second experienced scientist performing QA checks on each sample. Any animal whose identity was in doubt was sent to the DECCW for identification.

2.4 Data Analysis

2.4.1 Water Quality

The results of water quality analysis collected in situ during site inspections by Cardno Ecology Lab were used to assess water quality within the study area in terms of the health of aquatic ecosystems by comparison with the Australia, New Zealand Environment Conservation Council (ANZECC/ARMCANZ 2000) guidelines for upland rivers in south-eastern Australia.

As water quality data were collected at one time only, they were "snapshot" in nature, and do not provide information on possible variations through time.

2.4.2 Signal Scores

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

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

3 Results

3.1 Existing Information

3.1.1 Physical Setting and Hydrology

The Penrith Lakes study area is located on the Nepean River and adjacent floodplain, approximately eight kilometres upstream of the Grose River confluence and the origin of the Hawkesbury River.

The Penrith Lakes are a series of artificially constructed water bodies, formed as a result of rehabilitation works at a large 1,935 hectare sand and gravel quarry located on the Nepean River floodplain. Penrith Lakes currently operate as a 'closed system', the major sources of recharge are surface flow and stormwater runoff from the local catchment, rainfall discharge from onsite quarry pits and tailings dams and groundwater flow. Water quality within the lakes has generally been within or just outside ANZECC/ARMCANZ (2000) guidelines (I&I NSW 2009). Surface pH levels were above ANZECC/ARMCANZ (2000) guidelines at each lake and the Duralia Lake storage has previously stratified during summer months, with cold anoxic water accumulating at the bottom (I&I NSW 2009).

The reach of the Nepean River adjacent to the Penrith Lakes has been extensively modified by historical mining activities, flood mitigation works and surrounding agricultural and urban land use. The natural channel and alternating sequence of riffles and pools has been transformed into a relatively straight long pool, ranging from 0 – 8 m in depth. Flows in the Nepean River are regulated by water extraction and 12 major weirs along its length. Downstream of Penrith Weir the river bed has been degraded due to changes in the natural flow regime and increased sedimentation. Water quality is fair but has been affected by increased concentrations of nutrients and suspended sediments. Upstream of the study area the Nepean River is a popular recreation area, with considerable boating, fishing and swimming.

The Nepean River is considered major fish habitat (Class 1 Waterway) (DPI 2006). It contains deep pools, large overhanging rock platforms, cobble riffles, gravel beds, overhanging branches, submerged woody debris ('snags') and emergent and submerged macrophyte beds (DPI 2006). Fish surveys within Penrith Lakes found that the reservoirs have relatively healthy, functioning aquatic ecosystems and provide good fish habitat (I&I NSW 2009). There was an abundance of forage for the fish species present, species composition had remained relatively stable during survey years and all of the non-stocked native species were self sustaining (I&I NSW 2009).

The riparian habitat separating the eastern shore of the Nepean River and the Penrith Lakes has been heavily disturbed (PLDC 1997). Riparian forest associated with the endangered Sydney Coastal River-Flat Forest is present in the Penrith Lakes study area (Beveridge 2002). The riparian habitat was cleared in the past and the existing native fragments have regenerated naturally. The dominant tree species is river oak (*Casuarina cunninghamiana*) and other species include; forest red gum (*Eucalyptus tereticornis*), coastal myall (*Acacia binervia*) and white sallow wattle (*Acacia floribunda*). There are few native plants in the understorey due to invasion of weed species that dominate the majority of the riverbank, including; willows (*Salix* spp.), lantana (*Lantana camara*), balloon vine (*Cardiospermum grandiflorum*), castor oil plant (*Ricinus communis*), kikuyu grass (*Pennisetum clandestinum*), privet (*Ligustrum* spp.) and wandering jew (*Tradescantia albiflora*).

The banks of the Nepean River adjacent to Penrith Lakes are fringed by stands of cumbungi (*Typha orientalis*) and common reed (*Phragmites australis*) (Table 1) (PLCD 1997). Alligator weed (*Alternanthera philoxeroides*) is also common. The pool reaches are dominated by the submerged the native ribbonweed (*Vallisneria nana*) and the introduced dense waterweed (*Egeria densa*).

The macroinvertebrate fauna of Penrith Lakes is dominated by species from Trichoptera (caddisflies), Odonata (dragonflies and damselflies), Diptera (true flies) and to a lesser extent Hemiptera (true bugs) and Coleoptera (beetles) (I&I NSW 2009). Freshwater shrimp and prawns have also been frequently observed (I&I NSW 2009). These taxa are excellent forage for the larger and smaller fish species present within the Penrith Lakes system. Three species of freshwater mussels are also present in Hawkesbury – Nepean River system; *Hyridella depressa*, *Hyridella australis* and *Velesunio ambiguous*.

Twenty seven fish species were identified as potentially inhabiting or having historically inhabited the wider region of study area (Table 1). Of these, 24 are native species and three are exotic species; goldfish (*Carassius auratus*), carp and mosquitofish, the latter two are declared Class 3 noxious species under the FM Act. Two native species in Table 1 are listed as threatened. The FM Act lists the Macquarie perch (*Macquaria australasica*) as a vulnerable species and Australian grayling (*Prototroctes maraena*) as a protected species. The Macquarie perch and the Australian grayling are also listed under the EPBC Act as endangered and vulnerable, respectively.

Surveys within the Penrith Lakes from 1998 – 2009 have identified a total of 11 fish species (Table 1). Industry & Investment NSW did not distinguish between firetailed gudgeon (*Hypseleotris galii*) and western carp gudgeon (*Hypseleotris klunzingeri*) due to difficulties differentiating between the species in the field but both were formerly identified from samples taken. Australian bass (*Macquaria novemaculeata*) and carp were the most abundant large fish, whilst mosquitofish were the most abundant small fish (I&I NSW 2009). A stocking program from 1996 to 2005 introduced 129,000 bass into the Penrith Lakes.

Trout cod (*Maccullochella macquariensis*) are present in Cataract Dam (upper Hawkesbury – Nepean catchment) and the species is listed as endangered under both the FM Act and EPBC Act. However, this population has been translocated from the Murray – Darling system and is outside of its natural range (McDowall 1996). The population is a considerable distance upstream of Penrith Lakes and is unlikely to be affected by potential impacts arising from the proposed works. Freshwater catfish are present within the study area and have been observed in Penrith Lakes but the Hawkesbury – Nepean population is believed to have been translocated from the western part of its range in the Murray – Darling drainage, and is therefore also outside of its natural range (McDowall 1996). Olive perchlet have been recorded within Penrith Lakes and a similar small population has been observed nearby in the Nepean River (I&I NSW 2009). The natural distribution of olive perchlet extends as far south as the Clarence River catchment in northern NSW therefore these populations have been translocated outside their natural range. BioNet contained records of spangled perch (*Leiopotherapon unicolour*) and mouth almighty (*Glossamia aprion*) for the region of the study area. The Hawkesbury – Nepean drainage is not within the natural range of either species and as there are no records of translocated populations in the area it is likely these represent errors on the BioNet database or isolated specimens released without authorisation. I&I NSW (2009) surveys have identified western carp gudgeons in Penrith Lakes but the published distribution of the species along the coastal drainages only extends as far south as the Hunter River (McDowall 1996, Pusey *et al*. 2004). The presence of this species in the Hawkesbury – Nepean catchment indicates either a previously unidentified range extension or the persistence of a translocated population.

It is likely that not all species listed in Table 1 that naturally occur in the region actually inhabit the reach of the Nepean River potential effected by impacts associated with the proposed works. The various search tools and published distributions have a relatively coarse resolution and include nearby aquatic habitat not present in the adjacent Nepean River. For example, neither the mountain galaxias (*Galaxias olidus*) nor the climbing galaxias (*Galaxias brevipinnis*) are likely to be present in the study area. The former is only found at moderate to high elevations, such as in the nearby Blue Mountains, and the latter may be absent from the region due to habitat degradation (McDowall 1996). The pacific blue-eye (*Pseudomugil signifer*) is abundant in brackish coastal waters and does not usually penetrate far inland (although it has been observed considerable distances upstream in Queensland) (McDowall 1996, Pusey *et al*. 2004). Macquarie perch usually inhabit the upper reaches of clear watercourses and typically upstream of Australian bass populations. A recent study in the Nepean River only found Macquarie perch in the upper reaches, with the most downstream observation just below Pheasants Nest Weir, at approximately 150 m AHD, 6 – 12 km upstream of the highest elevation bass observation (DPI 2007). The Australian grayling is also unlikely to inhabit the Nepean River in the vicinity of the study area. Its historical distribution was believed to have extended as far north as the Grose River but has contracted considerably due to river regulation and habitat degradation and it has not been recorded in the Hawkesbury – Nepean system since the 1950s (McDowall 1996, Morris *et al*. 2001, Backhouse *et al*. 2008).

The native fish assemblage of the Nepean River in the study area is likely comprised of the taxa from the BioNet search (Table 1), with the addition of the shortfinned eel, western carp gudgeon and olive perchlet and removal of the pacific blue-eye. Of these 22 species, 16 species are endemic, three species are exotic and three native species have been translocated outside of their natural range (freshwater catfish, olive perchlet and western carp gudgeon).

Of the 16 endemic species present within the adjacent reach of the Nepean River, at least ten are diadromous, meaning that they migrate between fresh and salt water at some stage in their life history. Another two species are potentially diadromous (Cox's gudgeon and bullrout) although it is possible that they can complete their life cycle within freshwater (i.e. potamodromous life history). Four species (Australian smelt, flathead gudgeon, and dwarf gudgeon firetailed gudgeon) are potamodromous. The composition of the Nepean River fish assemblages changes upstream, with differences in habitat, species interactions, physical tolerances and the presence of barriers to passage (as many weirs on the Nepean River do not have effective fishways (DPI 2006, 2007)). Barriers to passage can cause diadromous fish to be absent from upstream reaches. A 2007 survey did not find empire gudgeon upstream of the Penrith Weir pool, freshwater herring were not sampled upstream of Wallacia weir, sea mullet and freshwater mullet were not sampled upstream of Theresa Park weir (DPI 2007). The shortfinned eel and longfinned eel are the only diadromous species naturally recruiting into the Penrith Lakes as they are able to climb banks and weirs and traverse short distances over moist ground to bypass barriers. The bass population within Penrith Lakes is only maintained by the stocking program and the restrictions to spawning migrations of adult bass downstream from the Lakes to the Hawkesbury River estuary. A survey in 2009 of Penrith Lakes found no bass aged younger than three years because stocking had ceased in 2005 (DPI 2007).

3.2 Threatened and Protected Species, Populations, Communities and Key Threatening Processes

3.2.1 Listings under the Environmental Protection and Biodiversity Conservation Act 1999

3.2.1.1 Threatened Species

The Environmental Reporting Tool linked to the EPBC Act indicated that one endangered fish species, the Macquarie Perch (*Macquaria australasica*), one vulnerable fish species, the Australian grayling (*Prototroctes maraena*) may either occur or suitable habitat for them may occur in the area.

Tall knotweed (*Persicaria elatior*) is listed as vulnerable under the EPBC Act. The DECCW Geographic Region Search tool indicated tall knotweed is present within the Cumberland sub-region of the HNCMA area, although the DEWHA Environmental Reporting Tool (using a smaller search area) did not predict or record the presence of this species.

Macquarie Perch

There are two distinct populations of Macquarie perch in NSW, a western form found in the Murray-Darling Basin, and an eastern form found in south-eastern coastal NSW, including the Hawkesbury-Nepean catchment (DPI NSW 2005). Macquarie perch have also been translocated into a number of river systems. They are found in lake and river habitats, particularly in the upper reaches of rivers and their tributaries. The species spawns in spring or summer in shallow upland streams or flowing parts of rivers. The eggs settle among stones and gravel of the stream or river bed. Macquarie perch is threatened by:

- Changes in water quality associated with agriculture and forestry;
- Modification of natural river flows and temperatures as a result of the construction of dams and weirs;
- Spawning failures resulting from cold water releases from dams;
- Competition from introduced fish species;
- Diseases, such as epizootic haematopoietic necrosis, which is carried by redfin perch; and
- Over-fishing in the past.

Australian Grayling

The Australian grayling were formerly widespread and their historical distribution included coastal waterways from the Grose River, west of Sydney, southwards through NSW, Victoria and Tasmania (DPI NSW 2006b). The species forms fast-moving shoals in clear streams and rivers with moderate flow. Eggs of grayling develop in gravel beds, and once hatched the larvae are swept downstream to marine habitat where they develop before returning upstream to freshwater at six months of age (DPI 2006b). Threats to Australian grayling include:

- Construction of weirs and dams, which prevent downstream and upstream migration;
- Land clearing that degrades water quality and causes siltation;
- Smothering of gravel beds by fine sediment
- Competition from the introduced brown trout.

Tall Knotweed

Tall knotweed has been recorded in the coastal catchments of NSW and Queensland. There are two records of the species from the Avon River in the upper Hawkesbury-Nepean catchment. Tall knotweed is found in damp areas, particularly beside streams and lakes. Threats to tall knotweed include:

- Clearing;
- Hydrological changes;
- Damage to road and track populations through maintenance.

3.2.1.2 Invasive Species

Environmental Reporting Tool has identified alligator weed (*Alternanthera philoxeroides*) and Salvinia (*Salvinia molesta*) as potentially occurring in the area.

Alligator Weed

Alligator weed is a Weed of National Significance. It poses a significant environmental and economic threat and is highly invasive. Infestations can take over wetlands such as creeks and drainage channels, displacing native vegetation, prevent flow and reduce oxygen exchange. It can also invade land and displace or cause the failure of agricultural crops. Alligator weed does not produce viable seed in Australia but instead grows through vegetative reproduction and is spread easily from fragments. It has been spread in landfill and attached to machinery and vehicles (e.g. bulldozers).

Alligator weed has been declared noxious for the Hawkesbury River County Council, which includes the local council areas of Penrith. It is considered a Class 3 weed and as such must be fully and continuously suppressed and destroyed.

Salvinia

Salvinia is Weed of National Significance. It poses a significant environmental and economic threat and is highly invasive. The species can rapidly spread from small single plants and infest still or slow moving waterways, displacing and shading out native aquatic vegetation, impeding oxygen exchange making the water unsuitable for fish and other animals. Salvinia spreads downstream during flooding and colonises new catchments by human activities, intentionally or attached to boats and other aquatic equipment.

Salvinia has been declared noxious for the Hawkesbury River County Council, which includes the local council areas of Penrith. It is considered a Class 3 weed and as such must be fully and continuously suppressed and destroyed.

3.2.2 Listings under the Threatened Species Conservation Act 1995

3.2.2.1 Threatened Species

The DECCW Geographic Region Search tool indicated tall knotweed (*Persicaria elatior*) is present within the Cumberland sub-region of the Hawkesbury – Nepean catchment. Tall knotweed is listed as vulnerable under the TSC Act.

The giant dragonfly (*Petalura gigantea*) is listed as endangered under the TSC Act. Whilst the species has been recorded from various sub-regions of the Hawkesbury-Nepean catchment, it is not present within the Cumberland sub-region and was not identified by the DECCW Geographic Region Search tool. This species will not be considered further.

3.2.2.2 Key Threatening Processes

Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is listed as a Key Threatening Process on Schedule 3 of the TSC Act. Human activities that reduce or increase flows, change the seasonality of flows, change the frequency, duration, magnitude, timing, predictability and variability of flow events, alter surface and subsurface water levels and change the rate of rise or fall of water levels can all alter the natural flow regimes of water courses. The proposal includes a weir on Hunt's Creek and discharge of Penrith Lakes flood waters into the Nepean River, both of which could potentially alter natural flow regime.

The flow regime is a key driver of river ecology, and changes to flow can alter the geomorphological process of sediment erosion, transport and deposition that structure a variety of important channel habitat forms, change macrophyte communities, influence water properties important to biological assemblages and alter in-stream connectivity, isolating habitats and populations.

Examples of impacts on aquatic biota associated with altering natural flow regimes include:

- Restricted access to habitat for foraging, refuge or reproduction (e.g. reduced fish passage);
- Disruption of natural environmental cues necessary for reproductive cycles;
- Reductions in flow can decrease the amount of organic matter on which invertebrates and vertebrates depend;
- Changes in flow can increase erosion and lead to sedimentation impacts on aquatic communities and degradation of the riparian zone;
- Deeper and more permanent standing water can facilitate the establishment and spread of exotic species.

These alterations can pose a threat to species, populations or ecological communities which rely on natural flow regimes for their short term and long term survival and thereby contribute to loss of biological diversity and ecological function in aquatic ecosystems.

3.2.3 Listings under the Fisheries Management Act 1994

3.2.3.1 Threatened Species

There are three species listed as endangered under the FM Act that may either occur or suitable habitat for them may occur in the region of the study area: Macquarie Perch (*Macquaria australasica*), Sydney hawk dragonfly (*Austrocordulia leonardi*) and Adam's emerald dragonfly (*Archaeophya adamsi*).

Sydney Hawk Dragonfly

Sydney Hawk Dragonfly (*Austrocordulia leonardi*) was discovered in 1968 from Woronora River and Kangaroo Creek, south of Sydney, and was subsequently been found in the upper Nepean

River at Maldon Bridge near Wilton. This dragonfly spends most of its life as an aquatic larva, with adults emerging from the water and living for only a few weeks or months. The larvae appear to have specific habitat requirements and have only been found under rocks in deep, cool, shady pools (DPI 2007b). This species is threatened by:

- River regulation and changes in flows that cause the disappearance of natural deep pools;
- Habitat degradation associated with removal of riparian vegetation, drainage works and sedimentation;
- Water pollution and sedimentation due to land clearing, waste disposal and stormwater runoff from urban, industrial and agricultural development in the catchment; and
- Chance events such as natural disasters (drought) that eliminate the remaining local populations.

Adam's emerald dragonfly

Adam's emerald dragonfly has only been collected in four localities, one of which was Bedford Creek in the Lower Blue Mountains. Bedford Creek flows into Erskine Creek which eventually flows into the Nepean River downstream of Warragamba River and Nepean River confluence. The aquatic larvae of Adam's emerald dragonfly are found in small creeks with gravel or sandy bottoms, in narrow, shaded riffle zones with moss and rich riparian vegetation (DPI 2009). Adam's emerald dragonfly larvae live for 7 years or so and undergo various moults before metamorphosing into adults. Adult dragonflies generally fly away from the water to mature before returning to breed. Males congregate at breeding sites and often guard a territory. Females probably lay their eggs into the water (DPI 2009). Threats to this species include:

- Habitat degradation resulting from the loss of riparian vegetation and drainage works;
- Water pollution and siltation due to land clearing, waste disposal and stormwater runoff from urban, industrial and agricultural development in the catchment;
- Chance events such as natural disasters.

3.2.3.2 Protected Species and Habitats

Australian Grayling

The Australian grayling is listed as a protected species under the FM Act.

Aquatic Habitat

Protected aquatic habitat in NSW (Fish Habitat Protection Plan No.1) that may be present in the study area includes: water and quality of water, sand and gravel substrates, reed beds and other aquatic plants, large woody debris and rocks.

3.2.3.3 Key Threatening Processes

Four of the key threatening processes listed under the FM Act are relevant to the proposed works; (i) *degradation of riparian vegetation*, (ii) *removal of large woody debris from NSW rivers and streams*, (iii) *instream structures and mechanisms that alter natural flow*, and (iv) *introduction of fish to fresh waters within a river catchment outside their natural range* .

Degradation of native riparian vegetation along New South Wales water courses

The term "riparian vegetation" refers to the plants that occur on the land that adjoins, directly influences or is influenced by bodies of water, such as creeks, rivers, lakes and wetlands on river floodplains. Riparian vegetation is important ecologically because it provides a source of organic matter; shade and a source of large woody debris. Riparian vegetation stabilises river beds and banks, protecting the channel against erosion and acts as a filter for sediments and nutrients entering watercourses.

Removal of large woody debris from New South Wales rivers and streams

Instream woody debris provides complex habitat for macroinvertebrates and particularly fish, including refuge from predation, habitat for prey and as damming structures that create pools.

Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams

Instream structures, such as floodgates, weirs, culverts, flow regulators, erosion control structures and causeways, can all modify natural flow regimes of waterways (See Section 3.2.2.2 above). Of particular concern can be the impacts these structures have upon the passage of fish. Crossings of watercourses, or construction in the vicinity of a watercourse, would minimize potential impacts on aquatic habitat and biota if they complied with the NSW Fisheries 'Guidelines and Policies for Aquatic Habitat Management and Fish Conservation' and 'Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings' (Fairfull and Witheridge 2003).

The introduction of fish to fresh waters within a river catchment outside their natural range

Eleven species of non-native fish currently have self-sustaining populations in NSW. The introduction of fish to fresh waters within a river system outside of their natural range has negative impacts on several threatened species and populations, including Macquarie perch. Impacts of introduced species on native flora and fauna include:

- Direct predation, particularly on eggs and larvae;
- Competition;
- Habitat degradation;
- Facilitate the spread of disease.

3.3 Field Assessment

The field assessment of sites along the proposal was undertaken on 17 – 18 February 2010. Each waterway was classified according to NSW Fisheries Guidelines (Table 2) and the guidelines for the criteria are contained in Appendix 2. Table 2 also contains RCE scores for each watercourse (Riparian, Channel and Environmental inventory). Appendix 1 details the categories and descriptors used to calculate RCE scores (after Chessman *et al*., 1997).

In general, the aquatic communities observed at the sites of the proposed pipe construction were relatively similar to one another and to two nearby reference sites. The six sites are located on one long pool reach and the processes that structure the assemblages at these sites are mostly the same.

Conductivity and pH were within ANZECC/ARMCANZ (2000) guidelines for lowland watercourses at all sites (Table 3, Appendix 3). Whereas, dissolved oxygen and turbidity were less than the lower ANZECC threshold limits, but in many cases only marginally (Table 3, Appendix 3).

Riparian habitat varied among sites as reflected in the RCE scores (Table 2). Trees and shrubs were sparse or absent at some sites with only pasture grass and annual weeds for ground cover, whereas other sites had relatively complete and continuous riparian habitat. Unfortunately, when present, riparian vegetation was often dominated by introduced willow trees (*Salix* spp.). Willow trees were often dense and over-hung the channel by a considerable degree, often over-shading emergent macrophytes (such as cumbungi, common reed and marsh clubrush) which were more abundant at sites without willow. Dense mats of the introduced alligator weed were common along this reach of the Nepean River. The submerged macrophyte communities were dominated by the introduced dense waterweed and to a lesser extent the native ribbon weed.

Aquatic macroinvertebrate communities at all sites had low Signal2 scores indicating the sites were severely polluted and/or degraded (Appendix 4). The most common taxa were pollution-tolerant, such as Chironomidae (true flies), Coenagrionidae (damselfly), Atyidae (freshwater shrimp) and the introduced Physidae (water snail) (Appendix 4), although more sensitive taxa such as Leptoceridae (caddisfly) and Baetidae (mayfly) were also relatively abundant. The diversity of sampled macroinvertebrate varied among sites, ranging from 13 to 30 (Appendix 4). Low macroinvertebrate diversity was more commonly observed at sites dominated by overhanging willow, and may be caused by low microhabitat diversity and/or complexity due to the decrease in emergent macrophytes.

The small flathead gudgeon and the introduced mosquitofish were consistently the most abundant fish species across all sites. The presence of larger species (such as Australian bass, carp and longfinned eel) was variable among sites but as these taxa can be highly mobile this difference may be caused by chance sampling rather than differences in fish habitat.

3.3.1 Southern Reference Site

The southern reference site had a moderate RCE score (Table 2) (Plate 1a). Riparian vegetation was continuous and dominated by introduced species such as willow tree (*Salix* spp.) and the introduced groundcover *Tradescantia albiflora*. Common reed, common rush and alligator weed (Plate 1b) were common along the bank and dense waterweed and ribbonweed dominated the deeper water out from the bank (Table 4). *Azolla* spp., duckweed and Salvinia were observed floating on the surface.

Conductivity and pH were within the ANZECC threshold limits for the protection of lowland rivers of south-east Australia (Table 3, Appendix 3). Turbidity values were marginally less than the lower ANZECC threshold limits whilst the dissolved oxygen was considerably lower (Table 3, Appendix 3).

Twenty four macroinvertebrate taxa were recorded, with an average signal score of 3.7 indicating a site experiencing severe pollution or habitat degradation (Appendix 4). The most common taxa were the pollution-tolerant Chironomidae (true flies), Coenagrionidae (damselfly), Atyidae (freshwater shrimp) and the introduced Physidae (water snail). The more pollution-sensitive Leptoceridae (caddisfly) were also relatively abundant.

The Nepean River at the Southern Reference site is major fish habitat (Class 1 Waterway). Five species of fish were recorded: longfinned eel, flathead gudgeon, striped gudgeon (Plate 1c) and empire gudgeon (Plate 1d) and the introduced mosquito fish (Appendix 5).

3.3.2 Main Lake South Site

Main Lake South site had a low RCE score (Table 2) (Plate 2a). Riparian vegetation was composed of sparse Casuarina trees and dominated by annual weeds and pasture grasses. Cumbungi (Plate 2b) was common along the bank and dense mats of alligator weed interspersed with water primrose (Plate 2c) and water hyacinth (Plate 2d) extended out into the channel (Table 4). The water was relatively shallow (less than 1 m) for ~ 30 m from the eastern bank. Ribbonweed (Plate 3a) and dense waterweed (Plate 3b) dominated but there were sections of cobble river bed clear of macrophytes.

Conductivity and pH were within the ANZECC threshold limits for the protection of lowland rivers of south-east Australia (Table 3, Appendix 3). Turbidity values were marginally less than the lower ANZECC threshold limits whilst the dissolved oxygen was considerably lower (Table 3, Appendix 3).

Twenty eight macroinvertebrate taxa were recorded, with an average signal score of 3.5 indicating a site experiencing severe pollution or habitat degradation (Appendix 4). The most common taxa were the ostracods and the pollution-tolerant Chironomidae (true flies) and Coenagrionidae (damselfly). The slightly more sensitive Baetidae (mayfly), Glacidorbidea (water snail) and Hydracarina (mite) were relatively abundant.

The Nepean River at the Main Lake South site is major fish habitat (Class 1 Waterway). Three species of fish were recorded: juvenile sea mullet (*Mugil cephalus*) (Plate 3c), flathead gudgeon and the introduced mosquito fish (Appendix 5).

3.3.3 Main Lake North Site

Main Lake North site had a relatively high RCE score (Table 2) (Plate 3d). Riparian vegetation was complete and but dominated by the introduced willow. Emergent macrophytes were less abundant relative to other sites with a more open and less overhanging riparian canopy (e.g. such as Main Lake South). Common reed was present in the southern, and open, section of the site. The bed was composed primarily of cobble, with boulders and sand. Ribbonweed and dense waterweed dominated the water column away from the bank.

Conductivity and pH were within the ANZECC threshold limits for the protection of lowland rivers of south-east Australia (Table 3, Appendix 3). Turbidity values were marginally less than the lower ANZECC threshold limits whilst the dissolved oxygen was considerably lower (Table 3, Appendix 3).

Fifteen macroinvertebrate taxa were recorded, with an average signal score of 3.6 indicating a site experiencing severe pollution or habitat degradation (Appendix 4). The most common taxa were the pollution-tolerant Chironomidae (true flies) and Coenagrionidae (damselfly). The more pollution-sensitive Leptoceridae (caddisfly) were also relatively abundant.

The Nepean River at the Main Lake North site is major fish habitat (Class 1 Waterway). Three species of fish were recorded: flathead gudgeon and the introduced carp and mosquito fish (Appendix 5).

3.3.4 Wildlife South Site

Wildlife South site had a moderate RCE score (Table 2) (Plate 4a). The riparian trees were Casuarina or introduced willow. The dense understory of invasive vines, annual weeds and pasture grasses had been recently cleared. Slender knotweed was relatively common along the sections of the bank edge not overhung by willow. Ribbonweed and dense waterweed dominated the water column away from the bank. Hydrilla (*Hydrilla verticillata*) (Plate 3b) and introduced elodea (*Elodea canadensis*) were mixed in amongst the dense waterweed beds.

Riparian vegetation was complete and but dominated by the introduced willow. Emergent macrophytes were less abundant relative to other sites with a more open and less overhanging riparian canopy (e.g. such as Main Lake South). Common reed was present in the southern, and open, section of the site. The bed was composed primarily of cobble, with boulders and sand.

Conductivity and pH were within the ANZECC threshold limits for the protection of lowland rivers of south-east Australia (Table 3, Appendix 3). Turbidity values were marginally less than the lower ANZECC threshold limits whilst the dissolved oxygen was considerably lower (Table 3, Appendix 3).

Twenty macroinvertebrate taxa were recorded, with an average signal score of 3.3 indicating a site experiencing severe pollution or habitat degradation (Appendix 4). The most common taxa were the pollution-tolerant Chironomidae (true flies), Coenagrionidae (damselfly) and introduced Physidae (water snail).

The Nepean River at the Wildlife South site is major fish habitat (Class 1 Waterway). Four species of fish were recorded: Australian smelt (*Retropinna semoni*), flathead gudgeon, empire gudgeon and the introduced mosquito fish (Appendix 5).

3.3.5 Wildlife North Site

Wildlife North site had a moderate RCE score (Table 2) (Plate 4c). Riparian vegetation was comprised of Casuarina and willow trees. Annual weeds and pasture grasses were dominant understorey. Emergent macrophytes were less abundant relative to other sites with a more open and less overhanging riparian canopy and dense waterweed was common in the water column beyond the overhanging willow (Plate 4d). The river bed was comprised primarily of sand with some gravel and silt.

Conductivity and pH were within the ANZECC threshold limits for the protection of lowland rivers of south-east Australia (Table 3, Appendix 3). Turbidity values were marginally less than the lower ANZECC threshold limits whilst the dissolved oxygen was considerably lower (Table 3, Appendix 3).

Thirteen macroinvertebrate taxa were recorded, with an average signal score of 4.3 indicating a site experiencing moderate pollution or habitat degradation (Appendix 4). The most common taxa were the pollution-tolerant Chironomidae (true flies) and Coenagrionidae (damselfly). The more pollution-sensitive Leptoceridae (caddisfly) were also relatively abundant.

The Nepean River at the Wildlife North site is major fish habitat (Class 1 Waterway). Two species of fish were recorded: Flathead gudgeon and the introduced mosquito fish (Appendix 5).

3.3.6 Northern Reference Site

Wildlife North site had a low RCE score (Table 2) (Plate 5a). Much of the riparian vegetation had been cleared and had been replaced with grass lawn. Cumbungi, marsh clubrush (*Bolboschoenus fluviatilis*) and alligator weed were common along the site banks. Dense waterweed and ribbonweed dominated deeper waters away from the bank.

Conductivity and pH were within the ANZECC threshold limits for the protection of lowland rivers of south-east Australia (Table 3, Appendix 3). Turbidity values were marginally less than the lower ANZECC threshold limits whilst the dissolved oxygen was considerably lower (Table 3, Appendix 3).

Thirty macroinvertebrate taxa were recorded, with an average signal score of 3.8 indicating a site experiencing severe pollution or habitat degradation (Appendix 4). The most common taxa were the pollution-tolerant Physidae (introduced water snail), Coenagrionidae (damselfly), and Chironomidae (true flies). Caenidae (mayfly) and Leptoceridae (caddisfly) were also relatively abundant.

The Nepean River at the Northern Reference site is major fish habitat (Class 1 Waterway). Five species of fish were recorded: Australian bass, flathead gudgeon, dwarf flathead gudgeon and the introduced mosquito fish (Appendix 5).

3.3.7 Hunts Gully

Hunts Gully was a highly degraded, ephemeral creek with a very low RCE score (Table 2) (Plate 5c). The creek was little more than a drainage channel. Riparian habitat had been cleared and the eroded channel banks had been colonised by annual weeds and pasture grasses. Slender knotweed and common rush were the only macrophyte species observed (Table 4). Approximately 150 m downstream of the proposed weir site, Hunts Gully entered a twin pipe culvert and continued underground for 170 m before re-emerging on the northern side of a private property and discharging into the Nepean River in a riffle section, downstream of the Northern Reference site (Plate 5d).

The Nepean River at the Southern Reference site was considered unlikely fish habitat (Class 4 Waterway).

4 Assessment of Impacts Associated with the Proposed Works

Potential environmental impacts associated with the construction and operation of the proposal on aquatic ecology within the study area are most likely to come from; sedimentation, pollution, loss of riparian habitat, removal of large woody debris, changes to water quality and the loss of Hunts Gully downstream of the weir.

4.1 General Environmental Constraints

4.1.1 Loss of Downstream Reach of Hunts Gully

The construction of the weir and subsequent diversion of flow from Hunts Gully into Wildlife Lake would entail the loss of all aquatic habitat and biota from the reach of Hunts Gully downstream of the proposed weir site.

Hunts Gully is an ephemeral and extremely degraded watercourse that flows only following significant rain events (Section 3.3.7). A large section of the reach that would be lost flows through a 170 m twin-pipe culvert. Water has been diverted from the upstream reaches of the drainage to a number of artificial reservoirs, including Lewis Lagoon. A survey of Lewis Lagoon in 2008 recorded two species of fish: longfinned eel and mosquitofish (I&I NSW 2009).

The redirection of Hunts Gully into Wildlife Lake via the proposed weir would not have a significant effect on upstream aquatic assemblages in Hunts Gully catchment. Longfinned eel is the only native fish species present, and although diadromous, it would still be able to recruit into these water bodies from the Penrith Lakes or potentially overland from the Nepean River. The loss of the downstream reach of Hunts Gully would not have a significant impact on the aquatic ecology of the Nepean River. See Conclusions and Recommendations (Section 5.1.2).

4.1.2 Sediment Mobilisation

The proposed works would involve significant earthworks at Hunts Gully and the Nepean River bank and bed adjacent to the proposed Wildlife Lake and Main Lake. Earthworks, run-off over disturbed land and erosive scour from flood discharge may result in the mobilisation of sediments into the Nepean River. Downstream aquatic habitats may also be at risk as increases in suspended sediment can be detectable for long distances (km) downstream of construction sites (Wheeler *et al*. 2005). Compaction in works areas may reduce infiltration of surface waters and also contribute to sediment load in run-off. Similarly, dust made airborne during construction works may also enter the local waters.

An increase in sediment load can degrade water quality and important habitat features resulting in a loss of biodiversity and a shift towards a more pollution-tolerant biotic assemblage. For example, sedimentation can cause:

- Mortality and decreased growth. Suspended particles can clog respiratory gills and/or feeding apparatus of fish and macroinvertebrates;
- Degradation of habitat. Siltation can infill deep water refugia and interstitial spaces in the stream bed and smother aquatic macrophytes beds and spawning grounds;
- Reduced water quality. Increased light attenuation could decrease primary productivity and nutrients bound in mobilized sediments could increase eutrophication.

Increased sedimentation and habitat degradation is considered a threat to Macquarie perch, Australian grayling, Sydney hawk dragonfly, Adam’s emerald dragonfly and protected aquatic habitat, such as gravel beds.

Freshwater habitat within the study area has been considerably degraded by historical and current regional land use practices, river regulation and flood mitigation. As such, the aquatic flora and fauna most commonly observed in these areas are relatively tolerant to sedimentation. Nevertheless, increasing sediment loads could further degrade the existing habitat and further impair biotic assemblages. The likelihood and magnitude of impacts would be greater closer to the construction site.

Scour from discharge would be minimised by the construction of energy dissipaters and scour mats (located on low gradient sections of river bank) at the outlet of every pipeline.

Potential impacts from mobilised sediment can be minimised with standard sediment control measures. Mobilised sediment is unlikely to pose a significant threat to the aquatic ecology of the study area, provided these control measures are implemented. See Conclusions and Recommendations (Section 5.2.1).

4.1.3 Pollution

The construction and operation of the proposal has the potential to mobilise contaminants into aquatic habitat within the study area. Possible pollutants may include (but are not limited to):

- Pollutants associated with heavy vehicles used on site during construction, such as aromatic hydrocarbons (lubricating oils and fuels) and heavy metals (e.g. copper in brake linings, and zinc and cadmium in tyres);
- Pollutants associated with materials used in construction. There is a diverse array of materials used in construction, for example: cementitious materials, cement admixtures and aggregates. Some of these can be toxic in their pure (non-amended) states (Eldin 2002) and contamination may result from spills on site into aquatic habitats;
- Pollutants bound to disturbed sediments may be mobilised into aquatic habitat.

Pollution is considered a threat to Sydney hawk dragonfly and Adam's emerald dragonfly.

Impacts from pollution would be minimised by ensuring the proper handling, storage, transport and disposal of hazardous materials onsite. See Conclusions and Recommendations (Sections 5.2.2).

4.1.4 Thermal Pollution

Water temperature is an important regulator of ecological processes that structure aquatic assemblages. The release of unseasonably cold water from the deeper layers of thermally stratified storages during the warmer months (known as cold water pollution) can cause serious impacts on the aquatic ecology of NSW rivers and streams (Preece 2004). Changes to temperature can reduce biodiversity by exceeding the thermal tolerance limits of aquatic biota or reduce population viability via reduced rates of growth or reproductive output (i.e. temperature can be an important cue for spawning/reproductive activity).

Previous studies have noted stratification of storages within the Penrith Lakes (I&I NSW 2009). A number of species, including the threatened Macquarie perch, may fail to spawn following cold water releases from thermally stratified storages.

However, the proposed drop pit inlets will have their opening at the lake operating levels and therefore would convey surface water inflows from the surrounding catchment or the flooding Nepean River into the draw-down pipelines. These waters would be at a similar temperature to receiving waters within the Nepean River and as such the proposed works would not create thermal pollution.

4.1.5 Invasive Species

Seven species of introduced macrophytes and three species of introduced fish (with an additional three native species outside their natural distribution) were identified from the Nepean River, including the noxious pests: alligator weed, Salvinia, carp and mosquitofish.

There are currently no invasive aquatic species within Penrith Lakes that are not already present within the adjacent reach of the Nepean River. As such the proposed works will not facilitate the spread or increased distribution of invasive species into new areas. See Conclusion and Recommendations (Section 5.1.3).

4.1.6 Water Quality

The physical and chemical characteristics of the Penrith Lakes may differ at times from adjacent reach of the Nepean River. Some of the reservoirs may stratify, with cold deoxygenated water lying on the bottom. The reservoirs would also become sinks for sediment, organic carbon and pollutants flowing in from the catchment. During the warmer summer months the lakes could develop conditions suitable for algal blooms. It is possible during discharge events that low quality water is released into the adjacent Nepean River, with concomitant effects on sensitive aquatic biota. See Conclusions and Recommendations (Section 5.1.4)

4.1.7 Bank Stability

The proposed works have the potential to degrade the Nepean River banks. This can lead to subsequent erosion, slumping and increased sedimentation. Potential impacts will be minimised with the proposed construction of energy dissipaters at the outlets and by employing mitigation measures outlined in Conclusion and Recommendations (Section 5.2.3).

4.2 Key Threatening Processes

4.2.1 Degradation of Riparian Vegetation

The benefits of riparian vegetation to freshwater biota are outlined in Section 3.2.3.3.

Riparian habitat at the proposed work sites was either extremely degraded and/or dominated by invasive species. It is unlikely that the proposed works could further degrade riparian such that it would cause a significant impact on aquatic ecology of the adjacent reach of the Nepean River. The proposal provides an opportunity to restore the degraded riparian habitat. See Conclusions and Recommendations (Section 5.2.5).

4.2.2 Removal of Large Woody Debris

The benefits of instream large woody debris to freshwater biota are outlined in Section 3.2.3.3.

There was no submerged woody debris (‘snags’) at the proposed weir site in the ephemeral Hunts Gully.

The proposed works associated with the construction of the outlet pipe energy dissipaters will extend several metres into the Nepean River channel. Submerged woody debris was common along the pool reach of the Nepean River adjacent to Penrith Lakes. The potential temporary loss of snags due to the proposed works would not have a significant impact on aquatic ecology providing the recommended mitigation measures are implemented. See Conclusions and Recommendations (Section 5.2.4).

4.2.3 Alteration to Natural Flow Regimes of Rivers, Streams, Floodplains and Wetlands

The listed Key Threatening Process ‘*Alteration to Natural Flow Regimes of Rivers, Streams, Floodplains and Wetlands*’ is equivalent to “*Instream Structures and Mechanisms That Alter Natural Flow*” and they will be considered as one in this section. The ecological importance of maintaining natural flows was outlined in Sections 3.2.2.2 and 3.2.3.3.

4.2.3.1 Weir Installation and Subsequent Diversion of Hunts Gully

The weir construction and diversion of Hunts Gully will result in the loss of the reach of Hunts Gully downstream of the proposed weir (see Section 4.1.1).

Hunts Gully is a small, ephemeral creek. The diversion of the remaining flow into Wildlife Lake would have no significant effect on environmental flows or aquatic biota in the upstream reaches of Hunts Gully or the downstream reaches of the Hawkesbury and Nepean Rivers.

4.2.3.2 Discharge from Penrith Lakes Draw-Down

Modelling indicated that the proposed works would not significantly change the hydrological profile of the Nepean River. The primary sources of discharged floodwaters from Penrith Lakes would be:

- the local catchment, which would normally discharge into the Nepean River a small distance downstream of the proposed Wildlife Lake pipes via Hunts Gully, and;
- the Nepean River itself, during rare flood events when it enters Penrith Lakes via Hunts Gully (10 year ARI) or by overtopping Weir 1 into Quarantine Lake and then subsequently into Main Lake (25 year ARI).

During rare large flood events (20 year and 100 year ARI) water levels in the Nepean River should return to within 1.5 m of "normal" river levels within approximately 3 days of the discharge peak.

4.2.4 Introduction of Fish to Fresh Waters Within a River Catchment Outside Their Natural Range

Six species of fish outside their natural range have been identified within Penrith Lakes (Table 1). Three species - carp, goldfish and mosquitofish – have been introduced to Australia, and another three species – olive perchlet, freshwater catfish and western carp gudgeon – although native to Australia, have been introduced into the Hawkesbury – Nepean catchment, which is outside of their natural range.

Whilst it is possible that these species could move into the Nepean River via flood discharge, all six species already have existing self-sustaining populations within the adjacent reach of the Nepean River and therefore such movement would not constitute an introduction. See Conclusions and Recommendations (Section 5.1.3).

4.3 Threatened and Protected Species, Communities and Populations

4.3.1 Macquarie perch, *Macquaria australasica*

The Macquarie perch is listed as endangered under the FM Act and the EPBC Act.

Macquarie perch usually inhabit the upper reaches of clear, freshwater water courses containing deep, rocky pools with upstream riffle and pool sequences for spawning (Allen *et al*. 2003, DPI 2005). They migrate upstream to spawn in October - November and their eggs settle and develop in the gravel and cobble found in riffle habitat. The distribution of the eastern form can also be a function of interactions with other species. For example, if Australian bass are found in a watercourse then typically Macquarie perch will only be found upstream of the bass population (McDowall 1996).

It is extremely unlikely that Macquarie perch inhabit the reach of the Nepean River potentially affected by the proposed works. There are no records of Macquarie perch from low elevation reaches of the Nepean River, whereas a healthy bass population is present for a considerable distance upstream of the study site. The upstream limit of bass distribution and the lower limit of Macquarie perch in the Nepean River appears to be just below Pheasants Nest weir (located 60 km to the south).

As significant impacts on Macquarie perch populations and/or their habitat were considered unlikely, a Seven Part Test was not considered necessary.

Conclusion: The proposed works would be most unlikely to affect Macquarie perch, hence no SIS is required, nor would it be necessary to modify the project with respect to the conservation of this species.

4.3.2 Australian Grayling, *Prototroctes maraena*

The Australian grayling is listed as protected under the *FM Act* and vulnerable under the *EBPC Act.*

Australian grayling (*P. maraena*) prefer watercourses with low turbidity and gravel substrata, and occupy lowland rivers through to high elevation reaches at 1000 m AHD (McDowall 1996). Grayling occur in streams and rivers on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria, and Tasmania (McDowall 1996, DPI 2006b).

The species has an amphidromous life cycle; newly hatched larvae are photo tactic and swim to the surface where they are swept downstream to estuarine/marine waters and only migrate back to adult freshwater habitats at the age of 6 months. Populations are therefore very susceptible to barriers to passage. Adults suffer heavy post-spawning mortality so it is possible after a few years without juvenile recruitment to result in local extirpation (Morris *et al*., 2001).

It is extremely unlikely that Australian grayling inhabit the reach of the Nepean River potentially affected by the proposed works. The Hawkesbury – Nepean drainage system represented the northern extent of the grayling's historical distribution, but despite considerable sampling within the region, the species has not been recorded from the catchment since the 1950s (Morris *et al*. 2001). It is likely that river regulation and habitat degradation are responsible for its disappearance.

As significant impacts on Australian grayling populations and/or their habitat were considered unlikely, a Seven Part Test was not considered necessary.

Conclusion: The proposed works would be most unlikely to affect Australian grayling, hence no SIS is required, nor would it be necessary to modify the project with respect to the conservation of this species.

4.3.3 Tall Knotweed, *Persicaria elatior*

Tall knotweed is listed as vulnerable under the TSC Act and the EPBC Act.

Tall knotweed grows on sandy, alluvial soil in swampy areas and riparian herblands along watercourses and lake edges. Associated plant species include *Melaleuca linearfolia*, *M. quinquenervia*, *Pseudognaphalium luteoalbum*, *Persicaria hydropiper* and *Floydia praealta*. There are two records of the species from the Hawkesbury – Nepean drainage system and both are from the upper parts of the catchment at Picton Lakes and the upper Avon River catchment.

Major threats to tall knotweed include localised disturbance from clearing and track maintenance. Neither tall knotweed, nor its commonly associated plant species, were observed at any of the proposed works sites during targeted surveys. It is considered highly unlikely that tall knotweed occurs within the study area, therefore impacts from localised disturbance during construction works will not affect the species. Hydrological changes can also threaten tall knotweed, but there are not anticipated to be significant changes to the hydrology of the Nepean River as a result of the proposed works.

As significant impacts on tall knotweed were considered unlikely, a Seven Part Test was not considered necessary.

Conclusion: The proposed works would be most unlikely to affect tall knotweed, hence no SIS is required, nor would it be necessary to modify the project with respect to the conservation of this species.

4.3.4 Sydney hawk dragonfly, *Austrocordulia leonardi*

The Sydney hawk dragonfly is listed as Endangered under the *FM Act*.

Historically the Sydney hawk dragonfly was known from only a few sites, one of which was the Nepean River at Maldon Bridge near Wilton, which is located approximately 60 km south of the study area. Numbers of the Sydney hawk dragonfly have declined at the Maldon Bridge site but it has since been recorded in the upper Hawkesbury-Nepean catchment at O'Hares Creek.

Sydney hawk dragonfly has only ever been collected from deep, shady river pools with cooler water. The reasons for its decline are believed to be river regulation, habitat degradation, water pollution from storm water runoff and agricultural development in the catchment. The Sydney hawk dragonfly was not identified from macroinvertebrate samples taken during the current survey. Given previous dragonfly sampling has failed to find specimens in the Nepean River sub-catchment and the history of disturbance to the local reaches of the Nepean River and surrounding catchment, it is considered highly unlikely that the species inhabits the study area or downstream reaches potentially affected by the proposed works.

As significant impacts Sydney hawk dragonfly were considered unlikely, a Seven Part Test was not considered necessary.

Conclusion: The proposed works would be most unlikely to affect Sydney hawk dragonfly, hence no SIS is required, nor would it be necessary to modify the project with respect to the conservation of this species.

4.3.5 Adam's emerald dragonfly, *Archaeophya adamsi*

Adam's emerald dragonfly is listed as endangered under the FM Act.

Adam's emerald dragonfly has only been collected in four localities, one of which was Bedford Creek in the Lower Blue Mountains, which eventually discharges into the Nepean River. The aquatic larvae of Adam's emerald dragonfly are found in small creeks with gravel or sandy bottoms, in narrow, shaded riffle zones with moss and rich riparian vegetation (DPI 2009). Threats to the species include habitat degradation (such as loss of riparian vegetation), siltation, storm water runoff and agricultural development in the catchment.

Adam's emerald dragonfly were not collected in the study area during the current survey. Given the species' rarity (it has only been collected in four localities), the absence of suitable habitat within the study area and the history of disturbance to the Nepean River and local catchment, it is considered extremely unlikely that Adam's emerald dragonfly inhabits the study area or downstream reaches potentially affected by the proposed works.

As significant impacts Adam's emerald dragonfly were considered unlikely, a Seven Part Test was not considered necessary.

Conclusion: The proposed works would be most unlikely to affect Adam's emerald dragonfly, hence no SIS is required, nor would it be necessary to modify the project with respect to the conservation of this species.

5 Conclusions and Recommendations

The main issues related to potential impacts on aquatic ecology to be addressed in the design and construction of the proposal are:

- Mobilisation of fine sediments into waterways;
- Loss of aquatic habitat and biota from the weir construction and diversion of Hunts Gully;
- Pollution;
- Invasive species;
- Bank stability;
- Degradation of riparian vegetation;
- Removal of large woody debris;

To minimise potential impacts arising from the proposed works it is recommended that PLDCs Construction and Environment Management Plan (CEMP) for the proposed works addresses these issues. Providing that the suggested mitigation measures are adhered to, it is unlikely that the works will have a significant impact on the aquatic ecology of the study area.

5.1 Design

5.1.1 Preferred Location for Draw-Down Pipelines

Given the similarity of aquatic biota and habitat between sites, the abundance of similar habitat and biota elsewhere in the reach and the absence of threatened or protected species, the two sites under consideration at Main Lake and Wildlife Lake draw-down pipelines are equivalent with respect to potential impacts on aquatic ecology.

5.1.2 Loss of aquatic habitat and biota from weir construction and diversion of Hunts Gully

The creation of 770 hectares of lacustrine (lake-like) aquatic habitat within the Penrith Lakes Scheme is considered a more than adequate environmental offset/compensation for the loss of the reach of Hunts Gully downstream from the proposed weir.

5.1.3 Invasive species

PLDC should attempt to keep Penrith Lakes free of invasive aquatic species where possible and cooperate with existing local eradication/control programs.

5.1.4 Water Quality

Regular water quality monitoring should be maintained to identify potential problems that might result from discharging water from Penrith Lakes into the Nepean River. For example: algal concentrations, nutrient levels, dissolved oxygen, toxicants could all be monitored, using breaches of ANZECC/ARMCANZ (2000) guidelines as triggers for management action.

It should be noted that during some discharge events, the Nepean River itself would be a major source of floodwater in the Penrith Lakes, and as such Penrith Lakes would not be entirely responsible for the potential poor quality of the discharged water (e.g. elevated turbidity).

5.2 Construction

5.2.1 Mobilisation of fine sediments into waterways

The mobilisation of sediment into aquatic habitats within the construction zone and further downstream would be minimised through the implementation of an Erosion and Sediment Control Plan (ESCP). Appropriate mitigation measures may include (but not necessarily be limited to):

- Erosion and sediment controls, such as: bunding, silt fences/curtains, sediment basins/ponds and drains. These measures should be able to operate effectively during high rainfall events;
- The use of coffer dams for works within the wetted width of the Nepean River channel. The coffer dam should be designed so that it has minimal impacts on geomorphology and hydrology of the Nepean River and should be surrounded by a sediment curtain;
- Diversion of clean water around disturbed areas;
- Diversion of runoff from disturbed areas into erosion and sediment controls;
- Minimisation of the area and duration of exposed unconsolidated soils;
- Revegetation and restoration of disturbed areas as quickly as possible. Erosion and sediment control measures should be in place to treat run-off from these areas until adequate cover is established;
- Restricting work within disturbed areas during rainfall;
- Fish passage should be considered where silt fences/curtains may be positioned across waterways. A permit may be required for works that require temporary blockage of fish passage.

Surface water quality monitoring should be incorporated into the ESCP with protocols in place for guideline breaches. Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads and can be measured as indicators of physical stress on aquatic biota. ANZECC (2000) trigger values for the protection of aquatic ecosystems (e.g. turbidity ranges of 6 – 50 NTU for lowland rivers) can be used as thresholds to trigger mitigating management responses (e.g. discovery and suppression of source or cessation of work). Monitoring should take place over the construction period, with preconstruction sampling and use of upstream ‘control’ sites to provide baseline information about background patterns in turbidity.

5.2.2 Pollution

Implement proper handling, storage, transport and disposal of hazardous substances within the study area. Management plans should include:

- Regular inspections of work practices; and
- Training of staff in correct handling, storage, transport and disposal of hazardous substances.

5.2.3 Bank stability

Plans to maintain and/or strengthen riverbank stability in the proposed works area should be included within the ESCP and Riverbank Plan of Management (RPOM). For example, the plan should minimise clearing of riparian habitat (including groundcovers), practice ‘cut-to-stump’ methods and leave stumps intact and rehabilitate native riparian habitat (i.e. regeneration and/or revegetation).

5.2.4 Removal of large woody debris

Where large woody debris is encountered, lopping should be considered the first management response. If this does not resolve the problem, re-alignment should then be considered and removal only adopted as a last resort. Any large woody debris removed during works should be replaced back in the river following completion of construction works.

5.2.5 Degradation of riparian vegetation

Removal of native riparian vegetation, where present, should be minimised and appropriate consideration given to the presence of threatened species or communities. Degraded riparian habitat and realigned channel banks should be rehabilitated by the removal of exotic species and regeneration and/or revegetation of native riparian species. Such plans should be incorporated into PLDC's existing RPOM.

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8 Tables

Table 1. Species of freshwater fish that have been recorded in the region of the proposed Penrith Lakes weir and pipeline construction area.

Table 2. Aquatic ecology assessment sites in the Nepean River catchment for the proposed Penrith Lakes weir and pipeline construction.

Table 3. Water quality measured in situ in the study area in comparison with ANZECC/ARMCANZ (2000) guidelines for lowland watercourses in south-east Australia.

Table 4. Macrophytes present in study sites.

Table 1. Species of freshwater fish that have been recorded in the region of the proposed Penrith Lakes weir and pipeline construction area. Highlighted taxa are listed threatened species and populations.

Family Name	Species Name	Common Name	Nepean River		Penrith Lakes				Region of Study Area (incl. Nepean River & Penrith Lakes)		
			Cardno Ecology Lab	I&I NSW (2007)[b]	I&I NSW (2006)[c]	I&I NSW (2007)[c]	I&I NSW (2008)[c]	I&I NSW (2009)[c]	Bionet[d]	McDowall (1996)	Allen *et al*. (2003)
Mordaciidae	*Mordacia mordax*	Shortheaded lamprey							●	●	●
Anguillidae	*Anguilla australis*	Shortfinned eel			●	●	●	●		●	●
Anguillidae	*Anguilla reinhardtii*	Longfinned eel	●	●	●	●	●		●	●	●
Clupeidae	*Potamalosa richmondia*	Freshwater herring		●					●	●	●
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias									●
Galaxiidae	*Galaxias maculatus*	Common jollytail							●	●	●
Galaxiidae	*Galaxias olidus*	Mountain galaxias									●
Retropinnidae	*Retropinna semoni*	Australian smelt	●	●	●	●	●	●	●	●	●
Prototroctidae	*Prototroctes maraena*	Australian grayling**								●	●
Cyprinidae	*Carassius auratus*	Goldfish[#]		●	●	●	●	●	●	●	●
Cyprinidae	*Cyprinus carpio*	Common carp[#]	●		●	●	●	●	●	●	●
Plotosidae	*Tandanus tandanus*	Freshwater catfish[@]		●	●	●	●	●	●	●	●
Poeciliidae	*Gambusia holbrooki*	Mosquito fish[#]	●		●	●	●	●	●	●	●
Psuedomugilidae	*Psuedomugil signifer*	Pacific blue-eye							●	●	●
Scorpaenidae	*Notesthes robusta*	Bullrout		●					●	●	●
Chanidae	*Ambassis agassizii*	Olive perchlet[@]			●	●	●	●			
Percichthyidae	*Macquaria australasica*	Macquarie perch* ***								●	●
Percichthyidae	*Macquaria novemaculeata*	Australian bass	●	●	●	●	●	●	●	●	●
Mugilidae	*Myxus petardi*	Freshwater mullet		●					●	●	●
Mugilidae	*Mugil cephalus*	Sea mullet	●	●					●	●	●
Gobiidae	*Philypnodon grandiceps*	Flathead gudgeon	●	●	●	●	●	●	●	●	●
Gobiidae	*Philypnodon* sp.	Dwarf flathead gudgeon	●						●	●	●
Gobiidae	*Gobiomorphus coxii*	Cox's gudgeon							●	●	●
Gobiidae	*Gobiomorphus australis*	Striped gudgeon	●	●					●	●	●
Gobiidae	*Hypseleotris compressa*	Empire gudgeon	●						●	●	●
Gobiidae	*Hypseleotris galii*	Firetailed gudgeon		●					●	●	●
Gobiidae	*Hypseleotris* spp.	Carp gudgeons			●	●	●	●		●	●

* = vulnerable species (FM Act), ** = vulnerable species (EBPC Act), *** = endangered species (EPBC Act)[#],= introduced species,[@] = translocated native species outside of its natural range.
[a] = The Cardno Ecology Lab fish survey was restricted to a 4.5 km reach of the Nepean River adjacent to Penrith Lakes.
[b] = The I&I NSW 2007 survey site was located on the Penrith Weir Pool.
[c] = I&I NSW survey of Penrith Lakes for the Penrith Lakes Development Corporation.
[d] = The BioNet search area (decimal degrees) was North -33.613 East 150.711 South -33.742 West 150.641. This search area was expanded to a minimum of 10km x 10km by BioNet.

Table 2. Aquatic ecology assessment sites in the Nepean River catchment for the proposed Penrith Lakes weir and pipeline construction. Datum: UTM WGS 84 Zone: 56H. Note: GPS points mark the southern end of each site.

Site	Easting	Northing	Fish Habitat Classification	RCE Score
Northern Reference	283092	6271818	1	30
Wildlife North	282976	6271473	1	32
Wildlife South	282925	6271239	1	36
Main Lake North	283177	6269144	1	44
Main Lake South	283125	6268620	1	30
Southern Reference	283052	6267823	1	35
Hunts Creek (site of proposed weir)	283322	6271616	4	24

Table 3. Water quality measured *in situ* in the study area in comparison with ANZECC/ARMCANZ (2000) guidelines for lowland watercourses in south-east Australia (See Appendix 3 for data).

Site	Conductivity (us/cm)	pH	Dissolved Oxygen (% sat.)	Turbidity (NTU)
	125 - 2200	6.50 - 8.50	85 - 110	6 - 50
Northern Reference	✓	✓	↓	↓
Wildlife North	✓	✓	↓	↓
Wildlife South	✓	✓	↓	↓
Main Lake North	✓	✓	↓	↓
Main Lake South	✓	✓	↓	↓
Southern Reference	✓	✓	↓	↓

↓ = below guidelines, ↑ = above guidelines, ✓ = within guidelines

Recorded by Cardno Ecology Lab (17/02/10 - 18/02/10)

Table 4. Macrophytes present in study sites. Recorded by Cardno Ecology Lab (17\02\2010 - 18\02\2010).

Family Name	Species Name	Common Name	Northern Reference	Wildlife North	Wildlife South	Main Lake North	Main Lake South	Southern Reference	Hunts Creek	Nepean River (PLDC 1997)
Amaranthaceae	*Alternanthera philoxeroides*	Alligator weed[#]	•	•	•	•	•	•		
Azollaceae	*Azolla pinnata*	Ferny azolla	•	•	•	•	•	•		
Azollaceae	*Azolla filiculoides*	Pacific azolla	•	•	•	•	•	•		•
Cyperaceae	*Schoenoplectus validus*	River clubrush				•				•
Cyperaceae	*Schoenoplectus mucronatus*	Clubrush								•
Cyperaceae	*Juncus usitatus*	Common rush						•	•	
Cyperaceae	*Carex appressa*	Tall sedge					•			
Cyperaceae	*Cyperus eragrostis*	Umbrella sedge[#]								•
Cyperaceae	*Bolboschoenus fluviatilis*	Marsh clubrush	•							•
Gramineae	*Phragmites australis*	Common reed				•		•		•
Gramineae	*Paspalum distichum*	Water couch								•
Hydrocharitaceae	*Egeria densa*	Dense waterweed[#]	•	•	•	•	•	•		•
Hydrocharitaceae	*Vallisneria nana*	Ribbonweed	•	•	•	•	•	•		•
Hydrocharitaceae	*Hydrilla verticillata*	Hydrilla	•	•	•	•	•			
Hydrocharitaceae	*Elodea canadensis*	Elodea[#]	•	•		•	•			
Lemnaceae	*Spirodella* sp.	Duckweed	•	•	•	•	•	•		
Onagraceae	*Ludwigia peploides* ssp. *montevidensis*	Water primrose	•		•	•	•	•		
Pontederiaceae	*Eichhornia crassipes*	Water Hyacinth[#]					•			•
Polygonaceae	*Persicaria decipiens*	Slender knotweed			•		•		•	
Salviniaceae	*Salvinia molesta*	Salvinia[#]	•	•	•	•	•	•		
Scrophulariaceae	*Veronica anagallis-aquatica*	Blue water speedwell[#]								•
Typhaceae	*Typha orientalis*	Cumbungi	•				•			•

[#] = introduced species

9 Figures

Figure 1. Penrith Lakes pipeline and weir construction Study Area.

Figure 1. Penrith Lakes pipeline and weir construction Study Area (Image Source: Google Earth).

10 Plates

Plate 1(a) – (d). (a) Southern Reference site, view upstream (b) Introduced alligator weed (*Alternanthera philoxeroides*) at Southern Reference site (c) Striped gudgeon (*Gobiomorphus australis*) at Southern Reference site (d) Empire gudgeon (*Hypseleotris compressa*) at southern reference site.

Plate 2(a) – (d). (a) Main Lake South site, view downstream (b) Main Lake South, cumbungi (*Typha orientalis*) lining the bank and a mat of alligator weed and water primrose (*Ludwigia peploides ssp. montevidensis*) extending into the channel (c) Water primrose at Main Lake South site (d) Introduced water hyacinth (*Eichhornia crassipes*) at Main Lake South site.

Plate 3(a) – (d). (a) Submerged ribbonweed (*Vallisneria nana*) at Main Lake South (b) Introduced dense waterweed (*Egeria densa*) at Main Lake South (c) Juvenile sea mullet (*Mugil cephalus*) at Main Lake South site (d) Main Lake North site, view downstream.

Plate 4(a) – (d). (a) Wildlife South site, view downstream (b) Hydrilla (*Hydrilla verticillata*) at Wildlife South (c) Wildlife North site, view downstream (d) Willows overhanging the bank at Wildlife North site.

Plate 5(a) – (d). (a) Northern Reference site, view downstream (b) Australian bass (*Macquaria novemaculeata*) from Northern Reference site (c) Hunts Gully, proposed weir site, view downstream (d) Hunts Gully, upstream of discharge point into Nepean River.

(a)

(b)

(c)

(d)

Plates 1a – 1d. (a) Southern Reference site, view upstream (b) Introduced alligator weed (*Alternanthera philoxeroides*) at Southern Reference site (c) Striped gudgeon (*Gobiomorphus australis*) at Southern Reference site (d) Empire gudgeon (*Hypseleotris compressa*) at Southern Reference site.

(a)

(b)

(c)

(d)

Plates 2a – 2d. (a) Main Lake South site, view downstream (b) Main Lake South, cumbungi (*Typha orientalis*) lining the bank and a mat of alligator weed and water primrose (*Ludwigia peploides ssp. montevidensis*) extending into the channel (c) Water primrose at Main Lake South site (d) Introduced water hyacinth (*Eichhornia crassipes*) at Main Lake South site.

(a)

(b)

(c)

(d)

Plates 3a – 3d. (a) Submerged ribbonweed (*Vallisneria nana*) at Main Lake South (b) Introduced dense waterweed (*Egeria densa*) at Main Lake South (c) Juvenile sea mullet (*Mugil cephalus*) at Main Lake South site (d) Main Lake North site, view downstream.

(a)

(b)

(c)

(d)

Plates 4a – 4d. (a) Wildlife South site, view downstream (b) Hydrilla (*Hydrilla verticillata*) at Wildlife South (c) Wildlife North site, view downstream (d) Willows overhanging the bank at Wildlife North site.

(a)

(b)

(c)

(d)

Plates 5a – 5d. (a) Northern Reference site, view downstream (b) Australian bass (*Macquaria novemaculeata*) from Northern Reference site (c) Hunts Creek, proposed weir site, view downstream (d) Hunts Creek, upstream of discharge point into Nepean River.

11 Appendices

Appendix 1. River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE).

Appendix 2. Fish habitat classification criteria for watercourses and recommended crossings types.

Appendix 3. Raw data for water quality measured in situ in the study area.

Appendix 4. Macroinvertebrate assemblage data for edge habitat sampled from sites in the Nepean River with Signal2 scores.

Appendix 5. Abundance of fish and mobile macroinvertebrate sampled with electrofisher and bait traps.

Appendix 1. River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) From Chessman *et al*. (1997).

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

Appendix 2. Fish habitat classification criteria for watercourses and recommended crossings types (Source: Fairfull and Witheridge, 2003).

Classification	Characteristics of Waterway Type	Minimum Recommended Crossing Type
Class 1 – Major Fish Habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species.	Bridge, arch structure or tunnel.
Class 2 – Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks and with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and / or fish observed inhabiting the area.	Bridge, arch structure, culvert or ford.
Class 3 – Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert or ford
Class 4 – Unlikely fish habitat	Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event (e.g. dry gullies or shallow floodplain depression with no permanent wetland aquatic flora present).	Culvert, causeway or ford

Appendix 3. Raw data for water quality measured *in situ* in the study area. Recorded by Cardno Ecology Lab 17/02/10 - 18/02/10 .

Site	Northern Reference		Wildlife North		Wildlife South		Main Lake North		Main Lake South		Southern Reference	
Replicate	1	2	1	2	1	2	1	2	1	2	1	2
Temperature (^{o}C)	27.25	27.70	25.70	25.80	25.28	25.26	23.72	23.72	23.62	23.61	23.17	23.18
Conductivity (ms/cm)	0.16	0.16	0.20	0.20	0.17	0.17	0.21	0.21	0.21	0.21	0.21	0.21
Conductivity (us/cm)	171	170	208	207	170	184	205	219	220	220	226	226
Salinity (ppt)	0.08	0.08	0.10	0.10	0.08	0.08	0.10	0.10	0.10	0.10	0.11	0.11
pH	7.58	7.47	7.36	7.31	8.06	8.08	7.17	7.17	7.17	7.18	6.97	6.99
ORP (mV)	440	441	413	420	412	414	434	435	421	422	378	383
Dissolved Oxygen (% sat.)	80.9	76.5	72.4	71.4	82.9	83.3	60.4	60.4	63.2	63.5	54.3	54.2
Dissolved Oxygen (mg/L)	6.5	6.0	5.8	5.8	6.8	6.8	5.1	5.1	5.4	5.4	4.6	4.6
Turbidity (NTU)	6.6	3.5	3.8	3.5	5.6	4.9	3.5	3.1	3.8	3.5	4.2	4.5
Turbidity (NTU)	4.7	3.8	3.8	3.5	6.1	5.2	3.1	3.3	3.3	3.3	4.5	4.5
Turbidity (NTU)	5.2	3.3	3.8	3.5	5.6	5.4	3.1	3.1	3.5	3.3	4.2	4.2
Alkalinity	28		29		28		28		27		28	

Appendix 4. Macroinvertebrate assemblage data for edge habitat sampled from sites in the Nepean River with Signal2 scores (as per Chessman 2003).

Order or Family	Southern Control	Main Lake South	Main Lake North	Wildlife South	Wildlife North	Northern Control	Signal2 Value
Dugesiidae	-	-	-	-	-	1	2
Nematoda	-	1	-	-	-	-	3
Ancylidae	1	4	2	1	1	2	4
Physidae	10	2	4	16	7	71	1
Glacidorbidae	-	16	-	1	-	4	5
Glossiphoniidae	-	1	-	-	-	2	1
Hirudinidae	1	-	-	-	-	-	4
Oligochaeta	-	2	-	-	-	2	2
Cladocera	-	3	-	-	-	1	-
Copepoda	-	6	-	-	-	-	-
Ostracoda	1	26	-	-	-	3	-
Atyidae	15	7	3	2	4	5	3
Araneae	-	-	-	-	-	1	-
Hydracarina	3	16	2	-	3	2	6
Hypogastruridae	2	-	-	-	-	-	-
Entomobryidae	-	1	-	-	-	-	-
Caenidae	1	4	2	-	-	24	4
Baetidae	6	20	13	1	2	5	5
Oniscigastridae	-	2	-	-	-	-	8
Coenagrionidae	43	21	16	20	20	59	2
Isostictidae	-	-	1	-	-	-	3
Diphlebiidae	-	-	-	-	-	1	6
Gomphidae	-	-	-	-	-	1	5
Lindeniidae	-	-	-	2	-	-	3
Hemicorduliidae	-	3	-	2	-	3	5
Libellulidae	1	1	-	-	-	-	4
Mesoveliidae	3	2	1	3	-	-	2
Hebridae	1	-	-	-	-	-	3
Veliidae	-	-	-	-	-	1	3
Gelastocoridae	-	-	-	-	-	1	5
Corixidae	1	-	-	-	-	-	2
Naucoridae	-	1	-	1	-	3	2
Notonectidae	-	1	-	1	-	-	1
Dytiscidae	1	4	-	-	-	1	2
Hydrophilidae	-	-	-	2	-	-	2
Scirtidae	1	-	-	-	-	-	6
Elmidae	-	-	-	-	1	-	7
Curculionidae	4	-	-	2	-	2	2
Tanyderidae	-	-	-	-	-	1	6
Chironomidae/Chironominae	28	121	15	42	41	16	3
Chironomidae/Orthocladiinae	-	1	-	-	-	-	4
Chironomidae/Tanypodinae	42	58	38	33	22	20	4
Ceratopogonidae	4	5	-	4	6	-	4
Empididae	1	-	-	-	-	-	5
Hydroptilidae	-	-	3	-	-	1	4
Ecnomidae	6	1	15	13	4	4	4
Calamoceratidae	-	-	-	3	1	8	7
Leptoceridae	48	2	19	9	20	15	6
Pyralidae	1	-	1	2	-	2	3
Number of Individuals	**225**	**332**	**135**	**160**	**132**	**262**	
Number of Taxa	**24**	**28**	**15**	**20**	**13**	**30**	
Signal2 Score	**3.7**	**3.5**	**3.6**	**3.3**	**4.3**	**3.8**	

Appendix 5. Abundance of fish and mobile macroinvertebrate sampled with electrofisher ("electro") and bait traps. Recorded by Cardno Ecology Lab (17\02\2010 - 18\02\2010).

Family Name	Species Name	Common Name	Northern Reference		Wildlife North		Wildlife South		Main Lake North		Main Lake South		Southern Reference	
			Electro	Bait Trap	Electro	Bait Trap	Electro	Bait Trap	Electro	Bait Trap	Electro	Bait Trap	Electro	Bait Trap
Anguillidae	*Anguilla reinhardtii*	Longfinned ee											1	
Retropinnidae	*Retropinna semoni*	Australian smelt					1							
Cyprinidae	*Cyprinus carpio*	Common carp#							1					
Poeciliidae	*Gambusia holbrooki*	Mosquito fish#	30		24		32		18		2	112	6	
Percichthyidae	*Macquaria novemaculeata*	Australian bass	2											
Mugilidae	*Mugil cephalus*	Sea mullet									1			
Gobiidae	*Philypnodon grandiceps*	Flathead gudgeon	8	7	7	2	8	2	8	2	26	3	13	5
Gobiidae	*Philypnodon* sp.	Dwarf flathead gudgeon		1										
Gobiidae	*Gobiomorphus australis*	Striped gudgeon											1	
Gobiidae	*Hypseleotris compressa*	Empire gudgeon	1	1			1	7					1	
Atyidae		Freshwater shrimp											>100	

= alien species