june 2007

aquatic biology technical report

hinze dam stage 3 environmental impact statement

Hinze Dam Alliance

ecosure

Aquateco
CONSULTING PTY LTD

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Reference	E11_HDS3EIS_AquaticEcologyTechnicalReport_Rev01_010607

Revision History

Revision	Date	Details	Authorised
00	18/05/07	First draft technical report for release to Hinze Dam Alliance for review	Phil Shaw
01	01/06/07	Final technical report for public release	Phil Shaw

Distribution

	Number of copies	Copy number
Hinze Dam Alliance	1	na
Aquateco Consulting	1	na
Ecosure	1	na

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E11_HDS3EIS_AquaticEcologyTechnicalReport_Rev01_010607

Acknowledgements

Ecosure/Aquateco gratefully acknowledges the following:

Dr Adam Uytendaal and Kevin McFarlane from Inland Fisheries Services (Tasmania) for their most valuable contributions to the peer review and field survey components of this study, respectively.

Tim Packer, of Gold Coast Water, for permission to use the data collected during a previous macroinvertebrate survey of the upper Hinze Catchment by Gold Coast Water.

Dr Rob Walsh of Australian Waterlife for the provision of taxonomic expertise.

Lauren Barnaby and Hunter Brownscombe from Sinclair Knight Mertz as part of the Hinze Dam Alliance for engaging our services and all the assistance they have provided during the course of the Project.

Executive Summary

Introduction

The Hinze Dam Stage Three Project (HDS3) plans to raise the existing dam wall by up to 12.5m to accommodate dam safety, flood mitigation, and additional water supply storage. Other associated works will also occur as part of this project such as road and bridge upgrades, construction of a new saddle dam and the upgrade/replacement of other ancillary services and structures. The Hinze Dam Alliance, a consortium involving both Council and specialists from the private sector will deliver the HDS3 Project. This report provides supporting material for an Environmental Impact Statement (EIS) in respect of the HDS3 Project.

The aquatic biology of the existing dam and associated waterways is an important indicator of the current health of the system. This aquatic biology assessment identifies the key environmental values and potential impacts on the aquatic ecosystem as a result of the proposed works and recommends mitigation measures to minimise those impacts

Objectives

The objectives of this report are to:

1. Describe the extant aquatic biota and substrate both upstream and downstream on the Nerang River and the Little Nerang Creek.

2. Determine the potential impacts of the proposed works on the aquatic biota

3. Discuss potential mitigation measures to offset those impacts

The specific aims are detailed in the Terms of Reference HDS3 project Coordinator-General, Department of Infrastructure, February 2007, section 3.7.

Identified Environmental Values

In-lake Aquatic Habitat

The Hinze Dam in its existing condition provides habitat for aquatic organisms. The majority of fish, macroinvertebrate, aquatic plant and aquatic macrofauna within Hinze Dam reside within the littoral, rather than pelagic, zone. Available habitat is reduced during times of stratification.

Sediment and Substrate

With the exception of the site on the Little Nerang Creek between the Hinze and Little Nerang Dams, all upstream sites are comprised largely of a combination of bedrock, boulder, cobble and pebble, with generally low levels of embeddedness. Riparian zones in the upper catchment are generally in good condition, and low-intensity agricultural landuse is thought to make a minimal contribution to upstream sediment loads.

The substrate within the dam is comprised of both soft sediments (silt/sand) and hard substrate (rock or highly compacted sediment). Sediments collected from below the current water level were finely divided and were dark brown to black in colour. All sediment samples from below the water level were unconsolidated and contained relatively high moisture content (71.4 – 83.2%). It is likely that this reflects the deposition of allochthonous material as a result of sedimentation within the lake.

Throughout the freshwater reach below the Hinze Dam, the substrate was found to consist mainly of cobble and pebble, with occasional patches of boulder or bedrock. There was dense coverage of aquatic macrophytes, dominated by noxious aquatic weeds. In some places this growth, along with the minimal environmental flow, had trapped some silt and sediment. There were occasional deeper holes, particularly toward the lower sections, in which the substrate was not visible but is likely to contain at least some silty material by virtue of slower flow velocities, excessive aquatic plant growth and agricultural/semi-residential landuse patterns.

Aquatic Macrophytes

Aquatic macrophytes, or vegetation which is visible to the naked eye, are made up of emergent, floating and submerged plants. Macrophytes play an integral role in an aquatic ecosystem. They act as physical filters, nutrient sinks, sediment stabilising agents, habitat and food (for aquatic fauna). Aquatic macrophytes are also important for carbon dioxide (CO_2) fixation, dissolved oxygen (DO) and nutrient cycling.

Nineteen species of aquatic macrophytes were recorded during field surveys including seven introduced species.

The freshwater reaches above Hinze Dam were generally shallow (<0.5m) comprised of bedrock substrate with sand in silt in the deeper holes. Terrestrial vegetation was frequently observed overhanging the channel and providing shaded conditions. Small sections of this reach had reeds or rushes along the bank margins. Apart from this, aquatic vegetation was relatively sparse and dominated by *Azolla* and *Cladophora*, *Isolepis* c.f. *fluitans* and *Vallisneria* c.f. *nana.*

There was sparse littoral vegetation in the zone below the FSL. The only vegetation found were lone stands of *Phragmites* sp. The lack of aquatic vegetation within Hinze Dam is possibly due to:

- the variability of water level inhibiting the proliferation of littoral communities;
- steep lake bed morphology; and
- moderate turbidity and therefore limited euphotic zone.

Downstream of the Hinze Dam to Weedons Crossing in Nerang was largely dominated by introduced species. There has been substantial encroachment of riparian and aquatic vegetation, including invasive alien species as well as oppurtunistic native species, effectively reducing channel size.

Aquatic Invertebrates

Previous studies undertaken in 2005-06 showed the upper Nerang and Little Nerang catchments in relatively good condition with a notable absence of many indicators of declining ecosystem health. PET richness, species richness, OE50 and OE50 signal scores across the catchment were generally indicative of high quality habitat and excellent water quality.

In contrast, when surveyed in April 2007 the monitoring sites downstream of the dam appeared to be in very poor health, exhibiting OE50 scores were generally lower, but signal scores were within a more normal range, suggesting impacts other than water quality may be affecting macroinvertebrate health. In conflict with the OE50 scores, PET richness was low at these sites, potentially indicating poor water quality.

There was a trend towards less diverse macroinvertebrate communities with lower PET richness the further a site was from the headwater areas. This is typical of most river systems, as the cumulative effects of upstream land use intensify the pressure on sites lower in the catchment. In addition, there was a clear decline in the macroinvertebrate assemblages at all downstream sites compared with sites above Hinze Dam. This is likely to be the combined result of more intensive agricultural land use, increased urbanisation and poor flow variability as a result of regulation of the river at Hinze Dam.

Fish and Fish Habitat

In addition to containing indigenous fish species, Hinze Dam is a stocked recreational fishery. Since 1991 stocked species have included Australian Bass, Golden Perch, Silver Perch, Mary River Cod and Saratoga. Although their presence in the Nerang system is unconfirmed, Harris (2006) predicted that two additional native species of interest to the Australian Society for Fish Biology (ASFB) could be present in the Nerang system; Freshwater Mullet (*Myxus petardi*), and Purple-spotted Gudgeon (*Mogurnda adspersa*). Further investigations should be undertaken to confirm the presence of these species. There are also a number of exotic species previously recorded from within the dam.

A total of 25 fish species were identified during field surveys undertaken in April-May 2007. Of these, two were exotic noxious species, Platy (*Xiphophorus maculates*) and *Gambusia holbrooki* and one, Barred Grunter (*Amniataba percoides*) is non indigenous to the area.

Species of Significance

No significant flora or fish species as listed under either the *Environment Protection and Biodiversity Conservation Act (1999)* or the *Nature Conservation Act (1992)* were recorded from the Nerang system during the 2007 HDS3 investigations. A number of fish species considered to be of conservation importance by the Queensland Department of Primary Industries and Fisheries (DPI&F) and the Australian Fish Biology Association may however potentially occur within the Nerang system.

Identified Impacts

In-lake Aquatic Habitat

- The HDS3 has the potential to increase the range of pest species to upper reaches of the Nerang River and Little Nerang Creek;
- Reduced water quality from inundated vegetation may have a deleterious effect on aerobic organisms. This may include the inadvertent production of methyl mercury, which can accumulate in fish and other biota;
- Replacement of a small area of lotic (riverine) habitat with lentic (stillwater) habitat in the vicinity of where the Nerang River enters the dam; and
- The volume of the lake will approximately double following construction of HDS3, however the available habitat will increase by only 25%. Hence, doubling of the current stocking rates may result in larger numbers of smaller or poorly conditioned fish.

Sediment and Substrate

The HDS3 project is expected to have a negligible impact on upstream geomorphology, apart from the conversion of a small area of riverine habitat to lake habitat.

The Project will create a greater area of aquatic habitat. There is however potential for the proportions of sand, silt and rock to be altered within the littoral zone of the existing dam, which may in turn influence the nature and availability of habitat by:

- Inundating new substrate that may be substantially different to the substrate currently within the littoral zone;
- Inundating vegetation, the decay of which may increase the organic content of the sediments; and
- Inundation of the new substrate may introduce nutrients and metals, such as cobalt in to the dam.
- The greatest impacts on sediment and substrate are expected to occur in the Nerang River downstream of Hinze Dam, although these effects are experienced currently to an extent:
- Reduced downstream flows can result in the deposition of sediments, as the lower energy hydrological regime is insufficient to keep particles in suspension. It can also lead to the proliferation of choking aquatic weed growth;

- A reduction in the frequency of floods (particularly 'bank full' floods), which reduces natural channel forming processes and results in the deposition of sediment at particular points throughout the downstream river system; and
- Reduction in sediment load in rivers can result in increased erosion of riverbanks and beds, loss of floodplains and degradation of coastal deltas.

Aquatic Vegetation

- Inundation and alteration of riverine habitat immediately above the dam thus creating lacustrine habitat, which will most likely cause a shift from lotic communities to lentic communities;
- The creation of new aquatic habitat may lead to the proliferation of weeds, as introduced species are often the first to colonize an area after disturbance;
- Loss of existing riparian vegetation and limitations on potential new riparian habitat caused by elevated water levels; and
- Reduced frequency of flushing flows in the Nerang River below Hinze Dam, thereby having effects on exotic species, mangroves, sediments, nutrients and habitat complexity.

Aquatic Invertebrates

Unmitigated, the construction of HDS3 will have two key impacts on macroinvertebrate ecology:

- The drowning of a small area of high quality aquatic lotic habitat at the upper ends of the dam; and
- A reduction of flushing flows in the Nerang River below the dam wall, which can be expected to cause further decline of an already highly disturbed aquatic system.

Fish and Fish Habitat

- Further restrictions to upstream fish passage;
- A reduction in flood passage which can be expected to result in further declines in habitat quality;
- HDS3 may result in more available habitat for fish species;

- The success of the current upstream and downstream passage of migratory species found within the Nerang system such as the Longfinned Eel (*Anguilla reinhardtii*) and the Short-finned Eel (*Anguilla australis)* is not fully understood although there is evidence that passage is already restricted. If some degree of movement over the current dam occurs, access would be further restricted by the increased wall height.

Suggested Mitigation and Management of Impacts

Mitigating actions that were identified as potentially benefiting the entire ecology of the aquatic environment include:

- As the existing dam has already created a significant impact on the aquatic biota and habitat from both within and up- and downstream of Hinze Dam, the greatest benefit to the regional aquatic ecology could be to apply an offset strategy. This approach would require considerable stakeholder engagement and scientific investigation prior to implementation. It is suggested that preliminary identification of a potential conservation site(s) be undertaken and a cost-benefit analysis completed to test this approach prior to further consideration; and
- Inclusion of flood gates to help improve downstream flow control and to help control rate of filling.

In-lake Aquatic Habitat

- The GCCC needs to provide a water supply to the Gold Coast and will fill the dam as quickly as rainfall allows. Water quality will be protected by leaving riparian roots intact and the understorey in place and by implementing a range of sediment and erosion control measures to limit the movement of sediment into the dam;
- Monitoring of methyl mercury concentrations in recreationally significant fish species annually prior to and following HDS3 completion. This program should be carried out until bioaccumulation can be ruled out; and
- Following the completion of HDS3, fish stocking in the dam should be limited to no more than 25% of the current rate. Any increases to stocking rates should be gradual and be dependant on water level. The stocking rate could be reassessed if it is determined that the carrying capacity of the dam has been increased.

Sediment and Substrate

- Management of the aquatic weeds, including Cumbungi, Water Hyacinth and Salvinia, all of which have substantially blocked the river at numerous points downstream of Hinze Dam.

Aquatic Vegetation

- Staggering the rate of inundation will allow for a gradual transition between the lotic and lentic habitat and will therefore provide conditions that vegetation can adapt too. This may occur naturally unless the dam is filled by large natural flood event; and
- The loss of lotic habitat cannot be mitigated against, but as it represents only 1.5% of the available upstream freshwater habitat, it is not deemed to be a significant loss.

Aquatic Invertebrates

- Performance of further macroinvertebrate surveys during Spring 2007, enabling combined season models to be employed and hence giving a more robust picture of downstream ecosystem health. Ideally, biannual sampling should be repeated over a number of years to establish a more accurate baseline.

Fish and Fish Habitat

- Additional fish research is recommended, including fish distribution patterns and fish passage, prior to the commissioning of Hinze Dam Stage 3;
- Two fish species considered to be of conservation significance by the Australian Society of Fish Biologists (1996) *M. pertardi,* (Freshwater Mullet) and *M. adspera*, (Purple Spotted Gudgeon) are considered likely to exist within the Nerang system based on their geographic range and habitat preferences, but have not been recorded in recent fish surveys. Increased sampling effort focused on capturing these two species would be of benefit to prove or disprove their presence within the catchment;
- Investigation into the feasibility of developing an upstream fish passage way: and
- Undertake further fish surveys to help reach a decision on the requirement for downstream fish passage.

Should fish passages be introduced, electrophoretic techniques should be used to determine whether the Australian Bass (*Macquaria novemaculeata)* hatchery populations within Hinze Dam are genetically distinct from the downstream wild population prior to allowing the two stocks to mingle.

Should fish passage be facilitated around the dam wall, pest species should not be reintroduced to the Hinze Dam catchment after collection in the fish transfer device.

Amphibians, Reptiles and Mammals

There are no suggested mitigation measures regarding aquatic and semi-aquatic amphibians, reptiles or mammals that were encountered or are likely to inhabit the Hinze Dam Catchment. A more extensive survey method to describe the distribution and abundance of these mammals in the HDS3 area could be beneficial to thoroughly identify potential impacts.

Glossary

Term	Definition
allochthonous material	Organic matter that is derived from outside of the aquatic ecosystem, such as leaves of terrestrial vegetation that fall into the stream.
amphidromous	Organisms which migrate between saltwater and freshwater environments however not for breeding purposes.
anadromous	Diadromous species that spend the majority of their life in saltwater and migrate to freshwater to breed.
anoxic	Without or depleted of oxygen.
aquatic macrophyte	Submerged, emergent or floating aquatic vegetation that is visible to the naked eye.
benthic	Pertaining to the bottom of a body of water.
biofilm	A thin layer of living cells, such as bacteria, protozoa and algae, which coat the surface of a living or non-living substrate.
biogenic sediment	Sediment produced by the actions of living organisms.
catadromous species	Diadromous species that spend the majority of their life in freshwater and migrate to saltwater to breed.
diadromous species	Organisms that move during their life cycle between freshwater and saltwater environments.
electrofishing	A fish sampling technique which uses electric fields and electric currents to capture fish by controlling fish movement and/or immobilising fish.
environmental flow	The flow of water that is required to maintain aquatic and riparian ecosystems in streams and rivers.
epilimnion	Upper waters of a thermally-stratified water body. The upper layer is characterised by warmer and lighter water.
euphotic zone	Surface layer of a body of water which receives enough sunlight for photosynthesis.
eutrophication	Process during which water bodies become enriched with dissolved nutrients resulting in excessive growth of organisms, such as algae, and the subsequent depletion of oxygen.
embeddedness	rates the degree to which rocks (gravel, cobble and boulders) and snags are covered or sunken into the silt, sand or mud of the stream bottom
FSL	Full supply level
holomixis	Complete mixing of the lake or water body, for example during Winter when the epilimnion starts to cool.
hypolimnion	Bottom layer of a thermally-stratified water body. This bottom layer is characterised by cold water which is usually low or lacking in oxygen.
lacustrine habitat	Lake environment, pertaining to standing water bodies.
lentic habitat	Standing or still water habitats such as lakes and ponds.
limnological process	Referring to the chemical, physical and biological properties of bodies of freshwater.
littoral vegetation	Vegetation that occurs within the littoral zone.
lotic habitat	Flowing water habitats such as rivers and streams.

macroinvertebrate	Organisms without a backbone which are large enough to be seen with the naked eye.
metalimnion	Middle layer of a thermally-stratified body of water. The metalimnion is the transition layer between the epilimnion and hypolimnion and is also referred to as the thermocline.
pelagic zone	The water column associated with the surface or middle depths of a water body, away from the bottom.
PET richness	Refers to the sum total of all taxa from the orders Plecoptera (the stoneflies), Ephemoptera (mayflies), and Tricoptera (caddisflies).
potadromous species	Organisms which complete their entire life cycle in fresh water.
thermocline	The zone of rapid vertical temperature change in a thermally-stratified body of water.

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2 Introduction

This report provides the basis for the Aquatic Biology chapter in the Environmental Impact Statement (EIS) for the HSD3 project and addresses the terms of reference set out in HDS3 project Coordinator-General, Department of Infrastructure, February 2007, section 3.7.

The EIS will be an important tool for managing the HDS3 Project within an ecologically sustainable framework.

2.1 Overview of the Hinze Dam Catchment

Gold Coast Water (GCW) is the local government agency responsible for the delivery of potable water and the management of wastewater for the Gold Coast Region of South East Queensland. GCW manages two potable water storage sources from which the majority of the region's potable supply is sourced, Hinze Dam and Little Nerang Dam.

Hinze Dam or Lake Advancetown is located in the mid-reaches of the Nerang River approximately 15km southwest of Nerang and 36km from the river mouth. At its completion in 1976 the storage had a capacity of 42.4 GL, by 1989 the embankment had been raised a further 18m, bringing the storage to its current capacity and surface area of 161 GL and 9.72 square kilometres respectively (ED&MPD, 2006). In addition to water storage, Hinze Dam provides a degree of flood mitigation for low-lying areas below the dam wall. The location of the dam resulted in inundation of both the Nerang and Little Nerang Basins, creating a 'U' shaped storage. The western arm of Hinze Dam receives drainage from the Numinbah Valley, nestled between the Darlington and Wunburra Ranges and the eastern arm from the Springbrook National Park, bounded by the Wunburra and Nimmel Ranges.

Hinze Dam is an earth and rock structure built immediately below the confluence of the Nerang River and Little Nerang Creek. The Little Nerang Creek emanates high on the Springbrook Plateau via a series of waterfalls over the Eastern Escarpment and from tributaries on the western slopes of the Nimmel Range. This system flows largely through rugged national park; hence, riparian zones are generally excellent through the mid sections. On the mid reaches of the Springbrook Plateau, the catchment has been moderately disturbed by the construction of Springbrook Village, assorted tourist facilities and agricultural enterprise.

The Nerang River is the most significant river on the Gold Coast. Water enters the system from the Lamington National Park to the east, and from the western slopes of the Springbrook Plateau, providing a relatively intact catchment with relatively healthy vegetation cover that assists in maintaining good water quality (EHMP 2005, GCCC 2006). Between Hinze Dam and the Lamington National Park, the Nerang River flows through a sparsely populated region; the main centres being the small rural village of Numinbah Valley, and the Numinbah Correctional Centre. Land use in the Numinbah Valley is predominantly pastoral agriculture (cattle grazing), and riparian zones remain reasonably well vegetated, although exotic riparian species are prevalent in places. The HDS3 expansion will provide greater storage capacity and serve as a flood mitigation strategy for land downstream of the Nerang River.

The Little Nerang Dam is on the Little Nerang Creek immediately upstream of Hinze Dam. The two storages have a combined catchment of 209 square kilometres and on average provide 169 ML of raw potable water daily. GCW augment supplies from the Nerang Catchment with water piped from Wivenhoe Dam via Brisbane's Mt Crosby Water Treatment Plant. The Little Nerang Dam is a gated concrete structure built in 1962 to supply potable water for the Gold Coast, and has remained a secondary water supply since the commissioning of the Hinze Dam in 1976. Little Nerang Dam has a surface area of 0.49 square kilometres and a storage capacity of 9.3GL (GCCC, 2006).

The Little Nerang Dam is a gated concrete structure built in 1962 to supply potable water for the Gold Coast, and has remained a secondary water supply since the commissioning of the Hinze Dam in 1976. Little Nerang Dam has a surface area of 0.49 square kilometres and a storage capacity of 9.3GL (GCCC, 2006).

2.2 Rationale of Hinze Dam Stage 3

The need for the HDS3 Project is threefold (GHD 2006):

1. To achieve flood mitigation objectives in line with Council's commitment. Currently over 4,000 existing properties downstream of Hinze Dam could potentially be affected in a 1:100 year flood event and result in $147 M in damages. Flood mitigation works would provide a reduction of approximately 3,400 affected properties and 80% ($114 million) reduction in community wide damage;
2. To increase capacity and reliability of water supply in line with the Gold Coast Water Futures & the Queensland Government's South East Queensland Regional Water Supply Strategy (SEQRWSS) findings; and,
3. To satisfy new dam safety requirements. Based on recent new methodology developed by the Bureau of Meteorology, Hinze Dam no longer conforms to safety requirements under State legislation for Probable Maximum Flood (PMF). Council has accordingly resolved to augment the dam to satisfy these requirements, and in doing so reduce the significant risk to downstream property

and life.

2.3 Description of Hinze Dam Stage 3

The Hinze Dam Alliance, a consortium involving both Council and specialists from the private sector will deliver the HDS3 Project. The Alliance has been formed as a one-project company, drawing on a cooperative incentive driven approach with the Council as the sole funding entity. The performance of Alliance based project teams to date have proven this method to be an effective and flexible means of delivering high quality infrastructure projects. The proposed works for the HDS3 Project include the following (GHD 2006; ED&MPD (2006):

- Raising of the existing dam wall by up to 12.5m to accommodate dam safety, flood mitigation, and additional water supply storage;
- Modification of existing spillway and possible installation of flood gates;
- Raising of the lower and upper water intake towers to accommodate the additional water storage capacity;
- Construction of a new saddle dam;
- Raising of the existing saddle dam;
- Upgrade/replacement of other ancillary services and structures including:
  - Parks and recreation facilities around dam wall;
  - Road and bridge upgrades; and,
  - Realignment of water pipeline.

The following related works may also be required as a result of the HDS3 Project:

- Upgrade of Gold Coast Springbrook Road to ensure that it is not flood prone where it passes close to Little Nerang Creek and at its intersection with Nerang - Murwillumbah Road;
- Upgrade of Nerang - Murwillumbah Road west of the impoundment and in the vicinity of Nerang River upstream of the existing impoundment; and,
- Decommissioning of the existing quarry on Lot 4 SP164198 or development of new quarries on Council owned land along the Nerang River above the current impoundment (Lot 11 WD2914, Lot 274 W312359 and Lot 275 W312359).

Downstream works, including possible future upgrade to Water Treatment Plants, are to be undertaken when required as separate projects.

2.4 Environmental Impact Statement

The project involves potentially significant environmental impacts stemming from construction activities and permanent inundation of part of the catchment. The Environmental Impact Statement (to be provided to the Hinze Dam Alliance) will identify the likely type and magnitude of impacts involved in of these impacts, and potential for mitigation or remediation works to be undertaken as part of the project. Project approvals may be dependant on the extent of the project. The detailed dam design will be run concurrent to the EIS. This will allow potential environmental and social impacts to be addressed in the design and project environmental management plans.

2.5 Terms of Reference

Ecosure/Aquateco were commissioned in February 2007 to undertake the aquatic biology component of the HDS3 Environmental Impact Statement (EIS). The Terms of Reference as set by the Coordinator-General (Department of Infrastructure) states that aquatic environmental values affected by the proposal are to be described including:

- Fish species, mammals, reptiles, amphibians, crustaceans and aquatic invertebrates;
- Any rare of threatened marine species in downstream environments;
- Commercial fish species which are present within the waterways;
- Discussion of the sensitivity of fish habitats to disturbance;
- Aquatic plants;
- Benthic substrate;
- Downstream habitat and potential impacts;
- Critical migration and breeding requirements for native aquatic species; and,
- Discussion of the requirement or otherwise for a fishway to be constructed.

Potential impacts and mitigation measures involve:

- Detailing strategies to protect Moreton Bay Marine Park and Ramsar Wetland as a result of changes to downstream flooding regimes;
- Any rare or threatened species should be described and any obligations imposed by State and Commonwealth legislation or policy or international treaty obligations should be discussed. Emphasis should be given to potential harm to downstream and intertidal communities;

- Discuss the effects of changes to flow regime downstream, including the effect of changes in water quality, salinity, habitat structure and flora; and,
- Determine effects of increased level in the impoundment and projected variations in the level of the impoundment on aquatic fauna, particularly in creeks flowing into the impoundment. Determine the potential impacts on commercial and recreational fisheries, addressing issues such as access, changes to stocks (species, population numbers and structure, recruitment to fishery) and the potential for fish kills and mitigation strategies.

2.6 The Case for Biological Monitoring of Waterways

Bioassessments and biological indicators have come into use because the traditional physical and chemical guidelines are too simple to be meaningful for biological communities or processes (ANZECC/ARMCANZ, 2000).

Historically, it has been assumed that a suite of physical and chemical water quality parameters were reasonable indicators of the ecological health of waterways. Parameters such as dissolved oxygen, pH, salinity, turbidity and a range of potential contaminants such as nutrients, heavy metals, pesticides and hydrocarbons were considered the simplest and most appropriate indicators for assessing the health of waterways. More recently, it has been recognised that this approach is subject to a number of shortcomings, such as:

- The extrapolation of instantaneous ‘snapshot’ water quality data over even short time periods (or conversely, the cost and labour intensity of collecting sufficient data to enable such extrapolation) can be very unreliable;
- The challenge of collecting representative samples when the parameters under scrutiny may be highly variable over relatively short temporal scales (i.e. the need for time monitoring to coincide with events such as rainfall); and,
- The significance of a particular water quality parameter on the health or ecology of a system can be extremely complex; hence, interpretation of data can be difficult.

The latter of these challenges has been overcome to some extent by the derivation of water quality guidelines for achieving environmental objectives, for example the Australian Water Quality Guidelines for Fresh and Marine Water (ANZECC/ARMCANZ, 2000). However, the authors of even these documents recognise the need for a more holistic approach to monitoring the health of aquatic ecosystems:

"The greatest threat to the maintenance of ecological integrity is habitat destruction…

…… The previous ANZECC (1992) guidelines foreshadowed the need for a broader, more holistic approach to aquatic ecosystem management, to consider all changes, not just those affecting water quality. Such changes could include serious pollution of sediments, reduction in stream flow by river regulation, removal of habitat (de-snagging, draining wetlands) or significant changes in catchment land use, any of which could cause significant ecosystem deterioration (ANZECC 1992). The guidelines for water quality management documented here are therefore a necessary but only partially sufficient tool for aquatic ecosystem management or rehabilitation" (ANZECC/ARMCANZ 2000 p3.1-2).

In order to overcome these difficulties, waterway managers are now adopting more holistic monitoring, most commonly by expanding water quality programs to include rapid assessment of biological communities, in-stream habitat modification, geomorphic processes and/or riparian change.

Bioassessment should be seen as a vital part of the monitoring and assessment process within aquatic ecosystems and as a tool to assess achievement of environmental values and attainment of associated water quality objectives. The benefits of bioassessment include:

- integration of multiple natural and human changes in physico-chemical conditions;
- temporal integration of disturbance data, assisting in overcoming short term, localised impacts;
- absorption of anthropogenic impacts into complex interacting biological communities and processes; and.
- direct linkage between water quality signals and ecological or biological impacts.

Biological assessment of waterways is based on significant departures from a relatively natural, unpolluted or undisturbed state, such as changes to species richness, community composition and/or structure; changes in abundance and distribution of species of high conservation value or species important to the integrity of ecosystems; and physical, chemical or biological changes to ecosystem processes.

Many of the objectives of bioassessment are of direct value to the Hinze Dam Alliance:

- Assessment of ecosystem health at the catchment scale using rapid, cost effective and relatively robust methodologies;
- Screening of sites to identify locations needing more detailed investigation;
- Early detection of short or long term changes impacting on conservation values and water quality issues of conservational or operational significance to the Hinze Dam Alliance;
- Preliminary assessment of biodiversity and identification of keystone taxa linked to particular water quality attributes; and,
- Providing a baseline against which sustainability objectives may be measured.

2.7 Legislation and policy

The following Commonwealth and State legislation are considered relevant to the aquatic biology component of the EIS:

- *Environment Protection and Biodiversity Conservation Act 1999*;
- *Nature Conservation Act 1992*;
- *Fisheries Act 1994*;
- *Land Protection (Pest and Stock Route Management) Act 2002*; and
- *Environmental Protection Act 1994*.

2.7.1 Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) provides for the protection of the environment and the conservation of biodiversity. In particular, this Act provides protection for recognised matters of national environmental significance. These matters of national environmental significance include:

- World Heritage properties;
- National Heritage places;
- Wetlands of international importance (Ramsar wetlands);
- Threatened species and ecological communities;
- Migratory species;
- Commonwealth marine areas; and
- Nuclear actions (including uranium mining).

Approval is required for any action that is considered likely to have a significant impact on any matters of national environmental significance.

2.7.2 Nature Conservation Act 1992

The object of the *Nature Conservation Act 1992* (*NC Act*) and its associated *Nature Conservation (Wildlife) Regulation 2006* is the conservation of nature which is achieved through elements such as the dedication, declaration and management of protected areas, community education and the protection of native wildlife and its habitat. The Regulation provides lists of flora and fauna species that are classified as Endangered, Vulnerable, Rare and Near Threatened pursuant to the *NC Act*.

The *Nature Conservation (Wildlife) Regulation 2006* contains declared management intents for rare and threatened species including:

- *to establish and maintain a database of information about the wildlife and its habitat*;
- *to the extent practicable, to prepare and put into effect recovery plans or conservation plans for the wildlife and its habitat*;
- *to take action to ensure viable populations of the wildlife in the wild are preserved or re-established*;
- *to regularly monitor and review the conservation status of the wildlife and its habitat*;
- *to encourage scientific research likely to contribute to an understanding of the wildlife or its habitat including, for example, the requirements for conserving the wildlife or habitat*; and
- *to protect the critical habitat, or the areas of major interest, for the wildlife*.

2.7.3 Fisheries Act 1994

The *Fisheries Act 1994* provides for the protection and management of fish habitats; the management of recreational, commercial and indigenous fishing; the management of aquaculture; and the prevention, eradication and control of disease in fish. These objectives are to be achieved by the application of the principles of ecologically sustainable development to ensure that the community's fisheries resources and fish habitats are used in a manner that maintains the ecological processes now and in the future. Marine plants such as mangroves are recognised as fish habitats and are protected under the provisions of this Act.

2.7.4 Land Protection (Pest and Stock Route Management) Act 2002

The *Land Protection (Pest and Stock Route Management) Act 2002* and its associated regulation provides for the management of pests and the management of stock route networks. To assist in achieving this purpose, the Act lists declared pest plant and animal species according to the following three categories:

Class 1 Class 1 pests are not commonly present in Queensland and would cause an adverse environmental, economic or social impact if they are introduced or become established.

Class 2 Class 2 pests are already established in Queensland and have, or potentially could have an adverse environmental, economic or social impact. The management of these pest species requires coordination via the landowner, community and local government.

Class 3 Class 3 pests are already established in Queensland and have, or potentially could have, an adverse environmental, economic or social impact. The impact of these pest species are primarily environmental and for areas within or adjacent to an environmentally significant area a pest control notice can be issued.

2.7.5 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (*EP Act*) aims to protect Queensland's environment whilst allowing for development in a sustainable manner that will maintain ecological processes and improve the total quality of life for both now and in the future. Several environmental protection polices have been developed which are subordinate legislation to the *EP Act*, such as the *Environmental Protection (Water) Policy 1997*. This policy aims to achieve the object of the *EP Act* in relation to Queensland waters by providing a framework for identifying the environmental values of Queensland waters; water quality guidelines; decision-making processes about Queensland waters; and community consultation and education.

2.8 Report Objectives

The objective of this technical report is to provide scientific information on the key ecological communities within the Nerang River (above and below Hinze Dam) and the Little Nerang Creek, through ecological investigations. The specific aims of this report are to:

1. Describe the extant aquatic biota and substrate both upstream and downstream on the Nerang River and the Little Nerang Creek;

2. Determine the potential impacts of the proposed works on the aquatic biota; and

3. Discuss mitigation measures to offset those impacts.

In addition, this technical report will form the basis of the Aquatic Ecology component of the Hinze Dam EIS.

3 Site Description and Methods

3.1 Site Descriptions

The study area encompasses three major reaches within the Nerang River and Little Nerang Creek; upper reaches of the Nerang River and little Nerang Creek, within the Hinze Dam (Lake Advancetown); and the Nerang River, below Hinze Dam. A total of 16 sites were chosen within the study area for surveys for aquatic habitat, sediment/substrate, macrophytes, macroinvertebrates and fish. The location study sites and survey methodology is shown in Figure 3.1. Detailed site descriptions for sites above and below the Hinze Dam are included in Appendix 1. Study site locations were selected to provide an indication of the aquatic communities of the upstream and downstream reaches of major freshwater streams and for the impoundment.

3.2 Background and Prior Studies

3.2.1 In-lake Habitat

Gold Coast Water (GCW) has routinely monitored the vertical temperature and DO profiles within Hinze Dam since 1999. This data set is comprehensive in the sense that the lake has been monitored weekly for a number of years, but suffers from lack of resolution (parameters are recorded at 3m intervals, where 1m intervals would be more appropriate, with even finer resolution within the metalimnion). As the metalimnion can occur within a 1m (or less) depth range the 3m resolution is a significant impediment in this analysis. The data set is also constrained by the depth to which parameters were measured, which was limited to a maximum of 24 metres.

Data provided by GCW was used to enable determination of stratification scenarios and to determine how changes to Hinze Dam will affect the availability of the littoral zone within the lake. Data was sorted on a monthly basis and the mean DO concentration at each depth interval was calculated, along with the 95% confidence interval (2 standard deviations from the mean).

3.2.2 Sediment and Substrate

There is a paucity of research on this facet in the Hinze Dam catchment. Aquateco Consulting (2006) represented the first report on sediment and substrate of the upper catchment. This facilitated the need to carry out field surveys to fulfil the EIS Terms of Reference.

3.2.3 Aquatic Macrophytes

There is also a lack of scientific research on the aquatic flora of the Hinze Dam catchment. Brizga (2006) has classified the reaches within the catchment in terms of change from reference condition (post European settlement). Changes to aquatic vegetation were important contributors in determining categories of change. The condition ratings for the Nerang River and Little Nerang Creek reaches are categorised as showing major to very major change from reference condition for most ecosystems, although impacts of water resource development are greater in Little Nerang Creek due to the effects of Little Nerang Dam. Brizga (2006) stated that moderate to major changes have occurred in the reach of Nerang River from Hinze Dam to the tidal limit. Major to very major change from reference conditions has occurred for most ecosystem components in Hinze Dam pondage. Major environmental changes have occurred in the Nerang catchment within the past 30 years due to the construction of the Hinze Dam and Little Nerang Dam impoundment. This is due to the alteration of riverine, floodplain and terrestrial ecosystems by impoundments.

A report by Harris (2006) found that the Nerang River downstream of Hinze Dam was generally in a degraded condition. A minimal flow was present with only a small proportion of the riverbed wetted, riffle-pool sequences were poorly defined and many habitat areas were shallow. Extensive vegetative and weed invasion of the channel was apparent in all areas visited, commonly restricting available aquatic habitat. Stream substrates in some areas were coated with accumulated biofilm layers and biogenic sediments consistent with the low flow experienced. Harris (2006) found stream habitat conditions for native fish at the upstream riverine sites appeared to be good to excellent, with little disturbance to riparian vegetation except for weed invasions near road crossings.

3.2.4 Aquatic Invertebrates

The AusRivAS protocols provide rapid sampling methods for the development and application of predictive models using macroinvertebrate communities and a 'reference' site database. Comparisons are made between the predicted and observed taxonomic composition of macroinvertebrate communities within various habitat types at each site. Where the observed communities are significantly altered from those predicatively modelled from a region-specific database of reference sites, a decline in ecological health is deemed to have occurred. These shifts in species assemblages may be the result of changes in water quality, altered hydrology, habitat availability/quality and/or geomorphic or catchment processes.

The field and data analysis methodology and protocols adopted in this study follow, as closely as practicable, to those of the Australian Rivers Assessment Scheme (AusRivAS); specifically those guidelines intended for south east Queensland practitioners of this form of bioassessment (AuSRivAS, 2001). AusRivAS is the accepted Australian standard for the assessment of the health of freshwater river systems using benthic macroinvertebrate communities. Macroinvertebrate communities are one of five classes of freshwater ecosystem health indicators utilised in the Ecosystem Health Monitoring Program (EHMP); hence, adherence to accepted sampling protocols allows data collected to be placed within a regional context.

3.2.5 Fish and Fish Habitat

Fish and collections and/or data collation exercises have been undertaken within the study area, including:

- Centre for Catchment and In-stream Research (CCISR) - Griffith University (M. Kennard unpublished data);
- Ecosystem Health and Monitoring Program (EHMP) as part of the Healthy Waterways, Moreton Bay Waterways and Catchment Partnership;
- Aquatic, Riparian Vegetation Mapping and Freshwater Fish Study for Gold Coast Waterways (AREA);
- Hinze Dam Post stocking surveys (Hamlyn & Cheetham 2005);
- Hinze Dam Fishway (Harris 2006); and
- Hinze Dam Stage 3 Fish Passage Assessment (Mefford 2005).

Unfortunately, each study had been designed to meet specific objectives for example the EPBC study has been designed to compare the ecosystem health across different waterways or have lacked long term or seasonal assessments. For this reason, these previous collections do not represent an indicative sample of the community structure of fish communities within the study area. Therefore more information is required to address the objectives of this study. Field surveys were undertaken to identify fish and to assess potential impacts that the HDS3 Project may have on them. Further to this, there is little information on aquatic reptiles, mammals and amphibians within the catchment. These could not be specifically surveyed for this report due to time constraints so a desktop study was carried out.

3.3 Field Surveys Undertaken

3.3.1 Sediment and Substrate

As the HDS3 upgrade will not affect sediment or bedload deposition or transport processes in the catchment above the proposed new FSL, extensive surveys of upstream substrate have not been performed. However, descriptions of the substrate were opportunistically gathered above Hinze Dam at five sites in the Nerang River and at three sites in Little Nerang Creek during macroinvertebrate field surveys (see section 3.3.3).

Sonar was used to map areas of hard and soft sediment within the existing FSL of Hinze Dam. This data was used to estimate the proportion of rocky and silty sediments within the system, particularly within the littoral zone during periods of stratification.

Soft sediments within the impoundment were collected at five sites within the water storage using an Eckman Grab sampler. These were subjected to chemical analysis (by ALS Environmental, a NATA accredited laboratory) to enable characterisation of the material, including nutrients, moisture content, organic content along with a suite of metals.

To enable an assessment of the extent to which the sediments within the littoral zone will be altered by increased water level, a further five soil samples were collected from between the existing FSL and the proposed new FSL ('inter-FSL') and subjected to the same suite of analysis.

A longitudinal survey of the river below the dam wall was performed via traversing the entire reach by kayak. Although substrate type was not mapped, the shallow, narrow nature of the river bed between Hinze Dam down almost to Weedons Crossing enabled observation of the main substrate features for the majority of the reach.

3.3.2 Aquatic Macrophytes

Baseline field surveys for aquatic macrophytes, including inspections of littoral vegetation, were conducted in the freshwater reaches of the Nerang catchment, within Hinze Dam and downstream freshwater reaches of the Nerang River. This included all sites used for macroinvertebrate, fish and sediment collection.

Aquatic vegetation surveys of sites below the Hinze Dam were carried out from 13 – 21 March 2007. Surveys of Hinze Dam and the upper reach were identified in the field from 18 – 20 April 2007. Where identification could not be made in the field, specimens were collected for further analysis. Macrophytes were identified using field guides (Sainty & Jacobs 2003; Entwisle et al. 1997; GCCC 2006).

3.3.3 Aquatic Invertebrates

Monitoring Program Design

This report builds on work commissioned by Gold Coast Water in 2005-06 assessing sites on the Nerang River and Little Nerang Creek above Hinze Dam. No further sampling of these sites was undertaken; the data previously collected being considered to be sufficiently recent and rigorous for the purposes of an environmental impact assessment. However, to enable an assessment of potential impacts of the HDS3 Project and development of potential mitigation strategies, macroinvertebrates were sampled at three sites on the Nerang River below the Hinze Dam and the results considered in the context of the existing data set.

As disturbance impacts typically accumulate progressively with distance from the source, sites low in the catchment tend to reflect the cumulative impacts of the entire upstream catchment. For the purposes of this program, it was considered desirable to locate a site immediately above Hinze Dam on each of the two river systems (the 'Education Centre/Fire Trail' and 'Little Nerang' sites, as well as three sites below Hinze Dam).

Sites located between the headwater sites and those close to the dam may be used to assess cumulative impacts throughout the upper catchment, or may reflect localised impacts (eg effluent outfall, tributary confluence etc). In this instance, the remaining sites were chosen based on accessibility and diversity of habitat, with the aim of creating as wide a geographical spread of sites as possible.

Ideally, macroinvertebrate sampling should be performed at each site twice annually. One sampling event should be timed to coincide with the early wet season (Spring sample), providing animals that have endured reasonable periods of low flow, and the second during the late wet season (Autumn sample) where animals have endured periods of higher flow (AusRivAS, 2001). Collection of the latter sample must be timed to correspond with periods of recessional baseflow, avoiding significant flood events.

The very tight timeframes for the Hinze Dam Stage 3 field studies precluded the preferred option of sampling the downstream sites again at the end of the dry season, and hence the less robust seasonal (rather than combined) models were used to assess these sites. It is strongly recommended that these sites be sampled again during Spring 2007 to provide a more thorough analysis.

As single season model outputs are not directly comparable to combined season model outputs, comparison of upstream and downstream sites necessitated re-modelling of the April 2006 field and laboratory data using a single season model. It is recognised that these data were collected some 12 months apart and that the biological assemblages observed in the 2007 sampling reflect the climate, hydrology and environmental conditions of the 12 months following collection of the 2006 data. Whilst this makes direct comparison of the sites a little challenging, this approach is considered adequate for the purpose of establishing an ecological baseline.

Field Sampling

Field methodology for macroinvertebrate surveys followed the guidelines for AusRivAS practitioners operating in Queensland (2001). Zooplankton (microinvertebrates) were collected at each site within Hinze Dam and the Nerang River, below Hinze Dam. Benthic and pelagic samples were collected by pumping water from each zone for 30 seconds through a 250µm mesh net. Zooplankters were rinsed into a specimen jar and preserved in 75% ethanol. All invertebrate (macroinvertebrate and zooplankton) samples were analysed by Dr Rob Walsh to family level.

Modelling and Data Analysis

Note: All invertebrate data are presented in Appendix 2.

Based on reference data, AusRivAS models predict the invertebrate assemblages expected to occur at a test site in the absence of disturbance impacts. When compared with the assemblages actually observed at the site the predicted assemblages provide a measure of biological impact and an indication of the nature of the impacts.

The modelling performed during this study utilised the online Queensland AusRivAS models for sites east of the Great Dividing Range, specifically the season pool, edge and riffle models.

The predictor variables utilised by the models and the derivation of associated values are described below and in **Error! Reference source not found.**

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Variable	Description	Model					Unit	Value
		Combined		Spring		Autumn		
		Pool	Rifle/Run	Edge	Pool	Pool		
ALTITUDE	Altitude was measured on-site using GPS.		✓	✓			m	Site specific
BEDROCK	Proportion of substrate at the site comprised of bedrock.		✓				%	Site specific
COBBLE	Proportion of cobble (particle size 64-256 mm) in substrate at the site.	✓	✓		✓	✓	%	Site specific
DFS	Length of longest upstream thread from sampling site, measured on a 1:25 000 scale topographic map.		✓			✓	km	Site specific
DRYRANGE	Range in dry season monthly rainfall means. Based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.		✓				mm	65.8
LONGITUDE	Longitude (in degrees and minutes) was recorded from a GPS at each site and was converted to degrees (four decimal places) for the purposes of modelling.		✓	✓			degrees	Site specific
MDMR	Mean rainfall over the dry season. Based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.	✓		✓	✓	✓	mm	65.2
MINTEMP	Based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004. Mean Daily minimum temperature.	✓		✓			°C	15.6
MWMR	Mean rainfall over the wet season. Based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.	✓	✓				mm	155.0
PROCESSZONE	Describes geomorphic processes at the site. 2 = erosional, 1 = transport, 0 = depositional.	✓			✓			Site specific
RAINFALL	Mean annual rainfall, based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.	✓				✓	mm	1321.5
RAINRANGE	Average range in mean monthly rainfall. Based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.		✓		✓		mm	156.3
RANGETEMP	Mean daily temperature range, based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.				✓		°C	13.1
RAWD	Mean wet season rainfall/Mean dry season rainfall. Based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.			✓				23.8
STORDER	Stream order: category based on the degree of branching.	✓						Site specific
WETR	Range in wet season monthly rainfall mean, based on BOM data for the Hinze Dam monitoring site (040584), 1974-2004.			✓			mm	65.7

3.3.4 Fish and Fish Habitat

Upper catchment

Much of the upper Nerang River and Little Nerang Creek is inaccessible due to private land ownership, dense riparian zones, limited navigability by canoe and/or extremely rugged terrain. As the dam upgrade will not physically alter the streambed or hydrology of the upper catchment, habitat surveys of the entire length of river were not attempted. Instead, habitat surveys were performed at the bridge crossings and macroinvertebrate sampling sites (Figure 3.1). Although only a small proportion of the overall river reach, these are considered representative of the overall status of the river.

Electrofishing was performed at seven sites within the upper freshwater reaches of the Nerang River and Little Nerang Creek. Where access and habitat availability allowed, the 'power on' fishing time was standardised to 1200 seconds per site, with all available habitat types sampled as thoroughly as possible, although fishing effort was lower at some sites. All fish and crustacea were identified to species, measured from anterior tip to fork length (fish) or carapace length (crustaceans), assessed for health and released.

Within Hinze Dam

Fish were collected from the littoral zones at each of four sites using:

- 10 traps deployed overnight at each site baited with cat food and cyalume light sticks;
- 4 fine mesh fyke nets per site, set along the shoreline and left overnight;
- 4 coarse mesh fyke nets per site deployed along the shoreline and left overnight;
- 1 x 50mm mesh size gill net (50m long x 2.5m drop), 1 x 100mm mesh size gill net (75m long x 2.5m drop) and 1 x 150mm mesh size gill net (50m long x 2.5m drop). Gill nets were set for 2 hours either early in the morning or late in the evening and were checked half hourly; and
- shoreline surveys using backpack electrofishing equipment with a 'power on' time of 1200s.

All surveys, except gill netting were conducted from 17 – 20 April 2007. Gill netting occurred from the 4 May – 9 May 2007. Fyke nets were fitted with platypus excluders or were buoyed at the cod end to prevent accidental drowning of aquatic macrofauna.

All fish and crustacea were identified to species, measured from anterior tip to fork length (fish) or carapace length (crustaceans), assessed for health and released.

Below Hinze Dam

Fish passage survey involved traversing this length of the river in kayaks and identifying barriers to fish passage. Electrofishing at Latimers Crossing, the Golf Course and Stevens Bridges was carried out from 17 – 20 April 2007 using 1200 second passes. All fish were identified to species, measured from anterior tip to fork length, assessed for health and released.

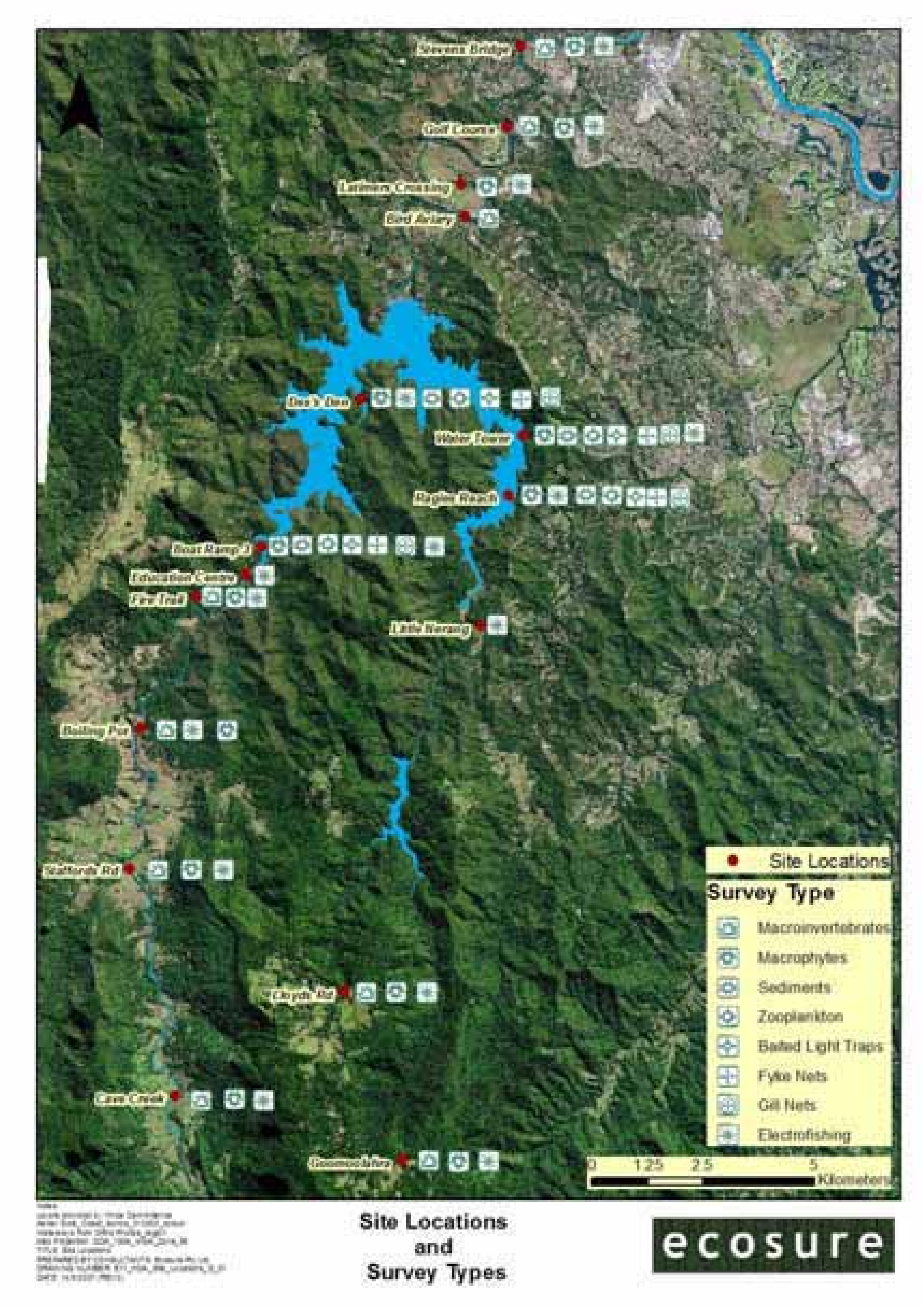


Figure 3.1 Site locations and survey methodology within the study area.

4 In-lake Aquatic Habitat

This chapter of the HDS3 Project examines the impact of raising the spillway level on the in-lake habitat. The availability of habitat is intrinsically linked to aquatic biota, including stocked recreational fish species, native fish and other aquatic fauna and flora.

4.1 Rationale

Intuitively, raising the spillway height of a dam and hence increasing the storage capacity and area could be expected to increase the habitat available to aquatic biota – assuming that the storage is maintained at a higher level (mAHD) than prior to the dam upgrade.

However, the ability of aquatic biota to utilise habitat within a storage area is dependent on the nature and quality of the habitat available, the species present and their habitat requirements. These variables are further dependent on a number of factors:

1. Natural stratification cycles within the storage area;
2. Basin morphology; and
3. Operating regime and hence water level.

4.1.1 Natural Stratification

Thermal stratification of deeper lakes and storages results when incidental solar radiation heats the water surface during the late Spring to early Summer, resulting in a layer of warmer water known as the epilimnion. This layer, being less dense than the water below, remains at the surface of the lake and is prevented from mixing with the cooler waters below by virtue of the thermal density gradient.

The cold water layer at the bottom of the lake (the hypolimnion) is isolated from gaseous exchange with the atmosphere by the epilimnion. Generally being below the euphotic, or light zone, the hypolimnion is also isolated from oxygen replenishing primary production. The biochemical oxygen demand exerted by the sediments and by material falling from the water column results in a violation of the balance between oxygen consumption by microbes and oxygen replenishment by the atmosphere and photosynthesis. Over the ensuing weeks or months, the hypolimnion becomes anoxic and is uninhabitable to all but sulphur reducing bacteria.

The transitional zone from epilimnion to hypolimnion is the metalimnion, but is also variously referred to as the thermocline, oxycline, redoxcline or chemocline, depending on the properties by which the stratification is defined. In a strongly stratified system, this zone is typically quite narrow and is characterised by rapidly changing water temperature, redox chemistry and dissolved oxygen (DO) concentrations over a short distance in the vertical water column.

During the Autumn/Winter period, cooling of the surface waters as a result of lower air temperatures and shorter day lengths results in the epilimnion becoming denser. This ultimately causes the epilimnion to sink and results in the mixing of the entire water column, eliminating anoxic conditions in the deeper parts of the lake (overturn, or lake turnover). This process may happen quite rapidly, over a period of a few days or even hours. Thus, stratification in most Australian lakes is an annual cycle.

During overturn, it is common for a temporary period of poor water quality to occur, typically lasting for a few days to several weeks, although sometimes longer. Occasionally, the prevailing weather conditions may result in gentle cooling, with the epilimnion extending progressively deeper into the water column until the lake is fully mixed and oxygenated without a distinct turnover event occurring.

Stratification is of interest in the context of the HDS3 investigations, as the presence of anoxic conditions below the thermocline reduces the available area of benthic habitat. The area of substrate that is within the epilimnion, containing sufficient oxygen to support aquatic life and experiencing sufficient penetration of light to support photosynthesis, is known as the littoral zone. The variability in the depth of the epilimnion from season to season results in continual expansion and compression (squeeze) of the littoral habitat.

4.1.2 Basin Morphology and Water Level

Basin morphology and storage water level has a role to play in the availability of aquatic habitat, particularly during times of stratification. A storage that is deep and steep sided will have less available habitat than a shallow, expansive storage when the depth to the thermocline is comparable. Conversely, habitat squeeze tends to be more significant in shallow storages during drawdown scenarios, as there is a proportionally greater loss of littoral habitat for every unit of vertical water level fall.

The rise and fall in water level can also influence the physical nature of the substrate within the littoral zone. For example, a lake near full supply level (FSL) may contain a high proportion of rocky substrate or woody debris, whilst substrate at a lower AHD may be predominantly sand or silt. Thus, as water levels fall the habitat available changes from rock to silt, a change that may well result in shifts in species assemblages as mobile species migrate to areas closer to being their preferred habitat.

As aquatic plants are typically sensitive to the amount of solar radiation that penetrates the water column, a rapid rise or fall in water level can affect aquatic flora within the littoral zone. As water level in a lake rises, aquatic plants on the deeper water margins of a macrophyte bed receive progressively less light, resulting in the loss of plants in this area. A deepening of water on the shallower margins encourages upslope colonisation by the plants. The reverse process may occur on the falling line of a lake hydrograph. This combination of processes can result in the migration of macrophyte beds upslope or downslope in concert with hydrological cycles. Variations in the bed morphology, substrate type or rate of water level change can therefore alter the area of macrophyte habitat available to aquatic biota for forage, spawning or predator avoidance.

4.2 Objectives

To determine how the new FSL and operating regime for Hinze Dam will impact on the availability of littoral zone habitat within the lake.

4.3 Determination of Stratification Patterns and Epilimnetic Depth

Within many Australian lakes, stratification cycles are often quite variable:

- The depth from the water surface to the metalimnion is variable both between seasons and within seasons, with ambient temperatures, basin morphology, wind influences, freshwater inflow and drawdown rate all playing a role;
- The onset of stratification is determined by ambient air temperatures, hence a cool Spring may delay stratification, whilst a warmer Spring period may result in stratification occurring earlier;
- Conversely, a cool Autumn may result in turnover occurring relatively early, whilst a warm Autumn may extend stratification until well into the Winter months; and,
- The sharpness of the temperature/oxygen gradient within the metalimnion is also quite variable within and between seasons, being influenced by the same factors as the depth to the metalimnion.

Figure 4.1 shows the transition from oxic to anoxic conditions for Hinze Dam during summer. It also shows that Autumnal stratification typically occurs at a depth between 6 and 9m from the lake surface, although the eplimnetic DO concentrations begin to decline somewhere between 3 and 6m.

To estimate the area of available habitat, a threshold for DO must be selected. The adoption of a DO concentration of less than 1m (i.e. the depth at which the metalimnion yields to the hypolimnion) is considered inappropriate, as most aquatic species would be placed under considerable stress by such low DO levels and would migrate higher in the water column where DO was more prevalent. Conversely, using the upper margin of the metalimnion for this purpose would likely underestimate the available habitat, since many aquatic species will utilise habitat that is within the upper margins of the metalimnion. The problem is further exacerbated by the coarse sampling intervals, since the inflexion point for DO might occur at any point within the 3m range.

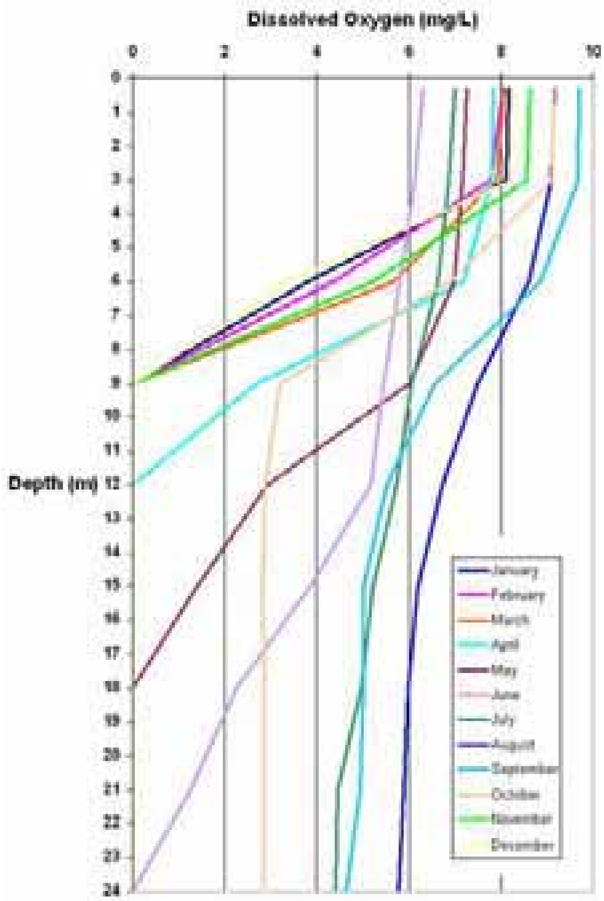


Figure 4.1 Mean monthly vertical DO profiles for Hinze Dam, 1999 - 2007

For the purposes of this assessment, a nominal 5mg/L trigger level for DO has been adopted. Hence the epilimnetic depth has been estimated as the distance from the water surface to the point at which DO falls below 5mg/L. While this figure has been arbitrarily selected, it is likely that most aquatic species could tolerate DO concentrations in this range. To estimate the depth at which the 5mg/L trigger would be obtained in an average year at Hinze Dam, the slope of the profile between the monitoring points immediately above and below the 5mg/L DO concentrations was calculated for each month and the depth at which 5mg/L oxygen trigger would be expected was calculated from the resulting equation. Figure 4.2 shows epilimnetic depth for Hinze Dam in an average year, along with 95% upper and lower confidence intervals.

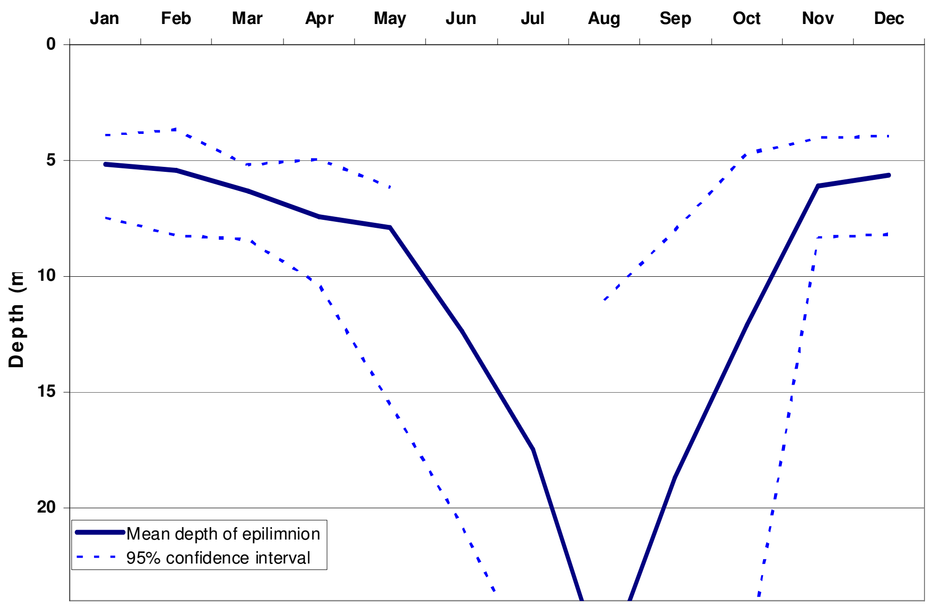


Figure 4.2 Mean depth of epilimnion (1999-2007) based on 5mg/L DO threshold. Broken lines indicate the 95% confidence interval.

It should be noted that on average, August is the only month in which DO concentrations within the storage exceed 5mg/L at depths below 24m. A break in the upper 95% confidence interval occurs for the months of June and July, as highly variable DO concentrations have been recorded in the upper layers of the lake over the past 6-7 years, presumably as a result of destabilisation of thermal stratification, senescence of algal and/or macrophyte populations and a range of other limnological processes. During this period, surface DO concentrations have often been below the arbitrary 5mg/L trigger level, hence the standard deviation of the data is very high.

4.4 Modelling of Useable Habitat Area

During periods in which the lake is not stratified, the area of useable habitat is, in theory, equal to the entire lake bed. If it is assumed that aquatic biota will avoid benthic substrate within zones at which the DO concentrations fall below 5mgL. Calculation of the areal extent of the littoral zone during months of stratification is simply a matter of subtracting the area of substrate over which the DO concentrations are less than 5mg/L from the total area of lake bed at a given water level. It is recognised that since the lake bed slopes, this approach will underestimate the surface area somewhat. However, the approximation is considered adequate in the context of this assessment.

A storage behaviour model has been developed by the Hinze Dam Alliance to investigate the impact on lake volume and surface area of raising the dam wall. This model has been applied retrospectively on a daily timestep to a 110 year data set extending from January 1890 to June 2000.

To assess the combined impacts of lake morphology, increased water level and variable thermal stratification on useable aquatic habitat, this model has been modified:

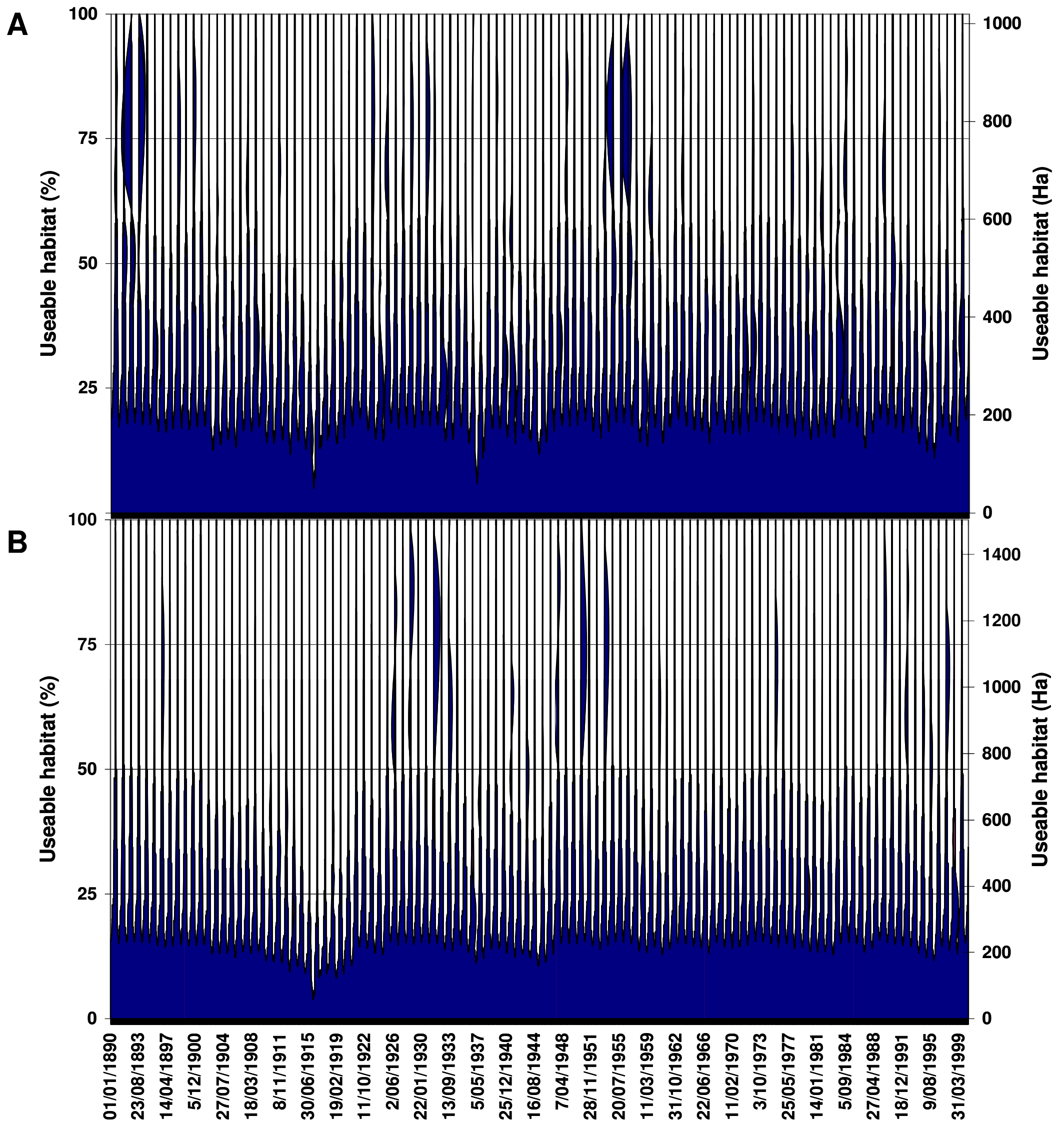


Figure 4.3 Useable habitat as inferred from the epilimnetic depth and expected storage behaviour (1890-2000) in Stage 2 (A) and Stage 3 (B) scenarios.

The surface area of the storage has been assumed to approximate the surface area of substrate:

- For each daily timestep, surface area has been calculated twice: once based on the water level in the dam (mAHD), and the second time based on the level (mAHD) at which the nominal 5mg/L DO trigger would be expected to occur; and
- Based on the data presented in Figure 4.3, the surface area of the littoral substrate has then been calculated by subtracting the area at 5mg/L DO from the total surface area of the storage at the corresponding date.

4.5 Modelled Habitat Area Outcomes

The outcomes of the available habitat modelling process are provided in Figure 4.4.

The annual turnover of the lake is indicated by the 100% availability of habitat, resulting in the annual spikes observed in Figure 4.4. Periods of stratification result in greatly reduced habitat availability (expressed in the Figure as the percentage of habitat at FSL), represented by the more solid area at the bottom of the chart.

4.6 Implications of Stage 3 for Aquatic Habitat

4.6.1 Area of Available Habitat able to Support Aquatic Biota

The relatively steep topography of the land between the existing and proposed FSL, coupled with the nature of the stratification, will have a significant influence on the availability of aquatic habitat following the raising of the Hinze Dam spillway. Thus, despite the volume of water being almost doubled, the increase in habitat area will be more moderate, typically in the vicinity of 25% during most months (Figure 4.1). During months in which the lake is not stratified or the epilimnion extends deeper into the water column (July, August and September in an average year), there will be a significant increase in the area of substrate (and hence habitat) within the oxygenated portion of the water column compared to the current FSL (Figure 4.3 and Figure 4.4).

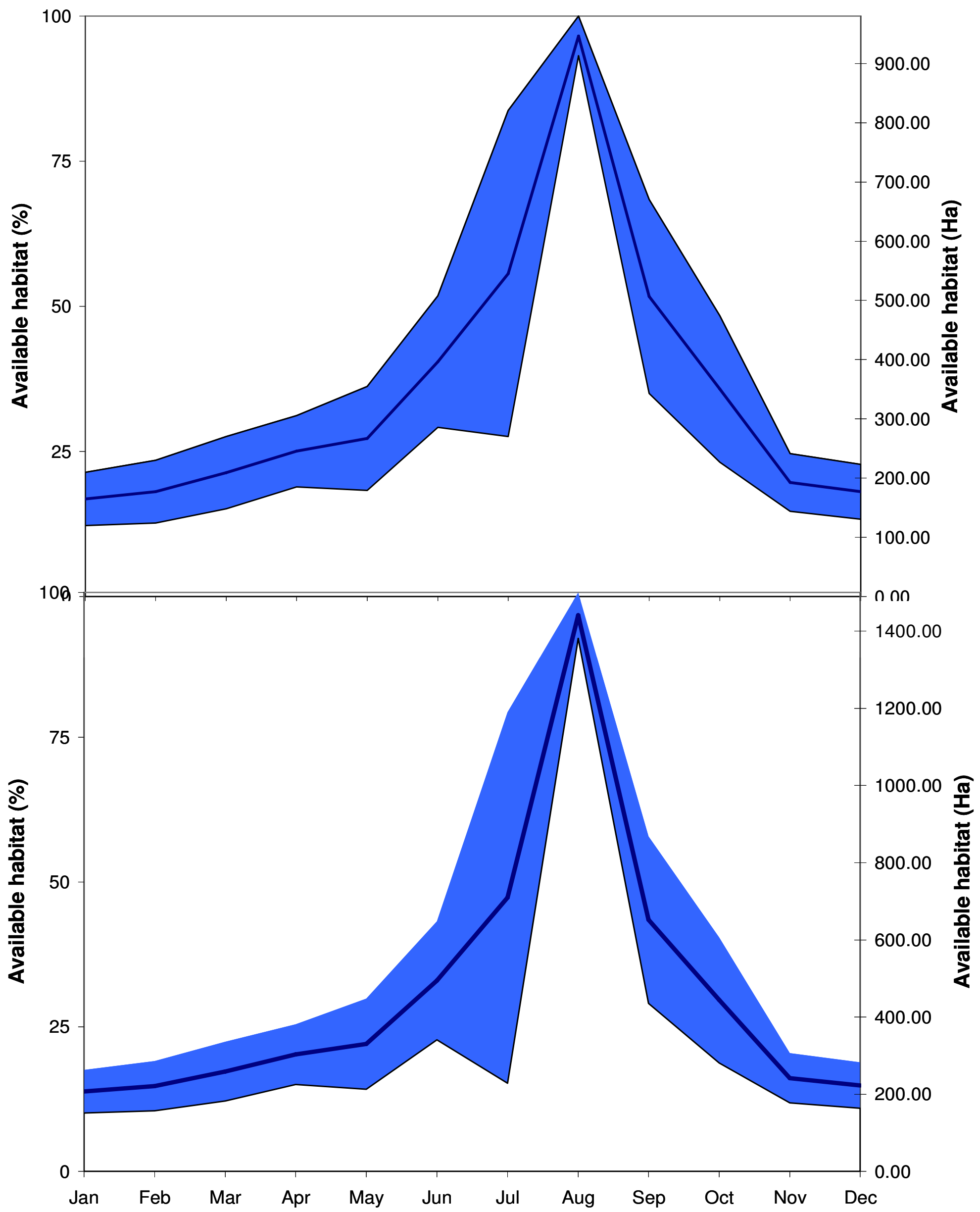


Figure 4.4 Available habitat under stage 2 and 3 scenarios (dark line).
The shaded area indicates the 95% confidence interval based on DO profiles from 1999-2007.

Table 4.1 Proportion of habitat area increase between Stage 2 and Stage 3.

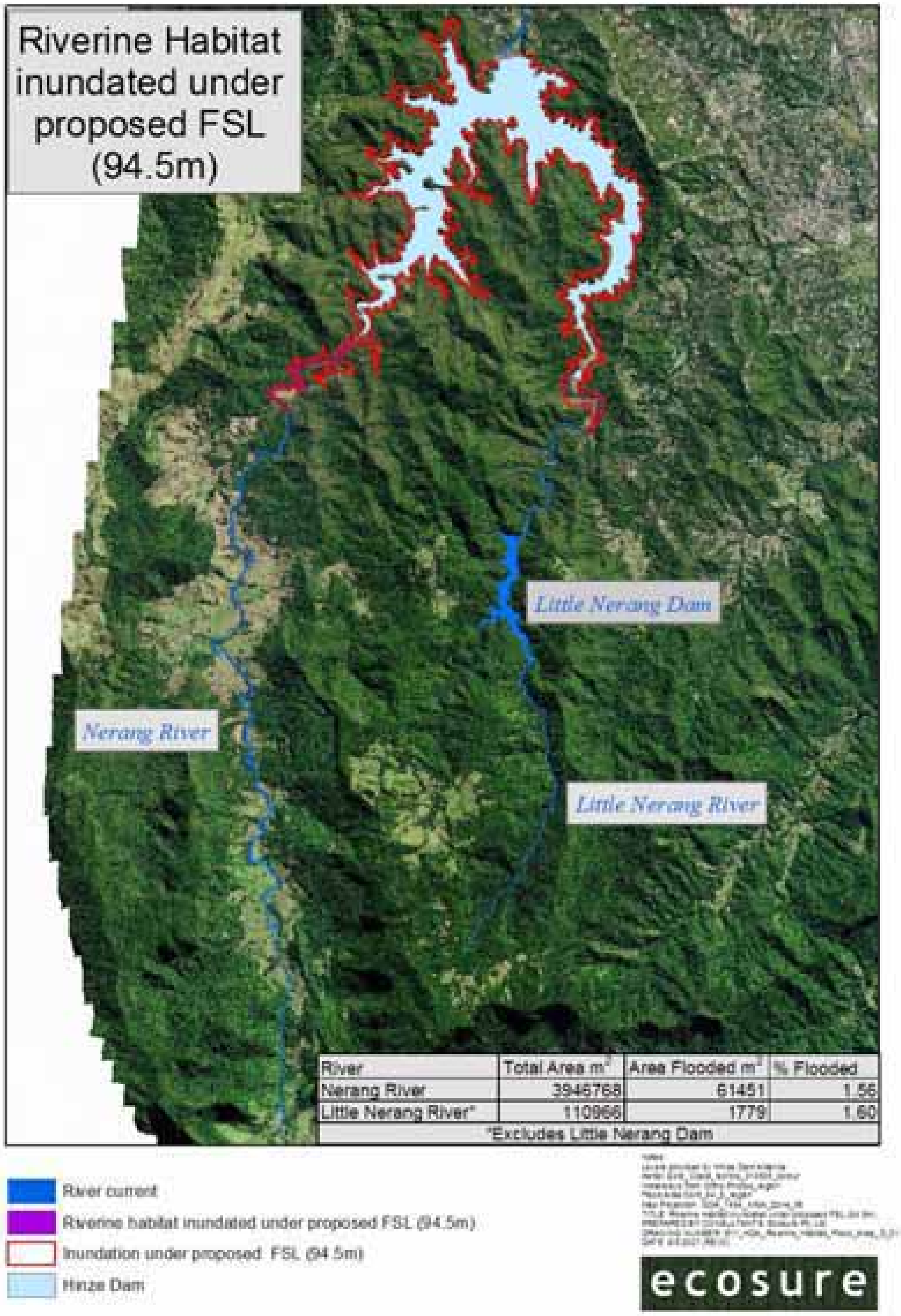
Month	Habitat Area (Ha) Stage 2	Habitat Area (Ha) Stage 3	Increase (%)
Jan	164.98	207.78	26
Feb	177.35	222.07	25
Mar	209.13	259.83	24
Apr	245.39	303.92	24
May	267.14	331.09	24
Jun	396.63	495.86	25
Jul	535.58	697.67	30
Aug	783.35	1186.35	51
Sep	506.76	653.79	29
Oct	350.26	445.18	27
Nov	192.62	242.64	26
Dec	177.02	223.42	26

The carrying capacity of the storage with respect to aquatic fauna is likely to be determined by the area of habitat available during the remaining 9 months of the year. During periods of holomixis (complete mixing of the lake), the carrying capacity for these species may be temporarily increased, although it is likely that many species would still favour the warmer, shallower margins of the lake where the forage is more abundant. It is likely that the raising of the dam will initially result in increased growth rates, condition and/or overall numbers of many species in the shorter term, due to the sudden increased availability of habitat for shelter, forage or spawning. However, this is likely to return to a more sustainable equilibrium in the years after the new spillway is commissioned.

Introduced fish species caught in Hinze Dam during fish surveys included Barred Grunter (*Amniataba percoides*), Mosquitofish (*Gambusia holbrooki*) and Platy (*Xiphophorus maculatus*). The latter two species were also recorded from the Nerang River below Hinze Dam during these surveys. However, only *G.holbrooki* was recorded in the Nerang River upstream of the dam. This is most likely due to the presence of rock bars and protruding bedrock upstream of the dam, presenting a physical barrier to the passage during low flows and a velocity barrier during higher flows (*G. holbrooki* and *X. maculatus* are better adapted to still waters than flowing systems). It is possible that inundation of rock bars immediately above the existing FSL may increase the distribution of these species by enabling their passage beyond the existing barriers. This may put pressure on native species by increasing competition for forage and habitat and through the fin-nipping behaviour of *G. holbrooki*.

4.6.2 Inundation of Lotic Habitat

Raising the spillway level will result in the inundation of 1.5% of lotic (riverine) habitat in the Nerang River and Little Nerang Creek immediately above the current FSL (Figure 4.5).



River	Total Area m^2	Area Flooded m^2	% Flooded
Nerang River	3946768	61451	1.56
Little Nerang River*	110966	1779	1.60
*Excludes Little Nerang Dam			

Figure 4.5 Riverine habitat inundated under proposed FSL

4.6.3 Change in the Nature or Quality of Aquatic Habitat

The majority of fish, macroinvertebrate, aquatic plant and aquatic macrofauna within Hinze Dam reside within the littoral, rather than pelagic, zone. Raising the dam wall will result in current snags, rocky ledges and other habitat falling below the littoral zone, and the inundation of new snags, rocky substrate etc. During sonar surveys of the lake, some patches of woody debris were observed on the sonar screen, but were generally quite sparse and were restricted to areas close to the shoreline and areas towards the points at which both the Nerang River and Little Nerang Creek enter the storage.

The storage behaviour curve (Figure 3.6) indicates that the water level in the dam will remain significantly higher than current levels, once the dam is filled. This will increase the length of shoreline, and potentially therefore the amount of habitat opportunities for aquatic species. Allowing the existing terrestrial vegetation to remain during filling of the storage would further increase the amount of large woody debris available to aquatic species. This would benefit most, if not all, species known to reside in the storage and may either improve the condition and capacity to spawn or in the case of recreational species may permit higher stocking densities without loss of fish size or condition.

However, the increased availability of shelter from predation may also favour the spawning and further proliferation of pest fish species such as *A. percoids, G. holbrooki* and *X. maculatus*.

A further potential impact of allowing stands of vegetation to remain during inundation is the impact on water quality and on the accumulation of heavy metals in biota. Canadian studies have shown that the concentrations of methylated mercury in fish are sufficiently high following the initial filling of new dams that human consumption must be limited (Bodaly et al. 1984; Kainz & Lucotte, 2006; Morrison & Thérien,1995). Heavy metal concentration in recreationally important fish species should be investigated in the Hinze Dam prior to and following HDS3.

Acute water quality issues may also arise when vegetation is inundated, resulting in a significant BOD load, which may result in short-term oxygen depletion.

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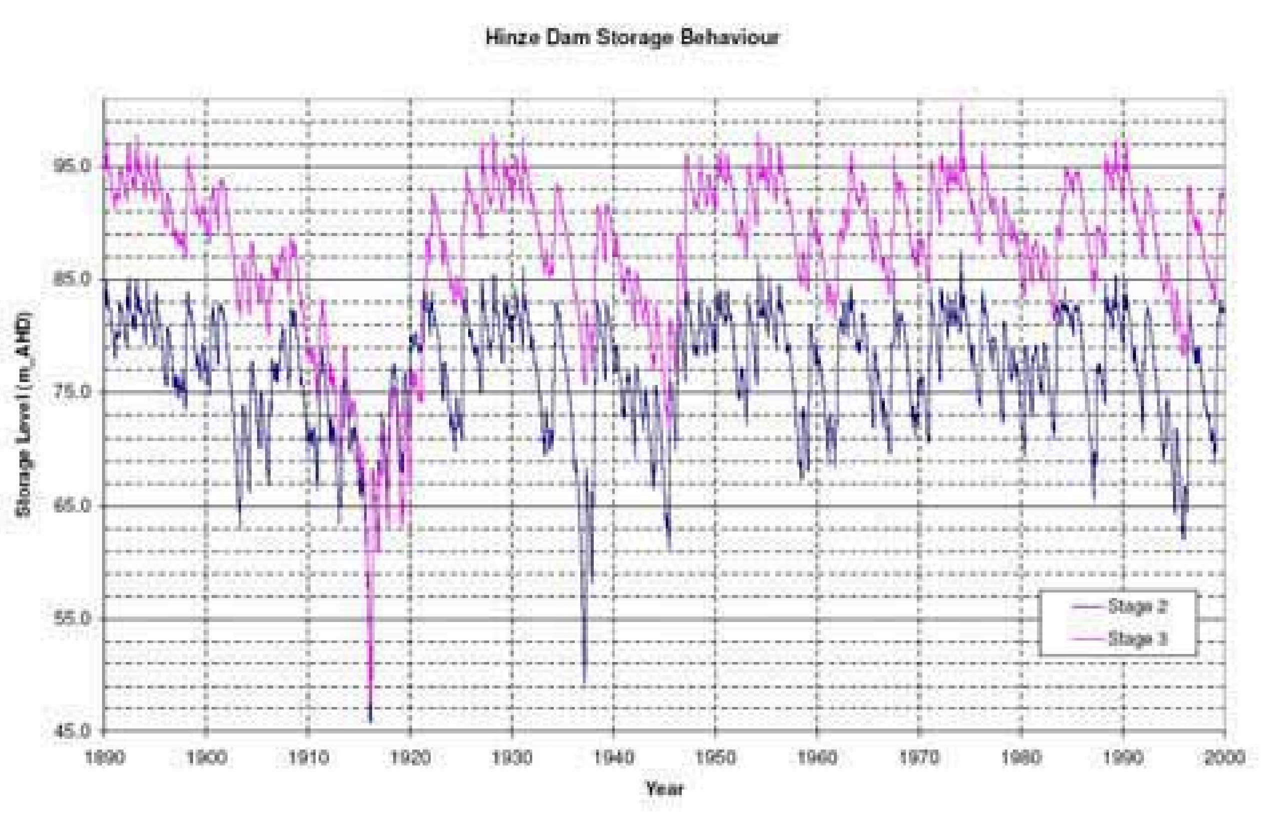

Figure 4.6 Storage behaviour curve for Hinze Dam Stage 2 and 3.
(source Hinze Dam Alliance 2007)

4.6.4 Potential Impacts on Habitat of Stocked Recreational Species

Australian Bass (*Macquaria novemaculeta*)

Australian Bass are stocked into Hinze Dam in larger numbers than any of the other recreational species. Within natural populations, only the females dwell in the freshwater reaches of river, the males tending to reside within the estuaries. The species is catadromous, with Winter floods triggering a migration of female fish to the estuaries to spawn. The proliferation of dams throughout the eastern seaboard is credited with causing a decline in numbers due to a lack of access to upstream habitat and reduced flooding of downstream and estuarine areas. *M. novemaculeta* often reside among snags and aquatic vegetation, but are also known to be pelagic at times, schooling close to the thermocline in lakes and storages. This adaptability probably renders this species less susceptible to the impacts of altered water level in Hinze Dam than species that rely on littoral habitat.

Saratoga (*Schleropages leichardti*)

Saratoga are solitary, surface feeding fish that prefer still, often turbid waters and generally live close to snags. Spawning tends to occur amongst snags in Winter, although it is not clear whether *S. leichardti* spawn within Hinze Dam. Saratoga would benefit from the additional shoreline and an increase in littoral habitat resulting from raising the spillway height. If the population in Hinze Dam is self-sustaining, this may result in an increase in overall biomass. If the population does not spawn in Hinze Dam, the additional habitat and associated increase in food availability may result in faster growth and better-conditioned fish.

Mary River Cod (*Maccullochella peeli mariensis*)

Mary River Cod have a preference for stillwater sites with deeper water and snags, undercuts and overhanging vegetation. They avoid shallow areas and have been shown to strongly favour woody debris over rocky habitat. As the HDS3 Project will increase the area of littoral habitat and potentially increase both the availability of snags and prey items, Mary River Cod populations should be favoured by the completion of Stage 3.

As cod require hollow logs and large woody debris for spawning, there is probably limited opportunity to spawn within Hinze Dam. However, this opportunity might be increased if vegetation that is below the 94.5m AHD level is allowed to remain, and if water levels remain sufficiently high that this material is below water level.

Golden Perch (*Macquaria ambigua*)

Golden Perch are now considered vulnerable in some states with the construction of dams and weirs having prevented upstream migration to spawning grounds and reduced larval survival rates. They will not spawn in dams, although stocked fish may thrive and grow quite large. Golden Perch will utilise both rocky habitat and snags, and tend to be relatively territorial.

The HDS3 Project will increase the area of littoral habitat, which is likely to favour this species, particularly if woody debris is allowed to remain when the dam fills.

Silver Perch (*Bidyanus bidyanus*)

Silver Perch have a preference for faster flowing waters, and reductions in flood passage are thought to be a key contributor to the marked decline in this species. Hinze Dam is probably only marginal habitat for Silver Perch due to the absence of flowing water (except in the upper reaches during floods), relatively sparse snags and absence of significant stands of macrophytes. This species may receive some benefit from the additional littoral habitat and potentially increase in the amount of woody debris present following the construction of Stage 3.

4.7 Potential Habitat Benefits

Additional fish habitat, foraging and spawning areas will be created if existing vegetation is left for inundation. Species likely to utilise this habitat are generally the stocked species *M. peelii mariensis*, *M. novemaculeta*, and *M. ambigua*.

4.8 Potential Impacts and Mitigation Measures

The foreseeable adverse impacts of Stage 3 are:

1 A proportionally higher degree of habitat 'squeeze' within Hinze Dam with the onset of stratification during the Spring months. This currently occurs to a slightly lesser degree on an annual basis and the increase in habitat squeeze under Stage 3 is probably not significant in the context of aquatic ecological health. No mitigation of this effect is required.

2 Replacement of a small area of lotic (riverine) habitat with lentic (stillwater) habitat in the vicinity of where the Nerang River enters the dam. No prevention or mitigation options are available for this impact, but the lost habitat represents only a small proportion of the upstream environment. Surveys and database searches of the upstream reaches have not identified any threatened or vulnerable species or communities that would be impacted by this loss. The possibility of improving fish habitat within the neighbouring Mudgeeraba creek to offset the lost habitat is being considered by the Alliance but required further ecological investigation at the time of reporting.

3 Replacement of a small area of lotic (riverine) habitat with lentic (stillwater) habitat in the vicinity of where the Little Nerang Creek enters the dam. No prevention or mitigation options are available for this impact, but the lost habitat represents only a small proportion of the upstream environment and is already impacted by the Little Nerang Dam a few kilometres upstream. No species of conservation significance have been detected during macroinvertebrate or fish surveys within this reach.

4 Potential to increase the distributional range of pest fish species through inundation of fish passage barriers where the Nerang River enters the dam. This may be mitigated by creating artificial barriers targeted at specific pest species. A feasibility study is required to determine if natural barriers will be inundated by HDS3 that could allow pest species to enter these reaches which may then displace native fish. If important barriers are found to limit the range of pest species then artificial barriers could be used to replace remnant barriers. Surveys after placement would be useful to determine success of barriers.

5 Allowing the vegetation between 82.4 and 94.5m AHD to remain during the commissioning and operational phases of the HDS3 Project may provide improved habitat for forage and spawning by recreationally significant species and smaller native species, but may also favour some of the less desirable species currently present in the dam, such as *A. percoids*, *G. holbrooki* and *X. maculatus*. The only mitigation would be to remove this material, however, as the pest species are already present in high numbers, improving the habitat available for larger species is probably of greater benefit.

6 Allowing the vegetation to remain in the lake may cause water quality concerns such as increased BOD and the lowering of DO. This would be of greatest concern during the months of June, July and August, when DO levels in the lake are often found to be relatively low. That the project is merely a deepening of an existing storage will aid in limiting this impact, as there is existing water mass to buffer the impact. Limiting the rate of water level rise in the first few years during which water levels exceed the current FSL would assist in minimising this impact. However the GCCC needs to provide water supply to the Gold Coast and will fill the dam as quickly as rainfall allows. Water quality will be protected by leaving riparian roots intact and the understorey in place and by implementing a range of sediment and erosion control measures to limit the movement of sediment into the dam;

7 There is some potential for the inundation of terrestrial vegetation to result in the formation of methyl mercury, which may accumulate in fish and other biota. Methyl mercury is formed from inorganic mercury (occurs naturally in soils & sediment) by the action of anaerobic organisms that live in aquatic systems. The only mitigation strategy for this impact would be removal of the vegetation prior to inundation. Again, the existing water body will assist in diluting this impact, and minimising the rate of water level rise will reduce the risk. High mercury levels have previously found in large fish within Hinze Dam (Appendix 4), such as Australian Bass (*Macquaria novemaculeata*). Monitoring of mercury concentrations in the tissue recreational species is recommended, in order to provide community health warning if required.

4.9 Considerations for Stocking with Recreational Fish Species

Hinze Dam is generally considered to be a well managed 'put and take' recreational fishery. Anecdotal evidence suggests that there are sufficient numbers of fish to sustain a recreational fishery, but that the numbers are not as high to impact on the condition or overall size of fish caught. Construction of HDS3 will alter the carrying capacity of the storage, hence some additional factors require consideration if the quality of the fishery is to be maintained:

- Although the volume of the lake will approximately double following construction of HDS3, the available habitat will increase by only 25%. Hence, doubling of the current stocking rates may result in larger numbers of smaller or poorly conditioned fish. If increased stocking rates are contemplated, it is suggested that the increase be capped at 25% higher than the current rates, unless further studies indicate that the quality of habitat is improved and that the storage can sustain a higher stocking rate.
- If increased stocking rates are contemplated, it is suggested that the number of fish released is gradually increased over a number of years, and that no increase in stocking rates occur until the storage is at or near current FSL and expected to rise further.
- Further monitoring of recreational fish populations should be performed following commissioning, to determine whether inundated woody debris is resulting in an increase in the carrying capacity of the storage.

4.10 Summary

Data provided by GCW was used to enable determination of stratification scenarios and to establish how changes to Hinze Dam will affect the availability of habitat within the lake. It was found that during periods in which the lake is not stratified, the area of useable habitat is theoretically equal to the entire lake bed. It is assumed that aquatic biota will avoid benthic substrate within zones at which the DO concentrations fall below 5mgL. However, although the volume of the lake will approximately double following construction of HDS3, the available habitat will increase by only 25%. Hence, simply doubling of the current stocking rates may result in larger numbers of smaller or poorly conditioned fish. If increased stocking rates are contemplated, it is suggested that the increase be capped at 25% higher than the current rates, unless further studies indicate that the quality of habitat is improved and that the storage can sustain a higher stocking rate. A profitable stocking rate could be reassessed if it is determined that the carrying capacity of the dam has been increased through scientific research. Any increases to stocking rates should be gradual and be dependant on water level. The stocking rate could be reassessed if it is determined that the carrying capacity of the dam has been increased.

The HDS3 project has the potential to increase the range of pest fish species through inundation of existing fish passage barriers in upper reaches of the Nerang River and Little Nerang Creek. We recommend a feasibility study for creating artificial barriers to limit pest species.

Reduced water quality from inundated vegetation can have deleterious effects on aerobic organisms, especially fish. Limiting the rate of water level increase over the first few years can alleviate this.

High mercury concentrations have been found in large fish within Hinze Dam. Other studies have found that increasing water levels due to damming have caused higher methyl mercury in fish. Monitoring methyl mercury concentrations of recreationally significant fish species is recommended annually prior to and following HDS3 completion. This program should be carried out until bioaccumulation can be ruled out.

5 Sediment and Substrate

Sediments are important sinks for potential contaminants that can ultimately end up in the water column and have effects on aquatic organisms. Sediment and substrate within the Nerang Catchment is therefore addressed in the Aquatic Ecology component of the EIS as per the Terms of Reference. This section describes the sediment characteristics of both submerged sediment in the lake as well as sediment between the current and proposed FSL.

5.1 Above Hinze Dam Nerang River and Little Nerang Creek

5.1.1 Description of Sediment and Substrate in Upper Catchment

With the exception of the site on the Little Nerang Creek between the Hinze and Little Nerang Dams, all upstream sites are comprised largely of a combination of bedrock, boulder, cobble and pebble, with generally low levels of embeddedness. Riparian zones in the upper catchment are generally in good condition, and low-intensity agricultural landuse is thought to make a minimal contribution to upstream sediment loads. Minor silt and/or sand substrates may exist in some deeper pools, however the steep gradient and flood prone nature of the upper catchment are likely to result in frequent flushing of this material into the impoundment. In the case of the Little Nerang Creek, this material can be expected to be trapped by the Little Nerang Dam. The regulation of this system may have resulted in some potential accumulation of sediment in deeper pools between the Little Nerang and Hinze Dams.

5.1.2 Potential Impacts of Hinze Dam Stage 3

Increasing the height of the dam wall will result in the conversion of a small length of lentic habitat into lacustrine habitat, and ‘backing up’ of water in the Nerang River immediately above the FSL. The same impact will be experienced in the Little Nerang system, but will have less impact as the system is currently regulated and hence altered from its natural condition. No additional impacts on upstream geomorphology have been identified.

5.1.3 Potential Benefits of Hinze Dam Stage 3

No benefits to upstream geomorphology have been identified.

5.1.4 Suggested Mitigation of Impacts

No mitigation is possible.

5.2 Within Hinze Dam

5.2.1 Description of Sediment and Substrate within the Dam

The substrate within the dam is comprised of both soft sediments (silt/sand) and hard substrate (rock or highly compacted sediment). A map showing the distribution of these two substrate types is provided in Figure 5.1.

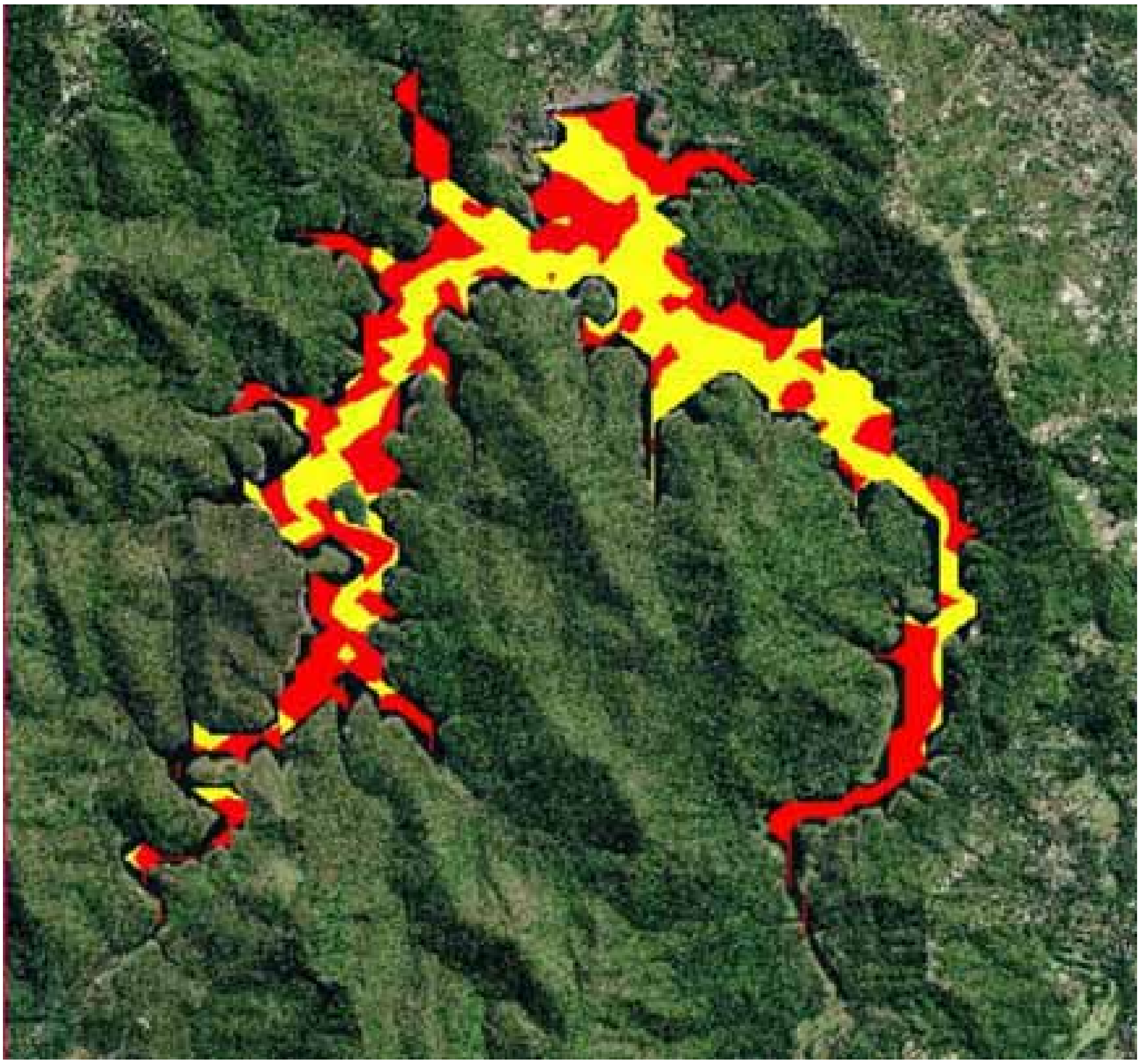

Figure 5.1 Sediment characteristics within the Hinze Dam. Note red indicates soft and yellow indicates hard substrate. (Aerial photograph provided by the Hinze Dam Alliance)

Sediments collected from below the current water level were finely divided and were dark brown to black in colour. Water quality data were not collected at the time that sediments were taken, but sonar data indicated the presence of a thermocline at approximately 9.5m depth. Despite this observation, material collected at all five sites using the grab apparatus were notably free of the hydrogen sulphide odours typical of anoxic sediments.

Table 5.1 provides the chemical data for submerged sediment samples. All sediment samples from below the water level were unconsolidated and contained relatively high moisture content (71.4 – 83.2%). It is likely that this reflects the deposition of allochthonous material as a result of sedimentation within the lake. This would have been contributed to by the decomposition of vegetation inundated when the dam was first created, as well as the downslope migration of material brought into the lake via the Nerang River, in particular the Nerang Catchment (much of the material contributed by the Little Nerang system would be expected to have been trapped by the Little Nerang Dam). Dams constitute obstacles for longitudinal exchange along fluvial systems and so result in "discontinuities" in the river continuum (Ward & Stanford 1995). Sediment is a sink for nutrients and the impoundment impedes sediment and associated nutrient transport downstream. It is expected that sediment within Hinze Dam will exhibit a cumulative increase in both nutrient and metal concentrations irrespective of the HDS3 Project.

Table 5.1 Submerged sediment chemistry by site as determined by laboratory analyses.

Analyte	Units	Site				
		Boat Ramp 3	Des's Den	Rowing Buoys	Ragsies Reach	Nerang Arm
Moisture	% w/w	71.4	83.0	80.6	83.2	74.0
Loss on Ignition	% DMB	15	14	13	18	13
Total Nitrogen	mg/kg DMB	420	460	380	580	320
Total Phosphorous	mg/kg DMB	702	1150	824	823	1500
Aluminium	mg/kg DMB	36100	54500	63500	33500	71900
Arsenic	mg/kg DMB	5	6	6	5	6
Cadmium	mg/kg DMB	<1	<1	<1	<1	<1
Cobalt	mg/kg DMB	22	22	27	17	31
Chromium	mg/kg DMB	67	34	36	26	39
Copper	mg/kg DMB	18	18	21	17	22
Manganese	mg/kg DMB	777	1040	824	823	1500
Nickel	mg/kg DMB	29	21	25	14	29
Lead	mg/kg DMB	14	14	16	14	17
Zinc	mg/kg DMB	65	78	91	62	110

5.2.2 Description of Sediment and Substrate Between Current and Proposed FSL

Soil removed from between the current FSL and proposed new FSL was very dry (<29% moisture), hard and lighter in colour. Despite these samples being collected from within areas of largely grassy vegetation, they appeared to contain a lower proportion of organic material than submerged sediments. Evidence of erosion of unvegetated drainage lines along steeper areas of shoreline may indicate that these soils are prone to dispersion. Chemical data for soils collected from between the current and proposed FSL is presented in Table 5.2.

Table 5.2 Sediment chemistry of soil between the current and proposed FSL by site as determined by laboratory analyses.

Analyte	Units	Site				
		Boat Ramp 3	**Des's Des**	**Rowing Buoys**	**Ragsies Reach**	**Little Nerang Arm**
Moisture	% w/w	9.2	28.5	2.5	19.3	19
Loss on Ignition	% DMB	12.4	17.5	2.6	8.8	9.6
Total Nitrogen	mg/kg DMB	3570	4020	500	2370	2550
Total Phosphorous	mg/kg DMB	1030	636	51	363	247
Aluminium	mg/kg DMB	19700	21900	4000	9450	11800
Arsenic	mg/kg DMB	<5	<5	<5	<5	<5
Cadmium	mg/kg DMB	<1	<1	<1	<1	<1
Cobalt	mg/kg DMB	385	236	3	5	4
Chromium	mg/kg DMB	63	19	<2	6	3
Copper	mg/kg DMB	31	31	<5	8	11
Iron	mg/kg DMB	49900	52800	13100	10800	12900
Manganese	mg/kg DMB	1450	762	42	668	436
Nickel	mg/kg DMB	56	18	<2	4	4
Lead	mg/kg DMB	14	7	8	10	17
Zinc	mg/kg DMB	295	18	<5	24	30

Bank sediment at sites within the Nerang River Arm (Boat Ramp 3 and Des's Den) generally had higher results of various analytes than submerged sediment. This may be a result of previous land uses along the Nerang catchment that have caused increased levels of analytes compared to the arm of Little Nerang Creek. Nitrogen concentration of bank sediments was generally higher than submerged sediments. This will most likely provide a potential nitrogen source to the Hinze Dam upon inundation. As a result, there may be impacts on primary productivity, in particular, phytoplankton communities within the impoundment. Excessive nutrient inputs may also lead to eutrophication and increase the risk of undesirable algal blooms.

Cobalt levels were quite high in the bank sediments (3 – 385 mg/kg) compared to the submerged sediments (17 – 31 mg/kg). Toxic effects on plants are likely to occur above soil concentrations of 40 mg/kg (Frank et al. 1976). However, plant species vary in their sensitivity to cobalt, as soil type and soil chemistry greatly influence cobalt toxicity, in particular, soil acidity. The more acidic the soil, the greater the potential for cobalt toxicity, at any concentration irrespective of the HDS3 Project.

Both the submerged and bank sediments contained high aluminium concentrations. This was is consistent with Geology Surveys (Claridge 2007), who found high concentrations of exchangeable aluminium which appeared to be naturally occurring. At low pH values, the amount of soluble and exchangeable aluminium increases so that its concentration can become toxic to plants and soil organisms. Because of its toxicity, exchangeable aluminium can have a strong limiting influence on plant growth. If the pH value drops under 5.5 (Ahern et al. 1998), exchangeable Al makes up almost the total of a soil's exchangeable acidity. Both measurements become therefore synonymous (Sparks 1995). Exchangeable aluminium does not vary much under natural conditions. Abrupt changes may however be found after land use changes (e.g. deforestation, liming).

5.2.3 Potential Impacts of Hinze Dam Stage 3

Reservoirs reduce flow velocity and so enhance sedimentation. The rate at which sedimentation occurs within a reservoir depends on the physiographic features and landuse practices in the catchment, as well as the way the dam is operated (McCartney & Sally 2002). Large magnitude and frequent fluctuation in water levels within reservoirs can cause bank erosion and add to deposition. It is estimated that between 0.5 – 1.0% of the storage volume of the world's reservoirs is lost annually due to sediment deposition (Mahmood 1987).

The project to raise the Hinze Dam storage level has the potential to alter the proportions of sand, silt and rock within the littoral zone by:

- Inundating new substrate that may be substantially different to the substrate currently within the littoral zone; and,
- Inundating vegetation, the decay of which may increase the organic content of the sediments.

The change in proportion of soft and hard substrate may in turn influence the nature and availability of aquatic habitat for macroinvertebrates, macrofauna, aquatic flora and fish.

As sediment analyses found high levels of nitrogen, aluminium and cobalt, inundation of the new substrate may introduce nutrients into the dam thereby causing a likely increase in present concentrations. This may have flow on effects to aquatic biota.

5.2.4 Potential Benefits of Hinze Dam Stage 3

The project will have no identifiable benefits to the substrate of Hinze Dam unless there is a higher proportion of rock after raising the water level. Rock, in contrast to unconsolidated soil, aids in bank stability and is more resistant to erosion.

5.2.5 Suggested Mitigation of Impacts

The removal of a proportion of the trees and other vegetation prior to the dam filling would reduce the amount of organic material entering the sediments following commissioning. However, this process would be expensive and the use of heavy machinery would itself result in alteration of the proportions of hard and soft substrate and sediment transport processes as a result of the disturbance of soils and is therefore not recommended.

Reservoir flushing (i.e. the selective release of highly turbid waters) is a technique that has been used to reduce in-reservoir sedimentation. Sediment flushing in the Hengshan reservoir in China, for a few weeks every 2-3 years enables the long-term capacity of the reservoir to be maintained at 75% of the original capacity (Atkinson 1996). Reservoir operations may periodically result in unnaturally high concentrations of sediment in downstream systems. This option should be further investigated.

Frequent measurements of exchangeable aluminium, colbalt and pH may be conducted to monitor its effect on soil properties following landuse changes. There is limited mitigation to these increases apart from best practice in sediment and erosion control.

5.2.6 Likely Impacts after Mitigation

Whilst removal of vegetation would reduce the proportion of organic material in the newly inundated substrate, the compaction, disturbance and increased erosion potential of soil within the newly inundated area would offset any benefits. It is a natural process for the organic component of lake sediments to increase as the lake ages, and this would be expected to occur even if vegetation was removed, largely due to catchment inputs.

5.3 Below Hinze Dam – Nerang River

5.3.1 Description of Sediment/Substrate in Lower Reaches

Throughout this reach, the substrate was found to consist mainly of cobble and pebble, with occasional patches of boulder or bedrock. There was dense coverage of aquatic macrophytes, dominated by noxious aquatic weeds. In some places this growth, along with the minimal environmental flow, had trapped some silt and sediment. There were occasional deeper holes, particularly toward the lower reaches, in which the substrate was not visible but is likely to contain at least some silty material by virtue of slower flow velocities, excessive aquatic plant growth and agricultural/semi-residential landuse patterns.

As silty and/or sandy sediments constituted only a small proportion of the substrate within this reach, no samples were taken for laboratory analysis.

5.3.2 Potential Impacts of Hinze Dam Stage 3

Dam projects typically have a profound effect on downstream environments for a number of reasons:

- Reduced flows can result in the deposition of sediments, as the lower energy hydrological regime is insufficient to keep particles in suspension;
- Reduction in sediment load in rivers can result in increased erosion of riverbanks and beds, loss of floodplains and degradation of coastal deltas;
- Removal of fine material may leave coarser sediments that protect the riverbed from scour. In some circumstances, material entrained from tributaries cannot be moved through a channel system by regulated flows, resulting in aggradation (McCartney & Sally 2002);
- Reduced flows can encourage the proliferation of aquatic vegetation that can choke a stream, resulting in dams, flow redirections, backing up and eddying that can cause erosion events when a higher flow event subsequently occurs. This is more likely if the system is rich in nutrients, and was observed along much of the reach between the dam wall and Weedons Crossing;

- Dense macrophyte growth can result in sediments becoming trapped, reducing the capacity of the river channel to handle higher flows;
- The water storage retains shifting bedload, hence cobble, pebble and gravel substrates below the dam wall are no longer replenished, resulting in scouring, armouring and other downstream geomorphological impacts; and,
- A reduction in the frequency of floods (particularly 'bank full' floods), which reduces natural channel forming processes and results in the deposition of sediment at particular points throughout the river system.

In the case of the HDS3 Project, excessive macrophyte growth and reduced flooding (compared to the un-regulated scenario) in the downstream environment is a current reality. However, other symptoms are less prominent than at upstream freshwater sites:

- Good water quality from the dam and often quite dense riparian zone (albeit largely comprised of exotic weeds) and stable stream banks aid in reducing sediment loads to the river, although these loads could be expected to increase progressively with passage downstream;
- The minimum environmental flow is probably not of sufficient magnitude to cause the transport of bedload, although the periodic passage of larger floods probably does. The lack of replenishment of bedload is therefore less problematic than might be the case at other dam sites; and
- The hydropower station does not operate as a hydropeaking facility, hence the rapid rises or falls in water level occur only during periods of heavy rainfall, minimising the opportunity for bank slumping.

The lower Nerang River is currently regulated by Hinze Dam and the downstream flow regimes will vary little during the construction or operation of the HDS3 Project. However, further reductions in the number and intensity of floods passing through the system will further be expected to fuel the already prolific growth of pest aquatic macrophytes, which in turn may create geomorphic challenges such as trapping of sediment, flow diversion resulting in bank erosion or backing up of water resulting in reduced sediment carrying capacity.

5.3.3 Potential Benefits of Hinze Dam Stage 3

Reduced flooding downstream of the dam wall will reduce the movement of bedload that cannot be replenished due to retention of this material within the storage.

5.3.4 Suggested Mitigation of Impacts

The most satisfactory mitigation would be to facilitate more natural environmental flow patterns downstream of the dam wall, introducing some variability to the flows and providing 'bank full' floods to facilitate channel forming processes and reduce choking of the river by macrophytes.

However, it is understood that there is little scope in the short term to alter the current environmental flows releases. An alternative strategy that would to some extent mitigate the loss of flow variability and flood passage would be to directly manage weeds in the downstream environment. Particular attention should be placed on the management of Cumbungi, Water Hyacinth and Salvinia, all of which have substantially blocked the river at numerous points.

The sediment flushing technique to alleviate sedimentation of the reservoir would also benefit the downstream reach by introducing "new" sediments to the system. Gravel has been added to the Rhine River, since 1977 downstream of dams, to reduce erosion and maintain channel morphology (Dister et al. 1990).

5.3.5 Likely Impacts after Mitigation

Whilst management of invasive aquatic weeds would not in itself restore channel forming processes to the lower Nerang River, it would reduce the potential for damming of the river by macrophytes and minimise the potential for bank erosion due to flow diversion. Fish passage, mosquito control and water quality could also be expected to be improved by this approach, although it would require ongoing commitment to management.

5.4 Summary

Sonar was used to estimate the proportion of rocky and silty sediments within the system, particularly within the littoral zone during periods of stratification. Soft sediments within the impoundment were collected at five sites within the water storage using an Eckman Grab sampler. To enable an assessment of the extent to which the sediments within the littoral zone will be altered by increased water level, a further five soil samples were collected from between the existing FSL and the proposed new. All sediment samples were subject to a suite of chemical analysis. In addition, a longitudinal survey of the river below the dam wall was performed via traversing the entire reach by kayak.

With the exception of riverine habitat that will undergo conversion to lake habitat, the additional impacts of the HDS3 Project on upstream geomorphology are expected to be negligible. The rate of sediment and/or bedload transport into Hinze Dam will not be altered. However nutrient and heavy metal constituents in the sediment between the current and proposed FLS has the potential to impact on aquatic biota and further monitoring is recommended.

Several impacts on aquatic biology in the Nerang River below the Hinze dam have been identified and could be ameliorated by altering the current environmental flow allocation. Although this may not be within the scope of the HDS3 Project, this study highlights the need for alteration of the current environmental flow regime to the Nerang River, below Hinze Dam and its estuary.

6 Aquatic Vegetation

Aquatic macrophytes, or vegetation which is visible to the naked eye, are made up of emergent, floating and submerged plants. Macrophytes play an integral role in an aquatic ecosystem. They act as physical filters, nutrient sinks, sediment stabilising agents, habitat and food (for aquatic fauna). Aquatic macrophytes are also important for carbon dioxide (CO2) fixation, dissolved oxygen (DO) and nutrient cycling (Vadstrup et al. 1995; Desmet et al. 2006; Caraco & Cole 2002).

The purpose of this component is to provide information on the existing aquatic flora of the Nerang River that may be impacted by the HDS3 Project. Within this section the potential impacts resulting from the construction and operation of the water storage are determined and assessed. Management measures are also recommended to mitigate these impacts and to enhance the existing environmental values.

Nineteen species of aquatic macrophytes were recorded during field surveys including seven introduced species (Table 6.1). No species of conservation significance was located.

Table 6.1 Aquatic vegetation collected at study sites

		Reach			
Common Name	**Species**	**Lower freshwater**	**Upper Freshwater**	**Hinze Dam**	**Status**
Floating Azolla	*Azolla* spp.	X	X		Native
Water Hyacinth	*Eichhornia crassipes*	X			Introduced
Duckweed	*Lemna* spp.	X			Native
Salvinia	*Salvinia molesta*	X			Introduced
Cape Waterlily	*Nymphaea caerulea*	X			Introduced
Water Snowflake	*Nimphoides indica*				Native
Hornwort	*Ceratophyllum demersum*	X			Native
Parrots Feather	*Myriophyllum aquaticum*	X			Introduced
Water Thyme	*Hydrilla verticillata*	X	X		Native
Common Reed	*Phragmites australis*	X		X	Native
Slender Knotweed	*Persicaria decipiens*	X			Native
Curly Pondweed	*Potamogeton crispus*	X			Native
Waterwort	*Elatine gratioloides*	X			Native
Ribbonweed	*Vallisneria* c.f. *nana*	X	X		Native
Cladophora	*Cladophora* spp.	X	X	#	Native
Apiaceae	*Hydrocotyle ranunculoides*	X			Introduced
Clubrush	*Isolepis c.f. fluitans*		X		Native
Cumbungi	*Typha latifolia*	X	X		Introduced
Fanwort	*Cabomba caroliniana*	X			Introduced

= assumed present but not confirmed

6.1 Aquatic Vegetation above Hinze Dam – Nerang River and Little Nerang Creek

The freshwater reaches above Hinze Dam were generally shallow (<0.5m) comprised of bedrock substrate with sand in silt in the deeper holes. Terrestrial vegetation was frequently observed overhanging the channel and providing shaded conditions (Figure 6.1 Example of aquatic macrophyte habitat within the freshwater reaches upstream of the Hinze Dam). Small sections of this reach had reeds or rushes along the bank margins. Apart from this, aquatic vegetation was relatively sparse and dominated by *Azolla* and *Cladophora*, *Isolepis* c.f. *fluitans* and *Vallisneria* c.f. *nana* (Table 6.1). A complete species list of reeds and rushes could not be prepared due to time constraints.

Figure 6.1 Example of aquatic macrophyte habitat within the freshwater reaches upstream of the Hinze Dam.

6.1.1 Potential Impacts of HDS3

The proposed maximum FSL (94.5m AHD) will inevitably cause inundation and alteration of riverine habitat immediately above the dam thus creating lacustrine habitat. This will most likely cause a shift from lotic communities to lentic communities (McCartney & Sally 2002). The creation of new aquatic habitat may lead to the proliferation of weeds, as introduced species are often the first to colonize an area after disturbance.

6.1.2 Potential Benefits of Hinze Dam Stage 3

HDS3 may create a more stable water level in the freshwater reaches that will be inundated when the maximum FSL is operational. This may benefit vegetation that prefers slow flowing habitats thereby creating aquatic macrophyte habitat. This effect will be dependant on factors such as the rate of draw down and substrate type.

6.1.3 Suggested Mitigation of Impact

Staggering the rate of inundation will allow for a gradual transition between the lotic and lentic habitat and will therefore provide conditions that vegetation can adapt too. This may occur naturally unless the dam is filled by large natural flood event.

The loss of lotic habitat cannot be mitigated against, but as it represents only 1.5% of the available upstream freshwater habitat, it is not deemed to be a significant loss.

It is important that potentially aggressive weeds, such as *Salvina sp*. and Water Hyacinth which are listed as declared pest plants pursuant to the *Land Protection (Pest and Stock Route Management) Act 2002*, are identified and controlled in as timely a manner as possible. Regular monitoring of the upper arms of Nerang River and Little Nerang Creek for aquatic weeds once the dam is operational is recommended. If weeds do establish in the upper reaches of Hinze Dam it is suggested that a weed management plan be developed and mitigation measures employed.

6.2 Aquatic Vegetation within Hinze Dam

There was found to be sparse littoral vegetation within the dam. The only vegetation found were lone stands of Phragmites *sp*. The lack of aquatic vegetation within Hinze Dam is possibly due to:

- The variability of water level inhibiting the proliferation of littoral communities;
- Steep lake bed morphology; and
- Moderate turbidity (Pers. Obs.) and therefore limited euphotic zone.

6.2.1 Potential Impacts of Hinze Dam Stage 3

Existing riparian vegetation will be lost due to drowning and the establishment of sustainable new vegetation communities along the pondage margins may well be precluded by variable water levels and the bank gradient. However, riparian vegetation within Hinze Dam is currently sparse which may well be a result of present fluctuations to water level, or may be due to other factors outside the scope of this study.

6.2.2 Potential Benefits of Hinze Dam Stage 3

More stable water level due to a water extraction yield similar to that which is current. As a result it is expected there will be less fluctuation in water height across the greater volume of water. As a result more permanent habitat will be created where reeds may be able to become established along any gentle sloping banks.

6.2.3 Suggested Mitigation of impacts

No mitigation is required although avoiding sudden fluctuations of water level through water level management within the storage would provide conditions where aquatic vegetation can become established.

Avoiding sudden fluctuations of water level through water level management within the storage will provide conditions were aquatic vegetation can become established.

6.3 Aquatic Vegetation Below Hinze Dam – Nerang River

Table 6.1 lists the aquatic vegetation that was found downstream of the Hinze Dam to Weedons Crossing in Nerang. This downstream freshwater reach was largely dominated by introduced species. There has been substantial encroachment of riparian and aquatic vegetation, including invasive alien species as well as oppurtunistic native species, effectively reducing channel size (Figure 6.2). The floating macrophytes, Water Hyacinth (*E. crassipes*) and *Salvinia molesta* were the most abundant along with thick stands of Cumbungi (*Typha latifolia*). Weed infestations were prevalent along most of this reach indicating problems with eutrophication. The section of the river that flows through the Grand Golf Course had noticeably less weeds as herbicides are used. The terrestrial, Singapore Daisy (*Sphagneticola trilobata*), which is listed as a Class 3 pest plant under the *Land Protection (Pest and Stock Route Management) Act 2002*, was also encroaching upon the river from the bank of many areas within this reach.

6.3.1 Potential Impacts of Hinze Dam Stage 3

The frequency, duration and magnitude of high flows will be significantly reduced in these downstream reaches. These flushing flows are often important in clearing the downstream reaches of accumulated sediment and introduced aquatic species. They often serve to "reset" the system. Flushing flows would also aid in the physical removal of floating weed species.

With reduced frequency of flushing flows, mangroves in upper estuarine reaches may migrate further upstream. Greater salinities, tidal influence and deposition of fine silty banks may lead to the expansion of mangroves in downstream reaches. However, the base flow of 7ML/day from the dam will be maintained following the HDS3, thus the influence of flow is questionable.

Figure 6.2 Example of aquatic macrophyte habitat within the freshwater reaches of the Nerang River downstream of the Hinze Dam. Note dense weed infestations and reduced channel width.

As a result of reduced flood peaks, an increase of biogenic sediment due to macrophyte growth and senescence cycles is likely. This increased sediment will provide further nutrients and rooting substrate for macrophytes, thus providing optimal conditions for macrophyte growth. However, this is not considered a benefit, as exotic species are most likely to be favoured.

The spatial and temporal heterogeneity of river systems is responsible for a diverse array of dynamic aquatic habitats and hence biological diversity, all of which are maintained by the constantly changing flow regime (McCartney & Sally 2002). The HDS3 may lead to reduced habitat complexity as a result of a reduction in the frequency of natural flood disturbance processes. Such processes contribute to natural habitat patchiness, without which homogenous habitat may be created, thereby favouring certain species over others.

In the Brisbane River, releases from Wivenhoe Dam led to increased growth of emergent macrophytes and semi-aquatic grasses along the water's edge Brizga (2006). This may be a likely scenario in the lower Nerang River, which is likely to favour alien fish species such as Mosquitofish (*Gambusia holbrooki*) and Platy (*Xiphophorus maculatus*).

Without intercession, choking and constriction of the Nerang River channel will continue as exotic macrophytes continue to proliferate. This may lead to continued displacement and exclusion of native macrophytes.

6.3.2 Potential Benefits of Hinze Dam Stage 3

No potential benefits are identified.

6.3.3 Suggested Mitigation of Impacts

A greater water storage capacity with the HDS3 provides the opportunity for a greater environmental flow allocation to the Nerang River below the Hinze Dam. These reaches currently receive a base flow of 7 ML/day, which remains consistent until water level in the dam reaches the current FSL (82.2m AHD) at which point overflow occurs. It is recommended that environmental flows mimic the natural seasonality of rainfall. Further research is required to determine the optimum environmental flow for the Nerang River and its estuary.

Active management of exotic weeds is recommended for the section of the Nerang River below Hinze Dam to Weedons Crossing. It is recommended that a weed management plan be developed and mitigation measures employed.

6.3.4 Likely Impacts after Mitigation

Increasing and/or altering the current environmental flow regime could have many benefits for the Nerang River below Hinze Dam. While it is not within the scope of this report to cover this scenario in detail, some benefits to aquatic vegetation include:

- Greater flushing capacity which will aid in physically removing exotic weeds;
- Increased flushing flows which would aid in channel forming processes, thus creating greater habitat complexity;
- Increased environmental flows remove the fine sediments and associated nutrients from the river that can promote weed growth;
- Natural flow regimes promote native vegetation species that are adapted to seasonal variability of flow; and ,
- An increase in the overall health of the waterway.

Weed management will lead to a reduction of introduced species and will provide additional habitat for native aquatic species to establish.

6.4 Summary

Aquatic vegetation surveys of sites within the Hinze Dam catchment were carried out. A total of 19 aquatic macrophytes, comprising 12 native and seven introduced species were found at sites with the Nerang River catchment. The freshwater reaches above Hinze Dam had generally sparse vegetation consisting of species adapted to fast flowing conditions. Hinze Dam had very little aquatic vegetation whereas the Nerang River below the dam wall was dominated by densely growing exotic weed species.

Potential impacts of the HDS3 expansion on aquatic vegetation include:

- Inundation and alteration of riverine habitat in freshwater sections above the dam, thus causing a shift from lotic communities to lentic vegetation communities and favouring weed species;
- Loss of existing riparian vegetation and limitations on potential new riparian habitat caused by elevated water levels; and
- Reduced frequency of flushing flows (flooding) in the Nerang River below Hinze Dam, thereby having effects on exotic species, mangroves, sediments, nutrients and habitat complexity.

Weed management is recommended for the upper arms of Hinze Dam if weeds become established and for the Nerang River below Hinze Dam. A review of the current environmental flow regime to the lower Nerang River is recommended to improve overall condition of this reach. This is recognised as an issue that is beyond the scope of HDS3.

Staggering the rate of inundation will allow for a gradual transition between the lotic and lentic habitat and will therefore provide conditions that vegetation can adapt too. This may occur naturally unless the dam is filled by large natural flood event. It is noted that GCCC are required to fill the Hinze Dam as soon as rainfall allows.

7 Aquatic Invertebrates

Macroinvertebrates are animals without backbones, large enough to be seen with the naked eye, (e.g. snails, mussels, shrimps, crayfish, dragonflies, mayflies and midges). They are essential components of the aquatic food web and an important food source for Platypus, fish and other vertebrates (Choy 1997). Aquatic macroinvertebrate communities are widely used in bioassessments because they are abundant and diverse, relatively easy to sample and are sensitive to changes in water quality, flow regime and habitat conditions. Impacts on these animals are relatively long lasting and can be detected for some time after the impact occurs (AusRivAS, 2001).

The purpose of this section is to provide information on the existing aquatic macroinvertebrates of the Nerang River that may be impacted by the HDS3 Project. The potential impacts resulting from the construction and operation of the water storage are determined and assessed. Management measures are recommended to mitigate these impacts and to enhance environmental values.

7.1 Monitoring Program Results

7.1.1 OE50 Score, Signal Score and AusRivAS Band

All invertebrate data are presented in Appendix 2. The AusRivAS models utilise only those taxa calculated to have a 50% or greater probability of occurring at a test site, based on reference site data. This level of resolution represents a compromise that reduces the occurrence of low probability taxa whilst maintaining sufficient analytical resolution to detect significant shifts in species assemblages. The ratio of observed over expected taxa with an occurrence probability of 0.5 (50%) is referred to as the OE50 score for a site.

The OE50 score assigned to a site is normally within the range within 0 – 1, with low scores indicating impacted sites at which the observed macroinvertebrate fauna are depleted in comparison to reference sites. Conversely, sites for which the OE50 score nears a value of 1 have returned observed macroinvertebrate assemblages similar to those expected from unimpacted sites. On some occasions the species richness may exceed that expected based on the reference sites, resulting in an OE50 score of greater than 1.

OE50 scores at the sites examined during this study were variable, ranging from 0.22 to 1.48 (i.e. 22-148% of expected taxa were actually observed). The lowest OE50 scores occurred at the sites below the dam wall and at the Education Centre site. The data are summarised in Table 7.1.

Table 7.1 OE taxa, OE signal, band and PET scores for Hinze Catchment sites 2005-07.

Site	Habitat	Model	OE50	OE50signal	Band	PET
Goomoolahra	Edge	Autumn	0.69	1.04	C	7
	Riffle	Autumn	0.66	1.10	B	8
Lloyds Rd	Edge	Autumn	-	-	-	2
	Pool	Autumn	0.68	1.00	B	2
Boiling Pot	Edge	Autumn	0.85	1.02	A	8
	Riffle	Autumn	0.50	0.94	C	9
Education Centre	Pool	Spring	0.63	0.94	B	3
	Edge	Spring	0.83	0.93	A	4
Staffords Rd	Pool	Autumn	0.72	0.95	B	6
Cave Crk	Pool	Autumn	0.84	1.04	A	6
	Riffle	Autumn	0.89	1.01	A	8
Lt Nerang	Pool	Autumn	0.84	1.04	A	8
	Riffle	Autumn	0.49	0.96	C	9
Fire Trail	Pool	Autumn	1.48	1.02	X	7
Bird Aviary	Edge	Autumn	0.78	0.93	B	4
	Riffle	Autumn	0.22	0.75	C	2
Golf Course	Pool	Autumn	0.36	1.00	C	2
	Edge	Autumn	0.26	0.84	C	2
McLarens	Edge	Autumn	0.26	1.27	C	1
	Riffle	Autumn	0.49	1.01	C	4

To simplify interpretation of modelled outputs, the AusRivAS models divide sites into bands based on the OE50 scores obtained. The thresholds for each of these bands are provided in Table 7.2, along with interpretive information. Almost all sites sampled during this study were within the X or A bands, indicating high quality sites with minimal disturbance impact. A number of sites fell within Band 'C' during this study, with only one site, Fire Trail, falling into Band 'X'.

Table 7.2 Species richness thresholds for AusRivAS assigned OE scores.

Band	Description	O/E Taxa	O/E Taxa Interpretations
X	Greater biological diversity than reference sites	O/E greater than 90th percentile of reference sites used to create the model.	More families found than expected. Potential biodiversity "hot-spot" or mild organic enrichment. Continuous irrigation flow in a normally intermittent stream.
A	Biodiversity similar to reference	O/E within range of central 80% of reference sites used to create the model.	Expected number of families within the range found at 80% of the reference sites.
B	Biodiversity significantly reduced	O/E below 10th percentile of reference sites used to create the model. Same width as band A.	Fewer families than expected. Potential impact either on water and/or habitat quality resulting in a loss of families.
C	Biodiversity severely impaired	O/E below band B. Same width as band A.	Many fewer families than expected. Loss of families from substantial impairment of expected biota caused by water and/or habitat quality.
D	Biodiversity extremely impaired	O/E below band C down to zero.	Few of the expected families and only the hardy, pollution tolerant families remain. Severe impairment.

In addition to OE50 scores, AusRivAS assigns a signal score to each of the test sites, based on the sensitivity of macroinvertebrate families to pollution. High signal scores indicate the presence of taxa that are sensitive to pollution. Again, a threshold of a 50% probability of a taxon occurring is considered appropriate for this assessment (the OE50 Signal score).

OE50 Signal scores were exceptionally high across all of the monitoring sites, indicating the presence of many pollution sensitive taxa and, by inference, low pollution levels within the catchment.

7.1.2 PET Richness

PET richness refers to the sum total of all taxa from the orders Plecoptera (the stoneflies), Ephemoptera (mayflies) and Tricoptera (caddisflies). These taxa are known to be sensitive to pollution, hence high PET richness indicates a high quality site. Figure 7.1 shows the PET richness for sites investigated during these studies.

With the exception of the Lloyds Rd site, all sites upstream of the dam exhibited high PET richness, although sites lower on the Nerang system (Fire Trail and Education Centre) were lower than other upstream sites. The sites below the dam wall showed generally PET diversity.

Figure 7.2 depicts OE vs OE signal scores for each site and habitat type, along with interpretive information.

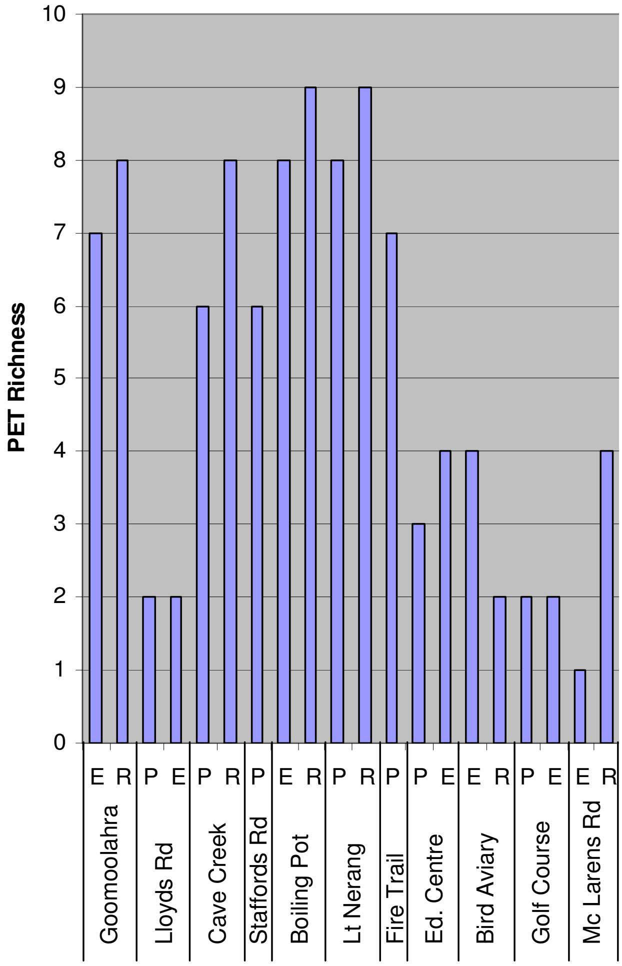

Figure 7.1 PET richness at Hinze Catchment AusRivAS sites 2005-07.

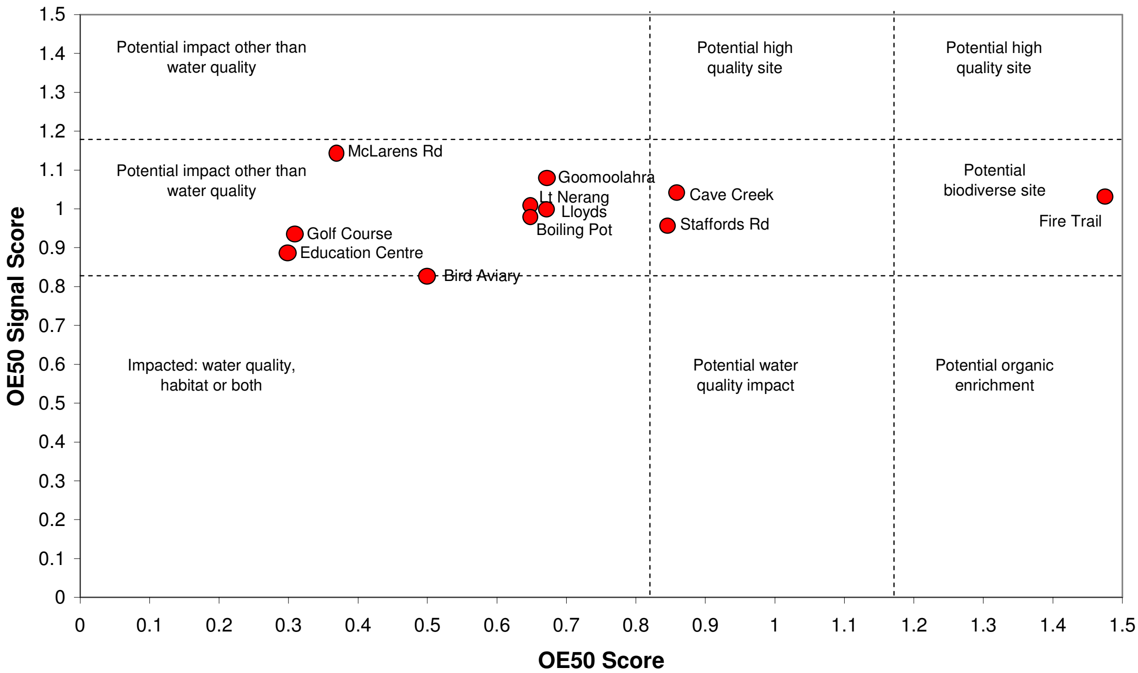

Figure 7.2 OE taxa vs OE signal scores for Hinze Catchment AusRivAS sites, 2005-06.

7.2 Discussion

7.2.1 Catchment-Wide Comments

The upper Nerang and Little Nerang catchments appeared at the time of these studies (2005-06) to be in relatively good condition. At most of the monitoring sites there is a diverse range of habitat types available to aquatic biota. Many of the readily identifiable indicators of declining ecosystem health were notably absent, for example:

- There was no evidence of filamentous algal growth on rocky substrates or in the vicinity of culverts, bridges etc, suggesting good water quality with respect to nutrient loads;
- There was little, if any, indication of erosion or depositional processes at any of the sites. Water clarity was generally excellent and the degree of embeddedness of rock and cobble substrates was generally exceptionally low. Scouring or channelisation were not observed at any of the sites;
- Well vegetated riparian zones generally contributed to excellent bank stability and provided shading and, in some instances, trailing branches. Perhaps the most noticeable environmental impact is the invasion of exotic vegetation within the riparian zone;
-
- Agriculture within the catchment is relatively light and in most places stock access

to the streambanks is limited by riparian vegetation and fencing;

- PET richness, species richness, OE50 and OE50 signal scores across the catchment were generally indicative of high quality habitat and excellent water quality; and,
- OE50 vs OE50 signal plots generally group the sites within a range typical of healthy aquatic ecosystems (Figure 7.2), although some sites appear to have been impacted by factors other than water quality (see below).

By contrast, when surveyed in April 2007 the monitoring sites downstream of the dam appeared to be in very poor health:

- Filamentous green algae covered almost every horizontal surface, often floating to the surface in thick mats;
- Riparian health was variable, with some reaches exhibiting good native riparian assemblages, but most areas overrun with exotic weeks;
- The river was frequently choked with Cumbungi or Water Hyacinth and in many places there were thick mats of Salvinia molesta present;
- There was very little clear substrate as most of the river bed was choked with macrophytes. Agriculture was moderate, but stock were permitted to access the river in many places, and there were numerous areas in which rubbish had been dumped;
- OE50 scores were generally lower, but signal scores were within a more normal range, suggesting impacts other than water quality may be affecting macroinvertebrate health; and
- In conflict with the above, PET richness was low at these sites, potentially indicating poor water quality.

There was general trend towards less diverse macroinvertebrate communities with lower PET richness the further a site was from the headwater areas. This is typical of most river systems, as the cumulative effects of upstream land use intensify the pressure on sites lower in the catchment. However, there was a clear decline in the macroinvertebrate assemblages at all downstream sites compared with sites above Hinze Dam. This is likely to be the combined result of more intensive agricultural land use, increased urbanisation and poor flow variability as a result of regulation of the river at Hinze Dam.

Zooplankton communities within Hinze Dam were extremely sparse at the time of sampling (Appendix 3). Hence, insufficient animals were present to enable a rigorous assessment of community structure. The paucity of zooplankton within the samples was probably the result of:

- Lack of aquatic macrophyte and/or other habitat that would support a healthy macroinvertebrate community; and,
- A high biomass of small fish species such as hardyheads, olive perchlet and smelt, many of which would prey on zooplankton species.

Downstream of Hinze Dam, zooplankton communities were much more diverse and exhibited a higher overall biomass (over 50 macro and microinvertebrate taxa were recorded at the downstream sites). This reflects the abundance of aquatic vegetation in the downstream reaches, being the preferred habitat for many zooplankton species. The species assemblages below the dam wall were indicative of nutrient rich, phytoplankton rich conditions.

Although zooplankton richness and abundance was relatively poor within the dam on this occasion, these communities typically follow a 'boom and bust' cycle. Zooplankton are a fundamental link in the trophic structure of lake systems, hence it is recommended that further monitoring be performed before, during and after the construction of Hinze Dam stage 3. This may be important in enabling assessment of the recreational fishery, particularly if terrestrial vegetation is allowed to remain within the storage during the commissioning phase.

7.2.2 Site Specific Comments (based on single season Autumnal model only)

Goomoolahra

Pool habitat at the Goomoolahra site exhibited one of the lowest OE50 scores observed during this study (0.69), indicating that the macroinvertebrate assemblages at the site were significantly depleted in comparison to reference sites. This categorised the site as Band B (significantly impaired).

The AusRivAS models were unable to provide outputs for the riffle habitat at Goomoolahra as the data collected were outside of the experience of the current reference sites.

The Goomoolahra site is high in the catchment, very close to the source and within a lightly populated area with minimal development, hence it would be expected to exhibit few signs of impairment. Instead, the diversity of aquatic habitat at the Goomoolahra site is extremely low with the bed comprised almost entirely of bedrock with minimal occlusions, undercuts or other features that provide habitat for aquatic organisms.

In this instance the relatively low OE50 score does not reflect an impacted site, but rather the paucity of habitat. This appears to be a natural feature of the site as there is little evidence of altered geomorphic or hydrological processes that would result in scouring of the substrate. The high signal score for the site (1.04) indicates a high proportion of taxa at the site are sensitive to pollution, despite the low species diversity. Further, the high PET richness at the site, particularly within riffle habitat, describes a site that has undergone minimal disturbance, further supporting the assertion that low aquatic macroinvertebrates diversity is a natural feature of the site, rather than a result of disturbance impacts.

Lloyds Rd

The Lloyds Rd site is geographically close to the Goomoolahra site and exhibits a similar substrate, although there is slightly increased diversity in the particle size of rocky substrate. It is therefore not surprising that the pool at this site exhibits similar OE50 and OE50 signal scores (0.96 and 1.00 respectively) to those observed at the Goomoolahra site. Like the Goomoolahra site, Lloyds Road fell into Band B, and riffle habitat again provided data outside of the experience of the model, indicating that the available reference data are unsuitable for assessing riffle at this particular site.

Once again, the low scores to some extent reflect natural conditions at the site (i.e. high proportion of smooth bedrock in the substrate), rather than disturbance impacts. Relatively high PET richness infers a site that has undergone minimal disturbance from human activities. However, the slightly higher proportion of rocky substrate could be expected to result in improved macroinvertebrate diversity. It is possible that these gains have been offset by the closer proximity of the site to a small population centre (Springbrook) and associated development. In addition, the existence of a small dam upstream of the site results in some alterations to hydrology, which may go some way toward explaining the low OE50 scores.

Again, the high OE50 signal score indicates a high proportion of pollution sensitive taxa, despite the lower than expected species diversity. This tends to indicate that pollution at the site is very low and is not contributing to a decline in species diversity.

Boiling Pot

The Boiling Pot site is characterised by relatively fast flowing water, comprising riffles and runs with limited pool habitat. It is likely that both pool and riffle habitat at this site might better be described as runs during periods of even moderately elevated flow, and this condition was observed during March 2006.

Both pool and riffle habitat at the Boiling Pot site returned excellent OE50 scores (0.87 and 1.02 respectively), both habitat types placing the site within Band A. This is indicative of a site that has experienced minimal disturbance from landuse activities or bed alteration. High OE50 signal scores (0.96, 1.04) and PET richness indicate that pollution sensitive taxa are well represented within the relatively diverse assemblages at the site, and suggest minimal pollution impacts.

Education Centre

The Education Centre site was sampled only during Spring 2005, the backing up of water from Hinze Dam resulting in the site becoming too deep for sampling in Autumn 2006. As these data have been modelled using only single season models they should not be assessed in the context of sites modelled using combined seasons data.

Data collected from the pool at the Education Centre site during Spring 2005 yielded an OE50 score of 0.63, the lowest of the sites assessed during this study. However, edge samples collected at the same time yielded a 0.83 OE50 score. The lower OE50 score for the pool habitat may in part be due to the profuse growth of aquatic macrophytes, which made the collection of animals from rocky substrates challenging. This may have skewed the data away from those expected from rocky substrates and towards an assemblage more typical of macrophyte habitat, for which the model is not intended.

The Education Centre site exhibited by far the lowest PET richness of all of the sites studied, suggesting that human activities have had a significant impact on the ecology of the site. This site was selected intentionally for its location as far downstream as possible, hence reflects the full cumulative impacts of disturbance within the system. In addition, the site is immediately below the point at which the Murwillumbah Road crosses the Nerang River. This is a relatively busy road, hence assemblages at the site may to some extent reflect the impacts of runoff from this infrastructure. However, it should be noted that PET richness in this instance is based on a single season sample, whereas most sites were sampled during both Spring and Autumn and the data combined. It is therefore possible that the low PET richness (relative to other sites in this study) reflects seasonal influences, or the fact that the sampling effort was effectively half that for most other sites.

As this site was selected for its location at the lower end of the system prior to entry into Hinze Dam, it was expected to display some loss of macroinvertebrate diversity as a result of the cumulative impacts of upstream landuse activities. Considered in this context, the site is in relatively good condition, falling into the B/A band based on pool and edge data respectively.

As was the case with all sites assessed during this study, the very high OE50 signal score indicates that a high proportion of pollution sensitive taxa exist at the site, hence pollution levels were very low at the time of sampling. It also suggests that the reduced biodiversity indicated by the OE50 score is probably an artefact of habitat disturbance, cumulative impacts or catchment processes rather than water quality.

Staffords Rd

Pool bed was the only habitat type available for sampling at the Staffords Rd site, but the data collected returned excellent OE50, OE50 signal and PET scores, indicating a high quality site with a healthy and diverse macroinvertebrate community and excellent water quality, despite the adjacent landuse (grazing). These results reflect excellent bank and streambed stability, good water quality, and a healthy riparian zone (though exotic vegetation comprised a significant component of the flora at the site).

Cave Creek

Cave Creek was the highest altitude sampling site on the Nerang River system, and the excellent OE50 and OE50 signal scores reflect the close proximity to the source, diversity of aquatic habitat, excellent water quality and moderate landuse. High PET richness is another feature of the site. The AusRivAs models place this site in the A band, indicating excellent diversity when compared with reference sites.

Little Nerang

Despite being located downstream of the Little Nerang Dam, this site displayed excellent species diversity when compared with reference sites, with pool samples falling in the A band using the Autumn model. There was a significantly lower than expected diversity of taxa in the riffle sites (OE50 = 0.49), with the site classified as band C based on Autumn riffle assemblages. This may be a reflection of the fact that the river is regulated only a few kilometres upstream by the Little Nerang Dam, hence Autumn flows may have been significantly less variable than would have been the case prior to regulation. This part of the system may also be receiving colder, lower dissolved oxygen and lower pH water as a result of release from the dam, which would have a greater effect on riffle assemblages when compared to those in the pools.The high OE50 signal scores and excellent PET richness reflect high water quality, which was expected given that the stream flows largely through pristine and rugged National Park.

Fire Trail

The Fire Trail site was not sampled in Spring 2005, but was included in the program in Autumn 2006 as a substitute for the Education Centre site. This site yielded extremely high OE50 scores, with almost 50% more taxa present than was expected from comparison with reference sites, indicating an exceptionally biodiverse site. In common with all of the sites sampled during this study, high OE50 signal scores indicate very low pollution levels, despite the fact that the site is low in the catchment and exposure to the cumulative impacts of upstream catchment activities is maximised. The site also exhibited excellent PET richness, indicating good water quality.

Bird Aviary

The Bird Aviary site was found to have relatively high macroinvertebrate diversity in the edge samples, but lower diversity in the riffles (OE50 = 0.78 and 0.22, respectively). This may in part reflect that the edges contained numerous undercuts and overhanging Lomandra *sp*, whilst the riffle was more exposed and had a significant amount of attached green algae on the rocks, hence providing poorer quality habitat. OE50 Signal scores of 0.93 and 0.75 are indicative of good water quality, although the PET richness scores were very low for this and the other two downstream sites, suggesting poor water quality. Overall, this site fell within the B/C band, indicating significant to severe impacts of regulation and landuse on macroinvertebrate ecology.

It should be noted that the Bird Aviary site was sampled due to the availability of edge and riffle habitat. This was the first such habitat in the reach from this point to the Hinze Dam, the remainder of the reach being of cobble substrate but severely choked with aquatic macrophytes. The site is therefore not truly representative of habitat within this reach, but the absence of a macrophyte habitat model for Queensland coastal sites dictated this site selection.

Golf Course

Species assemblages at the Golf Course site were of very low diversity compared with reference sites, and fell clearly within Band C (severely disturbed). Once again there was a discrepancy with regards pollutants at the site, with good OE50 Signal scores being opposed by low PET richness. This reflects two very different approaches to inferring water quality from the biota. However, the likelihood of poor water quality is corroborated by observations of excessive macrophyte and filamentous algae growth throughout the entire reach below Hinze Dam.

McLarens Road

Low OE50 Scores for samples collected at McLarens Rd indicate a high degree of ecosystem disturbance at this site. As observed at other sites, the OE50 Signal score indicates good water quality, but the low PET richness suggests that the site may be polluted. Observations made during other phases of this project tend to support the latter scenario.

7.2.3 Interpretation of Model Outputs.

Whilst it assists in providing an ecological baseline for the Nerang and Little Nerang aquatic ecosystems, a one-off, single season assessment of macroinvertebrates is at best indicative of conditions at each of the sites examined. As macroinvertebrate assemblages are often very sensitive to changes in the flow patterns, unusual climate conditions (such as extended drought) may cause shifts in the species recorded. The collection of data across a number of years is a more satisfactory approach to AusRivAS style ecosystem assessments.

Likewise, combined season (Spring + Autumn) models provide a more robust assessment of the ecological health of aquatic systems and are the preferred approach to this style of investigation. Macroinvertebrate assemblages can vary tremendously at a site between seasons, often a result of very different flow characteristics. However, water quality and catchment impacts may also differ between seasons, with point source pollution such as treated sewage discharge playing a larger role in water quality trends during the drier months leading up to Spring. Conversely, diffuse runoff from agricultural and urban land has a greater influence on water quality and hence aquatic ecology during the wetter months preceding Autumn sampling.

Table 7.3 Comparison of single and combined season model outputs

		Single season (Autumn)				Combined (Autumn+ Spring)			
Site	Habitat	OE50	OE50signal	Band	PET	OE50	OE50signal	Band	PET
Goomoolahra	Edge	0.69	1.04	C	7	0.69	1.04	B	7
	Riffle	0.66	1.10	B	8	-	-	-	11
Lloyds Rd	Edge	-	-	-	2	-	-	-	7
	Pool	0.68	1.00	B	2	0.69	1.00	B	7
Boiling Pot	Edge	0.85	1.02	A	8	0.87	0.96	A	8
	Riffle	0.50	0.94	C	9	1.02	1.04	A	9
Staffords Rd	Pool	0.72	0.95	B	6	1.06	0.97	A	6
Cave Crk	Pool	0.84	1.04	A	6	1.18	0.95	X	11
	Riffle	0.89	1.01	A	8	1.02	1.01	A	10
Lt Nerang	Pool	0.84	1.04	A	8	0.98	1.00	A	8
	Riffle	0.49	0.96	C	9	0.97	1.06	A	11

Table 7.3 compares the OE50 scores and disturbance bands for a number of sites for which there were sufficient data to perform both single season (Autumn) and combined season (Autumn + Spring) assessments. It is notable for these sites that the Autumn model indicates a catchment in generally poorer health, suggesting that storm driven impacts associated with the minimal agriculture in the catchment are the major drivers of aquatic ecosystem health.

7.2.4 Comparison with EHMP Macroinvertebrate Results

The freshwater assessment component of the EHMP includes an assessment of macroinvertebrate assemblages at 3 sites within the study area; Purling Brook at Springbrook which is a high altitude site on the Springbrook Plateau, the Nerang River at Priems Crossing which is above Hinze Dam and the Nerang River at Latimers Crossing, below the dam wall. Data collected from these sites were considered useful in the context of assessing the potential impacts of the HDS3 Project. However, the freshwater component of the EHMP is specifically designed for monitoring the medium to long term health of aquatic ecosystems at a regional scale. To make an assessment at a local scale, as was necessary for the Hinze Dam project, required a greater number of monitoring sites in order to account for local variability in habitat and environmental conditions.

The methodology utilised in both studies is directly comparable provided the modelling is performed on pooled Autumn and Spring samples. However, only Autumn data are available for the HDS3 studies, hence the direct comparison between EHMP and HDS3 data should be made with care. The comparison between single season and combined season model outputs for the Upper Nerang System in the previous section demonstrates the very different outcomes that are obtained from each approach. These differences are probably attributable to the different catchment processes at play in the months preceding sampling, and to the vagaries of the different models applied.

The 2006 EHMP report card for the freshwater reaches of the Nerang system doesn't provide site specific details. However, the report card assigns a score of C+ to the waterways within the Nerang catchment, describing their condition as 'fair'. The macroinvertebrate assemblages are noted as having consistently yielded the highest ecosystem health results.

When it is considered that this score is derived by averaging the scores from a diverse range of aquatic ecosystems (eg high altitude sites of bedrock substrate, highland streams with cobble substrate and regulated, macrophyte choked river), this is comparable to the findings of the HDS3 studies.

It is recommended that macroinvertebrate sampling at the HDS3 sites be performed again in Spring 2007 and data are modelled again using the combined season models. If EHMP model outcomes are obtained on a site-by site basis, the two data sets can be integrated to maximise the value gained from this assessment.

7.3 Implications for the Hinze Dam Project

This preliminary investigation indicates that there is excellent aquatic habitat and healthy accompanying macroinvertebrate assemblages in the reaches of the Nerang River above Hinze Dam. This observation extends to the Little Nerang Creek, although a naturally high proportion of bedrock at the Goomoolahra and Lloyds Road sites reduces macroinvertebrate diversity.

The proposed vertical rise in water level will effectively inundate a proportion of high quality lotic habitat at the point at which the Nerang River enters Hinze Dam. A similar loss will occur where the Little Nerang Creek enters the dam, although this site is already impacted to some extent as a result of regulation by Little Nerang Dam. No threatened or endangered invertebrate or fish species have been identified within this area during these studies or database searches, hence the loss of lotic habitat is unlikely to impact on species of conservation significance.

Below the dam wall agriculture, urbanisation and river regulation have resulted in a more heavily impacted aquatic ecosystem, and this is reflected in the invertebrate assemblages and lower PET richness, as well as the visible signs of poor flow and nutrient enrichment (choking with aquatic macrophytes, prevalence of filamentous green algae etc).

Table 7.4 Average recurrence interval (ARI) of floods in the Nerang River downstream of Hinze Dam under natural, Stage 2 and Stage 3 conditions.

Glenhurst GS	Pre-development	Hinze Dam Stage 2		Hinze Dam Stage 3	
ARI	ML/d	ML/d	% of pre-development	ML/d	% of pre-development
1.5	6314	762	12.1	655	10.4
2	10107	1194	11.8	959	9.5
5	22800	10071	44.2	4289	18.8
10	28918	17116	59.2	7320	25.3
20	36648	23469	64	10804	29.5
50	59976	31743	52.9	15633	26.1
100	63681	38510	60.5	21741	34.1

Table 7.4 shows the impact of the Stage 2 and Stage 3 projects on downstream flood passage. The Stage 2 project had a marked effect on 1.5 to 5yr ARI floods. Although larger magnitude floods were also reduced, the reduction in natural flows was proportionally less. The Stage 3 Project will have minimal impact on floods of 1.5 to 2 yr ARI, but will significantly reduce the magnitude of 5 to 100yr ARI floods. Although minor floods will still pass, the significant reduction of these larger flows will further reduce channel forming and flushing processes in the Nerang system below the dam wall. In the absence of improved environmental flow releases (volume and variability), this can be expected to exacerbate the decline in macroinvertebrate health and encourage further infestation with aquatic weeds and algae. Fish and other higher aquatic biota are also likely to decline as a result of these changes.

7.3.1 Mitigation of Downstream Impacts.

The main purpose of the HDS3 Project is to increase the storage capacity and mitigate the risk of flood damage to downstream urban communities, hence the environmental implications of reduced downstream flooding are to a large degree unavoidable. Strategies to minimise the impacts of Stage 3 and/or reverse the impacts of the Stage 2 project are limited, but include:

- Engineering more natural downstream flow regimes, potentially by increasing the volume of water released to the river during the Spring/Summer period and reducing it slightly during the Autumn/Winter period. Ideally, this should be staged over a monthly timestep to better mimic natural flow regimes;
- Active management of the riverine ecosystem, particularly the management of the aquatic weeds that currently choke the system and exotic fish species that displace native fish; and
- Improved catchment management, including exclusion of stock, riparian zone management and nutrient reduction strategies.

Implementation of the latter two strategies is likely to be expensive and ongoing (particularly aquatic and riparian weed management), and in the absence a more appropriate environmental flows regime is only likely to be partially successful.

An added option is an offset strategy. This approach is essentially an admission that the reach of the Nerang River between the dam wall and Weedons Crossing has been compromised by a range of catchment activities, will be further compromised by the Stage 3 project, is no longer of significant ecological value and cannot realistically and cost effectively be restored to good ecological condition. As an offset for this loss, conservation and/or restoration strategies might focus on a less impacted local river, preventing further loss of this type of aquatic and riparian habitat.

7.4 Summary

Surveys commissioned by Gold Coast Water in 2005-06 were used to assess sites in the Nerang River and Little Nerang Creek above Hinze Dam. To enable an assessment of potential impacts of the HDS3 Project and development of potential mitigation strategies, macroinvertebrates were sampled at three sites on the Nerang River below the Hinze Dam using the same methodology (AusRivAS) employed for the upstream reaches.

Visual inspections of the upper Nerang and Little Nerang catchments during these field surveys revealed catchments that are in relatively good condition, with few examples of erosion, bank slumping, scouring or sediment deposition. Streambank stability is generally excellent, with good to excellent riparian zones only marred by a high proportion of exotic vegetation. The absence of filamentous green algae or dense periphyton indicates that nutrient loads are generally relatively low. Good water quality in the catchment is probably aided by the dynamic, 'flashy' nature of the catchment, with rapid water level changes in response to localised rainfall events.

Macroinvertebrate assemblages in the upper reaches are also indicative of relatively healthy waterways, although single season modelling outputs painted a slightly less positive picture than combined season models. By contrast, the reach of the Nerang River between the dam wall and Weedons Crossing is highly degraded by catchment activities including river regulation. There were numerous signs of filamentous green algae and waterways choked by exotic weeds, and macroinvertebrate data indicated loss of species diversity, particularly those families that are susceptible to pollutants. Unmitigated, the construction of HDS3 will have two key impacts on macroinvertebrate ecology:

- The drowning of a small area of high quality aquatic lotic habitat at the upper ends of the dam; and
- A reduction of flushing flows in the Nerang River below the dam wall, which can be expected to cause further decline of an already highly disturbed aquatic system.

It is recommended that:

- Further macroinvertebrate surveys are performed during Spring 2007, enabling combined season models to be employed and hence giving a more robust picture of downstream ecosystem health. Ideally, biannual sampling should be repeated over a number of years to establish a more accurate baseline, particularly given the unusually dry weather patterns currently being experienced;
- Although it is recognised that the current water management regime is not due for review for approximately 9 years, the potential to engineer more appropriate environmental flows for the Nerang River downstream of the dam should receive further consideration in the context of the Stage 3 Project; and

- As the existing dam has already created a significant impact on the aquatic biota and habitat from both within and up- and downstream of Hinze Dam, greatest benefit to the regional aquatic ecology could be to apply an offset strategy. This approach would require considerable stakeholder engagement and scientific investigation prior to implementation. It is suggested that preliminary identification of a potential conservation site(s) be undertaken and a cost-benefit analysis completed to test this approach prior to further consideration.

8 Fish

The purpose of this component is to provide information on the existing fish populations in the Hinze Dam catchment including species of conservational significance that may be impacted by the HDS3 construction and operation. Fish habitat is discussed and focus is place on barriers to fish passage. Further research initiatives are also addressed.

8.1 Description of Fish Populations

In addition to indigenous fish species, Hinze Dam has been a stocked recreational fishery since 1991. Stocking has historically included Australian bass, golden perch, silver perch, Mary River cod and Saratoga. In addition to these native species, there are a number of exotic species that have been recorded from the dam. Table 8.1 presents a species list constructed from the surveys performed during this project and the. Table 8.2 further describes fish that were encountered or fish that may be present in the Hinze Dam catchment. Fish that have been translocated are described in Table 8.3 and noxious species are presented in Table 8.4.

Table 8.1 Fish species found during surveys of the Nerang catchment for the purpose of the EIS

Common name/s	Genus	Species	Upper freshwater reaches	Hinze Dam	Lower freshwater reach
Angassiz's glassfish, Olive perchlet	*Ambassis*	*agassizii*	X	X	X
Australian Bass	*Macquaria*	*novemaculaeta*	X	X	X
Australian Smelt	*Retropinna*	*semoni*	X	X	X
Barred Grunter	*Amniataba*	*percoides*		X	
Bullrout	*Notesthes*	*robusta*			X
Cox's Gudgeon	*Gobiomorphus*	*coxii*	X	X	X
Crimson Spotted, Duboulay's Rainbowfish	*Melanotaenia*	*duboulayi*	X		
Eel-tailed catfish, Freshwater catfish, cobbler, jew	*Tandanus*	*tandanus*	X	X	X
Empire Gudgeon	*Hypseleostris*	*compressa*			X
Estuary Perchlet*	*Ambassis*	*marinus*	X		
Firetail Gudgeon	*Hypseleostris*	*galii*	X	X	X
Flathead Gudgeon	*Philypnodon*	*grandiceps*	X	X	
Fly-speckled hardyhead	*Craterocephalus*	*stercumuscarum*	X	X	X
Gambusia, mosquitofish	*Gambusia*	*holbrooki*	X	X	X
Golden Perch,Yellow Belly	*Macquaria*	*ambigua*		X	
Lamington Spiny Lobster	*Euastacus*	*sulcatus*	X		
Marbled eel, Long-finned eel	*Anguilla*	*reinhardtii*	X	X	X
Ornate Rainbowfish	*Rhadinocentrus*	*ornatus*	X		X
Platy	*Xiphophorus*	*maculatus*		X	X
Redclaw	*Cherax*	*quadricarinatus*	X		
Southern Saratoga	*Scleropages*	*leichardti*		X	
Sea Mullet, Striped Mullet	*Mugil*	*cephalus*			X
Short-finned Eel	*Anguilla*	*australis*	X	X	
Silver Perch	*Bidyanus*	*bidyanus*		X	
Striped Gudgeon	*Gobiomorphus*	*australis*			X

* Not found during any other surveys within the Nerang catchment

8.1.1 Agassiz's Glassfish, Olive Perchlet (*Ambassis agassizii*)

This species has a preference for slower flowing and still waters with ample woody debris or rocky habitat. Spawning typically occurs in summer amongst aquatic vegetation and does not require up or downstream migration. This species has suffered a severe decline across much of it's distributional range and is listed as endangered under the NSW *Threatened Species Conservation Act* (1995).

A. agassizii was recorded only at lower altitude sites above the dam (Fire trail and Little Nerang) during the 2007 surveys, with only a single individual recorded at each site. The species has not been recorded at the Priems Crossing EHMP site over the period 2002-06.

Despite the relative scarcity of this species in the upstream reaches, *A. agassizii* was extremely prevalent within the Hinze Dam itself, with catches from fine mesh fyke nets, bait traps and electrofishing sweeps numbering in the hundreds at 3 of the 4 sites sampled. This suggests that the low abundance upstream of the dam may be due to the habitat preferences of the species rather than other environmental factors.

Downstream of the dam, electrofishing surveys carried out during the current study recorded low numbers of the species (3 individuals), this being comparable to EHMP data collected at the Latimers Crossing site over the period 2002-06.

Despite the species conservation status in NSW, *A. agassizii* appears to be prevalent in Hinze Dam. It is not known whether this species was historically more abundant in the lower reaches. However, the low abundance in the upper reaches of the catchment, despite large populations within the dam, suggest it favours a lentic environment. The need to facilitate passage of this species past the dam wall is probably negligible, given Hinze Dam appears to support a healthy, sustainable population of the species. Further work to establish if this endangered species reproduces within the Hinze dam would be highly beneficial and coupled with surveys of populations in neighbouring river systems, would shed further light on this issue.

8.1.2 Australian Bass (Macquaria novemaculeata)

M. novemaculeata is a catadromous species, males in natural populations tending to reside in the estuarine/brackish reaches of river systems, with females living in freshwater but migrating downstream to the saline waters to spawn in May-August.

M. novemaculeata has been observed in a number of the deeper pools and runs upstream of the dam and was witnessed in angler catches during upstream macroinvertebrate surveys. Four immature specimens (≤153mm) were captured using electrofishing techniques at the Little Nerang site, between the Hinze and Little Nerang Dams and a single specimen at the Boiling Pot site, but the species was otherwise not recorded from the upper reaches of the river during the April 2007 surveys. Occasional specimens have been recorded during EHMP fish surveys at the Priems Crossing site between 2002-06.

M. novemaculeata featured strongly in the netting surveys of Hinze Dam undertaken for this investigation, particularly in the gill nets. This was not unexpected given the stocking history of the dam and its reputation as a recreational fishery.

Two individuals were caught during electrofishing surveys below Hinze Dam at the McLarens Rd site. The species has not been recorded during EHMP surveys at the Latimers Crossing site over the period 2002-06.

Three decades of regulation in the Nerang and Little Nerang systems have limited opportunities for downstream migration to periods of spill (fish mortality during these periods is potentially high). Juvenile fish are then unable to migrate back upstream. Fish that have been recorded from the Upper reaches of the Nerang and Little Nerang systems are likely to be fish stocked into Hume dam that have moved and taken residence in these reaches.

Although it is likely that *M. novemaculeata* was present throughout the Nerang and Little Nerang systems prior to regulation, fish currently present in the dam and upper reaches of the systems are probably of little value in terms of conservation as they are not of the local genetic stock. Downstream of the dam populations may be comprised of remnant wild stock and/or fish that have passed over the dam spillway during floods. Upstream passage of this species past the dam wall would provide minimal benefit, as the small number of individuals migrating up from the lower reaches would have minimal effect on the much larger gene pool within the dam.

8.1.3 Freshwater Catfish (*Tandanus tandanus*)

This species is potadromous, and is thought to migrate within freshwater reaches of river systems in response to flooding. *T. tandanus* does not have migratory requirements for spawning and due to their preference for slow flowing rivers and lakes this species may have been favoured by increased habitat availability when the dam was constructed.

Large *T. tandanus* were observed in angler catches in the upper Nerang River during macroinvertebrate surveys (Aquateco, 2006) and have featured in electrofishing catches at all of the upper catchment sites except Cave Creek, Goomoolahra and Lloyds Rd. At Priems Rd the species has also been recorded by the EHMP program every year from 2002-06. The species featured strongly in surveys of Hinze Dam, the majority of fish being caught in gill nets, with some individuals being captured by fyke nets or electrofishing techniques. A further 2 specimens were recorded below Hinze Dam at the McLarens Road site. All fish captured during the April 2007 surveys were in excellent condition.

The downstream population of *T. tandanus* is more sparse than those upstream and in the dam itself, although the reasons for this observation are not clear. Potential factors contributing to this skewed distribution include the highly disturbed catchment, altered flow regimes and declines in water quality. Inability to recruit fish from the upstream sites also plays a role in the poorer fish stocks downstream.

8.1.4 Marbled eel, Long finned eel (*Anguilla reinhardtii*)

A. reinhardtii is catadromous, adults migrating from freshwater to the sea, breeding in deep oceanic waters off New Caledonia. Elvers make their way back to the rivers approximately 12 months later and swim upstream to the freshwater reaches, where they mature over a number of years.

A. reinhardtii was a relatively prevalent species throughout the upper catchment, being recorded during April 2007 surveys at many of the higher altitude sites, including Goomoolahra, above the falls. This species had also been recorded above Hinze Dam during EHMP surveys.

Only one individual was recorded from within Hinze Dam itself. This was an intersting observation given the wide variety of survey techniques employed, which included the overnight deployment of fyke nets – normally a highly effective technique for catching eels. This may suggest that at the time of sampling eels were not utilising the lake lentic habitats.

A large number of *A. reinhardtii* were recorded at the 3 downstream sites, this is also reflected in EHMP data from the Latimers Crossing site.

A. reinhardtii was less prevalent in the rivers above the dam than below, and the individuals captured tended to be large, mature fish. Individuals captured downstream were far more variable in size, with a high proportion of smaller fish. The 2007 Hinze Dam studies have identified a wide distribution in length, although length data were unfortunately not available for the EHMP surveys.

Although *A. reinhardtii* has been known to climb vertical surfaces and to travel overland on wet ground, it is likely that this observation reflects an ageing population of mature fish in the upper reaches with minimal recruitment as a result of the formidable barrier represented by Hinze Dam.

The failure to capture juvenile *A reinhardtii* in the upper catchment of Hinze Dam during the current survey, despite the considerable amount of effort expended, indicates an ageing population of mature fish with little or no recruitment to be present above the dam wall. The dam wall likely poses an impassable barrier to upstream migration, and this is supported by the increase in abundance and size classes of *A reinhardtii* downstream of the dam. These findings show that facilitating the passage of *A reinhardtii* past the dam wall would be highly beneficial to the overall ecology of the upstream reaches, but particularly to upstream populations of this species.

8.1.5 Short finned Eel (*Anguilla australis*)

A. australis has similar migratory requirements to *A. reinhardtii.* The species was found to be less prevalent within the Nerang system, only being recorded on the Springbrook Plateau at the Goomoolahra site (6 individuals) and in Hinze Dam (1 individual). They are a smaller species than *A. reinhardtii*, being less than 1m in length when fully grown (c.f. 1.5-2m). All fish captured during the 2007 surveys were relatively mature, being with 200-600mm in length. This species has not been recorded upstream during EHMP surveys, was found to be but has occasionally been present in surveys at the Latimers Crossing site, downstream of the dam.

The implications of limiting upstream migration of *A australis* is comparable to those of *A reinhardtii*.

8.1.6 Fly Speckled Hardyhead (Craterocephalus stercusmuscarum)

C. stercumuscarum lives entirely within the freshwater reaches of river systems and is normally thought to spawn among aquatic macrophytes. It is intolerant of low dissolved oxygen conditions. The species was found in small numbers at a single site in the 2007 survey, although larger populations were recorded from within the dam itself, which may indicate that the species has a preference for still waters, or that populations have migrated to the Dam to spawn (a high proportion of fish displayed the distinctive golden spawning colouration of male fish). This result is similar to what was found with *A. agassizii, and suggests that the Hinze Dam offers a favourable environment for several of the potadromous fish species found within the catchment*

Hinze Dam appears to support a reasonable population of *C. stercusmuscarum*, with a number of individuals being caught by electrofishing, fine mesh fyke nets and baits traps at all of the sampling sites within the dam.

Within Lotic habitats a single *C. stercusmuscarum* was recorded in the upper catchment at the Staffords Road site, and four individuals downstream of the dam at the Latimers Crossing site. EHMP surveys have recorded a single individual upstream at the Priems Crossing, and indicate that the species is usually present in relatively low numbers at the Latimers Crossing site.

Despite widespread distribution throughout southern and eastern Australia, little is known about the spawning and life cycle needs of *C. stercumuscarum*. The species is thought to spend its entire life cycle in freshwater and that migrations within freshwater reaches may occur during spawning. The low numbers found in both upstream and downstream habitat during this survey and the EHMP program, along with the higher numbers of well-conditioned spawning fish in Hinze Dam, may indicate a preference for still waters. Based on these observations, it is unlikely that *C. stercumuscarum* would benefit from the facilitation of either upstream or downstream passage.

8.1.7 Mosquitofish, Gambusia (*Gambusia holbrooki*)

G. holbrooki is a noxious pest fish and was prevalent in relatively large numbers at many sites within the upper Nerang River, Hinze Dam and the river below the dam during the 2007 surveys. Large numbers of Gambusia have been recorded at the Priems Crossing and Latimers Crossing EHMP sites over the period 2002-06, often significantly out numbering native fish species.

This species is tolerant of a wide temperature, salinity and water quality range. An aggressive livebearer matures quickly and displaces small native fish. Its fin-nipping habit can result in mortality of native fish, mostly because of fungal infection of the wound. Its prevalence throughout the system is unlikely to change as a result of the HDS3 Project, irrespective of fish passage arrangements.

8.1.8 Cox's Gudgeon (Gobiomorphus coxii)

G. coxii was recorded upstream of the dam at the Staffords Rd site on the Nerang River and the Little Nerang site, as well as at the McLarens Road site downstream of the dam. It has not been recorded in the upstream reaches during the EHMP surveys, but appears in surveys at downstream of the dam wall in low abundances. Within Hinze Dam, *G. coxii* was abundant at all sites, being recorded in electrofishing catches and in fine mesh fyke nets net catches.

It is believed that juvenile *G. coxii* are frequently washed downstream, from where they begin an upstream migration over Spring and Summer. Given the prevalence of this species within Hinze Dam and its ability to climb waterfalls, it is interesting that it was not more common in the upper reaches of these rivers.

Given the reasonable population of *G. coxii* recorded in Hinze Dam during the 2007 surveys, the relative scarcity of this species in the upper reaches can only be attributed some factor other than a lack of fish passage facilities at the dam wall, although the causal factor is not clear at this stage. With the exception of improving the gene flow, the installation of a fish passage is probably unlikely to significantly benefit this species.

8.1.9 Fire-tailed Gudgeon (*Hypseleotris galii*)

H. galii is common to coastal drainages in South east Queensland. Spawns occurs in Spring to Summer, with eggs being deposited in aquatic vegetation. Stable flows are required at this time. It has been suggested that while this species occurs predominantly in riverine environs, H*. galii* should breed quite well in the lake environment (RSP 2006).

H. galii was a relatively abundant species throughout the catchment and during the 2007 surveys and was recorded at most upper Nerang River sites (except Boiling Pot), as well as between the Hinze and Little Nerang Dams. It has periodically been very abundant at the EHMP site at Priems Crossing.

Within Hinze Dam, *H. galii* was extremely prevalent at all sites, with catches numbering in the hundreds in fine mesh fyke nets. Below the dam wall the species was recorded at the McLarens Road and Latimers Crossing sites. EHMP surveys at the latter site has previously been found to hold *H. galii*.

Despite a lack of fish passage for three decades this species is abundant at most sites above, below and within Hinze Dam. It is unlikely to benefit from the construction of a fishway.

8.1.10 Duboulay's Rainbowfish, Crimson Spotted Rainbowfish (*Melanotaenia duboulayi*)

M. duboulayi was recorded at the Boiling Pot and Cave Creek sites during the 2007 surveys, and has been regularly recorded during EHMP surveys at the Priems Rd site.

M. duboulayi has a preference for slower flowing waters and habitat containing dense macrophytes and/or woody debris. This species is believed to have a lifespan of 3-4 years in the wild, hence the upstream populations are probably self sustaining. *M. duboulayi* was not recorded downstream of the dam during the 2007 surveys, but has been sporadically present in EHMP surveys at the Latimers Crossing site. It is not clear why the species is less abundant downstream of the dam, although poor quality habitat, greater ecosystem disturbance (eg infestation with aquatic weeds), predation and lack of downstream passage may all play a role.

8.1.11 Flathead Gudgeon (Philypnodon grandiceps)

P. grandiceps is a benthic species that is commonly found in both freshwater and estuarine areas. It was recorded at the Cave Creek site on the upper Nerang system and had previously been recorded at the Priems Crossing site during EHMP surveys. It was also recorded within Hinze Dam, but has not been found below Hinze Dam during either the 2007 surveys or the EHMP monitoring program from 2002-2006.

P. grandiceps is not an obligate estuarine spawner; hence, downstream passage is not critical to populations living within Hinze Dam and above. Given that the species is not uncommon in estuarine environments, the lack of *P. grandiceps* in the downstream surveys may be the result of habitat destruction, poor water quality, predation and/or lack of recruitment from the upstream populations.

Comparing fish populations within the Nerang system and neighbouring streams would prove beneficial in determining whether lack of recruitment from upstream populations is a potential causal factor in the lower abundance of this species downstream of Hinze Dam.

8.1.12 Australian Smelt (*Retropinna semoni*)

Although there is evidence to suggest that some populations of this species may be diadromous, *R. semoni* is generally considered a potadromous species, known to undertake mass migration within the freshwater reaches in response to increased flow.

R. semoni was a very prolific species during the 2007 surveys of the upper Nerang and Little Nerang systems, being found (often in very high numbers) at all sites except those above the falls on the Springbrook Plateau. In some instances, the number of fish made the measurement of all individuals impractical and field staff had to be satisfied with counting the total number of fish. This species has generally been very abundant at Priems Crossing EHMP site also. The species was also recorded at all downstream sites and at one site within Hinze Dam itself.

The high relative abundance of *R. semoni* above, within and below Hinze Dam indicates that the species has not been affected by lack of fish passage since the construction of Stage 2 and hence is not likely to benefit greatly from the construction of a fishway during the Stage 3 Project, other than through gene exchange between populations.

8.1.13 Ornate Rainbowfish (*Rhadinocentrus ornatus*).

Rhadinocentrus ornatus congregate in small schools and occupy small, slowly moving creeks, backwaters of coastal streams and marshy swamps around melaleuca forest, usually over a sandy substrate. Spawning occurs among aquatic vegetation. Although not endangered, its has a restricted distribution and its habitat has been degraded in many areas due to dam construction, housing developments and land clearing (Allen et al. 2003).

R. ornatus was a rare find during the 2007 surveys, with only a single specimen collected in the Upper Nerang system at the Cave Creek site, and 2 individuals caught downstream of the dam wall at the Golf Course site. It had not previously been collected either above or below the dam wall during EHMP monitoring, although the species is listed as confirmed present in the Nerang system (Harris, 2006). It is normally considered a low altitude, Wallum wetland/stream species.

8.1.14 Western Carp Gudgeon (Hypseleotris klunzingeri)

H. klunzingerii is very common occurring among aquatic vegetation in a range of habitats including: coastal streams, slow flowing rivers, billabongs, lakes and dams. Spawning occurs late Spring to Summer when temperature rises above 22°C (Allen et al. 2003).

H. klunzingerii has been consistently recorded at both the Priems Crossing and Latimers Crossing sites during EHMP surveys but was not recorded during the 2007 HDS3 assessment.

8.1.15 Empire Gudgeon (Hypseleotris compressa)

Hypseliotris compressa is a small gudgeon that is tolerant of a wide range of temperatures and salinities. It is very resilient, with populations able to double in 15 months. Spawning occurs in the warmer months, with eggs adhering to weed, sand or rock and being maintained by the male. Although considered potadromous, *H. compressa* can tolerate salinity levels similar to that of seawater.

H compressa was recorded at all of the downstream sites during the 2007 Hinze Dam surveys and has previously featured in EHMP surveys at the Latimers Crossing site. It was not recorded within the dam or the upper reaches of the Nerang or Little Nerang systems during either the Hinze Dam or EHMP surveys.

It is not known whether *H. compressa* occurred in reaches of the system above the dam site prior to regulation. The absence of the species in these reaches in the current time could potentially be the result of predation by stocked recreational species, habitat alteration or lack of recruitment from the lower reaches. Ideally, surveys of neighbouring creek systems should be undertaken (stratified by altitude, habitat type etc) to determine whether *H. compressa* should be present above the dam wall and hence whether facilitation of upstream passage may be required.

8.1.16 Striped gudgeon (Gobiomorphus australis)

The migratory habits of *G. australis* are not clear, although it is generally considered either potadromous or amphidromous and has a clear tolerance for estuarine waters, with juveniles often being found in more saline conditions. Slow flowing and often muddy water is the preferred habitat of *G. australis*.

This species was recorded at all sites downstream of the dam during the 2007 fish surveys, and is frequently abundant in the EHMP data for the Latimers Crossing site. However it was not recorded upstream of the dam wall during the 2007 surveys and has not been recorded during EHMP surveys of the upstream sites over the period from 2002-06.

It is unclear whether the sites above the dam wall are beyond the normal distributional range of *G australis*. It is possible that the species requires passage to the estuaries for spawning and hence the upstream populations have been unable to spawn or recruit from downstream of the dam wall. Investigations should be undertaken to determine whether the species should be present above the dam wall. This should include surveys of neighbouring creek systems to examine the intra-river distributional range of *G. australis*.

8.1.17 Platy (Xiphophorus maculatus)

X maculatus is an introduced livebearing fish that was brought into Australia by the aquarium trade. During the 2007 Hinze Dam surveys it was recorded at all of the downstream sites and at the upper intake tower within Hinze Dam. The EHMP program has consistently documented the presence of this species at the Latimers Crossing site from 2002-06, however it is not known whether the species has been recorded from within Hinze Dam previously.

8.1.18 Estuary perchlet (*Ambassi marinus*)

A single specimen captured at the Golf Course site was identified at the time as *A. marinus*. Although *A. marinus*, the location suits the habitat requirements for *A. marinus*, this species has not been previously recorded in the EHMP surveys or the Gold Coast Councils Freshwater fish and habitat surveys, either within the Nerang River or neighbouring systems.

The species is visually very similar to *A. agassizii* and it is likely that the single individual recorded from the Golf Course site was incorrectly identified and was in fact this latter species.

8.1.19 Sea mullet (Mugil cephalus)

Mugil cephalus is a catadromous species, spending much of its time in estuaries and freshwater rivers but returning to the ocean to spawn. They are generally planktivorous once in freshwater habitats and play an important role in the ecology of many systems.

This species was very common throughout the reaches below the dam wall during the 2007 Hinze Dam surveys and was visible due to its large size and habit of schooling near the surface. In addition to the recent surveys, *M.* cephalus has been recorded at Latimers Crossing during EHMP surveys between 2002-06. *M. cephalus* was not highly represented in the surveys, being flighty and difficult to capture using the electrofishing equipment, however the species was clearly visible, moving in schools of large individuals near the water surface. It can be expected to comprise a large percentage of the downstream biomass due to its large size and relative abundance.

It is almost certain that this species once extended upstream well beyond the site at which the dam wall was constructed, but no records of its presence within the dam or upstream environments have been found, the species not having been recorded above the dam wall in the current surveys or the EHMP surveys. The contribution of the species to the upper Nerang Catchment prior to regulation is not clear and requires further investigation in order to determine whether passage of this species past the dam wall is required.

8.1.20 Bullrout (Notesthes robusta)

N. robusta is a benthic species of slow flowing freshwater streams and estuaries with rocky, muddy or gravel substrate, especially where there is abundant woody debris or macrophytes. This species breeds in freshwater, with juveniles having been recorded from upland streams.

A single *N. robusta* was recorded at the McLarens Road site during the 2007 Hinze Dam surveys. The species has also been infrequently recorded during EHMP surveys at Latimers Crossing but has not been caught during surveys above the dam wall.

It is likely that this species exists within Hinze Dam and in the upper reaches of the Nerang system but has not been recorded due to the relatively low sampling effort expended thus far. As *N. robusta* spawns in freshwater, including storages, this species does not require passage past the dam wall (although all species benefit from genetic exchange between upstream and downstream populations).

8.1.21 Saratoga, Spotted Barramundi (*Scleropages leichardtii*)

S. leichardtii is stocked into Hinze Dam for recreational purposes, although the dam is south of the species natural distributional range. It is probable that the population that has been established is self-sustaining, as this species is able to spawn in impoundments.

A number of individuals were captured during gill net surveys at the Boat Ramp 3 site in Hinze Dam. Anecdotally, they are widespread throughout the dam but were not recorded at other sites during these surveys. All fish were of a similar size, suggesting they were stocked fish rather than wild spawned fish.

As the downstream environment is highly degraded and probably represents poor quality habitat for *S. leichardtii*, it is desirable to contain this species within the dam. If downstream passage for other species is contemplated, the methodology should specifically exclude *S. leichardtii.*

8.1.22 Golden Perch, Yellowbelly (*Macquaria ambigua*)

M. ambigua is stocked in Hinze Dam for recreational purposes and is outside of its natural distributional range. An anadromous species requires a diet of yabbies to spawn successfully. It is unlikely that this species is self-sustaining within Hinze Dam due to lack of access to suitable spawning habitat.

A single specimen in very good condition was recorded from the Boat Ramp 3 site during the Hinze Dam 2007 gill net surveys. Although anecdotal evidence and fish stocking reports indicate that the species is widespread within Hinze Dam, it was not recorded at any other site within the dam, upstream or downstream on this occasion.

This species is maintained in Hinze Dam as a 'put and take' recreational species; hence, passage past the dam wall is not a requirement. To minimise further shifts in downstream ecology, it is desirable that *M. ambigua* is not translocated to the downstream environment; hence, care should be taken if downstream passage is contemplated for other species.

8.1.23 Silver perch (*Bidyanus bidyanus*)

B. bidyanus is stocked into Hinze dam for recreational purposes and is outside of its natural distributional range. The species has declined close to the point of extinction in the wild largely because of river regulation, although stocked populations have been reasonably successful. It is unlikely that the population is self-sustaining, as it rarely breeds in impoundments and does not thrive in the cooler faster upland rivers such as the upper Nerang.

Three individuals were caught during gill net surveys at the Boat Ramp 3 site in the Hinze Dam, although this species was not recorded at any other site within the dam, upstream or downstream. *B. bidyanus* has not been recorded during EHMP surveys either upstream or downstream of the dam.

This species is maintained in Hinze Dam as a 'put and take' recreational species; hence, passage past the dam wall is not a requirement. Numbers of this species have declined considerably due to the proliferation of manmade barriers to upstream migration (Allen et al. 2003) However, to minimise further degradation of the downstream ecology it is desirable that it is not translocated to the downstream environment.

8.1.24 Mary River Cod (*Maccullochella peelii mariensis*)

M. peelii mariensis is an endangered species pursuant to the *EPBC Act* that has been stocked outside of its natural distributional range for recreational and conservation purposes. It was not caught during the Hinze Dam or EHMP fish surveys, but anecdotally thrives within the lake and is regularly represented in angler catches.

It is not known whether this species can spawn in impoundments, although the spawning success of other Australian percichthyid fishes is low or non-existent. Observations during hatchery spawning suggest that impoundment spawning may be possible given suitable conditions.

This species is maintained in Hinze Dam as a 'put and take' recreational species; hence, passage past the dam wall is not a requirement. To minimise further ecological shifts it is desirable that it is not translocated to the downstream environment, hence care should be taken if downstream passage is contemplated for other species.

8.1.25 Barred Grunter (*Amniataba percoides*)

A. percoides is a widespread Australian freshwater species, but is considered a noxious pest in Hinze Dam, having been accidentally introduced as a result of cross contamination of fingerlings of other species stocked into the dam.

A. percoides was recorded at all sites within Hinze Dam during the 2007 surveys but has not been detected at sites upstream or downstream of the dam during any survey.

This species is outside of it's natural range and is considered a pest due to its aggressive nature and potential to displace other native fish. It is desirable that it is not translocated to the downstream environment, hence care should be taken if downstream passage is contemplated for other species.

8.2 Species of Significance to the Hinze Dam Stage 3 Project

8.2.1 Threatened or Rare Species

No significant species listed under either the *EPBC Act* or the *NC Act* were recorded from the Nerang system during the 2007 HDS3 investigations, the Environmental Health Monitoring Program (2002-06) or the Gold Coast City Council review of freshwater fish and habitat. However, a number of species of conservation significance pursuant to Commonwealth and State legislation and those considered to be of conservation importance by the Queensland Department of Primary Industries and Fisheries (DPI&F) and the Australian Fish Biology Association may potentially occur within the Nerang system. These species are detailed below.

Agassiz's Glassfish (*Ambassis agassizii*) was very abundant within Hinze Dam and was present throughout the riverine habitats in lower numbers. The western NSW population of this species is listed as an Endangered Population pursuant to the Fisheries Management Act 1994. Construction of Stage 3 is unlikely to negatively impact on this population provided water quality impacts minimised (A. agassizii is particularly sensitive to poor water quality). Deepening the lake can be expected to increase the lentic habitat available to this species, which may ultimately result in the lake supporting a larger population.

Mary River Cod (*Maccullochella peelii mariensis*) is listed as endangered and critically endangered pursuant to the EPBC Act and the International Union for the Conservation of Nature (IUCN) respectively and the Australian Nature Conservation Association (ANCA). Wild stocks of this species have been reduced to a few hundred individuals in scattered populations, some of which are in terminal decline.

The Nerang system is outside of the natural distributional range for this species, but Hinze Dam has been stocked with hatchery reared *M. peelii mariensis* for recreational angling and conservation purposes. The HDS3 Project is unlikely to have a detrimental impact on these populations, and may potentially benefit the species through the creation of additional habitat, particularly if trees between the current and proposed full supply levels are allowed to remain when the storage fills.

If downstream fish passage is considered, care should be taken to ensure that the mechanism by which fish transfer occurs excludes *M. peelii mariensis*.

Ornate Rainbowfish *(Rhadinocentrus ornatus)* is considered by the DPI&F to be locally threatened (Wagner, 1993) as a result of increasing urbanisation and disturbance of coastal catchments. A single *R. ornatus* was recorded in the upper reaches during the 2007 Hinze Dam surveys and 2 in the lower reaches. Raising the dam wall will not affect a population of this species in the upper catchment, however there is potential for downstream populations to be affected by further habitat decline as a result further reductions in the passage of floods. A longer term monitoring program on the Nerang system and on one or more neighbouring streams would assist in determining the significance of these populations and hence potential impacts and mitigation strategies for the HDS3 Project.

Cox's Gudgeon (*Gobiomorphus coxii*) is listed is listed as having a restricted geographic range by the DPI&F (Wagner, 1993). The species was recorded in the upper and lower catchments during the 2007 surveys, but was most prevalent within Hinze Dam itself. This suggests that G. coxii has not been disadvantaged as a result of lack of upstream passage since the construction of the existing dam wall, hence populations within Hinze Dam and the upper catchment are unlikely to be significantly impacted upon by the project provided appropriate measures are taken to manage water quality and other potential environmental impacts resulting from the construction and commissioning phases. Downstream populations of this species are more sparse and may potentially be impacted upon by a reduction in flood passage and hence further declines in water and habitat quality following the construction of Stage 3.

As with a number of other species, a longer term monitoring program on the Nerang system and on one or more neighbouring streams would assist in determining the significance of these populations and hence potential impacts and mitigation strategies for the HDS3 Project.

Australian Bass (*Macquaria novemaculeata*) is listed as potentially threatened by the Australian Fish Biology Association (WBM, 2002), largely due to significant reductions in habitat from the regulation of a large proportion of rivers along the Eastern Seaboard. As the species is catadromous, river regulation prevents mature fish from migrating to the estuaries to spawn and reduces the quality of habitat downstream of dam walls.

M. novemaculeata would have been present in the Nerang and Little Nerang systems prior to regulation. However, 30 years of river regulation are likely to have seen the passing of the majority (if not all) of the wild population within the dam and upper reaches, with systematic replacement by hatchery reared fish. This would have effectively diluted the local genetic stock.

M. novemaculeata were recorded in low numbers below the dam wall and there is anecdotal evidence from recreational anglers that a healthy downstream population of bass currently exists. It is not known whether these are wild spawned fish, or individuals that have found their way into the lower river reaches during spill from the dam. In the event that some or all of these fish are wild, it is important that the gene stock is not diluted with hatchery fish. Hence if the facilitation of downstream fish passage is considered it is important that the strategy ensures the exclusion of *M. novemaculeata.*

Alternatively, electrophoretic techniques could be used to determine whether the fish within Hinze Dam are genetically distinct from the downstream population prior to allowing the two stocks to mingle.

Marjorie's Hardyhead (*Craterocephalus marjoriae*) was not recorded during either the Hinze Dam 2007 studies or the EHMP surveys between 2002-06. However, the presence of this species in the Nerang system has been otherwise confirmed (Harris, 2006). Records of the species are not available, hence it is not clear as to when they were recorded from the Nerang system, nor the number or size of fish caught.

The Australian Society for Fish Biology lists this species as being of conservation interest due to its restricted distribution. *C. marjoriae* is thought to be non-migratory, spawning within vegetation in the freshwater reaches of river systems. Hence, if it is present within the dam or upper catchment of the Nerang system these populations will most likely be unaffected by the Hinze Dam Project provided mitigation strategies for example water quality are adhered to. If present downstream of the dam wall, *C. marjoriae* may be impacted upon by a reduction in flood passage, which can be expected to result in further declines in habitat quality.

Further investigations of the Nerang system and neighbouring streams should be undertaken to establish whether a downstream population exists and to determine appropriate mitigation strategies.

Australian Lungfish (*Neoceratodus forsteri*) like other lungfishes have the ability to surface and breathe air using a vascularised air-breathing organ. This is particularly useful during dry periods when streams become stagnant, or when water quality changes, The Queensland Lungfish has a single lung, whereas all other species of lungfishes have paired lungs. *N. forsteri* is normally found in still or slow flowing pools in river systems of south-eastern Queensland. It occurs naturally in the Burnett and Mary River systems although has successfully been introduced into other rivers and reservoirs in south-eastern Queensland and north-eastern New South Wales. This species spawns at night from August to December with peak activity in October. Fertilized eggs are stuck to aquatic plants and hatching takes about three weeks. Growth is very slow, with young reaching 6 cm in length after 8 months and 12 cm after two years. *N. forsteri* is listed as vulnerable pursuant to the *EPBC Act*.

Oxleyan Pygmy-Perch (*Nannoperca oxleyana*) listed as vulnerable pursuant to the *NC Act* and is listed as endangered pursuant to both the *EPBC Act* and IUCN. This species is restricted to coastal heath or 'wallum' habitats (Leggett 1990) along the north coast of NSW and the south coast of Qld (Arthington et al. 1996). *N. oxleyana* has also been found within shallow artificially constructed drains in NSW, suggesting that the species is capable of surviving in more degraded areas (Knight 2000). Subtle differences in habitat and water quality or chance dispersal and extinction events, and the effects of recent habitat loss or degradation, appear to be the probable influences on the patchiness of this species throughout its geographical range (Arthington et al. 1996).

The reproductive biology and migration patterns poorly known for *N. oxleyana*. The large majority of waterbodies found to support populations of *N. oxleyana* in northern NSW occur on a low-lying coastal plain. Floods intermittently connect these waterbodies, which potentially facilitates the dispersal of *N. oxleyana* (along with other aquatic organisms) within and amongst them (Knight 2000). The genetic analysis of populations from *L. Jabiru* and Spitfire Ck (Moreton I.) and the Noosa R., two very extensive systems compared to small coastal creeks, supports the view that fish move, mix and interbreed within individual drainage systems (Hughes et al. 1996). Spawning appears to vary from Spring to Autumn depending on the location. (Arthington & Marshall 1993; Arthington et al. 1996). Knowledge of ageing, growth, fecundity, spawning frequency, birth rates, recruitment processes and mortality factors would provide insights into population dynamics considered to be important baseline data for effective management of this species (Knight 2000).

8.2.2 Other Species

Although their presence in the Nerang system is unconfirmed, Harris (2006) predicted that two additional species of interest to the Australian Society for Fish Biology (ASFB) could be present in the Nerang system:

Freshwater Mullet (*Myxus petardi*) is a catadromous species, migrating to estuaries to spawn. If present in the Nerang system, it would probably be restricted to the reach below the dam wall, since there is no possibility of recruitment to the upstream reaches. The species is considered by the ASFB to have intermediate conservation status due to widespread habitat loss as a result of river regulation.

Purple-spotted Gudgeon (*Mogurnda adspersa*) is considered endangered under the IUCN (2006) due to its declining geographic range as a result of urbanisation, catchment impacts and river regulation. If present below the dam wall, this species may be impacted upon by further declines in habitat quality as a result of reduced flood passage.

Further investigations should be considered for these species. In the first instance, more intensive monitoring of the lower river reaches should be performed. For *M. adspersa*, additional electrofishing would be adequate. The use of gill or seine nets in addition to electrofishing may be appropriate for *M. petardi*.

8.2.3 Species Requiring Upstream or Downstream Passage

Migratory fish species that have been confirmed present in the system during these surveys and may be impacted upon by the HDS3 Project are discussed below.

Marbled Eel, Longfinned Eel (*Anguilla reinhardtii*) was recorded above, below and within the dam. It is a catadromous species, requiring access to the ocean to spawn, with juvenile fish migrating well up into river systems, where they reside and mature. It is thought that adult fish die following spawning in deep oceanic waters off New Caledonia.

A. reinhardtii was moderately abundant at the upstream sites, although all fish recorded were mature individuals of 550 – 1050mm length. Downstream of the dam wall this species was in greater abundance, with some large individuals recorded, but the majority of fish were in the <300mm size class. This is clear evidence that the population has been impacted upon by the lack of fish passage at the existing dam wall. Upstream populations may comprise of remnant individuals (there are records of *A. reinhardtii* exceeding 40 years of age), and/or minimal recruiting from the downstream population. As this species is unable to spawn in fresh water, the sustainability of the upstream population is strongly dependent on recruitment; hence facilitation of upstream passage for this species is critical.

The need to facilitate downstream migration is far less clear and is logistically more challenging. It is likely that some downstream passage occurs via the spillway when the dam is full, although high mortality rates are an inevitable outcome. The upstream habitat of *A. reinhardtii* has been severely reduced in South East Queensland and Northern NSW as a result of dam developments. Proposed new developments (eg Mary River, Tweed River) will further exacerbate this impact, the overall effect being a continued decline in the number of mature fish migrating to oceanic spawning grounds. Further research is necessary to clarify the migratory requirements of this species.

Short-finned Eel (*Anguilla australis*) has similar migratory requirements to *A. reinhardtii* but was less prevalent within the Nerang system, being recorded on the Springbrook Plateau at the Goomoolahra site (6 individuals) and in Hinze Dam (1 individual). They are a smaller species than *A. reinhardtii*, being less than 1m in length when fully grown (c.f. 1.5-2m). All fish captured during the 2007 surveys were relatively mature, being with 200-600mm in length. This species has not been recorded during EHMP surveys.

The presence of this species on the Springbrook Plateau indicates either that they have navigated the substantial vertical surface of the Goomoolahra Falls, or that they have been stocked into a farm dam and have subsequently escaped.

As per *A. reinhardtii*, the loss of available habitat and land locking of mature fish by man-made barriers has increased steadily on a regional level and has probably reduced the number of mature fish able to migrate to oceanic spawning grounds. New dam developments and existing systems undergoing refurbishment should therefore be cognisant of this cumulative impact and should facilitate both upstream and downstream passage of this species.

8.2.4 Species Requiring Further Investigation/Consideration

There are a number of species for which there is insufficient understanding of habitat requirements, natural distribution within the Nerang system, biology or ecology to enable a reasonable assessment of the potential impacts of the HDS3, or on which mitigation strategies might be formulated. These are discussed below:

Crimson Spotted Rainbowfish (*Melanotaenia duboulayi*) populations appear to be self-sustaining in lotic systems above the dam but may be more precarious below the dam wall.

It is possible that:

- This species was naturally present at lower abundances in the lower reaches even prior to regulation. Intensive surveys of the lower Nerang system and neighbouring catchments (stratified by habitat type, altitude, season etc) would be required to test this hypothesis;
- The downstream population has been impacted upon by altered flow patterns, declines in water quality and/or habitat destruction/disturbance, reduced spawning and recruitment; and
- That significant recruitment to the downstream reaches occurred prior to the regulation of the Nerang River. If so, facilitation of downstream passage of this species could be considered.

Further investigations are required to determine whether mitigation is required, and if so the most appropriate mitigation/offset strategies for this species.

Flathead Gudgeon (*Philypnodon grandiceps*) was present above and within the dam but has been absent at sites below the dam in both the 2007 Hinze Dam surveys and the EHMP surveys.

It is possible that:

- This species was naturally present at lower abundances in the lower reaches even prior to regulation. Intensive surveys of the lower Nerang system and neighbouring catchments (stratified by habitat type, altitude, season etc) would be required to test this hypothesis;
- The downstream population has been impacted upon by altered flow patterns, declines in water quality and/or habitat destruction/disturbance, reduced spawning and recruitment; and
- That significant recruitment to the downstream reaches occurred prior to the regulation of the Nerang River. If so, facilitation of downstream passage of this species could be considered.

Further investigations are required to determine whether mitigation is required, and if so the most appropriate mitigation/offset strategies for this species.

Striped Gudgeon (*Gobimorphus australis*) is a relatively common inhabitant of the Nerang River below Hinze Dam, but has not been recorded in or above the dam. Although the species is generally considered potadromous, it is tolerant of salinity and juveniles are often found within estuaries. The absence of this species at all landlocked sites gives rise to speculation that the Nerang population is catadromous, especially as *G. australis* is a reasonably abundant species at sites below the dam wall.

Estimation of the likely range of this species within the Nerang River prior to regulation could be performed by investigating its range in neighbouring unregulated catchments. The monitoring program would need to be carefully designed and stratified by altitude, habitat type, water quality and season/month. A program of this nature would enable assessment of the likely need to facilitate passage of this species past the dam wall.

Empire Gudgeon (*Hypseleotris compressa*) was recorded at all sites below the dam wall, but has not been recorded in the dam itself or in upstream waterways. As per *G. australis*, it is suggested that a well designed monitoring program be implemented to infer the natural range of this species within the Nerang system, as this will lead to a better understanding of the need to facilitate fish passage for this species.

Freshwater Catfish (*Tandanus tandanus*) was not common in the downstream reaches despite featuring strongly in the survey results from the dam and upper catchment. The reason for this is observation is not clear, hence further investigations are suggested in order to determine whether downstream migration of this species should be facilitated.

8.3 Fish Habitat and Impediments to Fish Passage

8.3.1 Above Hinze Dam – Nerang River and Little Nerang Creek

Aside from Hinze Dam itself, there are few, if any, artificial barriers to fish movement in the upper Nerang River. However, many natural rock bars, boulders and small waterfalls might impede fish passage, particularly during periods of low flow. In some places, these impediments might also create velocity barriers that impede the passage of some species during high flow periods. Lack of regulation of the upper reaches, along with the rapid hydrological response to rainfall events creates highly variable hydrology in this reach of the river, hence upstream and downstream movement of many fish species probably occurs opportunistically when the flow rates over or through a particular structure permit.

Above Hinze Dam, fish movement into Little Nerang Creek is limited by a number of structures both man made and natural. Multiple natural barriers to fish passage can be expected to exist in this area, but like the upper Nerang, hydrological variability would probably present opportunities for migratory fish to pass these structures.

8.3.2 Below Hinze Dam – Nerang River

The existing Hinze Dam wall comprises a zoned earth and rockfill main dam and a saddle dam with a concrete gravity spillway. The storage is comprised of two distinct arms extending along the flooded valleys of the Nerang River to the east and the Little Nerang Creek to the west.

The dam is surrounded principally by forested land. Low water levels at the time of this assessment had resulted in a band of shoreline between the current water level and full supply level that had been colonised by terrestrial grasses. Falling water levels had resulted in a second, narrower band of exposed sediment at the waterline.

As is typical of many storages, the complex topography of the drowned river basins valleys has resulted in a complex shoreline with numerous inlets and occlusions. This has resulted in a relatively long shoreline for the size of the lake and provides extensive littoral habitat. Conversely, the steep banks reduce the area of littoral habitat, the water depth falling steeply in close proximity to the shoreline in many places.

There is a paucity of woody debris within the dam, the existing terrestrial vegetation having been removed prior to commissioning of the storage. At the time of these surveys there was virtually no aquatic macrophyte component to the available habitat, possibly due to the relatively rapidly falling water levels and steep basin morphology. Rugged, submerged rocky substrates, areas of soft sediment and topographic relief therefore comprise the bulk of the benthic habitat, with occasional remnants of woody vegetation.

At the time of these surveys Hinze Dam was stratified, and the thermocline clearly provided habitat for pelagic species (probably Saratoga and Australian bass), which were clearly evident on sonar traces.

The Stage 3 Project will result in the crest height and spillway structure being raised and resulting in a 12.5m vertical rise in full supply level. This will result in a longer shoreline and greater littoral zone when the storage is at higher levels, increasing the habitat available to aquatic species. There is potential to further improve aquatic habitat by allowing some or all of the woody terrestrial vegetation within the new inundation zone to remain standing.

Throughout the reach below Hinze Dam there were obvious signs that the river system was in very poor health, including dense blooms of aquatic macrophytes (with exotic species very strongly represented), thick mats of biofilm on all submerged surfaces including filamentous and riparian zones that were heavily infested with weeds in many areas.

The substrate throughout the reach was almost invariably comprised of hard materials such as bedrock, cobble and boulder, with very little silty habitat evident, although the mildly turbid nature of the water may have concealed patches of silty substrate in a handful of deeper holes.

Notable shifts in the character of the river occurred below the Latimers Crossing Bridge and again below Stevens Bridge.

Hinze Dam to Below Latimers Crossing

The Nerang River in this reach comprised generally shallow water (0.3 to 1.5m depth), with occasional deeper holes. Water clarity was generally quite good. Where the substrate was visible or within reach of a kayak paddle, it was almost entirely comprised of rock, cobble and pebble, with rare patches of silt.

The reach was characterised by the presence of very heavy aquatic macrophyte growth, despite the predominantly hard substrate. In many places, the plants were emergent and attached species, suggesting the presence of at least some soft sediment beneath the cobble. Many of the aquatic flora species observed were exotic species, including Salvinia (*S. molesta*), Water Hyacinth (*E. crassipes*) and Cumbungi (*T. latifolia*).

The upper portion of this reach was comprised of a series of small, shallow pools connected by narrow, shallow channels that were heavily choked with Cumbungi. Further downstream, typha was replaced by increasingly heavy growths of water hyacinth, which in many places were of sufficient height and density that kayaks had to be portaged.

There was an abundance of lilies in some areas, again of sufficient density to inhibit the easy passage of kayaks. This was particularly the case in the vicinity of the small private golf club.

A number of larger fish species were positively identified, including Sea mullet, Australian bass and eel-tailed catfish. Some smaller fish were observed but could not be identified, with the exception of the Mosquitofish (*G. holbrooki*). Sea Mullet were by far the most highly represented species within this portion of the system, and due to the quite large size of many individuals, would represent a very significant proportion of the overall biomass.

Latimers Crossing to Stevens Bridge

A short stretch of river at the top end of this reach (approximately 1km upstream of the golf course) was inaccessible for the purposes of this survey.

There was a distinct improvement in the aquatic flora at this point, with far less cumbungi, Salvinia and the terrestrial weed, Singapore Daisy. Anecdotally, the golf course superintendent mentioned that the club actively manages these noxious species through biological, mechanical and chemical means. However, the river remained heavily overgrown with submerged and floating aquatic macrophytes in many areas.

Throughout this reach, there was greater diversity of habitat, with many riffles, runs, bends, boulders and undercuts providing both physical habitat and hydraulic diversity. In many places, the heavy biofilm indicating excessive nutrient concentrations was still evident.

The riparian zone along this reach was variable, with adjacent landuse typically agriculture, but with increasing urban influence further downstream.

The construction of two bridges at the Golf Course has created some minor impediments to fish passage. However, natural barriers to fish movement through this reach were numerous and took the form of rock sills, boulders and bedrock projections. In some places miniature waterfalls of 1-1.5 m height presented perhaps the greatest impediment to fish passage between the dam and Weedons Crossing. During periods of low flow, it is likely that many species would be unable to pass due to the expanse of very shallow water or the vertical climb required. However, during high flow periods it is quite possible that velocity barriers will inhibit the movement of some species.

As with the previous reach, fish passage beyond the many natural barriers is probably impeded more by lack of hydraulic variability than the physical barriers themselves.

Stevens Bridge to Weedons Crossing

Below Stevens Bridge, the river was generally wider and slightly deeper. Adjacent landuse became progressively urban and turbidity increased. The substrate still appeared to be largely cobble and pebble, although it is likely that the deeper areas immediately upstream of Weedons Crossing contained a proportion of silty substrate.

The proliferation of aquatic flora again became dominated by exotic species, in particular Salvinia, which formed dense mats in many areas. These mats completely covered the water surface to a depth of 15-20 cm over areas estimated at several hectares.

Nearer to Weedons Crossing the Salvinia vanished quite abruptly, and it is suspected that this may have been due to tidal influences.

There were few artificial structures that act as fish barriers within this zone that would represent significant barriers to fish passage during periods of even moderately elevated flow, an observation that is to some extent corroborated by the abundance of reasonably large fish in the reach. The barriers that were observed included:

- A small informal rock sill that had been constructed by arranging rock and cobble across the streambed. Under current flow regimes, it is probable that many fish species, particularly smaller ones are able to negotiate this structure, although mortality through predation might be slightly higher. Under even moderately elevated flow conditions, most species living within the system would most likely have little difficulty achieving either upstream or downstream passage.
- As noted by Harris (2006), the concrete apron beneath the bridge at Latimers Crossing creates an expanse of shallow water with a featureless substrate, which could be expected to impede the passage of many species and may increase predation by (eg) avian fauna.

By contrast, there were multiple natural barriers to fish passage, including many shallow riffles and areas that were very heavily choked with Cumbungi species. There are three species of cumbungi in Australia, two of which are native, and the third is an exotic that originated in Europe. All species are capable of choking waterways, particularly where there is an abundance of nutrients and relatively low flow conditions.

Prior to regulation of the Hinze system, it is likely that fish passage past these natural barriers would have been possible as a result of greater hydrological variability. Hence, fish passage would have occurred opportunistically when flow conditions were suitable, and the upstream migration of fish would have occurred in pulses, rather than as a continuous stream. Through the reduction of hydraulic variability and the facilitation of prolific macrophyte growth, uniform, seasonally unadjusted flow releases are probably a far greater impediment to fish passage than the physical barriers *per se*.

The only artificial impediment to fish passage in this reach is the causeway below the road bridge, as identified by Harris (2006). This structure includes culverts to allow minor tidal influx, and it is likely that these would provide some opportunity for fish passage. However, Harris (2006) highlights the issue of lack of light and lack of baffles, or other surface texture that might assist fish to pass through the pipe during periods of high water velocity.

A second impediment to fish passage may be presented by the extensive Salvinia infestation, which has created a large area that is permanently shaded from sunlight and is probably cooler than adjacent waters. Further, there is potential for oxygen sags if/when the Salvinia bloom dies back, which may result in fish kills or deter fish from passing.

8.4 Additional Fish Survey Work Required

The following additional fish work is recommended prior to the commissioning of Hinze Dam Stage 3. The programs outlined below are complex and significant effort will need to be expended on the scoping and program design phases. It is recommended that this is pursued promptly to ensure that fish passage and distribution issues are resolved prior to construction/commissioning of Stage 3.

8.4.1 Distribution of Fish Species in the Nerang Catchment

A number of observations regarding the distribution of confirmed fish species within the Nerang Catchment require further investigation. These include:

- The presence of a healthy population of *T. tandanus* in the dam and the upper catchment, but a much sparser population downstream. It is unclear whether it is the upstream or downstream populations that have been influenced by regulation;
- A very healthy population of *A. agassizii* within the dam, but much sparser populations within the riverine environments. It is not clear whether the population in the dam is abnormally high, or whether populations within the rivers are low. However, the increased abundance of a species listed as rare is of particular interest;
- A much higher abundance of *A. reinhardtii* and increase size/age class diversity in the downstream environments, compared with larger, older mature fish in the upper catchment;
- The presence of *A. australis* at high altitude sites in the upper catchment;
- A sparse downstream population of *G. coxii* below the dam wall despite strong populations within the dam, raising the question of whether downstream populations are in decline and/or whether passage for downstream migration of this species is required;
- A high biomass of *M. cephalus* downstream of the dam, with an absence of the species within or above the dam. This species is known to play an important role in algal grazing, hence the need for increased fish passage passage and the improvement of upstream stocks requires assessment;
- *M. duboulayi* and *P. grandiceps* were found in upstream environments but not below the dam wall. It is unclear whether this is a natural distribution, an artefact of altered downstream habitat or the result of reduced recruitment from upstream populations; and
- *G. australis* and *H.* compressa were recorded below the dam wall but not above. It is uncertain whether this is a natural distributional pattern or due to restricted fish passage since the river was regulated.

In addition to these observations, two fish species considered to be of conservation significance by the Australian Society of Fish Biologists (1996) *M. pertardi,* (Freshwater Mullet and *M. adspera*, (Purple spotted gudgeon) are considered likely to exist within the Nerang system based on their geographic range and habitat preferences, but have not been recorded in recent fish surveys. Increased sampling effort focussed on capturing these two species would be of benefit to prove or disprove their presence within the catchment. This would help streamline the allocation of resources for the management of fish stocks in the Nerang catchment.

A more intensive and focussed fish monitoring program is required to rectify these knowledge gaps. It is recommended that this program:

- Include all riverine fish monitoring sites used during the 2007 Hinze Dam surveys, but be expanded to include comparable sites in the Mudgeeraba Creek catchment so as to enable pre-regulation distributions of fish species in the Nerang system to be better assessed;
- Be carefully designed to enable multivariate analysis of the data that are collected, enabling a comparison of regulated versus unregulated river scenarios and lend increased integrity to the interpretation of survey results;
- Involve regular (monthly to quarterly) surveys to maximise fishing effort and hence the likelihood of capturing rare, cryptic and/or migratory species;
- Be stratified by habitat type, altitude, stream order and other applicable parameters to enable direct comparisons between catchments;
- Utilise a range of fish sampling techniques including electrofishing, netting and trapping. For example, gill, seine or cast netting may be a more efficient option than electrofishing when specifically investigating the presence of *M. pertardi*; and
- Run for a minimum of two years, to enable inter-annual comparisons to be made, especially of species that are migratory or suspected to be migratory.

8.4.2 Fish Passage Studies

Knowledge of the species requiring upstream and (potentially) downstream passage is necessary in order to design fish passage facilities and/or trap and relocate programs. The information required for these purposes includes the species involved, the biomass requiring passage and the timing and/or triggers for migration. Investigation of similar programs undertaken nationally and internationally would also be of benefit. For example, assessment of the success of trap and relocation programs to mitigate against fish passage issues of *A. australis* in the Derwent River catchment in Tasmania.

This program would ideally follow from the outcomes of the investigative program outlined above. However, monitoring would need to be performed over two years (and preferably longer) in order to gather this information required to ensure that fish passage issues are adequately addressed. It is recommended that this run in parallel with the above investigative studies. Fish passage studies downstream of the dam should involve:

- The design, installation and maintenance of fish traps downstream of the existing dam wall to capture fish migrating upstream;
- Daily operation of the traps during regular survey periods (eg 1 week per month) over a 2 year period, ensuring the numbers, species and size class of fish responding to seasonal migratory cues are recorded;
- Trials of various trap designs to test their efficiency in capturing the species of interest (as indicated from the above studies); and
- Condition assessment of individual fish, particularly noting animals in advanced spawning condition, so as to better understand the timing of migratory and spawning cues of specific species of interest.

If downstream passage of fish is to be contemplated, similar surveys should be conducted in the Nerang River immediately above the proposed new full supply level.

8.5 Summary

Previous studies have been designed to meet specific objectives or have lacked long term or seasonal assessments. Collections did not represent an indicative sample of the community structure of fish communities within the Hinze Dam catchment. For this reason, more information was required to address the objectives of this study. Field surveys were undertaken to identify fish and to assess potential impacts that the HDS3 Project may have on them. Various fish sampling techniques were employed to collect a range of fish species that could be representative of the communities within each reach of the Hinze Dam catchment.

The populations of the 25 fish species caught during field surveys were described. Populations that may be present in the Hinze Dam catchment, as established from other research were also described. No significant species listed under either the *EPBC Act* or the *NC Act* were recorded from the Nerang system during the 2007 HDS3 investigations.

Aside from Hinze Dam itself, there are few, if any, artificial barriers to fish movement in the upper Nerang River. Above Hinze Dam, fish movement into Little Nerang Creek is limited by a number of structures both man made and natural. The reach below Hinze Dam was characterised by the presence of very heavy aquatic macrophyte growth that may impede fish movement. Other potential impediments to migration were in the form of a small informal rock sill and the concrete apron beneath the bridge.

Two fish species considered to be of conservation significance by the Australian Society of Fish Biologists (1996), *Myxus pertardi,* (Freshwater Mullet) and *Mogurnda adspera*, (Purple Spotted Gudgeon) are considered likely to exist within the Nerang system based on their geographic range and habitat preferences, but have not been recorded in recent fish surveys. Increased sampling effort focused on capturing these two species would be of benefit to prove or disprove their presence within the catchment;

Overall, there are large gaps in the knowledge of the migratory requirements for fish within the Hinze Dam catchment. Additional fish research is recommended for areas including fish distribution patterns and fish passage, prior to the commissioning of HDS3. The programs involve significant effort will need to be expended on the scoping and program design phases. It is recommended that these are pursued promptly to ensure that fish passage and distribution issues are resolved prior to construction/commissioning of Stage 3. Specific research areas include:

- Investigation into the feasibility of developing an upstream fish passage way;
- Undertake further fish surveys to help reach a decision on the requirement for downstream fish passage;
- An investigation into the feasibility of creating artificial barriers targeted at pest species is recommended;
- Should fish passages be introduced, electrophoretic techniques should be used to determine whether the Australian Bass (*Macquaria novemaculeata)* hatchery populations within Hinze Dam are genetically distinct from the downstream wild population prior to allowing the two stocks to intermingle; and
- Should fish passage be facilitated around the dam wall, pest species should be manually removed when collected in the fish transfer device.

Table 8.2 Indigenous species found within Nerang system using available literature and most recent surveys

Common name	Species	Notes
Australian Bass	*Macquaria novemaculeata*	Naturally occurs in Nerang system, but also stocked into dam. Catadromous species. Adults migrate from river tot estuary to spawn in May- Aug. Juveniles and adults move upstream for dispersal and summer feeding (Sep - Dec)
Australian Lungfish	*Neoceratodus forsteri*	One anecdotal account of lungfish being caught in Hinze Dam by an angler some years ago. Species listed under EPBC due to very limited distributional range. Move up to 25 km within freshwater for habitat/dispersal, prefer still or slow-flowing areas with deep pools. Listed as vulnerable conservation status (EPBC)
Australian Smelt	*Retropinna semoni*	Caught during EHMP surveys of Nerang, Has been caught in the little Nerang system (GCCC, 2006). Prefers still or slow moving water. Spends entire life in freshwater although there are some reports of diadromous populations. Strong tendency to gather below barriers in rivers, suggesting that they might migrate (http://www.desertfishes.org/australia/fish/retrsemo.shtml). Mostly thought of as a potadromous species
Bony Bream	*Nematalosa erebi*	Potadromous species. Migration Aug – Apr. Classified as uncommon in the Gold coast region (Chapple et al. 2004)
Bullrout	*Notesthes robusta*	Possible a catadromous species, usually associated with aquatic vegetation. Species bears dangerous spines and should be handled with care. Classified as uncommon in the Gold Coast region (Chapple et al. 2004), found in the Nerang River below Hinze Dam
Common Jollytail	*Galaxias maculatus*	Catadromous species. Prefer still or slow flowing habitat. Adult migration occurs Apr – July, juvenile migration Sep - Oct
Cox's Gudgeon	*Gobiomorphus coxii*	Potadromous species. Classified as uncommon in the Gold Coast region (Chapple et al. 2004) onfirmed presence in the Nerang system
Duboulay's Rainbowfish	*Melanotaenia duboulayi*	
Dwarf Flathead Gudgeon	*Piylypnodon sp.*	
Eel-tailed Catfish	*Tandanus tandanus*	Has been recorded from the dam during previous fish surveys. This species occurs in the Nerang River both above and below the dam. Undergoes migrations within the freshwater zones possibly following high flow events
Empire Gudgeon	*Hypseleotris compressa*	Prefers habitats from upstream flowing areas to coastal swampland. Juveniles undertake massive migrations from flooded mangroves upstream along any flowing water (Jan – Apr), including road edges and agricultural drains, begin to settle out in pebble reaches
Estuary Perchlet	*Ambassis marianus*	Found in the Nerang River below Hinze Dam. Classified as uncommon in the Gold Coast region (Chapple et al. 2004)
Fire-tail Gudgeon	*Hypseleotris galii*	Potadromous species. Prefer areas with aquatic vegetation

Common name	Species	Notes
Flathead Gudgeon	*Philypnodon grandiceps*	A bottom dwelling species that inhabits still or flowing fresh or estuarine waters. Check migration
Fly-specked Hardyhead	*Craterocephalus stercusmuscarum*	
Fork-tailed Catfish	*Arius graefei*	Potadromous species
Freshwater Herring	*Potamalosa richmondii*	Catadromous species
Freshwater Mullet	*Myxus petardi*	Catadromous migration. Prefer slow-flowing areas, deep pools
Jungle Perch	*Kuhlia rupestris*	Catadromous. Adults thought to move to inshore reefs to spawn, then return upstream Nov - Feb. Juveniles move upstream for growth (Jan – Apr). Prefer fast-flowing perennial streams, coastal creeks, particularly very small streams on inshore islands and coastal floodplains. Females prefer headwaters.
Honey Blue-eye	*Pseudomugil mellis*	Vulnerable conservation status. Migration patterns are unknown. Prefer still areas with extensive vegetation
Lamprey	*Mordacia sp.*	Lampreys spend most of their adult lives at sea, but adults migrate into freshwater to spawn before dying (ie anadromous). Juvenile lamprey migrate back to the oceans to mature
Large-mouth Goby	*Redigobius macrostomus*	
Long-finned Eel	*Anguilla reinhardtii*	Observed during fish habitat surveys in the Lower Nerang River and freshwater reaches above Hinze dam. Catadromous migraton, adults Dec – May, juveniles Sep- Mar
Marjorie's Hardyhead	*Craterocephalus marjoriae*	Classified as rare in the Gold Coast region (Chapple et al. 2004). Has been confirmed present the lower Nerang System during EHMP surveys
Midgley's Carp Gudgeon	*Hypseleostris midgleyi*	
Mountain Galaxias	*Galaxius olidus*	
Mouth Almighty	*Glossamia aprion*	A mouth brooding species found in dense vegetation in freshwater streams.
Olive Perchlet	*Ambassis agassizii*	
Ornate Rainbowfish	*Rhadinocentrus ornatus*	Considered rare in the Gold Coast region, confirmed presence in the Nerang system
Oxeye Herring	*Megalops cyprinoides*	Amphidromous species. Classified as uncommon in the Gold Coast region (Chapple et al. 2004). Presence not confrmed in the Nerang system.
Oxleyan Pygmy Perch	*Nannoperca oxleyana*	Protected under the ICUN. Migration patterns are unknown, prefer still or slowly flowing water with aquatic vegetation
Sea Mullet	*Mugil cephalus*	Catadromous migration Feb- Sep. Found close to coast or within coastal watercourses

Common name	Species	Notes
Short-finned Eel	*Anguilla australis*	Prefers still waters, but often found in flowing water, particularly in slower currents. Adults undergo downstream migration (Dec – May) and are thought to die after spawning in the coral sea. Juveniles migrate back from the estuaries to freshwater in (Sep - Jan) in the Nerang system (catadromous). Classified as uncommon in the Gold Coast region (Chapple et al. 2004)
Snub-nosed Garfish	*Arrhamphus krefftii*	Classified as uncommon in the Gold Coast region (Chapple et al. 2004). Presence not confirmed for the Nerang system
Southern Blue-eye	*Pseudomugil signifer*	Migratory patterns uncertain,
Southern Purple-spotted Gudgeon	*Mogurnda adspersa*	Species in danger of extinction. Lives among weed in slow flowing freshwaters with hard substrates. Migration patterns are unknown, probably move within freshwater for dispersal. Can climb significant waterfalls. Found in all habitats, particularly attracted to small flows. Has not been found in the Nerang system.
Spangled Perch	*Leiopotherapon unicolor*	This species is very tolerant of a very wide range of ambient water quality and habitat conditions. Undergoes nocturnal upstream migration for spawning during Oct – Apr and dams have been known to impact on this process. Potadromous.
Striped Gudgeon	*Gobiomorphus australis*	Potadromous species that inhabit turbid waterholes, slow flowing areas close to coast
Western Carp Gudgeon	*Hypseleotris klunzingeri*	Prefers slow flowing, heavily weeded and often turbid waters. Thought to be one of the more migratory of the smaller freshwater fishes. Classified as uncommon in the Gold coast region (Chapple et al. 2004), confirmed presence in the Nerang system

Table 8.3 Translocated species found in the Nerang System

Common name	Species	Notes
Barred Grunter	*Amniataba percoides*	Inadvertent release to Hinze Dam during fish stocking
Golden Perch or Yellowbelly	*Macquaria ambigua*	Anadromous. Stocked for as a recreationally significant species
Mary River Cod	*Maccullochella peelii mariensis*	Endangered conservation status. Stocked to increase geographical range and as a recreationally important species.
Silver Perch	*Bidyanus bidyanus*	Amphdromous migration, potentially threatened conservation status. Stocked as a recreationally important species
Southern Saratoga	*Scleropages leichardt*	Restricted conservation status. Stocked to increase geographical range and as a recreationally important species. Migratory habits unknown. Prefer upper reaches and turbid areas. It is unknown whether this species reproduces in the Hinze Dam

Table 8.4 Species found in the Nerang System that are declared noxious under the Fisheries Act 1994 (Qld) (listed under Section 74 of the Fisheries (Freshwater) Management Plan 1999)

Common name	Species	Notes
Mozambique Mouthbrooder, (Tilapia)	*Oreochromis mossambicus*	Released into ornamental ponds and first recorded in South-east Queensland in 1977 and Townsville in 1978. Not yet recorded in the Nerang system
Platy	*Xiphophorus maculatus*	Escaped aquarium fish now in any coastal drainages in eastern Qld; urban creeks in the Brisbane region and the Wet Tropic Region.
Swordtail	*Xiphophorus helleri*	Escaped from ornamental ponds, now found in coastal drainages of south-eastern Qld; (Heckel) particularly abundant in urban streams of the greater Brisbane region and extending as far west as Ipswich.
Common Carp	*Cyprinus carpio*	Carp were first recorded in Victoria in 1862. It is likely that carp in the Murray–Darling spread from NSW and Victorian populations into Queensland. Carp have considerable potential to spread throughout Australia as a result of their wide environmental tolerances.
Gambusia or Mosquitofish	*Gambusia holbrooki*	Introduced to Brisbane in 1929 (by accident) subsequently spread by the military and local councils as a biological control agent for mosquitoes and hence malaria.
Goldfish	*Carassius auratus*	Escaped aquarium fish tentatively identified at the dam on 06/12/2006

9 Amphibians

Field surveys for the distribution and abundance of amphibians were not carried out as part of the Hinze Dam Stage Three (HDS3) Environmental Impact Statement (EIS) investigations. Individual amphibians were collected ancillary to fish surveys using electrofishing and netting techniques. Only two species of amphibians were encountered during field surveys: Cane Toad (*Bufo marinus*) and the Great Barred Frog (*Mixophyes fasciolatus*).

9.1 Distribution and Ecology

The natural range of the Cane Toad, *B. marinus*, extends from the southern United States to tropical South America. They were deliberately introduced from Hawaii to Australia in 1935, to control scarab beetles that were pests of sugar cane but they proved ineffective. Cane Toads occur throughout the eastern and northern half of Queensland and have extended their range to the river catchments surrounding Kakadu National Park in the Northern Territory. In New South Wales they occur on the coast as far south as Yamba and there is an isolated colony near Port Macquarie (Bennett 1996). Cane Toads can breed in most still or slow-flowing water, and tolerate salinity levels up to 15mg/L. Male Cane Toads start calling for mates in early Spring or when water temperatures reach 25ºC. Females lay 8,000 to 35,000 eggs at a time and may produce two clutches a year. The eggs hatch within 24-72 hours and the tadpole stage may last from three to twenty weeks, depending on food supply and water temperature - generally a range of 25-30ºC is needed for healthy development. The tadpoles gradually change (metamorphose) into toadlets 1 - 1.5 cm in length that leave the water and congregate in large numbers. Adult toads, toadlets and tadpoles were observed in the Hinze Dam.

The Great Barred Frog, *M. fasciolatus* is a large ground dwelling frog found along the coast and ranges from south-eastern Queensland to the south coast of NSW (Anstis 2002). This species inhabits forests (wet sclerophyll forest and rainforest), in areas with lower precipitation and intermediate temperatures in the warmest (Summer) quarter of the year (Parris 2002). Numerous individual *M. fasciolatus* tadpoles were collected in the fish sampling sites within Springbrook National Park.

9.2 Species of Conservation Significance

The Cane Toad (*B. marinus*) is not a declared pest in Queensland so there is no legal requirement to control them (NRW 2006). The Great Barred Frog, (*M. fasciolatus*) is considered to be a species of least concern under the IUCN (Hines et al. 2004).

9.3 Potential Impacts

Impacts of HDS3 on *B. marinus* populations are not considered pertinent to the EIS as the species are not native nor of conservational significance. The impacts of HDS3 are not likely to impact on the population of *M. fasciolatus* due to their location atop the Springbrook Plateau. Further studies could be carried out to determine the distribution and abundance of significant frog species in the Hinze Dam area.

9.4 Suggested Mitigation of Impacts

There are no suggested mitigation measures regarding amphibians that were encountered. It is recommended a frog management plan be implemented if conservationally significant frog populations are found within the HDS3 footprint.

10 Reptiles

Field surveys targeting freshwater aquatic or semi-aquatic reptiles were not carried out due to time constraints. Reptiles that were encountered were collected opportunistically, during fish surveys. Two freshwater turtles, Macquarie Turtle (*Emydura macquarii*) and Saw-shelled Turtle *(Elseya latisternum)* were collected during this study. Each individual was identified to species (Wilson 2005), its carapace measured, assessed for good health and released.

Other aquatic or semi-aquatic reptiles that are likely to occur in the Hinze Dam Catchment include the long-neck turtles *Chelodina longicollis* and *Chelodina expansa* as well as the Eastern Water Dragon, *Physignathus lesueurii* (Wilson 2005). The Hinze Dam Catchment is within the distributional range for these species.

10.1 Distribution and Ecology

E. macquarii as a widespread species occurring in the rivers of the Murray-Darling Basin as well as coastal rivers, creeks and wetlands of northern NSW and south-eastern Queensland (Cann 1998; Wilson 2005) where they are generally the predominant turtle species (Chessman 1988). Different sub-species exist in Queensland and it is unknown which sub-species occur within the Nerang Catchment. *E. latisternum* is also widely distributed but tends to prefer swamps, billabongs and creeks more than major rivers (Cann 1998). Both species utilise cloacal respiration and have a preference for well-oxygenated water.

The two species of long-necked turtle usually inhabit permanent billabongs or ponds (Tucker 1999; Arthington 2000) *C. longicollis* can achieve high abundance in ponds on the floodplain (Tucker & Priest 1998) although it has become more difficult to find in eastern Queensland, possibly because of adverse reactions to Cane Toads (Arthington 2000). *C. expansa* is typically found in low density streams in southeast Queensland (Limpus et al. 1997; Arthington 2000).

Freshwater turtles have an extremely varied diet, consisting largely of filamentous algae, vertebrate carrion, detritus, periphyton, aquatic insects, and aquatic plants (Chessman 1986). *E. maquarii* is regarded as a generalist omnivore, eating a wide variety of plant and animal foods. *C. longicollis* is carnivorous, feeding by foraging for moving prey such as macroinvertebrates, small fish and tadpoles. (Arthington 2000). *Chelodina expansa* is regarded as a dietary specialist (Tucker 1998), feeding on fish, crustaceans and molluscs in permanent waters. *E. latisternum* is a general carnivore, feeding on carrion and less active prey and thriving on Cane Toads in channels within cane fields (Arthington 2000).

The Eastern Water Dragon, *Physignathus lesueurii*, is very similar to freshwater turtles in both diet and breeding characteristics. Their diet consists of aquatic crustaceans, insects and small vertebrates as well as fruits from riparian vegetation. Studies in other catchments show that this species is able to tolerate conditions in semi-polluted drains and waterways (Arthington 2000).

10.2 Species of Conservation Significance

All reptile species sighted, or expected to occur within the study area are regarded as common (Stanger et al. 1998) and are not listed under the Environment Protection and Biodiversity Conservation Act 1999 (EBPC Act). However, Cogger (1993) stated that insufficient information is known about many turtle species for conservation status to be assessed accurately.

10.3 Potential Impacts

Water storages and flow regulation can result in the loss of riffle habitats, and possibly an alteration to macrophyte beds and riparian habitats, which represent important sources of macroinvertebrate food (Tucker 1999; AWT 2001). However, the species that have been observed in the study have successfully inhabited the already highly modified area. The 1.5% loss of riverine habitat estimated for the HDS3 will create more still water habitat. This should provide suitable habitat for many species of turtle providing the inundated area remains well oxygenated (for cloacal respiration). Sediment types at the existing and proposed full supply level (FSL) are quite similar (Section 4.1.1) and should not pose a problem to turtle nesting behaviour.

The distribution and abundance of turtle species in the area of proposed inundation has not been previously documented. However, it is reasonable to assume that healthy populations exist because of the presence of suitable habitat. The lack of numbers of species and individuals found within the study area are possible short-comings of the monitoring technique, which was not designed to target reptiles and the time constraints for this research. This gives rise to the need for a more extensive survey method to describe the distribution and abundance of reptiles in the HDS3 area.

10.4 Suggested Mitigation of Impacts

There are no suggested mitigation measures regarding reptiles that were encountered or are likely to inhabit the Hinze Dam Catchment. A more extensive survey method to describe the distribution and abundance of reptiles in the HDS3 area could benefit to thoroughly identify potential impacts.

11 Mammals

The Water Rat (*Hydromys chrysogaster*) is widespread in eastern Australia. It was observed during fauna surveys undertaken for this study. The Platypus (*Ornithorhynchus anatinus*) is widely distributed along the east coast of Australia from Tasmania to Cooktown. It too was observed opportunistically during aquatic surveys within Hinze Dam. Water Mouse (*Xeromys myoides*), although not encountered in this study, has been recorded in the Gold Coast Region and may be present in the Hinze Dam Catchment.

The abundance and distribution of aquatic and semi-aquatic mammals in the inundation area has not been assessed in detail for this EIS. However, they are expected to be present along the inundation length since suitable pool habitat exists. Detailed surveys should be undertaken prior to construction to fill this information gap and provide a baseline for monitoring.

11.1 Habitat Requirements

H. chrysogaster has broad habitat requirements including permanent headwater streams, slow moving reaches of permanent watercourses and (fresh and brackish) wetlands. They construct a nest at the end of a tunnel in the riverbank or occasionally in logs (Arthington 2000). *O. anatinus* may be found in a wide variety of habitats ranging from large riverine pools to fast flowing riffles. Ideal habitat is found in fairly shallow rivers and streams with relatively steep banks consolidated by the roots of native vegetation and with riparian growth overhanging the bank (Scott & Grant 1997). The presence of overhanging vegetation is an important component for several reasons. Roots help to consolidate the banks and prevent *O. anatinus* burrows from collapsing. Overhanging vegetation provides cover from predators when animals move in and out of their burrows and while they move and forage in shallow riffle areas (Gunninah 1997). However, these animals are able to live in disturbed waterways with little or no riparian vegetation flowing through agricultural lands, at artificial weir sites and in large impoundments (Gunninah 1997).

The semi-aquatic *X. myoides* inhabits saline grassland, mangroves, and freshwater margins (Menkhorst & Knight 2004). This species has a life cycle that depends on mangrove communities as well as a range of other wetland communities for survival. Mangrove and other coastal wetland communities are widely threatened by development for residential and recreational purposes and to a lesser extent for agriculture and aquaculture. Loss of mangroves has lead to a loss of habitat for the water mouse, a main cause of decline in its numbers.

11.2 Dietary Requirements

Water Rat diet consists primarily of aquatic invertebrates, fish, frogs and small birds. Mostly nocturnal feeders, they bring food to a platform to be eaten (Menkhorst & Knight 2004). Several middens of mussels were seen during field surveys of the Nerang River below the Hinze Dam. The Water Mouse has a diet of marine and freshwater invertebrates. Platypus have generalist diets, foraging on whatever macroinvertebrates are available in the benthos of pools, although other items including small fish and frogs may also be included. The area of river habitat available to individuals for feeding determines its carrying capacity and any reduction in invertebrate biomass in streams and rivers is of concern for population maintenance (Arthington 2000).

11.3 Species of Conservation Significance

The Platypus is listed as common in all states and territories of Australia, except South Australia, where it is listed as Vulnerable (Stanger et al. 1998). The Platypus is listed as Common under the *Nature Conservation (Wildlife) Regulation 1997* Qld. While it is a common mammal, it is generally considered to have cultural significance. The Water Mouse is listed as vulnerable under the *EPBC* Act.

11.4 Potential Impacts

The Water Rat is reported to be robust and tolerant to water resource development. Permanent inundation of temporary wetlands for water storage has been known to increase abundance of the Water Rat (Woollard et al. 1978). Increased FSL may affect the Platypus through the flooding of burrows. However, Platypus in the Hinze Dam have most likely adapted to fluctuations in water level since these are natural events (high rain levels and flooding) and they have already been subjected to a degree of artificial water level manipulation within Hinze Dam. Lower frequency and duration of flooding to the downstream reach of the Nerang River may benefit mammals in this section due to the prolonged period of calmer conditions. That is, less disturbance to habitat and nesting sites.

Table 11.1 Reptiles, mammals and amphibians recorded in the Hinze dam catchment during this study

Kingdom	Common name	Species	Upper Reach	Hinze Dam	Lower Reach
Amphibia	Great Barred Frog (Tadpole)	*Mixophyes fasciolatus*	X		
	Cane Toad (adult and tadpole)	*Bufo marinus*		X	
Reptilia	Macquarie Turtle	*Emydura macquarii*		X	
	Saw-shelled Turtle	*Elseya latisternum*		X	
	Saw-shelled Turtle	*Elseya latisternum*	X		X
Mammalia	Platypus	*Ornithorhynchus anatinus*		X	
	Water Rat	*Hydromys chrysogaster*			X

11.5 Suggested Mitigation of Impacts

There are no suggested mitigation measures regarding aquatic and semi-aquatic mammals that were encountered or are likely to inhabit the Hinze Dam Catchment. A more extensive survey method to describe the distribution and abundance of these mammals in the HDS3 area could benefit to thoroughly identify potential impacts.

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Appendix 1
Description of Riverine Sampling Sites

Site 1: Goomoolahra

Mundora Creek is a small headwater tributary of the Little Nerang Creek East Branch, emanating from close to the summit of Mt Thillinmam on the NSW/Queensland border. From its source, it traverses northwest for approximately 1km before passing over the Goomoolahra Falls. From the falls, Mundora Creek flows through the rugged Springbrook National Park, converging with the Little Nerang Creek East Branch before entering Little Nerang Dam.

Rationale for site selection

Goomoolahra is within 1km of the origins of the Mundora Creek; hence, the site was expected to contain fauna that are indicative of a relatively pristine stream with minimal disturbance. The site is not pristine, however, with the adjacent land supporting light agriculture and proving a popular spot for day-trippers and picnics. Nonetheless, Goomoolahra was chosen for comparison to more heavily impacted sites further downstream.

Access

The Goomoolahra site is a public access area. Take the Gold Coast-Springbrook Rd, following the signage to the Goomoolahra Falls. The road crosses Mundora Creek (un-signposted culvert adjacent to Goomoolahra Tea Gardens) and terminates at a car park within 100 m.

After passing under the road, Mundora Creek flows parallel to the road for a short distance before deviating off through the picnic area and passing over the falls. The selected sampling site is immediately downstream of the road crossing, and is accessed by climbing down a 1m high rock embankment on the Eastern side of the culvert.

Brief Site Description

At the sampling site, Mundora Creek is shallow and reasonably fast flowing, even during periods of minimal flow. The water was shaded, though the entire reach provides meagre habitat value, comprising largely of bedrock and with minimal hydrological variance. The riparian zone to the North is well vegetated, abutting the border of the Springbrook National Park. The southern riparian zone has undergone slightly greater disturbance, with the construction of a sealed road, car park, a number of buildings and a picnic area.

Summary of Key Geographic Information

GPS	28°13.470'S, 153°17.063'E
Map (1:25000)	"Springbrook" 9541-13, 528000E 6878000N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Parameter	Condition	Score
Upstream agriculture	Minor impact	4
Extractive Industry	Indiscernible impact	5
Urban Influence	Indiscernible impact	5
Point Source Wastewater discharge	Indiscernible impact	5
Upstream regulation	Indiscernible impact	5
Seasonal flow alteration	Indiscernible impact	5
Riparian zone alteration	Minor impact	4
Erosion/stock damage	Indiscernible impact	5
Geomorphic change	Indiscernible impact	5
Instream conditions/habitats	Indiscernible impact	5
	Total	48

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		March 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Fair	8	Poor	2
Embeddedness	Excellent	19	Excellent	19
Velocity/depth category	Fair	10	Fair	8
Channel alteration	Excellent	15	Excellent	15
Bottom scouring/deposition	Excellent	14	Excellent	15
Pool/riffle, run/bend ratio	Fair	4	Fair	5
Bank stability	Excellent	9	Excellent	10
Bank vegetative stability	Excellent	10	Excellent	9
Streamside cover	Excellent	9	Excellent	10
	Total	98		85

Field data - Pool habitat

Parameter		Unit	October 2005	March 2006
Velocity	Min	m/s	0.25	0.75
	Max	m/s	0.25	0.50
Channel	Mean depth	m	0.30	1.00
	Mean width	m	-	4
Width of riparian zone	Left bank	m	3	6
	Right bank	m	>10	>20
Riparian composition	Native	%	85	70
	Exotic	%	15	30
Riparian vegetation	Grass	%	5	0
	Shrubs	%	25	30
	Trees <10m	%	30	0
	Trees >10m	%	40	70
Substrate description	Bedrock	%	80	90
	Boulder	%	0	0
	Cobble	%	0	0
	Pebble	%	0	0
	Gravel	%	15	5
	Sand	%	5	5
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	0	3
	Moss	-	0	2
	Fil. algae	-	0	0
	Macrophytes	-	0	0
	Detritus	-	1	1
Canopy cover		%	90	85
Overhanging vegetation		-	Extensive	Extensive
Trailing vegetation		-	Slight	Nil

Field data – Run habitat

Parameter		Unit	October 2005	March 2006
Velocity	Min	m/s	0.50	0.75
	Max	m/s	0.50	1.00
Channel	Mean depth	m	0.20	0.60
	Mean width	m	1.50	2.3
Width of riparian zone	Left bank	m	2	6
	Right bank	m	>10	>20
Riparian composition	Native	%	85	70
	Exotic	%	15	30
Riparian vegetation	Grass	%	5	5
	Shrubs	%	30	25
	Trees <10m	%	30	0
	Trees >10m	%	35	70
Substrate description	Bedrock	%	65	90
	Boulder	%	0	0
	Cobble	%	0	0
	Pebble	%	10	5
	Gravel	%	15	0
	Sand	%	0	5
	Silt/clay	%	10	0
Substrate cover	Periphyton	-	1	3
	Moss	-	1	3
	Fil. algae	-	0	0
	Macrophytes	-	0	0
	Detritus	-	1	0
Canopy cover		%	70	70
Overhanging vegetation		-	Extensive	Extensive
Trailing vegetation		-	Slight	Slight

Site 2: Lloyds Rd

Purling Brook emanates from the Springbrook Plateau within the Wonburra Range and is a small headwater tributary of the Little Nerang Creek East Branch. The Lloyds road site is at the confluence of Eastern and Western branches of the brook, itself immediately above the Purling Brook Falls. Once over the falls the brook converges with the East branch of the Little Nerang Creek and flows through the Springbrook National Park to the Little Nerang Dam.

Rationale for site selection

The Purling Brook Catchment is relatively small but has undergone slightly greater disturbance than the Mundora Creek Catchment (Goomoolahra site). The greater influence of upstream agriculture and closer proximity to Springbrook were expected to have some influence on invertebrate species assemblages. However, the site still represents a relatively pristine highland waterway. The Western Branch of Purling Brook drains a slightly larger area, however due to the paucity of habitat at the Goomoolahra site (predominantly bedrock) it was decided that there would be benefits in collecting invertebrate data from a second, mildly impacted site, hence the Eastern Branch has been sampled on this occasion.

Access

The Lloyds Rd site is a public access area. From Mudgeeraba, take the Gold Coast-Springbrook Rd through the village of Springbrook. On the outskirts, turn left into Lloyds Rd (sealed and signposted) and park at its terminus. Take the dirt walking track at the end of Lloyds Rd approximately 15m and turn right at the paved Purling Brook Falls Lookout walking track. When the track reaches a small wooden footbridge, proceed to the opposite side, then leave the track and walk upstream to the first pool. The creek is split into two arms at the walking track; sample the first pool on the left branch, facing upstream.

Brief Site Description

Purling Brook is a highland stream, flowing mostly over bedrock in a series of small pools and runs before passing over the falls and into the Springbrook National Park just 50m below the monitoring site. The relatively deep run at the site has a predominantly rocky substrate, but is flanked along both edges by dense vegetative mats that provide shady habitat along the perimeter. On both occasions that the site was sampled tadpoles of several species were plentiful. In Autumn 2006 a large freshwater crayfish of the genus *Euastacus* was caught, photographed and released during the surveys.

Summary of Key Geographic Information

GPS	28°11.424'S, 153°16.274'E
Map	(1:25000) "Springbrook" 9541-13, 526700E 6881300N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Note: The mean score for the October 05 and March/April 06 surveys have been quoted.

Parameter	Condition	Score
Upstream agriculture	Moderate impact	3.0
Extractive Industry	Indiscernible impact	5.0
Urban Influence	Indiscernible impact	5.0
Point Source Wastewater discharge	Indiscernible impact	5.0
Upstream regulation	Indiscernible impact	5.0
Seasonal flow alteration	Indiscernible impact	5.0
Riparian zone alteration	Moderate impact	3.0
Erosion/stock damage	Minor/Indiscernible impact	4.5
Geomorphic change	Indiscernible impact	5.0
Instream conditions/habitats	Minor impact	4.0
Total		44.5

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		March 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Good	12	Poor	5
Embeddedness	Excellent	19	Excellent	18
Velocity/depth category	Excellent	16	Fair	8
Channel alteration	Excellent	15	Excellent	15
Bottom scouring/deposition	Excellent	14	Excellent	15
Pool/riffle, run/bend ratio	Fair	7	Good	9
Bank stability	Excellent	10	Excellent	9
Bank vegetative stability	Excellent	10	Excellent	10
Streamside cover	Good	6	Good	8
Total		109		97

Field data – Edge habitat

Parameter		Unit	October 2005	March 2006
Velocity	Min	m/s	0.05	1.25
	Max	m/s	0.05	0.75
Channel	Mean depth	m	0.25	1.30
	Mean width	m	3	2.0
Width of riparian zone	Left bank	m	20	5
	Right bank	m	20	10
Riparian composition	Native	%	60	80
	Exotic	%	40	20
Riparian vegetation	Grass	%	0	5
	Shrubs	%	60	60
	Trees <10m	%	30	15
	Trees >10m	%	10	20
Substrate description	Bedrock	%	80	85
	Boulder	%	20	0
	Cobble	%	0	15
	Pebble	%	0	0
	Gravel	%	0	0
	Sand	%	0	0
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	4	4
	Moss	-	0	0
	Fil. algae	-	0	0
	Macrophytes	-	0	1
	Detritus	-	1	0
Canopy cover		%	15	20
Overhanging vegetation		-	Nil	Slight
Trailing vegetation		-	Slight	Moderate

Field data – Pool/Bed

Parameter		Unit	October 2005	March 2006
Velocity	Min	m/s	0.10	0.50
	Max	m/s	0.10	0.25
Channel	Mean depth	m	0.50	1.80
	Mean width	m	3	4
Width of riparian zone	Left bank	m	20	>20
	Right bank	m	>20	15
Riparian composition	Native	%	85	90
	Exotic	%	15	10
Riparian vegetation	Grass	%	5	5
	Shrubs	%	30	50
	Trees <10m	%	30	15
	Trees >10m	%	35	30
Substrate description	Bedrock	%	65	50
	Boulder	%	0	0
	Cobble	%	0	25
	Pebble	%	10	0
	Gravel	%	15	0
	Sand	%	0	25
	Silt/clay	%	10	0
Substrate cover	Periphyton	-	1	3
	Moss	-	1	0
	Fil. algae	-	0	0
	Macrophytes	-	0	0
	Detritus	-	1	1
Canopy cover		%	70	30
Overhanging vegetation		-	Extensive	Slight
Trailing vegetation		-	Slight	Slight

Site 3: Boiling Pot

The Boiling Pot site is situated in the mid-reaches of the upper Nerang River, immediately downstream of the village of Numinbah. It is a particularly picturesque site, characterised by the presence of large instream boulders and bedrock projections, causing turbulent flow.

Rationale for site selection

As with the Stafford's Road site, Boiling Pot was selected to enable assessment of the whether catchment activities are resulting in cumulative ecological impacts that become progressively exaggerated with passage downstream. In addition to the generally light agricultural usage in the upper catchment, Boiling Pot is located below the Numinbah Township and the Numinbah Correctional Centre, hence receives minor urban input.

Access

The Boiling Pot site is a public access area. From Nerang, take the Muwillumbah Road past Hinze Dam. Continue past the Gold Coast-Springbrook Road turnoff on the left and drive approximately 2.5 km before turning right into a small, unsealed dirt track. Passing an 80 km/hr speed sign and the Numinbah Hall on the right indicates that the turnoff has been missed. The dirt track travels only 15-20 m before making a right angle turn to the left. Park at this point and walk approximately 10 m down to the river along the unsealed walking track. (Caution: the dirt track is steep and may be slippery after rain. It can be accessed at the other end near the Numinbah Hall if necessary).

Brief Site Description

At Boiling Pot, the Nerang River is a series of permanent runs and riffles, with large boulders and bedrock projecting into the stream and causing turbulent flow. Habitat is relatively diverse, with a substrate of varying size, patches of shaded water and limited overhanging vegetation. The banks are stable and well vegetated, with good riparian zones on both sides. On the western side, the riparian vegetation buffers the creek from agricultural use. Although there was no sign of stock damage to the banks (e.g. pugging), a very strong and distinct manure odour was noted during the March 2006 sampling event.

Summary of Key Geographic Information

GPS	28°08.202'S, 153°13.498'E
Map (1:25000)	"Beechmont" 9541-42, 522150E 6887800N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Parameter	Condition	Score
Upstream agriculture	Moderate impact	3
Extractive Industry	Indiscernible impact	5
Urban Influence	Minor/Indiscernible impact	4.5
Point Source Wastewater discharge	Moderate/Minor impact	3.5
Upstream regulation	Indiscernible impact	5
Seasonal flow alteration	Indiscernible impact	5
Riparian zone alteration	Minor/Indiscernible impact	4.5
Erosion/stock damage	Indiscernible impact	4
Geomorphic change	Indiscernible impact	5
Instream conditions/habitats	Indiscernible impact	5
	Total	44.5

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		April 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Good	15	Excellent	18
Embeddedness	Excellent	20	Good	12
Velocity/depth category	Good	11	Good	8
Channel alteration	Excellent	15	Excellent	15
Bottom scouring/deposition	Excellent	15	Excellent	15
Pool/riffle, run/bend ratio	Good	8	Excellent	12
Bank stability	Excellent	9	Excellent	10
Bank vegetative stability	Excellent	10	Excellent	10
Streamside cover	Good	6	Good	7
	Total	109		107

Field data - Run habitat

Parameter		Unit	October 2005	April 2006
Velocity	Min	m/s	1.00	1.00
	Max	m/s	1.50	1.25
Channel	Mean depth	m	1.15	0.60
	Mean width	m	1	6
Width of riparian zone	Left bank	m	10	15
	Right bank	m	>25	>20
Riparian composition	Native	%	90	60
	Exotic	%	10	40
Riparian vegetation	Grass	%	60	30
	Shrubs	%	10	15
	Trees <10m	%	50	30
	Trees >10m	%	25	25
Substrate description	Bedrock	%	0	15
	Boulder	%	10	15
	Cobble	%	65	50
	Pebble	%	10	15
	Gravel	%	5	2
	Sand	%	10	3
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	1	2
	Moss	-	0	0
	Fil. algae	-	0	0
	Macrophytes	-	0	0
	Detritus	-	1	0
Canopy cover		%	25	30
Overhanging vegetation		-	Slight	Slight
Trailing vegetation		-	Nil	Nil

Field data – Riffle habitat

Parameter		Unit	October 2005	April 2006
Velocity	Min	m/s	0.20	1.25
	Max	m/s	0.20	1.75
Channel	Mean depth	m	0.25	1.20
	Mean width	m	4.0	10
Width of riparian zone	Left bank	m	10	15
	Right bank	m	>25	20
Riparian composition	Native	%	90	60
	Exotic	%	10	40
Riparian vegetation	Grass	%	60	20
	Shrubs	%	10	25
	Trees <10m	%	5	30
	Trees >10m	%	25	25
Substrate description	Bedrock	%	5	15
	Boulder	%	5	15
	Cobble	%	80	50
	Pebble	%	10	15
	Gravel	%	0	2
	Sand	%	0	3
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	2	2
	Moss	-	0	0
	Fil. algae	-	1	0
	Macrophytes	-	0	0
	Detritus	-	1	0
Canopy cover		%	25	30
Overhanging vegetation		-	Moderate	Moderate
Trailing vegetation		-	Nil	Slight

Site 4: Education Centre

This site is the lowest altitude Nerang River site in this program, and is located immediately above the Nerang River arm of the Hinze Dam. At this point, the river is somewhat wider, deeper and flatter than at the higher altitude sites, resulting in a reduced water velocity. As a result, macrophytes become a major component of aquatic habitat at this point.

Rationale for site selection

The Education Centre site represents the lowermost site on the Nerang River prior to its discharge into Hinze Dam, hence represents the pinnacle of cumulative land use impacts on the aquatic ecosystem. The diversity of habitat types at this point is a feature that is maximises the power of the invertebrate assessment.

At the time of site selection, it was believed that this site would be above the influence of backing up when the dam is near to full. However, although the water was clearly flowing during the March/April 2007 sampling event, backing up from the dam resulted in deep water and rendered the site unsafe. In this instance, the 'Fire Trail' site was sampled as the closest accessible upstream point.

Access

From Nerang, take the Murwillumbah Rd past Hinze dam and continue until the first bridge over the Nerang River is reached. Turn left immediately after the bridge and follow the well made gravel road until it turns hard right towards the education centre (a gate at this point prohibits access to unauthorised personnel. Park at this point, cross a small drainage ditch and walk down the dirt vehicle track until the remains of the old bridge are reached. The river can be crossed at this point by using the many exposed rocks as stepping-stones. Once across the river, continue downstream approximately 50 m to the sampling site. (Note: If high water prohibits crossing the river, at this point the site should not be sampled. In this event, the 'Fire Trail' site remains accessible and should be substituted.

Brief Site Description

Habitat at the Education Centre site is relatively diverse, with rocky substrate or varying sizes, large patches of macrophytes, submerged grasses and a range of hydrological regimes. The river is wide here relative to the sites further upstream, and is virtually devoid of any shading from overhanging vegetation.

Summary of Key Geographic Information

GPS	28°06.257'S, 153°14.497'E
Map (1:25000)	"Canungra" 9541-41, 524300E 6890800N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Parameter	Condition	Score
Upstream agriculture	Minor impact	4
Extractive Industry	Indiscernible impact	5
Urban Influence	Indiscernible impact	5
Point Source Wastewater discharge	Indiscernible impact	5
Upstream regulation	Indiscernible impact	5
Seasonal flow alteration	Indiscernible impact	5
Riparian zone alteration	Minor impact	4
Erosion/stock damage	Indiscernible impact	5
Geomorphic change	Indiscernible impact	5
Instream conditions/habitats	Indiscernible impact	5
	Total	48

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		March 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Excellent	19	Site unsafe for sampling in Autumn 2006	
Embeddedness	Excellent	17		
Velocity/depth category	Excellent	18		
Channel alteration	Excellent	14		
Bottom scouring/deposition	Excellent	14		
Pool/riffle, run/bend ratio	Good	10		
Bank stability	Excellent	10		
Bank vegetative stability	Excellent	10		
Streamside cover	Fair	5		
	Total	117		

Field data – Pool/Edge habitat

Parameter		Unit	October 2005
Velocity	Min	m/s	<0.05
	Max	m/s	<0.05
Channel	Mean depth	m	0.40
	Mean width	m	10.0
Width of riparian zone	Left bank	m	100
	Right bank	m	50
Riparian composition	Native	%	70
	Exotic	%	30
Riparian vegetation	Grass	%	40
	Shrubs	%	20
	Trees <10m	%	20
	Trees >10m	%	20
Substrate description	Bedrock	%	15
	Boulder	%	20
	Cobble	%	20
	Pebble	%	15
	Gravel	%	15
	Sand	%	15
	Silt/clay	%	0
Substrate cover	Periphyton	-	3
	Moss	-	0
	Fil. algae	-	1
	Macrophytes	-	2
	Detritus	-	1
Canopy cover		%	0
Overhanging vegetation		-	Slight
Trailing vegetation		-	Nil

Field data – Macrophyte habitat

Parameter		Unit	October 2005
Velocity	Min	m/s	<0.05
	Max	m/s	<0.05
Channel	Mean depth	m	0.5
	Mean width	m	10.0
Width of riparian zone	Left bank	m	100
	Right bank	m	50
Riparian composition	Native	%	70
	Exotic	%	30
Riparian vegetation	Grass	%	40
	Shrubs	%	20
	Trees <10m	%	20
	Trees >10m	%	20
Substrate description	Bedrock	%	0
	Boulder	%	0
	Cobble	%	0
	Pebble	%	0
	Gravel	%	50
	Sand	%	50
	Silt/clay	%	0
Substrate cover	Periphyton	-	3
	Moss	-	0
	Fil. algae	-	0
	Macrophytes	-	4
	Detritus	-	0
Canopy cover		%	0
Overhanging vegetation		-	Nil
Trailing vegetation		-	Nil

Site 5: Staffords Road

Above and below the Stafford's Road monitoring site the Nerang River widens and deepens into smooth water, relatively slower flowing pool, flanked on both sides by agricultural land and with minimal riparian zone. The site was observed during sampling to be used recreationally for bathing, canoeing and angling.

Rationale for site selection

A characteristic of all streams is a progressive change in invertebrate species assemblages as the waterway passes from higher to lower altitude. This is in part a natural shift due as the stream transforms from a fast flowing, clear highland waterway to a slower flowing, more turbid lowland system. However, such shifts can also be the result of landuse activities such as urbanisation. The Stafford's Road site is between the origin of the river and Hinze Dam hence was chosen to assist in mapping any gradual shifts in species assemblages due to both natural and anthropogenic influences.

Access

The Stafford's Road site is accessible to the public. From Nerang, take the Murwillumbah Road past Hinze Dam and continue past the Numinbah Correctional Centre on the right hand side. Staffords Road is a well-made gravel road on the left hand side, approximately 500 m after the correctional centre entrance. Follow the road until a low concrete bridge is reached. The sampling point is immediately upstream of the bridge structure.

Brief Site Description

The Stafford's Road site is relatively depauperate in terms of habitat diversity, with little variation flow rate, substrate type, stream width, depth etc for some distance both upstream and downstream of the sampling point. The river at this point is relatively wide and slow flowing with sparse patches of macrophytes. However, even moderately elevated flows create conditions at the site that are more typical of a run.

Summary of Key Geographic Information

GPS	28°09.918'S, 153°13.297'E
Map (1:25000)	"Beechmont" 9541-42, 521750E 6884500N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Parameter	Condition	Score
Upstream agriculture	Minor impact	2.5
Extractive Industry	Indiscernible impact	5
Urban Influence	Indiscernible impact	5
Point Source Wastewater discharge	Indiscernible impact	5
Upstream regulation	Indiscernible impact	5
Seasonal flow alteration	Indiscernible impact	5
Riparian zone alteration	Minor impact	4
Erosion/stock damage	Indiscernible impact	4.5
Geomorphic change	Indiscernible impact	5
Instream conditions/habitats	Indiscernible impact	4
	Total	45

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		April 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Excellent	18	Excellent	18
Embeddedness	Good	13	Excellent	18
Velocity/depth category	Poor	4	Poor	4
Channel alteration	Excellent	15	Excellent	15
Bottom scouring/deposition	Excellent	15	Excellent	14
Pool/riffle, run/bend ratio	Poor	3	Poor	3
Bank stability	Excellent	9	Excellent	9
Bank vegetative stability	Excellent	10	Excellent	10
Streamside cover	Good	6	Good	6
	Total	93		98

Field data – Pool/Run habitat

Parameter		Unit	October 2005	April 2006
Velocity	Min	m/s	<0.05	0.10
	Max	m/s	<0.05	0.25
Channel	Mean depth	m	0.45	0.60
	Mean width	m	10.0	12
Width of riparian zone	Left bank	m	5	5
	Right bank	m	5	5
Riparian composition	Native	%	60	20
	Exotic	%	40	80
Riparian vegetation	Grass	%	30	40
	Shrubs	%	15	35
	Trees <10m	%	25	10
	Trees >10m	%	30	15
Substrate description	Bedrock	%	0	0
	Boulder	%	10	0
	Cobble	%	60	75
	Pebble	%	30	25
	Gravel	%	0	0
	Sand	%	0	0
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	2	1
	Moss	-	0	0
	Fil. algae	-	0	0
	Macrophytes	-	0	1
	Detritus	-	1	1
Canopy cover		%	10	5
Overhanging vegetation		-	Moderate	Slight
Trailing vegetation		-	Slight	Slight

Site 6: Cave Creek

Cave Creek is a small tributary of the upper Nerang River and emanates within 1 km of the Nerang River. The actual sampling site is on the Nerang River immediately below its confluence with Cave Creek. This is the highest site on the Nerang River, being approximately 7.1 km from its source on the southern slopes of Mt Merino. From this point, the river continues to flow in a northerly direction through the Numinbah Valley.

Rationale for site selection

The Cave Creek site was selected for access and close proximity to the source of the Nerang River. At this point, the river flows permanently and has had minimal exposure to population centres or catchment landuse activities, and is hence as close to pristine as possible.

Access

Access to the Cave Creek requires passage through private property. Take the Murwillumbah Road from Nerang, passing Hinze Dam on the left and the Numinbah Correctional Centre on the right. Continue to where the road crosses Cave Creek and turn left into the property marked “Glen Tumble” (private property) immediately after the Cave Creek Bridge. The private road crosses the Nerang River approximately 50 m from the Murwillumbah Road. Walk downstream to the sampling site.

Caution: The paddocks adjacent to the sampling site sometimes contain ostriches. These animals may be aggressive toward intruders. An inquisitive bull has also been known to interfere with field-based operations at this site.

Brief Site Description

Habitat is diverse at the Cave Creek site, with pool, riffle and run habitat available, along with extensive macrophyte beds. The sampling site is immediately downstream of the confluence with Cave Creek, a minor tributary. The main pool is relatively large and in many places too deep for wading. The steep eastern bank is well vegetated, although the Murwillumbah Rd cuts quite close to the River at this point. The eastern bank appears to harbour excellent habitat, with large rock and tree roots protruding into the water, whilst overhanging trees provide shading. The western bank, though largely cleared for agriculture, is quite stable as a result of plentiful grasses and exotic vegetation. The western bank is lightly grazed though there is no sign of stock damage to the banks.

Riffle habitat exists immediately downstream of the pool. the river breaking into several small channels and flowing between a combination of terrestrial and riparian flora species studded throughout a rock and boulder strewn substrate. These islands of vegetation and rock become submerged during periods of elevated flow.

Summary of Key Geographic Information

GPS	28°12.711'S, 153°147.002'E
Map (1:25000)	"Springbrook" 9541-13, 528000E 6878000N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Parameter	Condition	Score
Upstream agriculture	Moderate/Minor impact	3.5
Extractive Industry	Indiscernible impact	5
Urban Influence	Indiscernible impact	5
Point Source Wastewater discharge	Indiscernible impact	5
Upstream regulation	Indiscernible impact	5
Seasonal flow alteration	Minor/Indiscernible impact	4.5
Riparian zone alteration	Moderate impact	3.5
Erosion/stock damage	Minor impact	4
Geomorphic change	Indiscernible impact	4
Instream conditions/habitats	Minor/Indiscernible impact	4.5
	Total	44

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		April 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Excellent	18	Excellent	18
Embeddedness	Good	14	Good	13
Velocity/depth category	Good	15	Excellent	16
Channel alteration	Excellent	15	Good	11
Bottom scouring/deposition	Excellent	14	Excellent	12
Pool/riffle, run/bend ratio	Excellent	12	Excellent	12
Bank stability	Good	6	Good	6
Bank vegetative stability	Good	8	Good	8
Streamside cover	Fair	5	Good	6
	Total	107		102

Field data - Pool habitat

Parameter		Unit	October 2005	April 2006
Velocity	Min	m/s	<0.05	0.10
	Max	m/s	<0.05	0.25
Channel	Mean depth	m	1.00	0.7
	Mean width	m	15	15
Width of riparian zone	Left bank	m	25	15
	Right bank	m	10	10
Riparian composition	Native	%	30	40
	Exotic	%	70	60
Riparian vegetation	Grass	%	50	40
	Shrubs	%	5	10
	Trees <10m	%	10	5
	Trees >10m	%	35	45
Substrate description	Bedrock	%	0	0
	Boulder	%	20	10
	Cobble	%	60	50
	Pebble	%	10	20
	Gravel	%	0	10
	Sand	%	10	10
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	1	2
	Moss	-	0	0
	Fil. algae	-	0	0
	Macrophytes	-	2	1
	Detritus	-	-	1
Canopy cover		%	25	35
Overhanging vegetation		-	Slight	Slight
Trailing vegetation		-	Nil	Slight

Field data – Riffle habitat

Parameter		Unit	October 2005	April 2006
Velocity	Min	m/s	0.40	1.00
	Max	m/s	1.00	1.00
Channel	Mean depth	m	0.10	0.20
	Mean width	m	6.0	2.0
Width of riparian zone	Left bank	m	20	15
	Right bank	m	15	10
Riparian composition	Native	%	25	30
	Exotic	%	75	70
Riparian vegetation	Grass	%	70	45
	Shrubs	%	15	5
	Trees <10m	%	5	5
	Trees >10m	%	10	45
Substrate description	Bedrock	%	0	15
	Boulder	%	45	25
	Cobble	%	35	25
	Pebble	%	5	20
	Gravel	%	0	15
	Sand	%	0	0
	Silt/clay	%	15	0
Substrate cover	Periphyton	-	1	2
	Moss	-	0	0
	Fil. algae	-	1	0
	Macrophytes	-	2	0
	Detritus	-	1	0
Canopy cover		%	0	0
Overhanging vegetation		-	Nil	Nil
Trailing vegetation		-	Nil	Nil

Site 7: Little Nerang

The Little Nerang site is situated on the Little Nerang Creek between the Little Nerang Dam and Hinze Dam. It is nestled close to the Gold Coast – Springbrook Road, at the foot of Nimmel Mountain. The river is essentially fed by flow releases from the Little Nerang Dam approximately 2-3 km upstream of the sampling site. From the dam wall, the Creek passes through a relatively steep gorge. During rainfall events receives limited catchment pickup from a number of very small tributaries on both the Wunburra and Nimmel sides of the gorge. Immediately above the site, the Gold Coast – Springbrook Road winds its way towards Salmons Saddle, hence it is likely that pollutant-laden runoff finds its way into the Little Nerang Creek above the sampling site.

Reason for site selection

The Little Nerang site is immediately above the influence Hinze Dam; hence, data collected at the site allow an 'end of system' assessment of ecological health for the Little Nerang Creek. The close proximity of the Little Nerang Dam and the Gold Coast – Springbrook Road also provide an opportunity to test the impact of river regulation and road pollution on ecosystem health.

Access

The Little Nerang Site is situated on land owned by Gold Coast Water. From Mudgeeraba, travel southwards on the Gold Coast – Springbrook Road, crossing the Mudgeeraba Creek via a one lane bridge. The road then winds uphill for approximately 2 km before a right hand turn at a gated track entering GCW property (a key is required for vehicular access). Once through the gate, the track fords the Little Nerang Creek, then turns right and follows the creek. Continue to the right at all junctures; the track terminates at the sampling site.

Brief Site Description

Habitat at this site is relatively diverse. Upstream, a large pool of sufficient depth to be unwadeable, even during low flows, provides rocky substrate with occasional large woody debris and patches of submerged macrophytes. Downstream, riffles and runs provide faster flowing water over rocky substrates strewn with boulders. Riparian vegetation and bank stability are excellent at this site, although the abundance of exotic vegetation is relatively high, as was observed at other sites during this study.

Summary of Key Geographic Information

GPS	28°06.912'S, 153°18.148'E
Map (1:25000)	"Mudgeeraba" 9541-14, 529800E 6889800N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Parameter	Condition	Score
Upstream agriculture	Minor/Indiscernible impact	4.5
Extractive Industry	Indiscernible impact	5
Urban Influence	Minor/Indiscernible impact	4.5
Point Source Wastewater discharge	Indiscernible impact	5
Upstream regulation	Major/Moderate impact	2.5
Seasonal flow alteration	Indiscernible impact	3.5
Riparian zone alteration	Moderate/Minor impact	4
Erosion/stock damage	Indiscernible impact	5
Geomorphic change	Minor/Indiscernible impact	4.5
Instream conditions/habitats	Indiscernible impact	5
	Total	44

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		March 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Excellent	18	Excellent	19
Embeddedness	Good	13	Excellent	16
Velocity/depth category	Fair	10	Excellent	16
Channel alteration	Excellent	15	Excellent	13
Bottom scouring/deposition	Excellent	15	Excellent	12
Pool/riffle, run/bend ratio	Good	10	Good	8
Bank stability	Excellent	9	Good	8
Bank vegetative stability	Excellent	10	Excellent	10
Streamside cover	Good	7	Excellent	9
	Total	107		111

Field data - Pool habitat

Parameter		Unit	October 2005	March 2006
Velocity	Min	m/s	<0.05	1.25
	Max	m/s	<0.05	1.5
Channel	Mean depth	m	1.0	1.20
	Mean width	m	15	10
Width of riparian zone	Left bank	m	15	>20
	Right bank	m	5	5
Riparian composition	Native	%	80	70
	Exotic	%	20	30
Riparian vegetation	Grass	%	0	20
	Shrubs	%	20	30
	Trees <10m	%	20	20
	Trees >10m	%	60	30
Substrate description	Bedrock	%	10	0
	Boulder	%	30	0
	Cobble	%	30	85
	Pebble	%	20	5
	Gravel	%	5	5
	Sand	%	5	5
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	0	2
	Moss	-	0	0
	Fil. algae	-	0	0
	Macrophytes	-	1	1
	Detritus	-	2	1
Canopy cover		%	5	5
Overhanging vegetation		-	Nil	Slight
Trailing vegetation		-	Slight	Slight

Field data - Riffle habitat

Parameter		Unit	October 2005	March 2006
Velocity	Min	m/s	0.50	2.00
	Max	m/s	1.20	2.50
Channel	Mean depth	m	1.20	0.40
	Mean width	m	2.0	2.0
Width of riparian zone	Left bank	m	25	>20
	Right bank	m	15	10
Riparian composition	Native	%	100	70
	Exotic	%	0	30
Riparian vegetation	Grass	%	75	20
	Shrubs	%	15	40
	Trees <10m	%	15	20
	Trees >10m	%	5	20
Substrate description	Bedrock	%	0	0
	Boulder	%	15	20
	Cobble	%	80	75
	Pebble	%	5	5
	Gravel	%	0	0
	Sand	%	0	0
	Silt/clay	%	0	0
Substrate cover	Periphyton	-	2	2
	Moss	-	0	0
	Fil. algae	-	0	0
	Macrophytes	-	1	1
	Detritus	-	2	0
Canopy cover		%	45	35
Overhanging vegetation		-	Moderate	Moderate
Trailing vegetation		-	Slight	Moderate

Site 8: Fire Trail

This site is a lowest altitude Nerang River site, comprising almost entirely deep pool habitat, most of which is too deep to wade. The northwestern bank is particularly steep and provides numerous minor inflows from tributaries typically arising within a few kilometres of the Nerang River on the Southern slopes of the Beechmont Range.

Reason for site selection

The Fire Trail site was sampled as a substitute for the Education Centre site during periods of elevated water level. The site essentially provides an 'end-of-catchment' assessment of ecosystem health for the unregulated portion of the Nerang River. Unlike the Education Centre site, it is unlikely to receive significant inputs of road pollution.

Access

From Nerang, take the Murwillumbah Road to the bridge over the Nerang River. Proceed a further 300 m and turn right into a gated fire trail and park. After crossing the gate, continue down the trail on foot for approximately 250-300 m. The track terminates at the sampling site.

Brief Site Description

The river is quite wide and slow flowing, essentially a large pool with cobble substrate, patches of dense submergent macrophytes and occasional woody debris. The North Western bank is steep and is densely vegetated, although there is a significant proportion of an invasive vine. The riparian zone on this side is very wide and provides some trailing and overhanging branches.

The south eastern bank is somewhat flatter adjacent to the river, but becomes progressively steeper towards the road. A small tributary creek enters the pool at the sampling site and is densely flanked with reeds and terrestrial grasses.

Summary of Key Geographic Information

GPS	28°06.598'S, 153°14.177'E
Map (1:25000)	"Mudgeeraba" 9541-14, 523300E 6890600N
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Reference condition assessment

Parameter	Condition	Score
Upstream agriculture	Minor/Indiscernible impact	4
Extractive Industry	Indiscernible impact	5
Urban Influence	Minor/Indiscernible impact	5
Point Source Wastewater discharge	Indiscernible impact	4
Upstream regulation	Major/Moderate impact	5
Seasonal flow alteration	Indiscernible impact	5
Riparian zone alteration	Moderate/Minor impact	5
Erosion/stock damage	Indiscernible impact	5
Geomorphic change	Minor/Indiscernible impact	5
Instream conditions/habitats	Indiscernible impact	5
	Total	48

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	October 2005		April 2006	
	Assessment	Score	Assessment	Score
Bottom substrate/ available cover	Site not sampled		Excellent	18
Embeddedness			Good	14
Velocity/depth category			Poor	3
Channel alteration			Excellent	15
Bottom scouring/deposition			Excellent	15
Pool/riffle, run/bend ratio			Poor	2
Bank stability			Excellent	9
Bank vegetative stability			Excellent	10
Streamside cover			Excellent	9
	Total			95

Field data - Pool habitat

Parameter		Unit	October 2005	April 2006
Velocity	Min	m/s	-	0.10
	Max	m/s	-	0.20
Channel	Mean depth	m	-	0.20
	Mean width	m	-	15.0
Width of riparian zone	Left bank	m	-	>20
	Right bank	m	-	>100
Riparian composition	Native	%	-	60
	Exotic	%	-	40
Riparian vegetation	Grass	%	-	30
	Shrubs	%	-	15
	Trees <10m	%	-	15
	Trees >10m	%	-	40
Substrate description	Bedrock	%	-	0
	Boulder	%	-	0
	Cobble	%	-	30
	Pebble	%	-	50
	Gravel	%	-	10
	Sand	%	-	10
	Silt/clay	%	-	0
Substrate cover	Periphyton	-	-	3
	Moss	-	-	0
	Fil. algae	-	-	0
	Macrophytes	-	-	1
	Detritus	-	-	1
Canopy cover		%	-	10
Overhanging vegetation		-	-	Slight
Trailing vegetation		-	-	Slight

Site 9: Bird Aviary

This site represents the most upstream site of the Nerang River, below Hinze Dam.

Reason for site selection

Bird Aviary site was sampled as a site in the Nerang River below the Hinze Dam. Only one season of sampling (13 April 2007) was carried out as part of the Hinze Dam Stage 3 EIS. This site was one of few sites along this section of river that exhibited the habitat characteristics required by the AusRIVAS models.

Access

The site was accessed via kayak during fish habitat and barrier assessment. This site may otherwise be accessed by road. However permission for access from private property would have to be sought. The closest property to the site is 181 Latimers Crossing Road and there may be access from Gilston (Hinze Dam) Road. Access via these routes cannot be ascertained at the time of reporting.

Brief Site Description

The river is quite narrow and shallow, essentially a run with cobble/pebble substrate along a meandering channel. Overhanging vegetation consisted predominantly of large trees and the banks were covered in thick mats of the exotic Singapore Daisy (*Sphagneticola trilobata).* There as little buffer or riparian zone between, the (possibly commercial) bird breeding aviaries (~200m upstream of sampling site). The influence of the intensive bird breeding is unknown. Litter in the form of metal drums and car tyres were prevalent along this stretch of river. Unlike other sites used within this reach, this site was remote from roads and therefore has little influence from traffic.

Summary of Key Geographic Information

GPS	28°01.948'S, 153°17.894'E
Map	Brisbane UBD Refidex (2006) Map 46 N1
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	**April 2007**	
	Assessment	**Score**
Bottom substrate/ available cover	Excellent	20
Embeddedness	Excellent	17
Velocity/depth category	Fair	9
Channel alteration	Excellent	15
Bottom scouring/deposition	Excellent	15
Pool/riffle, run/bend ratio	Fair	7
Bank stability	Excellent	10
Bank vegetative stability	Excellent	10
Streamside cover	Good	6
	Total	109

Field data - Edge habitat

Parameter		Unit	April 2007
Velocity	Min	m/s	1.00
	Max	m/s	1.00
Channel	Mean depth	m	0.20
	Mean width	m	6.0
Width of riparian zone	Left bank	m	>100
	Right bank	m	>50
Riparian composition	Native	%	20
	Exotic	%	80
Riparian vegetation	Grass	%	0
	Shrubs	%	2
	Trees <10m	%	5
	Trees >10m	%	93
Substrate description	Bedrock	%	0
	Boulder	%	0
	Cobble	%	70
	Pebble	%	25
	Gravel	%	5
	Sand	%	0
	Silt/clay	%	0
Substrate cover	Periphyton	-	4
	Moss	-	0
	Fil. algae	-	4
	Macrophytes	-	3
	Detritus	-	3
Canopy cover		%	70
Overhanging vegetation		-	Slight
Trailing vegetation		-	Slight

Field data - Riffle habitat

Parameter		Unit	April 2007
Velocity	Min	m/s	1.00
	Max	m/s	1.00
Channel	Mean depth	m	0.20
	Mean width	m	5.0
Width of riparian zone	Left bank	m	>100
	Right bank	m	>50
Riparian composition	Native	%	20
	Exotic	%	80
Riparian vegetation	Grass	%	0
	Shrubs	%	2
	Trees <10m	%	5
	Trees >10m	%	93
Substrate description	Bedrock	%	0
	Boulder	%	0
	Cobble	%	70
	Pebble	%	25
	Gravel	%	5
	Sand	%	0
	Silt/clay	%	0
Substrate cover	Periphyton	-	4
	Moss	-	0
	Fil. algae	-	4
	Macrophytes	-	2
	Detritus	-	3
Canopy cover		%	70
Overhanging vegetation		-	Slight
Trailing vegetation		-	Slight

Site 10: Golf Course

This site is situated along the Nerang River below Hinze Dam. Representing the second site along this reach it is located on the grounds of the Grand Golf Club in Advancetown. The stretch of river is maintained by the club for mainly aesthetic reasons. The club actively remove aquatic weeds by means or spraying with herbicide. It is for this reason that this section of the river is largely free from weeds. The survey site was on the upstream side of a road bridge

Reason for site selection

The Golf Coarse was sampled as it was easily accessible by car and it was less impacted from weed infestations compared to other sections of the Nerang River, below Hinze Dam. It also exhibited habitat types required for the AusRivAS models.

Access

From Nerang, take Gilston Road. Turn right into Private Rd at a small roundabout. This is not well signed and the road was recognised by a new housing development at the time of surveying. The road winds down hill until the bridge across the Nerang River. Park on the right before the bridge. Sample the riffle and edge habitat to upstream (left hand side) of the bridge. Beware of cars using the bridge.

Brief Site Description

The river is quite wide and slow flowing, essentially a large cobble substrate with some fine sediments supporting moderate instream vegetation. Riparian zone was narrow and vegetation consisted mostly of exotic trees such as Willow (*Salix* sp.). There was a build up of vegetation and rock immediately upstream of the bridge culvert. Recently lopped trees had been placed under the bridge also.

Summary of Key Geographic Information

GPS	28°00.51.67'S, 153°18 28.25'E
Map	Brisbane UBD Refidex (2006) Map 36 N13
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	April 2007	
	Assessment	**Score**
Bottom substrate/ available cover	Excellent	18
Excellent	Excellent	16
Velocity/depth category	Poor	2
Channel alteration	Excellent	13
Bottom scouring/deposition	Excellent	4
Pool/riffle, run/bend ratio	Poor	3
Bank stability	Excellent	10
Bank vegetative stability	Excellent	10
Streamside cover	Good	6
	Total	82

Field data - Edge habitat

Parameter		Unit	April 2007
Velocity	Min	m/s	0.25
	Max	m/s	0.25
Channel	Mean depth	m	0.45
	Mean width	m	18.0
Width of riparian zone	Left bank	m	10
	Right bank	m	10
Riparian composition	Native	%	40
	Exotic	%	60
Riparian vegetation	Grass	%	10
	Shrubs	%	20
	Trees <10m	%	20
	Trees >10m	%	50
Substrate description	Bedrock	%	0
	Boulder	%	0
	Cobble	%	80
	Pebble	%	0
	Gravel	%	0
	Sand	%	0
	Silt/clay	%	20
Substrate cover	Periphyton	-	4
	Moss	-	1
	Fil. algae	-	3
	Macrophytes	-	4
	Detritus	-	3
Canopy cover		%	5
Overhanging vegetation		-	Moderate
Trailing vegetation		-	Slight

Field data – Pool/bed habitat

Parameter		Unit	April 2007
Velocity	Min	m/s	0.25
	Max	m/s	0.25
Channel	Mean depth	m	0.40
	Mean width	m	18.0
Width of riparian zone	Left bank	m	10
	Right bank	m	10
Riparian composition	Native	%	40
	Exotic	%	60
Riparian vegetation	Grass	%	10
	Shrubs	%	20
	Trees <10m	%	20
	Trees >10m	%	50
Substrate description	Bedrock	%	0
	Boulder	%	0
	Cobble	%	80
	Pebble	%	0
	Gravel	%	0
	Sand	%	0
	Silt/clay	%	20
Substrate cover	Periphyton	-	4
	Moss	-	1
	Fil. algae	-	3
	Macrophytes	-	4
	Detritus	-	3
Canopy cover		%	5
Overhanging vegetation		-	Moderate
Trailing vegetation		-	Slight

Site 11: Stevens Bridge

This site represents the most downstream site of the Nerang River system. It is situated in a semi-urban area where future development is likely. Land immediately surrounding the site is used for agriculture and the Nerang Pony Club. Stock have access to the waters edge on at least one bank.

Reason for site selection

This site was selected as it was easily accessible and considered representative of other areas along this reach below Hinze Dam with similar landuse patterns and weed infestations. This site also exhibited the habitat types required for the AusRivAS modelling

Access

From Nerang, take the Beaudesert - Nerang Road and turn left at the intersection to McLaren Road. Drive through one roundabout and Stevens Bridge is directly past the Pony Club. Alternatively, Alexander Drive (M1 Exit 73) turns into McLaren Road of travel from the south. Access to the river by may be required from the private land on the southwest of the bridge. Watch out for cattle and barbed wire fencing.

Brief Site Description

The river is quite narrow, shallow and slow flowing. Essentially a run with cobble substrate, with attached aquatic macrophytes. The riparian is quite broad as it possibly represents the remnant river channel before Hinze Dam as levy banks were present.

Summary of Key Geographic Information

GPS	27°59 52.19'S, 153°18 39.40'E
Map	Brisbane UBD Refidex (2006) Map 36 P6
Rainfall Station	Hinze Dam 040584
Weather Station	Hinze Dam 040584

Habitat Assessment (based on Queensland AusRivAS protocols)

Parameter	April 2007	
	Assessment	**Score**
Bottom substrate/ available cover	Excellent	17
Embeddedness	Good	13
Fair	Poor	9
Channel alteration	Excellent	15
Bottom scouring/deposition	Excellent	15
Pool/riffle, run/bend ratio	Fair	7
Bank stability	Excellent	10
Bank vegetative stability	Excellent	10
Streamside cover	Fair	5
	Total	101

Field data - Edge habitat

Parameter		Unit	April 2007
Velocity	Min	m/s	0.50
	Max	m/s	1.50
Channel	Mean depth	m	0.20
	Mean width	m	5.0
Width of riparian zone	Left bank	m	50
	Right bank	m	70
Riparian composition	Native	%	70
	Exotic	%	30
Riparian vegetation	Grass	%	10
	Shrubs	%	2
	Trees <10m	%	5
	Trees >10m	%	83
Substrate description	Bedrock	%	0
	Boulder	%	5
	Cobble	%	85
	Pebble	%	10
	Gravel	%	0
	Sand	%	0
	Silt/clay	%	0
Substrate cover	Periphyton	-	3
	Moss	-	0
	Fil. algae	-	0
	Macrophytes	-	3
	Detritus	-	0
Canopy cover		%	5
Overhanging vegetation		-	Slight
Trailing vegetation		-	Slight

Field data - Riffle habitat

Parameter		Unit	April 2007
Velocity	Min	m/s	0.50
	Max	m/s	1.50
Channel	Mean depth	m	0.20
	Mean width	m	5.0
Width of riparian zone	Left bank	m	50
	Right bank	m	70
Riparian composition	Native	%	70
	Exotic	%	30
Riparian vegetation	Grass	%	10
	Shrubs	%	2
	Trees <10m	%	5
	Trees >10m	%	83
Substrate description	Bedrock	%	0
	Boulder	%	5
	Cobble	%	85
	Pebble	%	10
	Gravel	%	0
	Sand	%	0
	Silt/clay	%	0
Substrate cover	Periphyton	-	3
	Moss	-	0
	Fil. algae	-	0
	Macrophytes	-	1
	Detritus	-	0
Canopy cover		%	5
Overhanging vegetation		-	Slight
Trailing vegetation		-	Slight