

Chapter 11 Aquatic ecology

This chapter considers the impact of the Proposal on aquatic ecology and fisheries resources. It documents the ecosystems of waterways existing in the path of the Proposal (including the fisheries resources), the likely impact of the Proposal on those habitats, and measures to mitigate impacts related to construction activities and longer term habitat loss.

11.1 Method of assessment

The study area for aquatic ecology investigations focussed on the six perennial waterways and intermittent creek-lines to be traversed by the Proposal. The perennial waterways are:

- Stewarts River
- Passionfruit Gully
- Stony Creek
- Camden Haven River
- Walkers Creek
- Herons Creek.

Detailed investigation of the aquatic ecology in waterways located within the EIS study area was carried out by The Ecology Lab. These investigations included the collection of data on fish, mobile invertebrates, water quality and aquatic habitat; an assessment of impacts based on these data; an Eight Part Test analysis for the Black Cod (*Epinephelus daemelli*); and identification of mitigation measures in planning, construction and operational phases of the Proposal.

Field sampling was undertaken in November 2001 for aquatic biota (i.e. fish and mobile invertebrates). Combinations of qualitative and quantitative sampling techniques were employed. An analysis of commercial and recreational fishing activities was based on published documents relevant to the area and verbal communication with a local commercial fisheries representative. Figure 11-1 shows the location and type of field sampling carried out within the study area.

Further detail on the material described in this chapter is provided in Working Paper No. 6.

11.2 Existing aquatic ecology characteristics

11.2.1 Aquatic habitat

The waterways in the study area comprise both freshwater and estuarine habitats and contain a variety of habitat features including snags, macrophyte beds, and pools of standing water, together with mangrove stands and seagrass beds in the Camden Haven River.

The grading applied follows the DPI classification system from Class 1 (major fish habitat) through to Class 4 (unlikely fish habitat) (see Table 11–1). These habitat classifications, the corresponding waterways of the study area and their habitat features are summarised in Table 11–1 and described below. Figure 11-2 illustrates the location of classified waterways in the study area.

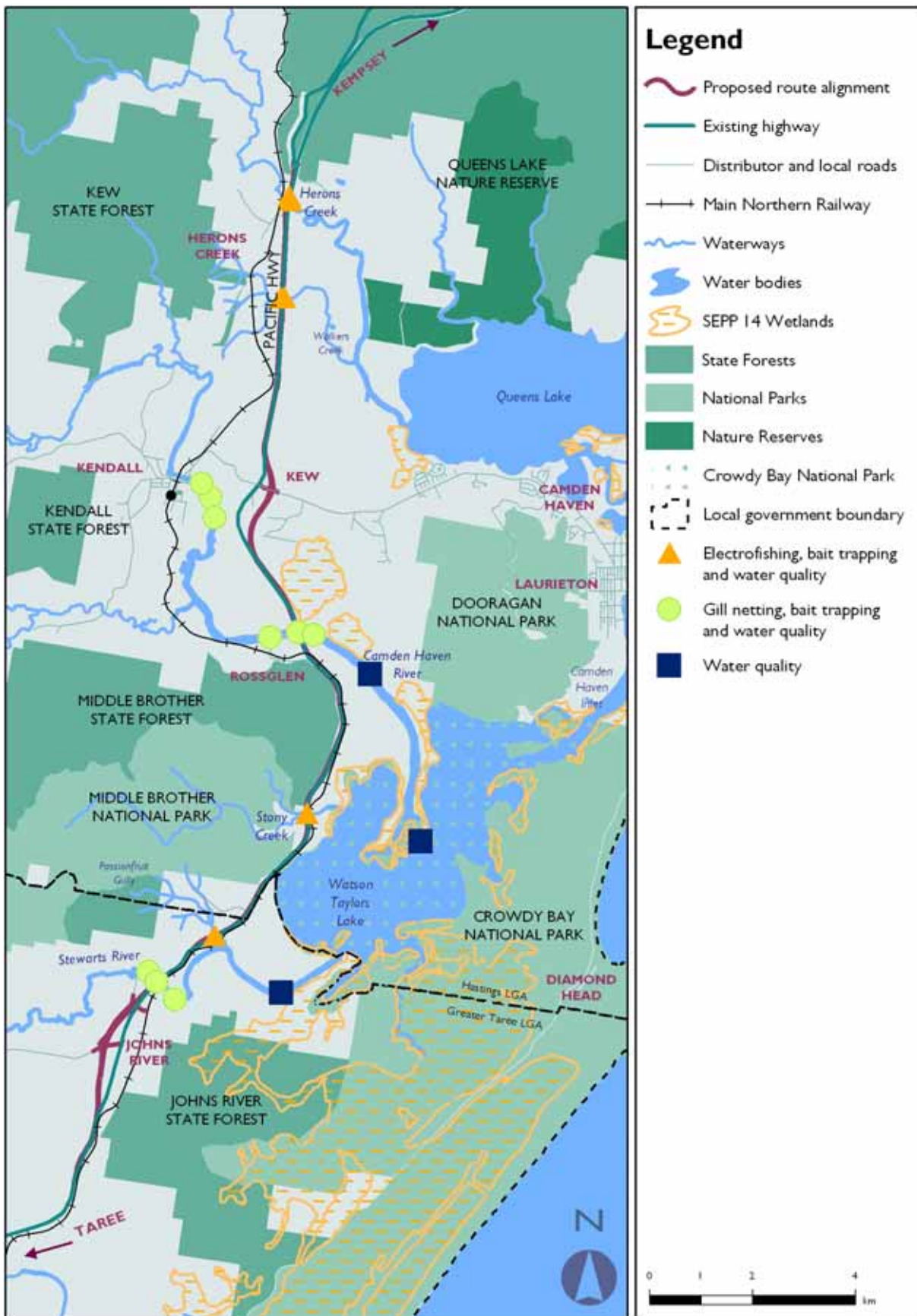


Figure 11-1 Aquatic ecology and water quality sampling locations

Table 11-1 Waterways classifications

Class	Type	Minimum preferred engineering solution	Waterways within study area
Class 1	Major Fish Habitat - large, named and permanently flowing streams, creeks or rivers. Known fish habitat, 'critical habitat' for threatened species (as defined under the TSC Act) or marine or freshwater aquatic vegetation is known to exist, or fish have been observed in these waterways.	Bridge or tunnel crossing only. Preformed spans or arches are the preferred option (up to 30 m width of streams) to minimise instream construction impacts, including foundations.	Stewarts River Camden Haven River Herons Creek
Class 2	Moderate Fish Habitat - smaller, named, permanent or intermittent streams, creeks or watercourses with clearly defined drainage channels, semi-permanent to permanent waters in pools or are connected to wetlands. Marine or freshwater aquatic vegetation is present and there is known fish habitat and/or fish are observed inhabiting the waterway.	A large box culvert or a bridge crossing. Cross-sectional area of structure should aim to equal the existing cross-sectional area of the watercourse at the culvert location.	Stony Creek Walkers Creek
Class 3	Minimal Fish Habitat - named or unnamed watercourses with intermittent flows. They contain potential refuge, breeding or feeding areas for some aquatic fauna such as fish or yabbies. The watercourse interconnects with wetlands or stream habitat and usually contains semi-permanent pools, ponds, and farm dams nearby or forms the watercourse after a rainfall incident.	Culverts required and designed to allow fish passage. Invert should be designed to ensure it is below the bed level of the watercourse, and that ponding can occur where possible.	Passionfruit Gully Small tributary of Herons Creek
Class 4	Unlikely Fish Habitat – named or unnamed watercourses with intermittent flows only during rain events, have little or no defined drainage channels, and little or no free standing water pools after the rain event finishes. There is no aquatic or wetland vegetation present in these habitats.	Causeway, floodway, or culvert with allowance for flow of water to downstream areas unhindered.	Unnamed waterways at Yaralin, 750 m north of Algona Road, 200 m south of Haydens Road, south of Ross Glen Road, and at Christmas Hill

Source: NSW Fisheries (now DPI) classifications, 1999a

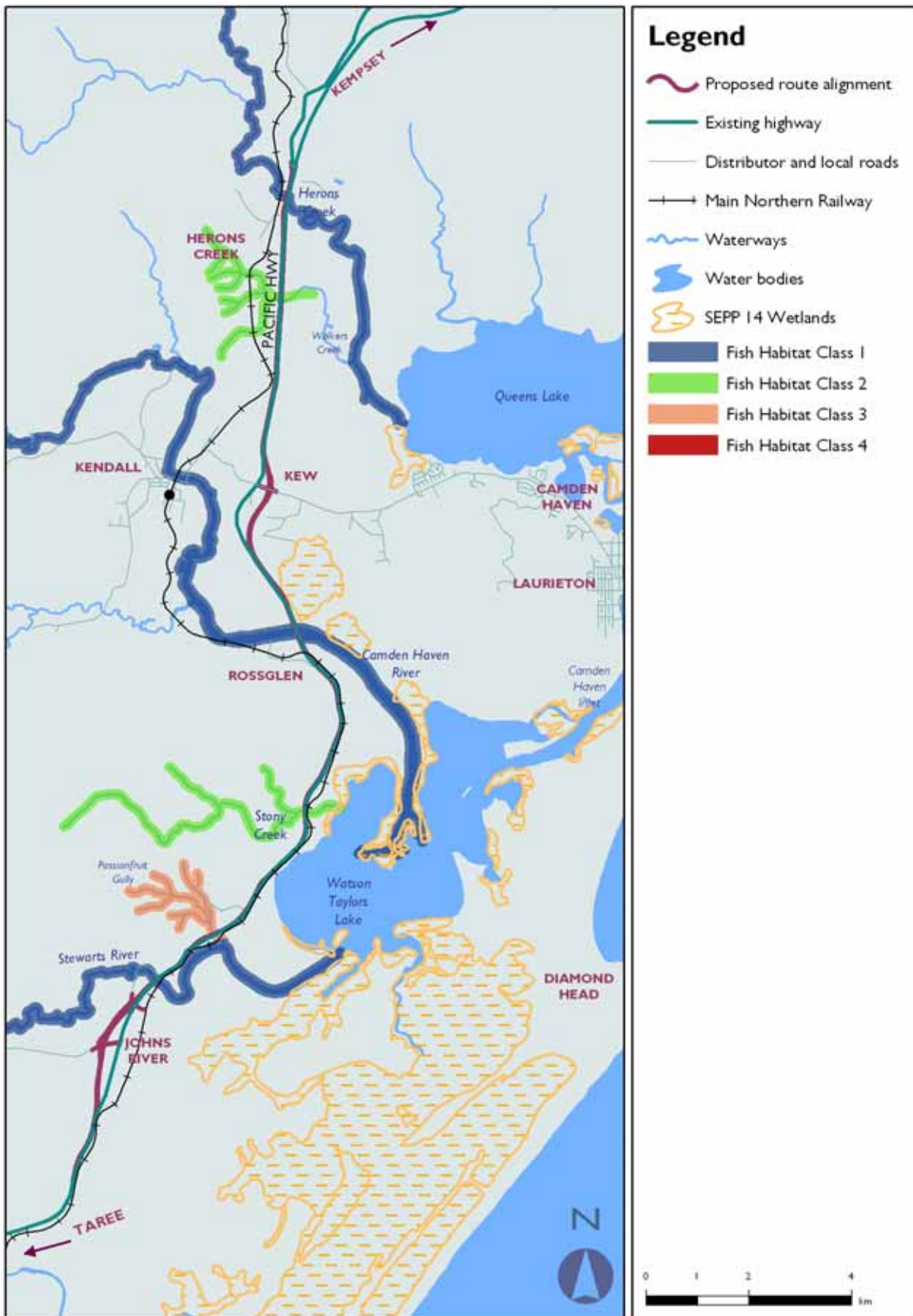


Figure 11-2 Location of classified waterways

Major fish habitats (Class 1)

Stewarts River is approximately 25 m wide where crossed by the existing highway. The average depth has been estimated at 1.5 m with moderately sloping banks and the existence of numerous snags throughout the river channel. Riparian vegetation consists of *Eucalyptus* species, *Casuarina* species, *Juncus* species, *Lomandra* species, and Lantana. Surrounding land uses are dominated by grazing pastures. Water clarity is good and a loose earth/rubble weir is located upstream of the highway crossing delineating estuarine and freshwater habitats.

The Camden Haven River is crossed by the existing highway via a multi-span, piled bridge structure. At this point the river is more than 100 m wide. A number of snags (principally toppled casuarinas) exist along the northern riverbank and provide a refuge for fish and other aquatic biota, however snags at the actual crossing point are considerably fewer than upstream and downstream. Trees and shrubs including casuarinas, eucalypts and lantana line the northern riverbank at this point. The southern riverbank, upstream of the bridge crossing, has been subject to extensive riparian vegetation clearance in the past and is susceptible to scouring and bank collapse. In the littoral zone, stands of common reed (*Phragmites australis*), and rushes (*Juncus spp*) were present both up and downstream of the crossing. Immediately upstream are a number of scattered mangrove saplings and mature mangroves also exist approximately 200 m downstream on the southern bank. At the same point, an approximately 100 m² patch of seagrass (*Zostera capricorn*) was identified on a sandy shallow flat of the southern shoreline. This is the only significant patch of seagrass between the Pacific Highway crossing and the river's confluence with Watson Taylors Lake and it may be an important habitat on a local scale.

Hérons Creek is a considerably smaller watercourse approximately 8 m wide and more than 1 m deep. The banks of the creek are steep and well vegetated supporting a mosaic of native and introduced species of trees and shrubs.

Moderate fish habitats (Class 2)

Stony Creek is characterised by steep sloping banks that are well vegetated and, at the highway crossing, the creek is approximately 8 m wide. The catchment upstream of the highway crossing is predominantly pasture with some pockets of riparian vegetation. At the time of the survey (November 2001), sections of the creek upstream were found to be dry and pools of water had collected in creek bed hollows.

Walkers Creek has a clearly defined channel approximately 3 m wide at the highway crossing. Shallow pools separate beds of macrophytes including *Triglochin* species, *Typha* species and *Juncus* species.

Minimal fish habitats (Class 3)

Passionfruit Gully flows under the existing highway via three box culverts. It is approximately 3 m wide with a series of small pools located on the downstream side of the crossing. No pools of water exist upstream as the channel is choked with various species including *Typha* species, *Juncus* species, *Bolbschoenus fluviatilis* and crofton weed. Riparian vegetation in the current road reserve is largely cleared. Agricultural land exists in the catchment to the west of the highway while to the east of the highway riparian vegetation remains largely undisturbed. A small farm dam exists upstream and was identified to be a possible barrier to fish passage.

Other waterways classified as having minimal fish habitat in the study area include a waterway at the intersection of Stewarts River Road and the existing highway, another unnamed waterway between the highway and Passionfruit Gully, and a small tributary of Herons Creek.

Unlikely fish habitats (Class 4)

Class 4 waterways identified in the path of the Proposal include unnamed waterways at Yaralin, 750 m north of Algona Road, 200 m south of Haydens Road, south of Ross Glen Road, and at Christmas Hill. All Class 4 waterways currently have some form of crossing incorporated into the existing highway and were not investigated in detail due to the lack of potential fish habitat present.

11.2.2 Aquatic fauna

Three species of mobile invertebrates and 20 species of fish inhabit the coastal estuaries and creeks in the vicinity of the Proposal. In estuarine habitat, fish were caught using a combination of bait trapping and gill netting at two points in the Camden Haven River and at the Stewarts River crossing. The most abundant estuarine fish species found included:

- Port Jackson Perchlet (*Ambassis jacksoniensis*)
- Flat-tail Mullet (*Liza argentea*)
- Pacific Blue-eye (*Pseudomugil signifier*)
- Empire Gudgeon (*Hypseleotris compressa*).

Invertebrates recorded in these estuarine habitats comprised:

- Carid Shrimp (*Palaemonidae*)
- Greasy Back Prawn (*Metapenaeus bennettiae*)
- Mud Crab (*Scylla serrata*).

No introduced species were caught in the estuarine habitats.

In freshwaters, seven species of fish and one macroinvertebrate were caught using an electrofishing technique. Freshwater fauna sampling was undertaken in the Stewarts River, Passionfruit Gully, Stony Creek, Walkers Creek and Herons Creek (refer to Figure 11-1). The species recorded included:

- Long and Short Finned Eel (*Anguilla reinhardtii* and *Anguilla australis*)
- Striped Gudgeon (*Gobiomorphus australis*)
- Empire and Firetail Gudgeon (*Hypseleotris compressa* and *Hypseleotris gali*)
- Common Jollytail (*Galaxias maculatus*).

The Mohawk Shrimp (*Atya striolata*) was the only freshwater macroinvertebrate species sampled and one introduced species, the Mosquito Fish (*Gambusia holbrooki*), was caught in both Stony Creek and Passionfruit Gully.

Threatened species

None of the species caught is listed as endangered or vulnerable under Part 7A of the *Fisheries Management Act 1994* (FM Act). Literature and database searches revealed that it is unlikely any threatened species occurred within or their habitat encroached upon the study area.

Discussions with local fishermen suggested that the threatened Black Cod (*Epinephelus daemeli*) may have been caught in the Camden Haven River as far upstream as Rossglen. These reports were anecdotal, and no specimens were sent to the DEC, DPI or the Australian Museum for identification and none were caught in the sampling performed during November 2001. Nonetheless, an Eight Part Test was conducted to determine worst-case scenario effects (see Section 11.3.1).

11.2.3 Fisheries

All fisheries resources in NSW are managed under the provisions of the FM Act.

Commercial fishing

Commercial fishing occurs in the Camden Haven River from the weir at Kendall (upstream of the highway crossing) to Watson Taylors Lake, and further downstream between the lake and Stingray Creek and to the entrance at North Haven. Within the vicinity of the existing and proposed second carriageway crossing, commercial fishing activities are undertaken including trapping for mud crab along riverbanks, mesh netting for mullet and trawling for prawns.

The Camden Haven estuary is ranked as the tenth most important estuary in NSW for the value of finfish landed (\$673,000 in 1998/99) and finfishing has been found to be stable for the period 1993/94 to 1998/99 (DPI 2000a, 2000b). Commercially important species of fish in the

estuary include the Sea Mullet (*Mugil cephalus*), Luderick (*Girella trichoptera*), Dusky Flathead (*Platycephalus fuscus*) and bream (*Acanthopagrus australis*). Prawning is primarily undertaken via pocket netting and important species include School Prawns (*Metapenaeus macleayi*) and Eastern King Prawns (*Penaeus plebejus*). Trapping is used to catch crabs, which include Mud Crabs (*Scylla serrata*) and Blue Swimmer Crabs (*Portunus pelagicus*).

Commercial fishing exists downstream of the existing highway at Stewarts River and Herons Creek. Prawning occurs in the Stewarts River up to the confluence with Passionfruit Gully (approximately 500 m downstream of the highway), whilst mesh netting for mullet is the primary commercial fishing activity in Herons Creek and is limited to the lower reaches near Queens Lake.

Recreational fishing

Recreational fishing is a popular activity year round in the Camden Haven estuary, focussed in the lower, more accessible reaches of the estuary such as at the mouth of the Camden Haven Inlet, Stingray Creek and Watson Taylors Lake. Fishing also occurs in the Camden Haven River above Watson Taylors Lake, but is primarily restricted to boat access. Prawning and crabbing also occurs on the shallow banks of the lake. Typical fish caught in the estuary include Bream, Flathead, Luderick, Whiting and Mulloway. The prized freshwater recreational species Australian Bass (*Macquaria novemaculata*) and Estuary Perch (*Macquaria colonorum*) have been reported in the Camden Haven River following flood events as far down as Watson Taylors Lake.

Oyster farming

Over 50 oyster leases exist within the Camden Haven estuary and the majority are situated downstream of Watson Taylors Lake with one site on the banks of the lake itself, and a number of sites in Queens Lake and Stingray Creek. The estuary cultivated 2% of the total NSW Sydney Rock Oyster production and was valued at approximately \$600,000 in the 1999/2000 financial year (DPI n.d.). Production data from NSW Fisheries indicated that production from 1994/95–1999/00 is relatively stable. Figure 11-3 shows the extent and location of oyster leases within or in proximity to the study area.

11.3 Impact assessment

The Proposal will cross six perennial waterways and a number of ephemeral watercourses. The Stewarts River, Stony Creek, Camden Haven River and Herons Creek will be crossed by either single or multiple span bridges, Passionfruit Gully and Walkers Creek will be crossed by box culvert structures and the ephemeral watercourses/drains will pass under the highway through either box or pipe culverts. New crossings over these waterways will be constructed either immediately west or east of the existing highway for a second carriageway except for the bypasses of Kew and Johns River where new dual carriageway crossings are required. These crossings are likely to cause impacts during construction and operational phases, which are discussed in detail below.

11.3.1 Construction impacts

The principal potential impacts associated with construction works on aquatic ecology in the study area include:

- changes in sediment loading
- changes in contaminant loading
- disturbance to ASS areas
- removal or physical alteration of habitat
- bridge pile and rubble removal
- impacts on threatened species
- impacts on fisheries.

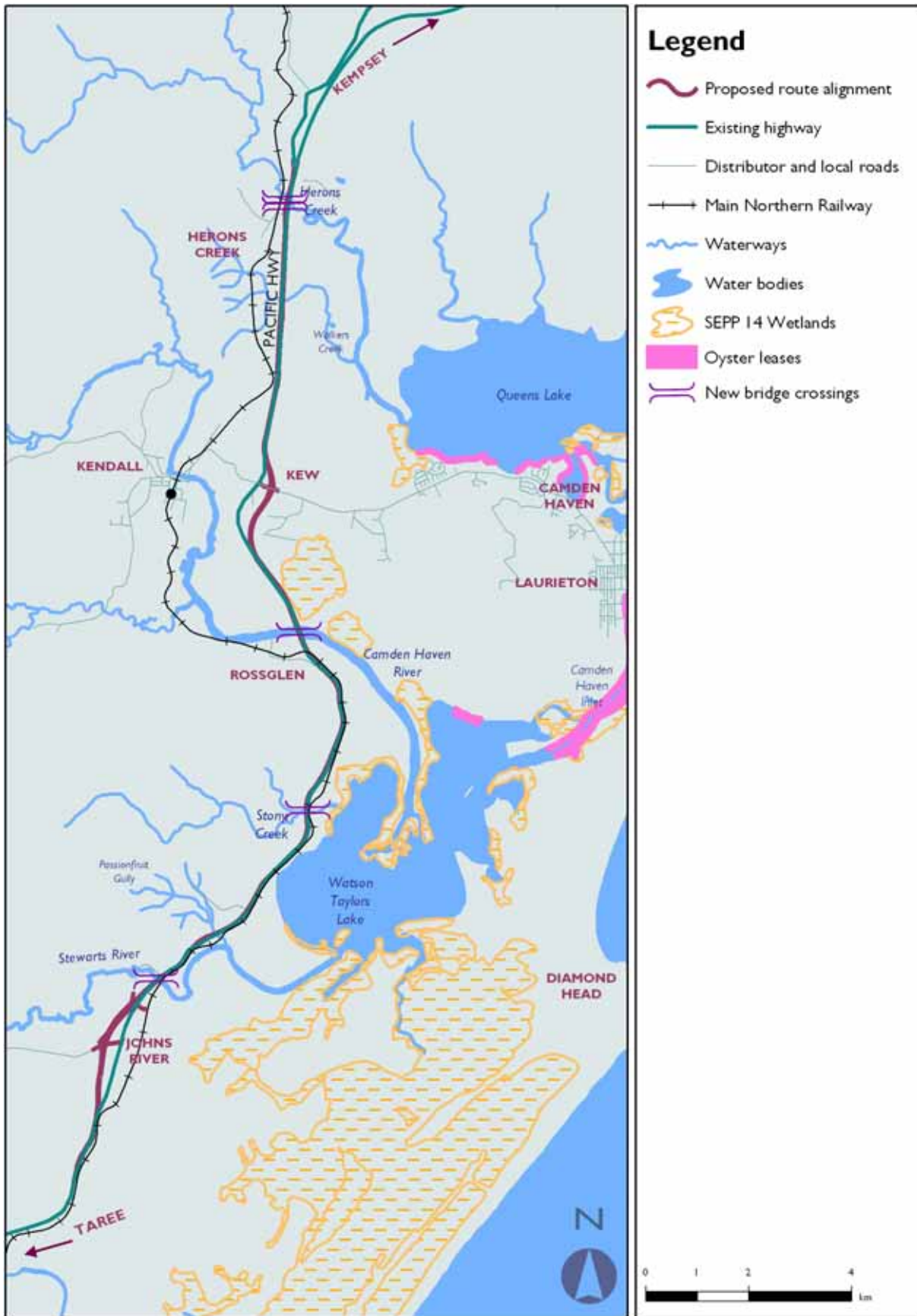


Figure 11-3 Oyster leases

Sediment loading

Both sediment-laden runoff and the driving of piles as part of the new bridge works within and in proximity to waterways have the potential to cause excess turbidity in the waterways. Turbidity due to large volumes of suspended sediment reduces light penetration, which in turn suppresses photosynthetic activity of phytoplankton, algae, and macrophytes and alters the ecological balance of aquatic systems.

Turbidity is often present in the form of a plume moving away from the source. Mobile animals such as fish and prawns may avoid the plume by moving away from it, but sedentary animals (such as oysters [*Saccostrea cucullata*]) are unable to escape its effects. However, oysters are adapted to natural periods of turbid water, and are likely to survive if the increase in turbid water is of short duration (up to several weeks), comparable to a storm event.

If high levels of organic particles are present in the sediment-laden runoff, further impacts may ensue due to a lack of dissolved oxygen. Biota living in the waterways use the organic matter as food and dissolved oxygen is also consumed during the digestion of such matter. This biological process is also likely to introduce extra nutrients into the waters, which have the potential to cause eutrophication (see below).

Contaminant loading

Contaminants may potentially flow to the waterways during construction activities from accidental fuel or oil spills. These petrochemical compounds are often toxic to the integrity of aquatic ecology systems. Exudates from recently heated bitumen may flow to waterways and these can contain complex mixtures that may also be toxic to aquatic life.

Small amounts of nutrients, such as nitrogen and phosphorous, may flow to the watercourses from construction activities such as use of fertilisers for landscaping purposes. However, any such amounts would be minor in the context of largely rural catchments where applications of fertilisers are made extensively in agricultural activities. Excess nutrients in a waterway may result in eutrophication, that is, excess nutrients are consumed by phytoplankton such as algae and encourage algal growth. Algae blooms block sunlight penetration during the day and respire at night using the dissolved oxygen in the water. Fish kills often result from extensive oxygen depletion.

Acid Sulfate Soils (ASS)

The Proposal will traverse the floodplains of the Stewart River and Camden Haven River. As discussed in Chapter 8, these floodplains and areas around most waterway crossings are mapped as containing PASS in the immediate surface layers. Water quality sampling undertaken indicated that there was no evidence of quality conditions attributable to ASS runoff, however this runoff can be ephemeral and difficult to detect. Runoff from ASS alters the pH of receiving waters and in the past has resulted in a number of major fish kills in the North Coast region. Impacts can be ameliorated with the investigation of soils prior to excavation, implementing an ASMP and various other mitigation measures.

Removal or physical alteration of habitat

The 'removal of large woody debris' and the 'degradation of native riparian vegetation' are both listed as Key Threatening Processes under the FM Act. The former includes large masses of trees/shrubs and snags, with the DPI preferring the relocation of these snags to other in-stream points upstream or downstream of highway crossings. Once construction is complete, it is preferred that these snags remain in their new positions to minimise additional disturbance. Riparian vegetation removal should be limited to narrow corridors where access tracks are erected and total revegetation should occur where any access tracks have been created.

A number of snags (mostly fallen casuarinas) are present upstream of the Camden Haven River crossing. The locations of the pylons for the new bridge structure are likely to result in the clearance of some of these snags during site preparation. The snags are likely to be important habitat for many aquatic species as snags are not common in this stretch of the

river. Therefore, in all waterways along the route where snag removal is required, snags should be carefully repositioned and left in the new in-stream locations to minimise breakage and disruption of habitat.

A small stand of mangroves exists along the foreshores of the Camden Haven River just upstream of the existing bridge in the path of the new bridge. A small number of trees (fewer than 15) along the foreshore would require removal to facilitate bridging over these mangroves. Disturbances to mud surfaces in mangrove habitats can increase the turbidity of the river locally. Large or long-term increases in turbidity can affect movement patterns of fish and aquatic invertebrates. Mangroves also function as bank stabilisers and their removal may increase the susceptibility of the river channel in this location to scouring effects and, in the worst case, bank collapse.

Though not strictly aquatic habitat, a major function of riparian vegetation is to stabilise banks. Some riparian vegetation disturbance cannot be prevented where new crossings are to be constructed across waterways. Setting bridge abutments back from the high banks helps to reduce the need for removal of this vegetation. If a boat launching/mooring facility will be required at the time of bridge construction or after, additional riparian vegetation may require removal.

Proven mitigation techniques such as revegetation of riverbanks and the application of geotextiles are known to prevent impacts in riparian vegetation communities. These can also be applied to patches of 'bare earth' existing underneath current bridges (see Section 11.4 for detail on mitigation measures). Any removal or physical alteration of habitat such as snag or mangrove removal would be undertaken in a manner consistent with DPI's preferred approach as set out in relevant guidelines (DPI 1999b).

Bridge pile and rubble removal

Two disused lift span piers, rubble and seven remaining piles of the superseded bridge will require removal from the Camden Haven River as part of the proposed upgrade. The primary impact on the aquatic environment is an increase in turbidity when removing the piles and rubble from the riverbed (comprised of river gravel overlain by soft silt). Another impact is the potential dropping of cut sections of piers into the river as they are being removed. This would affect the riverbed and disrupt the silt layer causing turbidity.

The threatened Black Cod (*Epinephalus daemeli*) may reside in the Camden Haven River, however the DPI is of the opinion that the piers to be removed do not represent prime Black Cod habitat. DPI (1999a) provides policy and guidelines for bridges and supports the removal of the piers and rubble so long as these are observed. No other waterways to be crossed by the Proposal require pile or other significant rubble removal.

Impacts on threatened species

An Eight Part Test was undertaken for the Black Cod on the basis that this species may occur within the area that would be disturbed by the Proposal. However, as noted above, the DPI does not believe the piers of the existing bridge are habitat for this species. Expert bodies have not identified Black Cod samples, nor are the reports of its presence verified with sampling undertaken in 2001 (targeted sampling is not supported by the DPI for this species). It is likely that the Black Cod's life cycle could be disrupted should individuals reside in the vicinity of the Proposal. A species impact report was not recommended as long as measures for the protection of the species are incorporated into the CEMP and Soil Water Management Plan (SWMP).

The TSC Act lists Coastal Saltmarsh as an endangered ecological community. SEPP 14 Wetland No. 544(c) is a protected segment of this community, and an unprotected wetland also exists to the north of the Camden Haven River. The route of the Proposal has been selected to avoid encroachment on these sensitive areas, either during construction or operation, and mitigation measures for controlling the quantity and quality of highway runoff are discussed in Chapter 9.

The TSC Act lists the predation by the Mosquito Fish (*Gambusia holbrooki*) as a serious threat to the survival of many native frog species. Mosquito Fish were recorded in Stony Creek and Passionfruit Gully in small numbers during the 2001 survey. This species often invades disturbed slow moving and/or still water environments such as cleared riverbanks and riverbed alterations created during construction activities. The species can tolerate a wide range of conditions including waters that are turbid, silty, swampy, still, acidic and oxygen deprived, and consequently can thrive while native biota diminish. The SWMPs to be implemented at each waterway should prevent population increase and destructive predation by the Mosquito Fish (*Gambusia holbrooki*).

Impacts on fisheries

The construction of waterway crossings is unlikely to have any effect on commercial and recreational fishing activities providing strict mitigation measures are implemented under the CEMP (including a Flora and Fauna Management Plan) prepared for the Proposal. This would include measures to prevent, or otherwise reduce, the incidence of sedimentation, impacts on fish passage, habitat removal and the planning of bridge construction so that a navigable path is always accessible to fishing vessels.

Oyster leases exist downstream of the crossing points in the lower reaches of Watson Taylors Lake and Queens Lake. All leases are more than 7 km downstream, however turbid and low quality waters may flow to these points and disrupt the feeding cycles of oysters despite their known ability to adapt to turbid waters. The implementation of mitigation measures outlined in the CEMP and Erosion and Sediment Control Plans to control impacts on water quality would mean no direct or indirect impacts on the oyster leases are likely to occur.

11.3.2 Operational impacts

Sediment and contaminant loading

Without appropriate mitigation measures in the design and construction phases, sediment and contaminant loading into local waterways may occur throughout the operational life of the Proposal. If embankments surrounding the highway are not sufficiently stabilised, erosion and subsequent sediment runoff is likely. Runoff of organic material is also likely to occur in the operational stages if measures such as sediment ponds are not installed. Potential impacts of sediment loading are discussed above.

Contaminants may also occur in operational stages from continual vehicular traffic movements. Fuels/oils from spills or from road accidents, settled combustion particles from exhaust and exudates from asphalt used in highway maintenance may all flow to waterways and be toxic to aquatic ecosystems. Therefore it is essential that appropriate mitigation techniques be implemented.

Shading impacts

One of the primary operational impacts from bridges and other waterway crossings is the effect from shading, especially in this case for the small stand of mangroves. While the duration and extent of the shadow would change with the season and time of day, its effect, if any, is likely to be greatest directly below the bridge. Mangrove seedlings are likely to continue to germinate under reduced light conditions, but may fail to survive to the reproductive stage of development (Clarke and Allaway 1993).

Shading from the proposed bridges would impair photosynthesis in aquatic or riparian plants to a certain degree. The level of light at which photosynthesis exactly balances respiration is called the 'light compensation point'. This point is unique for each species of plant and may vary according to a number of factors. Below this average level of light, plants may die or simply not grow and reproduce. However, these indirect effects (such as shading) are expected to be small and acceptable.

Impacts on fish passage

Fish and other mobile aquatic species rely on unrestricted passage between suitable habitats to feed, find shelter, disperse and reproduce. Barriers can be formed temporarily during construction through the erection of access pads, however long-term barriers are a particular hindrance and can result from the construction of inappropriate structures. Consequently, bridges with no piers in permanent water are preferred for Class 1 waterways with less than 30 m wetted width. During low flow conditions, Stewarts River, Stony Creek and Herons Creek are all narrower than 30 m. Should clear spans over permanent water not be achievable, DPI requires that bridge piers be set away from low flow channels in the riverbeds.

Replacement of bridges at Stony Creek and Herons Creek is likely to improve fish passage conditions through the installation of structures that are more favourable to biota movement. The second carriageway bridge to be constructed at Camden Haven River will require the installation of foundations into the riverbed. This installation would be staged and consequently the resulting limited noise or vibration should only affect small areas of the river at a time and not affect fish movement.

Walkers Creek and Passionfruit Gully pass under the existing highway via box culverts. While there is evidence to demonstrate that these structures do not impede fish passage under low to medium flow conditions (eels and fish were recorded upstream of the structures), the build-up of sediment and plants upstream suggest fish passage would be impeded under other flow conditions. The DPI recommends that new or replacement culvert designs aim to retain natural geomorphological features including stream width, bed composition, slope and flow. These factors would all be included in the design of the new and replacement culverts and thus fish passage is likely to be improved.

Water flow alteration

Depending on their placement, the presence of the bridge piles where bridges are to be constructed may alter the water flow. Water flowing around the piers may cause local scouring, and therefore alter the distribution of plants and animals in their vicinity. The positioning of bridge piers close to the riverbanks may result in scouring of riverbanks and beds. Observations of the existing Camden Haven River bridge showed that no greater scouring is present surrounding the piers than on banks upstream and downstream of the crossing.

Studies have shown the importance of small-scale changes in water flow and surface topography to the ecology of mangrove forest biota (Warren and Underwood 1986). Mitigation measures to reduce the possibility of scouring include re-levelling the soil surface around the piers after construction and planting with mangrove seedlings according to DPI protocol.

11.4 Mitigation measures

The concept design for the Proposal includes design requirements of agencies such as DPI in relation measures to maintain fish movements such as setting the bridge abutments away from the high banks to maintain scour protection in all bridges (see Section 6.1.3). Detailed descriptions of mitigation techniques will be provided in the CEMP, the Soil and Water Management Plan, the Erosion and Sediment Control Plan and the Operational Management Plan to cover construction and operational phases. Mitigation measures can also be implemented through design considerations and these are discussed below.

11.4.1 Design

Mitigation measures to reduce adverse impacts on aquatic habitats and biota to be incorporated into the detailed design of the Proposal include:

- Application of DPI Policies and Guidelines to design 'fish friendly' waterway crossings that minimise impact on fish passage and maintain connectivity between habitats.
- Where feasible, design of bridges which completely span the wetted waterway, especially for Class 1 waterways that are less than 30 m wide (Stewarts River, Stony Creek and Herons Creek).
- If bridges that completely span stream water were not possible at the crossings of Class 1 waterways, bridge piers would be located away from low flow sections of the waterways.
- Culvert design for the crossings of Walkers Creek, Passionfruit Gully and other waterways will be designed to allow for fish passage. This includes:
 - the incorporation of low flow cells into the design of the culvert
 - box cells set into the creek bed to allow a water depth of 0.2 to 0.5 m under base flow conditions (as per DPI recommendations)
 - design for rapid installation to ensure transverse drainage is in place during early stages of construction
 - the cells are appropriately located to cater for low, medium and high flows and accumulation of natural sediments.
- Further developing the strategies for the removal of defunct bridge pier structures and rubble piles which have been described in Chapter 6, including:
 - consideration of practicality
 - provision of effective erosion and sediment control measures
 - preparation of a Work Method Statement for this activity
 - liaison with DPI and DEC in regards to best practice and for review of the Work Method Statement
 - optimum timing of the works
 - water quality monitoring.

11.4.2 Construction

In addition to the general construction mitigation measures (see Chapter 21), the following specific mitigation measures should be undertaken during construction:

- A Soil and Water Management Plan and an Erosion and Sediment Control Plan are to be developed in accordance with the 'Blue Book' (Landcom 2004) and the *Road Design Guide* (RTA 1996) to achieve best practice on erosion control and mitigation including:
 - the use of sediment fences/curtains, vegetation barriers and rock barrier
 - retaining as much grassed or vegetated cover as possible during clearing activities to prevent soil erosion
 - divert clean runoff around construction sites
 - bund stored chemicals and contained machinery wash-down areas
 - use stabilised temporary and permanent diversion banks and drains to reduce water volume and reduce speed of runoff water from construction and operation sites

- divert road runoff away from environmentally sensitive areas such as SEPP 14 wetlands to temporary sedimentation basins
- quick installation of culverts
- installation of scour protection measures for creek and river banks and low flow channels
- revegetation and stabilisation of construction areas as soon as practically possible after completion
- regular inspection and maintenance of erosion, sediment and pollution control devices
- use of sediment curtains around each new pile to be driven into the riverbed
- to reduce the possibility of scouring, re-level the soil surface around the piers after construction and planting with mangrove seedlings according to DPI protocol
- Development of an ASSMP in ASS risk areas as part of the CEMP (refer to Chapter 8).
- Should the removal of riparian vegetation be required, the DPI preferred 'cut stump' method would be used to mitigate potential bank scouring.
- Revegetate areas to be cleared of vegetation as soon as practicable after construction activities are complete and include the use of geotextiles to help stabilise banks while vegetation becomes established.
- Ensure the removal of snags is kept to a minimum and if this is required the DPI preference is to relocate the snags at nearby in-stream points and leave them at their new positions once construction is complete to minimise habitat destruction.
- The shortest possible time will be taken where work in watercourses is required (e.g. installation of culverts).
- Bridge construction would be planned to provide a navigable path for all potential craft on the waterways (especially the Camden Haven River) at all times.

11.4.3 Operation

The following mitigation measures would be undertaken during the operation of the Proposal:

- The Proposal includes control measures to treat highway runoff before it enters sensitive areas such as wetlands and waterways. This includes the operation and maintenance of 22 permanent sedimentation basins near Stewarts River, Stony Creek and the Camden Haven River as part of the primary containment measures to collect and treat highway runoff.
- The concept design for the Proposal incorporates control measures that direct excess highway runoff away from SEPP 14 wetlands and other wetlands and waterways (see Chapter 9), however monitoring of these areas should continue into the operational phase so that analysis and possible optimisation of mitigation techniques can occur as soon as possible.
- The revegetation program should be monitored and maintained into the operational phase of the Proposal to ensure appropriate restoration of habitat.

11.5 Monitoring

11.5.1 Construction

Water quality monitoring prior to and during construction would be implemented for the Camden Haven River and other waterways where disturbance of the creek/river bed or near drainage lines may occur. Monitoring would focus on levels of dissolved oxygen, turbidity and pH in the context of background levels in similar habitats elsewhere in the system. Monitoring would be specified in the Soil and Water Management Plan. The potential for runoff from ASS is discussed in Chapter 8.

11.5.2 Operation

Monitoring after the opening of the Proposal would be undertaken to assess the condition of waterways and to quantify the effects of shading by the additional second carriageway bridges. The diversity and density of aquatic habitats would be monitored including areas shaded by the existing and newly constructed bridges and in areas of full sun.

Post construction water quality monitoring would focus on possible highway runoff components such as heavy metals, oil and grease with monitoring carried out during and after rain.

11.6 Implications for ESD

11.6.1 Precautionary principle

The aquatic ecology investigations concluded that no threatened or vulnerable aquatic flora or fauna species would be affected by the proposed upgrading. It is anticipated that the measures proposed would more than offset any possible waterway productivity loss in the study area, especially as culverts currently existing for creek underpasses (Walkers Creek and Passionfruit Gully) will improve fish passage, natural sediment flow and aquatic vegetation movements. This is providing appropriate mitigation techniques are implemented and maintained during design, construction and operational phases.

11.6.2 Social equity (including intergenerational equity)

With the implementation of the nominated mitigation measures, no long-term adverse impacts are anticipated on waterway productivity and fishery resources that would lead to a reduction in the quality or quantity of these resources available to users in the future.

This approach to Proposal design, construction and monitoring is consistent with the principle of maintaining social equity (including intergenerational equity).

11.6.3 Conservation of biological diversity

The design of proposed replacement and new bridges has had careful regard to the reduction of the footprint of the bridge piers and abutments on the rivers and creeks to be crossed so that the area of disturbance associated with such structures is kept to a minimum. Mitigation measures, especially during the construction period, would protect the ecological functioning of the key elements of the waterways and catchments surrounding them.

This approach to Proposal design, construction and monitoring is consistent with the longer-term conservation of biological diversity and the maintenance of ecological integrity.

11.6.4 Improved valuation and pricing of environmental resources

The importance of SEPP 14 wetlands and National Parks, which are protected areas of state significance, has been explicitly recognised in the route selection, concept design and environmental assessment phases of the Proposal. While economic valuation *per se* has not been made for these areas, their importance from an environmental perspective has been an integral factor in Proposal development.

The mitigation measures and monitoring program proposed reflect this emphasis on protecting these areas and thus reinforce their environmental and economic value.