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FISHERIES RESEARCH &
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Revitalising Australia's Estuaries

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the business case for repairing coastal ecosystems to improve fisheries productivity, water quality, catchment hydrology, coastal biodiversity, flood control, carbon sequestration and foreshore buffering

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Dead river worms after the 2013 'blackwater' flood in the Clarence river. These worms and most of the benthos died in their many millions because of low dissolved oxygen, highly acidic leachate from drained wetlands.

Repair the drainage, remove the unnecessary levees and reconnect the wetlands of Lake Wooloweyah, Everlasting Swamp and the Broadwater to the estuary and the Clarence could once again be the 'Big River' in high quality fisheries production.

healthy fish stocks = healthy communities

ecologically: Over 75 % of species contributing to Australia's commercial fish catch and probably up to 90% of all recreational catch spends part of their life cycle within estuaries and inshore wetlands.
Revitalising Australian estuaries will increase fisheries productivity and all aspects of coastal ecosystem biodiversity.

economically: Earning $2.2 billion a year, Australia's seafood production is the fifth biggest food industry in Australia.
Revitalising Australian estuaries will increase product available for harvest in inshore low-input–cost fisheries, improve industry profitability and guarantee high quality aquaculture product.

socially: Over 3.4 million Australians already recreationally fish as part of their relaxation lifestyle.
Revitalising Australian estuaries will increase the low-cost outdoor recreational choices, especially for our heavily populated urban centres.

culturally: All of our coastal indigenous communities rely on estuarine resources for food and custom.
Revitalising Australian estuaries will protect these renewable resources for their ongoing use.

healthily: Most of us include seafood, the healthiest source of protein and related oils in our diets. In 2007, the average Australian consumed over 23 kg of seafood.
Revitalising Australian estuaries will secure high-value low-cost food resources for all Australians forever.

A more productive coastal Australia

This proposal concentrates on repair of the more developed coastal catchments around Australia where major investment and Australian Government leadership is required to re-establish estuary productivity.

It seeks to deliver multiple benefits to the Australian community – to increase fisheries productivity, improve coastal water quality, enhance catchment hydrology, repair coastal biodiversity, finetune flood control, re-establish carbon sequestration and reinforce foreshore buffering against extreme events.

The business case sets out the rationale and the priority opportunities for investment, to repair and restore, under a 'no regrets' policy, estuary and inshore wetland and floodplain areas. It seeks to maximise community benefits from these important parts of our landscape while minimising costs and impacts upon adjacent land users of the coastal zone.

It builds upon the Australian love of coastal landscapes and the resources they provide and the Australian community's and political commitment to implement major natural resources initiatives such as the Natural Heritage Trust, Caring for our Country and the Biodiversity Fund. Like Reef Rescue and the *National Action Plan for Salinity and Water Quality*, the business case proposes a major focus, in this case on estuaries and their wetland ecosystems.

Most importantly, through ongoing fisheries productivity, the proposed once-off five-year Australian Government investment will return economic benefits year in and year out that will far outweigh the $350M costs of repairing these key estuary assets. Our estimates suggest a break-even for investment is well less than five years and from then on benefits exceed costs forever.

Further repair and management investment will be required following the proposed once-off five-year agenda-setting Australian Government investment. This business plan recognises this ongoing investment need. Similar to already successful schemes in USA and UK and building on schemes already underway in NSW and Victoria, this plan proposes various instruments and systems to ensure overall benefits can be incentivised into the future. This includes empowering industry groups, private landholders, Local Governments and communities to continue the repair of coastal assets and their management.

Acknowledgements

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Colin Creighton, August 2013

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CHAPTER 1 Return on investment ... forever

1.1 Placing a commitment to estuary and nearshore ecosystem recovery in context

A range of catchment management and water quality improvement activities has been undertaken in all states over the last 15+ years. Water quality improvements have been substantial and the ethos of catchment management is well understood across the community. Now is the time to rethink the focus and invest in the habitats of the receiving waters of this improved water quality.

Some limited but in some cases very beneficial works have been undertaken in estuaries. This reduced level of investment relates to the generally terrestrial and often private landholder engagement focus of much of the resources available for environmental repair, especially under the Landcare and Caring for our Country models. Likewise Natural Reserves System investments have been skewed to terrestrial landscapes. Where marine park investments have occurred, the emphasis has been on reservation. Little, if any, investment has been focused on repair of the causes of marine biodiversity decline.

Indeed the last time there was significant leadership from the Australian Government in estuaries was the 40% Australian Government 40% State Government and 20% Local Government wetland drainage and flood mitigation schemes that caused much of the problem we now seek to address.

Leadership from the Australian Government brings with it multiple benefits. Australian Government leadership and investment allows us to make the big repair investments that will deliver the equally big outcomes, it fosters an integrated and priority investment approach, it brings with it increased opportunities for co-investment from both the private sector and from State and Local Governments and most importantly Australian Government leadership fosters a series of discussions about how to improve public policy so that ongoing investment is at a much reduced level and focused on sustaining the improved condition of our public estuary assets with their multiple benefits to the Australian community. Most of this ongoing investment can then be achieved through smart state-level policies, through revenue collection activities such as boat licences that are then re-applied to fishing benefits and community action.

The alternate case needs to be put – the dilemma of doing nothing. With no focused investment in estuary repair the prognosis for Australian estuaries and their multiple community benefits are:

- continued decline in fishery stocks with flow-on loss of unskilled jobs in regional communities and reduced seafood production
- reduced availability of 'family seafood', whether purchased or caught recreationally especially the lower cost products that ends up on many families' dinner plates
- increasing reliance on seafood imports with implications for terms of trade, food security and food quality
- continued decline in the recreational amenity, ecology and biodiversity of these otherwise most productive of Australia's ecosystems, thereby making any repair in the longer term even more expensive;

- continued costs whether it be cleaning up massive fish kills, loss of amenity, poor water quality or algal blooms

To quote a professional fishing colleague from the mid 1970s when I was also professional fishing on Eastern King Prawns – *Rivers – they won't fix them unless they catch on fire.*

Research this year on the Clarence River, New South Wales just after the floods showed that there were no benthos – polycheates, bivalves or whatever – alive in the sediments from Grafton, just below the tidal limit through to the ocean (Ryder and Mika 2013). Certainly the impact of acidic anoxic floodwaters was equivalent to a fire.

1.2 Break-even analysis – the boundary conditions and assumptions

Any investment of public resources should be well justified. Break-even analysis has been applied to justify how the investment of $350M this initiative suggests must be invested in Australia-wide estuary repair will deliver long-term and enduring public benefits and indeed ongoing tax receipts by establishing a fully sustainable inshore seafood industry for Australia.

The suite of assumptions in this break-even analysis to ensure values are conservative and well below the likely increase in benefits is:

- Only selected regional fisheries will be analysed and only using the projected improved returns from commercial catch. Other regions will also benefit, ensuring that even from the Australia-wide commercial catch perspective the analysis is extremely conservative.
- Only selected species within these regional fisheries will be analysed and again, only using projected improved returns from commercial catch. Recognising the interactions between species, other commercial catch species will also benefit. Again this ensures that even from the region-specific commercial catch perspective the analysis is extremely conservative.
- The selected fisheries are:
    - A single regional fishery – Murray – Coorong, already a MSC-certified fishery in terms of methods and sustainability. Species used in this case study are juvenile and adult Mulloway, Black Bream, Greenback Flounder and Yelloweye Mullet.
    - A state – New South Wales, covering subtropical floodplain dominated-estuaries – essentially concentrating on the major estuaries of New South Wales while recognising the benefits will also accrue to south-east Queensland and to Gippsland Lakes. Case study species are Sydney Rock Oyster, School Prawn and Mullet.
    - An iconic region, the Great Barrier Reef – Tropical East Coast estuaries – essentially all the Great Barrier Reef estuaries requiring repair and using well-known species of Banana Prawns and Tiger Prawns.
- Value used in the analysis is 'at retail' to capture all the benefits along the value chain from fisher to processor and market to consumer. Dollar values are based on values of product for 2012/13.
- No non-market values or even estimates of recreational fishing benefit are included in the break-even analysis so that all dollar values are deliberately conservative. This project leaves it to others to speculate on dollar values for what this analysis regards as 'externalities', including the flow-on benefits to tackle shops, tourism, marine centres and so on. This is not to deny the multiple benefits of recreational fishing, but rather to ensure this analysis is very conservative and focuses on those aspects of a fishery that are easily valued.

- Likewise all the multiple non-market values of estuary repair such as biodiversity, landscape amenity, lifestyle improvements, water quality, flood control, coastal buffering and so on are not valued.
- Recognising that it will take some time for full ecological response, this analysis starts at Year 5 of the implementation of the initiative and assumes close to full biological response by that time. Fish populations do respond rapidly so there will be ecological benefits before that time. Again the estimate is conservative.
- Recognising that virtually all Australian fisheries are sustainable, current methods of catch and aquaculture practices together with any entitlement and other fisheries management arrangements are assumed to remain as is in 2013 for the period of analysis to reach break even point post 2018.
- Demand is assumed to be totally elastic. That is, demand expands to take up all the additional seafood productivity. At the very least it can probably be assumed that increase in Australian product available would replace the poorer quality and not as fresh imported seafood. Therefore price is assumed as a constant.
- For simplicity and to be conservative in all estimates, there will be no increases in value factored in from such as consumer price index or for buyer preference for the fresher Australian product or indeed any other market-related changes in product dollar value.
- Again for simplicity, the current partitioning of stock between wild-caught professional product, recreational catch and remaining wild population is estimated. Where professional fishing effort has declined to virtually nil (e.g. Shoalhaven school prawn fishery) and the proposed productivity increases suggests a professional fishery can re-establish, this proportion of catch will be estimated.

These assumptions lead to a deliberately very conservative break-even analysis, but as the next section demonstrates, even with this very conservative analysis the return on investment is almost immediate – less than seven years in all cases to return the benefits and probably closer to three to five years maximum across the entire Australia-wide initiative.

1.3 A single regional fishery – the Coorong – Murray Mouth fishery

The Murray–Darling once nourished and supported Australia's largest estuary system comprising the Coorong, Lower Lakes and Murray Mouth.

During dry phases, porpoises and their prey such as Herrings and Mullets once travelled at least as far upstream as the Murray River proper above Wellington. Up until the construction of the causeway and barrages there were over 100 Mulloway fishers based on the northern Coorong, providing Adelaide with most of its seafood needs.

Even with its ecological function grossly impaired because of the loss of interconnectedness between freshwater and estuarine ecosystems, the Coorong, Lower Lakes, Murray Mouth complex is of such high conservation value that it is on the World Heritage Register. Repair works will markedly improve its ecological values.

The commercial fishery, has a current annual economic value of $5.7M per annum. Estimated fishery productivity improvements of 20% across all key species could lead to comparable increases in the annual economic value (Brookes et al. 2013). These estimated values are based on South Australian market prices and are therefore conservative. For species that are sold interstate such as Mulloway and Pipi the price received is often higher.

While the fishery is comparatively small, the economic and employment benefits to the regional community are substantial.

Equally importantly, but unable to be valued at this time are the benefits of a productive Murray estuarine fishery to coastal waters and estuaries of the lower southeast in South Australia and all the southern estuaries of Victoria. It is likely that the Murray estuary is a key source for juvenile recruitment to the inshore and estuarine environments to the east.

Target species	Historical catch (tonnes)	2011/12 catch (tonnes)	Increased productivity (%)	$ 2012	$ 2018 (2013 $ values)
Mulloway	14 – 106	64	20%	$438K	$526K
Comments: Mulloway spend much of their postlarval and juvenile phases in sheltered environments such as the Murray – Coorong estuary, proceeding to sea to spawn. Being a piscavore (consumer of other fish), mulloway productivity is an excellent indicator of overall system health. Adult Mulloway age 5–6 years are caught nearshore.					
Yelloweye Mullet	110 – 346	144	20%	$585K	$702K
Comments: Yelloweye mullet are found in brackish and inshore coastal estuaries and have a preference for shallow estuaries. The mullet feed lower in the food-chain than the large piscivorous predators and while they regularly utilise estuaries during part of their life cycle they do not need access to low salinity water to complete their life cycle.					
Black Bream	1 – 47	3	20%	$37K	$44K
Comments: Black bream complete their entire life cycle within an estuary and tolerate a range of salinities from fresh to hypersaline. There appears to be a high degree of estuary fidelity. Bream are vulnerable to poor water quality and so maintaining river flows of appropriate quality is important for this fishery.					
Greenback Flounder	0 – 65	31	20%	$249 000	$298 000
Comments: Adult greenback flounder prefer sand, silt and muddy substrates in bays, estuaries and inshore coastal waters. Adults sexually partition habitat, with females more abundant in shallow water and males more abundant in deeper water. Post-settlement and juvenile greenback flounder tend to be found in shallower water and prefer unvegetated sand and mudflat habitat where they are well camouflaged. Juveniles tolerate a wide range of changes in salinity and are often found in the upper reaches of estuaries and occasionally in rivers.					
Total estimated productivity value increase for these selected species post 2018: at least $.0.26M per annum **Break-even point for proposed Coorong – Murray Mouth investment: less than 7 years**					

Pipis or Cockles are an integrator across the fishery in that diatoms dominate their feed, and a healthy and productive estuary linked to a healthy and productive freshwater system fostering a productive cockle resource. Congolli are an example of a major contributor to the food web and therefore feed stocks for higher order piscavores such as Mulloway. Congolli have a lifecycle that includes fresh water and marine/estuarine phases. Re-establishing connection through all the small creeks that once dominated the islands will foster a rapid increase in overall Congolli population to the benefit of the entire food chain.

Key non-costed and non-market benefits	
Recreational fishing	Mulloway, Black Bream and to a lesser degree Greenback Flounder are all target species. With estimates of productivity increases of about 20% the stock available for recreational catch will also increase. Equally important to the Murray recreational fishery are the likely flow-on benefits of increased populations across south-eastern South Australia and the many estuaries and related nearshore areas of the southern Victorian coast.
Coastal biodiversity	The Coorong is already recognised as a World Heritage Area. By increasing the area of brackish to saline mixing zone in the Coorong and commensurately reducing the excessive saline levels in the southern Coorong these World Heritage values will be benefited right across the food chain from benthic flora and fauna through to the many species of waterfowl and migratory waders that frequent the Coorong.
Carbon sequestration	Seagrasses are one of the key areas of carbon sequestration. By increasing the productivity of the mid to southern Coorong seagrass extent and vigour will markedly increase.
Tourism	The Coorong region attracts a number of tourists who undertake water sports, bird watching and general leisure. Low river flows and declining lake levels in the late 2000s significantly impacted tourism in the region. Increasing estuary productivity will increase tourism particularly associated with recreational fishing, bird watching and boating.
Indigenous and cultural values	The Ngarrindjeri have strong traditional ties to the land and sea. The ability to harvest from the Coorong is a cultural value of the indigenous custodians that will be enhanced by returning the Coorong to historical productivity levels. Many of species are totems for the Ngarthii culture and have cultural values.

1.4 A state, New South Wales – a key example of floodplain estuaries of eastern Australia

Many of those that enjoy coastal and floodplain New South Wales from the Tweed to the Shoalhaven, south into Victoria such as Gippsland Lakes and Corner Inlet and north including Moreton Bay through to the Burnett, do so through their activities in the coastal zone – fishing, recreating, bird watching or just relaxing. There are also still viable professional fishing and aquacultural businesses in most major estuaries.

Most of the popular species for catch or eating such as School Prawn, Eastern King Prawn, Sydney Rock Oyster, Yellowfin Bream, Dusky Flathead, Sand Whiting and Mullet spend much or all of their life history within estuary-wetland systems such as the Cobaki, Tuckean, Wooloweyah, Everlasting, Big Swamp, Tomago and Hexham swamps to name a few.

The repair works advocated in this business plan are estimated to at least double fishery productivity in New South Wales (Winberg et al. 2013). Commensurate flow-on increases in both recreational and inshore professional fishing for other species are expected.

Key characteristics

<table>
<tr><th>Target species</th><th>Historical catch (tonnes)</th><th>Current catch (tonnes)</th><th>Increased productivity</th><th>$M 2013</th><th>$M 2018 (2013 $ values)</th></tr>
<tr><td>Sydney Rock Oyster</td><td>140 000 bags Sydney Rock Oyster only</td><td>39 475 bags Sydney Rock Oysters
2720 bags Pacific Oysters</td><td>Return to at least 1970 production levels</td><td>$30.3M</td><td>$100.4M</td></tr>
<tr><td colspan="6">Comments: Oysters are an integrator of overall estuary condition and most importantly the net primary productivity within that estuary. Sydney Rock Oyster aquaculture production crashed from a peak in the 1970s due to a range of catchment stressors that include acid soil and anoxic runoff, poor sewage management systems, harmful algae blooms and major QX disease outbreaks. The QX resistant and more rapidly growing Pacific Oyster has been introduced as a replacement in many estuaries, although this species has also now been affected by catastrophic disease outbreaks.
Data sources from NSW DPI (2013). Aquaculture Production Report 2011–2012. NSW Department of Primary Industries. Port Stephens Fisheries Institute.</td></tr>
<tr><td>Mullet (Mugil cephalus & Myxus elongatus)</td><td><3000 tons
200 tons</td><td>>5000 tons
120 tons</td><td>Return to at least mid-1990s levels</td><td>$30M</td><td>$50M</td></tr>
<tr><td colspan="6">Comments: Mullet species (Mugil cephalus and Myus elongatus) are caught from the Estuary General and Ocean Haul Fisheries during its spawning migrations along the coast. Mullet is deceptively considered a low value family seafood, to some degree underrated by the consumer marketplace. However it is the biggest biomass of commercial catch in NSW and provides high value export roe products, as well as business operations for Aboriginal Australians. It is a very sustainable species with high fecundity, however in the last decade the average catches have dropped by close to 50% compared to prior long-term stable catches. Considering the high fecundity, is not logical that a lack of reproductive output is a significant contributor to this reduction, and the evidence for recent disease outbreaks of Red Spot lesions and reduced populations suggests that flood plain management systems as well as artificial flow regulation contribute to this decline. Mullet generally spawn inshore at age 3 onwards with larvae recruiting to estuaries and particularly fresh to brackish wetlands. Repairing the previously drained and barraged floodplain wetlands, as is the proposed focus of much of the eastern Australian investment will lead to markedly increased populations of mullet and will also alleviate the current fish diseases of red spot. Mullet are closely linked to the net primary productivity of the estuaries and fresh to brackish wetlands being low in the estuary food chain. This is expected to lead to comparatively rapid increases in their population.</td></tr>
<tr><td>School Prawn</td><td>>1000 tons</td><td>674 tons</td><td>Return to at least mid-1980s levels</td><td>$8M</td><td>$12M</td></tr>
<tr><td colspan="6">Comments: School Prawn (Metapenaeus macleayi) are highly fecund annual stock with close correlations between stock and climate – wetter years with more brackish estuaries and more connection between estuary and wetlands leading to higher populations. School prawn spawn close inshore with almost immediate recruitment to estuaries and provide the fifth highest biomass of commercial fish catches in NSW across three sectors, Estuarine General, Prawn Trawl and Ocean Haul. During early growth phases salt marshes and mangrove and brackish wetlands are preferred habitat. As the prawns mature they move to estuary muds and seagrass areas and once ready to spawn rise from the bottom during dark periods (no moon) and run against the tide to the ocean. Being highly fecund and an annual population it is assumed that once water quality, access and habitat is repaired the prawn population will rapidly respond. For example, prawns were found in open tributaries in seine net catches of up to 3–4 orders of magnitude greater than catches just below floodgated tributaries and their acid sulfate leachate. Thus the potential of a 3–4 fold increase in prawn productivity through floodplain repair is suggested and recognising the magnitude of the drained wetland and floodgate problem this is probably extremely conservative.</td></tr>
<tr><td colspan="6">Total estimated productivity value increase for these selected species post 2018:
at least $94M per annum
Break-even point for proposed New South Wales floodplains investment:
less than 3 years</td></tr>
</table>

Other key commercial species not valued in terms of productivity improvements but likely to benefit from estuary repair include Eastern King Prawn, Yellowfin Bream, Dusky Flathead, Luderick, Mulloway, Garfish, Eels and Whiting.

Key non-costed and non-market benefits	
Recreational fishing	Yellowfin Bream, Dusky Flathead, Sand Whiting, Luderick, Sea and River Garfish, Mulloway, Mud and to a lesser degree Blue Swimmer Crabs and School Prawns are all target species. With estimates of productivity increases as outlined the stock available for recreational catch will markedly increase.
Reduced likelihood of anoxic events and acidic leachate causing fish productivity / biodiversity losses and diseases	The major thrust of much of the investment is to re-establish key wetland complexes, removing levees and floodgates that isolate the tide and fish from these major nursery areas and rehabilitating drains within these complexes. The repair of these major assets will remove much of the cause of the low dissolved oxygen, acidic black water that characteristically is dumped from these grossly disturbed ecosystems. Major fish kills are expected to be reduced in frequency and severity with flow on benefits to overall estuary biota. Similarly, these extreme event discharges are implicated in major oyster kills and diseases.
Coastal biodiversity	These wetland complexes with their fresh to brackish to sometimes almost seawater salinity are extremely productive in their natural condition for many species of waterfowl – including at least seven species of duck, several species of cranes, and cormorants such as brolgas, darter, little cormorant, ibis and egrets.
Carbon sequestration	Many of the current poor condition wetland complexes export methane from their peaty soils, contributing to the overall pollution budget of greenhouse gases. Re-establishing their ecological functions will change these systems from net exporters of greenhouse gases to net sequesters. Noting that the 1% of Australia that is coastal wetland sequesters about 39% of Australia's carbon, the benefits are substantial.
Improved flood control	1960s style flood control systems and implemented as 'flood mitigation ' have proven to be inadequate, often holding up flood heights in the lower part of the catchments. Multi-objective redesign of catchment flood control and floodwater management will benefit urban, agriculture and fisheries.

1.5 An iconic region – the Great Barrier Reef catchments

The Great Barrier Reef is more than just the coral reefs – seagrasses, mangroves, salt marshes and brackish to freshwater wetlands are essential parts of the reef ecology.

Red Emperor spends its nursery phase within nearshore and estuarine environments. Likewise Coral Trout have larval phases close inshore. Without a healthy nursery there will be fewer adult fish with flow-on implications to coral ecosystems, commercial and recreational fishing, and diving and snorkelling experiences. The Great Barrier Reef tourist industry is estimated at between $4B and $5B per annum. The live Coral Trout professional fishery is worth between $15M and $40M or higher as a function of the proportion sold live per annum and with repair of nursery grounds, stocks available for fishing are expected to increase. Species that have a very clear estuary dependence and if the data were available could be more precisely estimated in terms of historical productivity decreases and potential productivity increases with repair are Barramundi, and Banana and Tiger Prawns.

Barramundi post larvae and juvenile phases up to at least three years of age feed and grow within estuarine to brackish to fresh environments. Spawning and re-recruitment then occurs from near estuary mouths. Because Barramundi exploit entire river systems, increase in Barramundi productivity would be a broad indicator of connectivity and associated increased area of improved habitat. For example the proposed work on the Fitzroy to provide passage through wetlands to the upper Fitzroy around the main weir just above Rockhampton will ensure Barramundi have access to at least another 120 km of main river channel – without counting side channels, contributing rivers and creeks. However actual increase in population of Barramundi let alone what proportion will be caught in the commercial fishery, or in the recreational fishery or will remain wild is not easy to predict.

Likewise, as yet there is no knowledge of carrying capacity and how it might vary with instream water quality, food stock available and so on. There are as yet no reputable scientific predictions of productivity increases per unit area of repaired waterway or wetland habitat. Therefore no estimate of dollar return can be made with any degree of accuracy.

Banana Prawns spend their larval, post larval and juvenile phases in estuarine environments, especially mangroves and salt marshes, with sub-adults then exploiting seagrass and both sandy and muddy bottom environments. As with other crustacea, the limited science available on their early phases suggests that Banana Prawns are likely to be an excellent indicator of improvements in salt marsh condition such as removal of bunds on ponded pastures and of increased tidal flows as accompany removal of all instream barriers.

Tiger Prawns spend their larval, post-larval and juvenile phases in lower estuarine environments, especially seagrasses. Increased productivity of Tiger Prawns follows from increased health and vigour of seagrass beds and thus improved water quality/reduced turbidity.

The science has yet to be done to fully understand reductions in productivity of Banana and Tiger Prawns with reduction in habitat available. Further the historical data on catch is very incomplete, let alone there being any useful estimates of catch as a proportion of total stock available. Many of the changes to habitat for both these prawn species were well underway by the late 1950s and 1960s. Excessive turbidity and the loss of seagrasses accompanied all grazing, agriculture and roading development. Drainage and loss of wetlands and connectivity, including the construction of bunds started in the same period. Ponded pasture construction was initiated in the early 1980s, probably came to a peak in the early 1990s and was discouraged from about 1995 onwards because of the impacts on prawn stocks and fisheries generally.

The actual decline in total population from 1950s onwards is simply impossible to predict without further science that starts with an estimates of carrying capacity for the various components of habitat and their interactions and then traces the losses of habitat through until the present day to determine a changed carrying capacity and thence projected reduced total biomass.

There has also been a very confounding variety of changes to effort, improvements in the methods of catch and gear, including moving to more efficient nets, triple and now quad gear, better knowledge of where to concentrate effort and changes in entitlements and restrictions on effort accompanying changes in Great Barrier Reef zoning. This further makes any estimates of reductions in prawn productivity very difficult to attribute to causes.

Nevertheless the data on tonnage production that is available from 1990 to 2009 suggests a total commercial catch decline from about 5500 tonnes to about 4000 tonnes over this period. Disentangling habitat causes from other causes is impossible. At the same time, even with the various restrictions on catch and entitlement there is certainly no indication that the wild uncaught stock has increased as a proportion of the total annual population (Sheaves et al. 2013).

Even if the most repair we can achieve is in such as returning habitat available and improved connectivity to the level of that of about 1990 and assuming 50% of the improvements is in the more valuable Tiger Prawn population then the approximate increased value of commercial product would exceed $45M per annum at today's prices.

Total estimated productivity value increase for these selected species post 2018: at least $45M per annum
Break-even point for proposed Great Barrier Reef region investment: less than 2 years

No estimates can readily be made for the many other species that would benefit. In terms of other key non-costed and non-market benefits the following summarises some of the key benefits.

Key non-costed and non-market benefits	
Recreational fishing	Recreational fishers target Mangrove Jack and Barramundi from fresh to brackish to estuarine to nearshore environments. Red Emperor, Estuary Cod and Coral Trout along with the many other coral reef species that spend the early life phases inshore are targeted whenever the weather is benign enough for small boat travel to the reef proper. Many other species such as the pelagics (e.g. Spanish Mackerel) are also targeted. Indeed virtually all recreational species with the exceptions of Tuna and Billfish rely on estuarine and nearshore environments so that any improvements in productivity will be reflected in their catch.
Coastal biodiversity	Iconic species such as Turtles and Dugongs will benefit from repair as indeed will the entire marine ecosystem towards a healthier total reef system. Improving the health of estuarine and inshore ecosystems is also expected to be addressing some of the core causes of Crown of Thorns outbreaks – far more effective and sustainable than harvesting mature Crown of Thorns.
Great Barrier Reef World Heritage standing and values	UNESCO has recognised that the Great Barrier Reef is comprised of a linked set of marine and estuarine ecosystems. This initiative focuses on the most degraded component of this system – the estuaries and wetlands.
Carbon sequestration	Mangroves, salt marshes and seagrasses comprise about 39% of Australia's carbon sequestration and have the greatest potential for carbon storage of any ecosystem on the planet, many times greater than tropical rain forests. Repair will increase carbon sequestration.
Tourism	There are many estuary/ecotourism companies that take nature appreciation and fishing tours within the reef's coastal landscapes.
Indigenous	Indigenous ecotourism ventures such as Mungalla focus on coastal wetlands. Major indigenous settlements on the coast (e.g. Yarrabah) are based largely around coastal resources.

1.6 Delivery as an Australia-wide program

There have been many unforseen impacts of estuary floodplain development right around developed Australia. Works undertaken in the past occurred without detailed knowledge of the importance of interlinked ecosystems, the benefits provided and the need for tidal flows and connectivity.

It is imperative that all components of the proposed program are delivered as a package. This will maximise outputs towards outcomes at minimal transition costs while also preparing the way for a legacy of ongoing management and protection of these key Australian resources.

The proposed Phase I investment within broad and inter-related cost areas is:

	Cost ($M)	**Proportion of total (%)**
Planning: all aspects to ensure approvals, undertake surveys such as tidal penetration, document proposals and likely return on investment of each proposed project	$21M	6%
Works, generally under some form of tender/contract arrangements with the owner: including fish passage, estuary and wetland repair and complementary works to ensure smarter floodplain and estuarine ecosystem management	$238M	68%
Monitoring based on sound science: covering habitat importance, repair and fisheries re-establishment priorities and habitat–population protocols to estimate likely improvements in productivity and selected monitoring to ground-truth these protocols. Will need to recognise climate variability and its influence on populations	$24.5M	7%
Reporting progress: summarising the outputs and longer-term likely benefits/outcomes of the total investment, undertaken annually and including an evaluation of progress and assessment of estuary condition in Year 4.	$10.5M	3%
Program **communication, legacy arrangements & marketing**: building on existing communication activities, marketing to the broader community the value of proactive repair and management of estuarine and nearshore ecosystems, linking to the Australia-wide Habitat Network and designing and fostering the implementation of community-led legacy arrangements. Also covers oversighting activities such as expert-based Australia-wide steering committee and program management activities	$17.5M	5%
Policy development: fostering comparable policy and regulations in each state for estuarine and nearshore habitat protection, repair and for development offsets	$17.5M	5%
Researching cost-effective repair and priority investments – building on existing knowledge of the estuarine dependence and preferred habitats of key species to predict priorities for all follow on works and activities post this five-year investment	$21M	6%
TOTAL	**$350M**	

1.7 Estimated maximum return period to achieve break-even analysis

This business case sets out the rationale and the priority opportunities for investment, repairing, under a 'no regrets' policy, estuary and wetland areas across the developed coasts of Australia and developing policy and procedures to protect the more natural northern Australian coastline. It seeks to maximise community benefits from these important parts of our landscape while minimising costs and impacts on adjacent land users of the coastal zone.

It builds on cooperation across Australia's coastal communities and their many stakeholders, recognises the entire Australian community as beneficiaries of secure high quality low cost seafood and seeks co-investment from all tiers of government and the community.

Even with only three regional case studies and the very confined consideration to only a sector of the commercial catch and aquaculture production within these case study areas together with the express exclusion of all other benefits, the return on investment to break even point is less than seven years for the Coorong – Murray Mouth and less than three years for both the larger NSW and Great Barrier Reef case studies. All benefits beyond that time are well and truly profit for the entire Australian community.

CHAPTER 2 Re-vitalising Australia's estuaries – the context

2.1 The problem

This business case seeks to address a key set of social, economic and ecological issues for Australia's developed coastal zones:

- **Socially, there has been alienation of a large sector of the Australian community.** The Australian professional and recreational fishing sectors have been estranged by a range of policy decisions, especially:
  - historically the drainage and disconnection of key wetland and floodplain habitats mainly for agricultural development
  - more recently the expansion of coastal urban development and associated infrastructure and
  - most recently, to add to the loss of fisheries productivity that these historical developments have caused, the loss of access to some of the remaining areas and perceived loss of stocks through the declaration of marine parks.

  A policy focus on optimising both public and private benefits of our coastal landscapes can repair these inequities.

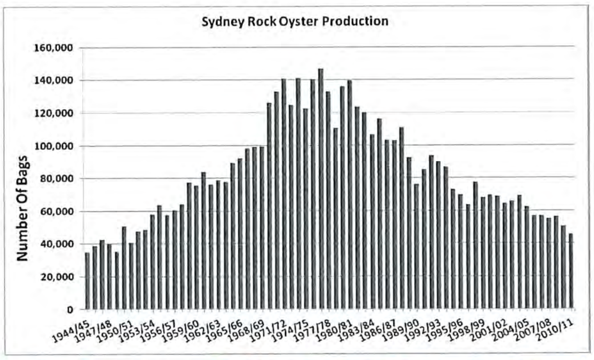
- **Unforseen ecological impact:** Historically, fisheries habitat within estuaries, their floodplains and wetlands has been lost or altered, often because works such as drainage, roadways, causeways, training walls, floodgates and levees did not consider these more public assets of fisheries production. Floodplain areas have been developed for a single objective – additional lands for agriculture. Yet in most cases we have ended up with wastelands between agriculture and the estuary that are neither useful for agriculture nor beneficial to estuary productivity. Many works such as levees, flood gates, culverts, causeways and drains were less than optimally designed and often poorly located. Through strategic works we can repair key parts of the landscape, often optimising both fishery production and floodplain agriculture.

- **The economic consequences of doing nothing:** Our inshore fisheries resources have declined and will continue to decline. Production levels are already down (e.g. school prawn fishery on Shoalhaven is now non-existent). There are already major fish kills in our estuaries associated with excessive wetland drainage and freshwater flows (e.g. Clarence and Richmond – 2009, 2010, 2011, 2013). Red spot and other fish and shellfish diseases that result from animal stress due to water quality are common occurrences. Most importantly we are losing the professional sector – important for high-value secure, low-input–cost food supply and the recreational sector – important from lifestyle and tourism perspectives with multiple values adds into regional economies.

An excellent example of production losses is demonstrated by Sydney Rock Oyster production in NSW. The Sydney Rock Oyster is chosen here as a simple example of the social and economic consequences of declining ecological health because Sydney Rock Oyster was previously naturally abundant and is cultured in a fixed location in the lower estuary. Its cultured production levels and organism health integrates impacts from the entire estuary, including both upstream influences and tidal flushing and by being cultured, aspects such as effort and climate influences are not as variable compared to that for other wild fisheries. The figure displays total NSW Sydney Rock Oyster production per year. Improved cultivation techniques were increasing production up till the 1970s.

However wetland loss, drainage and overall loss of estuary net primary productivity has meant production since then has declined. This is in spite of further improvements in growing technology, enhanced genetics and increased consumer demand and price. Many estuaries have now been totally abandoned as oyster growing areas and in other estuaries the more resilient Pacific Rock oyster is replacing Sydney Rock. Now with the recent spate of floods we are also seeing major kills of the more resilient Pacific Oysters.

Bags – Sydney Rock Oyster 1950 to 2011



Major production losses post 1970's relate to decline in estuary health, even though production techniques have improved.

Lisa Kirkendale, Pia Winberg, Ana Rubio, Peter Middelfart (in prep). "The Australian oyster industry: Challenges and Opportunities" Reviews in Aquaculture

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There are three interlinking components to healthy fisheries[1]: habitat, water quality and fishery management. Fisheries management in all states have delivered improved catch management systems such as reduced impact gear and methods for example to reduce by-catch; seasonal closures to avoid spawning aggregations; and permanent closures to protect habitat such as seagrass and critical species such as dugong. Water quality decline has been addressed though pollution control legislation for point sources and catchment management for diffuse sources. However little has been done Australia-wide to comprehensively address the various components of habitat loss.

A good example of decline in public and private benefits because of reduced estuary health is the NSW prawn and scale fish fisheries. School Prawn and Eastern King Prawn catches in NSW are considered fully exploited or overfished respectively at only 75% of the catch rates that were maintained historically during the 1970s and 1980s. Some rivers now only support recreational catches (e.g. Shoalhaven River). Similarly the Estuarine General Fishery has never surpassed Dusky Flathead average catches that were maintained in the 1960s and 1970s (NSW Industry & Investment 2010). Some of this decline could be due to improvements in the rigour of fisheries management to ensure long-term sustainability. However broad and consistent trends for most species in wild fisheries indicate other underlying factors, specifically limitations to recruitment due to loss of habitat and reductions in water quality. Much of the water quality decline, especially pH, heavy metals and anoxic or low dissolved oxygen conditions is due to the draining of floodplain wetlands. Repair the habitat and water quality will also improve.

There are individual success stories that indicate we can reverse the decline in fisheries productivity. In Wallis Lakes for example, measurable outcomes have been achieved with a focused and thorough investment in whole catchment – river, floodplain and estuary –

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1 'Fisheries' as a definition here includes all catch taken by professional and recreational fishers together with prey as part of an ecological food web and within estuary/inshore aquaculture.

improvement. Wallis Lakes was essentially closed as an oyster fishery after a hepatitis scare and poor water quality. Now it is amongst the cleanest oyster farming areas In NSW with open harvest. After comprehensive mapping of all the creeks, rivers and wetlands that flow into the lake, agricultural run-off and acid sulfate pollution were identified as key problems. The Great Lakes Council in partnership with state agencies and community groups used its levy to buy land to rehabilitate affected wetlands and to reconnect key areas of fresh to brackish habitat back to the estuary. The result is an oyster cultivation industry with certainty as to its future, increased overall fisheries productivity and improved ecological health – all with flow-on benefits in employment and income for the regional community.

2.2 Ecological context

Ecologically two key concepts underpin Australian fishery productivity – estuary/ floodplain/wetland dependence and linked freshwater/estuarine/marine systems.

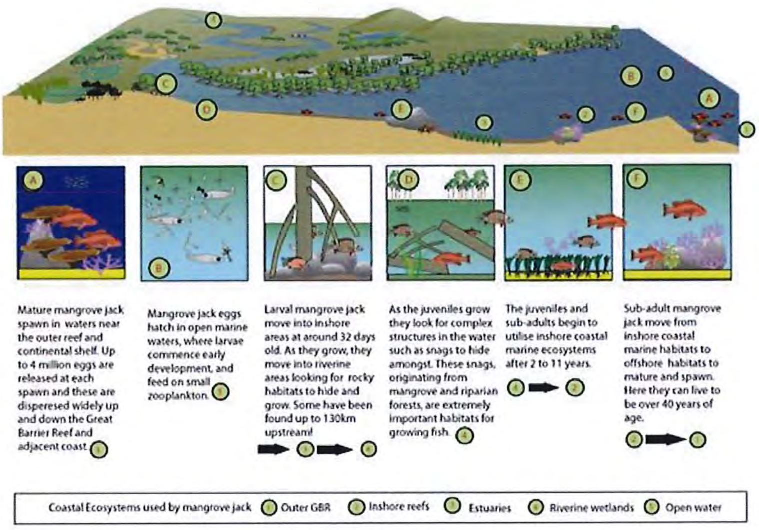
Virtually all Australia's target recreational species and some 70% to 80% of commercial target species are dependent on a life cycle phase within estuaries and wetlands. Most of the breeding of target species occurs inshore (e.g. Barramundi [*Lates calcarifer*] just outside estuary mouths, Common Mullet [*Mugil cephalus*] along ocean beaches) to well offshore in marine environments (e.g. Mud Crab [*Scylla serrata*] or Coral Trout [*Plectropomus leopardus*]). However most of the post larval and juvenile phases are sustained within the ecosystems of freshwater wetlands such as Melaleuca forests or sedgelands to estuaries with their mangroves, salt marshes, sand spits, muddy channels and seagrasses or inshore such as the seagrass and sands of the South Australian Gulfs. Both tidal and freshwater flows are essential, with estuaries and their fresh to brackish to saline mixing areas well recognised as the most productive of all ecosystems (e.g. Odum 1983).

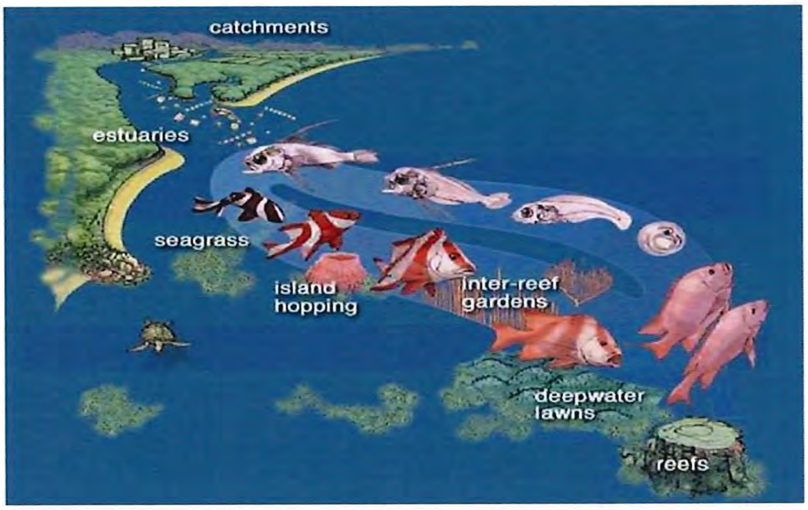
Works that will be of substantial fisheries productivity benefit are those that:

- re-establish connectivity between all these habitats and marine water and therefore makes these habitats biologically accessible or
- repair these habitats where they are in poor condition (e.g. drained) so that there will be a net increase in area of habitat or
- improve the physical drivers of tidal and freshwater flows and fluxes with their accompanying nutrients.

With linked freshwater – estuarine – marine systems and dependence dominating the life cycles of most Australian fish and prawn stocks, any conservation agendas such as marine park dedication will be less than optimum in its outcomes unless all the life cycle components of the stock the park seeks to protect are robust and the habitat supporting all the life cycle components is in good condition. Estuary – floodplain – inshore habitat and commensurate water quality, flows and fluxes are the missing links. Repairing estuary habitat will not only benefit professional and recreational fishing but will ensure the resilience of all marine park dedications.

Case study: Mangrove Jack *(Lutjanus argentimaculatus)* and the Great Barrier Reef catchment





Examples of the marine/estuary system: Mangrove Jack (*Lutjanus argentimaculatus*) and Coral Trout (*Plectropomus leopardus*).

2.3 Community benefits

There are multiple ecological, social and economic benefits in investing in repair of fisheries productivity.

Ecologically, increased fisheries production and flow-on benefits to all components of the natural coastal ecosystems are substantial benefits. Repair of estuaries and wetlands can bring back much of the lost habitat and will markedly increase fisheries production, possibly up to treble current production if historical catches can be used as a guide. This would include all the well-known targets for recreational and professional fishing – prawn species (e.g. School Prawn – *Metapenaeus macleayi* in the east and *Metapenaeus dalli* in the west, Banana Prawn – *Fenneropenaeus indicus*, formerly *Penaeus indicus* and Tiger Prawn – *Penaeus monodon*), Mud Crab (*Scylla serrata*), Silver or Yellowfin Bream (*Acanthopagrus australis*), Flathead (*Platycephalus fuscus*), King George and Sand Whiting (*Sillaginodes punctatus* and *Sillago ciliata*), Mangrove Jack (*Lutjanus argentimaculatus*), Barramundi (*Lates calcarifer*), Luderick (*Girella tricuspidata*), Snapper (*Chrysophrys auratus*), Garfish (including Southern Garfish – *Hyporhamphus melanochir* and River Garfish – *Hyporhamphus regularis*) and Coral Trout (*Plectropomus leopardus*) to name some of the most well known. Flow-on ecological benefits across the food chain include all predator–prey relationships and populations, whether its increasing dugong populations with more abundant seagrasses; crocodile populations with prey such as Barramundi; or jabiru, cormorants and egrets with prey such as crustacea, Herring, juvenile Tailor and Mullets.

Socially, our estuaries and nearshore zones provide cheap community access, be it for nature appreciation or recreational fishing. Much of the recreational effort, especially such as family fishing occurs within estuaries. Gear requirements are minimal and opportunities are multiple. Repairing the productivity of Australia's estuaries will have massive flow-on benefits to regional tourism, local economies and the Australian family lifestyle.

Economically, Australia is already importing substantial volumes of seafood at the lower priced end of the market for consumption. The input costs and gear complexity for professional fishers working within estuarine and nearshore areas are far less than the input costs, safety requirements and technical complexity of fishing offshore. Repairing fisheries productivity within estuarine and nearshore zones will increase the volume of comparatively cheap product, thereby substantially contributing to Australia's food security, its balance of trade and its export opportunities. Within estuary and inshore zone aquaculture will also benefit – especially shellfish (Sydney Rock Oyster – *Saccostrea commercialis*, Pacific Oyster – *Crassostrea gigas*, Blue Mussel – *Mytilus edulis*) and finfish such as Atlantic Salmon (*Salmo salar*). All of these first order economic benefits have immediate flow-on benefits to employment and support industries in Australia's coastal regions.

Flow-on co-benefits include:

- enhanced coastal water quality and resilience against hazards of flooding, drought and cyclones
- improved road and rail infrastructure and
- direct action carbon sequestration – wetlands and estuaries being the highest per hectare carbon sequesters of all ecosystems (Lawrence et al. 2012).

These co-benefits will ensure widespread community support and equally importantly imply that planning for all repair works must be done within a multi-objective context.

2.4 Long-term benefits of habitat repair

Experience to date principally overseas demonstrates that repair of habitat yields long-term benefits to food production, employment and lifestyle (Restore America's Estuaries 2012). Due to the limited extent to date of habitat repair in Australia there are very few detailed case studies. Wallis Lake provides one of the best examples. Local Government, the natural resources group, the fishing and aquaculture industries, state agencies and the community combined to repair major areas of wetland, fish passage and to reduce effluent streams into the lake. Benefits to the Oyster aquaculture industry, tourism and the local economy are substantial.

A recent USA report 'More Habitat Means More Fish' (Restore America's Estuaries in association with American Sportfishing Association and NOAA Fisheries 2013) found that restoring and expanding coastal and estuarine habitat leads to increases in fish populations, and has a positive impact on the communities and industries that depend on thriving and sustainable fisheries. Among the findings are:

- Over 75% of the USA commercial fish catch and 80% to 90% of the recreational fish catch depend on key estuary habitat at some point in their lifecycle. Australia's fish catch numbers have similar dependencies.
- *Fish populations can respond quickly to habitat improvement. Rebounds in fish populations can occur within months*. Australian experience is similar – and less than weeks after a block was removed as part of a pilot Biodiversity Fund project in the Burdekin, Barramundi and Mullet were exploiting the repaired habitat.
- *In San Francisco Bay, restored salt marshes have improved 41 fish species including steelhead trout, Pacific herring, green sturgeon and Chinook salmon*. Many of the project proposals for NSW in this business case would presumably result in similar increased populations for Australian species such as Mulloway, Yellowfin Bream, Mullet and Flathead.
- *Since 2000, in Massachusetts and New York, herring, shad and sturgeon have doubled and tripled in population due to habitat restoration projects. Just two years after a single culvert was repaired connecting Bride Brook to Long Island Sound, the herring population more than tripled from 75,000 to 287,000*. This business case includes proposals to improve fish passage where possible such as for the Murray and its Lower Lakes.
- *Within Chesapeake Bay one restoration project used oyster shell to rebuild the reef structures over a total of 86 acres. Native oysters repopulated these reefs, resulting in a 57 fold increase in the population to about 185 million oysters within 5 years*. This business case includes proposals to rebuild oyster and mussel beds within Moreton Bay, Port Phillip Bay and the sheltered areas of the Tasmanian east coast with expected flow-on benefits to the associated multi-species fin fisheries such as the Snapper fishery within Port Phillip Bay.

Most importantly, not only will fish populations rebound, but with sustainable management these populations will be present forever, an ongoing source of food and lifestyle benefits for the Australian community.

2.5 Criteria for a major initiative

2.5.1 Landscape optimisation through planning and consultation

Optimising the public and private benefits the Australian community can receive from estuarine and inshore ecosystems is challenging. Leadership and vision is essential as will be a strong emphasis on communication and developing shared community knowledge of the benefits to be achieved. Project-by-project detailed assessment and planning will be required to ensure maximum return on all repair investments, improving fisheries productivity and coastal ecology while paying equal attention to ensuring improvements in flood control, infrastructure and any private compensatory benefits on adjacent lands.

2.5.2 Capturing community commitment through leadership

There have been small initiatives to repair parts of Australia's estuaries. Community groups, State and Local Government have recognised past mistakes in our land use development of coastal zones. Most of the works and activities have had an emphasis on repairing estuarine and floodplain landscapes for multiple community public and private benefits. This Australia-wide initiative can build on the commitment and track record of these various activities.

One of the core reasons for an Australia-wide initiative is that the scale of the necessary repairs requires a major one-off investment best led and coordinated by the Australian

Government. Certainly internationally, many of the programs are characterised by the leadership and vision of an initial and substantial nation-wide program-level investment followed by ongoing management and finetuning through local community and industry groups.

2.5.3 Ongoing management and resources

Incentivising any one-off Australian Government investment is part of ensuring the success of any major investment. It is likely local management arrangements will vary from state to state. Offsets against port developments, boating and fishing licensing fees, 'blue carbon', differential rating and voluntary local action are all feasible and likely to be endorsed by regional communities. States such as NSW and Victoria already re-allocate boating and fishing licensing proceeds to works and management.

As an example, under the USA model 'blue carbon' is part of ongoing investment, the USA having endorsed carbon mitigation in coastal systems within its 'voluntary market'. Carbon sequestration from seagrasses, mangroves and salt marshes is the highest per hectare sequestration opportunity of all Australian landscapes.

Under the UK model 'local trusts' are set up to manage sections of streams and estuaries. These groups include fishers, the private sector and conservation groups.

2.5.4 Partnerships

Many groups and institutions are keen to participate in revitalising Australian estuaries. Local Governments recognise the importance of recreational and commercial fishing to their regional economies. Resource management groups such as natural resources, catchment management and Landcare groups, and water boards recognise the opportunities to optimise production and health of their coastal landscapes. Commercial and recreational fishing groups have habitat repair and management a high priority in their policy agendas. The Fisheries Research and Development Corporation and many states are actively involved already in habitat research and monitoring activities, albeit generally at a much lower level of activity than that proposed for this initiative.

Roll-out in each state would vary in terms of lead agency and institutional arrangements. This would be finalised through negotiations as part of the proposed first year of funding building on the strengths and opportunities in each state. The first year for many works will also be a planning year, time being required to finalise approvals across the plethora of State Government agencies involved in consent processes within public lands and tidal waters.

2.5.5 Knowledge for a high return on investment and to track progress

The Fisheries Research and Development Corporation, with its remit for both public and industry benefits from coastal ecosystems is the logical choice to oversight and co-ordinate the research, monitoring, and the reporting progress components. Chapter 13 suggests areas of priority for research and simple metrics for monitoring and reporting benefits.

2.6 Program components

2.6.1 Repair works and activities

An inventory of key thematic opportunities Australia-wide is collated in following chapters.

Great Barrier Reef estuaries and their repair are already recognised as important in a number of recent Great Barrier Reef Marine Park Authority and other reports. The focus is on reconnecting habitat and repair of the function of fresh to brackish to tidal wetlands currently isolated from tidal flows.

South East Queensland includes the same issues of connectivity and wetland repair, installing seagrass friendly moorings and re-establishing some of the historical oyster reefs within the sheltered bays of Great Sandy Strait and Moreton Bay.

New South Wales floodplain estuaries have suffered from many years of anoxic events and massive fish kills. Their coastal communities and Local Governments are keen to see action. New South Wales groups suggest action would be estuary by estuary, and focus predominantly on the larger floodplain estuaries of Tweed, Richmond, Clarence, Macleay, Hastings, Camden Haven, Lake Innes, Manning, Hunter and Shoalhaven.

Victorian and Tasmanian agencies and local communities recognise the need for wetland repair (e.g. Corner Inlet, Gippsland Lakes), re-establishing connectivity and both mussel and oyster reefs as the basis for multi-species fisheries.

South Australian natural resources groups, fishers and agencies suggest four key areas – Lower Murray and Coorong, the Gulfs, Coastal Salt Marsh complexes and the South East coastal lakes of Lake Bonney and Lake George.

Western Australia has a series of estuary-by-estuary water quality improvement plans for the southwest with the planning complete but insufficient resources to action these plans.

Northern Territory is predominately in near-natural condition except for centres of development such as Darwin Harbour. In the upper areas of several catchments there are abandoned mine sites with slime dams. If not rehabilitated these slime dams pose a heavy metal and sediment risk to the downstream riverine and estuarine environments. Much of the focus for the Northern Territory is on protection and policy development.

2.6.2 Underpinning works and outcomes with targeted research

The importance of inshore habitat – fresh to brackish wetlands, seagrasses, salt marshes and mangroves is well recognised. Likewise the damage caused by drainage, wetland loss, nutrient and sediment loading and changed pH is documented through various case studies. Knowledge needs requiring investment include:

- the benefits of repair and improved fisheries productivity compared to current land use as part of the impetus for change
- how best to address the dichotomy between private benefit of various estuary damaging land uses and the public benefits of estuary repair
- the relative importance of various types of estuary habitat and the various stressors such as water chemistry, temperature and hydrology on fisheries populations as input to smart habitat management decisions

- the specific habitat needs, both type and location of habitat, and the population management needs of key commercial and recreational species
- the role of key fisheries re-population nodes such as the Lower Murray for the Victorian south coast and
- opportunities to recast fisheries management arrangements to include adequate consideration of production levels from coastal habitats, their local carrying capacity and the variability in populations due to variable climate, especially catchment run-off.

In all, 16 broad topics for research have been identified within the two themes of Ecosystem Ecology & Responses and Human Interactions with Estuarine Ecosystems.

2.6.3 Reporting progress and return on investment

Monitoring and resource condition assessment to demonstrate the benefits of improvements is essential. These results then need to be projected out over the following 15 years to calculate the short-term return on investment of the works and activities. Monitoring will be done in partnership by state agencies, natural resource management groups, professional and recreational fishers and would include:

- water quality improvements (e.g. reduced pH and heavy metals and increased dissolved oxygen from repaired wetlands during run-off events and comparisons with those wetlands not yet repaired to their natural function)
- fisheries and prawn populations, especially juvenile populations in repaired tidal areas, seagrasses and wetlands with parallel monitoring in poor condition environments to demonstrate changes and to calculate overall biomass and fishery improvements
- area and type of wetland repaired and waterway area reconnected and
- changes to carbon balance in a series of selected paired sites that will provide much needed input data into a methodology for 'blue carbon'.

2.6.4 Resource condition assessment 15 years on

The last Australia-wide assessment of Australia's estuaries was undertaken by the National Land and Water Resources Audit in 2002. Revisiting and re-assessing under similar protocols the condition of Australia's inshore estuarine systems in 2017–18 would build on the prior work and provide an updated understanding of trends and condition 15 years on.

Priorities for any further investment post 2017–18 will be defined by combining this assessment and the findings from the monitoring activities.

2.6.5 Ensuring an enduring legacy through policy development

Investment towards fostering comparable policy and regulations in each state for estuarine and nearshore habitat protection, repair and for development offsets will provide the framework for ongoing management of these high value public resources.

CHAPTER 3 Key repair opportunities

3.1 Australia's coastal ecosystems and assets

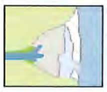
Australia's coastal ecosystems are made up of many complex components, all linked by water – fresh to brackish to estuarine tidal, nearshore and marine. Key to Australia's biological marine productivity are these estuarine and nearshore ecosystems – mangroves, seagrasses, salt marshes, sandy and muddy bottoms, fresh to brackish wetlands and inshore coral and rocky reefs. These are closely linked to catchment terrestrial ecosystems with one-way flows and fluxes of nutrients and sediments from the terrestrial ecosystems to the estuarine and nearshore ecosystems.

Most importantly, the estuarine and nearshore ecosystems are closely linked to Australia's marine ecosystems and there are two-way flows and fluxes of nutrients, sediments and biota between these coastal ecosystems and marine ecosystems. Much of the net primary productivity of the marine environment with Australia's generally nutrient poor marine waters and narrow continental shelf is driven by the health and productivity of the estuarine and nearshore ecosystems. These estuarine and inshore systems have suffered substantial degradation and by virtue of being the highly attractive coastal zone are most at risk from further development pressures.

The National Land and Water Resources Audit (Audit 2002) inventoried 972 Australian estuaries. Classification into six subclasses was based on the relative influence of the wave, tide and river energies that shape the estuaries. The overall geomorphology and habitats of an estuary along with its fish, crustacea and waterfowl populations are closely linked to these three main energy processes. The six subclasses are:

- wave-dominated estuaries: central basin is the dominant sedimentary environment
- wave-dominated deltas: mangroves/melaleuca and channels are dominant
- strandplains: intertidal flats, barrier/back barriers and channels are dominant
- tide-dominated estuaries: mangroves/melaleuca, salt marsh and channels are dominant
- tide-dominated deltas: mangroves/melaleuca are dominant and
- tidal creeks: mangroves/melaleuca and salt marsh dominate.

Conceptual models for all these types of estuary are included within the Audit's report and provide a basis for process understanding of how each estuary type functions. Understanding the processes that drive an estuary and its productivity is key to determining priority repair strategies.

	Type of coastal environment	Sediment trapping efficiency	Turbidity	Circulation	Risk of sedimentation
	Tide-dominated delta	low	naturally high	well mixed	low
	Wave-dominated delta	low	naturally low partially mixed	salt wedge /	low
	Tide-dominated estuary	moderate	naturally high	well mixed	moderate
	Wave-dominated estuary	high	naturally low partially mixed	salt wedge /	high
	Tidal flats	low	naturally high	well mixed	low
	Strandplains	low	naturally low wedge/partially mixed	negative/salt	low

Estuary types and their relative susceptibility to change. The estuary type diagrams illustrate key morphological features and diagnostic criteria for each type of system.

3.2 Australia's fisheries and estuary dependence

One of the main reasons many fish and crustacean species are particularly vulnerable and their biomass has declined is that their life history traits and behaviours include a dependence on estuarine and nearshore ecosystems – the Australian ecosystems that have been most degraded by our activities since settlement.

Case studies illustrate this dependence for Mangrove Jack and Barramundi.

Many other species have relatively long lives with a reliance on a small home range. This is a trait exhibited in part by dugongs and specifically by the recently described Australian Snub Fin Dolphin. Recent evidence also suggests commonly fished species such as King Threadfin Salmon and Grey Mackerel also exist as discrete local populations at spatial scales of less than 100 km. Genetic analysis of Barramundi has demonstrated that there appear to be discrete sub-populations. These localised inshore populations are particularly susceptible to cumulative impacts associated with declining water quality, coastal development and overall estuarine and nearshore ecosystem degradation (Jerry 2013).

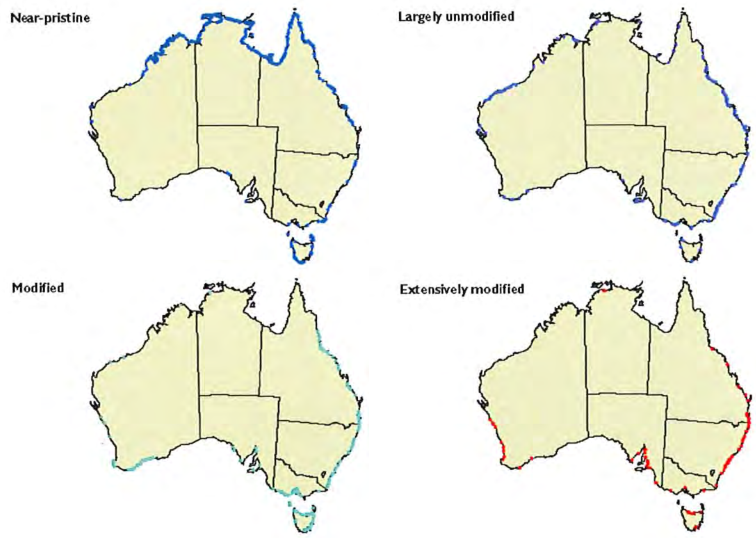
For other species such as Coral Trout, research is suggesting a somewhat homogeneous population across its range (Pratchett et al. 2013). Samples taken from near Lizard Island and from the Swains Reefs have demonstrated similar genetic traits and similar responses to stress such as changing ocean temperature. Vulnerability in this case is the condition of all estuarine and nearshore habitats along the range of Coral Trout.

3.3 Estuarine and inshore ecosystem condition

There has been substantial loss of estuarine wetlands accompanying catchment development for agriculture, infrastructure and urban uses around the developed Australian coast. These losses far outweigh the much more emotive community perceptions of loss to intensive developments such as ports in the otherwise undeveloped northern Australian stretch of coastline from above Geraldton in Western Australia around to and including most of Cape York in Queensland.

The Audit (2002) assessment of the condition of Australia's estuaries found that:

- 484 are near-pristine – most of these in tropical Australia, especially northern Western Australia, Northern Territory and Cape York and many of the rest on the west coast of Tasmania
- 210 are largely unmodified – many of these are also in tropical regions with a scattering of small estuaries, often within national parks along the east coast and Tasmania
- 186 are modified – predominantly along the east coast of Queensland, New South Wales, Tasmania and south-west Western Australia
- 92 are extensively modified – being predominantly along the east coast of Queensland and New South Wales, several in Victoria and Tasmania, South Australia and south-west Western Australia.



Condition of Australia's estuaries. Fifty percent are near-pristine, 22% are largely unmodified, 19% are modified and 9% are extensively modified.

Class	Subclass	Near-pristine	Largely unmodified	Modified	Extensively modified	Total
Wave	estuary	28	41	62	25	156
	strandplain	36	13	10	1	60
	other	40	30	22	17	109
Tide	estuary	57	25	9	4	95
	tidal flat/creek	210	43	16	15	284
	other	40	17	23	9	89
River	wave-dominated delta	28	24	30	12	94
	tide-dominated delta	36	16	11	9	72
Not classified		9	1	3	0	13
Total		**484**	**210**	**186**	**92**	**972**

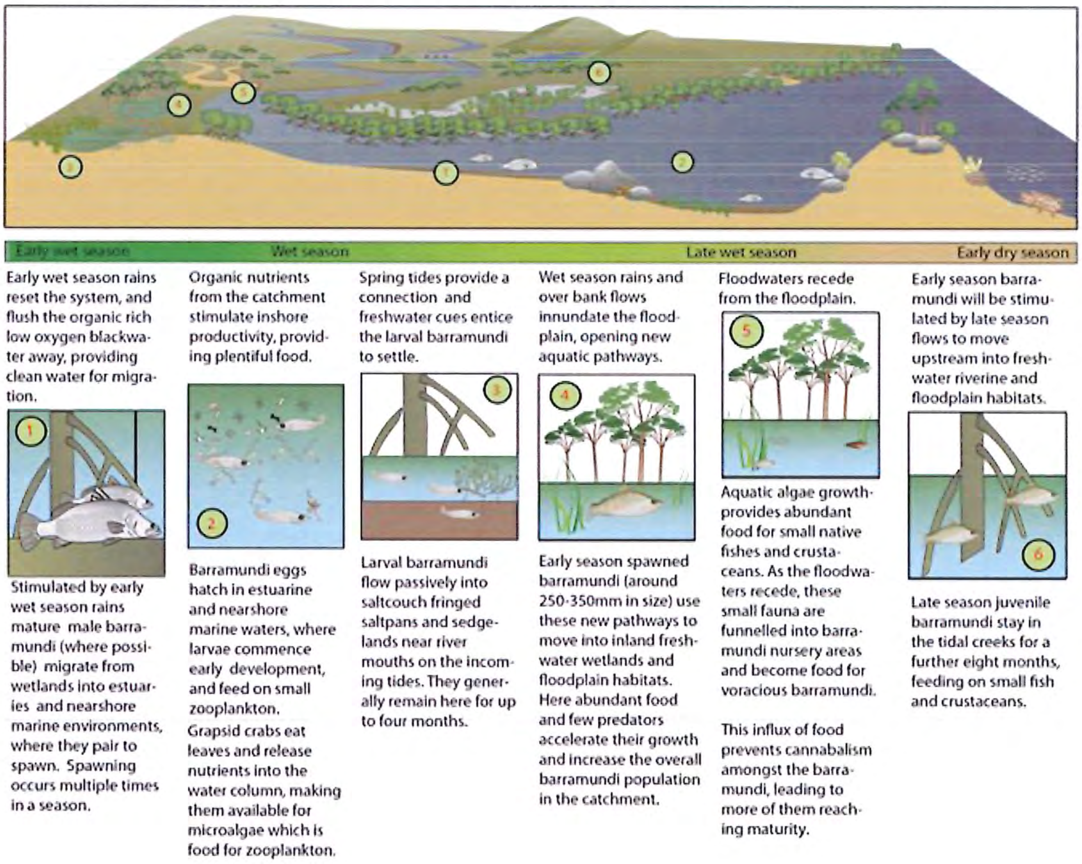
Condition of Australia's estuaries by process type.

This business case with its emphasis on repair concentrates on the extensively modified and modified estuaries.

3.3.1 One example: Great Barrier Reef catchments

Within the Great Barrier Reef catchments, fresh to brackish wetlands have been the most impacted, mainly from the drainage due to agriculture and grazing development. In excess of 80% of this wetland type has been lost across the Reef catchments, especially in the Wet Tropics and Mackay Whitsunday.

Case study: Barramundi *(Lates calcarifer)* and the Great Barrier Reef catchment



Case study of Barramundi and the Great Barrier Reef catchment.

Salt marshes have been impacted by drainage, especially by ponded pastures and cattle trampling. This is particularly prevalent in the drier more extensive floodplains. The top five basins with extensive areas of salt marsh/mangrove complex are:

- Shoalwater – 527 km^2 or 12% of Great Barrier Reef estuarine wetlands – with many areas outside the Shoalwater Defence Lands altered by ponded pastures
- Styx – 356 km^2 or 8% of Great Barrier Reef estuarine wetlands – with very extensive areas of ponded pastures
- Fitzroy – 332 km^2 or 8% of Great Barrier Reef estuarine wetlands – with very extensive areas of ponded pastures
- Haughton – 318 km^2 or 8% of Great Barrier Reef estuarine wetlands – with very extensive areas of ponded pastures and bunded off estuarine creeks
- Normanby – 335 km^2 or 8% of Great Barrier Reef estuarine wetlands – with the vast majority in excellent condition by virtue of very limited agriculture and grazing development.

Overall in excess of 30% of Great Barrier Reef salt marshes have been lost, and in some basins such as Fitzroy and Burdekin the losses are closer to 60% (GBRMPA mapping).

Seagrasses have reduced in extent with the major cause of losses being increased water turbidity/reduced light penetration.

The wetland type that has suffered the least is the mangrove ecosystem. Overall there has been in areal extent terms very limited loss of mangroves. Most of the catchments with their increased bed load of sediments have favoured mangrove colonisation of mudflats and sand spits. Mangroves have however lost much of their net primary productivity due to reductions in tidal flows because of causeways, road and rail, sedimentation and overall reduction in the extent of estuarine areas, especially levees and bunds isolating small creeks.

Riparian vegetation has often been removed from creeks and streams, both freshwater and within the tidal zones, especially in the upper tidal to brackish zones. This alteration extends throughout all the developed Great Barrier Reef catchments and has been the subject of various repair projects in the past, especially by Landcare groups, individual landholders and the previous river improvement trusts. Reef Rescue I has also had substantial impact, especially in grazing landscapes. Generally just fencing off riparian lands to restrict cattle access and facilitate natural regeneration is all that is required to re-establish riparian vegetation. It is anticipated that Reef Rescue II will continue the work with the grazing industry to rationalise cattle access and improve riparian condition. Riparian repair is included within this initiative where it directly supports estuarine and freshwater wetlands that benefit the Great Barrier Reef ecosystem.

Loss of connectivity and fish passage is the other key area of degradation of estuarine and nearshore ecosystems. As an example, there are over 1500 barriers or bunds across previously tidal creeks just in the Burdekin floodplain. The Great Barrier Reef Marine Park Authority has a detailed mapping dataset for the entire Great Barrier Reef region identifying most of these barriers. All the developed catchments have lost connectivity in both major rivers and in many second and third order streams and estuarine embayments/creeks.

A second example of the extent of barriers is the audit of the wet tropics region by Tina Lawson, Frederieke Kroon, John Russell and Paul Thuesen, 2010. The table summarises their findings, well over 5500 barriers inventoried in the wet tropics region.

Total number of potential artificial, physical barriers and total stream length in each of the Wet Tropics basins (after Lawson et al. 2010).

Basin	Number of barriers	Total stream length (km)
Barron	837	2 332
Daintree	377	2 198
Endeavour	34	81
Herbert	867	7 245
Johnstone	1 069	2 384
Mossman	233	470
Mulgrave–Russell	1 076	2 041
Murray	309	1 218
Tully	734	1 795
Total	**5 536**	**19 764**

Based on the authors' selection criteria for importance of the barriers to the instream ecology and productivity of these drainage basins they recommended 104 barriers as high priority for rehabilitation, 1476 as medium and 3957 as low priority. The Daintree basin has the highest number of high priority potential barriers (32), followed by the Mossman (19) and the Mulgrave–Russell (17), while the Barron has the lowest number (2). The largest basin in the Wet Tropics, the Herbert, has 10 high priority potential barriers within its extents.

The life cycle of Barramundi shows the importance of the total set of estuarine and nearshore ecosystems and their relationship to the life cycle of a key commercial and recreational target fish species. Barramundi exploit the range of estuarine and nearshore ecosystems at different times of the year and as their lifecycle progresses.

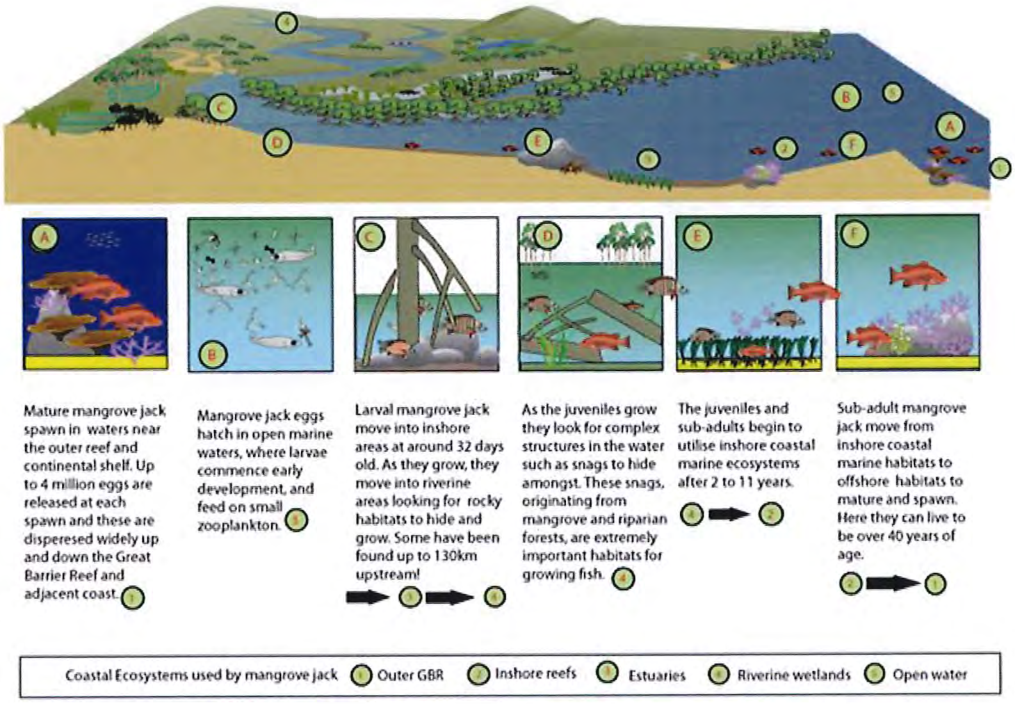
Other well-known examples of these lifecycle–ecosystem relationships are Red Emperor and Coral Trouts – with their juvenile phase in estuarine and nearshore ecosystems, Mangrove Jack travelling up into rivers and creeks and all species of prawns. Tiger Prawns especially exploit inshore and nearshore seagrass habitats with Banana Prawns predominating in estuarine, mangrove and salt marsh through to brackish wetland ecosystems.

Some 75% of the Reef's commercial fish and crustacean catch have lifecycles dependent on estuarine and nearshore ecosystems. For the recreational catch, by virtue of most of the effort being inshore the proportion of catch that is estuarine-dependent is probably closer to 90%.

For the Great Barrier Reef catchments, floodplain estuarine and nearshore ecosystem connectivity and function has been affected by multiple, small-scale activities. For example, bunds have been placed in many estuarine ecosystems to minimise tidal influence with the objective of fostering the extension of intensive agriculture or to provide grazing additional areas such as ponded pastures. In many cases this extension of agricultural pursuits has not occurred or has not been productive, the soils being unsuitable, often gleyed clays that remain waterlogged and with high salt loads.

The impact of these actions is often not immediately apparent, especially on a case-by-case basis, but when considered cumulatively the repercussions for overall productivity decline of the coastal and Great Barrier Reef as a system are substantial. Loss of ecosystems and function, declines in water quality, exposed acid sulfate soils, weed invasion and decline in natural net primary productivity and biodiversity, loss of feeding and nursery areas all imply loss of ecological health and most importantly public benefit from these assets.

Case study: Mangrove Jack *(Lutjanus argentimaculatus)* and the Great Barrier Reef catchment



Case study of Mangrove Jack and the Great Barrier Reef catchment.

The later chapter on NSW provides a further set of examples of very substantial estuary degradation, occurring largely through the drainage and floodgating of the major floodplain wetlands of the larger NSW estuaries. This was done as a major Australian Government – State Government – Local Government scheme in the 1960s through to early 1980s, was funded 40% – 40% – 20% and was done with the best intentions at the time to create additional agricultural lands.

3.4 Spring-boarding from existing community and government partnerships

All the essential elements are in place to effectively implement a major repair initiative that will revitalise Australia's estuarine and nearshore ecosystems. Key elements include:

- Natural resource management groups and other non-government organisations such as Oceanwatch and WetlandCare have built capacity to design, negotiate and then undertake repair works in partnership with landholders and state agencies.
- State Government agencies in all jurisdictions recognise the importance of the issue, the community support that will be engendered through a major initiative and have all the competencies required to oversee programs of works and related activities within their jurisdiction.
- Local Governments recognise the importance of their estuaries, their significance to regional economies and have capacity in engineering works such as road culverts to improve tidal ventilation and levee rationalisation for improved flood control and fish passage.

- Water supply authorities such as water boards have participated in repairing fish passage and are keen to seek further efficiencies in water delivery, use, re-use and quality.
- Non-government fishing organisations across both the recreational and professional sectors have habitat repair as one of their key policy priorities, have participated in various estuary repair projects and are especially proficient at monitoring the improvements in biodiversity that accompany repair works.
- Researchers within universities have internationally recognised skills in both research and monitoring of coastal ecosystems. Many of these researchers are already working within the project management, user engagement and communication protocols required by the Fisheries Research and Development Corporation in the conduct of its research programs.

The management challenge now is not only to ensure that any future development in and adjacent to Australia's coasts is ecologically sustainable but also to repair past mistakes in development.

> Coastal and estuary development will continue. Even with the best of planning and controls, some localised degradation will have to occur to allow rational development to meet the Australian communities' many economic and social objectives. Investment in repair provides a much needed buffer to any localised losses that will accompany development such as port works. The outcome will be a net economic and ecological gain, repairing Australia's estuaries for Australia's food security and lifestyle.

3.5 Repair opportunities

Following is summary illustrative information on some of the various opportunities for estuary repair.

3.5.1 Ponded pastures and the interface between grazing and wetlands

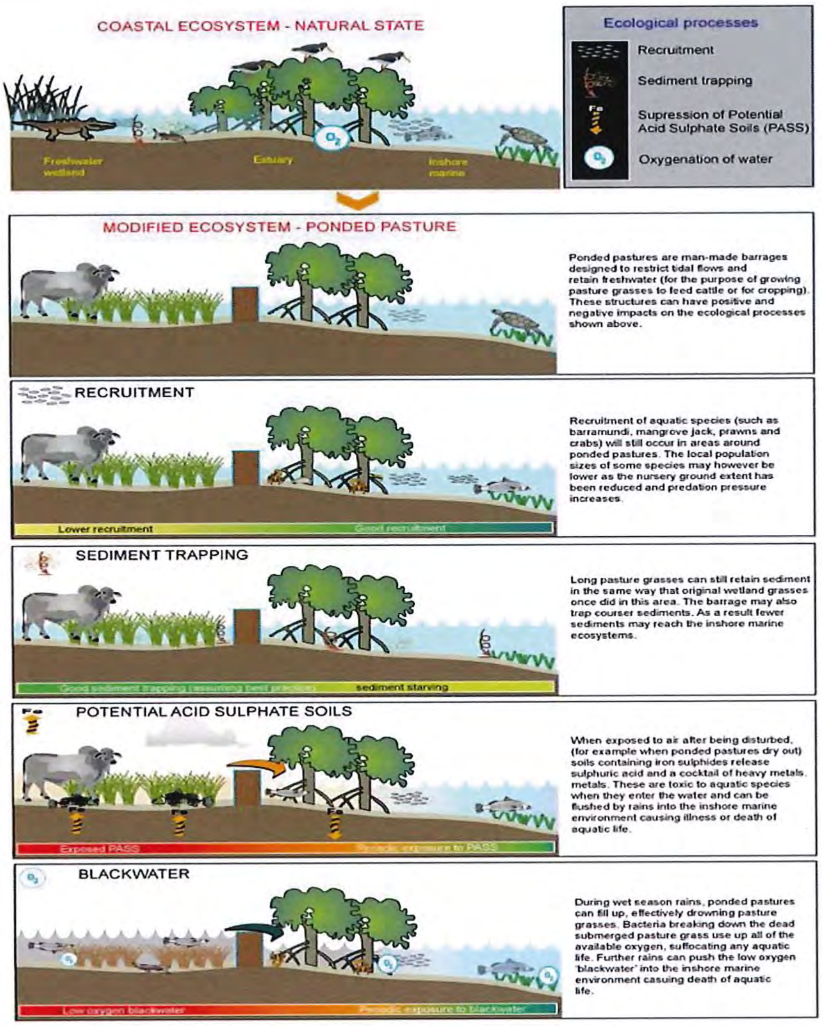
Ponded pastures predominate in the drier more extensive tropical catchments and were constructed initially as an attempt to improve cattle grazing carrying capacity. Pasture species such as Hymenachne and Parra grass, now considered to be major weeds, were introduced based on the work of the then CSIRO Division of Tropical Crops and Pastures and its somewhat mistaken vision of introducing novel pasture species to tropical Australia.

Many of the works are unauthorised or were done prior to legislative control, some are on private lands and many are on public lands and cut off named watercourses. From a food security perspective these areas are far more productive per unit area as a basis for fisheries production (e.g. Banana Prawns) than they are for beef meat production.

All works to repair salt marsh and mangrove complexes in these areas will need to be carefully designed and agreed to by adjacent landholders. Incentives for fencing and the installation of watering points will be required in some cases.

Similar issues of degradation due to grazing are found across all of temperate Australia. In these cases the issue is more to do with unrestricted access of cattle into salt marsh and sometimes mangrove ecosystems. Incentives for fencing to better manage stock movements and provision of watering points would provide benefits for both graziers and our estuaries.

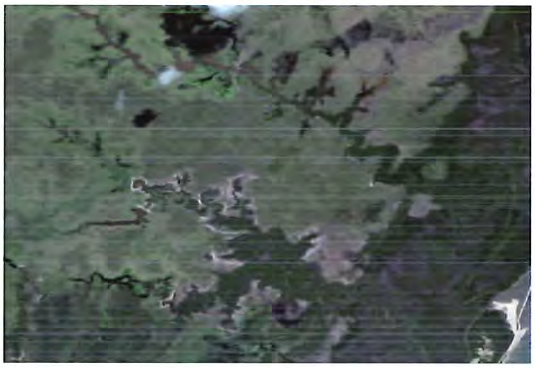
Resources however are limited. It is proposed that any such schemes in the various jurisdictions would be well promoted and seek producer uptake over a three-year roll out of incentives. After that time it is proposed the incentives scheme be phased out and replaced by appropriate planning and land management controls.



3.5.2 Bunds and weirs

Many weirs were constructed to provide weir pools for irrigation and urban drinking water supply. In many cases irrigation either did not proceed or the weir pool is now surplus to requirements with the development of regional irrigation water supply infrastructure or reticulated urban water supply. Most are instream, and can either be fully demolished as no longer needed or, because they are of relatively low height profile, modified to include fish passage. Generally because they are constructed within stream they are wholly on public lands, usually reserved bed and banks for named watercourses. Reinstatement of fish passage will ensure the upper stream areas are available for such as Barramundi, Mullets, many prawn species (e.g. School, Eastern King – *Penaeus plebejus*, and Banana Prawn), Mulloway and Yellowfin Bream.

Bunds are generally rock/earth mixes, sometimes just bulldozed up earth. Many bunds were constructed below the tidal limit to exclude tidal waters and were constructed to facilitate agricultural expansion and sometimes irrigation development, excluding tidal water from its previous extent along the fringes of floodplains. The bunds may go from freehold or sometimes public land on the banks across public tidal beds of the estuarine creeks and to freehold or public land on the other bank. The vast majority are unauthorised. Commonly the previous tidal beds of the creeks behind the bunds are dominated by weeds such as Parra grass, Hymenachnae and Typha spp. in the tropics; and Salvinnia and Water Hyacinth spp. in the more temperate regions. Reinstatement of tidal creeks and channels will advantage juvenile fish species including Barramundi and Mangrove Jack, juvenile crustaceans including Mud Crabs; and Banana, School, Eastern King and Tiger Prawns. Reinstatement will need to be carefully planned. Issues to be addressed include tidal surveys to determine the area of likely tidal influence, improved water management on adjacent farms and deep holes excavated to ensure refuges for fish during low tide events.



3.5.3 Wetland drainage, floodgates and levees

These often complex systems of constructed drains, floodgates and levees are predominant in all the major floodplain estuaries of Queensland, New South Wales, Victoria and south-western Western Australia. Initial objectives were to drain large areas of wetland to provide increased area for agricultural development and rapid shedding of floodwaters from cropping lands. Floodgates are employed to stop floodwaters from the main river flowing back up into the drained wetland system. Levees are upstream and were designed to divert overland flow away from agricultural lands – but often these levees simply diverted the issue onto a neighbour's farm.

The lower areas of these wetlands are often peaty soils that remain unsuitable for agriculture, are often slumping due to drainage and typically overly potential acid sulfate soils. Run-off events lead to anoxic, highly acidic water entering the estuary proper from these drained areas, often causing fish kills. Many of the upper better drained and less waterlogged soil areas of these systems have been developed for agriculture, such as sugar cane or cattle grazing. Some of the drainage works and barrages were authorised; many are not. Likewise many of the levees are somewhat ad hoc.

Reinstatement of the lower bottom wetland areas of these various drainage schemes together with automatic control systems on floodgates will markedly improve water quality, allow fish passage and if done strategically in cooperation with surrounding landholders will also benefit both upstream agriculture and catchment flood management.

3.5.4 Infrastructure redesign

Infrastructure such as road and rail has generally been developed and improved over time as regional Australia has developed. In many cases neither flood or tide and fish passage requirements were factored into the design of infrastructure crossing the coastal floodplains and associated waterways.

Lack of incorporation of flood behaviour in design has lead to roads and rail damming up and slowing down floodwater run-off, channelling its erosive force which in some cases has lead to costly repair works.

Tidal flows were generally of secondary priority to the design requirements of constructing crossings at minimal cost. Further, even if cost was not an over-riding consideration, many causeways, culverts and crossings were constructed without understanding the importance of tidal flows as a driver of fisheries productivity. Areas such as the Lucinda causeway reduce the productivity driving tidal flow into the mangroves upstream of the causeway, disadvantaging many species such as Mangrove Jack, Mud Crabs, and Tiger and Banana Prawns. Other sites such as Shallow Channel on the Clarence floodplain have been partially repaired (see NSW chapter).

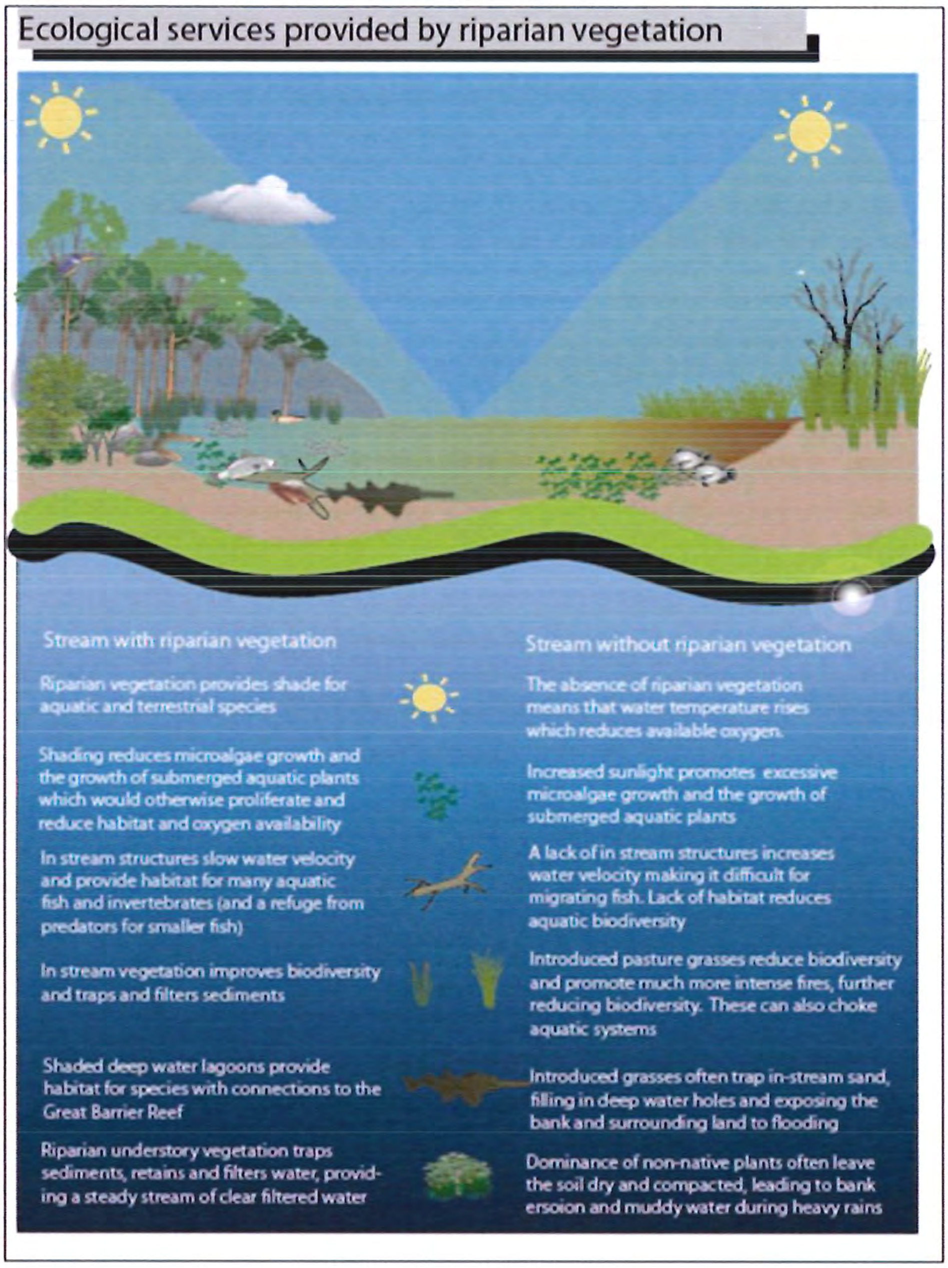
Likewise, even if crossings were deliberately designed with connectivity in mind, often there was limited knowledge of the fish passage needs of juvenile fish species. Fingerlings generally cannot swim against high velocity flows. A culvert that restricts the area for water flow will lead to higher velocity flows than that which a fingerling can swim against. Many secondary roads crossing wetland areas, while they have culverts built into their design, do not have sufficient width of culvert to facilitate low velocity flood flows and therefore flows that fingerlings can swim against to re-populate the wetland areas as part of their nursery phase.

Reinstatement of tidal flows and slowing the velocity of flood flows out of wetlands can be easily achieved through the addition of extra road and rail culverts. Generally adding more culverts will also be of advantage to the infrastructure by improving flood proofing and reducing the likelihood of high water tables thereby minimising potholing.

3.5.5 Riparian landscapes

Research by Tim Marsden (pers. comm., QLD DPI 2010) in the Mackay Whitsunday has shown that both water quality and habitat structure are important for fish species. The most bio-diverse and highest biomass river/creek systems were those with both high water quality and intact riparian areas.

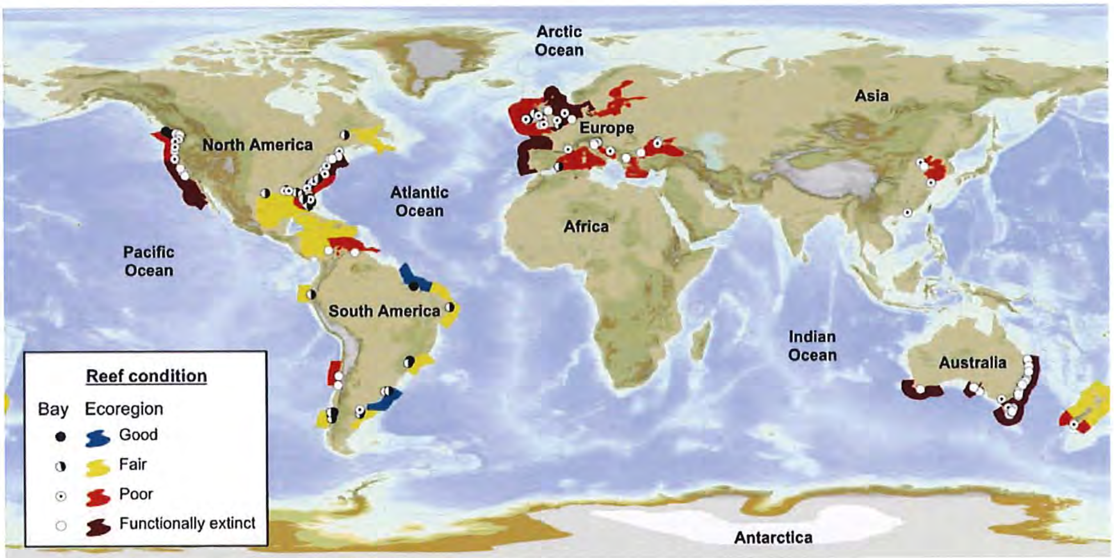
The improvement of riparian areas as part of more sustainable grazing and agricultural practices is generic across Australia, both estuarine and riverine reaches of all significant waterways.



3.5.6 Within-estuary seagrasses and shell beds

Seagrasses, a prime part of the estuarine nursery habitat across Australia have been lost due to urban and industrial pollution (e.g. the Gulfs of South Australia) or to mechanical damage (e.g. boat swing moorings in major urban environments such as Pittwater, New South Wales or Moreton Bay, Queensland. Seagrasses have also declined in extent due to increased turbidity/reduced light penetration and increased muddy sedimentation in most estuaries.

Oyster or mussel-based reefs and shell beds have been lost due to harvest for lime, over fishing, dredging, and prior industrial and urban pollution. This experience is replicated globally, with many of the world's previous shell beds now regarded as 'functionally extinct'.



Global condition of oyster reefs in bays and ecoregions. The condition ratings of good (less than 50% lost), fair (50% to 89% lost), poor (90% to 99% lost) and functionally extinct (more than 99% lost) are based on the percentage of current to historical abundance of oyster reefs remaining. Courtesy Beck at al. 2013.

Fisheries agencies across Australia have trialled the re-establishment of seagrasses and shell beds to the level where technologies for repair are now well established. The South East Queensland Natural Resources Group has demonstrated systems for improved swing moorings that markedly reduce seagrass damage.

USA experience demonstrates how improved shelter such as seagrasses lead to higher growth rates, for some salmonoids up to six times higher growth rates. Re-creating oyster beds have also proven to be beneficial to fish populations. In Mobile Bay, Alabama, constructing an oyster shell reef increased populations of several economically important species including a threefold increase in Blue Crab population, doubling the population of Red Drum and almost doubling Spotted Seatrout and Flounder populations (Restore America's Estuaries 2013).

CHAPTER 4 Goals and objectives

The Revitalising Australia's Estuaries goals are to:

- ✓ increase, through repair works, the quality and quantity of estuarine and coastal inshore wetland habitats that support a broad diversity of fish, prawns and other coastal species for the benefit of the Australian community – indigenous peoples, fishers, farmers, urban and industry stakeholders, and most importantly consumers with the increasing need for high quality reasonably priced seafood
- ✓ reverse declines in the quality and quantity of estuarine and inshore coastal wetland habitats and water quality to improve the overall health and resilience of Australia's coastal and marine landscapes, including fish populations recruiting to marine parks or to professional and recreational fisheries
- ✓ implement stewardship arrangements and incentive systems that recognise the substantial public benefit of these ecosystems and will ensure an ongoing legacy of improved management.

To implement these goals there are five interlinked objectives.

Objective 1: Targeted habitat repair and increased productivity

Objective: Achieve measurable habitat repair and increased productivity by re-connecting fish passage thereby restoring tidal and freshwater processes and re-creating estuary and nearshore coastal wetland habitats.

The focus will be on re-establishing habitat exploited by Barramundi, Mangrove Jack and prawn species (e.g. Banana and Tiger Prawns) in the tropics or Bream, Flathead, Mulloway, Whiting, Mullets and prawns (e.g. School and various King Prawn spp.) in more temperate Australia. This builds on our detailed knowledge of the habitat requirements from freshwater through to marine environments required by these species. The assumption is that if we re-create the nursery and juvenile habitats for this group of species then it will be an excellent surrogate for all aspects of improving estuarine and inshore coastal wetland productivity.

Assessment of progress in achieving the objective will include reporting against the physical targets set for this objective and the monitoring and modelling of population abundance changes for these key high-value well-recognised species.

<u>Outcome</u>

- More productive coastal ecosystems for the benefit of the Australian community.

<u>Targets</u>

- Modify or remove more than 500 constructed barriers and bunds to enable fish passage and tidal flow from estuarine area to estuarine area, estuarine area to coastal wetland, or estuarine area to freshwater creek and wetlands
- Reconnect more than 2000 km of estuarine creeks and freshwater rivers and creeks to existing estuarine areas

Objective 2: Improvements in coastal ecological condition

Objective: Achieve measurable improvements in the area of fisheries nursery habitat and overall coastal ecological condition by repairing and re-connecting inshore coastal wetlands and their ecological productivity.

The focus will be on re-configuring drains, levees, bunds and floodgates to re-establish floodplain nursery habitats of swamps and billabongs. These are areas that in their current degraded condition:

- are otherwise not productive for agriculture, usually some rough grazing if any agriculture at all
- often have freshwater weed problems
- may be subsiding due to the nature of their peaty soils and drainage
- export highly acidic water because of their underlying acid sulfate soils after rain events
- produce high oxygen demanding biological detritus that leads to anoxic events following major run-off events and
- emit methane in well above natural levels, contributing to greenhouse gas pollution.

If the wetland function of these areas is re-created, there will be reductions in deleterious exports of acid water, biological detritus causing low dissolved oxygen and methane and improvements in their performance as sinks for nutrients and sediments, as producers of biomass and thence carbon sequestration to their soils and as contributors to overall estuary and nearshore ecology, including contributing to the freshwater and estuarine food chains.

Assessment of progress in achieving the objective will include reporting against the physical targets set for this objective, and the monitoring and modelling of key water quality indicators such as pH in selected case study areas. Subject to 'blue carbon' becoming part of Australia's National Carbon Accounts, selected areas could also be used as reference sites to measure and calibrate carbon sequestration.

<u>Outcome</u>

- Improved area of fisheries nursery habitat and overall ecological condition for these key components of the estuaries as part of increasing estuary productivity and resilience to shocks such as extreme cyclonic events and floods.

<u>Targets</u>

- Reconfigure more than 25 000 ha of fresh to brackish wetlands and accompanying waterways – including re-establishing wetland natural drainage patterns, rationalising levees, repairing connections to freshwater and estuarine ecosystems, and returning biomass productivity towards natural levels.
- Return more than 5000 ha of salt marsh previously lost to ponded pastures developments or degraded through grazing to normal estuarine function, including improving adjacent grazing land management activities, watering points and fencing.

Objective 3: Community commitment and involvement in estuary repair and management

Objective: Broaden the community of support and commitment to estuary and coastal wetland management, empowering local ownership, investment and management.

Government leadership and investment in partnership with the community and its organisations can initiate the change and provide the resources for the high costs of repairing what in hindsight were inappropriate works and structures in Australia's estuaries. In most cases, once repaired and natural processes of tidal flow re-established, management activities and costs will be minimal. Nevertheless maintaining and managing these assets once repaired still requires local commitment and action.

Management systems will be required that incentivise the benefits locally, empowering such as Local Government and industry groups to continue the work that government investment initiates. This includes recreational fishers gaining access to reaches and improved fisheries, improved management of adjacent farms to the benefit of both the coastal ecosystems and the farmer, industry groups such as port authorities contributing as part of an offset to their developments, and professional fishers undertaking ongoing monitoring and reporting under the guidance of protocols set for reporting on trend and condition. Voluntary and formal carbon markets may in time also provide an opportunity. 'Blue carbon' is already endorsed as part of the USA voluntary market. Nevertheless it is recognised that including 'blue carbon' in Australia's National Carbon Accounts is unlikely to occur in the short to medium term, even though on a per hectare basis repair of coastal ecosystems is Australia's most attractive and cost-efficient mitigation opportunity (Lawrence et al. 2012).

Outcome

- Australia's estuaries and coastal wetlands managed locally and to a high standard in perpetuity.

Targets

- As the endpoint of each repair project, management plans detailing the ongoing activities and resources required will be developed and will be included as part of the handover of each of the repaired assets to local managers.
- Put in place formal partnerships to underpin this resourcing at a regional scale across State Government agencies, Local Government, industry and community groups.

Note – these management plans will vary from the simple (e.g. a 'farm plan' for managing the interface between grazing lands and salt marshes) through to the complex (e.g. a plan for an entire floodplain and community follow on actions).

Some of the priorities for repair will become rapidly mainstreamed as part of normal business. For example the catalytic investment of incentives for changing boat mooring systems to seagrass friendly systems should conclude after three years. This provides sufficient time for most boat owners to avail themselves of the incentives. During that same three-year period the responsible state agencies will be requested to draw up systems, procedures, protocols and if necessary regulations to make seagrass-friendly mooring systems mandatory.

A similar process would be followed for fencing exclusion of salt marsh and mangrove wetlands from wandering livestock. Incentives would be available for three years, probably through the relevant natural resource management group to foster high levels of uptake. During that same three-year period the responsible state agencies will be requested to draw up land management controls and protocols and if absolutely necessary, regulations as part of fisheries habitat protection to exclude stock from these high value fisheries habitat.

Objective 4: Enhanced knowledge to efficiently and effectively repair and manage

Objective: Fill priority gaps in the knowledge required to efficiently and effectively repair and manage Australia's estuaries and coastal wetlands

Knowledge collected through research in the first two years of the proposed initiative will need to be structured around two key questions:

- What are the benefits of repair? These need to be quantified sufficiently so that the return on investment is clear to all. There will be many trade-offs and compromises required between land uses of the Australian coastal zone. Quantifying benefits and costs such as through break even analysis is essential and will provide much of the information needed to determine the best balance between various uses of estuaries and their floodplains.
- What are the highest priority repair options and management activities to maximise estuary productivity? Case studies of asset types and determination of priority actions for various estuary types and assets within these estuaries will help inform all subsequent investments and will also build upon the lessons learnt from prior works.

The knowledge generated from answering these questions for key regions around Australia will help focus and allocate investment over the remaining three-year period of the initiative.

More longer-term and fundamental knowledge needs includes ecological information on biomass production, whether from soil carbon, prawn, fish or other key food chain components and improved information on the human-ecology management interface. Existing knowledge is scant and at most only available as specific case studies. Habitat preferences for the various life phases of fish and crustacea are not well documented. Likewise the impact of changes in catchment hydrology, water chemistry and loss of tidal ventilation has not been quantified for many estuary types, let alone calibrated to particular estuaries. By pairing up research activities with the monitoring of improvements following repair, the information generated will contribute to an adaptive process where the design and implementation of repair works continuously improves over the period of investment. A set of focused research and development topics around these issues is provided in Chapter 13.

<u>Outcome</u>

- Increased evidence of the comparative benefits and return on investment of various repair activities and management options as an underpinning for cost-effective and efficient investment in repair and management.

Targets

- By two years into the initiative, estuary and inshore coastal wetland investment planning is complete focusing on key benefit areas of fisheries habitat, water quality, catchment hydrology, estuarine tidal hydrology, carbon sequestration and flood control. This investment planning will identify the highest priority repair investments for the remainder of the five-year investment period.
- By five years into the initiative, the Australia-wide Audit of estuary and inshore coastal wetland assessment is re-done, documenting the improvements in condition, the progress towards the targets of Objectives 1 and 2 and including full detail of the various benefits attained from the investment to date. Most importantly this assessment will need to demonstrate the return on investment for those aspects central to community interest such as improved fish and prawn productivity.
- Over the initial five-year period, companion research and development investment will be encouraged though government agencies such as Fisheries Research and Development Corporation, state agencies and universities and will provide much of the underpinning knowledge required on biomass production (e.g. soil carbon, prawn, fish, key food chain components), habitat preferences and the impact of changes in catchment hydrology, water chemistry and loss of tidal ventilation. This research will need to be designed so that research conducted locally can be projected out to provide implications for other similar environments around Australia.

Objective 5: Increased understanding and commitment

Objective: Utilise a range of communication techniques and media to foster increased understanding and commitment to estuary repair across all sectors of the Australian community.

Repairing assets is challenging. Often the community will have become used to the previous alteration as part of the landscape – such as a weir or levee even though it may not serve any useful purpose and may indeed degrade their local environment. To change what is in place requires a full understanding of opportunities and benefits foregone if the repair works are not undertaken. Indeed, social change and understanding is central to the success of this entire proposed investment.

Working within estuaries also has its institutional challenges, there being multiple players, a suite of relevant legislation and complex approval processes. Confusion, suspicion, mixed messages and misunderstandings can result because of the multiple players and multiple agendas.

Communication of this initiative will need to remain focused on the benefits of repairing estuaries and inshore coastal wetlands while being structured to be fully cognisant and interact with all other communication activities underway within coastal Australia. Partnerships with the private sector such as those developing ports and other major infrastructure initiatives will be essential.

Outcome

- Strong community understanding and support for estuary repair and protective management.

Targets

- Estuary and coastal wetland condition, trends and repair become an integral part of reporting on the condition and trends of Australia's coastal landscape such as within State of Environment or Local Government reporting.
- Focus will be on net improvement, the need for development in specific sites will be recognised and will be demonstrably offset by improvements in estuarine habitat nearby.
- By the end of the first five years of this initiative, community support is very high, as gauged by the individuals, groups and industries stepping forward to participate in the longer-term legacy activities of protective management.

CHAPTER 5 Estuaries of Western Australia

5.1 At a glance

The estuaries of the southwest of Western Australia are the most impacted by development to date and are the major focus of further development in Western Australia, especially further urban, more intensive agriculture and lifestyle development. This proposed investment will increase management attention, especially within the overall objective of improving the human – estuary interface.

Western Australia has 166 estuaries ranging from the tidal rivers and creeks of the tropical Kimberley coast to small bar-closed estuaries along the south coast. It is the 40 estuaries of the greater southwest that have been severely modified by development and population. Background and description of the greater southwest can be found in the book, *Swanland* (Brearley 2005), which includes all estuaries from the Murchison River in the mid-west region to the Esperance area of the South Coast. These estuaries are sandbar estuaries classified as wave-dominated in the National Land and Water Resources Audit (Audit 2002) classification. In the greater southwest only the Broke estuary with its uncleared catchment and no development around the estuary is classified as near pristine.

In the semi-arid mid-west region extending from the Murchison to Moore River where river flow is ephemeral, the estuaries vary from the highly degraded such as the Bowes and Hutt to the eutrophic such as Greenough and Irwin to the Hill river estuary which is in reasonable condition but at risk from a highly degraded catchment. All catchments are extensively cleared with little or no riparian vegetation. Historically these estuaries provide good recreational fishing but eutrophic conditions have prevented professional fishing.

The Swan–Canning River estuary is highly modified through urban development as well as by run-off from highly cleared agricultural catchments. Water quality deterioration in the rivers and estuaries of the Swan–Canning has been a community and government concern for many years expressed through the establishment of number of management agencies. The Swan River Trust is the current estuary manager.

5.2 Background

5.2.1 Draining the coastal plain

A common feature of the southwest from the Swan coastal plain through to Wilson Inlet – Torbay catchments on the south coast is that large areas of wetlands were drained to create both agricultural land and room for urban development. It is primarily these drained and cleared catchments that have suffered the most in declines of water quality and ecological values. All are subject to algal blooms, seasonal deoxygenation and fish kills primarily in the waterways affected by drainage. Drainage for flood mitigation exacerbates poor water quality.

The drainage systems are operated for the single objective to manage flood risk and can be modified for multiple objective outcomes, including environmental, habitat and fisheries productivity outcomes. All of these areas have high potential acid sulfate risk.

5.2.2 Estuary improvement interventions to date

Since the ecological collapse of the Peel–Harvey estuary ecosystem and similar high profile algal blooms and fish kills in south west and south coast estuaries the focus of attention has been on catchment management as well as strategies to manage bar openings. The Peel–Harvey engineering-based response was an exception (see below).

Agricultural land uses and contaminants were identified as the principal cause of estuary decline throughout the region and action plans have focused on identifying the sources of nutrients and on interventions to reduce nutrient export off farm. In all cases the worst performing catchments were highly cleared and artificially drained on poor soils. On the south coast examples are the Wilson Inlet Nutrient Reduction Plan and the Watershed Torbay plan.

In the southwest, the nutrient reduction approach has evolved into the water quality improvement plans under the Australian Government's Catchments to Coasts Initiative. This has resulted in water quality improvement plans for the Swan–Canning, Peel–Harvey and Vasse–Geographe catchments and estuaries. The focus is on nutrient reduction from urban and agricultural sources. With each successive plan a wider range of interventions has been considered. Implementation of these plans has been funded by the Western Australian natural resource management program and the Australian Government's Caring for our Country initiative. Funding to date has been small compared to the scale of the problem. Concerted action and investment over a generation is probably required to make substantial improvements.

Using the same methods, two additional water quality improvement plans have been developed for the Leschenault and the Hardy estuaries. Within these plans a wider view of catchment actions including reduction of organic loading and integrated water management has been included. Implementation of these two water quality improvement plans is yet to be funded. An additional Stage 2 water quality improvement plan for the Hardy estuary is being developed to focus on the lower Blackwood River. The water quality improvement plans set nutrient load reduction targets for each subcatchment within the Swan–Canning, Peel–Harvey, Vasse–Wonnerup/Geographe Bay, Leschenault and Scott river estuarine systems and identified a range of actions to achieve those reductions. Investment is now required to implement these water quality improvement plans.

5.2.3 Estuary repair options

For this Australia-wide business case the focus will be on four key estuaries.

<u>Peel–Harvey</u>

The Peel Inlet – Harvey estuarine system is of considerable ecological, recreational, commercial and scientific interest, and forms part of the Peel–Yalgorup system. Its fringing environment contains ecologically important wetlands and lakes and was placed on the list of Wetlands of International Importance under the Convention of Wetlands (Ramsar, Iran, 1971) on 7 June 1990. The estuary is an internationally significant habitat for waterbirds and migratory wading birds. Tens of thousands of waterbirds gather each year with over 80 species recorded, of which 27 are listed on the Japan–Australia Migratory Bird Agreement (JAMBA) and the China–Australia Migratory Bird Agreement (CAMBA), Environment Protection Authority. The system is also valuable as a commercial and recreational waterway.

The Peel–Harvey system experienced a world-class example of ecosystem collapse from choking coverage of the toxic blue green alga, *Nodularia spumigena*, which in turn had followed extensive macroalgal blooms. While large-scale engineering intervention of the Dawesville channel, a new outlet cut to the ocean improved water conditions in the main Peel estuary, salt wedge effects now extend a long way up the Serpentine and Murray river estuaries. Toxic algae, chronic deoxygenation and frequent fish kills are summer features in the Murray and Serpentine rivers. The toxic cyanobacteria *Lyngbya majuscala*. has been found on occasion in the estuary and regularly occupies Lake Goegrup, a now brackish lake on the Serpentine river.

Recently a full survey was conducted by the Peel Harvey Catchment Council of sites around the estuaries where repair or realignment of drainage may yield a possible improvement. Most options involved quite complex approval processes. One site was selected and the works undertaken at Lake Mealup. This demonstration site has shown the worth of this type of intervention.

Leschenault

The Leschenault estuary is located approximately 200 km south of Perth and is one of the larger water bodies in southern Western Australia, covering an area of approximately 27 km^2. It is about 14 km long, 1.5 to 2.5 km wide, and is very shallow, being 1.2 to 2 m deep. It is the only estuary in Western Australia located behind a shore-parallel dune barrier.

Under current land use patterns, the Leschenault estuary and associated waterways are showing clear signs of stress. In the estuarine portions of the Preston, Brunswick and Collie rivers and at the Leschenault estuary's northern end, symptoms of estuary decline and collapse are evident as excessive algal growth (including toxic species), lack of oxygen leading to fish kills and odours. These are all exacerbated by low flows. Ecosystem decline also manifests as large-scale macroalgal blooms along the estuary shores. These incidents have the potential to increase due to further urbanisation and intensification of agriculture.

Work undertaken in preparation of the water quality improvement plan showed very poor water quality in the estuarine reaches of the Brunswick and Collie Rivers where fish kills are common and estuary habitat for fish is highly degraded. Repair options other than nutrient and organic matter reduction from the catchment are limited. Redirection of polluted urban stormwater away from these portions of the estuary would improve water quality.

The other potential area is in the northern basin of the Leschenault estuary itself where Parkfield drain enters bringing nutrient rich waters from an acid sulfate soil-affected environment. Redirecting this drain to the ocean though a pipe or to the nearby waste water treatment plant or onsite treatment are options to evaluate. The poorly flushed northern estuary is plagued by persistent and blanketing macroalgae that reduces fish foraging and nursery habitat.

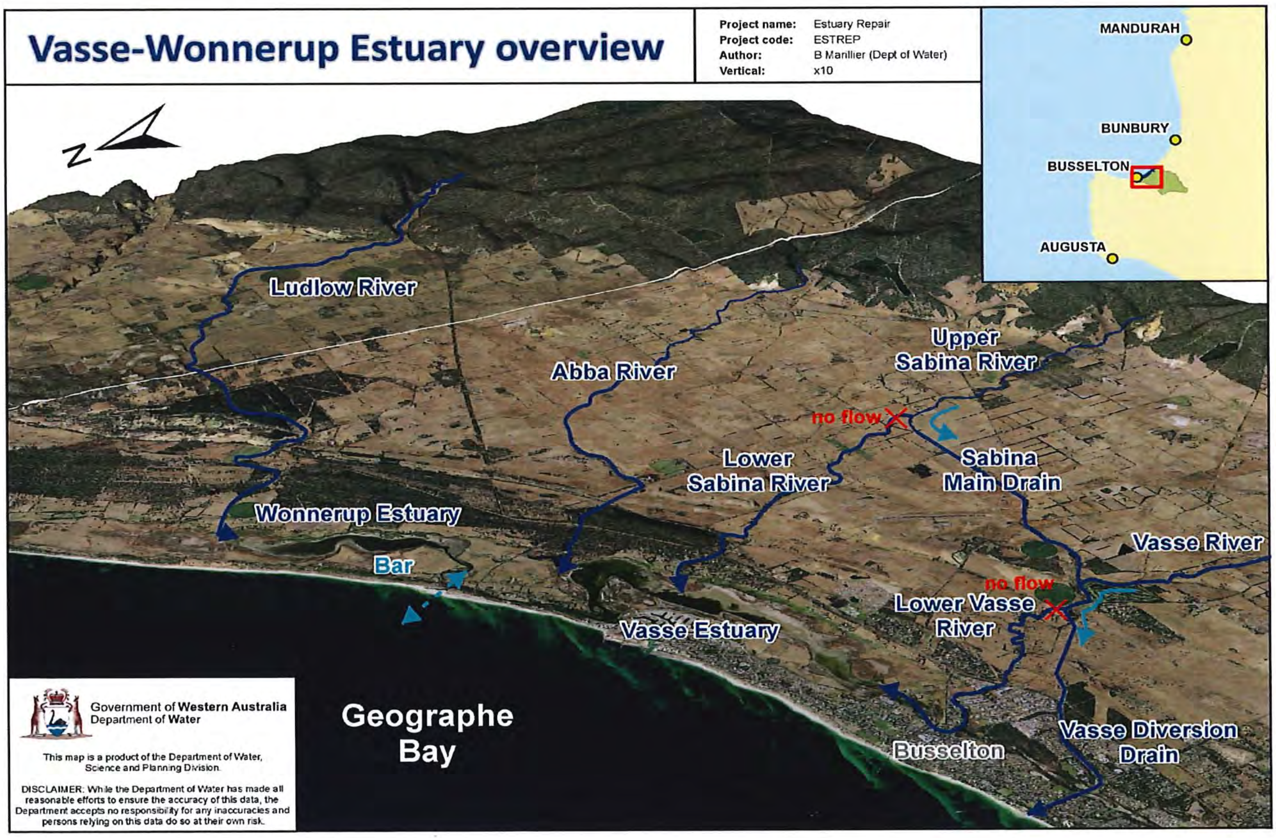
Another repair option is to recover the tidally affected land at Point Douro from private ownership through purchase of the land and rehabilitation of the foreshore vegetation and samphire which provides fish foraging during high tides. The area is highly degraded through 4WD and other activity. Point Douro is located where the riverine portions of the Brunswick and Collie meet the main estuary.

A third fish habitat improvement possibility is to evaluate the redirection of urban stormwater away from discharge into the Leschenault inlet, the estranged part of the estuary that passes through the city centre and is closed to the ocean by barrages. Fish habitat and recreational amenity has declined in the inlet to general community concern. The community has advocated reconnection to the ocean.

Vasse–Geographe

The Vasse–Wonnerup Wetlands system and Geographe Bay have outstanding ecological, social and cultural values. Thousands of waterbirds visit the wetlands each year including many migratory species. The importance of the wetlands for waterbirds is recognised on an international level under the Ramsar convention. Geographe Bay supports extensive seagrass meadows that serve important ecological functions, and a diverse array of marine life make use of the sheltered embayment. The 'Bay' is highly valued and used extensively for recreation by the local community and visitors to the area. The protection and management of these two systems is of utmost priority for the Geographe catchment.

Geographe Bay receives ephemeral surface flow from 16 waterways that dissect the catchment. Of these, only the Lower Vasse, Lower Sabina, Abba and Ludlow rivers drain into the Vasse Wonnerup Wetlands before discharging through the Wonnerup Inlet into Geographe Bay. A network of seasonal streams flow into the Toby Inlet before draining into the bay. All other waterways flow directly into Geographe Bay either through their natural outlets or artificially constructed drains, with the exception of Gynudup Brook and Tren Creek, which flow first to the Capel River. European settlement has seen many changes to the catchment's hydrology. Before these changes occurred, very few waterways flowed directly into Geographe Bay. They instead flowed first into an extensive chain of wetlands stretching along the coast that emptied into the Vasse or Wonnerup estuaries.



Vasse estuary and wetlands showing proposed re-diversion works to generate additional flow to wetlands and allow bar opening. Very recent flood modelling suggests that this diversion will also assist in flood management. The existing diversion will be maintained as a high flow by pass to prevent flooding.

Hydrological change in the catchment started as early as the 1880s when the Capel River was diverted from the Wonnerup Inlet into Geographe Bay through the Higgins Cut. From this time until the 1950s, a series of hydrological alterations were made, with drainage works escalating during the 1920s and again in the 1950s. These works included the construction of floodgates to prevent saltwater incursion, a network of small drains to remove water from farmland, and a series of large arterial drains and driver diversions to discharge surface flow directly to Geographe Bay. These changes enabled farming of coastal areas that were previously inundated during winter, reduced saltwater incursion into pasture that bordered the estuaries, and protected the growing town of Busselton from flooding – thereby allowing it to expand into floodplain areas.

These works also resulted in removal of the nutrient settlement and filtration functions once served by coastal wetlands, an increase in the velocity of water transport, reduced flushing of estuarine systems and increased sedimentation. Geographe Bay and the Vasse Wonnerup Wetlands now receive large loads of nutrient-laden flow delivered by the waterways during winter. Geographe Bay is one of only a few sheltered north-facing marine embayments in Western Australia and is protected from summer swells. In winter the north-westerly swells push into the bay and reduce the overall flushing time from about 15 days to four (Fahrner and Pattiaratchi 1995).

These flushing times are slow compared with open marine systems such as Whitfords lagoon in the Marmion Marine Park, which takes seven to two days to flush (Fahrner and Pattiaratchi 1995); though are more rapid than Cockburn Sound where flushing takes as long as 44 days in summer and 22 in winter. Since all waterways aside from the Capel River are seasonal, nutrient loads are delivered to Geographe Bay primarily during winter, with little or no flow occurring during summer. The Mediterranean climate combined with a prevalence of seasonal waterways may be providing some protection to Geographe Bay. The largest loads of nutrients are delivered only at a time when the water is cold, there is little light within the water column to assist algal growth, and water discharged from streams is flushed out to sea quickly, thereby dissipating and diluting over a short time. This may be reducing the likelihood of algal blooms.

The Vasse–Wonnerup Wetlands are comprised of the Vasse and Wonnerup estuaries and their exit channels, the Wonnerup Inlet, and the seasonal connection between the two estuaries known as Malbup Creek. Today only the Lower Vasse, Lower Sabina and Abba rivers flow into the Vasse estuary, while the Ludlow River flows into the Wonnerup estuary. Floodgates were installed near the mouths of the Vasse and Wonnerup estuaries during the early 1900s to prevent flooding of the surrounding agricultural land with saltwater. These floodgates have enabled the Busselton town site to expand into land that was previously inundated during winter. The floodgates have also served to maintain fresh–brackish water within the system for a longer period than would have occurred under 'natural' conditions. Large areas of the wetland system dry out during summer, though some water is retained in both estuaries and provides important summer refuge habitat for thousands of waterbirds.

The Vasse Wonnerup Wetlands and the Wonnerup estuary are separated from the ocean by floodgates to maintain water levels. This impounded system and the catchment waterways have experienced severe water quality problems for many years including regular blooms of toxic algae, sudden mass fish deaths, reduced recreational opportunities and unpleasant odours resulting from the decomposition of algae and exposure of anoxic sediments.

Limited flushing opportunities arising from the installation of floodgates at the mouth of the estuaries has increased the susceptibility of this system to excessive nutrient driven algal blooms. Thousands of waterbirds have continued to use the Vasse Wonnerup Wetlands each year despite severe nutrient enrichment, but there is concern that further increases in nutrient loads may alter food resources for the waterbirds. Managing the levels of nutrients that enter the wetlands from catchment sources is required to minimise risks to waterbirds, and will have the added benefit of helping to mitigate nuisance water quality problems in the area.

Torbay Marbelup

The catchment of the Torbay estuary lies between Wilson Inlet and the Albany Harbour on the south coast. It is highly modified for agriculture with extensive clearing and complex drainage works that affect Lake Powell and Marbelup Brook, resulting from modifications made to the system that commenced in 1912.

Lake Powell once received flows from Marbelup Brook, then flowed into North Creek and onto Torbay Inlet. The system was severely altered in the late 1970s and early 1980s when a plug was installed in Marbelup Brook to divert water from the lake. The objective at that time was for control of flooding in adjacent potato fields that were once a peat swamp coastal environment.

Both Lake Powell and Marbelup Brook (below the plug) now experience persistent toxic blue-green phytoplankton blooms during summer months.

Progressive nutrient enrichment of the lower Torbay waterways over several decades of catchment land use practices has contributed to lowered water quality within the system. Catchment surface run-off, groundwater input and sediment nutrient cycling have been identified as drivers of these toxic blue-green phytoplankton blooms. Low to no flow below the 'plug' due to altered drainage also exacerbates the retention of organic material, persistence of low dissolved oxygen and release of nutrients from the sediments.

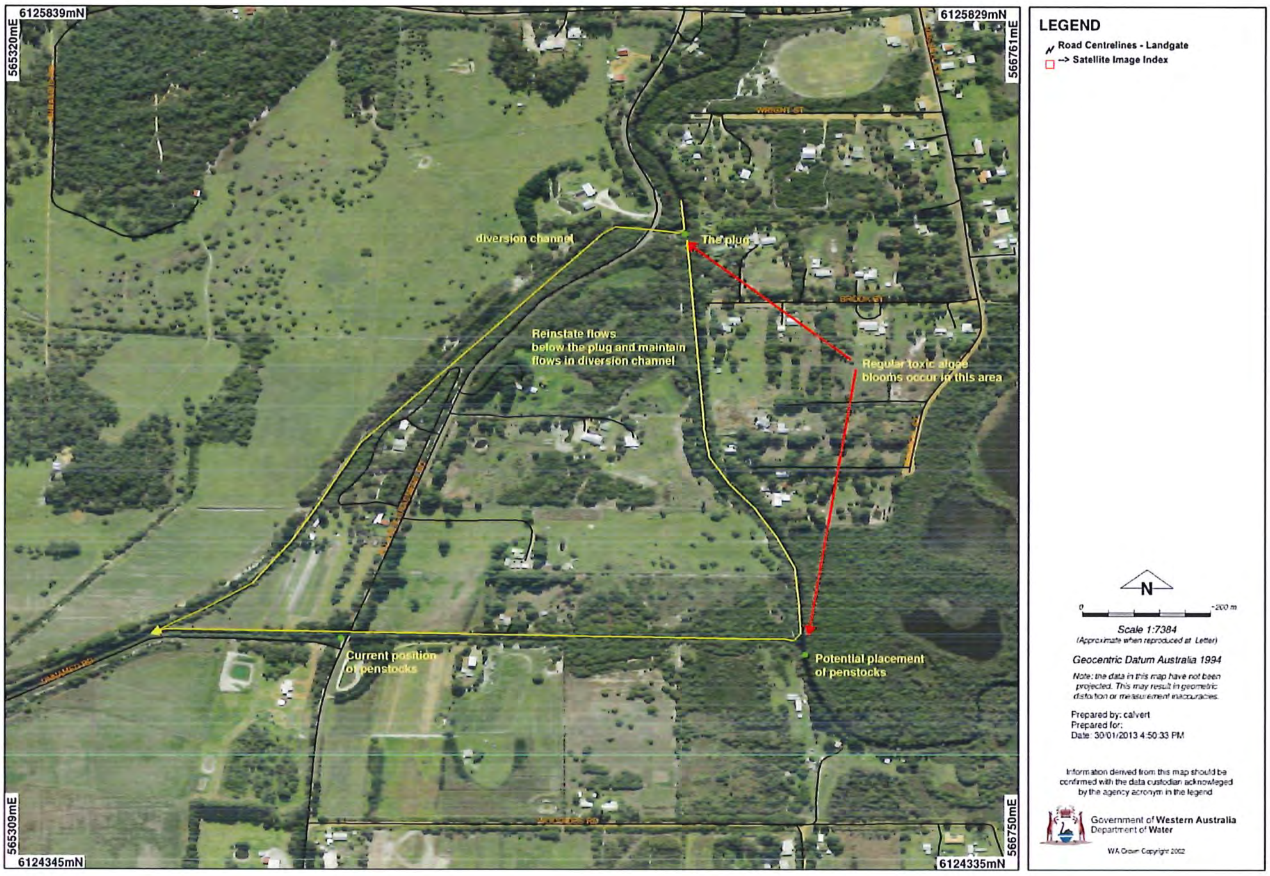
Persistent toxic algae blooms not only affect the ecology of the lake[2] and brook but also create issues for local residents and the tourism potential of the area.

The present drainage infrastructure is operated with three different drainage systems:

- **High level sub-system –** The high level sub-system is comprised of the Marbelup High Level Drain, the Torbay Main drain and Torbay Inlet including the inlet channel. The Marbelup High Level Drain was constructed to divert all or part of the water from Lake Powell. A plug with pipe and flap valve was constructed on the original Marbelup Brook to stop most Marbelup Brook water entering to Lake Powell. This plug structure is called the Marbelup Plug.
- **Mid level sub-system –** The mid level sub-system comprises the Grasmere Drain, Lake Powell, the section of the original Marbelup Brook between the Marbelup Plug and Lake Powell, and the Penstock Drain. Lake Powell now connects to the Marbelup Creek drain and the Marbelup High Level Drain through the Penstock Drain. Because the Penstock Drain conveys the flow from the mid level sub-system through the high level sub-system to Torbay Inlet, it is only possible to drain water when the downstream water level is lower than the water upstream of the Bridge 45.
- **Low level sub-system –** The low level sub-system consists of the North Creek Drain and Manarup Lagoon. The North Creek Drain flows underneath the Marbelup High Level Drain through an inverted siphon consisting of three pipes and continues to flow through

[2] Lake Powell is listed as an official state nature reserve and is an important breeding ground for migratory and local bird species).

a channel parallel to the Marbelup High Level Drain until it meets Manarup Lagoon. Floodgates and penstocks at the outlet of Manarup Lagoon separate it from Torbay Inlet.



Marbelup plug area leading to Lake Powell and Torbay Inlet.

The Water Corporation manages the drainage in the lower Torbay Catchment (under the Land Drainage Act 1925/1990). To manage flooding in the lower catchment the Water Corporation opens Penstocks to drain water from Lake Powell including the area below the plug into Torbay Inlet. The sand bar connecting the estuary of Torbay Inlet to the ocean is then artificially breached to drain out surplus water.

The Water Corporation is in the planning stages to upgrade the penstocks and bridge. Planning will be finalised in late 2013 and the upgrade is proposed to occur in early 2014. To improve the ecological function/biodiversity and aesthetic values of the brook it would be ideal to reinstate flows below the plug. It is proposed that the Water Corporation and the Department of Water with Torbay Catchment Group involvement, investigate relocating the penstocks (potentially back to where Lake Powell enters the Brook) and allow natural flows through the original channel. Increased flow and water movement in the brook would assist flushing, reduce occurrence of toxic algae blooms, improve habitat values/integrity, aesthetics and improve quality of lifestyle for residents.

5.3 Proposed investment

Strategy 1: Developing project plans and implement these plans through on-the-ground engineering works to improve connectivity, water quality and alleviate fish kills

Estuary repair work to be focused on the estuaries of the following catchments.

Peel–Harvey

- Evaluate and undertake the reconnection of estranged waterways from the main estuary, especially the connection of the Serpentine River, using the Peel Harvey Catchment Council survey as a guide.

Leschenault

The three key areas of activity are to:

- evaluate the diversion of the Parkfield drain either to the ocean or to the Kemerton waste water treatment plant or other treatment and undertake the most appropriate works to reduce algal growth in the upper estuary
- purchase and rehabilitate the area of Point Douro foreshore that is subject to frequent flooding to protect and manage essential fish foraging habitat and
- evaluate redirection of stormwater to improve water quality and fish habitat in Leschenault Inlet including enhancing ocean connectivity.

Vasse Wonnerup

The two key areas are to:

- plan and implement the reconnection of the upper Sabena River so that it flows through the estuary and Ramsar wetlands and improves connectivity with the ocean, including redesign of the floodgates and
- evaluate strategies and undertake works to improve water movement in Lower Vasse River thereby alleviating chronic blue-green algal blooms.

Torbay–Lake Powell system

- Plan and implement the reconnection of the Marbelup Brook to prevent algal blooms and fish kills, taking advantage of Water Corporation maintenance plans.

Strategy 2: Hybrid nano clays to bind dissolved phosphorus in river and estuary waters

CSIRO has developed a clay to bind dissolved phosphorus in both fresh and saline waters. This clay does not have the disadvantages of the previous Phoslock™ which is restricted to use in fresh waters. The new formulation is simple to make, contains no toxic compounds, and is easy to apply. The clay – hydrotalcite nanohybrid – has a phosphorus uptake capacity from 1% to 4% and could be used for soils, riparian zones, wetlands, rivers and estuaries.

All of the listed estuaries are subject to chronic algal blooms due to very high phosphorus loading from their catchments and the stores of phosphorus now in their sediments. Binding up phosphorus originating from previous land uses in the bottom waters and sediment of these estuaries is essential to the long-term remediation of these highly degraded waterways and is an adjunct or precursor to engineering on-the-ground works.

The proposal is to scale up manufacture so that large-scale trials and full-scale applications can be made. Priority areas are as previous, the Serpentine river estuary (Peel–Harvey), Vasse River (Vasse–Geographe) and the Lake Powell/Marbelup portion of the Torbay inlet. Implementation and funding partners exist for each of these locations. If successful, large-scale applications could also be made in the Canning River and the upper Swan estuaries. Substantial CSIRO Flagship matching funds are available to cover accompanying research and monitoring.

Strategy 3: Proving up an ecological estuarine response model for Western Australian estuaries and its implementation to improve estuary management

Western Australia lacks a readily transportable estuary response model to guide management actions. The Department of Water has recently evaluated the CSIRO environmental modelling suite that has been successfully used in the Derwent and Huon estuaries in Tasmania and in Moreton Bay in Queensland. The hydrodynamic components of environmental modelling suite have successfully been implemented in the Leschenault estuary, and have already demonstrated the value of the model in identifying fate and effects of delivered nutrients. The need to manage nutrients from Parkfield drain was identified using this model approach.

The next step is to add in the biological and food chain components that will then illuminate the connections to fisheries and habitats and allow testing of estuary modification scenarios.

In the Swan–Canning, the Department of Water and Swan River Trust are working with the University of Western Australia to develop an estuary response model for the upper Swan to provide guidance in applying oxygen through two oxygenation plants. This model is a coupled hydrodynamic-ecological model that includes fish and seagrass components. With additional resources this model could be applied to the whole Swan–Canning as an estuary response model to guide management actions.

One or both of these models would then be applied to the Peel–Harvey estuary and other managed estuaries of the South West and South Coast to guide further management actions.

CHAPTER 6 South Australia

6.1 At a glance

- Key drivers of fisheries productivity, high coastal biodiversity and community benefit are the Coorong, Lower Lakes and Murray Mouth; the coastal foreshore salt marshes; the seagrasses of the two Gulfs – St Vincent's and Spencer Gulfs; and the South East Coastal lakes – Lake Bonney SE (near Millicent) and Lake George (adjacent to Beachport).
- Investment in repair is recommended for:

  i. Coorong, Lower Lakes and Murray mouth – operating the barrages, re-establishing island creeks and increasing fresh water input to improve connectivity, restoring estuarine habitats in the Coorong and thus overall biological productivity

  ii. Coastal embayments – improving the condition of the surrounding salt marshes and their waters through better managing terrestrial land uses, enhancing tidal flows and optimising multiple use activities within the bays

  iii. St Vincent's and Spencer Gulfs – improving conditions for marine communities through the management of terrestrial run-off, coastal developments and multiple use activities within gulf waters

  iv. South East Coastal Lakes-Lake Bonney SE and Lake George – providing fish passages on the existing sanded outlets for each lake, enhancing tidal flows and providing multiple fish species access on a more regular basis, restoring habitat and overall biological productivity, and multiple use activities.

6.2 South Australia's estuaries and inshore environments

South Australia's climate is arid so many of the estuaries are coastal lagoons with little freshwater input. Others have small catchments with only periodic river flow into the estuary. South Australia has several 'inverse estuaries' where salinity increases towards the upper reaches away from the Southern Ocean. These comprise a number of large shallow embayments (e.g. Streaky Bay, Baird Bay and Venus Bay) and Spencer Gulf and St Vincent's Gulf, two of the world's largest inverse estuaries.

South Australia has 37 estuaries and substantial coastal foreshore lands dominated by salt marsh wetlands, some of the most southerly located mangroves as well as large areas of seagrasses that drive much of the net primary productivity. Of the 37 estuaries, three are in near-pristine condition, nine are largely unmodified, nine are modified and 16 are classified as severely modified (Audit 2002).

Two exceptions in terms of low fresh water inflow are the Coorong, Lower Lakes and Murray Mouth; and the Cygnet River estuary, Kangaroo Island. The Coorong, Lower Lakes and Murray Mouth was once Australia's largest estuary with saline water extending as far as 250 km upstream. It is now substantially modified by the series of barrages that create a distinct separation of marine and fresh waters. With the Australian Government legislation and re-establishment of significant freshwater 'environmental' flows in the Murray–Darling there is now the opportunity to manipulate this system to maximise the productivity associated with the inflow of freshwater.

The Cygnet River is a much smaller river and catchment system than that of the Murray River, but does drains about 11% of the land mass of Kangaroo Island, discharging its waters into Western Cove, within Nepean Bay. The Cygnet estuary comprises the island's only true delta, with extensive tidal channels, salt marshes and mudflats providing critical foraging areas for resident and migratory shorebirds. Its lower flood plain is listed as a Wetland of National Importance. Much has been done over recent years by the Kangaroo Island Natural Resource Management Board, supported through a series of projects funded by Australian, State and Local Government, to develop a catchment water, nutrient and sediment flow model; better manage catchment land use practices to control nutrient and suspended sediment loads; and begin to rehabilitate seagrasses. These efforts are a practical demonstration of a range of successful remedial activities. Many are still in progress and most tend to be focused on the catchment area and seagrasses of Western Cove, rather than the total marine ecosystem, including fisheries, of Nepean Bay.

6.3 Coorong, Lower Lakes and Murray Mouth

The Coorong, Lower Lakes (Albert and Alexandrina) and Murray Mouth are, or were, an estuarine and lagoon system situated between the River Murray and the Southern Ocean. The adjoining Coorong lagoons, south-east of the Murray Mouth, are separated from the ocean by a coastal barrier, the Younghusband Peninsula. The now remaining estuarine system below the Murray barrages and islands still exhibits a diverse range of estuarine, marine and hypersaline habitats. The Lower Lakes are in generally good condition in that they provide a freshwater habitat for fish. Productivity is likely to increase if they were returned to brackish conditions. The aquatic and terrestrial species found in this region are unique and as a consequence the area has been proclaimed a wetland of international significance (Government of South Australia 2012)

Prior to European settlement salinity levels fluctuated from brackish to hypersaline in response to seasonal changes in river flow. Since the 1930s regulation of water flows at the Murray Mouth has been managed by a series of barrages consisting of five separate structures with connecting roadways. Mixing of freshwater and seawater is now greatly restricted (Noell et al. 2009; Zampatti et al. 2010).

Coorong, Lower Lakes and Murray Mouth barrages. (Source: Australian Government 2010)

Many fish and other aquatic biota of the River Murray estuarine system evolved to move between marine, brackish and fresh water habitats to complete their lifecycle. As a consequence of the barrages and blocking of the creeks on the islands the pathways that enabled fish and other aquatic biota to migrate between these varied habitats have been severely obstructed. Lack of freshwater inflows and low water levels in the Lower Lakes necessitated the closure of the barrages and their associated fishways from March 2007 until the break of the drought in 2010/11 (Government of South Australia 2012). There have been dramatic declines in fish abundance and distribution for a number of commercial, recreational and conservation significance species in this region (Noell et al. 2009; Ferguson et al. 2013).

Water quality in the Murray River has fluctuated over time because of seasonal variation and drought, water allocation and use (Government of South Australia 2012). An improved allocation of freshwater flow down the Murray has been achieved as a result of substantial policy development, management actions and resource investments in the Murray–Darling Basin as a whole. South Australia is now well placed to build on this investment in the *Basin Plan 2012* (Australian Government). Benefits of improved water allocation can be maximised for the Coorong and Murray Mouth by increasing the flushing of waters through the Murray Mouth and increasing the residence time of freshwater in the system immediately upstream of the mouth. This will increase the volume of mixed ocean and fresh water thus providing a brackish wedge into at least most of the northern part of the Coorong. Such mixing is highly beneficial to a variety of fish species. Increased river flows offshore into the ocean also greatly increase productivity in this region, providing planktonic food for a wide range of species.

It is feasible to augment this increased mixing for estuarine productivity benefit by making some additional changes in the way freshwater is delivered to the Coorong. Current barrage water management strategies are primarily intended to maintain the opening of the Murray Mouth with fresh water releases predominately from the northern barrages. Existing strategies are ineffectual in reducing hyper-salinity in the South Lagoon of the Coorong.

Freshwater needs to be delivered further south to rebuild the productive capacity of this part of the lagoon system. It is recommended the barrages closest to Lake Alexandrina, situated well south of the ocean entrance, be fitted with automatic control gates. Automation would encourage more regular opening of the gates and thus allow more freshwater to enter the southern Coorong, maximising freshwater inputs and enhancing water quality and ecological health of both the north and south Coorong lagoons.

Increased fish passage between the Coorong and the Lower Lakes will facilitate the spawning and recruitment of estuarine and diadromous fish populations, including Black Bream (*Acanthopagrus butcheri*), Congolli (*Pseudaphritis urvillii*) and Greenback Flounder (*Rhombosolea tapirina*). Establishing an increased volume and area of ocean–freshwater mixing of the northern section of the Coorong will also advantage other aquatic and terrestrial species. Net primary productivity increases will in turn benefit both recreational and professional fishing.

The ecology of the southern Coorong has been altered by numerous land drainage schemes in the Upper South East that have decreased the flow of freshwater into this part of the Coorong ecosystem. Rationalisation of the drainage systems as part of further manipulation and improvement of the Upper South East Drainage Scheme would lead to seasons of increased freshwater flow into the otherwise often hypersaline southern Coorong, especially enhancing the environment for various migratory bird species. This increased freshwater inflow will reduce the salinity in the southern Coorong, leading to an increase in distribution and abundance of estuarine fish and an enhanced fishery.

<u>Proposal and key benefits</u>

- To enhance biodiversity and estuarine-based fisheries by improving connectivity and freshwater flows between various components of the Coorong, Lower Lakes and Murray Mouth ecosystems.
- Major benefits will be to the productivity, overall biomass and diversity of both the fishery and the bird life. Flow-on benefits include the re-population of estuaries to the east along the South Australian and Victorian coasts with juvenile to mature stocks of fish species that rely on the Coorong and Murray mouth for their nursery phase, in situ professional and recreational fisheries, tourism and bird watching.

<u>Strategies</u>

Coorong 1: Reactivate natural flow paths

The barrages (Tauwitchere, Boundary Creek, Ewe Island and Mundoo Island) are joined by connecting roads. The small islands that span the Murray Mouth between Goolwa and Pelican Point were once traversed by small creeks. When connecting roads were built for the barrages many creek lines were physically and permanently closed. The creeks provided an important pathway for fish to migrate between marine and fresh water habitats.

Placing culverts beneath the roads to reopen the old creek lines would provide opportunities for many juvenile fish to migrate to and from the Lower Lakes and estuarine brackish areas.

Coorong 2: Increase the number of fish passages (slot-ways and rock ramps) in all of the barrage structures in the region.

Construction of fish passages is proposed for up to eight sites within the Coorong Lower Lakes and Murray Mouth (Government of South Australia 2009) building on prior work including the Coorong Lower Lakes and Murray Mouth initiative. Different 'fishway' options are available and selection will take into account the specific requirements of each site. The construction of rock ramps, new fish locks, fish culverts, vertical slots, navigation locks and the removal of structures that obstruct the passage of fish are recommended (Government of South Australia 2009).

Coorong 3: Introduce improved barrage management

- Automate barrage gates for more flexible operation, safety and sensitivity to ecological needs.
- Develop and implement barrage operating guidelines to meet ecological needs.

According to Jensen et al. (2000) *... the most significant short to medium term recommendation (to meet the ecological needs of the Coorong, Lower Lakes and Murray Mouth) is for automation of the barrage gates and fine-tuned operation to maximise fish passage, increase water bird habitat, increase the area of estuarine habitat and maximise the control of water quality.* This recommendation remains relevant in 2013.

Coorong 4: Evaluate options for Lower South East to contribute freshwater to upper Coorong

Work is underway through the Government of South Australia to assess the options for improved fresh water flow to the southern Coorong (pers. comm. Dr Glenn Shimmin, Manager, South East Water). The nature of works and the level of investment will depend on the option selected.

6.4 St Vincent and Spencer Gulfs

Gulf St Vincent and Spencer Gulf include extensive areas of seagrass between the shorelines at about 15 m depth (e.g. Shepherd et al. 2008). Along the Gulf coasts, there are extensive areas of salt marsh and to a lesser extent, mangroves. The Gulfs are home to important commercial and recreational fisheries (e.g. Blacklip and Greenlip Abalone – *Haliotis rubra* and *Haliotis laevigata*, Blue Swimmer and Sand Crabs – *Portunus armatus* and *Ovalipes australiensis*, Cuttlefish – *Sepia* spp., finfish such as King George Whiting – *Sillaginodes punctatus*, Australian Salmon – *Arripis truttacea,* Southern Sea Garfish – *Hyporhamphus melanochir* and Snapper – *Pagrus auratus*, as well as Western King Prawn – *Penaeus latisulcatus*) and aquaculture sectors (e.g. Abalone, Mussels, Pacific Oysters and Southern Bluefin Tuna – *Thunnus maccoyii*).

The gulfs are impacted by the many human activities that occur within their waters as well as in their surrounding catchments. Significant centres of urban and industrial development, agricultural run-off, aquaculture, boating and shipping, ports and tourism impact on the environment and ecology of the species that live within the gulfs and surrounding coastal zone.

Whole-of-ecosystem management is needed to manage a coastal environment that is subject to increasing competing interests and threats, including the increased loading of nutrients and suspended sediments. Such multi-disciplinary approaches have been adopted elsewhere (e.g. Chesapeake Bay <http://ches.communitymodeling.org> the Gulf of Alaska and Monterey Bay <http://ourocean.jpl.nasa.gov/>) as traditional single issue studies do not capture interactions between multiple stressors nor allow informed decisions to be made about trade-offs between different users of the environment.

The South Australian Research and Development Institute (Aquatic Sciences) together with the South Australian universities, other government agencies and the seafood industry, have through their common collaborative network known as Marine Innovation South Australia

(MISA) proposed three major regional ecosystem studies. These include a pilot project on Spencer Gulf and funded in part by the Fisheries Research and Development Corporation, and two other projects in development, one focused on the Great Australian Bight and the other on Gulf St Vincent. Many independent datasets and past studies exist but there is a need to synthesise these, identify and fill gaps, and bring all together within a single integrated ecosystem framework. This framework will involve a series of models ranging from simple conceptual models to complex simulation models that will allow trade - offs and interactions among different uses to be explicitly considered, and provide stakeholders with a common basis for discussing these.

There is also an ongoing need to further reduce nutrient and sediment inputs into coastal waters, and to rehabilitate marine communities where the factors that caused the impacts have been largely ameliorated.

Proposal and key benefits

- To build a metadata base and ensure ongoing and new databases facilitate the development of detailed ecosystem models for Spencer Gulf and St Vincent Gulf.
- To continue to reduce nutrient, suspended sediment and other terrestrial discharges into the gulf environments from agriculture, urbanisation and industry, to enhance the health and productivity of gulf marine communities, especially seagrasses. The focus on seagrasses reflects their importance for biodiversity, carbon sequestration, sediment stabilisation and habitat for species of importance for recreational and professional fishing.
- To rehabilitate seagrass communities where the causes of past impacts on their decline have been addressed.
- Flow-on benefits include the demonstration of repair methods for seagrasses applicable to other coastal waters of Australia, and increased supply of fish stocks from gulf nursery areas to waters further afield, including east along the Victorian coast.

Strategies

Gulfs 1: Build information for ecosystem modelling

- Collate past information and build new databases as a result of the ongoing monitoring of coastal waters and catchments as core inputs to refined coastal zone and catchment model

Gulf St Vincent, like Spencer Gulf, is a centre for fisheries, ports, boating and shipping and tourism, and is surrounded by catchments that include a diverse range of agricultural activities as well as growing centres of urbanisation and industrialisation. The 'Adelaide Coastal Waters' face particular environmental pressure. All these factors interact and influence the health of the gulfs, yet presently many existing activities are managed in isolation.

The establishment of comprehensive and interlinked datasets will facilitate ecosystem models that can tie together recent hydrodynamic, biogeochemical and wave modelling studies (e.g. Middleton et al. 2009) with models of seagrass ecology and trophodynamics of consumers such as fish. This will enable improved, optimised, resource planning addressing the needs of the multiple users of these environments, as well as the conservation of the natural resources within them. What-if scenario analyses will enable better management of the causes of existing impacts and the potential consequences of cumulative impacts to be understood and managed. Coastal marine animal and plant communities will be better protected and their health and productivity enhanced.

Gulfs 2: Reduce nutrient and sediment inputs

Seagrasses are impacted by high nutrient loads and reduced water turbidity. Significant benefits can be achieved through various remedial actions that reduce transport of nutrients and suspended solids to gulf waters.

A range of engineering and biological solutions have already been implemented, primarily in the 'Adelaide Coastal Waters' area, to reduce the impacts of terrestrial discharges on the marine gulf environment. More are needed, particularly in growing coastal communities, where stormwater is often discharged into otherwise pristine seagrass meadows with little or no treatment, repeating the mistakes that have resulted in substantial seagrass loss off metropolitan Adelaide.

Adjacent to Adelaide, the impact of sewage discharge on seagrass communities has been greatly reduced by directing much of these wastewaters on-land for agricultural use; and organic and non-organic litter in terrestrial run-off has been greatly reduced by installing trash racks in major drains and creeks. Fencing of animals, revegetation of creek banks and the establishment of water retention basins have been used higher in the catchments to reduce the suspended sediment levels. Constructed wetlands can also further reduce nutrient and suspended sediment loads.

This investment would apply these solutions more broadly around the Gulfs.

Gulfs 3: Rehabilitate seagrass communities

After many years of research, a method has been developed for the rehabilitation of the seagrass (*Amphibolis* spp.), which can tolerate moderate wave environments, such as offshore metropolitan Adelaide (e.g. Irving et al. 2010, 2013). Small patches of restored seagrass four to five years old are now coalescing to form larger continuous patches, and preliminary work indicates that faunal abundance in restored seagrass is similar to that in nearby natural meadows.

Once this taxon has established and stabilised the seafloor sediments, there is increased potential for other seagrass species to colonise, with small amounts of both *Heterozostera* spp. and some *Posidonia* spp. having colonised into restored areas of *Amphibolis* spp. This method is cost-effective, at <$10 000 per hectare at a research scale, and likely much cheaper when scaled up. Further development of the technique with *Posidonia* spp. is showing promise, although is still in its early stages of investigation.

Large-scale implementation with *Amphibiolis* spp. in environments typical of those that need extensive rehabilitation (e.g. 'Adelaide Coastal Waters') will demonstrate their feasibility at the larger scales required for enhanced fisheries productivity. Parallel assessment of habitat functioning in restored seagrass will enable the benefits to local fisheries to be quantified.

6.5 South Australia's coastal embayments

South Australia has many large shallow embayments along its 5067 km (mainland and islands) coastline <http://www.ga.gov.au/education/geoscience-basics/dimensions/coastline-lengths.html> (e.g. Streaky Bay, Venus Bay, Baird Bay, Coffin Bay and Franklin Harbour on Eyre Peninsula; Nepean Bay and American River on Kangaroo Island; and Lake George and Lake Bonney SE in the southeast). Management of these bays and their catchments are already high priorities of natural resource management groups, with many bays affected by coastal development, aquaculture and tourism, changed flow regimes due to coastal engineering works such as roads and levees, poor water quality as a result of nutrient and other inputs from terrestrial run-off, disturbance by vessels and vehicles, and in some cases invasive species. In some locations population numbers have been increasing in response to new regional mining developments adding to the pressures on these coastal ecosystems.

The activities proposed would expedite the repair of these coastal embayments resulting in enhanced amenity, habitat and productivity for both these water bodies and the adjacent coastal waters utilised by many of the aquaculture and fisheries sectors of South Australia.

Key works, planned and implemented specific to each embayment are likely to include:

- managing agriculture, stock and human land use through improved fencing, signage and defining coastal access points so as to better conserve the coastal foreshore environment, including sand hills, mangroves and salt marshes
- incentives for seagrass friendly vessel moorings to reduce losses of seagrasses and allow recolonisation
- engineering modifications to roads and other infrastructure to re-establish tidal flow and reduce inflow of terrestrial wastes and
- various community-based activities to increase community understanding and modify behaviours.

Experience gained through the Kangaroo Island Natural Resource Management Board's program to rehabilitate the Cygnet River – Nepean Bay ecosystems will provide a useful basis for the proposed works. The Cygnet River program has demonstrated the importance of scientific and technical experts working together with local communities to identify and then address coastal issues using a mix of Local, State and Australian Government funding.

<u>Proposal and key benefits</u>

- The proposal is to enhance coastal amenity and land use by repairing the biophysical environment onshore and nearshore, including protecting and repairing salt marshes, re-establishing tidal flows to areas now partially or fully isolated from the aquatic environment, and reducing nutrient, suspended sediment and other terrestrial discharges into the embayments from agriculture and urbanisation. To decrease impacts offshore seagrass friendly moorings will be encouraged through a three-year incentives scheme similar to that proposed for NSW and southern Queensland.
- The proposed strategies will enhance the health and productivity of the coastal and marine communities within the embayments, which are often the nursery grounds of species of interest with flow-on benefits to aquaculturists and professional and recreational fishers not just the embayments and also adjacent gulf waters, and waters further afield such as southern Victoria.

<u>Strategies</u>

Embayments 1: Prioritise remediation activities

Marine embayments of the South Australian coastline have been studied relatively little and only in an ad hoc manner to date, with information poorly collated. There is a need to bring together the available biological, social and economic information; discuss past, present and future environmental challenges in consultation with local communities; and with these communities develop strategies to implement priority activities. The outcomes of such a process will benefit the significant salt marsh, mangrove and seagrass communities of these embayments and the aquaculture, professional and recreational fisheries and tourism sectors on which their communities depend.

Embayments 2: Undertake priority remediation activities

Address priority factors impacting on the coastal and marine ecosystems through engineering and biological solutions and monitor their success. This includes:

- targetting the return of areas isolated or affected by less-than-desirable tidal flows by the past creation of roads and other structures affecting the marine environment
- reducing the inappropriate uses of salt marsh areas, including for dumping and vehicle use
- seagrass friendly moorings under an incentives scheme to reduce the impacts of vessels on seafloor communities.
- re-establishing significantly impacted salt marsh and mangrove communities where natural remediation has been unsuccessful
- developing and running community education activities to increase awareness of the causes and consequences of impacts and foster behaviours that support coastal ecosystem repair and fisheries productivity.

6.6 South Australia's south-east coastal lakes

Lake Bonney South East is the largest freshwater, coastal lake in South Australia, assessed by the Environment Protection Authority at between 6400 and 7900 ha with intermittent sea access with the last sea access occurring in 1993. The lake is recorded (EPA 2003) as having one recreationally attractive fish, Yelloweye Mullet (*Aldrichetta fosteri*), and five other smaller fish despite the pollution sink that it has been since the late 1940s, receiving paper mills and wastewater effluent.

As context, the following information is summarised from: <http://www.epa.sa.gov.au /environmental_info/water_quality/legislation_and_programs/lake_bonney_se>.

Lake Bonney SE is a large coastal lake about 10 km south of Millicent in the southeast of South Australia. Canunda National Park, is located on the north and western shores.

The Booandik people lived on the land around Lake Bonney SE, and early records indicated that ... *it was a happy hunting ground for its aboriginal inhabitants* (District Council of Millicent 1956-59). There are very substantial aboriginal sites (middens), and is a well regarded bird site.

Lake Bonney SE was well regarded by the population for its fishing and recreational uses.

Like most of the region, it has been extensively altered since European settlement, particularly by the effects of drainage schemes and various agricultural land use impacts.

Lake Bonney SE.

Lake Bonney SE has been damaged by the discharge of large amounts of nutrient and contaminants from pulp and paper mills for over 70 years, and smaller volumes have also entered the lake from the Millicent wastewater treatment plant for over 45 years. This has prompted a range of responses from both the industries involved and government, particularly over the past two decades, to try and improve the quality, and reduce the volume, of wastewater that is discharged to the lake. These actions were carried out with the aim of improving the environmental condition of the lake. The recent closure of the Tantanoola Mill in 2012, for example, has significantly reduced the amount of coloured substances and nutrients discharged into the English Gap Drain and ultimately into the eastern side of Lake Bonney SE. The Department of Environment, Water and Natural Resources (DEWNR) has advised that the change in mill processes has reduced the daily inflow from 40 ML per day to 4 ML per day, which may impact on water levels due to the significant evaporation from the lake surface

The lake is no longer the foaming, red coloured water body that it was in the 1980s, when it was locally considered too polluted for the public to visit. Over the past few years, the lake has become much clearer and today most of its yellow-brown colour is caused by large blooms of small algae called phytoplankton.

The lake is still brackish, alkaline, well oxygenated and it remains highly enriched with nutrients such as nitrogen and phosphorus. It is in the biology of the lake, however, where major improvements to the plants and animals inhabiting the lake have been noted over the period from about 2005 to the present. Several types of native fish breed in the lake, some in large numbers, and include threatened species such as Southern Pygmy Perch and Dwarf Galaxias that typically occur in well-vegetated habitats around the edges of the lake. Aquatic plants grow a few hundred metres into the lake and include a wide range of submerged and fringing species.

Large numbers of waterbirds regularly use the lake as a feeding and breeding site, tortoises and yabbies are often recorded in low numbers throughout the lake, and an increasingly diverse range of aquatic macroinvertebrates (e.g. waterbugs, beetles and crabs) inhabit the lake compared with what was recorded during the 1970s to 1990s.

Despite these improvements, the nutrients in the lake remain too high and they present an ongoing risk of a significant bloom of blue-green algae (or cyanobacteria) potentially resulting in major losses of many of the fish, plants and invertebrates. Consequently, future management will be directed towards trying to reduce the addition of new nutrients from the paper mill, wastewater treatment plant and also from cattle and sheep that graze along many of the drains in the lake's catchment and along the northern shoreline.

In November 1996 the Lake Bonney Management Committee published the *Lake Bonney Management Plan 1996–2000* to provide guidelines for the future management, which will allow the continued recovery of the lake, protection of the natural values and the establishment of an amenity for use by the wider community.

In 2003 the EPA, Office of Economic Development and Kimberly–Clark Australia funded a three-year project to assess the condition of Lake Bonney SE and identify actions that could be taken to improve the health of the lake. Between 2004 and 2006, the results were discussed with representatives of the local community and interest groups and the consistent view expressed after completion of this project was that the Lake should be restored to a healthy ecosystem mainly through avoiding or significantly reducing the inflow of nutrients from all sources in the future.

The study, which concluded in 2007, identified the high nutrient load from the mills presented a high risk for the ecology of Lake Bonney SE as the receiving environment for the wastewater. Negotiations are underway in terms of the licences that will be required for the mills in 2014.

In recent years Kimberly–Clark Australia have made the following changes in how they operate which has improved water quality in the lake:

- ceased using bleaching processes in paper manufacturing
- reduced water use resulting in smaller volumes of wastewater
- closed the pulp mill which significantly improved water quality.

The Environmental Protection Authority South Australia declared Lake Bonney SE suitable for recreational contact in 2008, with 3000 EC. Reports now show that the water quality of the lake has improved, and this provides the ideal time to re-establish fishery productivity Lake Bonney SE, as suggested by the Environmental Protection Authority. Productivity, in terms of the wide range of andromous species, is likely to return after 70 years, if the lake were to have more frequent access to the sea and was managed as a coastal lake.

Up till now Lake Bonney SE has been managed predominantly for industrial water supply requirements and to ensure appropriate winter lake levels, stop logs have been used across the 20 m entrance created in 1972, rather than to allow the natural processes of opening and closing of the sand berm entrance to occur. Recognising prior concerns over water quality and the possibility of release of polluted water into Gerloff Bay, this has to some degree been justified. Now the water quality has improved as indicated by the biological improvements and Environmental Protection Authority's water quality monitoring it is now time to reassess fish passage and ocean entrance management.

Increased fish passage between the sea and the lakes will provide habitat for estuarine and diadromous species including Greenback Flounder, Black Bream, Mulloway and Australian Salmon and potentially facilitating the spawning and recruitment of Black Bream and other recreationally attractive species. Net primary productivity increases will benefit predominantly recreational fishing within the Lake and professional fishing within Gerloff Bay.

This proposal suggests fishing within Lake Bonney SE would be recreational only, while recognising the flow-on benefits to professional fishing in nearshore ocean waters. The substantial recreational infrastructure expenditure for boat access, including boat ramps, pontoons, car parks, toilets, and possibly navigational markers could come over time from existing dedicated recreational boaters funds. This proposal is therefore limited to improved ocean entrance management.

Forty kilometres to the northwest of Lake Bonney SE is Lake George.

Lake George is a large freshwater/estuarine, coastal lake of approximately 5600 ha that has substantial, but intermittent, freshwater and marine water access. The lake fluctuates from freshwater, to brackish, to estuarine, to saline, to hypersaline, and has supported some 16 species, recorded in 1990, but more normally, Yelloweye Mullet (*Aldrichetta forsteri*), Australian Salmon (*Arripis truttacea*), Black Bream (*Acanthopagrus butcheri*) and Greenback Flounder (*Rhombosolea tapirina*), and occasional other species.

This lake previously supported three commercial net licences, which have been bought out by Department of Primary Industries and Regions of South Australia after the latest fish kill in 1999, and has many existing recreational netting licences.

The lake levels are managed generally by stop logs across the approximately 20 m entrance which may be removed for several months each year, allowing marine water access when high tides and swells in the Southern Ocean occur. The South East Water Conservation and Drainage Board digs channels between the lake and the sea, and removes substantial sand quantities from near the regulator.

The Lake George Management Committee developed the *Lake George Management Plan*, with considerable community input, in 1996 that has guided activities for a considerable period.

Improved ocean entrance management and fish passage will benefit fisheries productivity. Increased sea access will also benefit bird life, general aquatic and estuarine biodiversity and other uses of both lakes.

<u>Proposal and key benefits</u>

- It is proposed to improve the connectivity of Lake Bonney SE and Lake George between the ocean and the lakes.
- Major benefits will be to increase diversity and productivity of fish in both lakes, greatly enhance their fisheries nursery values and deliver flow on benefits to the regional lakes and the estuaries, especially to the east including southern Victoria. Increased biodiversity and diversity of bird life will accompany the improvements to fishery productivity.

Strategies

South East Lakes 1: Fish passage at Lake Bonney SE

Lake Bonney SE is joined to the sea at its 20 m wide entrance using stop logs, which are frequently sanded up. Lake Bonney SE is managed for human purposes of winter lake levels, rather than fish access. It is proposed to install fish passage devices that allow fish movement between ocean and lake on appropriate tides.

South East Lakes 2: Fish passage at Lake George

Lake George is joined to the sea at its 20 m wide entrance using a regulator, and requires annual channel digging to allow sea access, sometimes three times each winter. Lake George has a substantial sand channel to the sea from the Lake.

It is proposed to install fish passage devices that allow fish movement both ways on appropriate tides.

6.7 Proposed investment

Investment in repair is recommended for:

- Coorong, Lower Lakes and Murray mouth – operating the barrages, re-establishing island creeks and increasing fresh water input to improve connectivity, restoring estuarine habitats in the Coorong and thus overall biological productivity
- Coastal embayments – improving the condition of the surrounding salt marshes and their waters through better managing terrestrial land uses, enhancing tidal flows and optimising multiple use activities within the bays
- Gulf St Vincent and Spencer Gulf – improving conditions for marine communities through the management of terrestrial run-off, coastal developments and multiple use activities within gulf waters, and rehabilitation of degraded habitats where stressors have been removed
- South East Coastal Lakes-Lake Bonney SE and Lake George – providing fish passages on the existing sanded outlets for each lake, enhancing tidal flows and providing multiple fish species access on a more regular basis, restoring habitat and overall biological productivity, and multiple use activities.

CHAPTER 7 Victoria

7.1 At a glance

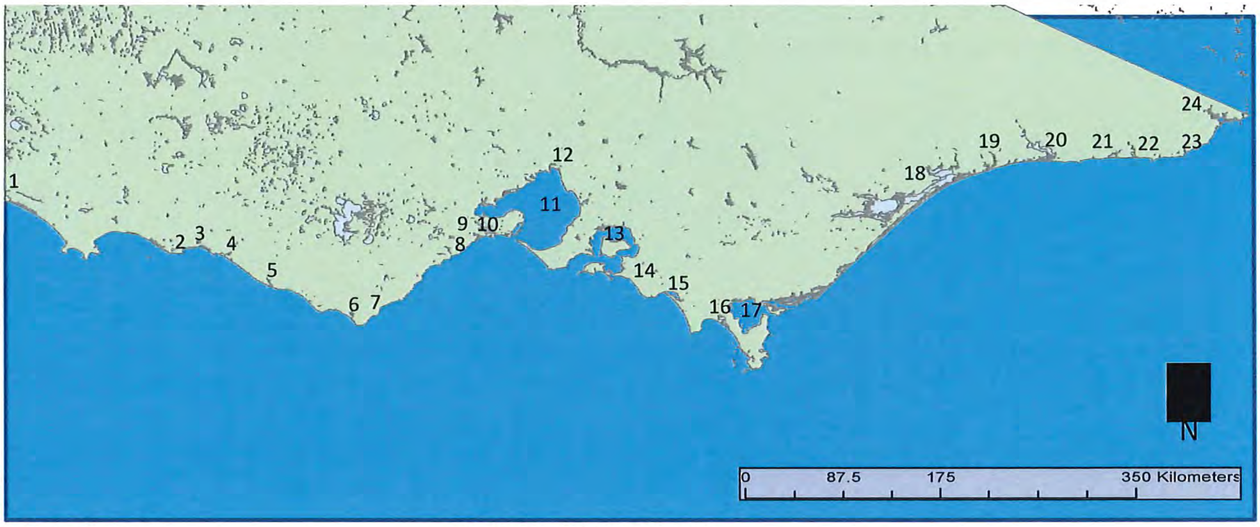
- Key drivers of fisheries productivity, high coastal biodiversity and community benefit are the major embayments of Port Phillip and Western Port, along with Corner Inlet and the Gippsland Lakes.
- Overall there are about 60 estuaries in Victoria varying from small wave- and river-dominated estuaries in the west to the large embayments in central Victoria to a network of small wave-dominated estuaries and coastal lagoon systems in the east.
- About 13 of these are near pristine and generally small and located within national parks, about 21, also generally small are largely unmodified, 24 are modified and four are extensively modified.
- Many of the smaller estuaries have intermittently opening mouths that are often opened artificially. The timing of these openings is crucial for fisheries productivity in these small waterways.
- This chapter concentrates on the modified and extensively modified estuaries. Investment in repair is recommended for:
    - Large embayments – especially re-establishing shellfish beds (Oysters and Mussels), and protecting/rehabilitating seagrass beds as the basic building block for multi-species fisheries.
    - Fish passage and tidal flow – manipulating flood barrages, road causeways and various blocks and culverts to improve connectivity and productivity. While some work has been completed there remains several larger investment sites where improvement to connectivity would be beneficial.
    - Floodplain wetlands and salt marshes – re-establishing lateral connectivity, rationalising drainage, restricting cattle access to salt marshes and reducing the risk of acidic anoxic water discharge from acid sulfate soils to estuaries while enhancing their condition for both biodiversity and fisheries habitat.

View to Mallacoota Inlet showing reclaimed land near entrance.

Sediment slug in the Snowy River near Marlo.

7.2 Victoria's estuaries and inshore environments

Victoria's estuaries have long been important to Victoria's traditional owners and many contain sites of cultural significance. Sheltered estuarine waters across Victoria were among the first areas to be settled by non-indigenous peoples. Many estuaries in the late 1800s and early 1900s supported important industries such as ports and commercial fishing and these early settlements have since developed into some of Victoria's most densely populated areas. Victoria's estuaries are valued for recreational use (e.g. camping, swimming, boating and fishing) and contribute to local, regional and state economies through tourism and commercial or recreational fishing. Many also contain sites of international conservation significance (i.e. Ramsar sites). Victoria's estuaries support a range of distinctive aquatic and terrestrial plants and animals, including rare and threatened species and communities. They provide important drought refuges, significant breeding and foraging areas for birds and spawning/nursery areas for fish. The vegetation and marshes adjacent to the estuaries are important for water quality, nutrient cycling, and provide buffers to catchment-derived sediments and pollutants entering the marine environment.



1 – Glenelg River
2 – Moyne River
3 – Merri River
4 – Hopkins River
5 – Gellibrand river
6 – Aire River
7 – Barham River
8 – Anglesea River
9 – Thompsons Creek
10 – Barwon River
11- Port Phillip (also refer Figs. 2, 4)
12 – Yarra/Maribyrnong Rivers

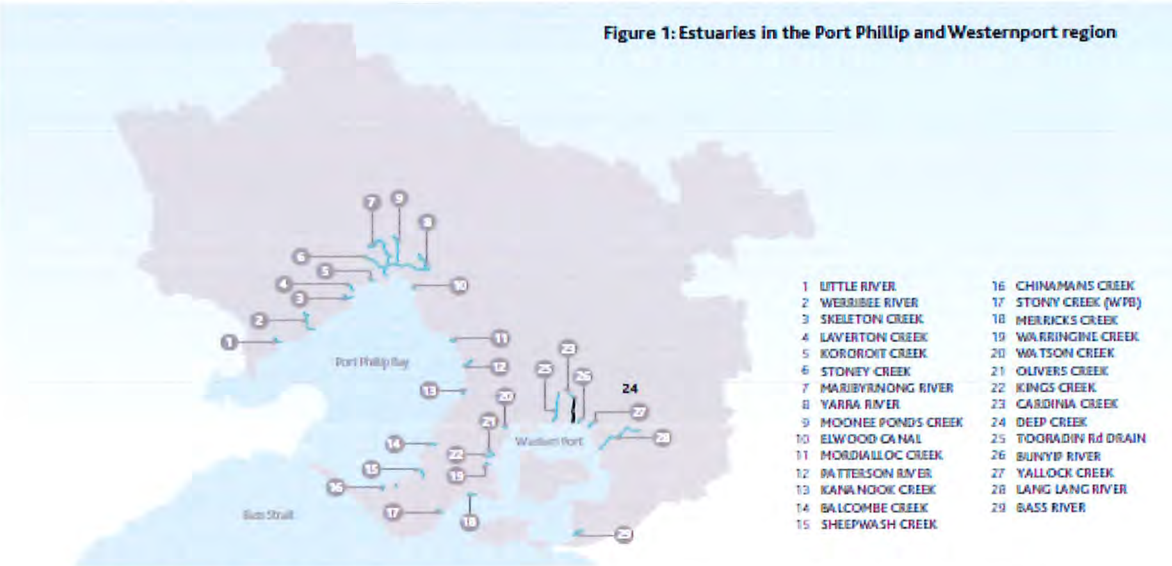
13 – Western Port (also refer Fig. 2)
14 – Powlett River
15 – Anderson inlet
16 – Shallow Inlet
17- Corner Inlet - Nooramunga
18 – Gippsland lakes
19 – Lake Tyers
20 – Snowy/Brodribb River
21 – Sydenham Inlet
22 – Tamboon Inlet
23 – Wingan Inlet
24 – Mallacoota Inlet

Victorian coastline with locations of 24 important sheltered bays and estuaries.

The 21 estuaries from Andersons Inlet to the Mallacoota in the far east of Victoria are characterised by being wave-dominated, with many being near-pristine (Audit 2002), including 12 within the Croajingolong National Park. One tide-dominated estuary is present – Corner Inlet. Corner Inlet/Nooramunga is a Ramsar site and supports important professional and recreational fishing industries. It contains the world's most southerly stands of white mangroves (*Avicennia marina)*, and large areas of seagrass habitat, including Victoria's most extensive areas of *Posidonia australis*.

Gippsland Lakes and the iconic Snowy River estuary have been substantially altered due to drainage of wetlands; loss of shoreline/fringing vegetation (i.e. Phragmites); changed tidal regime and entrance conditions; reduced freshwater flows; and substantial levels of sediments, pollutants and nutrient enrichment from the catchment. Much work has been done to improve water quality by reducing the inflow of pollutants and nutrients, although algal blooms that can lead to closure of fisheries and considerable economic loss to the local economy remain an ongoing problem in the Gippsland Lakes. Maintaining a safe entrance to the Gippsland Lakes is essential for both recreational and commercial fishing as well as other commercial port uses, though this has altered the natural dynamics of the system. Further repair of the fringing wetlands and increased lateral connectivity through rationalisation of drainage, levees and cattle access would benefit agriculture, water quality (including algal blooms) and fisheries productivity in both the Gippsland lakes and Snowy River estuary.

Central Victoria has 13 estuaries from the Barwon River to Powlett River including the large embayments of Port Phillip Bay and Western Port. Many of the 13 estuaries with their contributing rivers, creeks and wetlands are within these two large embayments. Prior to urban and industrial development these estuaries, rivers and creeks, sometimes now replaced by drains or altered by channelisation works, played a substantial role as fishery and waterfowl nursery habitat as well as sediment and nutrient traps. Man-made barriers to fish migration and marine-freshwater connectivity still exist in many of these systems.



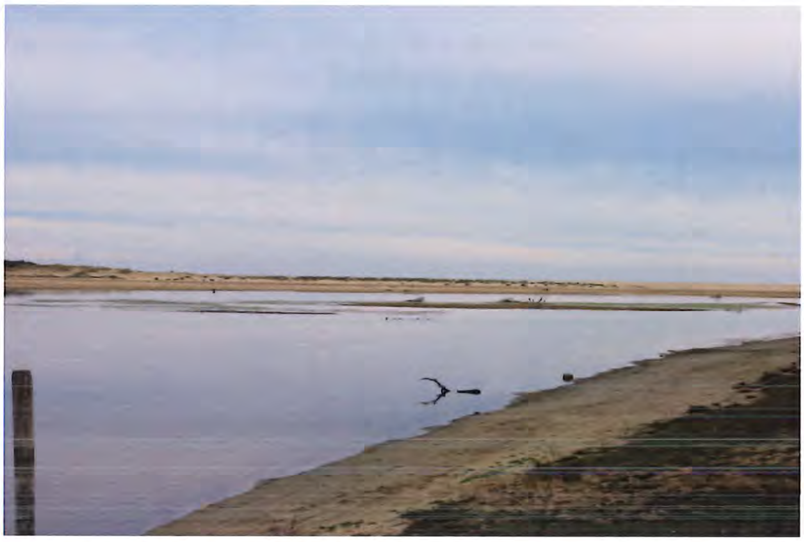
Port Phillip and Western Port and surrounding estuaries (courtesy of Melbourne Water).

There are comprehensive data sets for both Port Phillip and Western Port. Further development will continue in these highly urbanised/industrialised catchments. The challenge is to maintain and improve fisheries productivity through the multi-objective rehabilitation where possible of the habitat values of contributing creeks, rivers, wetlands and estuaries, and the re-establishment of favourable water quality and bottom environments. Improved water quality and fisheries management practices, including banning of dredge fishing in Port Phillip, now open the door to rehabilitation of lost or degraded habitats such as historic shellfish beds (i.e. key structural habitats for multi-species fisheries).

The 25 estuaries from the Glenelg to the Thompson are mostly small, many with ephemeral entrances. Twenty-one of these 25 estuaries are wave-dominated. There is only sparse seagrass coverage and mangroves are absent but fringing reed beds, flood plains and marshlands are important to the water quality, fish life and general ecological health. Many of their catchments are extensively cleared for agriculture and urban uses and most of the estuaries are known to have surrounding acid sulfate soils. Poor water quality and excessive inflows of nutrients and acidic waters have led to anoxic conditions and major fish kills in some of these estuaries.

Developing and implementing multi-objective estuary opening strategies is challenging, but important for many Victorian estuaries. The need to artificially open estuaries can be reduced by investment in works to modify floodable shoreline infrastructure and changes to adjacent floodplain land use (including land buy-back). Other issues that need to be considered in management of estuary entrance conditions include catchment runoff, within estuary water quality, timing of openings to maximise fisheries and waterfowl productivity, control over localised flooding and the general public perceptions that running tidal water is cleaner than high level closed entrance conditions. These high level conditions generally reconnect fringing wetland areas to the estuary and provide additional habitat for nursery phases of fish as well as breeding sites for waterfowl and important wetting of acid sulfate soils.

Aerial view of Lake Tyers estuary, eastern Victoria, with entrance closed by sand build up.



Lake Tyers estuary closed entrance.

Like many areas around the Australian coast, roles and responsibilities for managing estuaries across government agencies and the community have been ambiguous and there has been a general lack of strategic direction for estuarine policy and management in Victoria. As a result estuaries have been neglected when it comes to investment towards works to improve their environmental and ecological condition, and their habitat value for fisheries. The new Draft Victorian Waterway Management Strategy makes an important step forward by explicitly dealing with estuaries and identifies five specific estuary management issues to be addressed by regional management authorities <http://www.water.vic.gov.au/data/assets/pdf_file/0004/147514/Victorian_Waterway_Management_Strategy_WEB.pdf>:

- management of estuary entrances
- protecting and improving environmental conditions in estuaries
- setting water quality objectives for estuaries
- determining environmental flow requirements for estuaries
- managing coastal and acid sulfate soils.

It is expected this new strategy will lead to greater emphasis by regional waterway management agencies (through regional waterway strategies) on identifying the needs and priorities of individual estuaries for works to improve water quality, habitat and connectivity. The regional waterway strategies will provide clear priorities to guide investment in estuary improvement works. These work priorities will also provide guidance to Local Governments, the Australian Government and communities or philanthropic donors about where investment/action is required in the region over an eight-year period. This provides investors with confidence that their funding of management activities is linked to a longer-term, strategic plan for estuary improvements in Victoria.

7.3 Improving multi-species fisheries production in Port Phillip Bay

Port Phillip Bay covers an area of 1930 km^2 and has a maximum depth of 24 m in the central basin (Harris et al. 1996). It connects to the ocean across a region of shallow sand bars and channels (the Great Sands) through a narrow entrance (The Heads). The narrow entrance means that Port Phillip Bay has limited tidal flushing and long water residence time (approximately one year) (Harris et al. 1996) and therefore is particularly susceptible to water quality changes due to variability in catchment inputs (i.e. freshwater, nutrient and sediment) and longer-term climatic variations (i.e. salinity shifts of 4 to 5 ppt can occur between extended dry and wet periods, Lee et al. 2011). The bay is surrounded by a population of over 4.5 million people, major industries and a waste water treatment plant. It is the major shipping port and the most important sheltered water for recreational and commercial fishing and boating/sailing. While the bay is one of Victoria's most important and iconic natural assets, it is continually under threat from poorly planned development.

Port Phillip Bay.

The main freshwater and nutrient input to the bay is from the Yarra/Maribyrnong Rivers. Many other smaller rivers, creeks and drains also discharge nutrients, sediments, refuse and toxicants to the bay from highly urbanised catchments. The Western Treatment Plant is a major source of nutrients (Harris et al. 1996). Much work has been done by various management agencies (i.e. Environmental Protection Authority, Melbourne Water, Port Phillip Western Port Catchment Management Authority) to improve water quality entering the bay, and ongoing programs aimed at improving water quality discharging to the bay continue.

The sheltered productive waters of the bay are important for a variety of recreational and commercially valuable finfish and invertebrate species (i.e. Snapper, King George Whiting, several Flathead species, Anchovy, Calamari, Scallop, Abalone) as well as aquaculture (i.e. Mussel and native Flat Oyster). The bay is particularly important for Snapper (*Pagrus auratus*), a symbol of Port Phillip. Snapper migrate into the bay from coastal waters to spawn each spring/summer, and the resultant young use the bay as a nursery area. Studies have indicated that Port Phillip is the most important spawning and nursery area for Snapper in Victoria (Hamer et al. 2011), and production of the Snapper fishery in central and western Victoria depends on the water and habitat conditions in the bay.

King George Whiting, enter Port Phillip from coastal spawning areas as small post-larvae (20 mm length), and once in the bay they depend on shallow seagrass beds as their main nursery habitat (Jenkins et al. 1997; Jenkins and Hamer 2001; Hindell et al. 2004). Seagrass beds are critically important to King George Whiting along with other key species such as Calamari, Garfish and Rock Flathead.

While reef habitats constitute a small proportion of the total area of Port Phillip, they provide important structural habitats and harbour significant biodiversity. Their small area makes them a limiting habitat for production of many species (i.e. Abalone, reef-associated fishes such as Wrasses and Leather Jackets) and they are highly vulnerable to poor water quality, sedimentation, Sea Urchin over-grazing and invasive exotic species (i.e. Japanese kelp – *Undaria pinnatifida*).

The Department of Environment and Primary Industries has recently invested into research on seagrass and reefs habitats in Port Phillip Bay <http://www.dse.vic.gov.au/coasts-and-marine/marine/seagrass-and-reefs-program-for-port-phillip-bay>. The seagrass and reefs program, now well underway, aims to provide the scientific basis to underpin improved environmental management of seagrass and reef habitats in Port Phillip, with a focus on impacts of sedimentation and nutrification. The research funded through the program is targeted towards informing future practical management and it is hoped will offer up options for future investment in works to improve the quality, resilience and ecological function of the bay's reefs and seagrass. Funding for works is not included in this program.

Project 1: Re-creating Port Phillip Bay's lost shellfish beds

The sediment habitats and associated faunal communities of Port Phillip have undergone the most significant change of all habitat types in the Bay since white settlement, due to a combination of human impacts; including sedimentation, pollution, introductions of exotic species and dredge fishing for shell fish. A major change that has occurred, beginning in the 1800s, is the loss of shellfish beds (in particular native Flat Oyster [*Ostrea angasi*], and Blue Mussel [*Mytilus edulis planulatus*]) that were once ecologically important features of significant areas of the Bay (Winstanley 1982; Nell 2001). The native Flat Oyster was an important part of the diet of indigenous people, as evidenced by its conspicuous presence in middens (Nell 2001). Comparison of data on mussel densities presented by Winstanley (1982) and Cohen et al. (2000) suggest a decline in the abundance of mussels in north-east Port Phillip Bay of over 80% since 1980. Long-term changes in oyster abundance are less clear, however, similar to observations of oyster decline worldwide (Beck et al. 2011), the most significant reduction of the bay's oyster populations are thought to have occurred in the nineteenth century due to an oyster dredge fishery for human consumption and the use of oyster shells for lime production (Saville-Kent 1891; Nell 2001). In fact the importance of oysters in the 1900s is indicated by the first fisheries act established in Victoria being the Oyster Act in 1859.

Live native Flat Oyster (*Ostrea angasi*).

Dense healthy Blue Mussel bed (*Mytilus edulus*).

Shell from historic Oyster bed exposed in sediments.

Degraded Mussel bed.

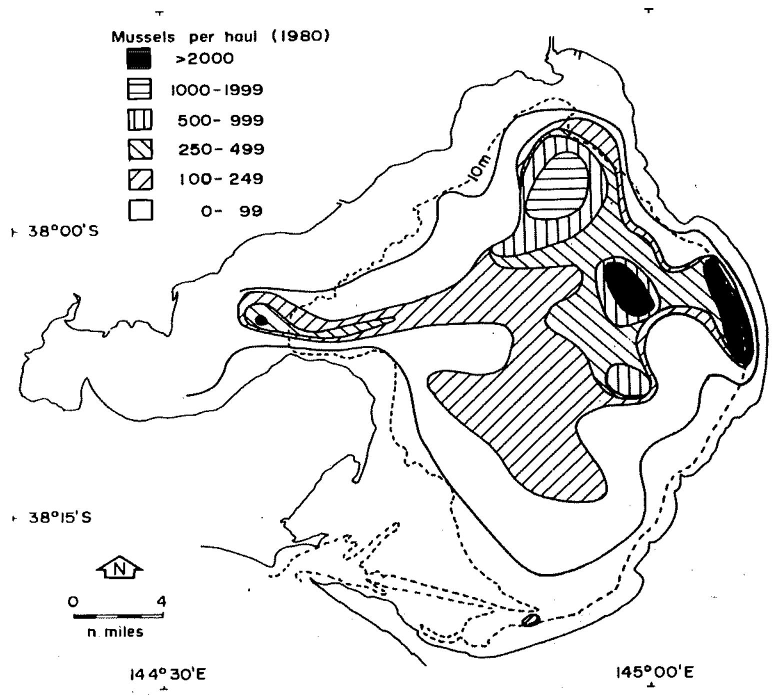
Removal of shell material (by fishing and for lime) that provides the substrate for settlement of new Oysters and Mussels has likely been an important factor in limiting regeneration. The dredge fishery for Scallop and Mussel that operated between 1963 and 1996 had a significant impact on Mussel populations and possibly the recovery of the bay's Oyster populations. At its peak during the 1980s the dredge fishery involved up to 250 000 dredge tows per year in the bay and dredging activities were widely distributed throughout the bay (Coleman et al. 1997). Between 1979 and 1987 an average of 900 tonnes of Mussels per year were removed from the bay (Winstanely 1982).

Historic Oyster and Scallop dredge fisheries in Port Phillip Bay.

Recreational and professional fishers have long lamented the loss of shellfish beds in the bay as they were seen as providing important feeding and nursery habitats for fish. Early (Winstanley 1983) and more recent (Restall 2001) studies on Snapper diets indicate that Mussels and other bivalve molluscs are important food for Snapper. Interestingly the occurrence of Mussels in the diets of larger adult Snapper was four to five times higher in the earlier study when Mussels were known to be more abundant in the Bay. Sand Flathead (*Platycephalus bassensis*) biomass in the bay has declined by 70–80% since the 1990s and while poor recruitment has been a factor in driving the decline, growth rates and maximum size of Sand Flathead in the bay are significantly lower than in coastal waters, and this is thought to be linked to limited availability of benthic food resources.

Studies in a number of estuary systems worldwide have indicated that shellfish beds provide important structural habitats for a variety of invertebrate and fish taxa (Breitburg and Miller 1998; Breitburg 1999; Coen et al. 1999; Peterson et al. 2003; Dealteris et al. 2004; Coen et al. 2011) and provide increased protection from predators for newly settled fish (Stunz and Minello 2001). Studies in the USA have demonstrated that increasing the area of Oyster beds can increase net fisheries production (Peterson et al. 2003). In the USA Oyster reefs have been defined as 'essential fish habitat' (Coen et al. 1999).

Aside from their value as fish habitat, shellfish reefs provide other 'ecosystem services' including nutrient cycling, water filtration, benthic – pelagic coupling, substrates for settlement of other invertebrates and algal species (i.e. building blocks for biological reefs), sediment stabilisation and carbon sequestration (Coen et al. 2007; Grabowski and Peterson 2007; Coen at al. 2011; Tang et al. 2011).



Distribution of Mussels in Port Phillip in 1980, with dense beds, no longer present, indicated in the eastern region of the Bay (from Winstanley 1982).

This project proposes to re-establish both native Flat Oyster and Blue Mussel beds in suitable historical locations in the bay. Now that dredge fishing has been banned in the bay, water quality has improved, and a commercially viable Mussel and Oyster hatchery and aquaculture industry has been established, the re-establishment of shellfish beds is now feasible. This project will follow a phased/adaptive approach to re-establishing shellfish beds, underpinned by the prior learning from large-scale ongoing programs in the USA (i.e. Chesapeake Bay Oyster Foundation, <http://www.youtube.com/watch?v=f-zt8lo0dgA&feature=plcpChesapeake Bay>) and will tap into the local knowledge of the shellfish farmers in the bay and recreational and professional fishers with knowledge of historical shellfish bed locations. Significant scoping work has already begun to guide the implementation of this project and design of pilot projects to investigate methodology and predation risks (i.e. native and exotic sea stars) are underway. The multiple benefits derived from increasing the abundance of shellfish in the bay will extend the interest and ongoing support for this project beyond the recreational and commercial fishing community, with a long-term vision to establish an ongoing partnership program supported by a diverse stakeholder and funding base to develop and implement projects for continual improvement/enhancement of the bay's benthic habitat forming species.

Output: Increased fisheries production and local biodiversity from the re-creation of significant areas of structural shellfish and biological reef habitat.

While the focus of the shellfish reefs project is mostly on benefits for fisheries, the additional ecosystem services and biodiversity provided will attract the interest and support of other stakeholders in the bay's environment.

Project 1: Pilot phase includes development and testing of approaches (lab and field), a small-scale trial with performance evaluation at three approximately 1 ha sites, community education and extension, and engagement of potential funding sources to support a larger ongoing program.

During the expansion phase from Year 3 onwards the project would capitalise on findings and support/interest generated from the pilot to expand the pilot sites to 5 ha, establish three new areas of shellfish restoration, and establish a larger ongoing partnership program, with longer-term targets. The ongoing program would include revenue generation strategies for the next 10 years through a business case (i.e. contributing investment from public and private investors). Public investment could come partly from existing recreational fishing licence funds.

Proposal and key benefits

- To re-establish shellfish reefs in Port Phillip as a basis for increased fisheries production, biodiversity and ecosystem health benefit.
- Major benefits will be for the recreational and professional fishing sectors, and other stakeholders in the health and ecological values of the bay.

Project 2: Improving the habitat value of estuaries connecting to Port Phillip Bay

Port Phillip Bay's catchment and feeding rivers and their estuaries are some of the most highly modified in Victoria. The main freshwater input to the bay is from the Yarra/Maribyrnong Rivers. Discharge from the Yarra/Maribyrnong estuary has a profound influence on water quality of Port Phillip Bay and no doubt the production dynamics of a range of fishery species that breed in the bay (e.g. Snapper, Flathead, Anchovy). The Yarra/Maribyrnong estuary is also an important habitat in itself for several recreational and commercial fishery species, including Bream, Mullet and Mulloway. Much of the shoreline of the Yarra/Maribyrnong estuary is modified by man-made structures such as rock walls and Melbourne's port infrastructure. Many of the rock walls have deteriorated and require major repair works.

Besides the Yarra/Maribyrnong a number of other rivers and creeks are important, both in terms of their potential to input undesirable chemicals, sediments and nutrients to the bay, but also their potential role as fish habitats. Foremost among these are the Werribee River, Kororoit Creek, and Patterson River. The estuaries of each of these rivers have been neglected in terms of their habitat value and investment in on-the-ground works to improve habitat value for fish is warranted. Most of the estuaries feeding the bay still have barriers to fish migration and tidal mixing. Finally there are numerous areas around the bay where storm water drains discharge urban runoff directly onto seagrass beds.

This project proposes to identify priorities and conduct works to increase habitat area, protection of sensitive seagrass habitats from storm water, improve/re-habilitate existing habitats and remove barriers to connectivity and fish passage within Port Phillip Bay's feeding estuaries. The project will link with strategic planning and works program priorities being identified by Melbourne Water (i.e. Healthy Estuaries Strategy) and other relevant agencies and will involve trialling novel engineering solutions, such as improving the fish habitat value of rock walls, and installing new in-channel habitat features. This project would involve significant community engagement via linking with and expanding Victoria's EstuaryWatch program to the Port Phillip and Western Port region.

Project 2: Port Phillip estuaries habitat revitilisation works

<u>Proposal and key benefits</u>

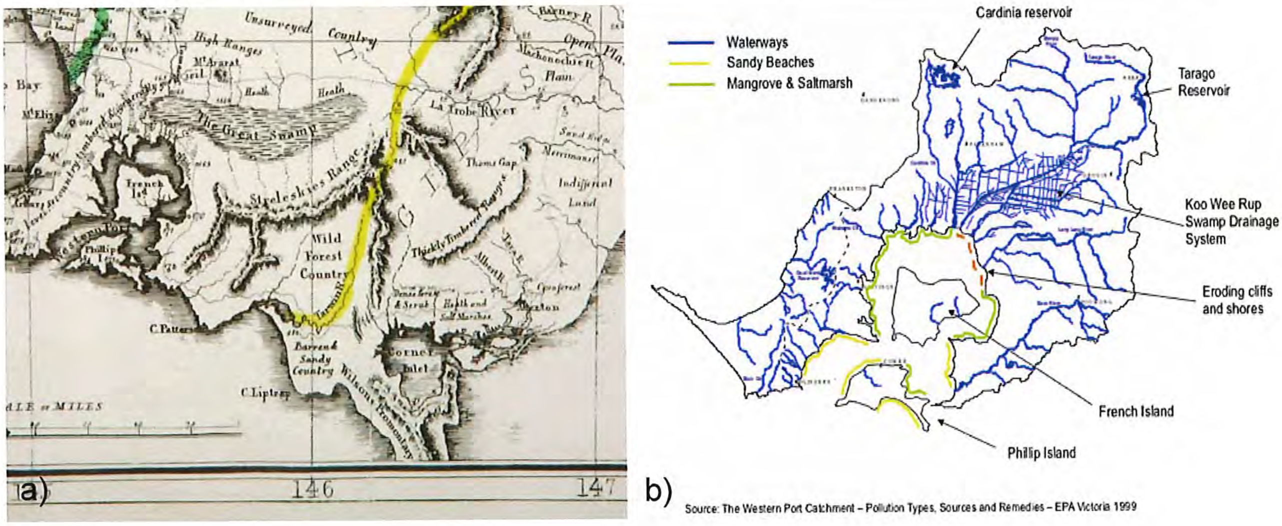
- To revitilise Port Phillip's estuaries by improving in-channel and shoreline habitats.
- Major benefits will be to recreational and professional fishers, biodiversity and the general community who use the Bays estuaries for recreation.

7.4 Improving water quality and seagrass habitat in northern Western Port

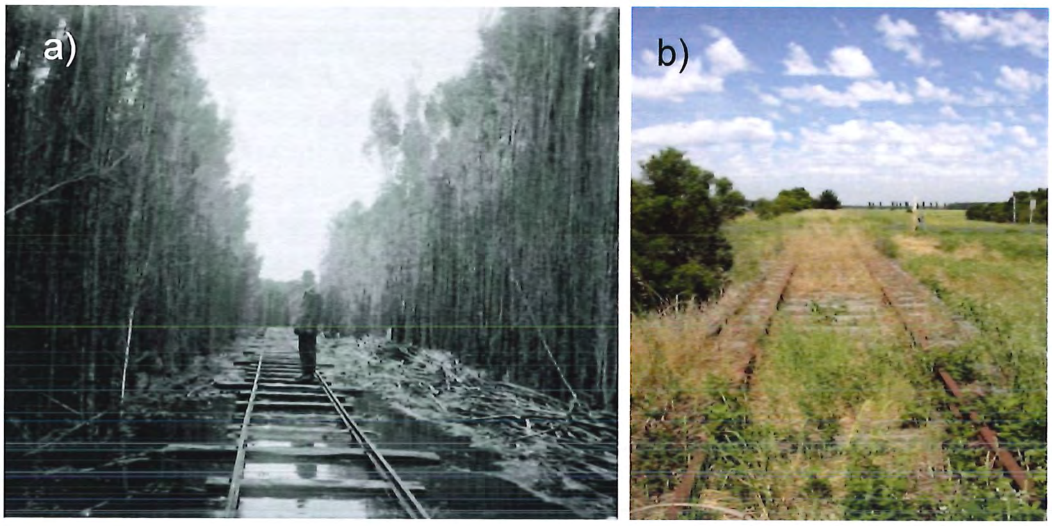
Western Port is the second largest bay in Victoria, it is a Ramsar site, wetland of international significance, and is highly valued for recreational fishing, boating and tourism, being situated less than one hour from Melbourne. Major tributaries of Western Port are Bunyip River, Lang Lang River, Bass River, and Cardinia Creek.

Channelised Bunyip River draining sediments into Western Port.

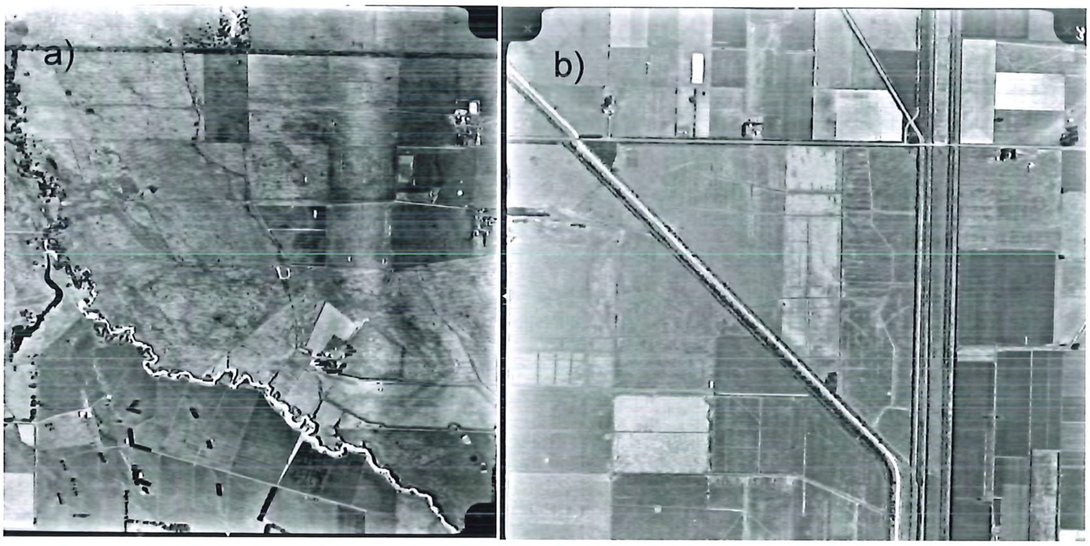
A common historical practice was to reclaim swamps and floodplains for agriculture. This was often achieved by removing vegetation and channelising water courses to improve drainage and limit flooding. One of the most dramatic Victorian examples of this practice is the Koo-Wee-Rup Swamp ('The Great Swamp') which formed a large area of the catchment draining into Western Port. In the 1800s the Koo-Wee-Rup Swamp extended over an area of approximately 40 000 ha. It was covered by dense stands of swamp paperbark (*Melaleuca ericifolia*), reeds (*Phragmites australis*) and bullrushes (*Typha* spp.) and provided a natural barrier between Melbourne and West Gippsland. In the 1860s clearing and draining of the Koo-wee-rup Swamp was initiated to create land for agriculture, and this continued in various phases through to the 1970s to further improve flood mitigation (*From Swampland To Farmland* by David Roberts). The rivers that drain to northern Western Port used to meander through, and flood into, the Koo-wee-rup Swamp. Nowadays these rivers are linear channels (drains) with high flow rates and limited in-stream habitat which have over the years eroded and delivered huge sediment and nutrient loads into Western Port. This is thought to have culminated in the major loss of seagrass habitat in Western Port recognised in the 1970s, particularly in the north-east (Bulthius 1983). This seagrass loss was followed by a major and sustained reduction in the production of seagrass associated fish such as King George Whiting (Jenkins et al. 1993). Seagrass has not recovered in the north-eastern area of Western Port, and the waters are now consistently turbid due to the lack of seagrass to stabilise the sediments in the shallow waters.



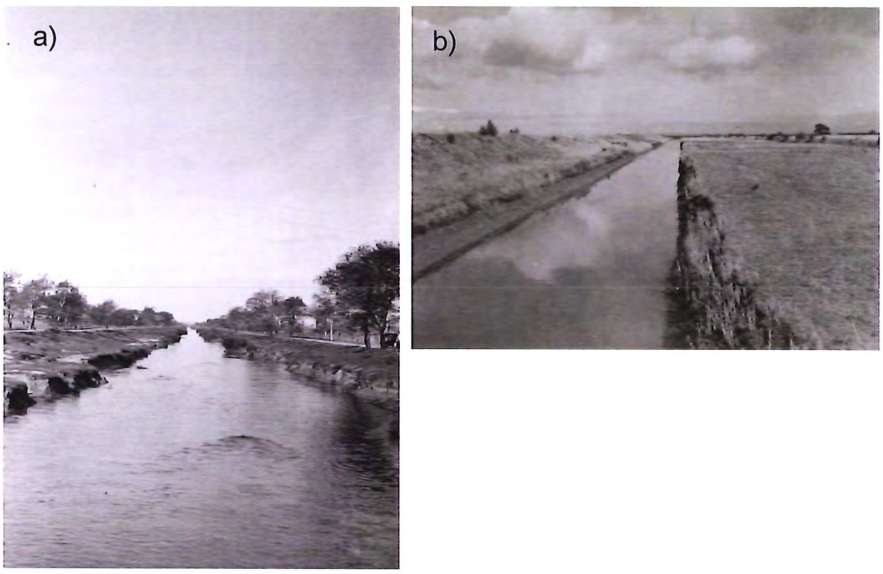
Western Port and its catchment: a) 1847 showing 'The Great Swamp', b) recent times showing the extensive drainage network, and region of eroding shoreline.



Railway through the Koo-wee-rup Swamp, a) 'circa' mid 1800s, b) now.



Cardinia Creek: a) before channelisation works, b) after channelisation.



The large-scale impacts on Western Port's catchment have left an enduring legacy of environmental and ecological damage. The Western Port catchment continues to develop and be subject to urban sprawl and the Koo-wee-rup Swamp will never be returned to its pre-European state. There are options for rehabilitation of water quality (particularly reducing sedimentation and turbidity) that could allow seagrass to naturally recover in northern Western Port. These include changes to the channel forms and addition of in-stream habitat (i.e. snags, rocks) to reduce flow rates, construction of sediment traps, and purchase of land adjacent to the main drains to allow significant alterations to channel forms along with rehabilitation of wetlands.

Within Western Port there are also issues with shoreline erosion, particularly in the northern eastern region, and these contribute significantly to the high water turbidity. Efforts to establish mangrove stands to reduce shoreline erosion have had mixed success, and seagrass replanting is being attempted. These efforts are largely based on volunteers, for example the 'Western Port Seagrass Partnership' <http://www.seagrass.com.au/> and perhaps require a more serious investment to support studies to improve the approaches and scale of works (Kirkman and Boon 2012). Other approaches to reducing wave action such as large geo-textile sand bags are also being trialled in conjunction with mangrove replanting. Significant funds will be required to move from trials to larger-scale works to prevent shore-line erosion and ongoing turbidity impacts in northern Western Port.

This project will focus on works to reduce the sediment loads and water column turbidity in northern Western Port. The objective is to return suitable water quality for the re-establishment of seagrass beds in the north-eastern region of Western Port. It will focus on reduction of sediment loads by modifying channel forms, addition of in-stream structures/sediment traps, along with works to reduce shoreline erosion in north-eastern Western Port. It will provide funds to support and significantly enhance the capacity and scale of community efforts currently underway in this area, and allow further investigation/trials of alternative approaches to reduce shoreline erosion and turbidity levels that will be of benefit in other areas.

Project 3: Returning seagrass to north-eastern Western Port

Proposal and key benefits

- To improve water clarity and return seagrass to north-eastern Western Port.
- Major benefits will be to recreational anglers, tourism, local communities, biodiversity.

7.5 Improving the habitat value and condition of Victoria's regional estuaries

7.5.1 Overview

This component addresses the need to improve the habitat value of estuarine systems (outside of Port Phillip Bay and Western Port) to support and enhance fish production and increase biodiversity and natural values. It focuses on the most impacted and modified systems that require action so that maximum benefits can be obtained from investment. Prioritisation of a major state-wide works program requires further discussion with relevant management agencies, however, most of the key agencies are well on their way towards developing priority works lists for regional estuaries, many of which will have clear benefits for improving fish habitat value if they eventuate.

Key management issues requiring attention across many of Victoria's regional estuary systems, include:

- barriers to fish passage and tidal mixing (longitudinal connectivity)
- barriers to lateral connectivity between channels and fringing vegetation and floodplains
- channelisation of wetlands and resultant high sediment loads delivered to estuarine and bay waters
- general degradation of estuarine habitats (seagrass, salt marsh, mangroves, fringing reed beds – Phragmites, other structural habitats, woody debris etc.)
- acid sulfate soils/prevention of acid water drainage to estuaries
- reducing the need for artificial estuary entrance openings
- increasing community awareness and stewardship.

7.5.2 Connectivity

Connectivity among marine and estuarine waters, freshwater reaches of rivers, flood plains and fringing wetlands is important for the completion of life cycles of many fish species in Victoria, including a number of threatened and listed species. Salt-wedges often extend well inland from the sea allowing marine and estuarine species to utilise riverine habitats and food sources. If longitudinal connectivity between the marine and freshwater end members of an estuary is impacted by barriers to fish movement and tidal mixing, the value of the estuary as fish habitat and for contributing to fisheries production will be severely reduced. Similarly lateral connectivity between the estuary channels and adjacent wetlands and flood plains is important for filtering sediments, nutrients and other chemicals from the water, thereby improving estuarine water quality and reducing impacts of poor water quality on adjacent inshore coastal habitats such as seagrass beds and reefs. Improving connectivity will improve overall estuarine dynamics and ecological health. Barriers include concrete banks, weirs, channelisation and sand banks.

Sea level rise may result in wetland and estuary habitats naturally migrating inland, but this adaptive process will be hindered by built assets and infrastructure. Management activities to enhance connectivity and condition, such as riparian restoration and barrier removal, along both river and estuarine reaches are critical for waterway health.

Management activities include: upgrading/installation of regulators, removal of barriers, land purchase, fencing, riparian restoration.

Key areas for investment: Gippsland Lakes, Glenelg River, Snowy River, Great Ocean Road estuaries.

Following is a list of key sites for connectivity repair as provided by Ivor Stewart (pers. comm. Kingfisher Research P/L ivor.stewart@gmail.com).

River	Barrier	Fishway
Yarra River (Melbourne)	Dights Falls	Vertical-slot constructed 2012
Barwon River (Geelong)	Tidal Breakwater	Vertical-slot constructed 2013
Thomsons Creek (Geelong) Minya Farm Weir	Tidal weir	Nil
Maribyrnong River (Melbourne)	Werribee Mansion tidal barrier	Nil
Cardinia Creek (Melbourne)	Tidal barrier	Old ineffective rock fishway
Anglesea River (Anglesea)	Coalmine Road crossing	Nil
St George River (Otways)	Crossing & stream gauge	Nil
Maffra Weir	Macalister River	Nil
Aire River crossing	Aire River	Nil
Glenelg River	Dartmoor Gauge	Nil
Patterson River (Melbourne)	Tidal barrage	Ineffective rock chute
Genoa River (Mallacoota)	Tidal barrage	Nil

7.5.3 Maintaining and improving environmental condition

The environmental condition of in-stream and riparian estuarine habitat, vegetation communities and animal species can be affected by threats from the surrounding catchment. Erosion and sedimentation can impact on the water quality of estuaries. The protection and improvement of these habitats (and their associated values) is vital for improving estuary health as these habitats provide food, cover, migratory corridors and breeding/nursery areas.

Management activities include: upgrading/installation of regulators, removal of barriers, land purchase, fencing to prevent livestock access, riparian/wetland restoration.

Key areas for investment include: Gippsland Lakes, Snowy River, Glenelg River, Corner Inlet.

7.5.4 Reducing the need for artificial estuary entrance openings

Many of Victoria's estuaries close intermittently as a result of sand bar formation at the estuary entrance. This usually occurs during periods of low freshwater inflow. Intermittently closed estuary entrances are a natural feature of the Victorian coastline and can be critical to estuary ecology and physical form. For example, changes to the entrance position of Mallacoota Inlet after artificial opening may have been partly responsible for increased sediment deposition in the entrance region and loss of estuarine habitat.

The closure of an estuary entrance can result in an increase in water level and inundation of adjacent land. Inundation is a natural process and plays an important role in the life cycle of many species and the cycling of nutrients. Periodic inundation of adjacent wetlands and fringing vegetation is also necessary to ensure their ongoing health. However, high water levels and prolonged inundation can have social and economic impacts through flooding of adjacent agricultural or residential land, roads and structures and has led to regular and sometimes unnecessary artificial openings in many Victorian estuaries.

Management activities: upgrading/replacing infrastructure that trigger opening requests (e.g. raising a jetty or replacing with a 'floating' jetty), landholder agreements and/or covenants, land purchase.

Key areas for investment include: Great Ocean Road estuaries (in particular the Anglesea, Aire and Gellibrand rivers), Powlett River, Bourne Creek, Glenelg River, Merri River, Lake Tyers, Mallacoota Inlet

7.5.5 Increasing community awareness: expanding the EstuaryWatch program

Efforts to maintain or improve estuary condition require community support. Several initiatives that raise community awareness of waterway management issues already exist, such as Waterwatch, EstuaryWatch, Coastcare Victoria, Land for Wildlife, Fishcare and Landcare. Of these, EstuaryWatch is the only program specific to estuaries. EstuaryWatch is a community-based estuary monitoring program that collects water quality and other estuary data. It aims to help local communities learn more about the unique characteristics and health of individual local estuaries and to provide information to inform estuary management. EstuaryWatch was established by the Corangamite Catchment Management Authority and the Western Coastal Board in 2006 and pilot programs exist in several other catchment management authority regions in Victoria.

Key areas for investment include: state and regional coordination, equipment purchase/maintenance

7.5.6 Acid sulfate soil mitigation

An emerging issue for estuary management is the disturbance of acid sulfate soils in estuarine wetlands and marshes. Acid sulfate soils are soils or sediments that contain (or once contained) high levels of reduced inorganic sulfur. When exposed to oxygen, the soils or sediments undergo a chemical reaction (called oxidation) that produces acid.

If the amount of acid produced is greater than the system's ability to absorb that acid, the pH of the system falls (that is, it becomes acidic). The oxidation of acid sulfate soils consumes oxygen. In extreme cases this can remove all the oxygen from the water column, resulting in the death of aquatic plants and animals. Oxidation of acid sulfate soils can also lead to the release of metals (e.g. cadmium and lead) and metalloids (e.g. arsenic) into the environment. Disturbance of acid sulfate soils can occur as a result of drainage, dredging, drilling for bores, drought that induces drying of soil profiles, extractive industries, infrastructure works, land use changes that alter water tables, urban and tourism development and water extraction.

The *Victorian Coastal Acid Sulfate Soils Strategy* (2009) was developed to protect the environment, humans and infrastructure from the potentially harmful effects of disturbing coastal acid sulfate soils. The development of the *Best practice guidelines for assessment and management of acid sulfate soils in Victoria* provides land managers with guidelines to address this problem.

A map of where coastal acid sulfate soils are a potential issue in Victoria is provided by the *Victorian Coastal Acid Sulfate Soils Strategy*. Locations where immediate action/protection or installation of detailed monitoring networks might be warranted are identified.

Management activities include: development of site-specific management plans, various 'works' options.

Key areas for investment include: Gippsland Lakes, Anglesea River, Great Ocean Road estuaries.

Project 4: Improving the habitat value and condition of Victoria's regional estuaries

Proposal and key benefits

- To support priority works across a number of high value estuaries in regional Victoria to improve habitat values and environmental condition.
- Major benefits will be to recreational and professional fishers, local communities, tourism, general amenity, recreational and natural value, biodiversity.

CHAPTER 8 Tasmania

8.1 At a glance

- Nowhere in Tasmania is more than 115 km from the coast so estuaries and coastal waters play an important role in the Tasmanian economy.
- Key drivers of fisheries productivity, high coastal biodiversity and community benefit are the major embayments of the lower Derwent – Storm Bay and the D'Entrecasteaux Channel separating Bruny Island from the eastern mainland, and to a lesser degree, the many smaller estuaries on the east and north coasts.
- Salt marshes and fresh to brackish sedge lands are dominant in estuarine wetlands but most estuaries and their wetlands have been modified by land clearing for agriculture and urban development.
- Tasmanian commercial species with a close link to seagrasses or estuarine and coastal habitats include Sand Flathead (*Platycephalus bassensis*), Greenback Flounder (*Rhombosolea tapirina*), Black Bream (*Acanthopagrus butcheri*), Southern Garfish (*Hyporhamphus melanochir*), Yellow-eye Mullet (*Aldrichetta forsteri*) and Australian Salmon (*Arripis trutta*), especially during juvenile stages.
- Both seagrasses and nearshore kelp forests provide shelter for nursery phases of many finfish and crustaceans such as the Southern Rock Lobster (*Jasus edwardsii*) as well as being important in nutrient cycling and net primary productivity of the estuarine and nearshore marine food chains.
- Overall Tasmania has some 124 estuaries, as inventoried by the National Land and Water Resources Audit (Audit 2002), varying from small wave- and river-dominated estuaries to the large embayments.
- The nearshore environments are also particularly important and like estuaries are impacted by excessive sediment and nutrient export from Tasmania's catchments.
- Approximately 48 of the estuaries are near pristine, such as Bathurst Harbour and New River lagoon within the south-west world heritage area. Another six are largely unmodified, 59 are modified and 11 are extensively modified.
- Tasmanian estuaries are diverse, due mainly to extreme differences in wave energy and rainfall between the west and the more sheltered east coasts, a greater tide range on the north coast and variation in local geomorphology and shelter, such as provided by Maria Island. Limited information is available on the ecology of most estuaries in Tasmania. Those with more detailed ecological knowledge are the major drowned river valley estuaries of the Huon, Derwent, Tamar and Bathurst Harbour.
- This chapter concentrates on the modified and extensively modified estuaries. Investment in repair is recommended for:
    - large embayments – especially re-establishing oyster and scallop beds as the basic building block for multi-species fisheries, predominantly for recreational catch
    - fish passage and tidal flow – manipulating flood barrages, road causeways and various blocks and culverts to improve connectivity and productivity
    - salt marshes and sedge lands – re-establishing connectivity, rationalising drainage, restricting cattle access to salt marshes and sedge lands and reducing the likelihood of acidic anoxic water discharge

- improved freshwater flows especially small flushing events to maintain estuarine habitats and enhance oyster production
- reduced siltation of the Tamar estuary.

8.2 Tasmania's estuaries and nearshore environments

North coast estuaries, from Cape Grim to Cape Portland, which flow in to Bass Strait are characterised by relatively high tidal range of 2.5–3 m, seasonal rainfall which is much higher in the north west and catchment land uses that include agriculture, forestry, and urban and industrial development. These estuaries are generally modified but well flushed and mostly tide-dominated. The Tamar estuary has extremely high plant, invertebrate and fish diversity in its lower reaches.

The estuaries on the east coast from Cape Portland to Southport have a lower tidal range of 1–1.5 m and are subject to comparatively lower rainfall, which is more variable both in annual quantity and time of year. Land use is dominated by agriculture, town settlements and forestry. Modified estuaries are largely wave-dominated and poorly flushed, and often have restricted entrances. The region also contains a large number of coastal lagoons, many of which are periodically closed. South-eastern Tasmania has a convoluted coastline with many protected embayments. These estuaries have high levels of animal and plant endemism. Land use includes agriculture, forestry, and urban and industrial developments. The estuaries are generally modified, include both wave- and tide-dominated systems and are generally poorly flushed with the exception of the large drowned river valleys of the Derwent and the Huon.

The south and west coasts from Southport to Cape Grim have high rainfall and a low tidal range of ~1 m. Much of the coastline is exposed to extremely high wave energy. Sand transport on the west coast is an important factor controlling entrances to these estuaries. The south-west coast is fully contained in national parks, with one small exception at Cox's Bight, where mining tenements are located. Grazing dominates catchments at the northern end of the west coast. These estuaries are predominantly near pristine with tannin rich waters. Unique biotic communities occur in the dark tannin coloured waters of Bathurst Harbour.

The predominantly wave-dominated estuaries of King Island, Flinders Island and Cape Barren Island are mostly in near pristine to modified condition. Rainfall is seasonal and the land is primarily used for grazing with consequent impacts on estuary condition.

Both the professional and recreational fishing industries of Tasmania are of high value. The Tasmanian Abalone (Blacklip – *Haliotis rubra* and Greenlip – *Haliotis laevigata*) industry supplies greater than 25 % of the world's commercial abalone and the Rock Lobster fishery is a long established and productive industry Aquaculture includes high volumes of Pacific Oysters and all of Australia's Atlantic Salmon production. Farming Atlantic salmon is the largest seafood sector in Australia, producing almost 40 000 t each year.

Changing climate and sea temperatures are altering nearshore habitat. For example, urchins (*Centrostephanus rodgersii*) are moving south, causing declines in kelp beds along the east Tasmanian coast.

8.3 Re-creating multi-species fisheries in D'Entrecasteaux Channel and eastern Tasmanian estuaries

Early settlement of the east coast of Tasmania led to strong demand for lime. Much of the early settlement used convict labour to harvest and treat Oyster shell to provide lime. Lime burning kilns are still evident along the coast, such as those being restored at Little Swanport. This harvest led to the decline of many of the previous bottom Oyster beds. Beds of the native Oyster (*Ostrea angasi*) were extensively harvested by dredging in eastern and south-eastern Tasmania in the mid 1880s. Clearing and the increased sedimentation that accompanied it further declined the productivity of these shell beds, such that by 1880–1890 this fishery had collapsed and it has never recovered. Similarly, highly productive beds of Scallops (Commercials – *Pecten fumatus*, and Queens – *Equichlamys bifrons*) in the D'Entrecasteaux Channel were an important fishery in the early-mid 1900s until overharvesting by dredging and increased siltation decimated the stocks.

Experience in the USA has demonstrated that strategic investment in shell bed and shell reef repair can lead to re-established multi-species fisheries (RAE 2013). Re-creation of selected shell beds in selected locations where they historically occurred and where the water quality is now much improved and sedimentation no longer an issue would foster increased productivity of both shellfish and multi-species fisheries. Of particular significance is the last remaining bed of native Oysters in the entire range of this species from New South Wales to Western Australia, which occurs in Georges Bay on the east coast (Beck et al. 2011). This bed provides a significant opportunity to commence enhancement of native Oyster beds in the region.

Georges Bay.

The first stage would be to collate information on where the major shell beds historically occurred and then cross-correlate with the water quality at these sites to determine two or possibly three experimental areas of about 3 to 5 ha where shellfish beds could be re-created.

Proposal and key benefits

- To re-create a series of shellfish beds as the basic building block for multi-species fisheries.

8.4 Fish passage and tidal flows

As with the Great Barrier Reef catchments, and the New South Wales and Victorian coasts, there are many sites where fish passage and connectivity between freshwater environments, brackish wetlands, and the tidal components of the estuaries have been lost. Likewise in many cases the tidal flows driving productivity have been constricted. A good example is the Tasman Highway, restricting the total volume of tidal flows to both the Upper Pitt Water and to Orielton Lagoon.

Pitt Water and Orielton Lagoon.

All the issues and opportunities already identified in other chapters apply. The techniques and methods to reduce the impact of these generally historical changes in estuary productivity are also the same. There are many ways from outright removal through to bypass fishways and re-engineering of culverts, road and rail crossings that can be applied. Works will depend on the site in question and will need to take account of other objectives such as flood control.

Methods to prioritise works investment are also readily available including the protocols developed by Oceanwatch.

Proposal and key benefits

- To repair where practical fish passage linking fresh and brackish components of the estuary ecosystems to tidal and marine components, and to increase tidal flows, where this has been constricted.

8.5 Salt marshes and sedge lands – repairing their productivity

With Tasmania's low tidal prisms, salt marsh and sedge lands dominate the estuarine wetlands. Many of these areas are underlain by peaty soils that when disturbed, such as by drains, lead to an acidic leachate, changing the pH of receiving waters.

Some of these wetlands, as well as being drained in the past were leveed excluding tidal interchange. Much of the drainage and levee works are recognised in hindsight as mistakes. The works did not create additional good quality agricultural lands and these areas are now 'wastelands' – neither of agricultural nor estuarine value, or poor quality grazing land. Many of these areas are also subject to uncontrolled access, especially by grazing cattle, reducing their overall productivity as estuarine ecosystems.

Rationalising drainage and levees to improve tidal interchange and restricting cattle access will increase the extent of wetland fisheries nursery habitat. Each area will need to be examined on a case-by-case basis as many of these salt marshes and sedge lands are freehold. Repair works will require the cooperation of landholders and may include the provision of fencing and watering points. Important wetlands that have been significantly modified are around Robin's Passage in the northwest, the northeast including Ringarooma estuary and Musselroe Bay, Moulting Lagoon on the east coast and Pitt Water – Orielton Lagoon and the Derwent estuary in the southeast.

Proposal and key benefits

- To selectively repair estuarine wetlands – salt marshes and sedgelands.
- Major benefits will be increased estuarine habitat for fish, birds and other aquatic organisms.

8.6 Reduction in siltation of the Tamar estuary

Build up of sediment followed by dredging has been an ongoing issue in the Tamar estuary for many decades. This is a significant waterway in Tasmania as it has high biodiversity and nursery habitat and contains a major port. Past solutions have attempted to reduce sediment influx from upstream clearing and agriculture. This has not reduced the siltation because it is lack of water flow through modification of natural watercourses that began with European settlement that is the fundamental cause of the problem.

Tamar River.

Solutions that work with natural processes are required. These include the release of flows, mainly from small floods in conjunction with silt raking, from the Trevallyn Dam through the Gorge. An increase in tidal flushing in the North Esk is also part of the solution through wetland restoration, creation of tidal lakes and reinstating an ancient meander system.

Reduction in siltation and hence the need for ongoing dredging would result in a reduction in ongoing maintenance costs and significantly increase the health of both the upper Tamar and lower South Esk and the lower estuary, providing increased recreational opportunities and enhanced commercial fisheries.

Proposal and key benefits

- Reduction in siltation of the Tamar estuary through works that increase flushing.
- This will improve the health of the estuary and provide better habitats and water flow for commercial and recreational fish species.

8.7 Maintenance of estuarine flushing

In recent years construction of dams and increased irrigation have significantly enhanced agricultural production from otherwise relatively low agricultural production areas. This has affected the health of a number of estuaries through a reduction in regular freshwater flushing from small flood events. These reductions in flow are also changing the estuarine habitat to more marine conditions, thus reducing the habitat for estuarine recreational species and nursery areas for commercial fish. For example, the Coal River – Pitt Water estuary has recently experienced several toxic blue-green algal blooms. Sediment has built up in the estuary and marine conditions have penetrated further upstream.

By understanding the catchment hydrology and then building diversion channels for dams and water extraction points to enable flushing flows from regular small floods to more closely mimic natural conditions and flow through to the estuary, the health of these impacted estuaries and their fish habitats can be repaired. This would also benefit shellfish farming in many estuaries by increasing nutrient input that enhances the production of the algal food for oysters.

Estuaries where such works would occur will need to be prioritised according to the feasibility of increasing flushing and likely improvements to the estuary. Generally, estuaries most impacted by reduced flushing are located on the east and south-east coasts, where flushing is naturally low due to low rainfall and small tidal range.

Proposal and key benefits

- To increase estuarine flushing through increased flows from small flood events.
- Major benefits will be increased estuarine habitat for commercial and recreational fish, and more productive estuaries for farming Oysters.

8.8 Proposed investment

8.8.1 Re-creating multi-species fisheries in D'Entrecasteaux Channel and east coast estuaries

- A focused investment on recreating Oyster and Scallop beds as the basic building block for repairing overall fisheries productivity.

8.8.2 Re-establishing fish passage

- A prioritised investment over five years to repair and reconnect fish passage and tidal flows across all key estuaries.

8.8.3 Salt marshes and sedge lands, repairing their productivity

- Priority works to restrict cattle access, rehabilitate and if needed relocate drains, where needed modify levees and reconnect these important wetlands to the tidal components of the estuaries.

8.8.4 Reducing siltation of the Tamar estuary

- Works to increase tidal and freshwater flushing to improve the condition of the estuary and enhance the habitat of commercial and recreational fish.

8.8.5 Increasing flushing flows to estuaries

- To enhance estuarine flushing through increasing flow from small flood events. This will improve estuarine health, oyster production and fish habitats.

CHAPTER 9 New South Wales – repairing major floodplain wave-dominated estuaries and deltas

9.1 The case for action

9.1.1 At a glance – NSW estuaries and coastal floodplains

The National Land and Water Resources Audit, 2002, undertook a full inventory of estuary type and condition (see pp. 326–331, vol. 2 of *Australian Catchment, River and Estuary Assessment*, Audit 2002). In brief, NSW has more than 130 estuaries ranging from wave-dominated estuaries and deltas often with developed floodplains and extensive catchments, through to tidal flats and small creeks draining coastal sand dunes.

The NSW business case for repair focuses predominantly on the larger floodplain wave-dominated estuaries and deltas. Most of these are extensively modified by development for agriculture with floodplains urbanised, wetlands drained and previously tidal creeks and tributaries dammed off by levees and floodgates.

Many estuaries also have constructed training walls at their entrance, initially built to aid coastal shipping. These training walls have altered the tidal hydrology of the estuaries and replaced the myriad of sand spits and channels that once dominated the interface between estuary and ocean with single permanent, deep, high volume exchange points. As an example, Flinders' diaries (copied extracts held in Yamba Historical Museum) recorded the sand spits and channels of the Clarence, noted the aboriginal long huts on the headland and surmised there may have been a major river behind the sand spits but could not find a passage into the estuary.

Virtually none of the floodplain wave-dominated estuaries and deltas remain in near pristine condition. The Sandon estuary, to the south of the Clarence is the exception. Most of the Sandon's catchment is within Yuragir National Park and much of the catchment is within the extensive Pleistocene and Holocene sand dunes, with very minimal alluvial soil floodplain development.

All of these floodplain wave-dominated estuaries and deltas once supported very productive inshore fisheries and nursery areas. Key species include School and Eastern King Prawn, Mullet, Yellowfin Bream, Flathead, Whiting, Mulloway, Mud Crab, Sydney Rock Oyster, several species of Garfish, and Snapper. The massive modification of floodplains, predominantly as a result of agriculture has reduced available nursery areas and led to water quality issues of acidic effluent from drains and anoxic water from altered wetlands. Key example locations in New South Wales are the Richmond, Clarence, Macleay, Manning and Hunter River estuaries.

This business case concentrates on re-establishing tidal flows to important fish nursery areas; rehabilitating wetlands, creeks and drains; and repairing the natural hydrology of these floodplain wave-dominated estuaries and deltas.

A quite separate issue requiring attention is the management of entrance openings for the intermittently opening coastal lagoons and lakes or as they are called, ICOLLS. With their wave-dominated intermittently open and closed entrances, these lake systems comprise about 60% of all estuaries in NSW and are in varying condition from pristine (e.g. Lake Arragan) to extensively modified (e.g. Lake Illawarra which now also has an almost permanent training wall entrance). A major issue for these is the mechanical opening of the bars because of the threat of localised flooding and the potential impact on infrastructure and coastal urban settlements. Mechanical opening is generally undertaken at lower water levels than is optimum for the ecology and hydrology of these systems. Impacts on their fisheries, water quality and waterfowl populations are substantial. Mechanical opening at lower water levels than optimum also usually imply the cycle of entrance open – entrance closed is truncated creating additional impacts.

Creighton (1983) detailed the impacts on waterfowl and fisheries of too frequent openings for the Lake Cathie – Lake Innes system. This particular system is included within this business case as an example of the need for improved management of these systems and most importantly, how the repair of Lake Innes as a fresh to brackish nursery area would greatly advantage both fishery and waterfowl values.

9.1.2 Condition and value of estuaries, documenting major losses in productivity

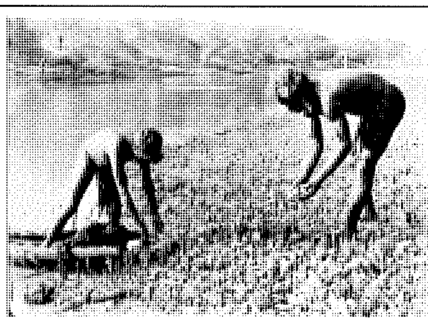
Historic estuarine and floodplain condition

At the time of European settlement our coastal floodplains looked, and more importantly functioned, quite differently to the ecologically compromised systems that remain today.

Mangroves – shelter for all

In the lower estuaries, the riverbanks and small creeks were fringed with thousands of hectares of mature mangrove forests. The five mangrove species found in NSW are Grey Mangrove (*Avicennia marina* variety *australasica*), River Mangrove (*Aegiceras corniculatum*), Large Leaved or Orange Mangrove (*Bruguiera gymnorhiza*), Red Mangrove (*Rhizophora stylosa*) and Milky Mangrove (*Exocoecaria agallocha*). Grey and River Mangroves dominate. Red and Orange Mangroves are confined to the more subtropical northern NSW and Milky Mangrove is found close to tidal limits, often in more brackish waters along with the Mangrove Fern (*Acrostichum speciosum*). These provided a year-round food source and direct habitat benefits for fish and crustaceans such as School and Eastern King Prawns, Mud Crabs and in the sandy channels and sand spits that dominated ocean entrances, Blue Swimmer Crabs. The thicket of aerial mangrove roots gave juvenile fish and crustaceans a safe refuge at high tide from predators.

The mangrove roots also provided a settling place for Oyster spat that once developed into an adult population that sustained a huge, regular harvest. The town of Ballina in northern NSW derives its name from a local Bundjalung word meaning 'place of many oysters' and annual gatherings of the clans were held there. Early settlers later derived considerable income from harvesting these abundant resources and selling them to the burgeoning capital city populations. Most of the lime for the early settlements in Sydney, Newcastle and Port Macquarie came from these oysters and names like Limeburners Creek illustrate this important input to early settlement construction.



Oysters were historically abundant throughout the mangrove systems of NSW.

Saltmarsh – food factories

Saltmarsh flats abutted the mangrove-lined estuaries. At slightly higher elevations than the twice daily flushed mangroves, the saltmarshes bound together the carbon-rich sediments, keeping the river clear and clean. Research has indicated that the saltmarshes also provided shelter for delicate, developing crab larvae as well as for prawns. Juvenile and adult crabs directly consumed the fallen leaves of the saltmarsh and mangrove plants, their droppings becoming a vital source of nutrients for the receiving waterways and their dependent aquatic life.

Fishing from a fallen snag, with mangroves visible behind the saltmarsh flats.

Seagrass – the nurseries

The environmental services provided by saltmarsh and mangroves provided clean clear estuarine water able to sustain large meadows of seagrass in the shallow areas. These seagrass meadows provided large areas of habitat for juvenile fish and their food sources such as worms and molluscs. The seagrass meadows also stabilised the estuarine sediments and sequestered large amounts of carbon into the sediment and biota.

Key seagrass species in New South Wales include Strapweed (*Posidonia australis*), Ribbonweeds (*Zostera capricorni, Z. muelleri* and *Heterozostera nigricaulis*) and Paddleweeds (*Halophila ovalis* and *H. decipiens*).

Recent research has shown that the amount of carbon that is sequestered by marine vegetation communities (mangrove, saltmarsh and seagrass) far outweighs that locked up by an equivalent area of any terrestrial ecosystems, including woodlands and rainforests. (Lawrence et al. 2012).

Lakes and lagoons – growing zones

Part of a 3½ ton sea mullet haul from Boambee Creek, near Coffs Harbour.

An intricate network of tidally flushed channels linked the mangrove/saltmarsh areas with large saltwater lagoons and lakes that played a vital role as nurseries. These were core areas where fish would feed and grow to spawning age, including what are now our recreationally and commercially important species – Yellowfin Bream, Whiting, Flathead, Mulloway, Mullet, plus School and Eastern King Prawns.

Backswamps – driving productivity

The coastal floodplains were dominated by vast areas of low-lying wetlands (or backswamps) that typically remained inundated for much of the year. The title of 'backswamp' reflects their position in the floodplain. Closest to the main channel of the rivers were the alluvial levees, where much of the silt dropped out of suspension as the mud rich rivers flooded over the banks and rapidly lost velocity and silt carrying capacity. All floodplains have a higher local elevation close to the river with depressions or 'backswamps' away from the river. Early settlement, agriculture and roads were usually developed close to the river on the alluvial levee.

Freshwater lagoon, Clarence River, 1892.

These backswamps were significant ecological drivers of thriving fish populations that were described so eloquently by early settlers:

> *All through the forest country are immense swamps miles in extent...they are as level as a table, except a central channel, and I have seen them covered from end to end with couch grass eighteen inches high, one dense mass of luxuriant vegetation...*

The backswamps were linked to the main river by vegetation-choked, sinuous channels that allowed adequate fish passage, but slowed the exit of waters from the wetlands after each successive flood.

Backswamp contribution to floodplain ecologies was massive, as they provided juvenile fish with an ideal source of food, shelter and refuge from predators. Depending on their estuarine location, connectivity and local rainfall patterns these wetlands offered a rich tapestry of habitats for a diverse range of fish species whether they were dependent on saline, brackish or freshwater conditions.

Shooting wild fowl in the (back)swamps.

The backswamps also provided habitat for immense flocks of waterbirds as described in 1908:

> *The swamps and marshes and long, broad lagoons of the eastern regions are often living masses of game...*
>
> *Water fowl of all descriptions are very plentiful on the swamps and lagoons of the Richmond River. One could take any small chain of water-holes or medium sized swamp and there spend the whole day beating to and fro, shooting till he wearied of the sport.*
>
> *It was nothing to see ducks rise from the pools here in such clouds as to throw a deep shadow covering ten acres, and with a sound like the rumbling of thunder, or the rushing of water over the precipice.*

While the benefits of an intact mosaic of wetlands are clearly apparent for fish, it is equally important to recognise that they had a far-reaching range of positive effects for other floodplain fauna, including waterbirds, frogs, insects and tortoises and equally importantly, for overall estuary water quality.

Riparian – food, shade and shelter

Riparian vegetation bordered the rivers, from the mangroves in the lower estuary all the way to the gallery rainforest-lined banks further upstream, the thick mass of plant life holding the banks together. Pioneer settler/explorers on the Clarence River in 1841 described how ...

> *... owing to the denseness of the brush on the banks, no part of the country could be seen from the vessel but was completely covered by a mass of most luxuriant vegetation; the stems of gigantic trees, covered with climbing plants of various descriptions, and which fall down in graceful festoons from the upper branches, produced an effect observable only in a region fresh from the hand of nature.*

Riparian trees on the Tweed River, 1884.

This 'brush' or rainforest included high value timber such as Red Cedar (*Toona ciliata*). Cedar cutters were often the first European settlers to explore the estuaries of NSW. This tightly knitted riparian framework also contributed directly to the aquatic food chain by dropping fruit and seeds as well as insects and the occasional larger animal, either directly as food for fish or indirectly as nutrients for other parts of the system.

The potentially destructive power of run-off caused by heavy rainfall was limited by the vegetation, with stream base flows being released slowly from the catchment and much of the nutrients being taken up by the plants before the water entered the river. Overall the catchment hydrograph was a damped sinusoidal shape with long low slope run-off and return periods of freshwater entering the estuary following each rain event. These gradual changes in freshwater and salinity favoured estuarine ecology, brackish water, intermixed between fresh water and marine water being the most productive of all global ecosystems (Odum 1983).

In-stream habitat

Mature trees falling into the waterway continued their contribution to the estuarine ecology, if anything the net contribution then increased. These 'snags' became habitat structure for fish, then decayed and provided a slow-release source of nutrients into the estuary. This pattern was repeated all the way to the upper limits of the catchment, hundreds of kilometres upstream from the estuary mouth.

As well as snags, a range of ribbon weeds and other aquatic plants provided shelter and food for fish and crustaceans. The dense beds also slowed river flows, holding gravel beds together and filtering nutrients and sediment from the water column.

Good riparian condition near Lismore, 1860s.

The value of estuaries

There has long been an understanding that various types of estuarine vegetation are central to the overall abundance of estuarine and marine species. This has been highlighted through positive correlations between the area of estuarine vegetation and commercial fish catch. It is estimated that 67% of the entire commercial catch in eastern Australia comes from species with some relationship to mangrove habitats.

In international contexts, this has been estimated to be as high as 80% for the combined commercial and recreational catch in Florida, USA. Aburto-Orepeza et al. (2008) placed these associations into economic terms, estimating the monetary value of mangrove habitat to the commercial fishing industry in the Gulf of California as being worth $US 37 500 /ha/year of mangrove fringe (Aburto-Orepaza et al. 2008).

Similar studies for Australian conditions (Moreton 1990) estimated this figure to be in excess of $A13 000 /ha/year on then current market values. This estimate was based only on the legal, marketable fish present per hectare at any given time, and did not account for commercially important juveniles or non-commercial species that contribute to the overall estuarine productivity. While translating this figure to a recreational or conservation context is difficult, it is clear the abundance and diversity of estuarine species is inextricably linked to the quality of adjacent habitat. Certainly the 67% related to professional catch would be higher, probably more like 80% or 85% for recreational catch as most of the recreational effort is either inshore or nearshore.

Linkages between fish production and habitat are scientifically established for a range of differing habitat types. Saltmarsh has been shown to provide permanent or temporary habitat for a range of species and their prey, including many that are recreationally and commercially important (West et al. 1985). Research has indicated that of the 16 fish species captured in a saltmarsh intertidal zone in Botany Bay, six were of direct recreational or commercial importance (Morrisey 1995).

When sampling fish in NSW seagrass beds, researchers (West et al. 1985) collected 93 species of fish – 37 of economic importance, and 10 of the top 26 most abundant species being important to the recreational and commercial fishing industry. A similar trend has been found when sampling for prawns in Queensland seagrass beds where juveniles of five commercial species formed the majority of the catch (Coles et al. 1993).

Estimated value of estuarine fish habitats per hectare per year.

Habitat	Value ($/ha/annum)	Measure
Mangroves	8 380*	Commercial fishery value
Mangroves/saltmarsh	11 320	Ecosystem services**
Wetlands/floodplains	19 650	Ecosystem services
Seagrass	21 730	Ecosystem services

* Figure based on 1990 prices. This represents an estimate of over $13 000 in current value.

** Ecosystem services include: gas regulation, climate regulation, disturbance regulation, water regulation, water supply, erosion control, soil formation, nutrient cycling, waste treatment, pollination, biological control, habitat, food production, raw materials, genetic resources, recreation and cultural.

Similar relationships between habitat and fish abundance have been found for a range of non-commercial species with the abundance of native species in the Hawkesbury–Nepean system shown to be between 3.3 and 13 times greater in reaches with a vegetated riparian zone compared to non-vegetated sections (Growns et al. 2003)

As well as the contribution made by specific habitat types, the benefit of estuarine habitat to fisheries is likely to be far greater than individual components, being the sum of the whole and providing all the habitat requirements of species as they grow from larva to juvenile to pre-adult to adult. Habitats should be viewed as a mosaic with species moving between compartments over the tidal cycle, or employing different habitats at different points in their life cycle (Santilan et al. 1999; Gowns et al. 2003). Skilleter et al. (2007) demonstrated the influence of varying habitat types on prawn production by showing a clear relationship between the proximity of inter-tidal seagrass beds to adjacent mangrove habitats and the abundance of three different prawn species. Only by maintaining this range of habitats can we make sure we have healthy fish populations into the future.

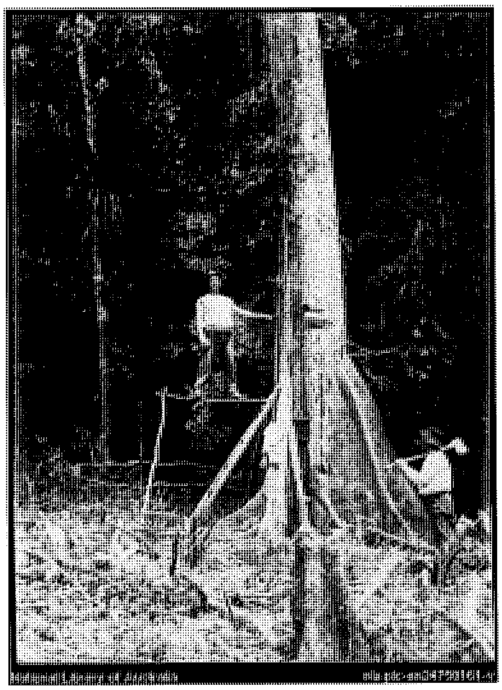
In addition to the economic and conservation contribution of various habitat types, the overall contribution of fish and fish habitats to socioeconomic and environmental values is being increasingly recognised. Often summarised as ecosystem services the role of healthy fish communities and fish habitats in people's lives and broader ecosystem health is yet to be fully explored.

Changes and the current condition

Riparian landscapes and sediment increases

Following European settlement, the first physical changes to the landscape happened on the alluvial levees along the river, the higher points in the floodplain landscape. The vegetation was rapidly cleared away and replaced with farms and settlements.

Sediment transport into estuaries from catchments increased with clearing. Creighton (1982) documents phases in the Sydney Rock Oyster industry, the loss of bottom oysters and the incidences of mud worm associated with high levels of turbidity and increased muddy sediments.



'Scrub-felling' (1891).

Floodplain or 'backswamp' wetlands

The most significant single driver of change to NSW coastal floodplains and estuarine health was the loss and degradation of the enormous expanse of backswamps. These were recognised by farmers as an asset during drought conditions. During wetter years this resource was inaccessible and as a result drainage of these wetlands commenced as this was thought to increase the viability for farming. Some farmers had experimented with the excavation of minor drains that serviced their properties alone. The first major wave of drainage on NSW coastal floodplains began in the early 1900s, when inundated Crown land was drained by large government-funded schemes. Some further government schemes were undertaken in the 1930s as Depression job creation schemes. Lake Innes was connected to the Lake Cathie estuary during this period and drainage started on some of the major swamps such as the Everlasting Swamp.

Drainage has had a significant impact on coastal floodplains (minor drain in Tuckean swamp, c.1912).

The next major wave of major drainage occurred post World War II in the late 1950s, through the 1960s and 1970s. This was done under the guise of 'flood mitigation'. Flood mitigation authorities used major earthmoving equipment under a scheme proportionally funded by the Australian, State and Local Governments, generally 40:40:20 percent respectively. By the late 1970s the job had been largely completed – there was virtually nowhere else left to drain. Many of these drainage endeavours did little to increase the agricultural productivity as soils were peaty or gleyed clays and unsuitable for agriculture. In many cases the drainage, quite apart from the negative impacts on the fisheries, meant that drought forage for grazing was lost.

Fish disease such as red spot started to become prevalent, and oyster production was decreasing due to disease. A conference (Our River – Our Future) held on the Clarence in 1978 (Creighton 1982) was instrumental in bringing farmers, fishers and ecologists together to strongly advocate and end drainage schemes. Local members of State Parliament attended the conference and assisted the community in ensuring the previous flood mitigation scheme with its emphasis on draining wetlands was bought to an end. A Clarence catchment committee, well before these became public policy, was also formed at this time and was instrumental in activities such as getting the use of key organochlorines already banned in the USA (e.g. dieldrin) banned from use in the sugar industry in Australia.

Seagrasses

Seagrass distribution throughout NSW has suffered with increasing urbanisation of the coastal fringe. A significant factor responsible for the loss of seagrass is a decline in water quality and therefore increased turbidity and reduced light penetration caused by poor catchment management practices. Shading and or destruction by foreshore infrastructure and scraping by boat moorings and propellers have also reduced seagrass areas in those locations still able to provide suitable growing conditions.

- Many major estuaries in NSW have lost as much as 85% of their seagrass beds in the past 30 to 40 years (NSW DPI 2007).
- In estuaries within the Northern Rivers region the coverage of *Zostera capricorni* has declined by up to 50% in the past 40 years (NSW DPI 2007).

Mangroves

Mangrove habitat has changed markedly since European settlement, with significant losses in areas associated with urban expansion. Nevertheless due to increased muddy sediments replacing sand spits and sandy shoals the overall extent of mangroves has remained relatively stable. Mangroves are aggressive colonisers and changes in riverine sediment loads have led to increases in other areas previously sandy and/or with seagrasses (NSW DPI 2008).

- The increase of mangroves within river channels masks the loss of mangroves lining small creeks and channels. These have been lost due to floodplain drainage schemes and their floodgates, which impede tidal exchange.
- Much of the expansion of mangroves has been at the expense of saltmarsh habitat or sand spits and shoals, providing little overall gain to the productive capacity of estuarine systems.

Saltmarsh

Increasing urbanisation adjacent to estuarine fringes as well as elevated sediment loads have had a detrimental impact on saltmarsh communities.

- Losses within the Hunter and Parramatta Rivers are estimated to be 67% and 80% respectively over the last 50 years.
- The losses have been so widespread that saltmarsh within the North Coast, Sydney Basin and South East corner Bioregions of New South Wales that saltmarsh is now listed as an endangered ecological community under the *Threatened Species Conservation Act 1995* (NSW).

Coastal wetlands

The traditionally productive fish habitats within coastal wetland systems have been substantially degraded due to drainage practices that have produced a marked change to natural inundation patterns.

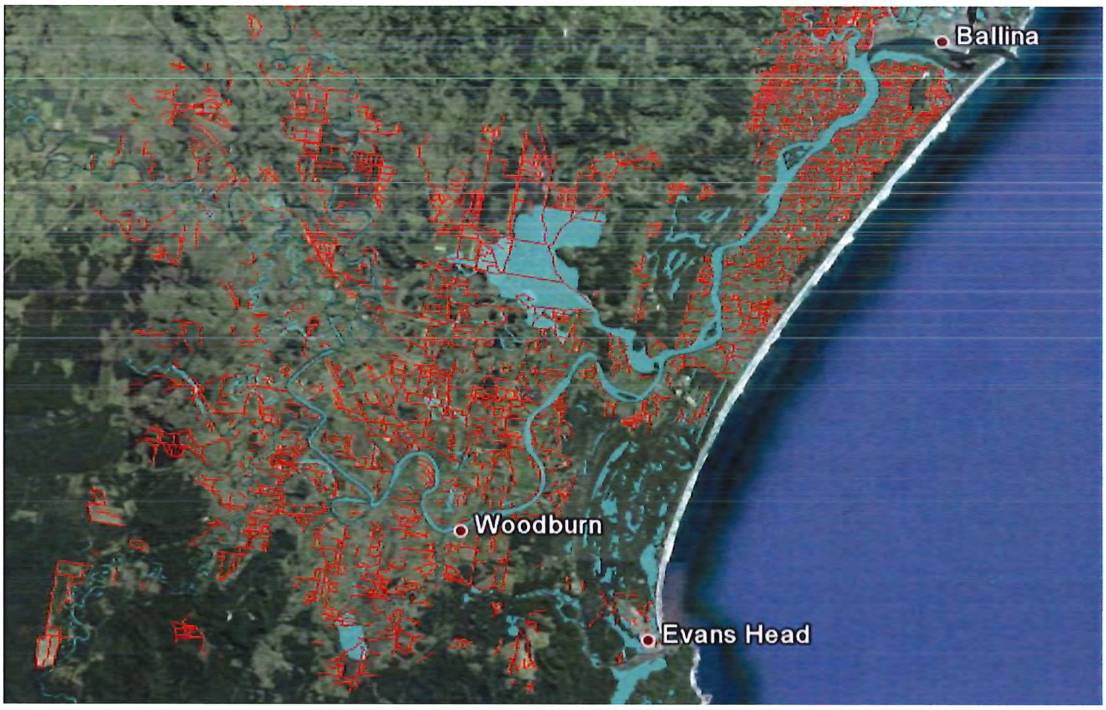
- Low-lying coastal wetlands account for more than 4% of all wetland habitats in Australia, but estimates from as early as 1970 indicate that up to 60% of these habitats had been lost to agricultural and urban expansion.
- Inappropriate drainage of coastal wetlands and floodplains along the coast of NSW has created enough acid sulfate soils to generate 50 000 tonnes of sulfuric acid every year. This causes up to $23 million worth of damage to the state's fishing industry each year.

The impacts of flood mitigation on fish stocks was well known by fishermen who were pointing out these issues very early on and described them in the local newspapers by 1929.

> *A great contributor to the scarcity of fish can be found in the continued wet season and the drainage of large areas of swamp lands into the river. This is responsible for a large quantity of rubbish of a poisonous (to the fish) nature being carried to the river, and it is common knowledge that this alone has been responsible for the death of tons of fish...It is also worthy of note that before the Tuckean drains were cut into the Broadwater, splendid fishing could be got there. This condition is altered greatly today.*

The draining and floodgating of coastal wetlands has radically altered the floodplain and estuarine hydrology. The resulting loss of connectivity, reduced habitat, changed pH and anoxic water have all contributed to massive declines in fisheries productivity.

Richmond River floodplain wetlands (blue) around the early 1840s.



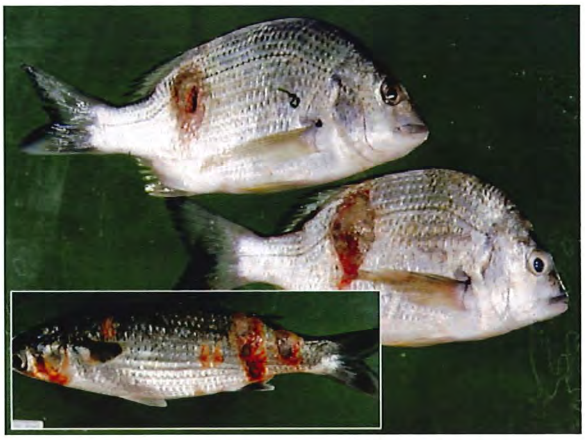
Richmond major drainage systems (red) and the current remnant wetland extent (blue).

Acid sulfate soils

The lowest portions of the floodplain/backswamps are underlain by acid sulfate soils. These formed naturally over previous millennia and while they are wet, they remain harmless. Upon exposure to the atmosphere (i.e. by removing the overlaying water by drainage) they react with oxygen to form sulfuric acid. This acid is then flushed downstream through the drains in the rainfall, where it enters the main river and then leads to acute impacts such as fish kills, and chronic issues that include red-spot disease, diminished oyster growth, prevalence of oyster diseases such as QX and devastated fisheries.

Blue/green aluminium flocculant.

Highly acidic, iron-stained water.



Red-spot disease is caused by a fungus that is normally excluded from fish by their external mucus coating. Acid dissolves this protective layer, leaving them susceptible to the ravages of red-spot.

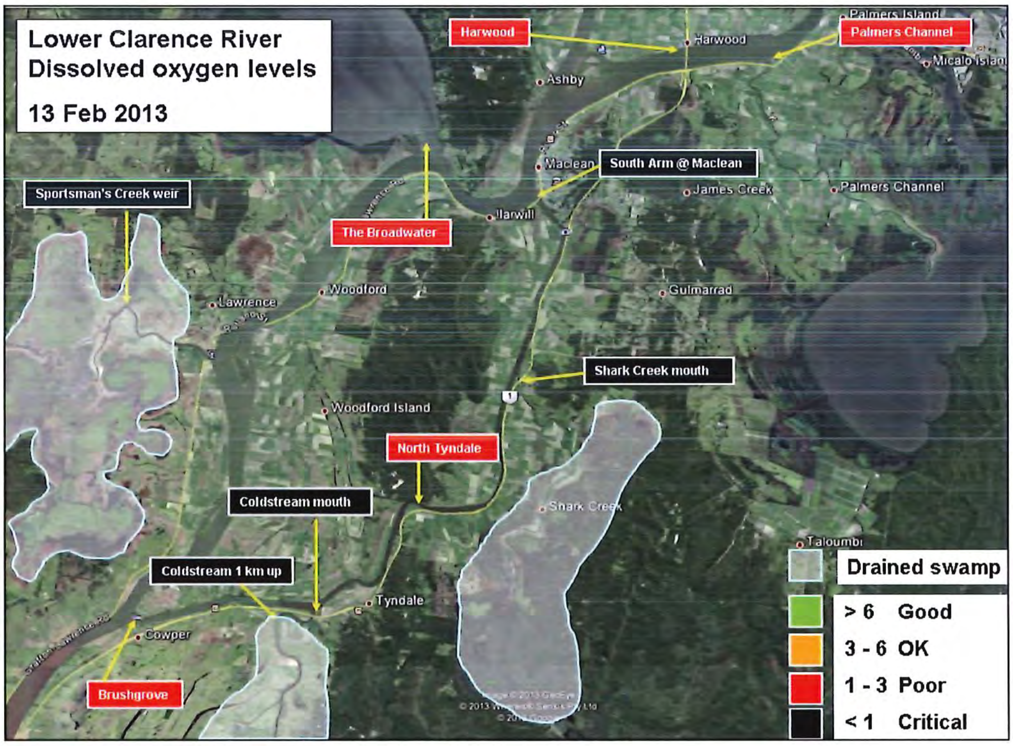
Drained acidified swamp in the Clarence River.

Blackwater formation

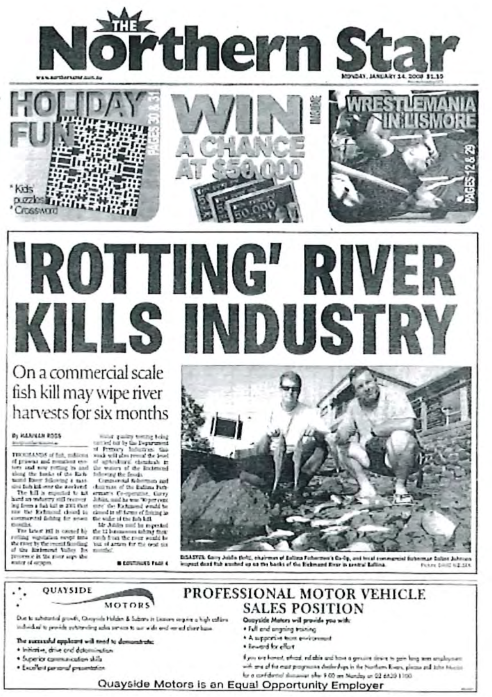
Introduced plant species such as pasture grasses decay rapidly following flood inundation. The microbes that perform this role remove the oxygen from the water column, leaving it black in colour. When this anoxic 'blackwater' enters the river, any form of aquatic life including fish, crabs and prawns that cannot immediately relocate away from the plume, suffocate and die.

The extensive modification of the NSW floodplains by complex networks of drains, levees and floodgates combine to reduce the post-flood inundation period of the floodplains. As soon as the level in the main river falls below the height of the floodgates, the floodwaters rapidly discharge into the river and overwhelm the capacity of the river to absorb the impact. This has enhanced the magnitude, frequency and duration of estuarine deoxygenation or anoxic events and massive fish kills.

Recent research has shown there to have been literally dozens of these blackwater flood events just in the Richmond River alone since the construction of the floodplain drainage systems with the latest blackwater events in 2013 occurring in most North Coast rivers (see below).



Blackwater fish kill in the Richmond River, January 2008 (over 30 tonnes of dead fish were removed).



THE Northern Star

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'ROTTING' RIVER KILLS INDUSTRY

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Dead river worms after the 2013 blackwater flood in the Clarence River. These worms died in their millions and were able to be trawled from where they lay on the riverbed. The professional fishermen were distraught by this occurrence as they understand all too well the vital role in the food chain that these animals provide.

The result of these blackwater floods has been the continued recurrence of tens of kilometres of anoxic river that has wiped out resident biota and led to rivers being closed to all forms of fishing for months at a time. In the Richmond River in 2001 for example, all aquatic life for approximately 30 km was killed outright. An estimated 2 000 000 individual fish were killed during this event. The same weather system led to blackwater events in the Clarence and Macleay Rivers, which also experienced large fish kills and closures to fishing.

The impacts were widespread and affected ecological processes, as well as socioeconomic values for local communities.

Blocking fish passage

Floodgates were designed to regulate upstream inundation during flood events. Floodgates have had another major consequence – they block the movement of fish both up- and down-stream. The movement of fish is important for accessing food supplies, for accessing nursery grounds and for breeding. Countless kilometres of stream are no longer available. Fisheries productivity has declined particularly wherever natural tributaries have been blocked off.

Floodgates prevent fish from accessing former wetland 'grow-out' areas further upstream.

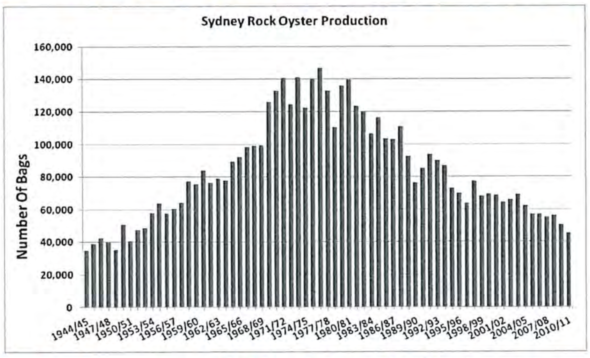
Fish passage has been blocked by a vast number of other artificial structures as well, including weirs and dams for water extraction, road and rail crossings, unauthorised farm crossings and constructed levees. Today, there are very few NSW estuaries without significant blocks to fish passage. As detailed in the table below, well in excess of 3500 blocks have been mapped and of these about 2000 could be re-configured to allow fish passage without substantially impacting on upstream land uses.

NSW Coastal CMA Region	**Road crossings**		**Weirs (on named watercourses)**		**Floodgates**		**Total number of fish passage barriers**	
	Barrier	Recommend remediation	Barrier	Recommend remediation	Barrier	Recommend remediation	Barrier	Recommend remediation
Northern Rivers	524	524	197	39	1 004	220	**1 725**	**783**
Hunter–Central	427	363	128	15	439	322	**994**	**700**
Hawkesbury	99	62	154	42	15	9	**268**	**113**
Sydney–Metro	–	–	28	8	3	1	**31**	**9**
Southern Rivers	578	372	119	22	64	50	**761**	**444**
Total	**1 628**	**1 321**	**626**	**126**	**1 525**	**602**	**3 779**	**2 049**

Poor water quality

Water quality in the coastal environment is under considerable pressure from increasing urban and industrial development and poor farming practices. Increased levels of sediments, nutrients, and pathogens are indicators of this poor water quality. In all cases sustainable practices are available that would minimise the impact on downstream water quality. The Sydney Rock Oyster industry is one example of the impact of these conditions as Oyster productivity is very closely correlated to the condition of the estuary. Many estuaries have been abandoned by Oyster growers and the overall NSW Sydney Rock Oyster production, even with all the improvements in technology, is now less than 35% of what it was in the 1970s.

Bags – Sydney Rock Oyster 1950 to 2011



Major production losses post 1970's relate to decline in estuary health, even though production techniques have improved.

Lisa Kirkendale, Pia Winberg, Ana Rubio, Peter Middelfart (in prep). "The Australian oyster industry: Challenges and Opportunities" Reviews in Aquaculture

9.1.3 Progress in estuarine and floodplain ecosystem repair

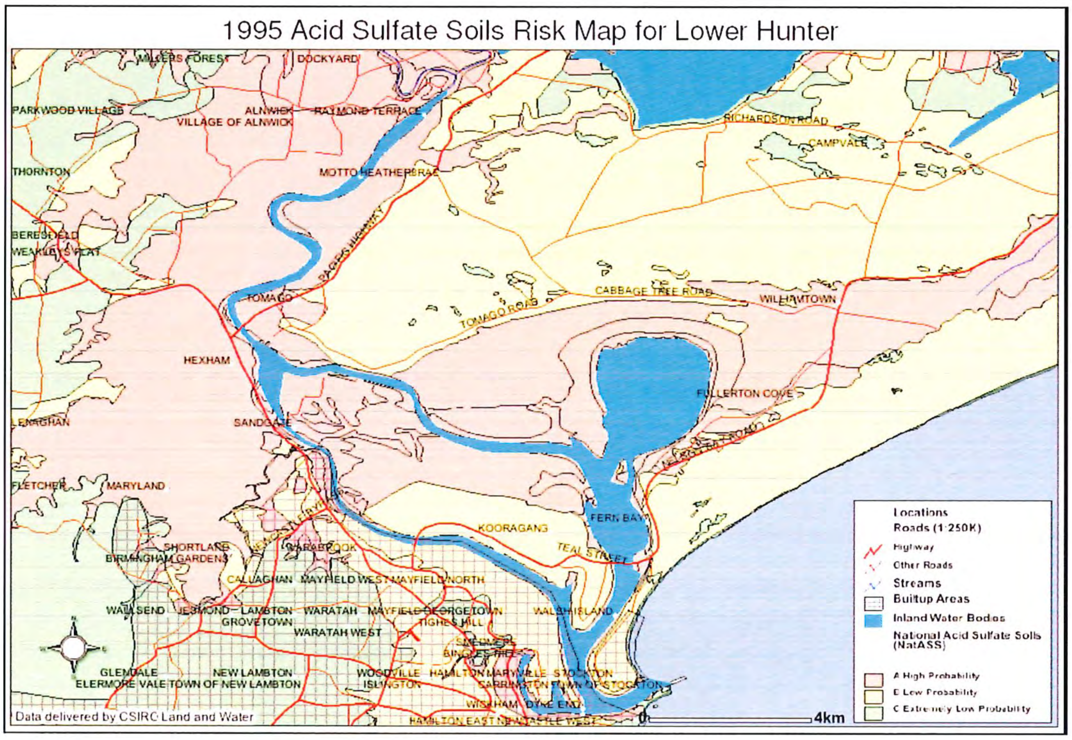
What has been done

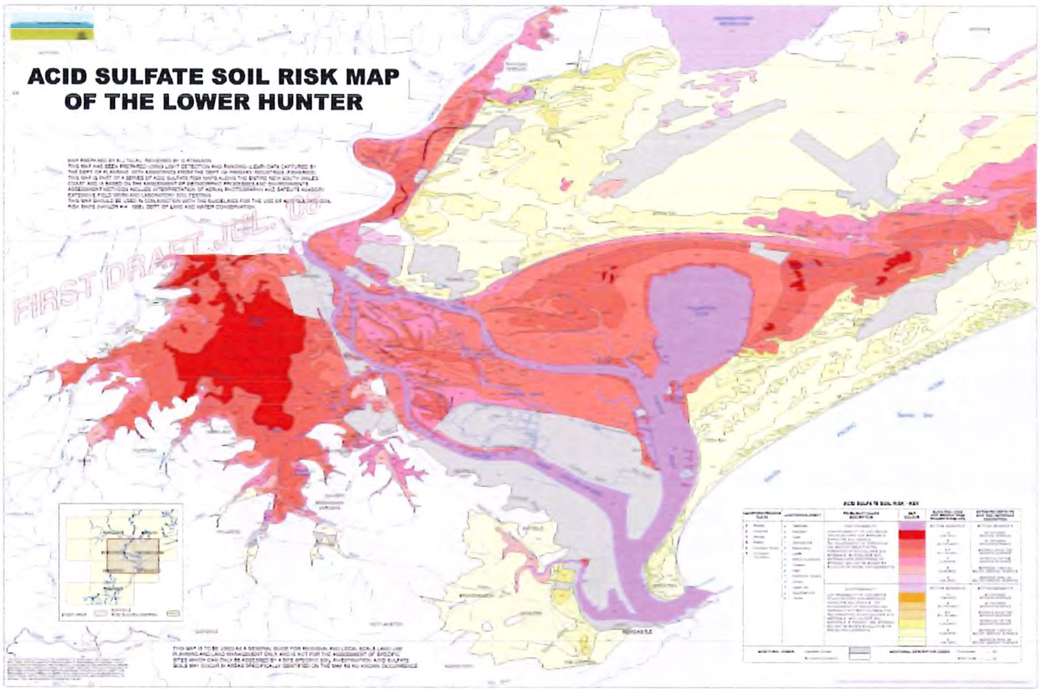
Over the last twenty years community environmental awareness has markedly increased. This has driven a greater recognition of environmental issues and fostered a strong public desire to see them addressed. The estuary and floodplain ecosystems of NSW are no exception to this general trend and a series of positive initiatives have been completed or are progressing well.

However, much of the work undertaken so far, while having some very important outcomes on a local level and as some very useful demonstration projects, falls far short of addressing the scale of the issue that faces NSW estuaries. The array of change that has been achieved to date puts us in a good position to use it as a 'stepping stone' that can propel us towards re-establishing enhanced estuary productivity.

Mapping

A detailed risk mapping exercise for acid sulfate soils along the entire NSW coastline was completed in the late 1990s. This series of 1:25 000-scale mapping products enabled planners at State and Local Government levels to identify areas that would require greater levels of assessment in development applications. It also confirmed that those areas at greatest risk of having extremely volatile acid sulfate soils were the low-lying, former backswamps. More recent innovations in technology particularly through the development of aerial LiDAR systems, have allowed the risk mapping to notably increase in accuracy (see below).





Extension

Expenditure has been devoted to activities designed to persuade landholders to change their practices to those that more suited farming acid sulfate soils country (i.e. keeping groundwater levels higher). While there were some initial successes, in particular through working with landholder 'champions', this strategy by itself was not able to deliver its desired outcomes. There is still acidity and poor water quality emanating from most of those identified hotspot areas; the predominant land-use in these former backswamps is marginal beef grazing, certainly at well below the levels of food productivity if these areas were returned to fisheries habitat.

Communication

The communication of the issues, impacts and solutions associated with NSW estuaries is various and includes:

- a biannual newsletter of national acid sulfate soils – ASSAY
- a quarterly electronic newsletter targeted at recreational fishers and environmental groups
- *Newstreams* and
- a variety of local council and catchment management authority monthly natural resource management updates.

A vast array of relevant information is available via brochures, posters, scientific literature and especially from departmental websites.

Research

The research literature is comprehensive and thorough. A good example of how this has cross-pollinated an improved management focus is the production of *Restoring the Balance – guidelines for managing floodgates and drainage systems on coastal floodplains* (Johnston et al. 2003). In a collaborative exercise by NSW Fisheries and NSW Agriculture staff, nearly a decade after its first publication 'Restoring the Balance' still remains a relevant publication for floodplain managers.

On-ground works

Another area of intensive activity has been the trialling, development and deployment of techniques and modifications to improve fish passage and remediate acid sulfate soils. Managers now have the ability and know-how to restore more natural hydrological regimes to former drained swamps.

Excavators are used to re-shape or completely fill in drains

Floodgate manipulations

Tidal gates will open and close with the tide.

In-stream structures

Adjustable drop-boards used for water retention.

Head and discharge gate for more precise control.

Before tidal flushing (weed choked drain with no fish passage).

After tidal flushing (weed free and fish passage restored).

Wet pasture farming

Wet pasture farming is the maintenance of high subsurface water levels for farmers trying to repair the productivity of previously drained swamps. It fosters growth of native, wetland pasture grasses. Wet pasture conditions are generally physically achieved by the use of dropboards or similar style structures to hold water back in local drains. In many cases this involves particular farmers within a drainage area who are seeking to better manage their property but are constrained by being part of a larger drainage area so that works are undertaken specific to their farm.

In comparison to introduced dryland species; these wetland pasture grasses offer better yields per unit area, are more digestible for stock and also contain greater protein content. An example of this is water couch, which does not require any further management (such as seeding or sowing) beyond the restoration of a higher water level – it will come back of its own accord.

This technique offers direct benefits to participating farmers and also some limited downstream water quality improvements (mainly though keeping the acid sulfate soils moist and inert). The full potential for fish habitat restoration is not achieved.

Water couch thrives in wet conditions and stock will preferentially graze it, given the opportunity.

The major challenge ahead

The main opportunity to repair fisheries productivity is in repairing natural wetland processes and tidal flow connectivity to the large areas of degraded coastal wetlands that after the flood mitigation schemes of the 1960s, 1970s and early 1980s characterise all NSW floodplains. This will restore the key elements of NSW estuaries and their floodplains and will have the biggest positive impact on productivity and water quality.

Several of these many major floodplain wetlands have already been repaired. The challenge is to undertake this on all key NSW estuaries. Lessons have been learnt from each of those projects that will streamline further investment. Major floodplain wetlands repaired are:

- Hexham Swamp, Hunter River
- Yarrahappini wetland, Macleay River
- Darawakh Swamp, Wallamba River.

Lessons learnt include:

- Significant investment is required to repair wetlands. Most often acquisition of the core wetland areas will be necessary so that drains can be filled in, floodgates removed and the overall ecology of fishery and waterfowl productivity repaired. All acquisitions require careful management, the application of normal government valuation and acquisition protocols and may take some years to effect so that individual landholders business and lifestyle planning is accommodated.
- Where acquisition is not required to affect the repair of wetland function or adjacent to the core wetland area, landholder payments for changed management practices need to be formalised with legal agreements. An example is the 'easement for inundation' process used at Hexham Swamp, Hunter River.
- The advantage of retaining fringe areas to the core wetland in private ownership is that there are on-site stewards to assist in land, water and weed management. Landholders continue their grazing or other agricultural enterprises on those land areas most profitable for agriculture; there are multi-objective returns for fisheries and agriculture on those areas; and the core wetland area returns to its most productive value – fisheries, waterfowl and improved water quality.
- Support from the local community, fisher and conservation groups and the involvement of passionate champions have all proved to be very effective tools to facilitate change.

9.1.4 Spring-boarding off existing community and government partnerships

Investment in NSW estuaries and their floodplain wetlands can build on a suite of existing institutional structures, the experience of past activities and regional communities that are now well aware of the issues surrounding fish kills and loss of estuary productivity.

State agency leadership: The Conservation Action Unit of NSW Department of Primary Industries has been operating on these issues since the early 1990s with the scale of their success limited by resources. Their efforts have been pivotal in increasing community understanding and thereby securing the cooperation of other stakeholders to improve fish stocks. By engaging the attention of floodplain natural resource management agencies, local councils, industry bodies, non-government organisations and research providers, the cause of estuarine repair has been significantly advanced.

Natural resource management groups: The four (previously five) coastal catchment management authorities have been instrumental in providing funding support for fish habitat repair and also in undertaking repair activities directly through their own works (e.g. Hexham Swamp). The Bringing Back the Fish program provides a good example of how a partnership initiative can work across government and community and was only limited in outcome by resources.

Bringing Back the Fish

Bringing Back the Fish was a $3 million Australian Government-funded project that took place over three years under the Natural Heritage Trust. It involved collaborative partnerships with all levels of government, regional natural resource management organisations and community stakeholders. On completion, the total project value, including in-kind contributions, reached $9 million. The success of the project was ultimately recognised with a Banksia Award.

Eighty-six fish passage barriers were fixed, opening up fish access to 1235 km of additional waterway and nearly 2000 ha of aquatic habitat was improved. The success of the project lay in the partnerships that were developed with key stakeholders including recreational and professional fishermen, local councils, state agencies and water management authorities. Through its innovative techniques and active engagement, Bringing Back the Fish established a legacy of people within all levels of government and the community 'thinking like a fish' and actively seeking opportunities to fix NSW waterways.

Local Government: A number of local councils have been key participants in initiatives allied to the restoration of fish habitat and water quality. Over the last decade, councils have been encouraged to undertake floodgate, weir and road crossing modifications to enhance fish passage. Some have closely engaged floodplain farmers to restore moderate amounts of subsurface water to foster the growth of wet pasture species (e.g. Clarence Valley and Kempsey Shire Councils).

Northern Rivers Floodplain Network: The Northern Rivers Floodplain Network fosters partnerships and shared activity. It has over 60 members, covering a range of organisations and stakeholders from Taree to the Queensland border, including State and Local Government bodies, universities, non-government organisations and floodplain farmers. While the initial purpose of the Floodplain Network at its inception in 2004 was to enhance knowledge-sharing opportunities between the practitioners, in more recent years there has been a greater emphasis on collaborative delivery of on-ground action.

Fish Habitat Network: The Australia-wide Fish Habitat Network began in 2009 and is comprised of organisations and individuals dedicated to increasing fish numbers naturally by rehabilitating fish habitat. Partners include government, recreational fishing, peak body, research and trade organisations Australia-wide. The network continues to develop long-term partnerships with people who share similar values and philosophies.

Non-government organisations: Oceanwatch and WetlandCare Australia have been two of the non-government organisations most active in the issues of fisheries habitat. Oceanwatch has traditionally worked to ensure the sustainable operations of professional fishers around the nation. More recently, its 'Tide to Table' program has attracted interest for its work to address fish habitat repair and water quality improvement initiatives. WetlandCare Australia has undertaken a range of mapping, extension and rehabilitation functions and is about to complete their Coast20 program, which has worked on 20 NSW and Queensland coastal wetlands by targeting pest and weed control aspects and further value-adding with supplementary tree plantings.

9.2 Priority opportunities

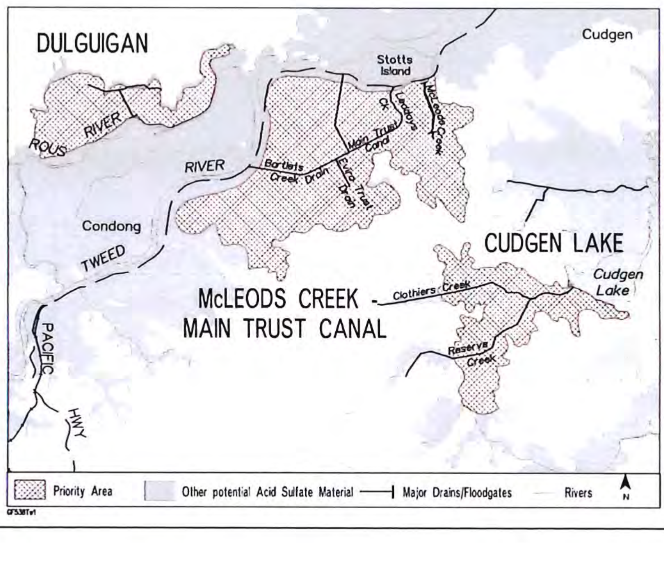
After more than a century of degradation there is no shortage of sites that are potential candidates for repair to benefit fisheries productivity. This chapter highlights priority sites and actions that will have the greatest positive impact for re-establishing NSW estuary and floodplain fisheries productivity.

9.2.1 Tweed Estuary and Cudgen Lake

The Tweed is a comparatively small catchment with a small floodplain. It has a calibrated hydrodynamic model. Following rain events it is highly acidic and there have been some investigations as to how best to ameliorate this rapid change in pH. Much of the lower Tweed is highly developed urban; cane and horticulture dominate the floodplain. There has been some floodgate manipulation because of prior fish kills but much remains to be done. Interestingly, the Cobaki reverse delta islands are a relic of dredge spoil and have created a more diverse suite of estuarine habitats in the Cobaki Broadwater, demonstrating that dredging to foster navigation can sometimes prove to be beneficial.

Dulguigan and McLeods Creek are former backswamp sites worthy of repair working in concert with the cane industry. Potential cost sharing for backswamp rehabilitation may be sourced from stakeholders with key interests including support from Tweed Shire Council and the fishing industry, through the Tweed River Committee utilising resources such as those generated through the dredging fund.

Cudgen Lake is a shallow lake approximately 1–2 m deep located 7 km south of Kingscliff and is immediately adjacent to the Tweed catchment. The low elevation floodplains surrounding the lake have been extensively drained and cleared for farming (tea tree oil and sugar cane) and for a planned tourist development. Historically Cudgen Lake was renowned for its value as Eastern King Prawn hatchery and fishing area. The increase of acid sulfate effluent accompanying wetland drainage together with urban and agriculture development pressures has degraded the water quality and fish habitat. Large fish kills due to acidification of the Lake occurred in 1991 and 1998 following heavy rainfall. Repair of Clothiers and Reserve Creek wetland complexes would be of substantial benefit to Cudgen Lake ecosystem health and fishery productivity.



9.2.2 Richmond (Tuckean, Rocky Mouth Creek, Bungawalbyn)

The Richmond River is a relatively large catchment and the largest floodplain in NSW. The river and estuary have been extensively modified from pre-European conditions including land clearing, draining and changes to tidal and river flow conditions. Approximately 34 000 ha of floodplain on the Richmond system is considered to be underlain by high-risk acid sulfate soils. A calibrated hydrodynamic model is available and shows that the large floodplain has very poor flushing, making repair of floodplain wetlands an imperative if water quality is to be improved and fisheries productivity is to be returned.

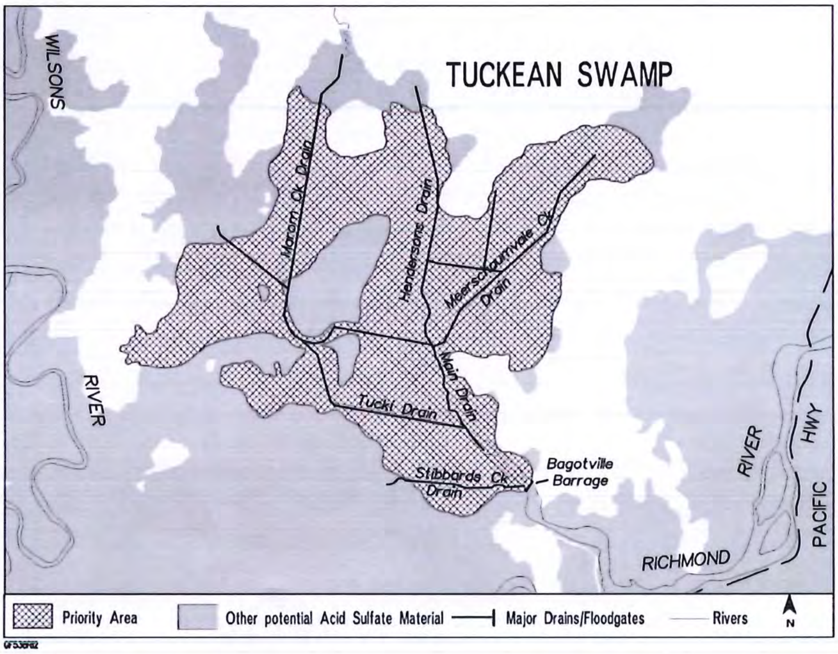
Richmond River Country Council is actively trying to manage fish passage and outflows during low dissolved oxygen periods. This at least reduces the large fish kills but may not actually increase productivity. There is a much-reduced professional fishing effort due to decline in estuary productivity. Richmond River County Council maintains a barrage to keep the Evans estuary separate. These two estuaries were previously connected as part of the Flood Mitigation scheme for the Richmond floodplain. Keeping the two estuaries separate is important in reducing the likelihood of low dissolved oxygen water from the Richmond floodplain floods affecting the smaller, comparatively less disturbed Evans River.

Priority areas in the Richmond catchment include Tuckean Swamp, Rocky Mouth Creek and Bungawalbyn Creek – all due to the presence of acid sulfate soils in these previously brackish but now freshwater environments and most importantly their potential to re-instate fisheries productivity.

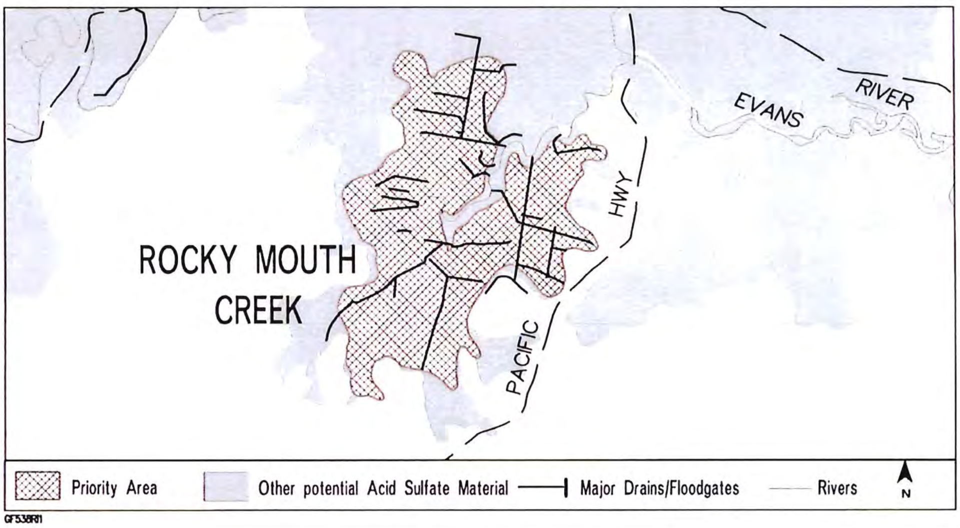
Tuckean Swamp: The significant issues associated with Tuckean Swamp are acid run-off, fish kills, poor water quality, land degradation, reduced agricultural productivity, loss of estuarine fisheries habitat, and degraded vegetation and wildlife values. Widespread remediation of these problems would require totally redesigning the Bagotville Barrage as at most a flood management structure only if the Barrage is kept at all. The objective would be to allow tidal and freshwater full connectivity to foster fisheries productivity while designing the repair to also favour the higher value agriculture lands well upstream of the core wetland area. Repair of the wetland would include restructuring and in many cases removing wetland drains. Maintenance of higher water tables across broad areas of the upstream wetland is essential to improve water quality and fisheries productivity.

Bagotville Barrage.

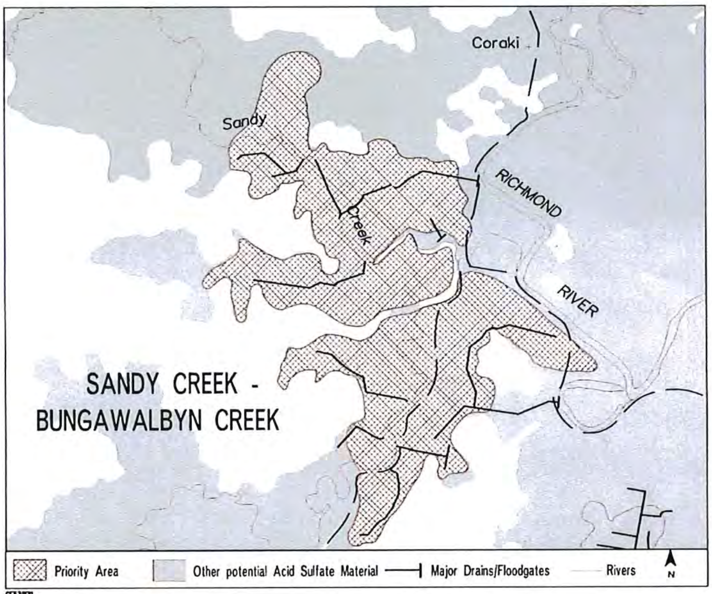
These actions could only proceed with agreement from the private landholders. This is only likely to be possible through acquisition of the lower core wetland areas to add to the area already under public ownership. This offers the best and most cost-effective management option to achieve these fishery and water quality outcomes. Much of the core wetland areas are at most marginal for beef production.



Rocky Mouth Creek: Rocky Mouth Creek is a low-lying cleared floodplain and is dominated by extensive cattle grazing and sugar cane farming. As with Tuckean, the lower areas are of marginal agricultural value. The floodgate cuts off connection from the main channel to the creek. The main floodgates have been opened in non-flood periods for over a decade. Nevertheless acid sulfate soils, fish kills and the discharge of poor water quality remain as issues. This site requires major hydrological manipulation following acquisition or agreement of the landholders to enable improved inundation of at least the lower core wetland areas.



Bungawalbyn: Bungawalbyn Creek wetland complex comprises two large low basins to the north and south of Bora Creek. The major land uses are agricultural (cattle grazing, tea-tree plantation and sugar cane farming) with some conservation reserves. The area contains one of the last remaining coastal freshwater wetlands, representing a confluence between tropical and temperate fauna and flora with high biodiversity. As with the Tuckean and Rocky Creek complexes detailed planning and consultation with landholders is required to determine how best to improve overall water management for surrounding agricultural production, reduce water quality issues and improve fisheries productivity.



9.2.3 Clarence (Everlasting, Shark Creek, Coldstream, Wooloweyah, Broadwater)

The Clarence River catchment is the largest river catchment with the largest river flows in coastal New South Wales. It supports the largest estuary-based fishery in NSW. The calibrated hydrodynamic model shows that the lower main river channel is comparatively well flushed. Because of this flushing the main channel below Harwood Island – Palmers Island and the training walls rapidly assimilates acidic/low dissolved oxygen waters thereby reducing the likelihood of fish kills in this main river channel in all but major events such as the 2013 event. Bottom sampling immediately following the 2013 event suggests that virtually all benthic fauna between Grafton and the ocean entrance was killed during this anoxic acidic event. (pers. comm. Darren Ryder and Sarah Mika, School of Environmental and Rural Science, University of New England).

The training walls were built in three phases, moving the estuary entrance east across the myriad of sand spits that confounded explorer Flinders. Deeper marine water and an underwater rock bar now dominate the actual entrance. The middle wall, part of the early training wall construction while providing a fish aggregation device (e.g. Luderick, Mulloway) partially restricts the volume of tidal flows to the southern part of the estuary, especially immediately adjacent to the urban area of Yamba. Several of the lower estuary islands such as Hickey Island are now predominantly sand islands, being dredge spoil. Freeburn Island, now a Crown Reserve provides an excellent example of a natural lower estuary delta island.

Approximately 53 000 ha of floodplain below Grafton is underlain by high-risk acid sulfate soils. The land uses adjacent to the Clarence River are beef and dairy grazing in the upper floodplain and sugarcane farming in the coastal, more frost free floodplain. Flood mitigation and drainage works have contributed to high acid sulfate soil impacts, poor water quality and the isolating of much of the prior fisheries nursery areas from the estuary.

The Clarence can be segmented into six estuary waterway and wetland sections based on their contribution to fisheries productivity:

- Wooloweyah and lower estuary, including many of the 99 islands in the floodplain
- Esk River and natural brackish to fresh wetlands
- Broadwater and surrounding drained wetlands
- Sportsman's Creek, weir and partially drained/floodgated Everlasting Swamp
- South Arm with Shark and Coldstream wetland complexes
- Upper floodplain with multiple ox bows, billabongs and prior channels.

Wooloweyah Lagoon and Lower Estuary: Wooloweyah Lagoon is a shallow tidal barrier lake approximately 23 km^2, and 15 km from the Clarence River mouth at Yamba. It is connected to the main estuary through Oyster, Shallow, Romiaka and Palmers Channels with its own reverse delta of islands and wetland areas. These islands are comprised of private land and unallocated Crown land and Crown reserves with extensive draining and clearing of the floodplain alluviums and wetlands for sugarcane farming. This area offers potential for the restoration of saltmarsh and mangrove communities on a significant scale through drain and levee rationalisation.

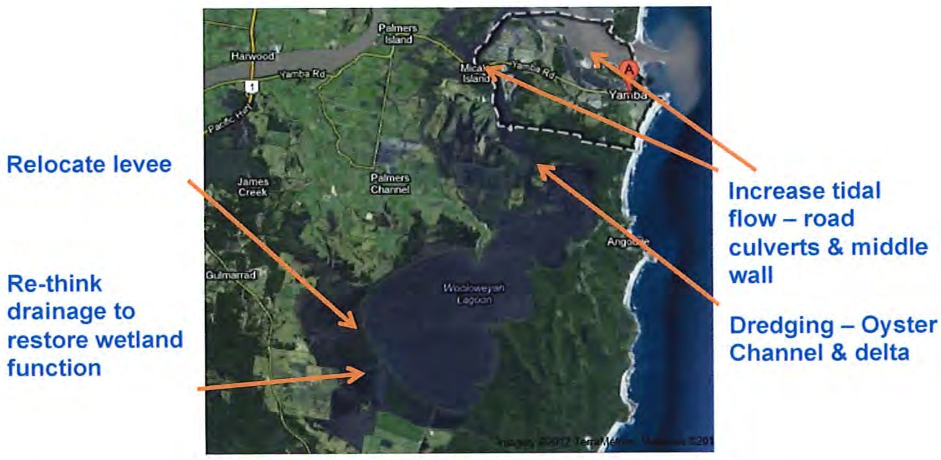
All of the channels except Palmers Channel have road bridges and causeways that markedly constrict tidal flows. Muddy mangrove-dominated flats and sand spits have formed in what were previously tidal channel areas with this constriction of tidal flows.

Shallow Channel was a total block with shallow mud, low dissolved oxygen and algal growth behind the block. The road was constructed across the channel in the 1920s to provide access to the town of Yamba. This road completely prevented tidal flows and fish passage from Lake Wooloweyah – Shallow Channel to the main body of the Clarence River until 2008 when two culverts were installed to allow water exchange and fish passage.

This has proved beneficial with sand spits and seagrass replacing what was previous backwater muds and algae. Unfortunately two culverts are simply not enough available volume for what was once a major channel over 300 m in width. Significant velocities of water race through the two culverts at most stages of the tidal cycle. Indeed it is difficult to stand up against the water velocity in even ankle deep water. Additional culverts or replacing the entire rock causeway with a bridge would significantly improve tidal flows, fish passage and with increased tidal flows, net primary productivity at this highly visible and popular fishing location.

The south-western shoreline of Lake Wooloweyah was an extensive area of salt marsh and mangrove complex. It extended for at least 10 km around the lake foreshore and landward in parts up to 6 km. As part of a flood mitigation and drainage scheme, a levee and ring channel was constructed immediately adjacent to the Lake foreshore, lateral drains dug through the wetland complex and floodgates installed. The soils are either gleyed clays or acid sulfate and while the intention was to create farmland, these soils are totally unsuited to any form of agriculture. Rough grazing is at best marginal on these lands.

Prior planning studies by Bob Smith, (in *Integrated Development Application, Taloumbi Drainage Scheme Redesign*, WetlandCare Australia 2002) demonstrated the higher productivity returns from fisheries if the drains were rehabilitated and the wetland was returned to salt marsh and mangroves. Even a landward extension of the ring drain of 1 km would re-create over 800 ha of saltmarsh – now an endangered vegetation type within NSW. Hydrodynamic surveys at the time established that removal of the levee would lead to tidal inundation on at least 264 days per year. Saltmarsh is well recognised as essential for Mud Crab, and School and Eastern King Prawn fisheries. The works were ready to proceed at that time but with the end of the Natural Heritage Trust and the time hiatus until Caring for our Country the project lapsed.



Lake Wooloweyah, bring back the key drivers of productivity – tidal flow and wetland function.

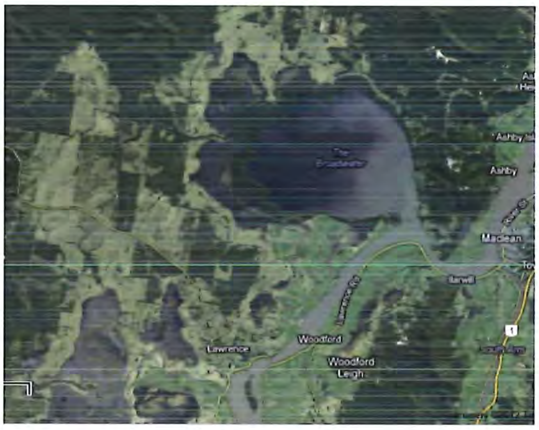
As with Tuckean on the Richmond, repair will entail either agreements or acquisition from the existing landholders. The design for rehabilitation of and changes to the drainage systems and the removal of the levee as detailed within the WetlandCare Australia 2002 Report will require review and presumably upgrading. The benefits to the fishery are possibly now even higher, recognising that the dredging of the Palmers Channel entrance and the two culverts in Shallow Channel has improved tidal flushing.

Esk River and natural brackish to fresh wetlands: All of the Esk River catchment is within Bundjalung National Park. As with other estuary islands in the lower Clarence, parts of the lower Esk with the mangrove and saltmarsh complexes can be improved with better management of the interface between cane lands and tidal lands.

Broadwater and surrounding drained wetlands: The Broadwater, upstream of Maclean and on the northern arm of the Clarence is a large shallow seagrass bottom lake area and associated wetlands at the fresh to brackish to sometimes tidal end of the spectrum. From a fisheries perspective the Broadwater ecologically complements the mostly tidal to sometimes-brackish Lake Wooloweyah. As with Wooloweyah, major wetland complexes fringe the Broadwater and again, drains, levees and blocks have markedly reduced its fishery production potential.

Broadwater Creek itself has an unauthorised blockage to tidal flow and fish passage there being no Crown Lands permit for these works over the bed of the estuary. These works when constructed were purportedly for irrigation water supply. However there are no irrigation pumps installed and indeed the water licence required for water abstraction has not been paid for some years. Most recently a Biodiversity Fund initiative attempted to have the block removed. The project total timeframe of one year proved to be insufficient to gain all approvals and do the works. A 'review of environmental factors' is complete.

Reluctantly the actual works have had to be shelved until all Departmental approvals can be put in place. The opportunity exists for significant remediation of this important area. Most of the wetlands are largely intact, are of no benefit to productive agriculture and could cost-effectively be returned to the fishery while simultaneously reducing the likelihood of acidic water from the acid sulfate soils that have been intersected by the drainage network.



Broadwater Creek: unauthorised works have led to major deoxygenation / water quality impacts on nursery.

Sportsman's Creek, weir and partially drained/floodgated Everlasting Swamp: Everlasting Swamp is an infilled back lagoon system on the north-western side of the Clarence River, north arm near Lawrence comprised of approximately 2857 ha of acid sulfate soil priority area. This area requires a restoration of its natural hydrology as first identified by Goodrich (1970). Re-instatement of wetland function including tidal connection in the Little Broadwater has demonstrated what can be achieved to benefit both grazing and the fishery.

Business as usual is drained poorly productive wetlands.

Floodgate and drain removal Little Broadwater, adjacent to Everlasting Swamp on Sportsman's Creek – soil carbon + biodiversity + productivity + carbon + water quality

Sportsman's Creek bisects the Everlasting Swamp complex. As the names suggest, this wetland and creek complex was critical habitat for a multitude of fish, birds and other wetland fauna that were once pursued by sporting anglers and hunters.

There has been significant change since the construction of an artificial weir across Sportsman's Creek in 1927. This was built to prevent the tidal inundation of Everlasting Swamp for agricultural purposes, but it has also restricted fish passage for 107 km upstream. Now 85 years old, Sportsman's Creek weir is falling apart and the local Drainage Union do not have the need or sufficient funds available for its repair.

A major fish passage opportunity is available to totally remove the weir. By augmenting the (largely in place) secondary infrastructure further upstream, this project would protect existing agricultural productivity as well as greatly improve fish passage and water quality outcomes.

Everlasting Swamp, similar to Tuckean and Wooloweyah wetland complexes requires a rationalisation of constructed drainage, preferably the restoration of natural surfaces and water management systems and complementary works and activities in the surrounding catchment to foster a return of fisheries productivity and waterfowl habitat. Again, as with these other major wetland complexes, negotiation with landholders towards either agreement to a changed water management strategy or acquisition is required.

South Arm with Shark and Coldstream wetland complexes: Shark Creek and Coldstream wetland complexes are two of the three largest freshwater wetland areas on the lower Clarence, the third one being Everlasting Swamp. For Shark Creek the northern parts are generally cleared and extensively drained for sugar cane. Fish kills and poor water quality occur in both Shark Creek and the Coldstream. The extensive Coldstream complex likewise has a mix of cane on the higher areas and grazing in the lower, poorer soil areas.

Both wetland complexes would benefit from detailed re-assessment of the drainage network and where possible re-institution of natural water management within the core lower wetland areas which are also the key areas of acid sulfate soils. Cooperative activities with graziers to sympathetically manage surrounding wetland areas would need to accompany any drainage rationalisation for fishery productivity outcomes.

Upper Clarence floodplain: Most of the Clarence floodplain and its relict water features of ox bows, billabongs and prior channels are now drained for grazing. Selected waterways and wetlands could be manipulated for more multiple objective outcomes of water quality and fisheries wherever the landholders are supportive.

9.2.4 Bellingen/Nambucca (100 acre swamp, Gumma Gumma)

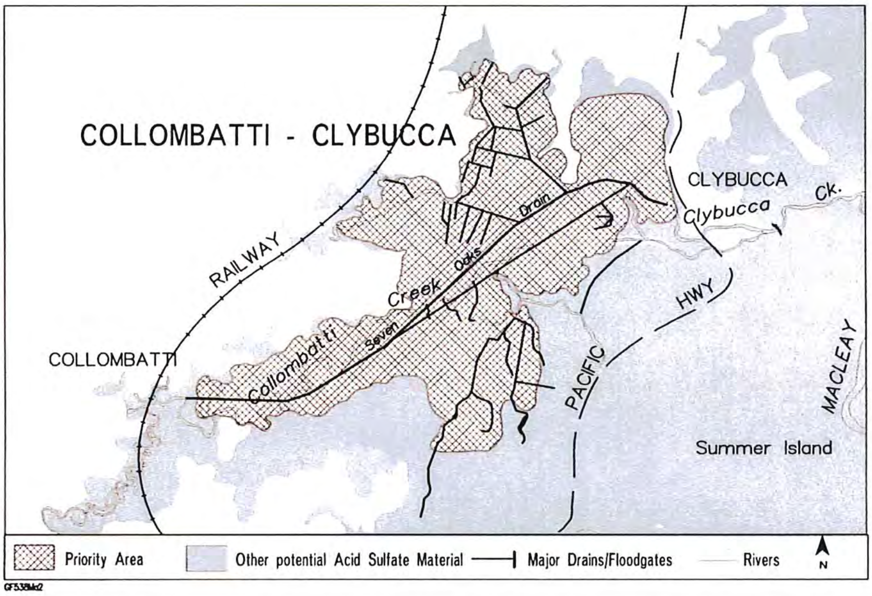
The Bellinger and Nambucca catchments are on the mid north coast of NSW. The catchment area is 1000 km^2, about 70 km long and 20 km wide. Much of the area is mountainous with limited areas of floodplain associated with river and creek valleys. Steep areas of the catchment are under forest cover, while the narrow floodplains and associated foothills have been cleared for grazing, cropping and other uses. Due to a high density of rural settlement, the region's rivers and estuaries are affected by changed run-off conditions caused by land clearing, agricultural use and urban areas. Many streams on the coastal floodplain have been straightened and channelised.

The floodplain backswamps are numerous but due to the restricted areas of the floodplains are smaller in areal extent than those found in other catchments. The one exception is Gumma Gumma swamp, which was a large freshwater wetland that was heavily modified by the construction of artificial drainage. Rethinking the drainage system from a multiple objective outcome is recommended and is likely to involve rationalisation of drainage and repair of 'natural' water management conditions for core lower wetland areas. This will only be possible with agreement of the private landholders.

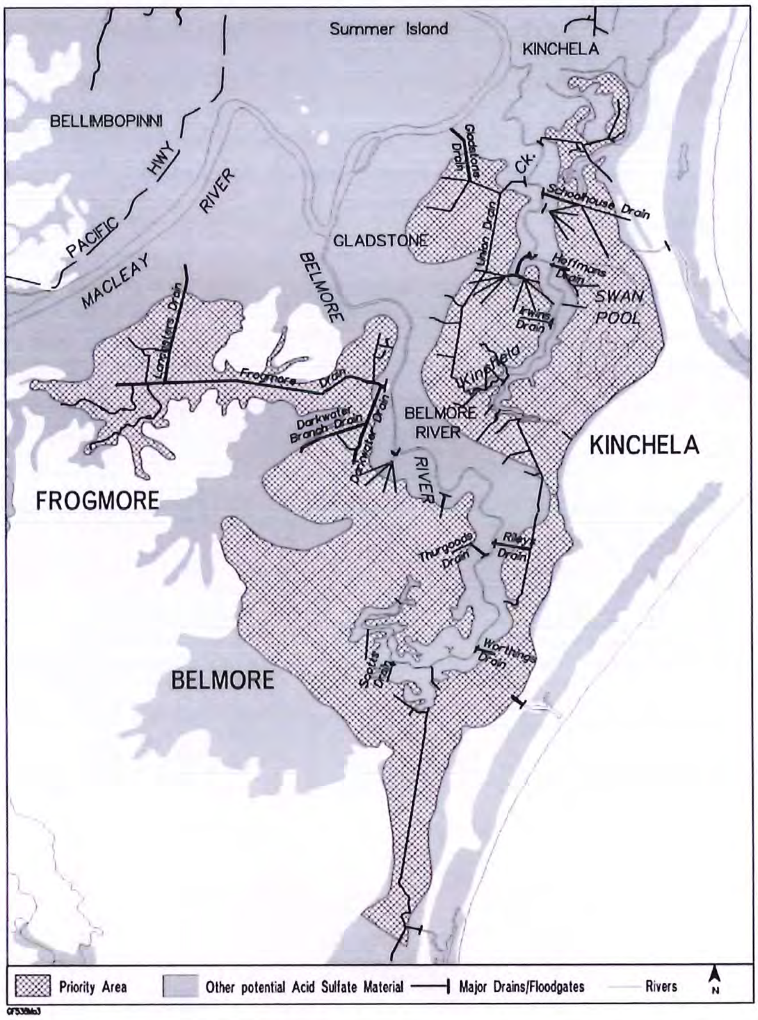
9.2.5 Macleay (Swan Pool, Belmore swamp, Frogmore, Clybucca)

The Macleay catchment is a moderately sized catchment and extensive floodplain. The estuary is a large contributor to School and Eastern King Prawn and finfish fisheries. Acid sulfate soil priority areas are mapped, identifying key areas where drainage has led to poor water quality. The catchment has as yet no hydrodynamic modelling. The priority areas in the Macleay include Yarrahappini wetland that is already partially repaired, the very extensive Collombatti-Clybucca swamp, Kinchela swamp (Swan Pool), Belmore swamp and Frogmore swamp.

Collombatti-Clybucca: The area of this wetland that is acid sulfate priority is approximately 298 ha. Works to remediate acid sulfate soils have occurred in this complex. Similar to the works already undertaken at Yarrahappini, repair including rationalisation of drainage and re-instatement of wetland complexes with adequate connection to the estuary proper is recommended. This will require agreement with private landholders.



Belmore, Frogmore and Kinchela swamps: All of these sites have been identified as acid sulfate soil risk areas with poor water quality, damaged vegetation and loss of estuarine habitat due to engineered drainage and flood mitigation. Kempsey Shire Council has manipulated levels in Scotts Drain by partial opening to assist in rehabilitation of acid scalds by pasture growth at south Belmore. No major rehabilitation has been completed at Frogmore and Kinchela Swamps. Repair including rationalisation of drainage and re-instatement of wetland complexes with adequate connection to the estuary proper is recommended.



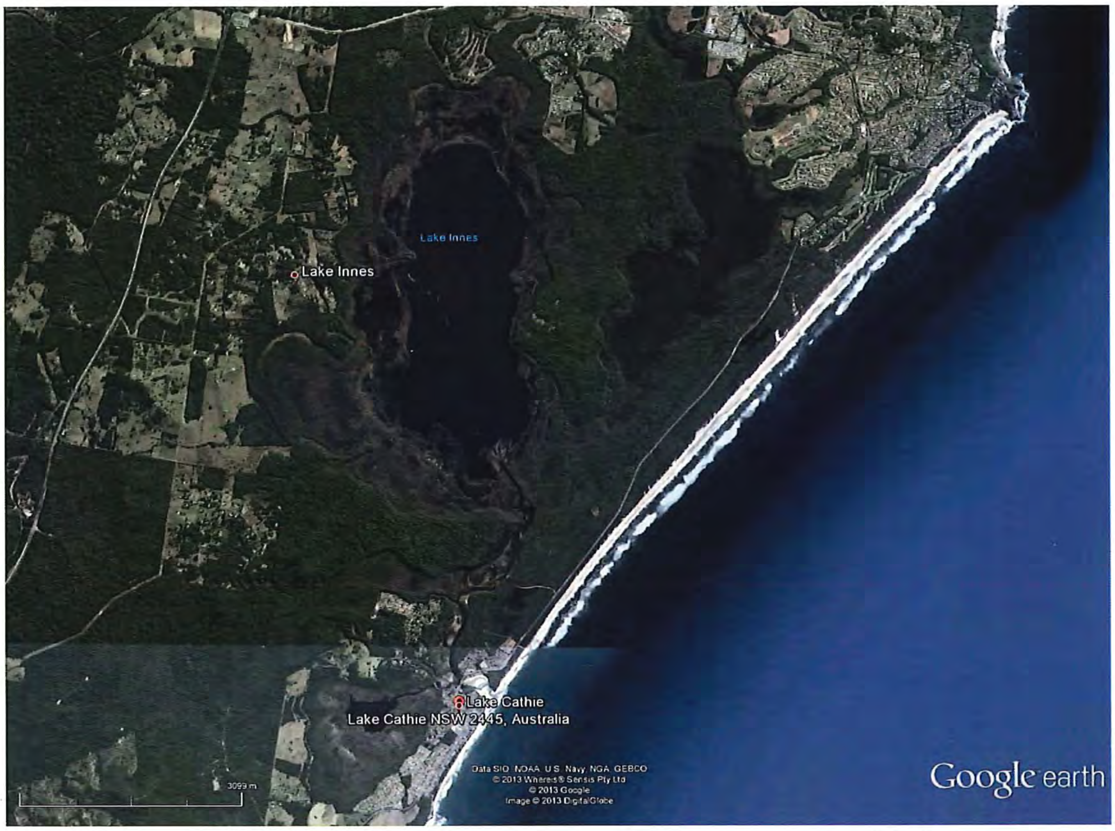
9.2.6 Lake Cathie – Lake Innes

The Lake Cathie – Lake Innes system, just south of Port Macquarie is a special case of floodplain drainage, Lake Innes being naturally a predominantly fresh and sometimes part brackish system when connected due to high water levels to the Lake Cathie ephemeral entrance lagoon. These high water levels occurred when the Lake Cathie ocean entrance was closed. Lake Innes was one of the two occurrences in Australia with floating vegetative islands, the other being the Lagoon of Islands in Tasmania.

The freshwater Lake Innes was connected to the estuarine Lake Cathie system by works in the 1930s depression. The dug channel was expected to lower the Lake Innes water levels so that agricultural development could then occur. However most of the Lake Innes fringing wetlands are peat-based soils, totally unsuitable for agriculture.

Creighton (1983) drew on Albert Dick's diaries to document the ecological changes that followed drainage of Lake Innes including the massive loss of waterfowl habitat. Over the period 1980 to 1983 a period of ocean entrance closure including deliberately keeping the ocean entrance closed to recorded changes in waterfowl, improvements to fish populations, physical chemistry and overall productivity of the system was undertaken and contrasted with low productivity following the deliberate opening of the ocean entrance.

Recommendations were made then on re-establishing Lake Innes as a freshwater fisheries and waterfowl habitat connected only to the Lake Cathie system during phases of high water level. These recommendations are as relevant today as they were then to restore the historical ecological productivity of the system.



9.2.7 Hastings – Camden Haven (Partridge Creek, Rossglen, Upper and Lower Maria Rivers)

The Hastings River has a catchment of 3600 km^2 with a broad floodplain. The Camden Haven estuary comprises the two major lakes of Watson Taylors Lake in the south and Queens Lake in the north. The Camden Haven catchment is the second most productive Oyster producer on the north coast and supports recreational and commercial fisheries. Acid sulfate soil priority areas that have previously been drained and need to be remediated include Partridge Creek, and Upper and Lower Maria Rivers on the Hastings and Rossglen and Stewarts River on the Camden Haven.

Partridge Creek: Partridge Creek is a backswamp distributary system approximately 5 km west of Port Macquarie on the southern side of the Hastings River. Wetlands occur as semi-permanent bodies of shallow fresh water in areas of low relief. Much of the area has free water at or near the surface for most of the year. Partridge Creek acid sulfate soil priority areas comprise 542 ha.

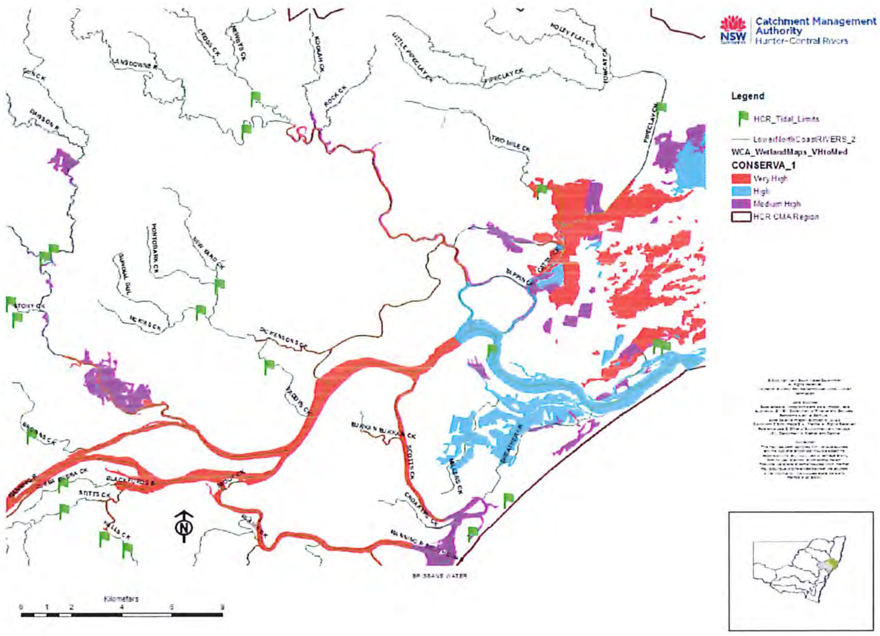
Maria River: The Maria River has a low elevated floodplain with large acid sulfate priority areas. There are also freehold areas of mangrove and salt marsh being degraded through rough grazing, such as 'The Hatch', midway up the Maria River. Works to exclude cattle through fencing and watering points would complement repair works in acid sulfate areas.

Rossglen: The Rossglen acid sulfate priority area is situated on the northern side of the Camden Haven River floodplain at the Pacific Highway crossing, approximately 8 km west of Laurieton. Rossglen comprises 272 ha of acid sulfate priority area.

At all of these sites raising water levels across core wetland areas through drain infilling following negotiations with landholders is recommended.

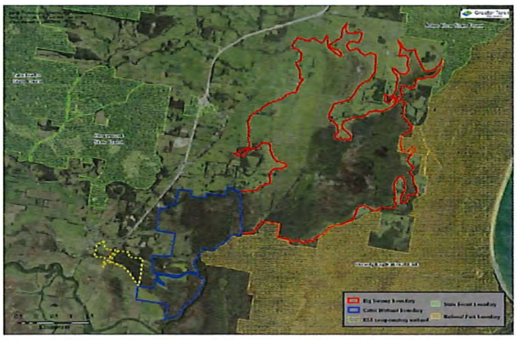
9.2.8 Manning (Cattai wetlands, Moto swamp, Dickensons)

Manning catchment is approximately 8420 km^2, with a broad floodplain, much of which is underlain with acid sulfate soils. Wetland Care Australia has mapped riparian and wetland habitat as summarised in the accompanying map.



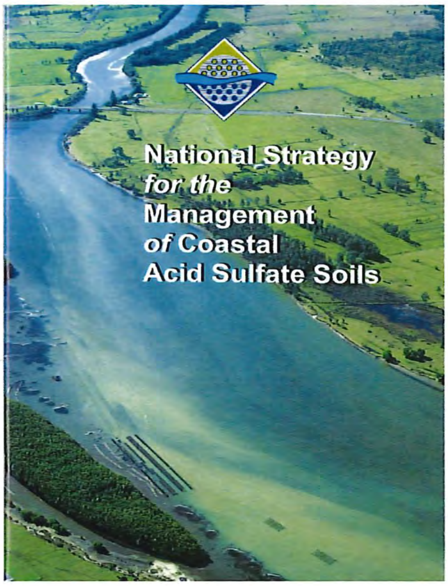
Calibrated hydrodynamic modelling of catchment and 80 years of river records provides a sound history of the catchment's tidal and freshwater interchange. The Landsdowne River and most of the main Manning River channel becomes highly acidic following run-off events. Priority areas from an acid sulfate soil perspective include Cattai wetlands, Moto swamp and Dickensons Creek.

Cattai wetlands: Cattai wetland is a large backswamp in the north-eastern section of the Lower Manning floodplain. Before drainage, this area was known as the Big Swamp, consisting of a vast area of shallow open water famous for waterbirds. Now the area is intersected by the 6 km long Pipeclay Canal. Cattai Creek acid discharges degrade water quality within the Manning catchment affecting several oyster producing areas. Re-establishment of natural drainage via the infilling of selected segments of drains and the acquisition of some land parcels has been achieved. Further work, including additional property acquisition and raising of water levels is required to allow the restoration of the wetland and reduction of the water quality risk.



Big Swamp, Manning estuary.

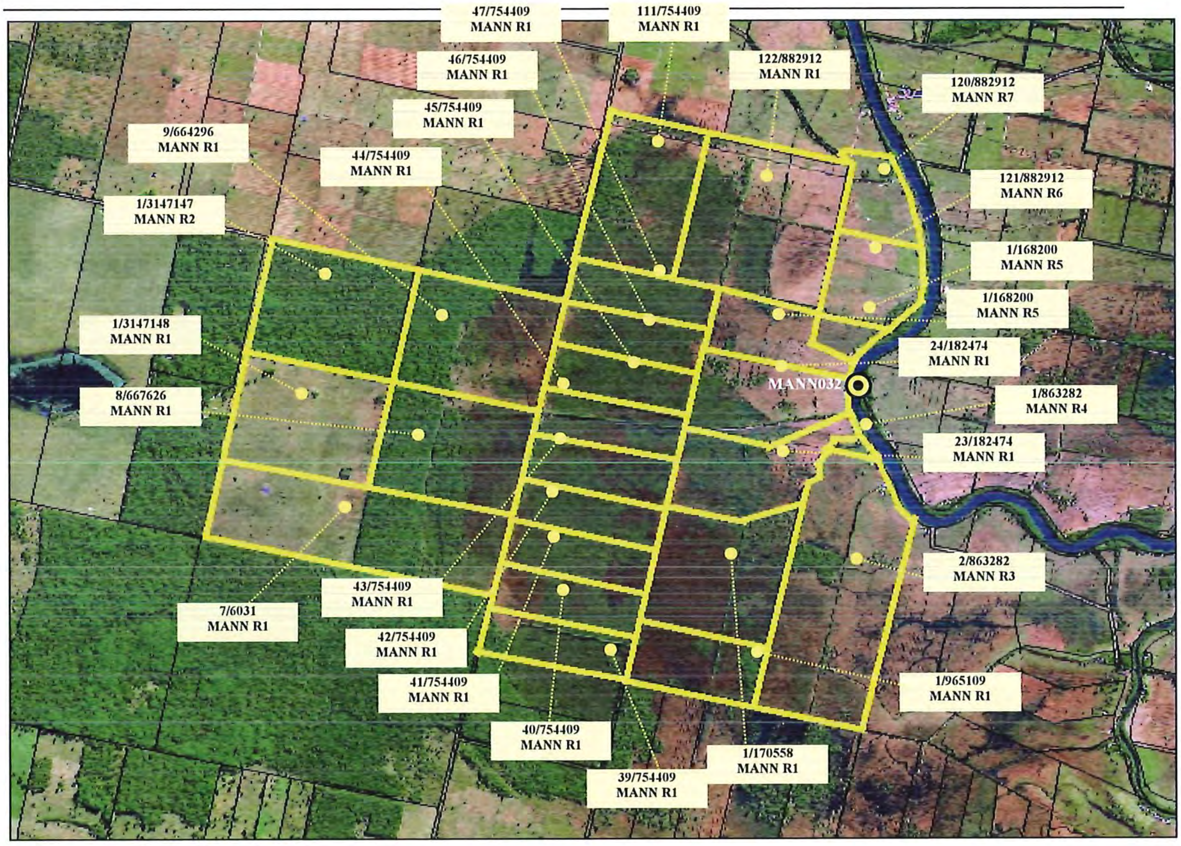
Big Swamp minor flooding January 2013.
(Crowdy Head in background)



Aluminium plume Cattai Creek (1998)
generated within Big Swamp.

Iron staining Big Swamp.

Moto Swamp: Moto is a large backswamp and floodplain located in the northern central part of the lower Manning floodplain, either side of the Lansdowne River. Moto swamp is the largest single expanse of acid sulfate-affected land in the Manning catchment. No oysters have been grown in the Lansdowne or Ghinni Ghinni Creek for many decades due to acidic waters following rain events. Rehabilitation of Moto Swamp would provide improved fish and prawn habitat as well as ameliorate the acidic water quality problem. Ecologically, as with many other disturbed floodplain wetlands, the most effective management solution would be to return the site to a freshwater wetland by drain infilling and related works to replicate natural conditions. This would benefit fisheries and waterfowl as well as estuary water quality.



Landholder lots surrounding MANN032, Motto Swamp

9.2.9 Hunter

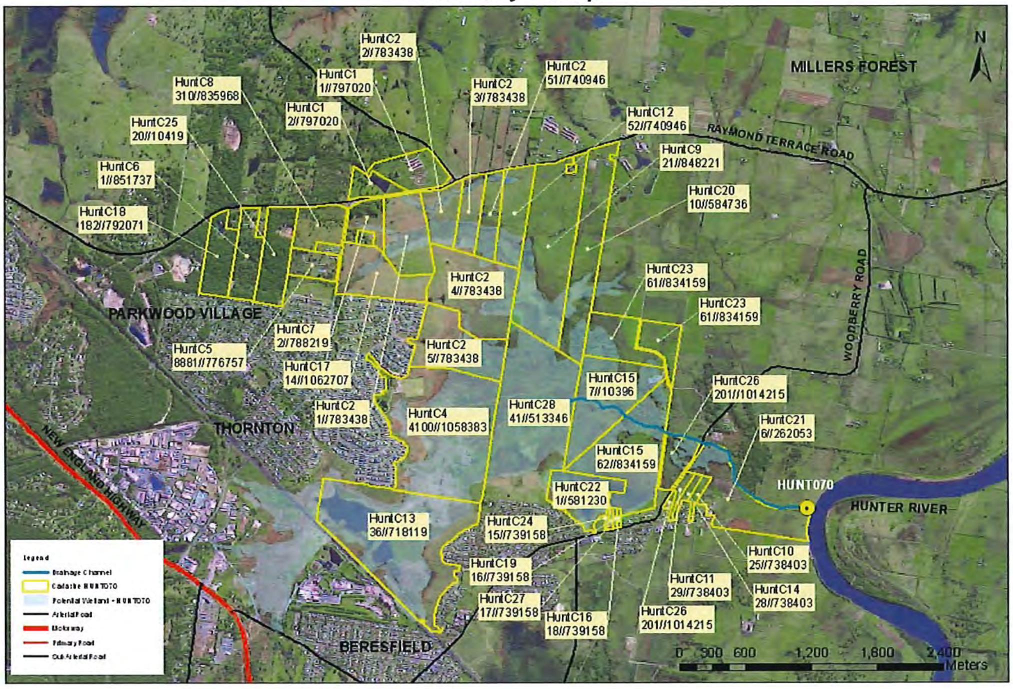
In the lower Hunter estuary significant gains have been made in reinstating tidal flushing to large areas of previously drained floodplain wetland, such as at Hexham, Tomago and Ash Island. If further investment were available the entire lower estuary could be rehabilitated, providing a useful reference base for evaluating the benefits of total estuary repair. As a first step to collating information on improved estuary productivity Fisheries Research and Development Corporation has recently funded a major research project centred on the fishery productivity improvements of the repaired Hexham Swamp.

The key large areas that are still drained and hydraulically disconnected where opportunities to complete the floodplain rehabilitation could continue are Woodberry Swamp, Purgatory Creek and Seaham Weir.

Woodberry Swamp: Greenways Creek drains the Woodberry Swamp complex, a floodplain wetland located between the suburbs of Thornton, Beresfield, Woodberry and Millers Forest with a catchment area of 5340 ha. An acid sulfate soil investigation of Woodberry Swamp identified the presence of surface sulfides in the north-east corner of the wetland. Restoring some degree of tidal flushing to the wetland has been recommended to neutralise and buffer acid sulfate product discharging from the site.

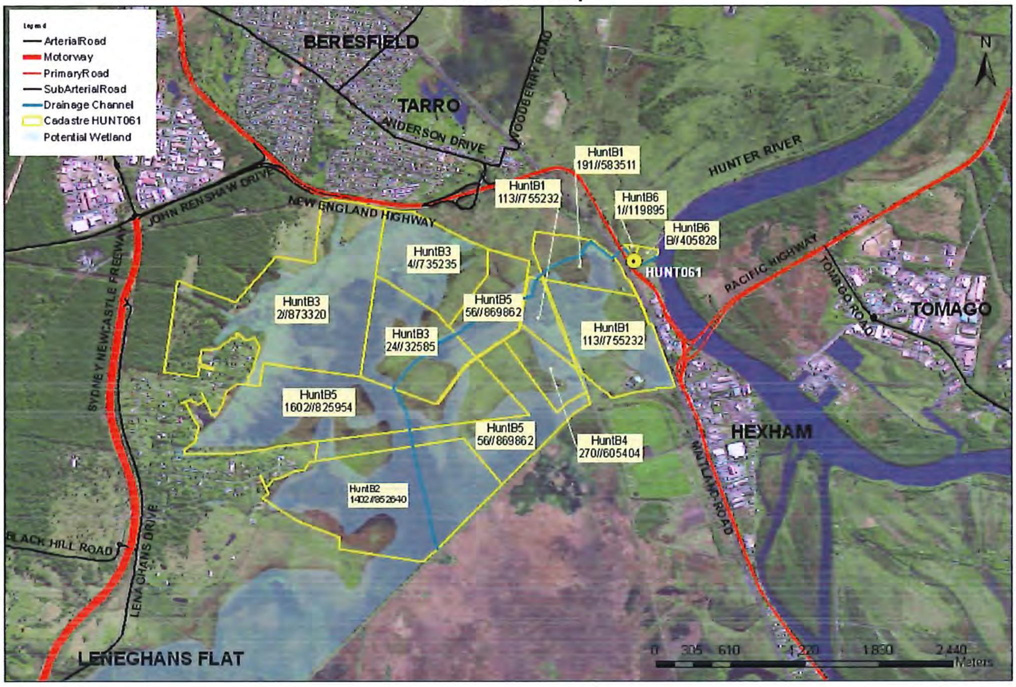
The main adjacent landholder concerns relate to the flood capacity of the system and its ability to effectively drain during significant rain events, thereby not exacerbating local flooding. Hydraulic studies and appropriate design should be able to allay any landholder concerns.

HUNT070 Cadastre and Potential Wetland Extent
Woodberry Swamp



Purgatory Creek: This catchment is artificially separated at the north-western edge of the larger Hexham Swamp area. Unlike Hexham, the Purgatory Creek catchment is still privately owned. To date adjacent landholders have not been in favour of rehabilitation activities due to the likelihood of increased flooding. Nevertheless the two areas were originally a single large floodplain wetland and major fish habitat area. Most of the Purgatory Creek catchment has been listed as now having a high probability of acidic material and would be a key location for property acquisition as part of the repair strategy to recreate fisheries and waterfowl habitat.

HUNT061 Cadastre & Potential Wetland Extent
Hexham Swamp



Seaham Weir: Seaham Weir is on the Williams River, a major tributary of the Hunter. The weir is a tidal and fish passage barrier for over 100 km of upstream waterway. The weir pool is used to supply Newcastle's residential drinking water. Improved fish passage at the site would provide significant improvements to the aquatic biota either side of the barrier.

9.2.10 Shoalhaven

The Shoalhaven is the largest floodplain catchment in southern NSW. It has similar characteristics, land use pattern and water quality issues as the larger northern NSW floodplains. These include development for grazing leading to excessive drainage, exposure of acid sulfate soils, acidic effluent following major rain events and loss of fresh to brackish fish and prawn/crab nursery habitat.

Also as with most other catchments, riparian vegetation has been largely denuded leading to high levels of riverbank erosion. The acidic run-off following rain events together with the loss of nursery habitat and salt marsh has precipitated the end of commercial prawning and markedly reduced the remaining recreational catch.

The upper Shoalhaven catchment is fully regulated, being a major supply source for Sydney Water. Shoalhaven Council is keen to reinvigorate the estuary productivity as well as protect the remaining lower estuary oyster industry. Council has recently commissioned a study of all floodgated areas and a hydrodynamic model with a view to identifying priority wetlands for repair. This is likely to include the Broughton Creek wetland. Remedial actions including reconnecting tidal flows, re-establishing water levels by drain removal and implementing water management regimes in partnership with landholders and/or acquisition are similar to those suggested for the northern NSW floodplains.

9.2.11 Protecting wetlands from grazing

Many areas of mangroves and saltmarsh in coastal NSW whether in public or private ownership are grazed, destroying their micro-topography and impacting severely on their fisheries habitat values. If fenced and stock were excluded, these remaining high value habitats would deliver multiple biodiversity objectives through carbon sequestration, increased habitat connectivity, fisheries production, water quality improvement and biodiversity enhancement.

A NSW-wide devolved grants and community education program project could achieve these outcomes. The quantum of investment required is difficult to estimate. Nevertheless these are high value habitats that, with a comparatively small investment in fencing and sometimes watering points, would deliver substantial benefits.

9.2.12 Restoring seagrass with fish friendly moorings

Seagrass is a vital component of the marine ecosystem, providing aquatic organisms with food and habitat, reducing erosion, improving water quality and storing carbon.

Due to a range of impacts one of the six species in NSW, *Posidonia australis* is listed as an endangered population in six estuaries. One of the key impacts on seagrass is the demand for moorings in NSW that has seen thousands of moorings located directly over seagrass beds. As boats with traditional block and chain moorings move with the wind and tides, their chains drag over seagrass, wearing it away until a halo of exposed sediment is formed.

A specific NSW-wide project could work with existing mooring owners to replace existing moorings with seagrass friendly moorings and through inter-Departmental planning gradually exclude key areas of seagrass from mooring permits.

9.2.13 Fish passage improvements

The 'Bringing Back the Fish' project made a significant contribution to re-establishing connectivity. Eighty-six priority sites were addressed over a three-year period.

Nevertheless, just counting the highest priority sites there are at least another 300 high priority barriers that require investment. Many of these priority sites are associated with the previously listed high nursery value wetlands.

Investment to repair fishery connectivity is essential and will need to be planned and implemented on a case-by-case basis. Provision of a specific fund to undertake these works is warranted.

9.2.14 Restoration of water quality and the Oyster industry

Over recent years three separate initiatives have produced a list of sites known to be directly affecting the environmental values of the adjacent estuary, primarily through significant contributions to poor water quality and/or riparian degradation. These prioritised sites will be targeted for on-ground works to remediate the impacts and improve the estuarine environment and water quality. In particular many creeks and rivers have been closed for long periods to Oyster production significantly affecting the now much reduced $40 million per year NSW Oyster industry.

To achieve these objectives the following approaches will be employed:

- Oyster growing estuary-by-estuary identification of priority water quality pollution sources for that estuary
- for diffuse sources – incentives program for farmers to implement on-ground works to protect and restore coastal environments, including constructing wetlands to catch and assimilate runoff
- For point sources – incentives program with Local Government to addressing high risk urban pollution sites primarily storm water and sewerage input sites.

9.3 Implementing repair in NSW

9.3.1 Planning, works approvals and community participation

NSW-specific detail is provided in the following sections to complement the more generic chapters on implementing and monitoring repair and research needs that conclude this business case.

<u>Planning context</u>

The four NSW coastal catchment management authorities each have catchment action plans that articulate their visions, strategies and planning frameworks for improved natural resource management on NSW coastal floodplains. This includes incorporating activities to mitigate and adapt to a changing climate.

Estuaries and floodplain ecosystems are important from both climate change mitigation and adaptation perspectives and will be prominent in the revision of all regional natural resources strategies.

<u>Site planning</u>

The catchment action plans all provide context to this works-orientated initiative. Nevertheless at the site-specific level further investigations, planning and most importantly consultation will be required.

Year 1 of this five-year initiative will need to give emphasis to site planning, negotiation, obtaining any approvals required for works from government agencies, negotiating with adjacent landowners and building broad-scale community awareness of the opportunities to repair these components of the floodplain landscape to the benefit of the estuarine ecosystem, agriculture, urban interests and industry. Some of the bigger projects will need to include formal community consultation phases.

Most catchments also have a series of 'shovel ready' projects – projects where natural resource management agencies and their partners have already invested in the planning and consultation phases and are ready to implement the works. Accordingly, while it is proposed the overall investment flow will ramp up with most of the expenditure in Years 2, 3 and 4, there will need to be funds for works also in the first budget for Year 1.

For the floodplain wetland repair sites there are likely to be more sites, acquisition and works costs than the funds available. Selection criteria and processes for project selection and approval will need to be put in place in Year 1 through the leadership of the proposed Australia-wide steering committee.

Project selection criteria are likely to include:

- clear outputs in terms of estuarine habitat and productivity
- relatively high return on investment based on comparing costs of works to key indicators of improved productivity
- low, long-term management costs and the responsibilities for any ongoing management well defined and ready to be put in place with the owner of the asset; and most importantly
- willingness of the community, the landholders, Local Government authorities and State Government approval agencies to effect the changes back to a more natural water management regime with tidal connectivity, works to repair drainage, modify levees, ensure flood control where necessary and complementary land use management on the fringing areas to these high value fish nursery resources.

Many of these floodplain wetland repair sites are complex in that they will require substantial negotiation, planning, data collection, further modelling, land valuation and approvals. The suggested approach is that the steering committee would accept and review proposals to initiate such longer-term more complex and challenging projects. Regional groups could nominate specific sites within these broader complex areas that can be strategically selected to demonstrate the capacity and outcomes of repair and identify the next steps in planning and delivery for these more complex systems.

<u>Block funding</u>

Three broad areas are well scoped and require block funding as a basis for some form of devolved grants processes, managed either as state-wide initiatives or within each of the four catchment management authorities. These are:

- seagrass friendly moorings
- mangrove and saltmarsh fencing and stock management
- fish passage re-connection.

<u>Indicative budget components for NSW</u>

NSW is arguably the state requiring the most extensive repair works. All its major floodplain estuaries were severely impacted by the previous Australian, State and Local Government flood mitigation and drainage schemes.

Many excellent flood protection works around major urban centres were done as part of this scheme. However the multi-level government scheme with its 40% Australian Government, 40% State and 20% Local Government formalised investment over more than two decades of works had another legacy. Where the scheme attempted to create additional agricultural land through drainage in most cases due regard was not taken of the soil type and agricultural productivity potential that might follow drainage. These drains, levees and floodgates across the rural components of the floodplains are the damage to estuary condition and fishery productivity this business plan now aims to rectify. The scheme's legacy is of fish kills, anoxic and acidic water and markedly reduced fisheries and oyster productivity.

Putting a dollar figure on the cost of repair is difficult. The best this business plan can do is develop estimates based on the experiences provided of works to date such as the successful works in Hexham and Yarrahappini Swamps, as well as the Bringing Back the Fish initiative to repair connectivity.

In brief, based on the costs of works to date over the proposed five years of this business case it is proposed:

- floodplain/wetland repair
- fish passage repair
- seagrass friendly moorings – as an incentives scheme over three years with this initiative moving to a user pays and regulatory framework for all boat owners within three years
- stock exclusion from saltmarsh and mangroves – over three years, as an incentive scheme with this clear end point of three years for uptake of the incentives. By Year 3 land management controls to be put in place to require landholders to exclude stock from all state-designated wetland areas as per State Environmental Planning Policy 14.
- water quality for the Oyster industry.

The quantum of public investment required is high but the enduring public benefits of this investment are much higher. In addition, as with the Bringing Back the Fish project many of the actions proposed would carry with them significant cash and in kind contributions from State and Local Government as well as landholders.

CHAPTER 10 South East Queensland

10.1 At a glance

- Key drivers of fisheries productivity, high coastal biodiversity and community benefit are the extensive areas of seagrasses and mangroves with remnant areas of salt marsh and now very limited extent of fresh to brackish wetlands.
- The National Land and Water Resources Audit (2002) inventoried 33 estuaries, sandy embayments and creeks in South East Queensland.
- The vast majority of these systems are either extensively modified or modified, with extensive urban development and pockets of agriculture along most of the south-east coast.
- Rivers such as Mary, Mooloolabah, Brisbane and Burnett have developed floodplains, though much of the previous wetland areas has been drained and in more rural catchments often floodgated for agricultural development. Brisbane, Coomera, and Pine Rivers and Creeks such as Tingalpa, Nundah and Kedron Brook are systems with high biodiversity values under increasing pressure from development and are wholly within urban landscapes. Objectives such as flood control and urban amenity and infrastructure take precedence.
- Hervey Bay, the Great Sandy Strait, Pumicestone Passage, northern and southern Moreton Bay are all significant seagrass and mangrove resources. Substantial investment in Moreton Bay is continuing and plans are in place to further reduce pollutant, nutrient and sediment loads from the catchments to the Bay.
- A detailed appraisal of estuarine habitats was undertaken in 2008 (BMRG et al. 2009; Mackenzie and Duke 2011). These provide an excellent baseline of current condition upon which to implement this initiative.
- This chapter concentrates on key areas for fisheries productivity especially retaining the high values of the Great Sandy Strait and Moreton Bay, from the perspective of seagrass re-establishment and fisheries connectivity. Investment in repair is recommended for:
  - Great Sandy Strait, especially wetlands and nearshore seagrass resources
  - Boat moorings – reducing risk of impact on seagrasses and moving in three years to a fully user-pays system
  - Connectivity – restoring fish passage wherever possible without compromising flood control and other instream developments such as irrigation water supply
  - Re-establishing high priority oyster reefs.

10.2 Great Sandy Strait

The entire Great Sandy Strait (including Tin Can Bay) is listed as a Ramsar wetland. The Strait is the largest area of tidal swamps within the south-east Queensland bioregion and is one of only three double-ended sand passage estuaries in Queensland.

Hervey Bay/Great Sandy Strait.

The Strait is an exceptionally important feeding ground for migratory shorebirds. It provides feeding grounds for dugong and turtles and is an important nursery and feeding ground for prawns and finfish. The mangrove communities represent a transition between temperate and tropical fauna.

Because of their high values, management of the Great Sandy Strait is already a high priority. Key issues include coastal development, aquaculture and tourism, changed tidal flow regimes due to engineering works such as roads and in-stream structures, poor water quality as a result of nutrient and other terrestrial run-off, and disturbance by vessels and vehicles.

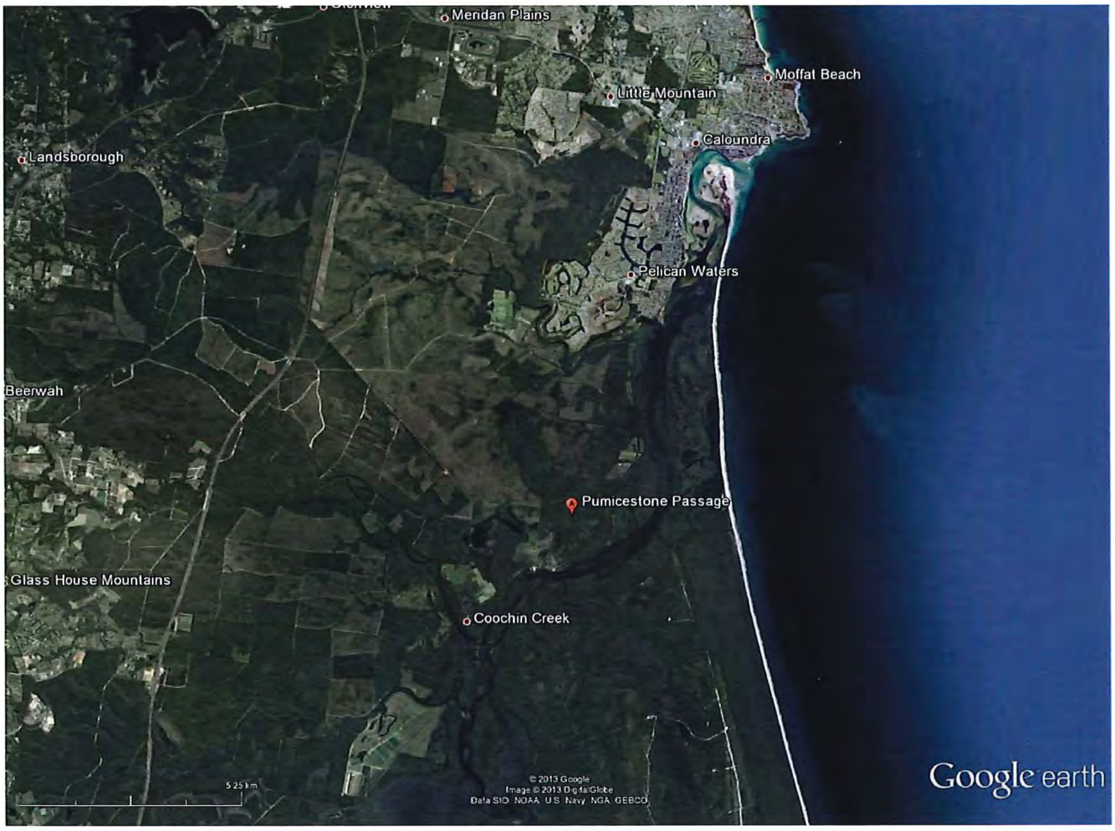
Key works include:

- reducing the impact on fisheries, especially nursery areas from agriculture, stock and human land use through fencing off salt marsh, mangroves and foreshores from cattle; and defining coastal access points so as to better conserve the coastal foreshore environment
- improved vessel mooring systems so as to reduce impacts on seagrasses and allow re-colonisation, as detailed in Section 10.3 for the entire south-eastern Queensland region and

- engineering modifications to roads and other infrastructure to re-establish tidal flow and allow fish passage into and out of freshwater streams and fresh to brackish wetlands, as detailed in Section 10.4 for the entire south-eastern Queensland region.

10.3 Seagrass repair and conservation for fisheries productivity and marine biodiversity

Seagrass meadows form one of the most important marine habitats globally and occur in all the shallow coastal waters of the Great Sandy Strait – Hervey Bay, Pumicestone Passage, North and South Moreton Bay and in the lower more estuarine components of all the major rivers – Mary, Brisbane, Burnett, Noosa, Maroochy, Caboolture, Burrum and Elliot Rivers. There are at least seven seagrass species in these subtropical environments as part of the gradation from tropical mangrove – salt marsh – seagrass-dominated systems to seagrass – salt marsh-dominated systems of temperate Australia. These productive habitats support the area's commercial, recreational and indigenous fisheries (Skilleter and Loneragan 2007) as well as iconic species such as sea turtles, dugongs (Lanyon 2003) and wader birds (Geering et al. 2007; Bamford et al. 2008)



Pumicestone Passage.

The extensive seagrass meadows and sandflats support important fisheries, through their role as foraging grounds and/or nursery sites. The increased physical structure provided by seagrass provides protection for juvenile fish and decapod crustaceans, and dead seagrass leaves decompose providing detritus and associated microbial communities, an important component of estuarine food webs. Seagrass also help to stabilise sediments, providing a relatively benign environment for juvenile organisms to hide and feed.

Moreton Bay and the waterways of Pumicestone Passage, Great Sandy Strait and Hervey Bay to the north are now the most intensively recreationally fished areas along Queensland's coastline.

An estimated 475 000 people in just South East Queensland alone participate in recreational fishing each year (a participation rate of 22.6%). These figures show an annual total expenditure by South East Queensland resident anglers of approximately $194.2 million; 98% occurring in the coastal Local Government areas. Loss of seagrass and waterways degradation and the consequent impact on fish stocks will lead to a reduction in the recreational fishing experience. The commercial fishing sector is also highly reliant on the natural resource base for its ongoing livelihood.

Analysis of historical fishing effort and catch data indicates a potential downward trend in catch rates in recent years. Some of this decline is likely to be attributable to declining resource condition including the extent and health of seagrass beds and impacts on wild fishery stock condition.

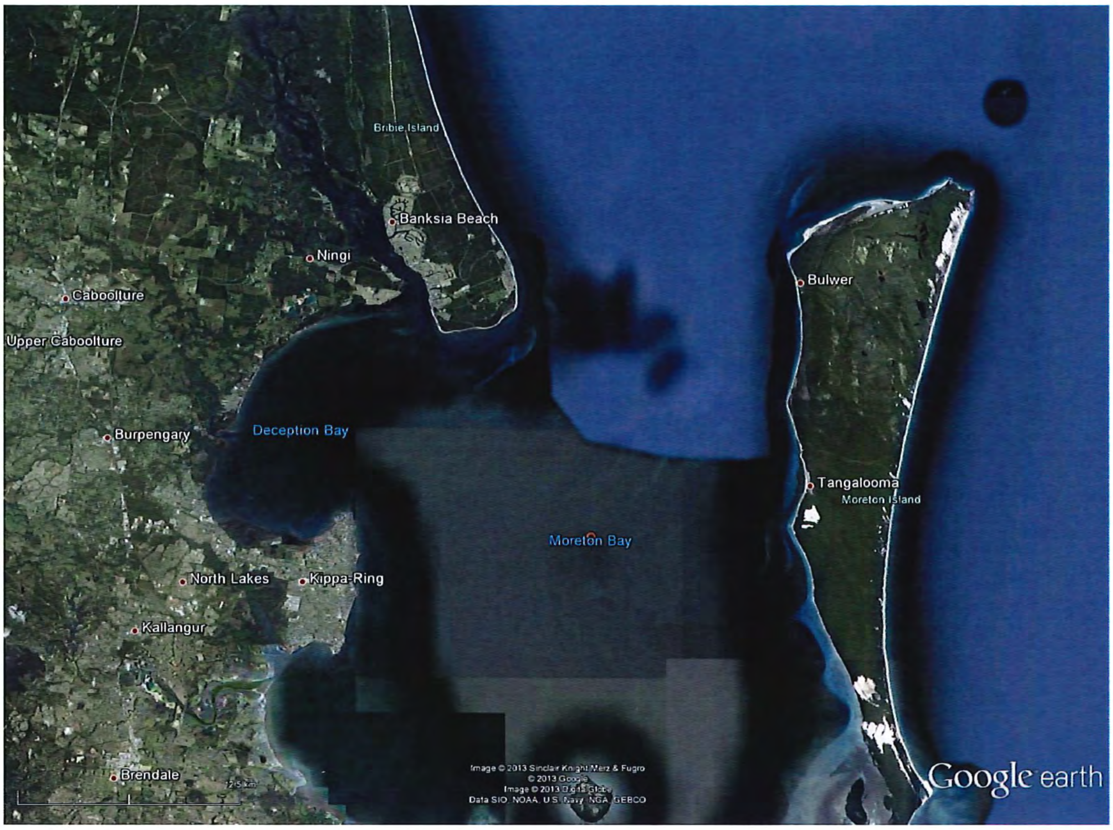
Seagrass beds face a number of threats – sediment runoff reducing light penetration and replacing sandy sediments with muds; excessive nutrients causing algal blooms, again reducing light penetration and increasing algal growth on seagrass leaves; and damage from traditionally designed block and chain moorings.

Catchment management initiatives in both South East Queensland and Burnett–Mary natural resources management groups are addressing the excessive nutrient and sediment issues from the contributing catchments.

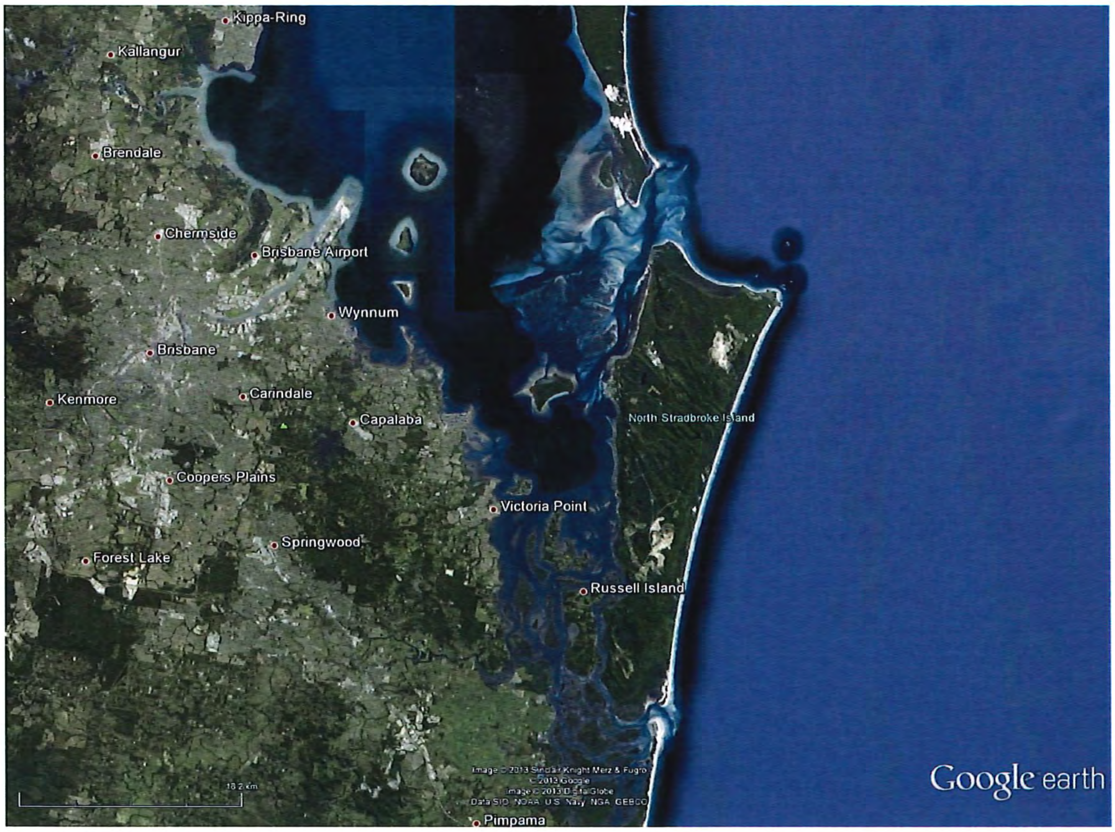
This proposal is for the within-marine environment of boat mooring.

10.3.1 Traditional block and tackle moorings

Boating and related recreational activities such as fishing, diving and other aquatic pursuits are iconic parts of the Queensland lifestyle and an important contributor to local and regional economies. Buoy moorings are a means of securing vessels, providing a safer alternative to anchoring and a more cost-effective option than marina storage. Mooring chains of 'traditional' block and tackle buoy moorings drag on the substrate around their moorings, resulting in disturbance to seagrass and benthic fauna.

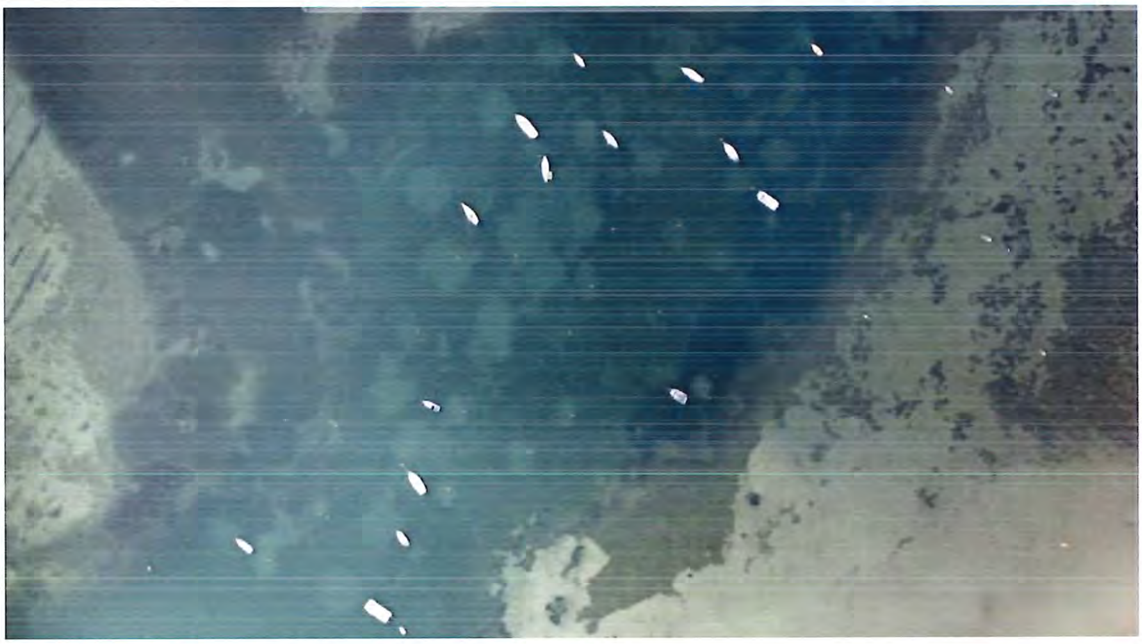


Northern Moreton Bay.



Southern Moreton Bay.

Recent aerial photographs of boat-mooring areas in Moreton Bay (and other estuarine systems – see Chapter 3, NSW priorities) show images similar to that of crop circles. These aerial photos show damage to seagrass meadows. The amount of disturbance depends on the length of the mooring chain but can be up to 1.2 ha per mooring which includes direct physical damage and indirect sediment disturbance deposition and reduction of macroinvertebrate populations. When this area is multiplied by the large number of moorings plus the predictions for future needs, this represents a significant area of seagrass being damaged and disturbed. There are already approximately 1200 authorised moorings in Moreton Bay with a large demand for new moorings – the wait time is currently up to two years.



Traditional 'block and tackle' buoy mooring designs can affect seagrasses, algae and other marine plants growing on the marine substrate by scouring caused by the heavy mooring chains, or in some cases contact of the moored vessels at low tide. Clearly visible from the air, this scouring forms a 'halo' where no marine plants grow.

10.3.2 Replacing traditional moorings with environmentally friendly moorings

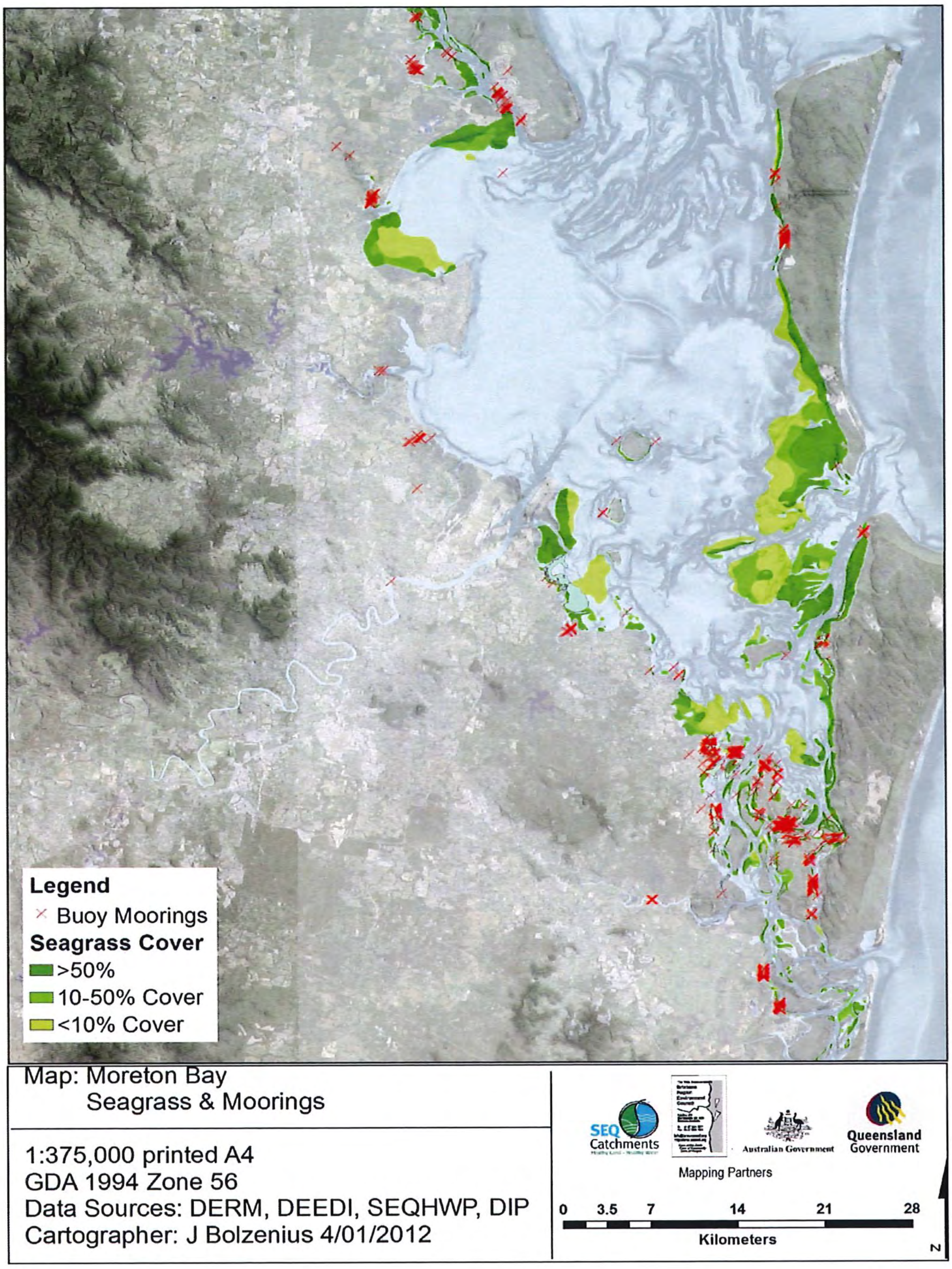
Environmentally friendly moorings keep mooring tackle off the seafloor and therefore result in little or no disturbance to marine flora and fauna.

An environmentally friendly mooring is a mooring that:

- minimises the area of disturbance of the mooring anchor system and
- keeps the vessel and mooring chain off the seabed at all stages of the tide.

After a small amount of disturbance during installation, environmentally friendly moorings allow seagrasses and other marine plants, and soft-sediment animals to remain, live and grow uninhibited while maintaining a secure vessel boat mooring anchorage.

Approximately 54% of moorings within Moreton Bay are causing damage to seagrass beds and associated benthic habitat. This project has the potential to remediate the area of high density seagrass cover in Moreton Bay (i.e. replacing moorings that are impacting on seagrass in the 25–50% cover category with an environmentally friendly mooring will increase the amount of seagrass beds in Moreton Bay with greater than 50% cover). There are approximately 10 000 ha of seagrass meadows in Moreton Bay with over 10% of that area impacted by moorings.



Seagrass cover in relation to traditional buoy moorings located in Moreton Bay.

10.4 Re-establishing fish passage

As with the Great Barrier Reef catchments and the NSW coast, there are many sites where fish passage and connectivity between fresh to brackish wetlands, fresh sections of rivers and the tidal components of the estuaries have been lost. Likewise in many cases the productivity driving tidal flows have been constricted.

All the issues and opportunities identified in the Great Barrier Reef Business Case (see companion document) apply. The actual density of these discontinuities in connectivity is higher, predominantly because of the highly developed nature of southern Queensland, both through urban and agricultural development.

The techniques and methods to reduce the impact of these generally historical changes in estuary productivity are also the same. There are many ways from outright removal through to bypass fishways and re-engineering of culverts, road and rail crossings that can be applied. Works will depend on the site in question and will need to take account of other objectives such as flood control.

Methods to prioritise works investment are also readily available including the studies already undertaken on high value ecosystems, the protocols developed by Oceanwatch and the work underway through the National Water Commission.

Proposal and key benefits

- To repair where practical fish passage linking fresh to brackish components of the estuary ecosystems to tidal and marine components and to increase tidal flows, where this has been constricted.
- Major benefits will be for fisheries and general coastal ecosystem productivity, especially for the nursery phases of many fish and crustacean and for waterfowl.
- The cost of these works varies immensely. Some are simple improvements and can be done for less than $30 000. Others such as culverts for secondary roads will cost at least $250 000 per culvert. Investment across the two natural resource management regions will need to be prioritised based on the benefits to accrue across objectives of improved fisheries productivity, enhanced ecosystem health, more beneficial flood control and improved water quality.

10.5 Re-establishing Oyster beds

Historically. Sydney Rock Oysters (*Saccostrea glomerata*) were abundant throughout the intertidal and subtidal zones of south-eastern Queensland and there were extensive oyster beds within all the sheltered embayments.

Intertidal Oyster bank, Toorbul Point, c. 1906. Photo from John Oxley Library (courtesy Diggles 2013).

Toorbul Point seen over 100 years later in July 2011. There is a very high number of dead Oysters, and a lack of Oyster recruitment. Abundant algal growth has trapped a signi• cant amount of sediment, giving the rocks a dirty appearance (courtesy Diggles 2013).

Mushroom shaped Oyster clump at the mouth of Ningi Creek, Pumicestone Passage, January 2011. Large numbers of shell fragments litter the sand bank from decaying clumps that were formerly monolithic in shape. The arrow points to the delineation between the mud/silt layer (far • eld) and the sand from the original Oyster bank. Scale shows height in metres above gauge datum (courtesy Diggles 2013).

Mr Alexander Archer described a trip to Pumicestone Passage in 1862 as follows:

> *... the water teems with fish, great and small and as for the oysters, I never saw anything like it. This day we saw something like a reef of rock about 3 feet out of the water and 300 yards long. On pulling up to see what it was, we found it to be a huge and apparently solid bed of oysters, large enough to load several large ships.* (Lergessner 2008, 2011)

During the early years of European settlement, prolific Oyster spatfalls were observed to occur in intertidal and subtidal areas of Moreton Bay and areas further north. In Tin Can Bay and the Great Sandy Straits, *S. glomerata* spat grew abundantly on rocks within the intertidal zone and also on the bottom of the channels (Brown 2000). In the late nineteenth century, while inspecting the Great Sandy Straits, forester Jules Tardent described ... *the astronomical quantity of seed-oysters, stretching for miles, which has to be seen to be believed* (Brown 2000). Indeed, the intertidal and subtidal sand flats of Tin Can Bay, Great Sandy Straits and Hervey Bay became well-known as a prolific source of seed Oysters (also known as culture) that were used after 1870 to restock Moreton Bay Oyster beds after commercial harvest (Smith 1981; Lergessner 2008).

Oysters are important ecosystem engineers in estuaries worldwide (Grabowski and Peterson 2007; Beck et al. 2011). Like corals, Oysters can completely structure entire ecosystems, providing hard subtidal and intertidal reef structure, food and habitat for invertebrates and fish, as well as services such as filtration of phytoplankton, nutrient uptake and fixation, benthopelagic coupling, and shoreline stabilisation (Newell 2004; Kemp et al. 2005; Grabowski and Peterson 2007; Beck et al. 2011). Historically, wild Oysters have also supported important fisheries and aquaculture industries worldwide.

Diggles (2013) notes that today subtidal oyster reefs are extinct, and loss of around 96% of the vertical zonation suitable for oyster habitation has occurred. As with other estuaries in developed Australia, land use development caused large increases in sediment flux, changes in nutrient status and multiple pollutants. Subtidal oyster reefs declined after major flood events in the late nineteenth century, probably associated with infestations by spionid polychaete mudworms as detailed by Creighton (1982) in a similar study of the Camden Haven and the onset of mudworm accompanying land clearing.

Mortalities of *S. glomerata* in the broad region from South East Queensland to mid New South Wales are associated with QX disease caused by *Marteilia sydneyi*. Increased virulence of *M. sydneyi* is likely due to a combination of increased abundance of intermediate hosts in habitat utilised by Oysters, together with immunosuppression of the Oysters. Declining water quality drives these processes.

The aim is to re-create Oyster beds as a basic building block towards re-establishing fishery and ecosystem health. Sites to be chosen will mimic the reef's historical locations in South East Queensland sheltered waters, subject to other key uses such as navigation channels for shipping, both commercial and recreational, trawl areas and marinas. It will attempt to mimic natural pre-conditions on a large scale. To determine the best locations for the reefs, readily available data will be collated and analysed and where necessary further data collected. Attributes include sediment type, the extent of muds over prior beds, salinity levels, water quality, and current velocities and current flow directions. The sites that are chosen will have suitable conditions for the placement of cultch and for spat recruitment.

The benefits of re-creating reefs are multiple. USA studies have shown shellfish reefs are complex ecosystems providing habitat for over 300 species of invertebrates such as shrimp, crabs, clams, snails, and worms as well as many fish species (Kroeger 2012).

The communities inhabiting reefs form the base of an estuarine food chain that provides forage for many important fish species. Many fish species that live as adults on the offshore reefs spend the juvenile phase of their life cycle on oyster reefs.

Oysters are filter feeders, meaning that they take in the surrounding water, filter out and consume the plankton and microorganisms inhabiting that water, and release the filtered water back into their environment.

Clearer water allows greater penetration of sunlight that can lead to expansion of seagrass beds, another important habitat within a healthy estuary. Reefs may also help in shoreline stabilisation, reducing effective wave height and erosive power on the foreshore proper. Other advantages including carbon sequestration and buffering against water acidity.

Proposal and key benefits

- To re-establish shellfish reefs in sheltered South East Queensland waters as a basis for increased fisheries and overall ecosystem health benefit.
- It is proposed to allocate resources for two pilots, established in areas of highest current water quality such as Pumicestone Passage. Following evaluation in Year 4, this might lead to a major follow-on program. This staged approach has proved to be the pathway to major repair initiatives and multi-investor interest in the USA.

10.6 Proposed investment in summary

10.6.1 Great Sandy Strait foreshores and coastal environments

- A focused investment on Great Sandy Strait to reduce the impact on fisheries, especially nursery areas from agriculture, stock and human land use through fencing off from cattle salt marsh, mangroves and foreshores, signage and defining coastal access points so as to better conserve the coastal foreshore environment.

10.6.2 Seagrass repair and conservation for fisheries productivity and marine biodiversity

- A three-year investment of incentives to foster the uptake of environmentally friendly moorings across all rivers and embayments of South East Queensland with companion policy development so that all renewed and new licences and leases after that time require environmentally friendly moorings.

10.6.3 Re-establishing fish passage

- A prioritised investment over five years to repair and reconnect fish passage and tidal flows across key estuaries and creeks in South East Queensland.

10.6.4 Re-establishing Oyster reefs

- Using spat and cultch in historically known Oyster reef locations to re-create Oyster reefs with flow on benefits to multi-species fisheries and within estuary biodiversity, nutrient cycling, reduced turbidity and acid buffering.

CHAPTER 11 Northern Territory

11.1 At a glance

- Key drivers of fisheries productivity, high coastal biodiversity and community benefit are the extensive areas of seagrasses, mangroves, salt marsh and fresh to brackish wetlands along with the generally high quality near-pristine nature of most of the Northern Territory coast and much of the catchments.
- Overall there are about 150 estuaries in the Northern Territory with about 100 of these being tide-dominated estuaries, creeks and flats.
- About 140 of these 150 are in near pristine condition, another six are largely unmodified, three are modified and only two are extensively modified (Audit 2002).
- Protectively managing all of the Northern Territory coast and its near-pristine estuaries is essential and is more about controlling and directing any development that might occur.
- Site-specific uses such as infrastructure for ports will need to be developed as the Northern Territory capitalises on its mineral wealth. The challenge is to minimise impact and where possible offset any losses in habitat with works to improve overall catchment and estuary health.
- The areas of improvement in habitat relate to minimising the risk of prior mining (the legacy mines) that was poorly rehabilitated, reducing excessive sediment export from grazing catchments, and minimising salinity intrusion and disturbance of fresh and fresh to brackish wetland systems caused by feral animals such as buffalo.
- Various programs are already underway through the Northern Territory Government, the mining industry and the Natural Resources Management Group.
- Therefore the emphasis of any investment in habitat within the Northern Territory is aimed more at the protective rather than the repair end of the spectrum and would probably involve support for further policy formulation within the government to maximise habitat protection while recognising that further development will occur. Policy frameworks in other states such as the Qld Fisheries Habitat Areas or Western Australian Offsets Policies might need to be evaluated and refined to meet the Northern Territory's particular needs.

11.2 Northern Territory's estuaries and inshore environments

Northern Territory estuaries are all located in the wet/dry seasonally contrasting tropics of Northern Australia with much of the rainfall being the wet season summer rainfall. Coastal catchments discharge to the Gulf of Carpentaria to the east, the Arafura Sea to the north and the Timor Sea to the west. In the north, monsoonal activity during the wet season is responsible for high rainfall. In the eastern and western regions a combination of weaker monsoonal effects and cyclonic activity influences annual rainfall. Flows in rivers discharging to estuaries are highly variable. Depending on the extent of the monsoon fronts and cyclonic activity the magnitude of annual floods varies between years. During the dry season freshwater discharge from rivers to estuaries often ceases.

A feature of Northern Territory estuaries is the extensive mangrove habitats and macro-tidal regime along the northern and western coastlines. The estuaries and nearshore areas provide significant habitat for some of the most dense populations of estuarine crocodiles in the world, roosting areas for sea and waterbirds, and habitat for a wide range of tropical marine organisms. Along with Torres Strait, the seagrass beds support very large populations of dugong and turtle.

With the exception of the Darwin region and Nhulunbuy in the northeast, the Northern Territory coastline is sparsely populated, with a large proportion of estuaries remote and inaccessible by land. The population in these areas consists of indigenous communities and the homesteads of pastoral properties.

Approximately half of the Northern Territory coastline is indigenous land, with much of the remainder either freehold or pastoral lease. The dominant and often only land use in many catchments is grazing. Prior mining activity, being generally unmanaged and dating from when rehabilitation was not part of the mining lease requirements is a problem in some catchments and is known colloquially as the 'legacy mines'.

Northern Territory estuaries are valuable for traditional harvesting, eco-tourism and pearling as well as commercial and recreational fisheries. The estuaries and associated extensive salt marshes of the Gulf of Carpentaria support the nationally important Gulf prawn and finfish fisheries.

11.3 Salinity inundation and loss of freshwater wetlands

Salinity encroachment is affecting and putting at risk a number of important freshwater fish habitats across the Northern Territory.

In rivers such as the Mary, Adelaide, South Alligator and Finniss as well as in important natural areas such as Kakadu National Park and Arnhem Land, salinity encroachment is having a devastating effect on freshwater billabongs, floodplains and paperbark swamps. It is already having a major effect on the productivity and biodiversity of these important and unique freshwater habitats.

The larger, longer-term issue is that some of the Northern Territory's most recognisable and loved assets such as Corroboree Billabong and the Kakadu wetlands are under serious threat from salinity inundation and encroachment.

11.4 Case study: the Mary River floodplains

The issue of salinity encroachment has been a major issue on the Mary River wetlands and floodplains for a number of decades. The cause, while mostly anthropogenic, is a complex mix of human actions including:

- introduced species such as buffalo creating swim channels
- failed and inappropriate human intervention in the form of barrages and weirs on the floodplain in an attempt to control tidal flows and
- the deepening of the entrance channel to allow boat access by early industries such as buffalo and crocodile hunting.

Increased tidal flows have pushed further into freshwater areas killing off the freshwater-dependent vegetation and making the areas subject to high erosion risk and the deepening and widening of channels. Increasing sea levels due to climate change will in time add to this issue of saline intrusion.

Proposal 1: Salinity intrusion reduction

The key aim of this project is to undertake strategies and works to protect priority freshwater systems from salinity encroachment and inundation.

Following the assembly of all existing information, strategies and works activities will be detailed for selected at-risk fresh water systems wetland floodplains and billabongs.

Strategies

- Understanding what is at risk and developing plans of action for those areas where intervention is likely to succeed
- Investment in preferably soft engineering options establishing mangroves and strengthening the coastal Chenier ridges while increasing efforts in feral animal control

Proposal 2: Establishing the policy framework for ongoing habitat protection and management, northern Australia

The key aim of this project is to work cooperatively across the Queensland and Western Australian State Governments and the Northern Territory Government on a specific policy development activity around protecting existing the high quality fisheries habitat of northern Australia – fresh, fresh to brackish, estuarine and nearshore for the ongoing benefit of commercial, recreational and indigenous fishing. Offsets from specific points of development such as ports will contribute to ongoing maintenance activities, such as for example, providing certainty of funding for the ghost net initiative.

Strategies

- As part of the policy development component of this Australia-wide initiative, a specific project focusing on protecting and managing northern Australia's near-pristine fisheries habitats will be initiated.
- Contributing expertise will include Queensland with their Fisheries Habitat Program, Western Australia with initiatives such as 'Royalties for the Regions' and Northern Territory with their knowledge and existing activities in habitat protection.
- A key output will be to work towards fostering comparable policy and regulations across northern Australia for freshwater, estuarine and nearshore habitat protection and for management through such as development offsets.

CHAPTER 12 Implementing repair

12.1 Planning, policy development, works approvals and community participation

12.1.1 State planning and policy context

All states have a series of agencies that include in their remit ecosystem health, water quality, water quantity, catchment management and biodiversity objectives. Likewise all states have specific lead agencies for fisheries. While many of the fisheries agencies focus on fisheries management, both recreational and professional catch, most agencies also undertake a range of management-related activities and often regulations to protect remaining fish habitat.

Some states (e.g. New South Wales – State Environment Planning Policy 14; Queensland – Habitat Protection Regulations within their Fisheries Act) have policy and legislation requiring the protection of remaining fisheries/wetland habitat. No state has specific legislation for repair of habitat. Several states, such as New South Wales and Victoria have been active in fostering repair of habitat, generally at a small scale due to the limit on the funds available from such as recreational fishing licences. Several states also have offset policies to encourage repair where developments such as urban or port infrastructure adversely impacts on remaining habitat.

Recognising that the responsibilities of many state agencies intersect and in some cases overlap the roles and responsibilities of other agencies within the estuarine and inshore zone, nomination of a lead agency for each state will be essential for implementing this plan.

Implementation will need to include as a cross compliance activity for funding on repair, specific planning and policy actions at the state level so that the long-term needs of habitat protection and repair to ensure fisheries productivity is ensured. The goal would be towards a net improvement in estuarine and nearshore habitat while recognising that further localised losses of habitat will occur accompanying further development.

A checklist of issues to be covered in a specific project within each state would include:

- assessment of capability and policy responsibility and then designation of the lead agency within each state to take carriage of the initiative for their state
- review and where necessary improvements in policy and/or regulations for habitat protection
- development and implementation of policies on habitat repair, especially linking to and cross-correlating with existing policies and legislation such as the various water and environmental acts, regulations and environmental assessment procedures
- review and where necessary initiation of policies for habitat offsets so that any development activities that adversely affect estuarine and nearshore productivity can positively contribute to habitat repair close to the locality where development is to occur.

12.1.2 Lead community groups and their engagement

Both professional and recreational fishing non-government organisations are active in all states and in all cases have habitat protection and repair as high priority policies. Other non-government organisations such as WetlandCare and Oceanwatch have various offices and are active in some states. All these non-government organisations are likely to seek to be actively involved in the delivery of various repair works and the monitoring of productivity improvements.

Likewise, all states also have natural resource management regions as part of the strong links needed to their local communities. These natural resources management groups are often terrestrially focused and only limited works have been done in estuarine and nearshore areas. Nevertheless these groups are revising their regional natural resources strategies, including incorporating activities to mitigate and adapt to a changing climate. Estuaries and inshore ecosystems are important from both climate change mitigation and adaptation perspectives and presumably will be prominent in the revision of all regional natural resources strategies.

Implementation of this business case will need to include an assessment of the capability and the roles that various community groups might be able to play in its delivery. The goal would be towards maximising ongoing community involvement and cost sharing with the community as the initiative is delivered while ensuring all repair works were undertaken at minimal transaction costs. Delivery of this goal should also set the framework for ongoing community action, leadership and stewardship to manage estuarine habitat into the longer term.

A checklist of issues to be addressed by the nominated lead agency in each state as part of a specific project to foster community engagement within each state would include:

- review of the capability of the various community groups to undertake on behalf of the state various repair activities and then the development of protocols and procedures to engage these groups under contract in works activities
- identification of the lead players capable of undertaking monitoring activities and delivering monitored data to a consistent and comparable framework so that reporting state by state is seamless and can be aggregated Australia-wide.

12.1.3 Engaging the stakeholders, adjacent landholders and local interest groups

Engagement of the stakeholders and various local interest groups is also essential for this initiative's success. The key focus of interaction with the stakeholders will be on optimising the benefits Australians as a community can gain from the landscape. That is, how with careful planning and works the landscape can be repaired to deliver the benefits of improved fisheries productivity and other benefits such as biodiversity and water quality with minimal and preferably positive impact on other land uses and values. This optimisation can only be achieved where there are win-win 'no regrets' solutions. For example, some of the investment will need to link in to other investments (e.g. urban development proposals, port works and other infrastructure, improved flood control, improved drainage for high value agriculture lands, tail water recycling for irrigation and possibly even acquisition of very high value resources that would be best managed and secured as part of the public estate).

All projects will require careful negotiations. These negotiations take time, leadership and signing on to a joint vision. Much of the task is in gaining acceptance from the community to change key elements of the landscape back to previous, highly productive aquatic ecosystems. Change is threatening. Change takes time to accept and implement.

A range of legality issues is also likely to be uncovered as various projects proceed. In many cases lands will be public and structures such as bunds and levees may be 'unauthorised'. Nevertheless each project will need to meet all environmental approval processes across agencies and community.

The nature of community consultation will also need to vary with the projects. For example, if a project will deliver very high benefits but will also lead to some community contention, then it may be appropriate to have a formal community consultation process including press releases, well-promoted meetings and a formal phase of submissions. Other less complex projects may benefit from information sharing meetings with community, recreational and professional fishers.

Overall this component is crucial and will require the type of expertise that has made the Great Barrier Reef Marine Park Authority Reef Guardians a success.

12.1.4 Facilitating broader community understanding

Community awareness at the Australia-wide level will require a broader approach and often a different skill set to project-by-project stakeholder engagement. Uniform and consistent messages will be required across Australia. The types of media products usually employed include fact sheets, television advertisements, short documentary style articles in both print and electronic media and probably, activities on various social media websites.

Co-investment from the private sector as has happened with the Great Barrier Reef's Project Catalyst (Coca-Cola Foundation) or with the USA Restore America's Estuaries initiative in re-establishing massive oyster beds provides very valuable third party endorsement that captures community imagination and ensures widespread community support.

Simple messages will also be important. For example many Australian's are not aware of the estuarine dependence of well over 70% of all professional catch and well over 80% of all recreational catch ... and thus, most of the seafood on their dinner tables.

Communication expertise might need to be contracted to deliver specified deliverables under the oversight of the proposed Australia-wide steering committee. A whole-of-program communication plan will be essential and will need to incorporate both key Australia-wide and more specific messages for local and regional communities so that it can be delivered and made relevant locally.

12.1.5 Leadership

An expert-based Australia-wide steering committee is proposed to oversight the entire initiative. This committee will include within its remit all aspects relating to:

- strategic direction, ensuring the program remains focused and delivers to its objectives and targets
- quality assurance, including ensuring all plans for communication, works, monitoring and reporting are of high standard
- investment planning, including the final selection and approval of projects for works, probably as state-by-state packages

- community, stakeholder and industry engagement, especially across the entire initiative while devolving all project-related engagement and negotiations to the various state-based works project proponents
- risk management, including oversighting all matters relating to program accountability and financial reporting.

These aspects will ensure good governance of the entire initiative.

Membership, by virtue of being expert based will need to include the following skill sets:

- implementation of natural resource management programs
- estuarine and nearshore ecological science, covering both research and monitoring
- policy development and implementation within government, and especially ensuring strong links to a range of natural resources-related initiatives by both the Australian and State Governments
- expertise in land-use management and community, especially covering the key beneficiaries of indigenous, professional and recreational fishing, agriculture and grazing
- community engagement, communication and consensus building.

In line with good governance, underpinning the initiative would be the appointment of an independent Chair. A program manager and any program support staff would report directly to the steering committee.

An organisation would be selected as the 'proponent' or 'coordinator' in terms of the interface of the entire contract with the Australian Government, presumably through the Department of Agriculture, Fisheries and Forestry. This lead Australia-wide coordinator would preferably be closely aligned to and probably co-located with the Australian Government's key knowledge provider on matters fisheries and estuarine and nearshore ecosystem health – the Fisheries Research and Development Corporation.

12.1.6 Investment by state and by project

Selection criteria and processes for state allocation and then project selection and approval within states will need to be put in place in Year 1 as a two-tiered process through the leadership of the proposed Australia-wide steering committee.

Tier 1, being allocation to each state will depend on the quantum of resources made available Australia-wide. If close to the recommended investment, this might be best expedited at least as an indicative allocation simply as a proportional allocation to that recommended in this business case. Each state through its lead agency would still need to prepare an investment plan and submit this within six months of the start of the initiative for review and approval by the proposed Australia-wide steering committee. These investment plans would need to detail:

- co-investment from within the state
- proposed set of works and their likely outcomes for estuarine and nearshore productivity
- activities to ensure complimentary policy development and where necessary legislation as part of the ongoing legacy of this major investment
- activities to engage with the community and its various interest groups, including in the delivery of works and monitoring of the outputs of the initiative
- communication strategies

- annual progress reporting, both outputs and inputs
- ongoing efficiency evaluations to continuously improve delivery and an effectiveness evaluation in Year 4
- Year 5 final reporting.

Tier 2 allocation is within each state and while still overseen by the Australia-wide steering committee would rely on the advice of the lead agency within each state. Project selection criteria used to collate the proposals in each state within this business case and that will need to be re-applied as a function of the resources made available at the state level are likely to include:

- readily measured benefit to the health and productivity of the estuarine and nearshore ecosystem
- clear outputs in terms of estuarine habitat and productivity
- relatively high return on investment based on comparing costs of works to key indicators of improved productivity
- low long-term management costs and the responsibilities for any ongoing management well defined and ready to be put in place with the owner of the asset.

Other factors such as ensuring that a subset of the works sites provides readily accessible demonstrations of the opportunities and benefits of repair will need to be incorporated as part of the processes to maximise community understanding and support for the initiative.

With the focus of this initiative on estuarine and nearshore ecosystems a set of clear exclusion rules will also need to be defined by the steering committee. Focus will ensure maximum benefit from the limited resources available. For example, this initiative will build on but should not replicate the various catchment management and riparian repair activities already undertaken by state agencies and natural resources groups. Any works proposed to be undertaken in freshwater components of catchments such as freshwater riparian revegetation will need to demonstrate how the investment delivers to health and productivity of the estuarine and nearshore ecosystems.

Part of the selection criteria for project investment will be the consideration of any implications in terms of long-term and ongoing management costs. While necessarily all design should preferably focus on minimal ongoing management costs, in some cases this might be unavoidable. A good example is the seasonal manipulation of flood barrages to allow fish passage while not losing flood protection functionality during high threat flood periods. All projects will need to document and then implement long-term management arrangements for each repaired asset. Long-term local management is preferred, with priority given to the nominated owner of the asset – preferably at minimal cost to government.

Some funds will be allocated in this program to explore and initiate local management arrangements at the broader estuary-by-estuary scale. Offsets against port developments, boating and fishing licensing fees, 'blue carbon', differential rating and voluntary local action are all feasible and likely to be endorsed by regional communities. Certainly overseas experience is demonstrating that local asset management can work and is preferable to what dominates in Australia – 'the tyranny of the commons'. For example, under the USA model 'blue carbon' is part of ongoing investment, the USA having endorsed carbon mitigation in coastal systems within its voluntary market. Also under the USA model, fisheries habitat and its repair is undertaken locally and organised nationally, including a core team to develop five-year strategies, lobby Congress and state legislature, work closely with key state and federal agencies, and foster community action. Under the UK model 'local trusts' are set up to manage sections of streams and estuaries. These groups include fishers, the private sector and conservation groups. Again, action is undertaken under a strategic approach that recognises the multiple values that estuarine, coastal and river habitats provide to the community.

12.1.7 Site planning

At the site-specific level further investigations, planning and most importantly consultation will be required. Year 1 of this five-year initiative especially for the larger project proposals will need to give emphasis to:

- ✓ site planning
- ✓ obtaining any approvals required for works from various government agencies
- ✓ negotiating with adjacent landowners and
- ✓ building broad-scale community awareness of the opportunities to repair estuarine and nearshore environments to the benefit of fisheries productivity, overall ecosystem health and local communities.

Many of the activities will need to be multi-objective, including improving flood control and meeting the needs of other land uses such as agriculture, urban development and industry.

Some of the bigger projects will need to include formal community consultation phases and some will trigger the need to comply with Australian Government legislation, especially the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1979.*

A lead state agency will be essential as for many of the proposed activities multiple planning approvals and related activities such as acquisition of lands and the decommissioning of existing structures such as drains and floodgates will require central coordination and leadership.

Most states also have a series of 'shovel ready' projects – projects where the agencies, the natural resource management groups or various non-government organisations have already invested in the planning and consultation phases and are ready to implement the works. Accordingly, while it is proposed the overall investment flow will ramp up with most of the expenditure in Years 2, 3 and 4 there will need to be funds for works also in the first budget for Year 1.

A checklist of the types of activities and detail required for site planning would include:

- Australian, State or Local Government approvals
- community interaction and support
- adjacent landholder negotiations and support
- if a major project – at least a 'statement of environmental affects' plus an advertised period for formal community interactions and in some cases, full assessment of environmental impacts, including under the *Environment Protection and Biodiversity Conservation Act, 1979* (Cwlth)
- physical measurements such as likely tide penetration surveys, elevation mapping to determine the likely areas of re-established wetland types and any flood control mapping required

- applying established modelling protocols of expected changes in productivity to provide estimates of benefits (see later section)
- any partnerships for works in place
- if needed, tender processes for works in place to comply with normal government tendering processes
- photo point monitoring sites defined and 'before' photography complete
- press releases.

12.1.8 Performance auditing

One of the underpinning advantages of focused initiative-based funding over project-by-project-based funding is the minimisation of transaction costs for all parties. Nevertheless, accountability and transparency remains an imperative. This initiative could undertake the following processes as part of reducing transaction costs while providing fully accountable and transparent allocation of all funds towards Australia-wide outcomes:

- lead Australia-wide coordinator, closely aligned to and probably co-located with the Fisheries Research and Development Corporation as the Australian Government's agent
- budget and expenditure sheets by all states will use consistently defined line items so rational and sensible dissections of budget and expenditure can be reported on across the initiative
- consistent and comparable project proposals so that the Australia-wide steering committee's task in oversighting project selection is rigorous
- aggregated and consistent reporting, coordinated by the Australia-wide coordinator on behalf of all parties
- summaries of state-by-state, and within that, project progress to be consistent and across an agreed set of attributes
- summaries of return on investment for all projects using specified modelling protocols that estimate changes in productivity for key species and habitats.

12.2 Monitoring, modelling and mapping outputs on a sound science base

To assess relative return on investment and to demonstrate to the community the benefits of all works a set of consistent output indicators are required that also reflect likely long-term outcomes for overall estuarine and nearshore health and productivity. During Year 1 in partnership with Fisheries Research and Development Corporation and lead science teams from across Australia it is proposed two sets of metrics be developed and then used in all project assessment, communication and reporting activities.

12.2.1 Modelling indicators of increased fishery productivity

A modelling protocol for productivity improvements that accompany change of estuarine and wetland conditions and connectivity will be developed and will entail modelled metrics for high profile and high value species. Examples would include:

- Barramundi (especially juveniles – Year 1 and 2 age class) as an indicator of fresh to brackish habitat repair and connectivity, especially tropical systems

- Mangrove Jack (juveniles – Year 1 and 2 age class) as an indicator of connectivity and habitat repair, both tropical and subtropical systems
- Banana Prawns and School Prawns (will need to be normalised against previous years rainfall) so probably upper and lower estimates as a function of wet and dry years as an indicator of overall estuarine habitat repair – both tropical and temperate
- Mulloway (especially early juveniles – Year 1 and 2 age class) as an indicator of estuarine habitat and connectivity, subtropical through to temperate estuaries, including Murray River estuary and Coorong lagoons
- Mud Oyster, Sydney Rock Oyster and Mussel reefs – with emphasis on the survival and growth rates of these proposed reefs and in later years including an analysis of the multi-species fish populations starting to utilise these renewed habitats
- a series of lower order piscavores to best represent the improved biomass of the entire food chains (e.g. River and Sea Garfish, Herrings and Sardines).

These suggested well-known species are surrogates for overall marine biomass improvement. They also are the species for which there is well-documented life history knowledge and can be readily ground-truthed with sampling. Other species such as Coral Trout, while well understood in terms of their dependence on nearshore environments, by being in larval and post-larval phases while within estuaries are too difficult to readily sample especially by volunteer supporters of the initiative – members of recreational fishing clubs and professional fishers.

12.2.2 Mapping indicators of overall biodiversity improvement

Australia's estuarine and nearshore areas include a huge variety of species of plants, birds and animals. These are linked through complex flows and fluxes of nutrients, sediments, chemicals, sustaining microscopic communities that underpin food webs such as algae, bacteria and plankton and maintaining species important to the livelihoods and lifestyles of the Australian community such as fish, prawns and crabs. The best and most easily identifiable and monitored indicators will be actual wetland habitat. A modelling protocol for habitat improvements that accompany change of estuarine and wetland conditions and connectivity will be developed and will entail modelled metrics for the following plant assemblages:

- seagrass – estimated increased area/productivity/condition and recognising that seagrass beds do naturally alter in extent
- mangrove – estimated increased area/productivity/condition
- salt marsh – estimated increased area/productivity/condition
- fresh to brackish re-connections and therefore estimated increased waterway and wetland area available as a basis to infer improved productivity
- soft bottom – especially reconnected to the marine environment and therefore estimated increased area as a basis to infer productivity
- estuary hydrology – especially changes in tidal flows and improvements towards natural of freshwater flows, again as a broad indicator of improved ecosystem health.

12.2.3 Monitoring to cross-correlate the modelling and mapping

To accompany these modelled indicators of improvement, monitoring will be undertaken at all works sites. Monitoring will be done in coordination with science advice and will entail:

- Photo point monitoring – before, during and after the completion of works for the following three years. Undertaken at all sites.
- Sampling by netting and other means that compares the modelling protocols with real time changes, probably at least 75% of the works sites, if not all works sites, as their local communities will be interested with the results. Where possible community support will assist in this monitoring (e.g. professional fishing gear, recreational fishers). Concerns such as safety will preclude monitoring in some sites.
- Selective case study-type before and after bird census surveys for several sites, especially where there is a local active bird group.

12.3 Evaluating the success of the initiative

An evaluation of the overall benefits of the investment will be undertaken in Year 4/Year 5. This assessment will be against the initiative objectives and targets and aggregate the modelled, mapped and measured outputs such as fish and prawn productivity, improvement in key marine protected areas such as seagrass for dugong and prawn habitat, improvement in other biodiversity such as migratory waders, improvement in water management and flood control, and implications for community benefits such as fishing satisfaction and waterfowl observation.

This evaluation will also need to gauge 'what next' and will need to link in with those activities put in place to ensure ongoing stewardship and management of Australia's estuarine and nearshore assets – the legacy activities that hopefully will be self sustaining and not require further Australian Government investment.

The evaluation report will need to identify, based on program outcomes, the overall return on investment. By integrating this evaluation activity with the monitoring outputs and all the financial reporting, including all other cash and in-kind resources bought to bear over the five-year initiative an indication of return on investment by state and for the entire program will be achieved. This assessment of return on investment will help guide the design of any follow on Phase II.

12.4 Underpinning the initiative with research

Linking knowledge to works is essential if Australia is to maximise the returns on the investment in repairing Australia's estuaries. Following are a broad set of potential topics that would benefit from further research:

12.4.1 Ecosystem ecology and responses

Estuary event management for landscape optimisation

Undertake multi-objective analysis of selected flood-prone systems such as southern Queensland (e.g. Mary River) and a northern New South Wales river (e.g. Clarence) to understand how best to optimise floodplain management across multiple land uses and objectives. For this study good hydrographic models are needed as a base. The research would establish how best to utilise wetlands, levees, estuary, dredging, flood infrastructure and so on for the multiple objectives of fisheries, biodiversity, water quality, flood protection and agriculture.

Output – Multi-criteria analysis method for optimising outcomes for the landscape, both human and ecological benefits.

Tidal hydrology and repair of estuary morphology

Sedimentation from catchment loads and infrastructure such as training walls, crossings and causeways has changed estuary tidal hydrodynamics and therefore net primary productivity. Repair dredging (e.g. Manning entrance plus many within-estuary sites), changes to historic training walls (e.g. Middle Wall, Clarence; Googleys Lagoon, Camden Haven) and changes to causeways and sedimentation patterns (e.g. Clarence – Shallow Channel, Romiaka Channel, Oyster Channel and Palmers Channel feeding Lake Wooloweyah) may all be useful. In thinking through improved tidal ventilation it will also be essential to think through how such works would improve wetland productivity and provide repaired habitat for seagrass re-establishment.

Output – design guidelines for repair of selected estuaries that also provide a model for application in other estuaries.

What is the estuary carrying capacity and how should this be used to improve fisheries management, including resource sharing?

Recreational effort is increasing inshore, particularly around major urban centres. Variable climate plays out in fish population fluctuations. If the carrying capacity is known then the impacts of major development will also be better defined and may lead to better development decisions. Linking fishing effort to stock available should also make fisheries more profitable.

Output – changed paradigms for fishing effort management, resource sharing and development approvals.

Priority locations – do they exist for Australian inshore species?

New Zealand research suggests some species may have priority location nursery habitats for up to 80% of their stock in a particular estuary, later dispersing widely. Does this occur in Australia (possibly Murray?) and if so, how would we best protect these extra important areas.

Output – better understanding of locational preferences and a basis for improved population management.

The freshwater–brackish–saline interface and net primary productivity

Brackish, intermixed systems are the most productive. How can we change catchment hydrographs back towards a more sinusoidal long recession curve-mixing system?

Output – better understanding of catchment hydrology links to net primary productivity, especially important for more regulated estuary systems.

Larval recruitment – has it been influenced by training walls and other structures?

Major wave-dominated estuaries pre-settlement were a maze of entrance sand spits. Much of the spawning (Mullet, Bream, Whiting) presumably occurred here with a high probability of rapid larval recruitment back into the estuary. Where do these species spawn now and can any manipulation of estuarine entrance areas assist higher recruitment back into estuaries?

Output – Better understanding of larval dispersal and opportunities to enhance recruitment to nursery areas.

12.4.2 Human interactions with estuarine ecosystems

Mixing the public and private benefits of estuary and wetland conservation – should fishers pay farmers or what?

Much of the challenge with estuary management lies in the public benefits that estuaries provide compared to the private benefits that come from land development. On Australia's floodplains development has been for private benefit, especially agriculture and grazing with increasingly urban development at the expense of the more public benefits of biodiversity, water quality and fisheries. Fisheries can lead to private benefit when professionally harvested for food or caught as part of recreation and lifestyle. How can these various benefit streams be bought together to ensure ongoing investment in estuary repair and management?

Output – Exploration of the opportunities for cross-subsidisation between public and private beneficiaries; better understanding of the externalities to our economic systems.

Sustainable fisheries management – should this be based on habitat condition and the habitat's potential for productivity?

Historically fisheries management has been preoccupied with management of single species through input controls such as fishing gear, size of boat, temporal closures etc. Fisheries management is gradually moving towards output controls based on the presumed, sometimes modelled and monitored, size of the population available for catch and therefore some estimate of 'sustainable yield'. Yet with well over 70% of all professional catch Australia-wide having an estuary-dependent phase in their lifecycle, these estimates of sustainable yield should also be taking account of factors at the ecosystem rather than species level. For example, estuary condition, improvement or decline provides a basic level upon which, through repair we can increase sustainable yield, or as is currently the case, do nothing so that sustainable yield will ultimately likely decline.

Output – Linking habitat condition to sustainable yield should give further impetus to better manage our estuarine and nearshore habitats, or at least foster understanding that further degradation has a direct impact on seafood security.

Fostering local stewardship – what works?

Recreational fishers have a lead role in estuary and nearshore management, repair and protection in both the UK and USA. Australia has over 3.4 million recreational fishers. Galvanising this sector of the population to a lead role in estuary management, repair and protection will reduce the need for ongoing government investment.

Output – Schemes and engagement models in place overseas could be explored to provide a toolbag of possible schemes for Australia for the various recreational fisher groups to consider.

Understanding and valuing the multiple outcomes that accrue from good estuary management

Multiple benefits besides fishery productivity accrue from good estuary management including flood control, coastal biodiversity, extreme climate event buffering, water quality, landscape and general public amenity and carbon mitigation. Most of these are public benefits. Understanding these and their overall value can influence public investment and community behaviour.

Output – A better understanding of the role and benefits of improved estuary management.

Policy, legislation and regulations – what works?

Various states have differing levels of environmental policy pertaining to estuaries and wetlands. That this initiative in estuary repair has been developed attests to their aggregate failure in maintaining estuary productivity for the Australian public good and seafood food security.

Output – An evaluation of the various approaches to policy, legislation and regulations and the development of model provisions may be the first step towards improved policy in all states.

Resource sharing within repaired estuarine environments

Estuaries by virtue of their location and being the more sheltered easily accessible waters are generally areas of high recreational effort. Professional catch also has a high estuarine dependence. Re-building such as mussel or oyster reefs in Port Phillip or Moreton Bay is likely to lead to increased recreational pressure. How can any increases in productivity be best shared? If recreational fishing was to say fully fund a mussel reef then should all the benefits accrue to recreational fishing. Is this a vehicle whereby increased private sector investment in repair could be encouraged?

Output – Exploration of the various options for resource sharing and how it might link to investment in estuary repair.

12.5 Indicative budget components

A suggested budget allocation to broad cost areas follows. Most importantly, finite dollar costs aside, this table indicates the relative emphasis in effort that is believed essential to implement this challenging initiative.

The proposed Australia-wide steering committee in close partnership with the Australian Government would oversight the application of all funds and any variation in expenditure from the agreed final budget.

Budget allocation to broad cost areas

	Cost ($M)	Proportion of total (%)
Planning– all aspects to ensure approvals, undertake surveys such as tidal penetration, document proposals and likely return on investment of each proposed project	$21M	6
Works, generally under some form of tender/contract arrangements with the owner – including fish passage, estuary and wetland repair and complementary works to ensure smarter floodplain and estuarine ecosystem management	$238M	68
Monitoring based on sound science – covering habitat importance, repair and fisheries re-establishment priorities and habitat-population protocols to estimate likely improvements in productivity and selected monitoring to ground-truth these protocols. Will need to recognise climate variability and its influence on populations	$24.5M	7
Reporting progress – summarising the outputs and longer term likely benefits/outcomes of the total investment, undertaken annually and including an evaluation of progress in Year 4.	$10.5M	3
Program communication, legacy arrangements & marketing – building on existing communication activities, marketing to the broader community the value of proactive repair and management of estuarine and nearshore ecosystems, linking to the Australia-wide Habitat Network and designing and fostering the implementation of community led legacy arrangements. Also covers oversighting activities such as expert-based Australia-wide steering committee and program management activities	$17.5M	5
Policy development – fostering comparable policy and regulations in each state for estuarine and nearshore habitat protection, repair and for development offsets	$17.5M	5
Researching cost-effective repair and priority investments – building on existing knowledge of the estuarine dependence and preferred habitats of key species to predict priorities for all follow on works and activities post this five-year investment	$21M	6
TOTAL	**$350M**	

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Key contributors

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