Corner Inlet **Water Quality Improvement Plan** 2013

CornerInletConnections
Committed to a Healthy Corner Inlet

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Accessibility

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This document acknowledges the Aboriginal Traditional Owners of the Corner Inlet catchment and recognises their connection to their ancestral lands and waters.

Contents

Executive Summary

Corner Inlet supports outstanding environmental values that have been recognised through its listing as a wetland of international importance under the Ramsar Convention. Its tributaries also have important economic, environmental and social values.

Due to its size and diversity of habitats, Corner Inlet supports many nationally and internationally significant aquatic and semi-aquatic plant and animal populations. Corner Inlet, including the area known as Nooramunga, is the most southerly marine embayment and tidal mudflat system of mainland Australia. The area also has significant cultural value to the Traditional Land Owners, the Gunaikurnai, Bunurong and Boon Wurrung people.

The inlet and surrounding catchment supports commercial fishing, tourism and recreation activities. The region has a strong agricultural history, including beef, mixed grazing enterprises and dairy, and supports production forestry.

The condition and extent of important habitat including seagrass meadows, sandflats, mangroves and saltmarsh are threatened by nutrient and sediment pollution that results mostly from catchment land uses.

The Corner Inlet Water Quality Improvement Plan (WQIP) has been developed to significantly improve the quality of water entering the Corner Inlet Ramsar Site in order to protect its unique and significant values. Achieving this aim requires a measurable reduction in the level of nutrients and suspended sediment loads from surrounding catchments.

The WQIP provides a consolidated understanding of the water quality issues within the Corner Inlet catchment, particularly those related to sediment, nitrogen and phosphorus. Of all the values of and within the Ramsar site, seagrass was selected as a critical ecosystem component that is sensitive to impacts from elevated loads of nutrient and sediment. As well as being likely to adversely affect the extent and condition of seagrass (and other key habitats), there are probable flow-on impacts from nutrient and sediment pollution on other important ecosystem components including fish and bird populations. The WQIP has been based on the assumption that reducing sediment and nutrient loads entering the Ramsar site will lead to an improvement in the condition and extent of seagrass within Corner Inlet.

Actions and management practices to reduce sediment and nutrient loads have been selected using models and decision-support tools based on available science, current knowledge and data, and supplemented by comprehensive economic considerations. Past and current studies have been important sources of information.

The Albert River and the Jack River catchments contribute the greatest amount of sediment and nitrogen to Corner Inlet, with the Franklin, Agnes and Tarra Rivers and the Western Tributaries also being important. The Western Tributaries contribute the most phosphorus to Corner Inlet, followed by the Jack and Albert catchments.

In addition to considering amount of nutrient and sediment transported, actions to reduce catchment nutrient and sediment inputs into Corner Inlet should consider other issues including impacts on environmental flow and the degree of acceptability and adoptability of management actions to local landholders. Impacts relating to climate change, such as increased frequency of extreme storm events, reduced water availability, sea-level rise and increased shoreline erosion, are also important. While not able to be considered with the available information for this WQIP, as knowledge improves, climate change factors will be a major future consideration.

Water quality objectives set for the WQIP have been based on ‘SMART’ principles; those that are specific, measurable, attainable, realistic and time-bound. The water quality objectives are as ambitious as possible in order to protect the environmental values of Corner Inlet, whilst balancing the needs to maintain income from agriculture and other social, economic and environmental enterprises.

Yanakie farmland with a view across Corner Inlet to the Hoddle Range. Photo – InDetail Comms & PR.

The agreed and achievable WQIP targets are:

- Corner Inlet catchments, at least 15% total nitrogen, 15% total phosphorus, 10% total suspended sediment reduction by 2033
- Nooramunga catchments, at least 10% total nitrogen 10%, total phosphorus, 5% total suspended sediment reduction by 2033.

State-of-the-art techniques, including integrated bioeconomic modelling and INFFER (Investment Framework for Environmental Resources) analyses were used as the basis for assessing the costs and benefits of achieving water quality objectives using available scientific, expert and local knowledge.

The Corner Inlet WQIP sets an Australian benchmark in terms of realistic costs to achieve water quality improvements. Given its high environmental values and relatively small catchment area (approximately 2,300km2), protecting the values of Corner Inlet will be easier than for many other threatened national water quality hotspots.

To achieve the most cost-effective nutrient and sediment load reductions, extensive actions are required in all river catchments flowing to the embayment. The largest reductions are predicted to be required from the Western Tributaries (for nitrogen and phosphorus), the Albert and Jack catchments (nitrogen, phosphorus and sediment), and the Franklin and Agnes catchments (sediment).

Given that agriculture makes up 50% of catchment land use, and because of the scale of the actions required to meet identified water quality objectives, the WQIP identifies that payments will need to be made to landholders to encourage the adoption of Best Management Practices (BMPs). The WQIP assumes that payments to landholders will need to be based on lost opportunity costs to production to offset profit losses. In addition, continued works will be required for traditional waterway management activities, including gully and streambank rehabilitation. The costs to achieve and maintain water quality objectives are estimated to be in the order of $8.95m/year for direct works, with additional funds required to enable activities and investigations to fill identified knowledge gaps. Should this level of funding not become available, the West Gippsland CMA and partners will do what they can to work towards the objectives with available funds, political and community will.

Strong partnerships within the region are crucial to the implementation of both on-ground works and the associated enabling activities identified in the WQIP. The West Gippsland CMA and the Corner Inlet Connections Program partnership, involving government agencies (national, state and local), industry, landowners and the community, will oversee the implementation of the WQIP.

As well as focusing on the short to medium term, long-term (30+ year) thinking is required regarding the vision for Corner Inlet. If it is determined that aspirational-level water quality targets are required to protect Corner Inlet, particularly in the context of agricultural intensification trends, the values of Corner Inlet (and many other national water quality hotspots) will be difficult to maintain. These trends, combined with predicted future impacts from climate change, pose considerable challenges for maintaining the ecological integrity of Corner Inlet.

It is important to begin a discussion with the community and public funders about the trade-offs involved between maintaining environmental values and productive land use in the catchment. Such discussions will ensure that active decisions can be made and will provide the community with information and time to think about the trade-offs involved. Institutional arrangements, assembling a stronger evidence-base, development of appropriate metrics and innovative market-based approaches (such as nutrient trading schemes) are also important elements to investigate for achieving beneficial outcomes at low cost and within the limits of community and political acceptability.

1. Introduction

1.1 The need for a water quality improvement plan

A World Renowned Ramsar Wetland

Corner Inlet supports outstanding environmental values that have been recognised through its listing as a wetland of international importance under the Ramsar Convention. The Corner Inlet Ramsar Site includes the areas known as Corner Inlet and Nooramunga and is the most southerly marine embayment and tidal mudflat system of mainland Australia.

Corner Inlet is valued as:

- a feeding, nesting and breeding area for thousands of waterbirds and one of the most important areas in Victoria for resident and migratory and shorebirds
- a unique system of barrier islands and tidal mudflats
- the world's most southerly population of White Mangrove *(Avicennia marina)*
- the largest area of Broad-leafed Seagrass *(Posidonia australis)* in Victoria
- habitat to more than 390 native plant and 160 native animal species and a diversity of marine invertebrates
- an area of outstanding fish habitat that contributes to commercial fishing, tourism and recreation opportunities in the region.

These values are highlighted in the Ecological Character Description (ECD) for Corner Inlet (BMT WBM 2011).

People and Production

Situated in south-eastern Victoria, the Corner Inlet catchment is approximately 2,300km2 in size and stretches along the South Gippsland coastline from Woodside to Wilsons Promontory. It is a highly productive area, supporting dairy, beef and mixed grazing enterprises and significant areas of production forestry. The region supports a significant Victorian commercial bay and inlet fishery, including 18 licensed commercial fishers.

Impacts Upon Habitats

The health and extent of the Corner Inlet Ramsar Site's important habitats, such as seagrass meadows, sand flats, mangroves and saltmarsh, can be affected by nutrient and sediment pollution.

This pollution has an impact on the delicate balance of organisms that rely on these habitats. Over recent years, changes in local seagrass health and distribution and the presence of algae have been of concern to local fishers, recreational users and local community members.

Protecting Corner Inlet's Ecological Values

To help to protect the ecological character of this significant wetland, the West Gippsland Catchment Management Authority (WGCMA), with funding provided by the Australian Government, is developing a Water Quality Improvement Plan (WQIP) for the Corner Inlet catchment.

This plan will guide investment in on-ground actions within the catchment to address water quality issues in the Corner Inlet and identifies the research and monitoring required to improve knowledge about the site. The plan has an emphasis on working with local communities to achieve the identified priorities.

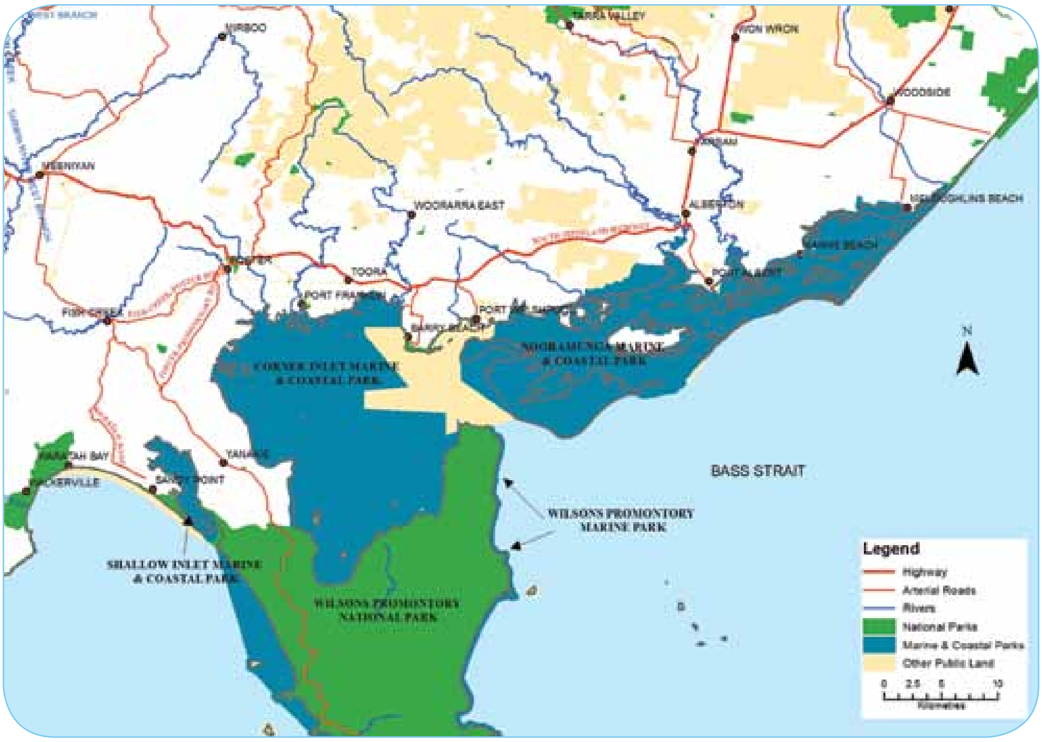


Figure 1.1.1 Corner Inlet Ramsar Site (including coastal and marine park boundaries and surrounding catchment)

1.2 Overview and aims

Understanding the Corner Inlet Catchment

The Corner Inlet Water Quality Improvement Plan (WQIP) provides a strategic approach to reducing sediment and nutrient loads to the waterways, estuaries and marine environments of the Corner Inlet Ramsar Site. It is supported by a detailed 8-year plan of on-ground actions.

The WQIP provides a consolidated understanding of the water quality issues within the Corner Inlet catchment, particularly sediment, nitrogen and phosphorus and their sources.

The actions and best management practices contained in the plan have been selected using models and decision-support tools based on best available science, using the most current knowledge and data, and supplemented by comprehensive economic considerations.

Providing Clear and Achievable Advice

The management practices described in the plan have also been selected using scientific models and decision-support tools based on current knowledge and data. Where limitations in knowledge and data are known they have been identified and measures put in place to fill these gaps. The aim of the WQIP is to provide clear and achievable advice about the best-possible mix of management tools and actions to implement in order to move towards reduction targets for nutrient and sediment loads from the catchment over the next eight years and in the longer term.

Raising Awareness and Taking Action

It is expected that the WQIP will be a tool for raising awareness of water quality issues in the catchment and their impacts on the condition of the Corner Inlet Ramsar Site. It will also start a long-term discussion about the degree to which on-ground actions and best management practices within the catchment can protect the waterways, estuaries and marine environments of the Ramsar site.

Involving Community and Stakeholders

The WQIP has been developed with input from the local community and key stakeholders in the catchment.

It is expected that the WQIP will guide activities of Local, State and Federal Government agencies as well as interested individuals, community groups and organisations.

1.3 Scope

What Constitutes Corner Inlet?

Throughout the WQIP, several terms are used to refer to or describe the Corner Inlet Ramsar Site and its surrounding catchment.

- **Corner Inlet Ramsar Site (the Ramsar site)**

  The whole of the Ramsar site will be referred to as the Corner Inlet Ramsar Site or the Ramsar site and references within the marine areas will be Corner Inlet for the western part of the Ramsar site and Nooramunga for the eastern part. The Ramsar site includes the areas of Corner Inlet and Nooramunga Marine and Coastal Parks and the Corner Inlet Marine National Park (refer to figure 1.1.1). Also refer to Section 2.1 for a broader description.

- **Corner Inlet**
  Unless otherwise stated, Corner Inlet refers to the collective water body that is Corner Inlet and Nooramunga.

- **Corner Inlet catchment**
  Unless otherwise stated, this term refers to the land and waterways that are adjacent to the entire Corner Inlet Ramsar Site.

- **Corner Inlet and Nooramunga**
  These are the two halves of what constitutes the Corner Inlet Ramsar Site. They have very different physical features and hydrodynamics and the WQIP acknowledges this through the development of separate objectives and works programs for each.

- **The catchments of Corner Inlet and Nooramunga**
  On occasion, it may be necessary to refer separately to the areas that constitute the catchments of the two halves of the Corner Inlet Ramsar Site:

  - Corner Inlet catchment – the land adjacent to the western part of the Corner Inlet Ramsar Site

  - Nooramunga catchment – the land adjacent to the eastern part of the Corner Inlet Ramsar Site.

Sediment and Nutrient Loads

The Corner Inlet WQIP addresses the specific threat from increased loads of nutrient and sediment to the estuaries, waterways and marine areas of the Corner Inlet Ramsar Site.

All other planning arrangements relating to the management of the Ramsar site are described below.

Other issues in Corner Inlet and Nooramunga

At a federal level the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) establishes a framework for managing Ramsar sites. This includes the preparation of a Ramsar Site Management Plan. A number of Ramsar Site Management Plans are currently due for renewal in Victoria, including Corner Inlet.

In Victoria, the Victorian Waterway Management Strategy brings wetlands, rivers and estuaries into a single planning framework. Regional implementation of the Victorian Waterway Management Strategy will occur through the development of ten Regional Waterway Strategies (formerly River Health Strategies).

To avoid duplication of planning activities, it is anticipated that the Regional Waterway Strategies will, where possible, align with any existing planning requirements for waterways.

The Corner Inlet WQIP is based on available data and modelling. As such it has not been able to account for climate change impacts. It is acknowledged that future impacts from climate change on the coastal and estuarine environments of Corner Inlet could be significant. Notwithstanding this, the proposed actions in this WQIP are worthwhile and likely to be effective in protecting the values from the impacts of excess nutrient and sediment. As the ability to predict impacts from climate change improves, this knowledge could help inform adaptive management measures for the Corner Inlet WQIP.

Regional Waterway Strategy

The Victorian and Australian Governments have agreed that the renewal process for Ramsar Site Management Plans will occur through the development of the ten Regional Waterway Strategies. Within the Regional Waterway Strategy, Ramsar site planning will provide for the conservation and wise use of Corner Inlet so as to maintain and, where practical, restore the ecological values that are the basis for its recognition as a Ramsar site.

The planning will provide a framework and the necessary information to make sure that decisions regarding the use, development and ongoing management of Corner Inlet are made with full regard to the Ramsar values.

Within the Regional Waterway Strategy, planning for the Corner Inlet Ramsar site will:

- set out the Ramsar site management planning arrangements
- describe the values of the Ramsar site
- set long-term resource condition targets for the Ramsar site
- describe the threats to the values of the Ramsar site
- describe how the ecological character of the Ramsar site will be monitored, evaluated and reported
- develop a work program for the Ramsar site.

1.4 Approach and supporting projects

The development of the Corner Inlet WQIP broadly involves the following inter-related activities:

1. Capturing current knowledge
2. Establishing water quality dependant environmental values
3. Developing water quality objectives that integrate land management, catchment water quality and marine ecosystem considerations
4. Identifying appropriate management strategies to achieve water quality objectives
5. Developing a works program, and modelling, monitoring and adaptive management strategies
6. Preparing a reasonable assurance statement that describes how implementing the plan will achieve the plan's objectives and any policy or legislative impediments to implementation and long term protection of the ecosystem.

This WQIP has been developed in accordance with the Framework for Marine and Estuarine Water Quality Protection (DEWHA, 2002), which was developed as a nationally consistent approach to protecting the marine environment from the effects of land-based pollution. The key stages of the WQIP development are set out in figure 1.4.1.

The Investment Framework for Environmental Resources (INFFER) is a structured decision-making process to assess the benefits and costs of making investments in the environment. It applies benefit:cost analysis thinking to the environment by taking into account all factors that need to be considered in making cost-effective and transparent decisions. The INFFER process uses all available and relevant knowledge and information (science, expert opinion), to calculate a benefit:cost ratio. It offers a published and proven method, providing an internationally state-of-the-art approach to environmental decision-making.

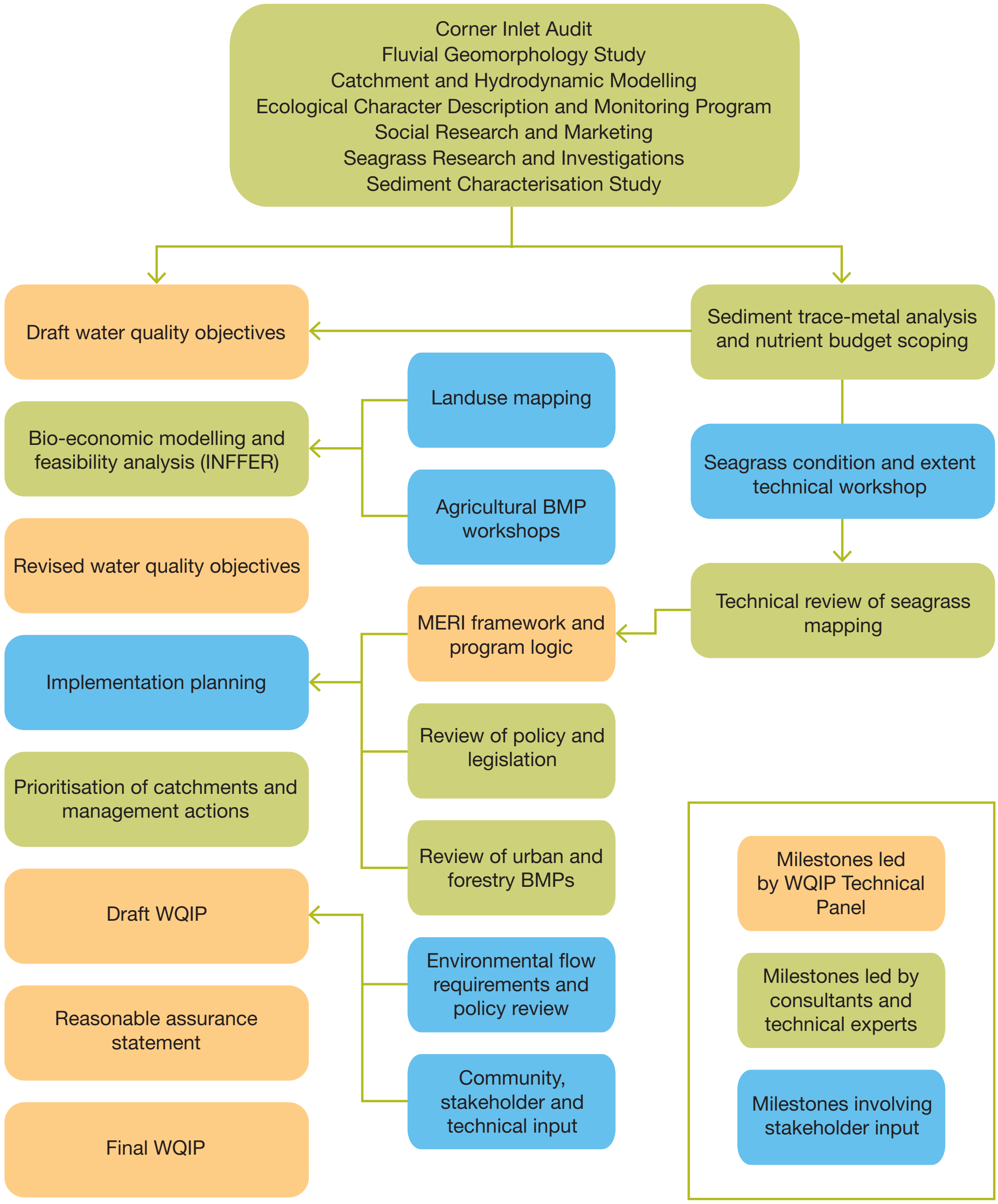


Figure 1.4.1 Key stages for developing the Corner Inlet WQIP

In 2005, the WGCMA and the Gippsland Coastal Board commissioned CSIRO (Malloy et. al., 2005) to undertake an environmental audit of the embayment of Corner and Nooramunga and their surrounding catchments. The audit concluded that the values of the Ramsar site were threatened by inflows of nutrient and sediment from the catchment.

Following the CSIRO findings, the Corner Inlet Ramsar Site was included on the list of National Water Quality Hotspots by the Australian Government. The listing of the area as a water quality hotspot enabled funding to be obtained for studies into the environmental values at risk from poor water quality, and allowed for the collation of baseline data to understand and address water quality issues.

The CSIRO audit (Molloy et. al., 2005) and the Corner Inlet Ecological Character Description (BMT WBM, 2011) point to a threat to Corner Inlet from elevated loads of nutrient and sediment within rural runoff. Potentially, it has an impact on seagrass through reduced light availability due to increased turbidity and/or epiphyte or algal growth. This, in addition to anecdotal evidence from commercial fishers of loss of seagrass as far back as 1972 (Poore,1978) and perceived relationship between these changes and poor water quality from the catchment, have been key drivers for work to date in Corner Inlet.

Support for investigations into catchment water quality has been underpinned by the assumption that reducing sediment and nutrient loads from catchment sources will lead to an improvement in the condition and extent of seagrass in Corner Inlet and Nooramunga.

There have been many studies that have informed the development of the Corner Inlet WQIP. Some of these studies were specifically commissioned to support the WQIP, whilst others were already underway or had other objectives. Collectively, these studies have focused on five essential areas, which are:

1. Condition Assessment
2. Seagrass Research and Investigations
3. Catchment Research and Investigations
4. Catchment and Water Quality Monitoring
5. Works Planning.

Table 1.4.1 outlines the main reports that have informed the development of the WQIP.

Aerial view of Port Albert. Photo – WGCMA.

Table 1.4.1 Important projects/reports informing the development of the Corner Inlet WQIP

Corner Inlet Condition Assessments	Seagrass Research and Investigations	Catchment and Inlet Research and Investigations	Catchment and Water Quality Modelling	Works Planning
Malloy et. al, 2005, **Corner Inlet Environmental Audit** WGCMA and Hyder 2009 **Catchment Condition Report** BMT WBM, 2011, **Corner Inlet Ramsar Site – Ecological Character Description**	Brett Lane & Associates, 2008, **Corner Inlet Ramsar Site – Ecological Monitoring Program** Ball et. al., 2010, **Victorian Multiregional Seagrass Health Assessment, 2004-2007** Monk et. al., 2011, **Corner Inlet and Nooramunga Habitat Mapping Project** Kirkman, 2013, **Historical Changes in Seagrass Extent and Condition in Corner Inlet and Nooramunga**	Alluvium, 2008, **Fluvial Geomorphology of the Tributaries of the Corner Inlet Ramsar Site** Coastal Environmental Consultants, 2008, **Corner Inlet Sediment Characterisation Study** McLean and Jones, 2012, **Corner Inlet Sediment Trace Metal Study** Boon, 2012, **Corner Inlet Nutrient Budget Scoping**	Water Technology, 2008, **Corner Inlet Sediment and Nutrient Modelling** Water Technology, 2011, **Corner Inlet Modelling Report – Modelling Update**	Alluvium, 2009, **Draft Report: Corner Inlet Decision Support System, Implementation Plan** WGCMA, 2012, **Water Quality Objectives Background Paper, and Environmental Flow Objectives Briefing to Technical Panel**

1.5 Governance and stakeholder engagement

The development of the Corner Inlet WQIP was led by the WGCMA with funding from the Australian Government.

The Australian Government and the WGCMA jointly appointed an independent Technical Panel. The Panel oversaw many of the scientific studies that informed the development of the plan and were responsible for approving the plan’s key outputs.

In addition to the Technical Panel, the WGCMA worked with the Corner Inlet Steering Committee (CISC). This committee has experience in providing oversight to the supporting projects and in the planning and delivery of natural resource management activities within the Corner Inlet Ramsar Site and its catchment. The CISC is made up of government agencies, community organisations and industry bodies with an interest in the natural resources of Corner Inlet and its surrounding catchment (figure 1.5.1).

Community and stakeholder engagement are implemented under the auspice of the CISC through the ‘Corner Inlet Connections’ brand. Corner Inlet Connections aims to raise awareness within the local community of the connection between the condition of the catchment and the condition of the Corner Inlet Ramsar Site. Activities including newsletters, press articles and feature, reports, canoe tours, field visits and community days all assist in meeting this aim and have taken place during the development of the Corner Inlet WQIP.

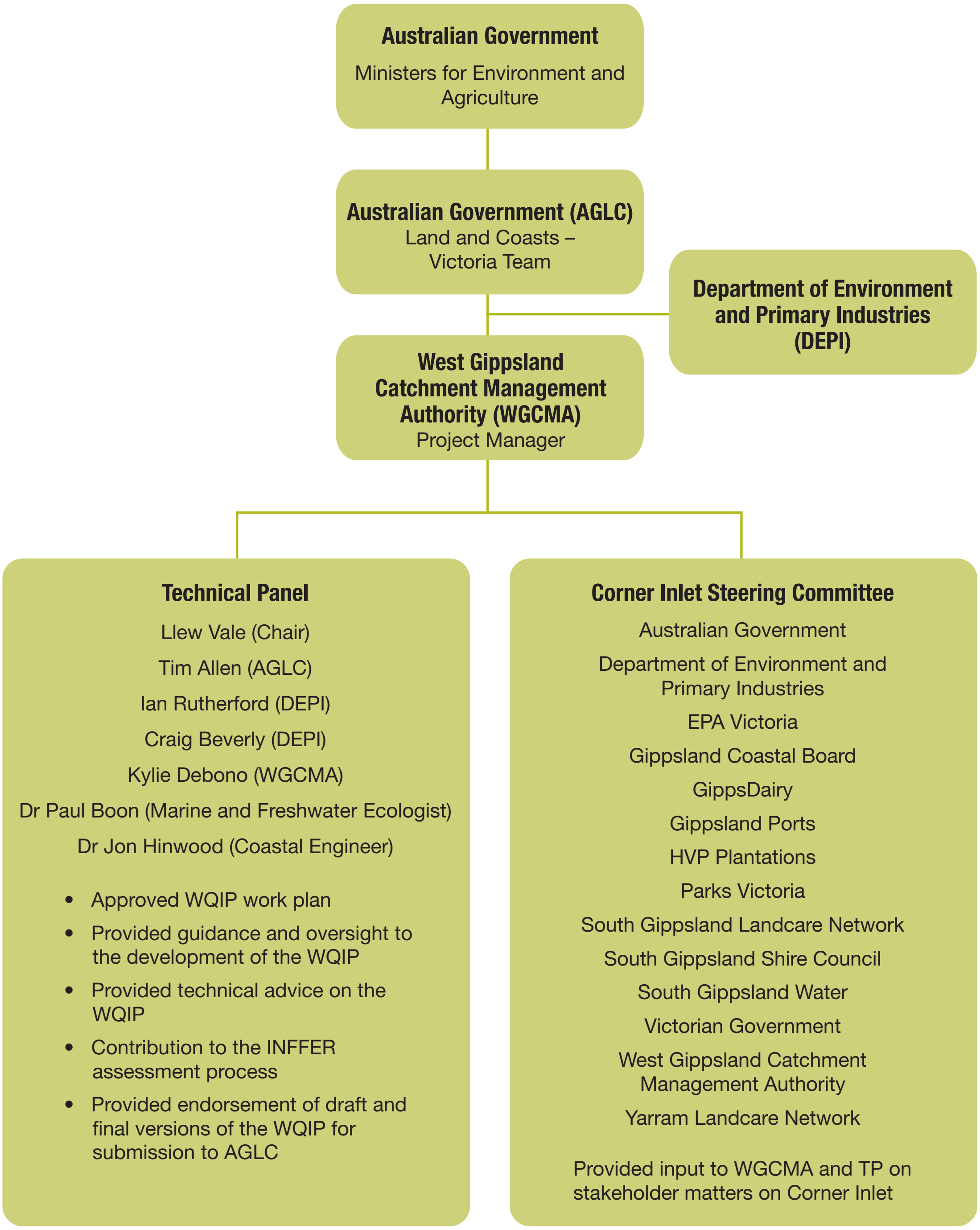


Figure 1.5.1 Water Quality Improvement Plan Governance and Engagement Structure

2. Catchment Characteristics

2.1 Location and landscape

Corner Inlet Ramsar Site

The Corner Inlet Ramsar Site is located approximately 260km south-east of Melbourne, near Wilsons Promontory in Victoria, figure 2.1.1. It includes the areas of Corner Inlet and Nooramunga Marine and Coastal Parks and the Corner Inlet Marine National Park.

The 67,186ha Corner Inlet Ramsar Site is Victoria's third largest and southern-most embayment and is dissected by a network of deep tidal channels. These channels drain and fill from the inlet's entrance point to Bass Strait in the east of the embayment and provide access to four small ports – Port Franklin, Port Welshpool, Port Albert and Barry Beach.

The Corner Inlet Ramsar Site incorporates an area of approximately 630km^2 of which approximately 540km^2 is water, sand and mudflats with the area remaining accounted for by islands and fringing wetlands (Parks Victoria, 2005).

Corner Inlet Catchment (including Nooramunga)

With national parks, waterways, farmland and coast, the land surrounding Corner Inlet is a place of natural beauty, productivity and internationally recognised environmental values.

The catchment surrounding the Corner Inlet Ramsar Site is bound to the north by the Strzelecki Range, with the Hoddle Range forming the north-west boundary.

The catchment occupies an area of 2300 km^2 and curves around the inlet from Woodside to Wilsons Promontory. The landscape is characterised by steep slopes and short gullies and the inlet is bordered by a narrow crescent of undulating coastal plains at the foot of the hills.

Corner Inlet supports important areas of coastal saltmarsh vegetation and mangrove, including the world's most southerly occurrence of White Mangrove. Its upper catchment, high in the Strzelecki Range, has stands of tall, wet forest and pockets of both cool and warm temperate rainforest still intact (but much reduced from their pre-European extent), mostly preserved in Tarra-Bulga National Park.

The Corner Inlet Ramsar Site is fed by a system of waterways stretching from the Strzelecki and Hoddle Ranges, through fertile countryside, to the coast. Collectively known as the Western Tributaries, a number of small streams, including Old Hat, Poor Fellow Me, Dead Horse, Silver, Golden, Stockyard and Muddy Creeks, flow into the Ramsar site. Larger freshwater flows from this area come from the Franklin and Agnes Rivers. To the east, and draining to Nooramunga, are the Bruthen, Nine Mile and Shady Creeks and the Jack, Albert and Tarra Rivers (figure 2.1.2).

The mountainous northern coastline of Wilsons Promontory National Park, with its iconic granite formations and diverse vegetation communities, rises to form the southern boundary of the Corner Inlet Ramsar Site. Most of the northern part of Wilsons Promontory is classified as a wilderness zone. From these northern shores the Yanakie Isthmus and a number of islands within the embayment can be seen.



Left: Solitary corals. Photo – Parks Victoria.

Centre: A Silver Sweep amongst a sea sponge garden. Photo – Parks Victoria.

Right: The northern coastline of Wilsons Promontory. Photo – WGCMA.

Figure 2.1.1 Location of Corner Inlet

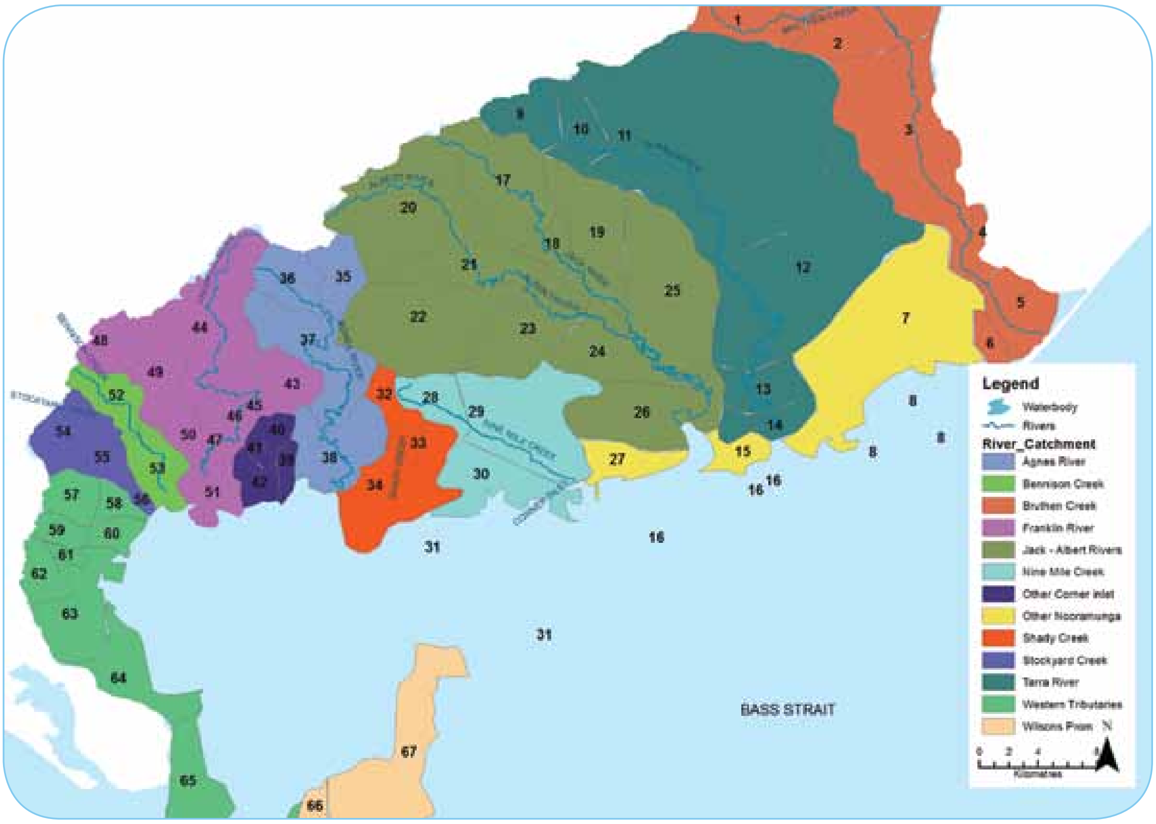


Figure 2.1.2 River Catchments of Corner Inlet and Nooramunga

N.B Numbers featured on this map relate to modelling units as described in figure 10.1.1 on page 72/73.

2.2 Geology and topography

The steep slopes of the Strzelecki and Hoddle Ranges dominate the topography of the Corner Inlet catchment. The hills contrast starkly with the coastal flats which, in the west, extend only several kilometres from the high tide mark and increase in extent towards the east of the catchment. Elevation varies from 300m in the headwaters of the Western Tributaries of Corner Inlet to more than 600m in the Tarra River catchment in the east.

The landforms, geology and sediment types of the catchment are a result of temporal and spatial variation in geologic processes. The catchment was formed by the uplifting of a major marine trough in the Palaeozoic era (545 to 251 million years ago), during which time the granites typical of Wilsons Promontory also formed. Subsequent infilling with sediments in the Mesozoic and Cenozoic eras (251 to 1.7 million years ago) and uplifting of the eastern highlands during the Pliocene period (5 to 1.6 million years ago) occurred. Sediments liberated from weathering of the highlands include clays, silts and sands that form the foothills of the catchment (Tertiary deposits) and coastal flats (Quaternary deposits ageing from 1.6 million years to present) (Molloy et. al., 2005).

The surrounding Strzelecki Range is predominantly underlain by Lower Cretaceous (approximately 76 million years ago) fluvial lithic sandstone, siltstone, minor conglomerate, coal and pockets of basalts.

The Corner Inlet catchment lies within the broader Gippsland Basin, which includes significant groundwater aquifers, coal deposits and substantial oil and gas deposits (both on and off-shore).

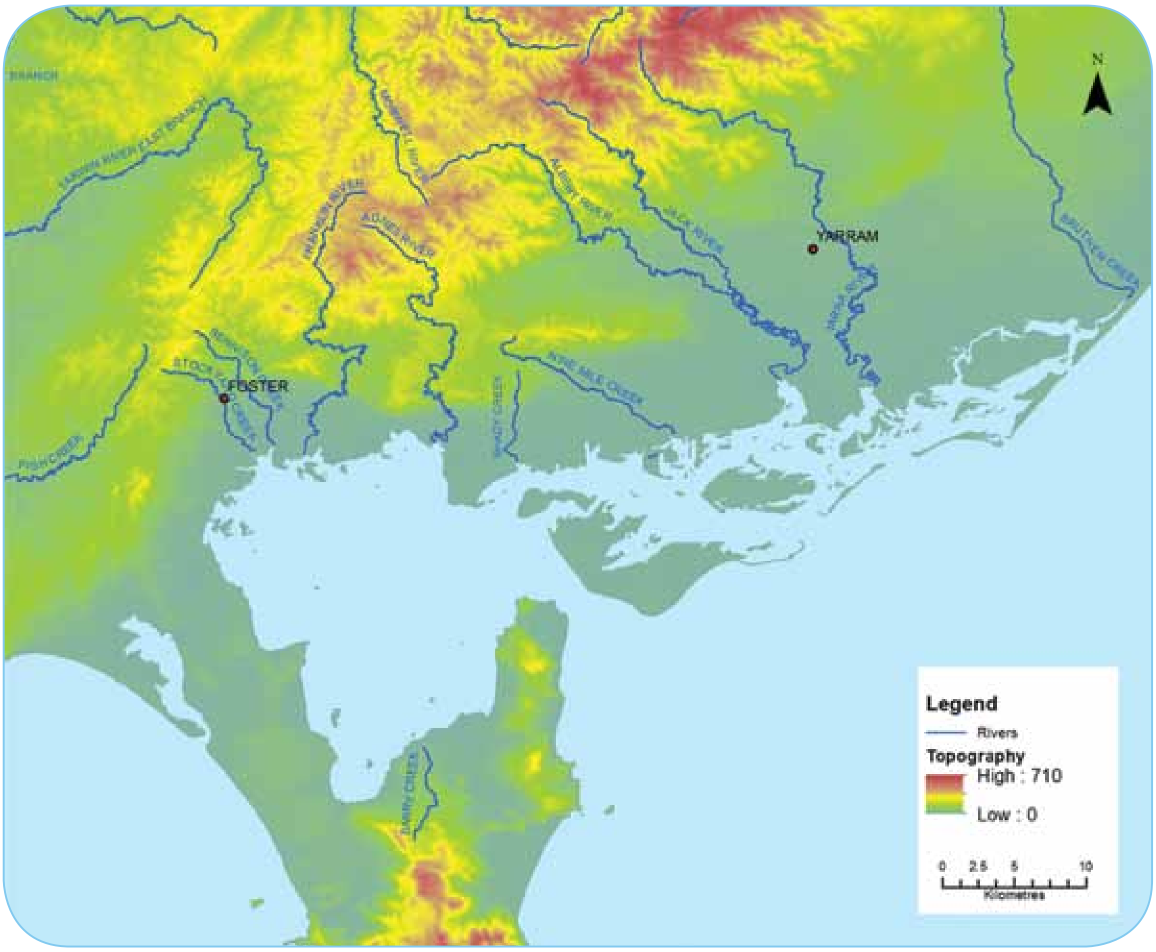


Figure 2.2.1 Topography within the Corner Inlet and Nooramunga catchment

2.3 Historical and current land use

The First Inhabitants

The Corner Inlet catchment has significant cultural value to the Gurnaikurnai people, with the Corner Inlet and Nooramunga area located on the traditional lands of the Brataualung people who form part of the Gunaikurnai Nation.

The Brataualung people travelled the waterways and estuaries of Corner Inlet in canoes as the coastline yielded abundant food including fish and shellfish and the eggs of wader birds. The forest provided materials for shelters, canoes, weapons, tools and other implements. The area has a large number of cultural heritage sites that provide significant information for the Gunaikurnai people of today about their history.

The Bunurong and the Boon Wurrung peoples also have areas of cultural significance in this region.

European Settlement

European colonisation of the catchment occurred as early as 1797, mostly associated with sealers and whalers. During the 1850s the ports within the embayment were used to service the mining industry of central Gippsland, as there was little opportunity for the development of agricultural, fishing or timber industries at this time.

In the 1870s the area was opened up for selection, with land bordering waterways being taken up first. Gold mining supported a large population at that time.

Originally, the steep slopes of the Strzelecki Ranges were thickly covered with both cool and warm temperate rainforest, featuring giant Mountain Ash, ancient myrtle beeches, Southern Blue Gums and tree-fern gullies. Reliable rainfall and fertile soil made the area particularly suitable for farming. Trees were harvested for timber and land was cleared to make way for cattle and sheep. The sowing of pasture grasses led to dairy becoming the dominant industry within the catchment. Native forestry and commercial fishing were also established in the area during this period.

With a history of sealing, whaling, timber milling and cattle grazing during the 1800s, Wilsons Promontory was also a mecca for field naturalists and intrepid hikers and campers. In 1898, the Victorian government temporarily reserved most of Wilsons Promontory as National Park. Its permanent reservation occurred in 1908, with the Yanakie area north of Darby River added to the National Park in the 1960s.

The early 1900s saw significant areas of the Corner Inlet catchment, particularly throughout the Strzelecki Range, protected as reserves. In 1986, these reserves were combined to form the Tarra-Bulga National Park.

Throughout the 1900s dairying remained a strong industry. In the 1920s soldier settlement led to further agricultural development and earthen sea walls were constructed along the coastline to protect agricultural land from tidal inundation and storm surges. After World War II, further soldier settlement occurred, particularly around the Yanakie area, which led to further clearing of native vegetation and the draining of wetlands for pasture. Bird (1993, figure 167 on page 243) shows the very large area of wetlands that have been cleared from around Shallow Inlet and the Yanakie region.

Significant growth in forestry operations occurred during the 1960s through APM Forests and the Forest Commission.

The Barry Beach Marine Terminal, near Port Welshpool, was established in 1968 as the main supply depot to service Bass Strait's oil and gas fields.

Agricultural land uses are an important value of the Corner Inlet catchment.
Photos – Left: Gillian Hayman, Centre: WGCMA, Right: InDetail Comms & PR.

Current Land Use

Current land use is mapped in figure 2.3.1 using updated data from 2012 regarding agricultural land uses. The proportion of each land use is shown in figure 2.3.2. Agriculture is the dominant land use activity in the catchment, constituting just over 50% of total land use. Dryland grazing (beef and sheep) comprises approximately 40% of total land use, with dairying comprising 10% (figure 2.3.2).

During recent times there have been two important changes to land use in the Corner Inlet catchment. The first is the consolidation of dairy farms into larger enterprises. The second is the increase in smaller scale dryland grazing and growth in lifestyle-type properties.

In 2006 dairying occurred on 42% of farms within the broader South Gippsland catchment (Day et. al., 2012). The decade to 2012 was difficult for dairy and dryland grazing due to drought and tight terms of trade. Day (2012) reports that in 2010 there were around 20 dairy farms in the Corner Inlet and Nooramunga catchment, and it was estimated there would be a further drop in the total number of dairy farms by 2012. By 2012 it was estimated that there were 122 dairy farms in the catchment that were adjacent to a tributary waterway of Corner Inlet and Nooramunga. Some dairy farms have converted to dryland grazing enterprises but other dairy farms have merged, resulting in farms that are larger and often (but not always) more productive (Day, 2012).

The productivity of beef and sheep industries during a similar time period was also volatile due to drought conditions. Strong productivity gains were recorded amongst larger producers and appear to be associated with increasing economies of scale, and greater use of feedlots to finish cattle. Medium producers achieved productivity growth by more efficiently using inputs. Small producers appear to have turned off stock and significantly reduced input requirements to try and avoid the consequences of higher input costs (MLA, 2008).

Production forest covers approximately 21% of the catchment. Eighty per cent of this is available for logging and the rest is set aside as buffers and reserve. On average 3% of production forest land is logged in any given year (Riverness, 2013).

Significantly, 28% of the catchment is protected and set aside as Parks and Reserves. This includes parts of the Wilsons Promontory National Park, Tarra Bulga National Park, Corner Inlet and Nooramunga Marine and Coastal Parks, Crown water frontages and numerous smaller reserves.

Estimates suggest urban growth and development in the catchment over the next 30 years will be minimal, averaging around 2.3% (Ipsos-Eureka, 2010). The current extent of urban areas is less than 1% of the total catchment area.

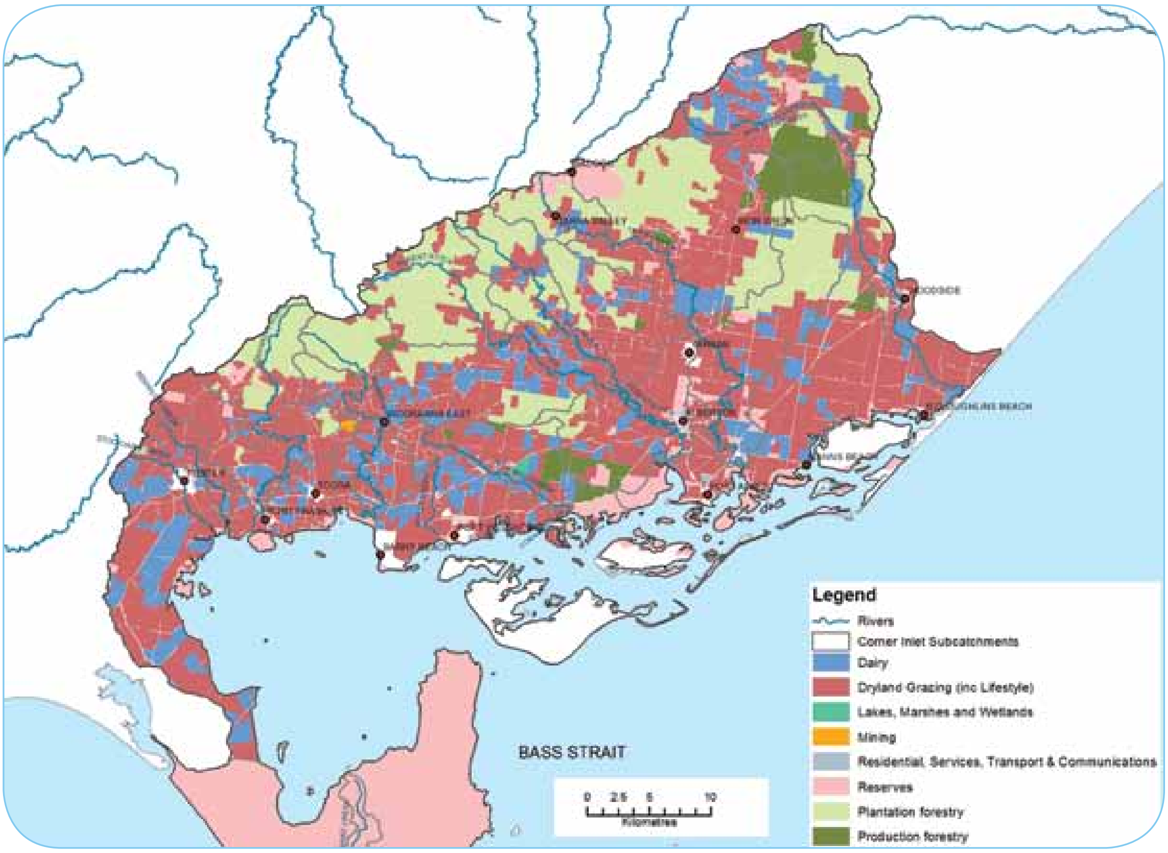


Figure 2.3.1 Current land use

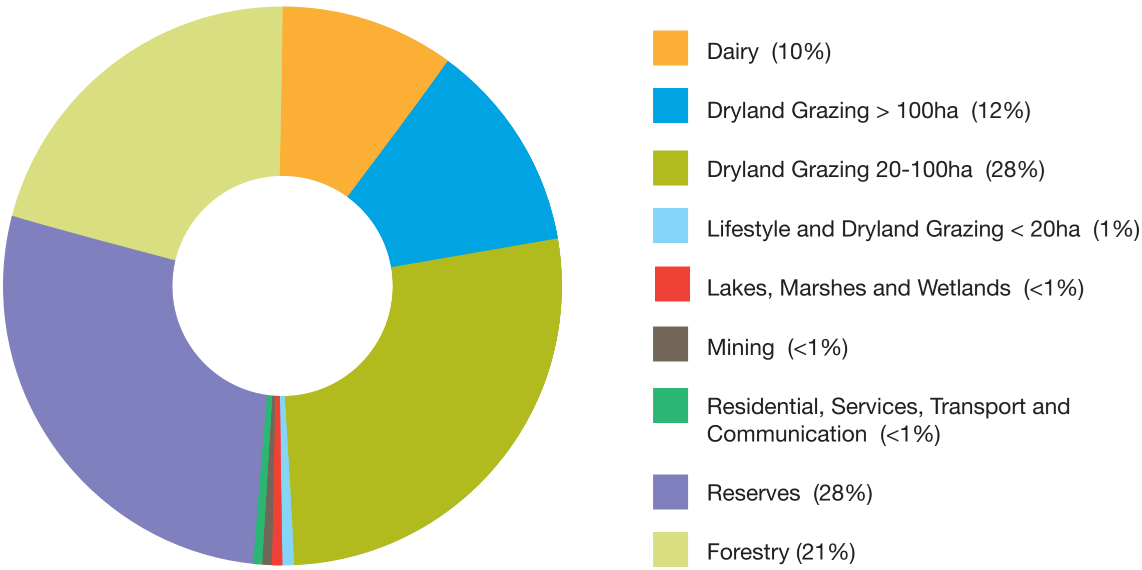


Figure 2.3.2 Proportion of each land use in the Corner Inlet catchment

3. Values and Significance

Corner Inlet was listed as a Wetland of International Importance under the Ramsar Convention in 1982. Due to its large area and diversity of habitats, it supports a number of internationally significant aquatic and semi-aquatic plant and animal populations. The site has high environmental value and is largely in a near natural condition (BMT WBM, 2011).

Historically undervalued as a mud and mangrove coastline, Corner Inlet's unique environmental features are increasingly recognised as assets worth protecting.

The area encompassed by the Ramsar site is a large tide dominated embayment. It consists of a submerged plain covered by sand and mudflats with well-developed seagrass beds and large sand islands, particularly in the Nooramunga end of the site. A system of channels drain and fill from the inlet's entrance point with Bass Strait to the east.

The values supporting the listing of the Corner Inlet Ramsar Site are:

- Diversity of wetland mega habitats – seagrass, mud and sandflats, mangroves, salt marsh, permanent shallow marine water.
- Abundance and diversity of waterbirds, in particular the barrier sand islands provide important bird breeding sites. Thirty-two species of wading birds have been recorded at the Corner Inlet and Nooramunga with populations often reaching close to 30,000 birds or more than 20% of Victoria's summertime wading bird population. Nearly 50% of the migratory wading birds that spend their winter in Victoria do so in Corner Inlet and Nooramunga.
- Presence of nationally threatened species; Orange bellied parrot, Australian grayling, Fairy tern and Growling grass frog. In addition, fifteen threatened flora species and twenty-two threatened fauna species have been recorded in Corner Inlet and it supports the most southernmost mangrove community in the world.
- Supports outstanding fish habitat values that contribute to the ecological condition and sustainability of the region.

  (BMT WBM, 2011, and Corner Inlet Steering Committee, 2008).

The critical components, processes and services of the Corner Inlet Ramsar Site as described in the Ecological Character Description are set out in table 3.1.1.

Left: Pot-bellied Seahorse in one of Corner Inlet's important seagrass meadows. Photo – Parks Victoria.

Right: Foster Cubs learning about the importance of coastal vegetation from Parks Victoria staff. Photo – 1st Foster Cub Group.

Table 3.1.1 Summary of Critical Components, Processes and Services/ Benefits of the Corner Inlet Ramsar Site (taken from BMT WBM, 2011)

Critical Components	Critical Processes	Critical Services/Benefits
Several key **wetland mega-habitat types** are present: • Seagrass • Intertidal sand or mudflats • Mangroves • Saltmarsh • Permanent shallow marine water**.** Abundance and diversity of waterbirds.	**Waterbird breeding** is a key life history function in the context of maintaining ecological character of the site, with important sites present on the sand barrier islands.	The site supports **nationally threatened fauna species** including: • Orange-bellied parrot • Growling grass frog • Fairy tern • Australian grayling. The site supports **outstanding fish habitat values** that contribute to the health and sustainability of the bioregion.
Supporting Components	**Supporting Processes**	**Supporting Services/Benefits**
Important **geomorphological features** that control habitat extent and types include: • Sand barrier island and associated delta system • Extensive tidal channel network • Mudflats and sandflats. **Invertebrate megafauna** in seagrass beds and sub-tidal channels are important elements of biodiversity and control a range of ecosystem functions. **Diverse fish communities** underpin the biodiversity values of the site.	**Climate**, particularly patterns in temperature and rainfall, control a range of physical processes and ecosystem functions. Important **hydraulic and hydrological processes** that support the ecological character of the site includes: • Fluvial hydrology. Patterns of inundation and freshwater flows to wetlands systems • Physical coastal processes. Hydrodynamic controls and marine inflows that affect habitats through tides, current, wind, erosion and accretion • Groundwater. For those wetlands influenced by groundwater interaction, the level of the groundwater table and the groundwater quality. **Water quality** underpins aquatic ecosystem values within wetland habitats. The key water quality parameters for the site are salinity, turbidity, dissolved oxygen and nutrients. Important **biological processes** include nutrient cycling and food webs.	The site supports **recreation and tourism values** (scenic values, boating, recreational fishing, camping etc.) that have important flow-on economic effects for the region. The site provides a range of values important for **scientific research**, including a valuable reference site for future monitoring.

3.1 Seagrass

The 67,186ha Ramsar wetland features seagrass meadows that are of high ecological value. They are a crucial component of the feeding and breeding cycles of many organisms and are the backbone of the inlet's complex ecosystems.

There are four species of seagrass in the inlet:

- *Heterozostera nigricaulis*
- *Zostera muelleri*
- *Halophila australis*
- *Posidonia australis* (Roob et. al., 1998).

An additional species, *Amphibolis antarctica,* occurs in more exposed waters in the vicinity of Corner Inlet and Nooramunga (Hindell et. al., 2009).

The areas of *Posidonia australis* (broad leafed seagrass) in Corner Inlet and Nooramunga are the only large patches of this species in Victoria (Kirkman, 2013; Ball et. al., 2010).

Seagrass is a driver of the marine ecology and has a critical role in carbon sequestration, providing habitat and food for fauna including fish and migratory and resident wader birds. The seagrass meadows also support an array of marine life such as the Pot-bellied Seahorse, King George Whiting, seastars and sponges, and communities of sea squirts and anemones.

Although the conservation of all species of seagrass in Corner Inlet and Nooramunga is important, the protection of areas of *Posidonia australis* is particularly crucial as this species is rare in Victoria and, at least on the east coast of Australia, takes decades to re-establish following disturbance and loss.

In 2011, Monk et. al., undertook the Corner Inlet and Nooramunga Habitat Mapping Project which used aerial photograph and satellite image interpretation to map *Zostera spp*. and *Posidonia australis*. In two large areas of Corner Inlet and Nooramunga (but not the entire Ramsar site), 4,608ha of *Posidonia* and 4,229ha of *Zostera* in Corner Inlet and 4,060ha Zostera in Nooramunga was mapped.

Subsequent mapping of the same area in 2013 (Pope et. al., 2013) identified 5,513ha of *Posidonia* and 5,504ha of *Zostera* in Corner Inlet and 3,122ha *Zostera* and 182ha *Posidonia* in Nooramunga. No visible seagrass coverage was identified across 9,059ha in Corner Inlet and 6,294ha in Nooramunga (Kirkman, 2013).

The location of *Zostera* and *Posidonia* beds as mapped by Monk et. al. in 2011 is shown in figure 3.1.1 and figure 3.1.2 for Corner Inlet and Nooramunga respectively.

Figure 3.1.1 Corner Inlet seagrass mapping (Monk et. al., 2011)

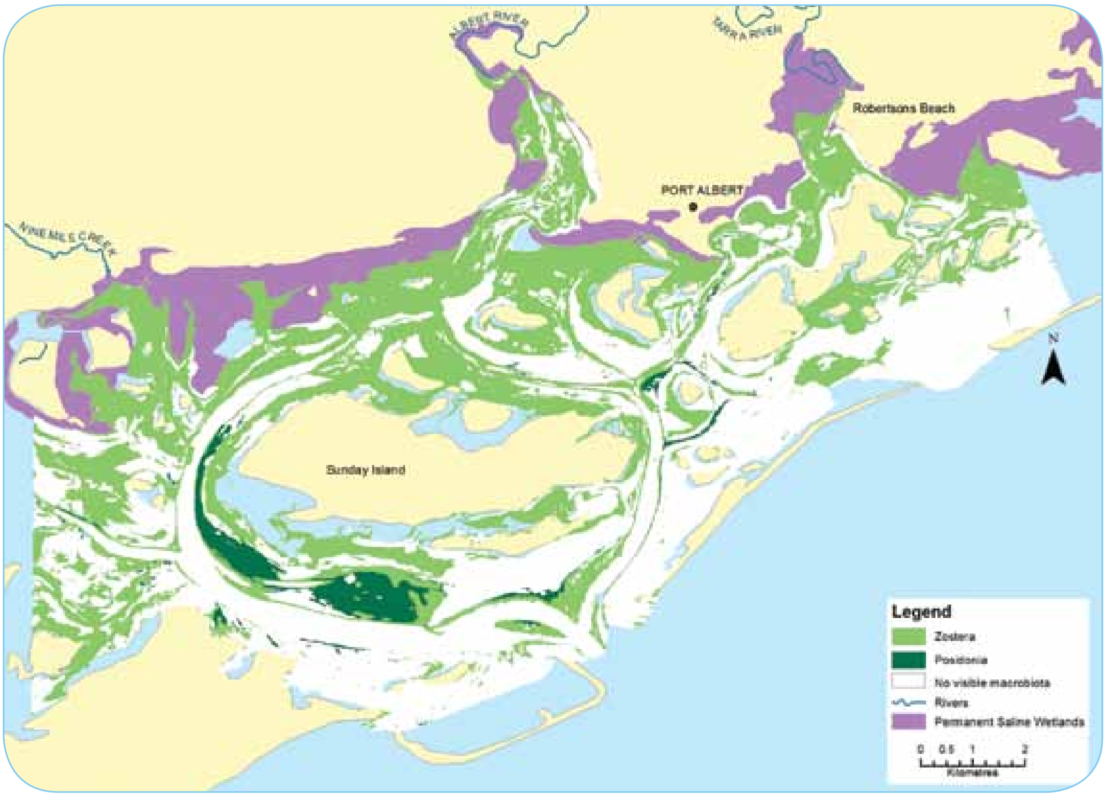


Figure 3.1.2 Nooramunga seagrass mapping (Monk et. al., 2011)

Within the context of the Corner Inlet WQIP, seagrass has been chosen as the environmental value to link with water quality because of its role in the ecosystems of Corner Inlet and Nooramunga and the well-established susceptibility of seagrass to deterioration in water quality. Loss of *Posidonia* from the north-west corner of Corner Inlet has been reported by local commercial fishers and a review of historical mapping undertaken in 2013 confirms that a decline has occurred in this area since 1978, although the cause cannot be confirmed and the amount has not been quantified (Kirkman, 2013).

The expected impacts on seagrass to occur in ecosystems such as Corner Inlet and Nooramunga are:

- elevated nutrient and sediment inflow from the surrounding catchment
- rapid growth of micro and macro algae
- altered habitat availability for fish
- mechanical damage and fragmentation of seagrass
- reduced underwater light regimes and therefore loss of seagrass
- re-suspension of sediment, leading to altered light regimes and/or burial of seagrasses
- altered capacity to store carbon.

(from Warry and Hindell, 2009)

The science and assumptions underpinning the link between seagrass and water quality are described in Appendix 1.

3.2 Social and economic values

Corner Inlet and Nooramunga are protected as Marine and Coastal Parks, with a smaller area off the northern shoreline of Wilsons Promontory protected as the Corner Inlet Marine National Park. The stunning landscape and natural beauty of the area make it a popular location for boating, camping, fishing and passive recreational activities such as bird watching and walking. Visitors to Corner Inlet are attracted from the local area as well as from further afield, particularly Melbourne (DSE, 2003).

Corner Inlet is estimated to attract 150,000 visitor days per year, with tourism inputs to the local economy estimated at $22.5 million (DSE, 2003). Visitors to Corner Inlet are often attracted to the area by its proximity to Wilsons Promontory National Park and easy driving distance from Melbourne.

Corner Inlet is one of only three bays or estuaries in Victoria where commercial fishing is allowed. In March 2011 there were 89 Bay and Inlet Fishery Access Licences with 18 of them in Corner Inlet (DPI Commercial Fish Production Information Bulletin, 2011), providing a valuable portion of fresh, locally caught finfish for Victorian seafood consumers. The average annual commercial value of major fish species in Corner Inlet between 2005 and 2010 was $2.4M. However, the full economic and social value of commercial fishing operations in Corner Inlet should not be measured by wholesale production value alone with the industry playing an important role in providing employment in coastal centres across South Gippsland (DPI, 2011).

The catchment's steep slopes and coastal flats have been farmed for generations, and the region is renowned for its productive primary industries.

In 2006, milk produced in the Corner Inlet and nearby Ninety Mile Beach sub-region had a gross value of $195.8M (IPSOS, 2010). Dairying is very important to the local economy, accounting for 62% of the local agricultural production value. Beef is the second most valuable commodity in the Corner Inlet and Ninety Mile Beach sub-region with annual production worth $70.5M; this is followed by crops and pastures cut for hay ($17.8M) and sheep ($11.4M).

Estimates of the overall economic, cultural and environmental values are clearly substantial, but also limited by data availability. The economic value of tourism, while already large is expected to grow significantly over time.

The area is also experiencing diversification with many new and emerging enterprises taking hold in the area as a result of South Gippsland's increasing popularity as a destination for sea-changers and tree-changers.

The Corner Inlet catchment has a strong history of natural resource management and on ground works. There are long serving and active networks of Landcare groups, and active participation by farmers in industry best management practise programs to reduce the impact of nutrient and sediment run-off from their land. This stewardship ethos is driven by community members and landholders passionate about caring for the land, preserving and enhancing the environment and contributing to the health of Corner Inlet and its surrounding catchment. The WGCMA and industry bodies such as GippsDairy also act as stewards of change through the delivery of projects that encourage and support adoption of best management practices through programs such as GipRip and Core4.

Left: Migratory waders in flight, mostly Bar-tailed Godwits. Photo – Parks Victoria.
Centre: Doughboy scallop amongst broad leaf seagrass. Photo – Parks Victoria.
Right: Fishing boats at Port Welshpool wharf. Photo – InDetail Comms & PR.

Aboriginal Cultural Heritage

Indigenous Australians have a strong cultural connection to country and the preservation of cultural heritage is extremely important. There are many areas of Aboriginal cultural sensitivity within the West Gippsland Catchment Management region and the Corner Inlet and Nooramunga area that have significant cultural value to the Traditional Land Owners. The Corner Inlet and Nooramunga region of the West Gippsland Catchment is significant to the Gunaikurnai people, the Bunurong people and the Boon Wurrung people.

Who are the Gunaikurnai?

There are approximately 3,000 Gunaikurnai people and the Gunaikurnai people are made up of five major clans. Below is the official spelling of the clans endorsed by the Gunaikurnai Elders' Council, and a brief description of each clan area:

- **Brabralung** people in Central Gippsland.
  Mitchell, Nicholson and Tambo Rivers; south to about Bairnsdale and Bruthen.
- **Brataualung** people in South Gippsland.
  From Cape Liptrap and Tarwin Meadows east to the mouth of Merriman Creek; inland to near Mirboo; at Port Albert and Wilsons Promontory.
- **Brayakaulung** people around the current site of Sale.
  Providence Ponds, Avon and Latrobe Rivers; west of Lake Wellington to Mounts Saw Saw and Howitt.
- **Krauatungalung** people near the Snowy River.
  Cape Everard (Point Hicks) to Lakes Entrance; on Cann, Brodribb, Buchan and Snowy Rivers; inland to about Black Mountain.
- **Tatungalung** people near Lakes Entrance on the coast.
  Along Ninety Mile Beach and about Lake Victoria and Lake Wellington from Lakes Entrance southwest to mouth of Merriman Creek; also on Raymond Island in Lake King.

In 2010, the Federal Court determined under the *Native Title Act 1993* that the Gunaikurnai people hold native title over much of Gippsland, encompassing parts of the Corner Inlet and Nooramunga area. In addition to this, the Gunaikurnai people have entered into an agreement with the Victorian Government under the *Traditional Owner Settlement Act 2010*, which formally recognises them as the traditional owners over land within that area. The determination and agreement area extends from West Gippsland near Warragul, east to the Snowy River and north to the Great Dividing Range and includes 200m of sea country offshore.

There are over 400 Cultural Heritage sites in the West Gippsland Catchment Management region. These provide a link to the past for contemporary Aboriginal people. All Aboriginal sites found in Victoria are protected. Aboriginal sites and places are important because of their historic and cultural value to Aboriginal people and the wider community. Sites may be located on private and public land and need to be protected to prevent damage from erosion and land use changes. Sites that show Aboriginal occupation of the region include:

- significant scar trees
- grinding grooves
- stone arrangements
- sacred sites.
- artefacts
- rock shelters
- ceremonial grounds
- campsites
- art sites
- quarries

The Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) is the Registered Aboriginal Party for this region, they should be contacted for all enquiries regarding Aboriginal Cultural Heritage.

The WGCMA works very closely with Traditional Owners on all projects. This document acknowledges the Aboriginal Traditional Owners of the Corner Inlet catchment and recognises their connection to their ancestral lands and waters.


Left: Aboriginal grinding grooves. Photo – WGCMA.
Right: Freshwater shell midden. Photo – WGCMA.

3.3 Values of the tributary waterways

The waterways that flow into Corner Inlet and Nooramunga have environmental, social and economic values in their own right.

The Franklin and Agnes Rivers have high economic values that include the supply of water for agricultural production. The estuary of the Franklin River is associated with commercial fishing and tourism.

The Agnes River Falls are the highest single-span falls in Victoria and are a popular destination for picnicking and sight-seeing. Below the falls the Agnes River flows through a gorge before making its way through farmland to Corner Inlet. At the top of the falls, off-take is diverted to a water treatment plant that provides potable water for many towns in the surrounding district.

The upper reach of the Tarra River flows through a National Park and reserve where there are camping and recreational opportunities along its banks. The Tarra River provides water for the township of Yarram and agricultural production in the district.

The Jack and Albert Rivers flow from forested areas in the Strzelecki Range, through farmland that supports dairy, beef and sheep enterprises. The Hiawatha Falls are locally important for site-seeing. The Jack and Albert Rivers have significant remnant vegetation in the upper sections and numerous tributary waterways. The Jack and Albert Rivers, combined, have the highest catchment area in Corner Inlet and Nooramunga and are subject to erosion processes particularly in the mid reaches. There is an avulsion risk just upstream of the current confluence of the two rivers that has the potential to liberate a large amount of sediment to Corner Inlet.

In the far east of the catchment, Bruthen Creek has undergone significant changes in physical form as a result of clearing and dredging and draining of swamps and continues to undergo active erosion. The estuary of Bruthen Creek flows out at McLoughlins Beach and is associated with the high recreational use of this area including boating, fishing and camping.

The Western Tributaries and Bennison and Stockyard Creeks are short waterways that drain through farmland before entering Corner Inlet in the west of the catchment. Stockyard Creek flows through the township of Foster and is valued for its scenic amenity.

A number of other smaller waterways including Nine Mile Creek, Muddy Creek and Shady Creek flow to Corner Inlet through farmland and coastal wetland vegetation. In addition, several small waterways including Barry Creek flow into Corner Inlet from the northern coastline of Wilsons Promontory. See figure 2.1.2.

The environmental condition of waterways in Corner Inlet and Nooramunga was assessed in 2010 as part of the state-wide Index of Stream Condition (ISC) program. This program assessed the majority of the tributary waterways as being in moderate condition, with three reaches in good condition (Tarra, Albert and Jack Rivers) and one reach in excellent condition (Barry Creek). Those reaches in moderate condition were largely located in areas of agricultural use or production forestry and had impacts to their hydrology, riparian vegetation, water quality and aquatic biodiversity. The reaches in good and excellent condition were located in areas of public land and were ranked highly across all metrics of the ISC.

The West Gippsland Regional Waterway Strategy (in development) will address the management of these waterways through a prioritised eight-year work program. A summary of the high values associated with the major catchment waterways of Corner Inlet and Nooramunga is provided in table 3.3.1.

Table 3.3.1 Summary of the high values associated with the tributaries of Corner Inlet and Nooramunga[1]

	High Environmental Values				High Social Values					High Economic Values			Index of Stream Condition (2010)
Waterways	Significant vegetation communities	Naturalness	Drought refuge	Threatened fauna and flora	Hunting	Heritage values	Boating	Recreational fishing	Beside water activities	Water supply – rural production	Water supply – urban	Timber production	
Bennison Creek	✓	✓		✓	✓	✓			✓				Moderate
Franklin River	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	Moderate
Tarra River	✓	✓		✓		✓		✓	✓	✓	✓	✓	Moderate (lower and mid reaches) Good (upper reach)
Barry Creek	✓	✓		✓		✓			✓				Excellent
Nine Mile Creek													Moderate
Agnes River	✓		✓	✓		✓			✓		✓	✓	Moderate
Albert River	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	Moderate (lower and mid reaches) Good (upper reach)
Jack River	✓	✓		✓	✓	✓			✓			✓	Moderate (lower reach) Good (upper reach)

[1] *Data is sourced from the West Gippsland CMA AVIRA database that reports on Index of Stream Condition Reaches only. Terminology is consistent with the guidelines for AVIRA to be used in the development of the Regional Waterway Strategy.*

3.4 Values of the surrounding catchment

Many people connect with Corner Inlet and its catchment because of its unique, fertile landscape and its important environmental values. With national parks, waterways, farmland and coast, the areas surrounding Corner Inlet are a place of natural beauty, productivity and internationally recognised environmental values.

This diverse combination of natural features makes it an attraction for tourists and the number of visitors from Australia and overseas increases each year.

The northern coastline of Wilsons Promontory National Park, which forms the southern border of the Corner Inlet catchment, is ecologically significant and popular with tourists.

To the north of the catchment, the Strzelecki Range supports old-growth Mountain Ash and Myrtle Beech forest and the genetically unique Strzelecki Koala. The ranges are significant for their cool temperate rainforests, most notably Tarra Bulga National Park, which present an array of activities for tourists to enjoy, including native bird watching, walks and picnic areas. Pockets of warm temperate rainforest still remain in the Strzelecki Range.

Vegetation communities closer to the coast, such as mangroves and coastal saltmarsh, provide shelter and feeding and breeding habitat for a range of wildlife such as a range of migratory and resident waterbirds and the endangered Orange-bellied Parrot. Coastal vegetation is also of high value as it helps protect the coastline from erosion (Gedan et. al., 2011).

Fauna including the South Gippsland Spiny Crayfish, River Blackfish and Australian Grayling are recorded in the major waterways that drain to Corner Inlet. Other native fish including Australian Smelt, Tupong, Southern Pygmy Perch, Estuary Perch and Short-finned Eels have also been recorded in the Agnes and Tarra Rivers (DSE, 2009).

The cool temperate rainforest of Tarra Bulga National Park. Photo – Jonathon Stevenson.

4. Hydrology and Water Quality

4.1 Catchment hydrology

Rainfall in the catchment of Corner Inlet varies significantly from north to south, and to a lesser extent west to east, with a range from 800mm to 1250mm per annum. The observed daily rainfall in the catchment can be highly variable in response to weather patterns including east coast lows and south-westerly fronts. As a result, stream hydrology is also highly variable in time and space (BMT WBM, 2011).

Flow in the short permanent waterways of the Corner Inlet catchment is 'flashy' in the sense that the waterways respond very quickly to heavy rainfall due to their small catchment areas and relatively short river length (Alluvium, 2008; Australian Government, 2011). Flows are strongly seasonal, with high flows in winter-spring (August-September) and low flows in summer (Water Technology, 2008). High flows may flush the estuarine reaches of the waterways of all salt water, and import large volumes of freshwater, sediment and nutrients to the embayment (Water Technology, 2008).

The catchments that drain to Corner Inlet have higher flows than those flowing to Nooramunga. Average annual inflows to Corner Inlet (105,000ML/yr) are about one and a half times the inflows to Nooramunga (77,000ML/yr). This is largely due to higher rainfall in the western end of the catchment, but geological and topographic differences are also likely to be contributing factors.

A number of rivers and creeks drain the southern foothills of the Strzelecki Ranges and flow into Corner Inlet and Nooramunga. Over both catchments the largest in terms of average annual flow, in descending order, are the Tarra, Albert, Agnes and Franklin Rivers, and Bruthen Creek (figure 4.1.1 see also Note[1]), all of which are gauged waterways. The flow from ungauged tributaries is also understood to be substantial (figure 4.1.1), particularly for Corner Inlet. Surface drains constructed to drain low-lying farm land also outflow into the Ramsar site.

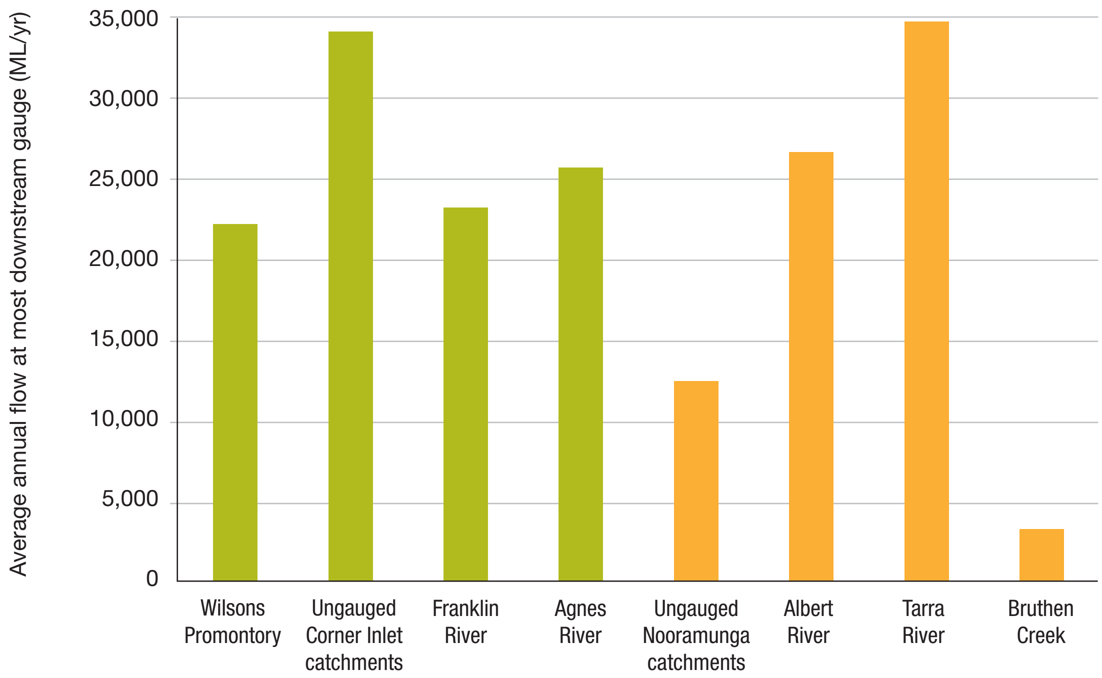


Figure 4.1.1 Average annual flow in tributary streams

Green = Corner Inlet tributaries; Orange = Nooramunga tributaries. Flow in named tributaries is based on data from most downstream gauge (from Alluvium, 2008). Flow in other tributaries (Wilsons Promontory and ungauged catchments) has been estimated by factoring gauged flows (using ratio of mean annual flow generated using catchment characteristics from the Victorian Sustainable Diversion Limits project).

The frequency of high flow events resulting from rainfall is an important factor for catchment hydrology and the resulting water quality. The frequency of such events, where mean daily flow is > 100ML/day, in the Agnes and Tarra Rivers were analysed for the period 1987-2006 to inform the development of the Corner Inlet catchment model. The analysis showed that high flow events commonly occur between six and 14 times per year.

During the period analysed, the frequency of high flow events declined in line with increased drought conditions in the mid 2000s with only two high flow events recorded in 2006 (Water Technology, 2008). As outlined in the Reasonable Assurance Statement (Section 12) the model was calibrated in a relatively dry period (1997-2006) and there was acknowledgement that high flow (and therefore high load) events were not captured and, as such, the nutrient loads from the calibrated model have been under-estimated.

In the years since 2006, high winter and spring rainfall has re-established and with it an increased frequency of high flow events, likely resulting in higher loads of sediment and nutrient to the Corner Inlet Ramsar Site.

Note[1] – The surface water inflows reported here are based on data from the lowest active gauge in each catchment. While the total annual surface water inflow to Corner Inlet and Nooramunga is very similar to that estimated by the catchment modelling undertaken for the study area (182,775 ML/yr and 181,770 ML/yr respectively), the proportion of these inflows contributed by the various individual streams differs significantly. For example: the highest contributing stream based on gauge data, the Tarra River (34,804ML/yr) (figure 3), is estimated to be the third largest contributor by the catchment model (19,995ML/yr). The second highest contributing stream, the Albert River (26,718ML/yr) (figure 3), is estimated by the catchment model to be the highest contributor (47,260ML/yr). This could be due in part to some gauges being located relatively high in their catchments, therefore not capturing all tributaries e.g. Albert River at Hiawatha.

4.2 Groundwater

Groundwater may contribute flows to the Corner Inlet Ramsar Site either directly as a groundwater discharge into the marine embayment or indirectly via discharge to inflowing streams. Little is known about direct groundwater discharge to Corner Inlet and Nooramunga. Slomp & Van Cappellen (2004) concluded that “submarine groundwater discharges were most important in shallow, permeable aquifers comprised of sands or limestone”, which is a category that most of the aquifers surrounding Corner Inlet fall into, ”with high rates of groundwater recharge” (Adams et. al., 2008). An estimate of direct groundwater discharge to Corner Inlet, made to inform the development of the catchment model of the study area, was that groundwater contributed about 10% of total annual modelled surface runoff (Water Technology, 2008).

The Latrobe Group Aquifer (LGA) underlies the Corner Inlet catchment and contains significant volumes of good quality water that is used predominately for irrigation (approximately 11,300ML/year) around the town of Yarram (SRW, 2010). A further 110,000ML/year is extracted through off-shore oil and gas production (CSIRO, 2004). Evidence suggests that this off-shore extraction has made a significant and consistent contribution to decline in groundwater levels on-shore, with levels dropping by an average of 1m/year over the last few decades (SRW, 2010).

The declining groundwater levels in the LGA are linked to a reduction in base flows to a number of streams across the Corner Inlet catchment, where the aquifer outcrops or is close to the surface (SKM, 2005). This includes the southern edges of the Strzelecki Ranges north of Yarram, where the aquifer is intersected by the Tarra, Jack and Albert Rivers. Work is currently underway through the Department of Environment and Primary Industries to quantify the extent and magnitude of these base flow reductions.

While total annual direct groundwater discharge to Corner Inlet and Nooramunga may be insignificant relative to total annual surface water inflows, groundwater contribution to river base-flows may be significant during periods of low surface water flows, and direct groundwater discharge could be of localised importance in some areas. Increased groundwater salinity (resulting from seawater intrusion), reduced base-flows and coastal subsidence, are potential consequences of declining groundwater levels that are of relevance to the long-term environmental condition of the Corner Inlet Ramsar Site.


Left: White mangrove fringe the coastline and estuaries of the Corner Inlet Ramsar Site. Photo – InDetail Comms & PR.
Right: Tidal mudflats and barrier islands characteristic of the Nooramunga Marine and Coastal Park. Photo – WGCMA.

4.3 Embayment hydrodynamics

The majority of the area of Corner Inlet and Nooramunga is made up of shallow marine waters and of intertidal flats, with the remainder being barrier islands and fringing wetlands, some of which may be inundated by marine waters during the very highest tides or during storm surges. The intertidal area of the Corner Inlet Ramsar Site is dissected by a network of channels that drain and fill via five permanent entrances that allow exchange with Bass Strait.

Hydrodynamic modelling completed in 2008 indicates that the embayment is well flushed with more than 60% of water volume exchanged over an average tide cycle (Water Technology, 2008). There is variability, with Corner Inlet being much better flushed than Nooramunga. This is a function of the fast draining channels between the intertidal flats in Corner Inlet compared with the network of barrier islands in Nooramunga. This results in very low residence times in Corner Inlet, perhaps only a few tidal cycles, where as in Nooramunga it is estimated to be up to a week.

In addition, the hydrodynamic modelling results indicate that:

- More than 40% of the area of the Corner Inlet Ramsar Site is exposed during a typical spring low tide. Not all of the intertidal flats are exposed due to their flat slope and because of friction there is insufficient time during a tide cycle for all the water to drain completely before the next incoming tide.
- Exchange does occur between Corner Inlet and Nooramunga, particularly through Lewis Channel between Port Welshpool and Little Snake Island.

A simulation linking catchment and receiving waters (hydrodynamic) models was also completed in 2008 (Water Technology, 2008). The simulation included representations of tide, wind and river flow conditions, and the use a simple tracer to follow river flows as they enter the embayment. The simulation did not consider mixing, settling or ecological processes.

The simulation indicated that the zones of influence for each river outlet were limited to localised regions and the river flows (and their sediment and nutrient load) diluted very quickly upon entering the embayment.

Whilst the modelling results are understandably a simplified representation of a very complex environment, they align with investigations (CEC, 2008; McLean and Jones, 2011) into sediment characteristics within Corner Inlet and Nooramunga, which reported that as described in Section 4.4.


Left: Aerial photo showing the extent of sediment flow into Corner Inlet after a heavy rain event in 2013. Photo – Parks Victoria.

Right: Regular monitoring of seagrass condition is conducted by Parks Victoria and trained volunteers at a variety of locations within the Corner Inlet Ramsar Site. Photo – Parks Victoria.

4.4 Water quality issues

Local community members, farmers, commercial fishers and natural resource management (NRM) agencies working within Corner Inlet and Nooramunga have long been concerned that nutrient and sediment flowing into the embayment may be putting seagrass meadows and other habitats, including mangroves, mudflats and saltmarsh, at risk.

Following large rainfall events plumes of ‘dirty water’ can be seen extending into Corner Inlet and Nooramunga from the main river channels. In addition to reports of seagrass loss, commercial fishers have observed blooms of marine algae within the seagrass beds in summer and autumn. These blooms have included ‘Slub’ (a filamentous brown algae of unknown taxonomy), macroalgae on the sediments between the seagrass plants and microalgae on the seagrass leaves.

Slub is reasonably common within the Corner Inlet Ramsar Site in the autumn months, with a number of those involved in the local fishing fleet remembering its presence as far back as 50 years. However, the presence of green algae in mid-summer and slub in the spring period is of concern. The most recent bloom of macroalgae occurred in late autumn of 2013, following a wet winter and spring, and dry and hot summer conditions.

Despite these anecdotal reports of poor water quality and associated ecological impacts, there is very little data available on water quality conditions within the estuarine and marine waters of the Corner Inlet Ramsar Site.

Waterwatch data for the parameters of Reactive Phosphorus (a measure of orthophosphates, as well as other easily hydrolysable organic and inorganic forms of P) and Total Phosphorus (TP) and Turbidity is available for a number of sites for the period between 2001 and 2009.

The data from the Waterwatch program and data collected by Hindell et. al. in 2007, indicates that Phosphorus concentrations (Reactive and Total) and Turbidity were elevated in the near shore area of north western Corner Inlet. Data from the Waterwatch program in this location provides figures that exceeded the State Environment and Protection Policy (SEPP) guidelines between 6-10 times higher for TP and 3.5 times higher for turbidity over the time period assessed. In addition, a number of the sites were influenced by the operation of wastewater treatment plants, most of which have since been phased out or have diverted waste material for re-use.

Results for TP and Turbidity at sites in Nooramunga were typically low (below the SEPP guideline of 0.03mg/L TP) with the exception of the site at McLoughlins Beach (Bruthen Creek estuary) which exceeded the SEPP guideline by two times (BMT WBM, 2011).

An investigation into water quality in Corner Inlet and Nooramunga was completed as part of a project to monitor seagrass health in 2007 (Hindell et. al., 2007). Water quality data was collected at six sites on seven occasions across the Ramsar site between 2005 and 2006.

The key findings relating to water quality were:

- The surface waters within the embayment of Corner Inlet and Nooramunga are usually of ocean-water salinity, except for short periods in summer when evaporation can cause salinities to slightly exceed those of sea water. Nutrient sampling undertaken through this project indicates that Phosphate concentrations were typically quite low (consistent with Waterwatch observations), however elevated Nitrogen concentrations (ammonium and nitrate/nitrite) were apparent, particularly around Yanakie but also around Port Franklin, Foster and Welshpool. The levels of ammonium in water samples at some sites were more than 20 times the SEPP guideline for estuaries.
- Nutrient levels throughout Corner Inlet and Nooramunga were lower than those recorded in the Gippsland Lakes, but significantly higher than those found in Port Phillip Bay.
- Metals and pesticides do not appear to be significant issues in Corner Inlet and Nooramunga.

Sediment analysis within Corner Inlet and Nooramunga was undertaken by the University of Wollongong in 2011 (McLean and Jones, 2011). This analysis found that:

- Deposition of clays and silts takes place mainly in the upper estuarine reaches of the tributaries of Corner Inlet and Nooramunga, prior to entering the embayment.
- Fine sediment that enters the embayment during high flows does not settle in the energetic main channels and sandflats and is only found in backwater areas.
- Sediments within Corner Inlet and Nooramunga all fall within the ANZECC guidelines for sediment quality.

The absence of long-term water quality data for the marine waters of Corner Inlet and Nooramunga makes it difficult to determine the level of change in water quality conditions over time and the relationship this has with the issues observed by members of the local community. Given the importance of the Corner Inlet Ramsar Site, the degree of data available and community observations, there is cause for concern about maintaining values.

4.5 Current catchment water quality status

The status of water quality in the Corner Inlet catchment was reported in 2010 for the Corner Inlet Catchment Condition Report (WGCMA and Hyder, 2010). Water quality objectives for individual parameters are set in the State Environment Protection Policy (SEPP) Waters of Victoria. Trigger limits (guidelines) are set within the SEPP based on accepted ranges and minimum and percentile values for sampling sites over the period of a year (WGCMA and Hyder, 2010).

Water quality data for the Corner Inlet catchment can be summarised as:

- Dissolved oxygen could only be assessed at five of a potential 12 sites due to insufficient data. The SEPP objectives for dissolved oxygen were not met at any of the five eligible sites.
- SEPP objectives for Total Phosphorus were not met at any of the sites in the Franklin and Agnes Rivers and Bennison Creek.
- There was insufficient data to make conclusions regarding Total Nitrogen.
- Water quality in the Corner Inlet catchment is generally better in the upper catchment areas and deteriorates downstream.
- SEPP objectives for pH were met at all sampling sites.

Data from Nooramunga Corner Inlet Community Water Monitoring Project was utilised to assess attainment of SEPP objectives for water quality parameters at selected sites during 2008. It should be noted that 2008 was a particularly dry year with high temperatures and low rainfall, which is uncharacteristic for the region. In addition, the results do not provide for the influence of rainfall events on water quality. It is possible that the SEPP levels are exceeded more than indicated in figure 4.5.1 because of the acknowledged lack of capture data for high flow events in water quality monitoring.

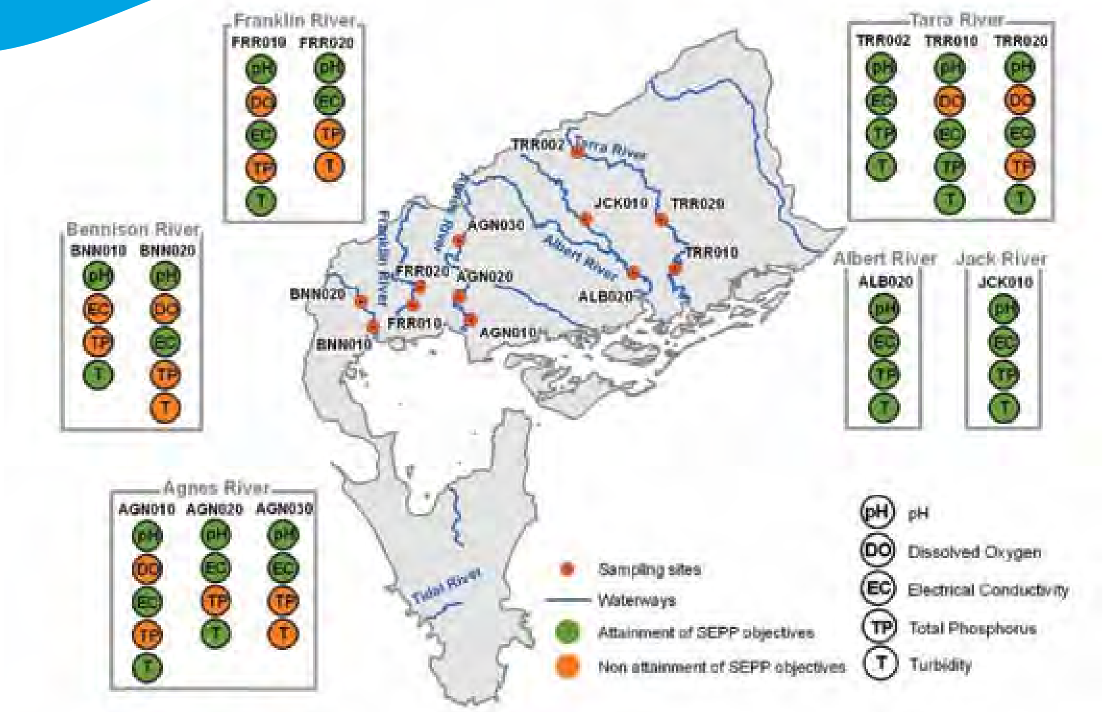


Figure 4.5.1 Attainment of SEPP water quality objectives for selected sites in the Corner Inlet catchment (WGCMA and Hyder, 2010)

4.6 Catchment modelling

An environmental audit of Corner Inlet and Nooramunga was completed in 2005. One of the recommendations was that further investigations should be undertaken to identify and quantify the sources and loads of sediment and nutrient from the surrounding catchment. It also recommended that on-ground actions be implemented to reduce the loads of sediment and nutrient coming from the catchment (Malloy et. al., 2005), as have now been quantified (with available knowledge) and recommended within this plan.

Development of a sediment and nutrient model (E2 / WaterCast) of the catchments of Corner Inlet and Nooramunga was completed in 2008. The project incorporated the development of separate calibrated catchment and receiving waters models. The development of the models enabled the sources of sediment and nutrient for particular sub- catchments to be examined, identified and modelled.

The integration of the results from both models through a simple relationship was developed to understand the potential fate of sediment and nutrient once they leave the catchment and enter the marine environment of the Corner Inlet Ramsar Site.

The catchment model was calibrated against the available water quality data. As the existing data was not event-based, a sampling program undertaken during model development to capture the effects of high rainfall events on water quality.

Development of the model involved dividing the mainland catchment and islands into 67 sub-catchments based on considerations including topography, river basins, land use and the location of existing water quality and flow monitoring stations.

The catchment modelling platform utilised the concept of functional units to describe areas that have similar hydrologic response and sediment and nutrient generation characteristics. Land use and topography are the prime indicators for defining functional units within each subcatchment.

Subcatchments were comprised of one or more functional units. Eight major land uses were utilised based on land use mapping available at the time (Water Technology, 2008).

Hydrologic response was determined by a detailed analysis of rainfall evaporation and stream gauge data and SIMHYD (a rainfall-runoff model). Water quality algorithms in the catchment model were defined by Event Mean Concentration (EMC) and a Dry Weather Concentration (DWC) to predict stream flows. DWC and EMC values were initially designated using literature values and were then calibrated against Victorian Water Quality Monitoring Network and Waterwatch data. Data collected through the event-based sampling program was used for a final calibration of the EMC and DWC values. A further calibration of the EMC and DWC values was undertaken in 2011 using additional event-based monitoring data collected in the spring of 2010.

4.7 Catchment modelling results

The results from the catchment model developed for Corner Inlet in 2008 are presented in this section. Additional water quality monitoring and modelling undertaken in 2011 to inform the catchment model, and advice from experts indicates that there are uncertainties around some of the DWC and EMC values used to underpin the 2008 modelling. The EMC and DWC values appear to result in both overestimation and underestimation in the contribution of loads from particular land uses, however the overall end of catchment loads do calibrate to gauged water quality and quantity data. (Water Technology, 2011; Craig Beverly Personal Communication, 2012).

The catchment model was calibrated to gauged water monitoring data in a relatively dry period (1997-2006) and it is known that the normal pattern of high flow events was not well captured. Nevertheless, the modelling used was the best available at this time.

Below is a summary of the 2008 model results that have underpinned the development of water quality objectives, prioritisation and works program for the WQIP.

- All land use in the catchment contributes to the modelled end-of-catchment loads and concentrations of nutrient and sediment, including native forests and reserves.
- The modelled contributions for forestry land uses were not able to be replicated in 2011 and there are uncertainties around the EMC values used in 2008. The contribution of forestry to the overall load can not be confidently quantified at this time and requires further investigation.
- Dryland agriculture (incorporating dairy, beef and sheep production) generates the greatest nutrient loads in absolute terms to Corner Inlet and Nooramunga due to the large amount of this type of land use (50%) in the catchment. Loads from agricultural land uses are further discussed in relation to implementation planning in Section 7.
- Whilst the overall loads from urban sources were low (resulting from low flows and seasonal operation of treatment plants), concentration of suspended sediment and nutrient were very high at waste water treatment plant (WWTP) outlets. It should be noted that significant work was undertaken by South Gippsland Water since 2008 to upgrade or decommission a number of existing WWTPs in the area, thereby reducing outfalls to the Corner Inlet Ramsar Site. Plans are underway to upgrade the Foster WWTP to include new maturation and reuse facilities on land to the south west of the existing site (South Gippsland Water, Water Plan 3, 2012).
- Urban areas do not generate a significant proportion of the sediment or nutrient loads under the current population and percentage land use within the catchment (less than 1%). Population growth estimates for the region indicate that this situation will not significantly change in the lifetime of this plan (South Gippsland Water, 2011).

Modelled nutrient and sediment loads from sub-catchments grouped by their overall river catchment are shown in figure 4.7.2 to figure 4.7.4. Figure 4.7.1 provides a comparison of sediment and nutrient loads from each river catchment.

Left: Fencing and restoration of native vegetation along the lower Franklin River. Photo – WGCMA.

Right: Port Franklin moorings. Photo – WGCMA.

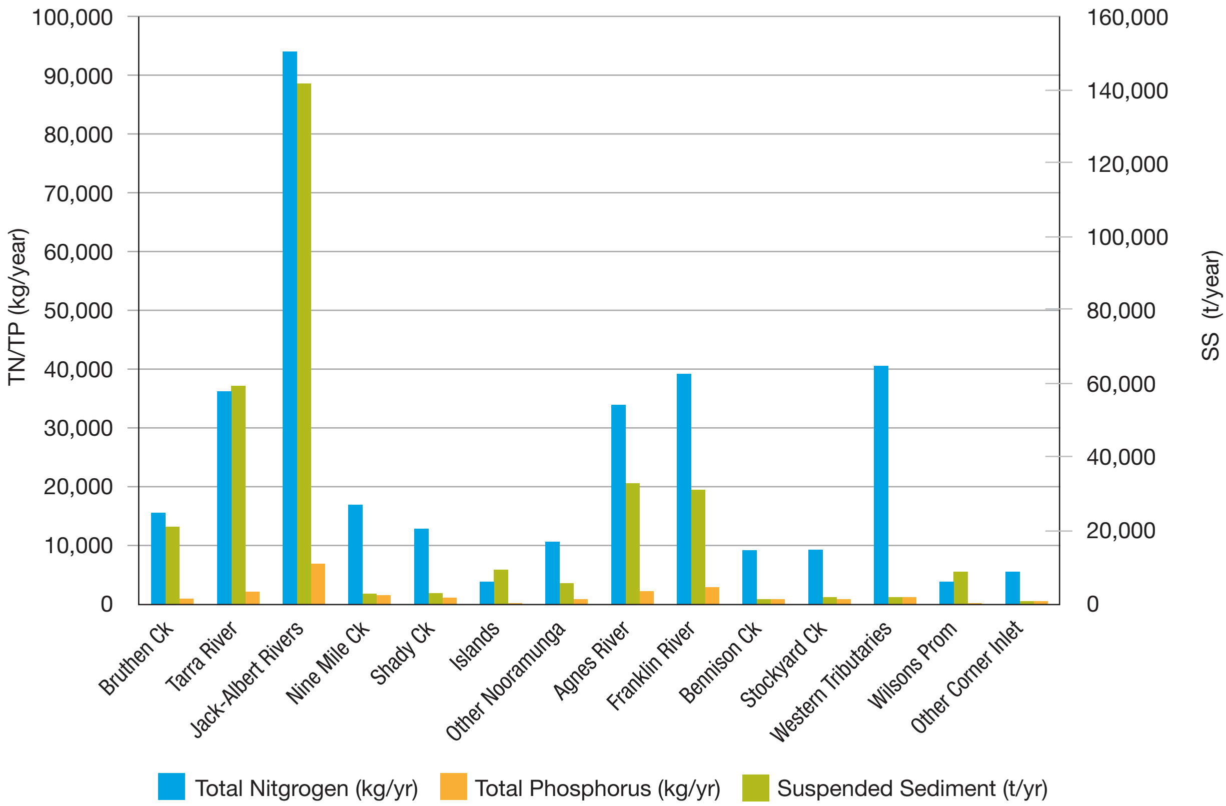


Figure 4.7.1 Modelled suspended sediment (tonnes/year), Total Nitrogen and Total Phosphorus (kg/year)

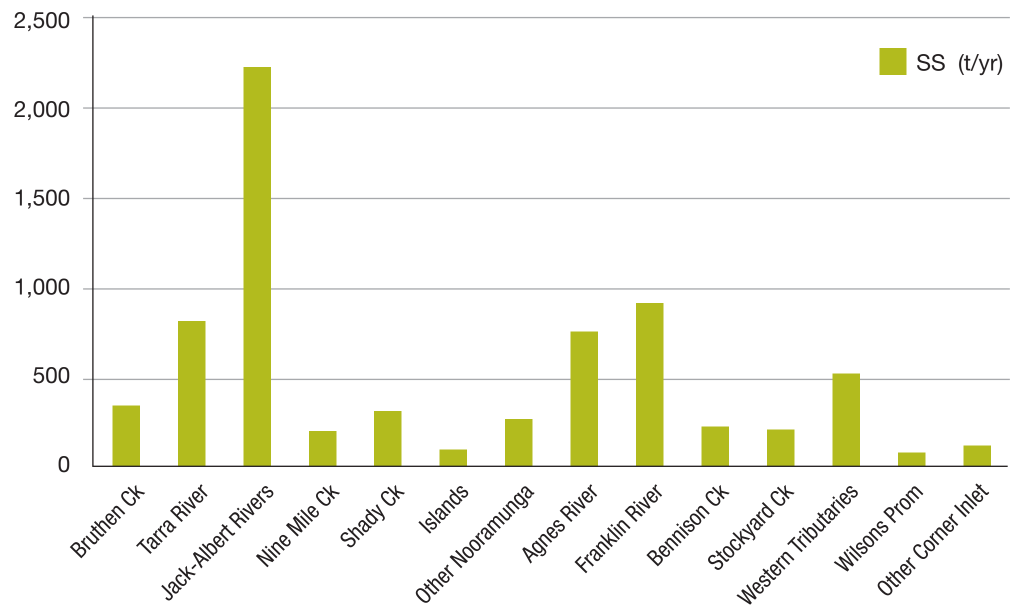


Figure 4.7.2 Modelled suspended sediment load in tonnes/year

Figure 4.7.2 shows that the Albert River contributes the greatest amount of sediment (over 2000 tonnes per year). The Franklin, Agnes and Tarra Rivers and the Western Tributaries each contribute over 500 tonnes/ year.

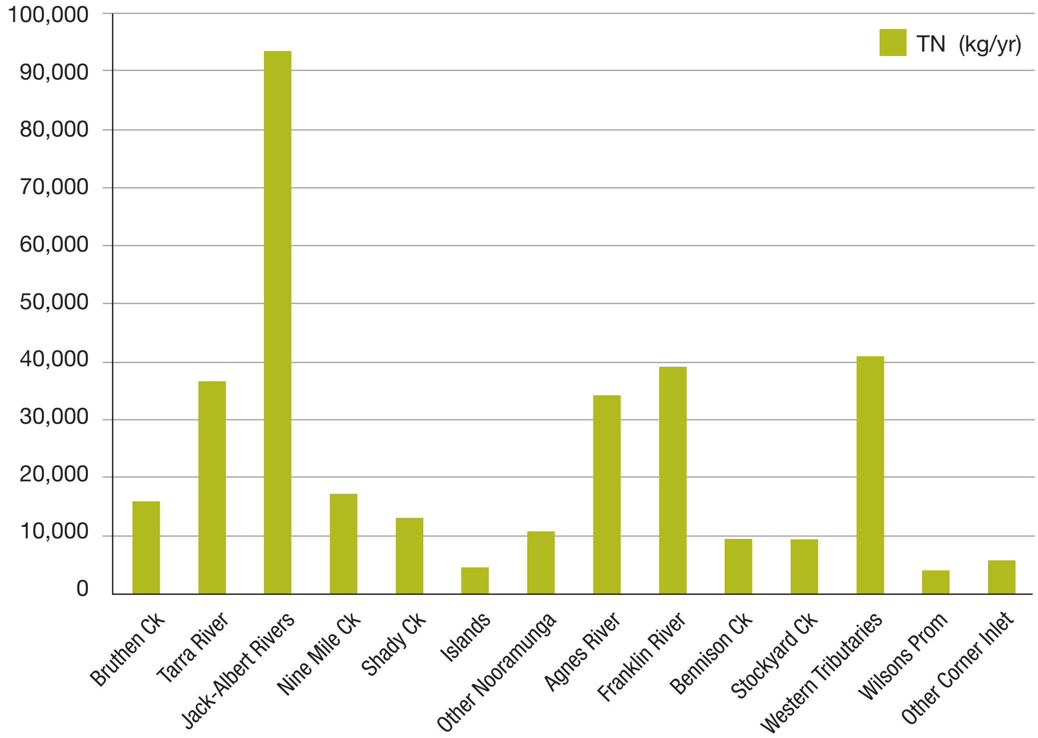


Figure 4.7.3 Modelled Total Nitrogen load in kg/year

The Albert River catchment also contributes the greatest Total Nitrogen load (figure 4.7.3) to Corner Inlet and Nooramunga. The Western Tributaries, Franklin, Agnes and Tarra River catchments also make a large contribution, with a modelled estimate exceeding 30,000 kilograms per year.

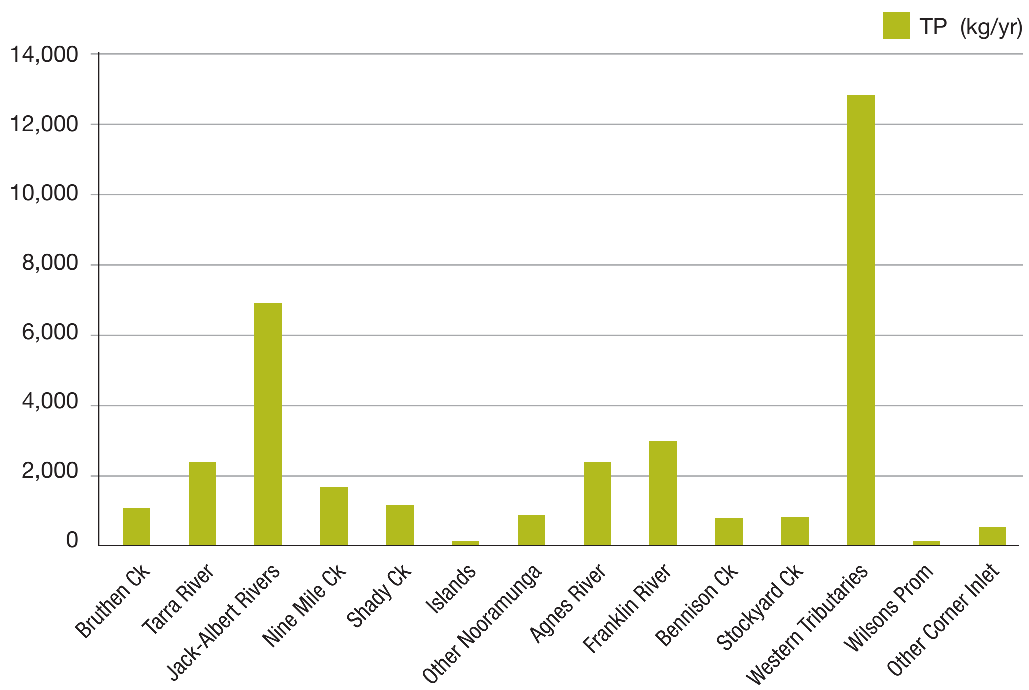


Figure 4.7.4 Modelled Total Phosphorus load in kg/year

In contrast to sediment and nitrogen, the Western Tributaries are the dominant contributor of Total Phosphorus, with an annual modelled load estimate of almost 13,000 kilograms per year (figure 4.7.4). The Jack and Albert Rivers catchment is the next largest contributor (approximately 7,000 kilograms per year).

5. Environmental Flows

5.1 Environmental flow objectives for Corner Inlet and Nooramunga

The volume, pattern and timing of inflows to Corner Inlet and Nooramunga from catchment sources (i.e. waterways, drains, direct surface run-off and groundwater) strongly influences the delivery of nutrients and sediments to the river estuaries and marine embayments. These catchment-sourced inflows also play a critical role in the broader ecological health of the receiving waters.

Previous technical investigations into the effects of catchment processes on Corner Inlet and Nooramunga have focussed on water quality issues, and while river and groundwater inflows have been included in these investigations, the emphasis has been on water as a transport mechanism for nutrient and sediment rather than its direct effects (positive or negative) on the downstream environment. The focus has also been on the marine embayments: there are few studies on the estuarine segments of the Corner Inlet Ramsar Site. Hence there is very little site-specific information about the ecological influence of freshwater inflows in the estuarine reaches of the inflowing streams or the marine embayments.

However, a review of existing information (WGCMA, 2013) highlighted that despite the limitations of the current state of knowledge, it is clear that the magnitude, timing, frequency and duration of freshwater inflows can influence water quality and water regimes in the estuaries and embayments of Corner Inlet and Nooramunga, and therefore their dependent ecological values. A judgement about the flow components that are likely to be of importance to the critical components, processes and services identified for the Corner Inlet Ramsar site ECD (Australian Government 2011) has been made, based on the current state of knowledge, relative to the recommended flow objectives (see table 5.1.1).

Left: Fencing and excluding stock from fragile saltmarsh vegetation has benefits for water quality. Photo – WGCMA.

Right: The health of saltmarsh and mangrove vegetation communities is linked to the quality and quantity of estuarine flows. Photo – InDetail Comms & PR.

Table 5.1.1 Flow objectives for Corner Inlet and Nooramunga

No.	River flow objective	Critical component / process / service	Ecological basis
1	Protect natural low flows (base flows)	• inter-tidal sand or mudflat • fish habitat	Important for maintenance of: • habitat connectivity between freshwater and estuarine river reaches • freshwater conditions in upper estuary and, hence, diversity of habitat for biota in the river estuaries
2	Protect important rises in water levels (freshes and high flows)	• mangroves • saltmarsh • seagrass • waterbirds • orange bellied parrot • Australian grayling • fish habitat • shallow marine water	Required for: • flushing river estuaries of sediment and salt • importation of sediment, nutrient and organic matter to the lower estuaries and embayments • fish life cycle cues • elevation of water levels and lowering of salinity concentrations to allow sexual reproduction of plants
3	Maintain wetland and floodplain inundation (bankfull events and overbank flows)	• wetlands • growling grass frog	Occasional connectivity between wetlands/ floodplains and the river estuaries and embayments facilitate movement of sediment, nutrients, organic matter and biota. This connectivity may be important for: • replenishing or reducing stores of materials • completing critical life cycle stages NB. The opportunity for lateral connectivity is significantly reduced where streams have deeply incised e.g. Albert and Franklin Rivers and Bruthen Creek
4	Maintain natural flow variability	All	Required to: • maintain temporal and spatial habitat diversity and condition • provide biological cues at the appropriate time for breeding and migration
5	Maintain or rehabilitate estuarine processes and habitats	All	Critical to the condition and values of Corner Inlet and Nooramunga, especially the critical and supporting components, processes and services identified in the ECD.
6	Manage groundwater for ecosystems	• inter-tidal sand or mudflat • fish habitat • potentially others	Relevant due to known and likely direct and/or indirect connections between aquifers and Corner Inlet and Nooramunga.

Of the range of flow components covered in the flow objectives above, management influence is restricted to low flows and freshes. Nevertheless, these flows will contribute to the achievement of all objectives except number three. The downstream influence of 'manageable' flows is however unlikely to extend beyond the near-shore backwaters close to the mouths of the inflowing streams.

Left: Agnes Falls, a significant tourist attraction for the region. Photo – WGCMA.

Centre: Toora's drinking water comes from the Agnes River and is treated before being supplied to customers by South Gippsland Water. Photo – SGW.

Right: Cows grazing on farmland above the Agnes River. Photo – WGCMA.

5.2 Environmental flow provisions

There is no specific environmental flow allocation for the waterways that enter Corner Inlet Ramsar Site or the embayment itself. No direct environmental water holdings exist in the area, as there are no major storages on any of the inflowing waterways. While limits on licensed consumptive use from the inflowing waterways do in effect provide 'environmental flows' to the system, the basis for these limits have not always explicitly considered the environment's need for water (e.g. minimum passing flows). The environmental flow 'provisions' for Corner Inlet and Nooramunga, as defined in the relevant policies, entitlements and licences to take and use water from their inflowing streams, are summarised below in two parts:

1. A general description of the provisions, indicating which streams they apply to (table 5.2.2).
2. The source of the documented provisions and the key provisions for the major streams and aquifers (table 5.2.3).

The limitations, risks and opportunities related to the environmental flow provisions for Corner Inlet and Nooramunga are summarised in table 5.2.1. The key points are as follows:

- All existing bulk entitlements and take and use licences are recognised under Victoria's water allocation framework, and opportunities to make permanent changes to them are very limited, thereby severely restricting the ability to improve environmental flows (if there is an identified need).
- The impact of consumptive use on environmental flows to Corner Inlet and Nooramunga is likely to increase due to growth in unlicensed consumptive water use (e.g. volumes harvested for stock and domestic use including the number or size of bores), increased uptake of existing surface and groundwater licences, and new allocations.
- Reviews of water allocation policy and plans present an opportunity and a risk to the environmental flow provisions for Corner Inlet and Nooramunga.

Therefore a key action of the WQIP over the next decade is to ensure that these opportunities and risks to water quality and flow are appropriately considered, so as to ensure that the environmental flow provision is not eroded and where possible, improvements are made.

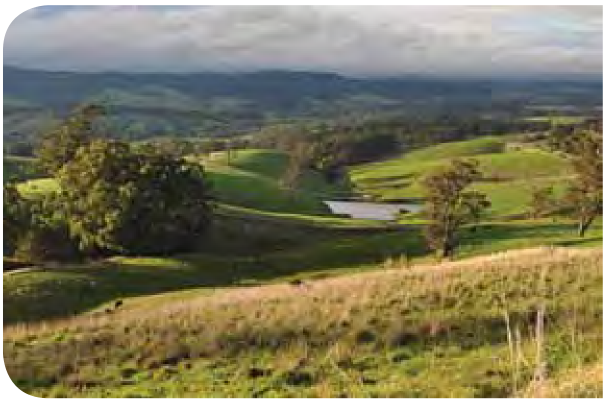
Table 5.2.1 Implications of Victorian water management legislation and policy for the Corner Inlet WQIP

Issue	Limitations/risks	Opportunities
The majority of the environmental flow provisions (above cap water) for Corner Inlet and Nooramunga is not secure.	The 'above cap' component of the environmental flow provisions can be eroded by: • water uses outside of Victoria's water allocation framework, e.g. domestic and stock use including the number or size of small catchment dams and bores; riparian water use; interception of rainfall, surface and/or groundwater by vegetation (i.e. forestry, crops and fire); and mining or earth resource projects • growth in usage of existing surface and groundwater licences and entitlements, e.g. urban water use – Agnes, Franklin and Tarra systems and potential introduction of high flow harvesting outside of the winter-fill period • increases in water use caps • climate change.	Victorian agencies will monitor, track and report on water use outside the entitlement framework annually.[1] Guidelines have been prepared for reasonable stock and domestic use. Victoria's approach to stock and domestic use management will be reviewed following release of the Murray-Darling Basin Plan.[1] The *Water Act 1989* will be amended to enable the declaration of 'intensive management areas' to control water intensive land use changes by the end of 2013. An example is the case where new forestry developments replace existing pasture or crops.[1] Downstream water impacts will be considered when planning burns and other bushfire control measures.[1] Approvals and licensing decisions for new mining, earth resource or emerging technology projects must consider the potential impacts on water resources.[1] Upgrades to urban water supply systems (particularly Agnes and Franklin catchments) and review of SGW's Water Supply Demand Strategy in 2016. Local Management Plans are to be prepared for all major streams, Giffard Groundwater Management Area and other aquifers outside of the Yarram Water Supply Protection Area.[1] Strategic groundwater resource assessments will consider groundwater dependent ecosystems.[1] Identification and explicit consideration of high value Groundwater Dependent Ecosystems in water allocation and waterway management.[1, 2] The Gippsland Region Sustainable Water Strategy (GRSWS) will be reviewed by 2021.[1]

Continued from page 39... **Table 5.2.1 Implications of Victorian water management legislation and policy for the Corner Inlet WQIP**

Issue	Limitations/risks	Opportunities
The ability to modify existing bulk entitlement/licence rules and oil/gas extraction licences, and therefore freshwater inflows to Corner Inlet and Nooramunga, is very limited.	Bulk entitlements issued under the *Water Act 1989* can only be permanently changed at the request of the bulk entitlement holder, or following a statutory 15 year water resource review. Take and use licences issued under the *Water Act 1989* can only be amended when they are due for renewal, through a statutory management plan or following a 15 year water resource review.	A statutory review of water availability in Victoria is required in 2019. Improving knowledge of groundwater-surface water interaction and the effects of declining water levels in the Latrobe Group Aquifer (LGA) on stream flow in the Yarram Water Supply Protection Area (WSPA). The need for a review of the Yarram WSPA monitoring program and/or groundwater management plan is considered annually by SRW. The Victorian Government will advocate for oil/gas extraction environment plans to be revised if significant new risks are identified, including risks associated with the LGA.[1]
A lack of quantitative knowledge of site specific relationships between inflows and aquatic species and communities (including ecological thresholds) for Corner Inlet and Nooramunga.	This prohibits an understanding of the effects of current and future water use/management on Corner Inlet and Nooramunga and their inflowing streams.	Revised winter-fill caps and review of these in 2021[1] provides time to improve flow-ecology understanding and, in the interim, places the onus on those seeking greater volumes to undertake detailed assessments. An approved method for determining the environmental flow requirements of Victorian estuaries now exists.[2] The GRSWS will be reviewed by 2021.[1]

[1] *Policy/actions contained within the Gippsland Region Sustainable Water Strategy (DSE 2011)*
[2] *Policy/actions contained within the draft Victorian Waterway Management Strategy (DSE 2012)*



Left: The upper catchment of the Jack and Albert Rivers. Photo – Sally-Anne Henderson.

Right: Canoeists paddling the lower reach of the Albert River. Photo – WGCMA.

Table 5.2.2 General description of the environmental flow provisions for Corner Inlet and Nooramunga

Description	Franklin River	Agnes River	Albert River	Tarra River	Bruthen Creek	Other tributaries	Yarram Water Supply Protection Area (WSPA)	Giffard Ground-water Management Area (GMA)	Other aquifers
Minimum passing flows (SGW)[1]	✓	✓	NA	✓	NA	NA	NA	NA	NA
Minimum passing flows (licensed surface water diverters)[2 & 3]	✓	✓	✓	✓	✓	✗	NA	NA	NA
Restricted diversion rates/volumes for South Gippsland Water[1 & 3] and licensed diverters[2 & 3]	✓	✓	✓	✓	✓	✓	✓	✓	✓
Prohibition of new entitlements[3]	Nov-Jun	Nov-Jun	Nov-Jun	✓	✓	Nov-Jun	✓	✓	✗
Cap on new entitlements	✓	✓	✓	✓	✓	✓	✓	✓	✗
Prohibition of upstream transfer of surface water licences[3]	✓	✓	✓	✓	✓	✓	NA	NA	NA
Rules governing transfer of groundwater licences to minimise risk of seawater intrusion and stream interference	NA	NA	NA	NA	NA	NA	✓	✗	✗

1 Prescribed in Bulk Entitlements
2 Prescribed in licences and/or Local Management Rules (which are to be documented in Local Management Plans)
3 Provided for in state-wide 'Policies for Managing Take and Use Licences'

Table 5.2.3 Environmental flow provisions for Corner Inlet and Nooramunga

System	Source of documented provisions	Maximum annual volume	Minimum passing flow	Maximum diversion rate	Water available for new entitlements
Franklin River	Bulk Entitlement (Foster) Conversion Order 1997 (Deep Creek)	326 ML/yr	0.2 ML/d or natural	3.5 ML/d	-
	Franklin River Local Management Rules	555 ML/yr (total licensed volume)	1.5 ML/d after the last irrigation pump	Licence specific	-
	Sustainable Diversion Limits	Variable depending upon location	Variable depending upon location	Variable depending upon location	Revised in GRSWS (see below)
	Gippsland Region Sustainable Water Strategy	-	-	-	300 ML/yr during July-October
Agnes River	Bulk Entitlement (Toora, Port Franklin, Welshpool and Port Welshpool) Conversion Order 1997	1,617 ML/yr	1ML/d or natural	4.8 ML/d	-
	Agnes River Local Management Rules	339 ML/yr (total licensed volume)	6 ML/d or natural above Agnes Falls	Licence specific	-
	Sustainable Diversion Limits	Variable depending upon location	Variable depending upon location	Variable depending upon location	Revised in GRSWS (see below)
	Gippsland Region Sustainable Water Strategy	-	-	-	Share of 500 ML/yr up to SDL limit during July-October*
Albert River	Agnes River Local Management Rules	1,259 ML/yr (total licensed volume)	4 ML/d or natural (Albert River) 3 ML/d or natural (Jack River)	Licence specific	-
	Sustainable Diversion Limits	Variable depending upon location	Variable depending upon location	Variable depending upon location	Revised in GRSWS (see below)
	Gippsland Region Sustainable Water Strategy	-	-	-	300 ML/yr during July-October

Continued form page 42... **Table 5.2.3 Environmental flow provisions for Corner Inlet and Nooramunga**

System	Source of documented provisions	Maximum annual volume	Minimum passing flow	Maximum diversion rate	Water available for new entitlements
Tarra River	Bulk Entitlement (Devon North, Alberton, Yarram and Port Albert) Conversion Order 1997 & Conversion Amendment Order 2006	853 ML/yr	Minimum passing flow is variable depending on river flow upstream of off-take	Daily extraction rate is variable depending on river flow upstream of off-take	-
	Tarra River Local Management Rules	2,156 ML/yr (total licensed volume)	5 ML/d or natural at Yarram (Tarra River and Macks Creek) 1 ML/d or natural at Berryman (Griegs Creek)	-	-
	Sustainable Diversion Limits	Variable depending upon location	Variable depending upon location	Variable depending upon location	Revised in GRSWS (see below)
	Gippsland Region Sustainable Water Strategy	-	-	-	0 ML/yr
Bruthen Creek	Bruthen River Local Management Rules	431 ML/yr (total licensed volume)	2 ML/d or natural	Licence specific	-
	Sustainable Diversion Limits	Variable depending upon location	Variable depending upon location	Variable depending upon location	Revised in GRSWS (see below)
	Gippsland Region Sustainable Water Strategy	-	-	-	0 ML/yr
Yarram WSPA	Yarram WSPA Management Plan	25,317 ML/yr	NA	Licence specific	0 ML/yr
Giffard GMA	Gippsland Region Sustainable Water Strategy	5, 670 ML/yr	NA	Licence specific	0 ML/yr

** To be shared across the entire South Gippsland Basin*

Left: The Tarra River rises in the cool temperate rainforest of the eastern section of the Strzelecki Range. Photo – Jonathon Stevenson.

Top right: The Tarra River fishing platform provides safe river access for anglers and reduces bank erosion. Photo – WGCMA.

Lower right: Water from the Tarra River services towns in the Yarram district, provides for irrigation and supports wetlands in it's lower reaches. Photo – WGCMA.

5.3 Integrating water quality and flow

Given the strong association between water quality and quantity, it is possible that management options to improve water quality may have positive or negative consequences for river and/or groundwater flows.

The following principles are proposed to guide future considerations of catchment-sourced inflows in the context of water quality management. Given the current data and water quality modelling used it is not possible to complete this work at this point. However, should actions be proposed in the future that would substantially change the use of land and water in the Corner Inlet catchment it would be prudent to implement them in the light of the principles outlined below.

Principle 1: Avoid, and where not possible, minimise adverse effects on catchment derived inflows on receiving waters of the Corner Inlet Ramsar Site.

It is recommended that the actions to improve water quality in the catchment also aim to protect catchment-derived inflows to Corner Inlet and Nooramunga. It is appreciated however that it may be necessary to trade-off river flow impacts against water quality improvements in some instances. Assessment of management options should include consideration of impacts relative to river flow objectives, and any trade-offs should be made transparent.

Principle 2: Maximise environmental benefits to catchment-derived inflows arising from water quality management.

Under the current water allocation framework, and because of the unregulated nature of the streams in the Corner Inlet catchment, there are limited opportunities to improve environmental flows in the streams flowing to the Corner Inlet Ramsar Site. The opportunities listed in table 5.2.1 should be carefully considered in the context of implementing the WQIP.

5.4 Considering climate change

Victoria's climate is expected to become warmer, with an increased frequency of extreme storm events and reduced availability of water. Increased sea level rise is predicted across the Victorian coast, and evidence of such change is already occurring internationally (Rahmstorf et. al., 2007; Rahmstorf, 2010). In addition, there is evidence that sea temperatures are rising and will continue to rise, and that there will be more hot days. These factors are known to affect seagrass health (see figure 2 in Appendix 1) and make the task of determining the relationship and isolating the thresholds for water quality and seagrass more challenging.

Under modelled climate change scenarios it is predicted there will be changes to both catchment flows and the hydrodynamics of the embayment (BMT WBM, 2011; Water Technology, 2008). The two main implications of this for the Corner Inlet WQIP are:

1. Large rainfall events, including those resulting from extreme storms, will continue to be a major contributor to loads of sediment and nutrient entering the embayment, however the frequency and duration of events are likely to reduce (in line with the time period modelled by Water Technology in 2008 and used as the basis for the WQIP).
2. Wind speeds will increase as a consequence of a larger number or increased severity of storms. This will result in increased erosion along the shores of the Corner Inlet Ramsar Site and increased re-suspension of benthic material within the embayment.

It is critical that natural resource management plans take account of the likely implications of climate change. At this point in time the available climate models and the current state of knowledge make it impossible to explicitly predict the implications of climate change for Corner Inlet. In the absence of this information, the planning approach has been to ensure that the WQIP works program is robust should the likely impacts eventuate.

As implementation of this WQIP progresses, and as the resolution of climate models improves, it will be important to ensure that regular reviews of the plan take account of the changes in rainfall, temperature, evaporation, wind speed and sea levels that may result from climate change.

Left: Stockyard Creek in Foster during a high rainfall event, November 2013. Photo – InDetail Comms & PR.

Right: A storm crossing Corner Inlet and the northern shore of Wilsons Promontory. Photo – WGCMA.

6. Program Logic – linking water quality and environmental values

6.1 Values, threats and water quality

The program logic for the WQIP was developed to describe what is required to achieve agreed water quality objectives for the Corner Inlet Ramsar Site (see figure 6.1.1).

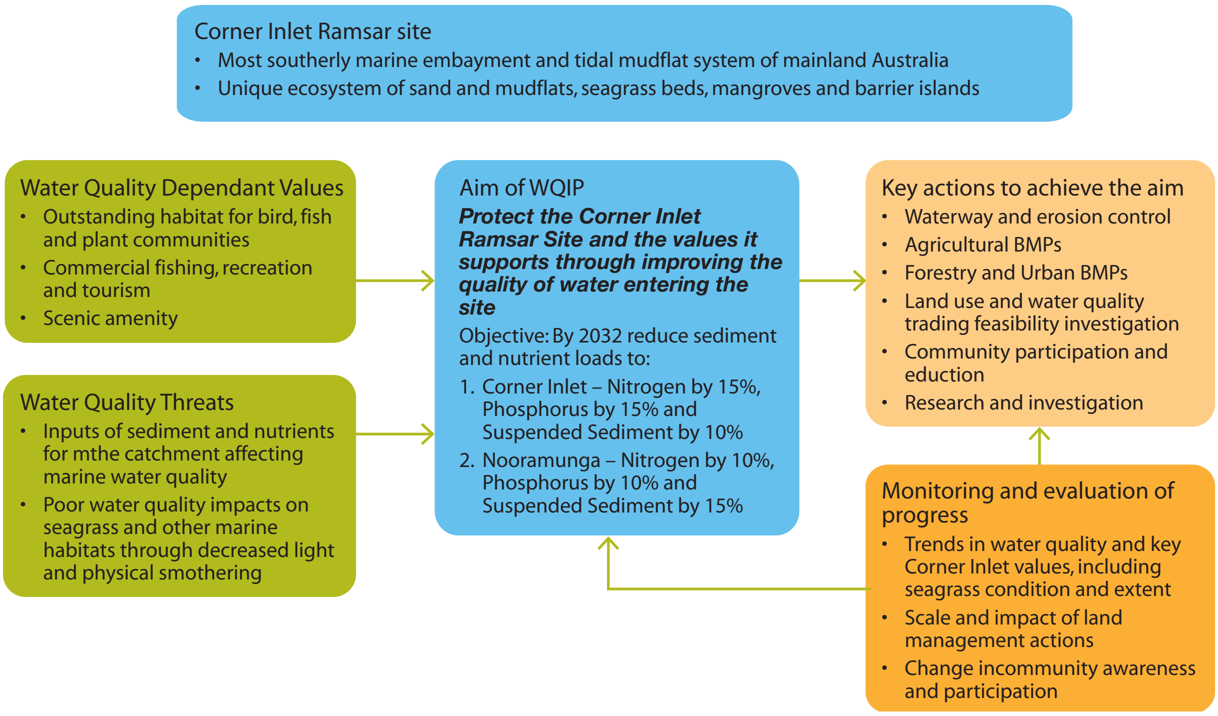


Figure 6.1.1 Simplified Program Logic for Corner Inlet WQIP

The overall aim of the WQIP is to improve the quality of water entering the Corner Inlet Ramsar Site in order to protect its unique and significant combination of ecological, social and economic values. Achieving this aim requires a measurable reduction in the loads of nutrient (Nitrogen and Phosphorus) and suspended sediment entering the Ramsar site from surrounding catchments. Elevated loads of nutrient and sediment are likely to adversely affect the extent and condition of seagrass (and other key habitats) in Corner Inlet with subsequent flow-on consequences for key asset values including significant fish and bird populations. Current knowledge regarding the link between water quality and seagrass condition is outlined in detail in Appendix 1, a summary of which is provided below.

Support for investigations into catchment water quality has been underpinned by the assumption that reducing sediment and nutrient loads from catchment sources will lead to an improvement in the condition and extent of seagrass in Corner Inlet and Nooramunga. The CSIRO environmental audit of Corner Inlet (Malloy et. al., 2005) concluded that the values of the Ramsar site were likely to be threatened by excessive inflows of nutrient and sediment from the catchment. The more detailed modelling of Water Technology (2008) confirmed that catchment derived nutrient and sediment were expected to be significant within and near the mouth of rivers and streams entering Corner Inlet. Potentially, these nutrient and sediment inflows have an impact on seagrass through reduced light availability due to increased Turbidity and/or epiphyte or algal growth.

Seagrass is one of a number of wetland mega-habitat types that forms a critical component of the Corner Inlet Ramsar Site, and which underpins critical ecosystem processes and the services and benefits that result (BMT WBM, 2011). The conceptual model developed by Warry and Hindell (2009), highlights the ecological importance of seagrass communities for a range of economic, social and environmental values. The model also outlines the deleterious impacts of elevated nutrient and sediment from catchment run-off on these values.

Given all these factors, central to the Program Logic for the Corner Inlet WQIP is a focus on reducing sediment and nutrient loads to the Corner Inlet Ramsar Site in order to maintain and improve the extent and condition of seagrass communities.

Agreed water quality objectives have been based on 'SMART' principles; those that are Specific, Measurable, Attainable, Realistic and Time-bound. SMART objectives are required as a basis for linking and quantifying the actions required to achieve specified nutrient and sediment load reductions in the Corner Inlet and Nooramunga catchments. Two decision support tools were used to assess the costs and benefits of reducing water quality threats. These tools, bioeconomic modelling and INFFER (Investment Framework for Environmental Resources, www.inffer.org, Pannell et. al., 2011) were implemented using available scientific, expert and local knowledge (more detail of the approach and results is provided in Section 7).

Setting SMART objectives supported an understanding of the scale of works and actions required. It also required definition of clear assumptions about the effectiveness (technical feasibility) of proposed actions including best management practices, waterway and erosion fencing activities and changes in land use if other actions could not meet objectives. The scale of works required to meet these objectives is significant and will require large-scale adoption across the land use areas examined. Therefore the method assumes that payments to farmers would be required in order to recognise lost opportunity costs to production in order to offset profit losses that may result from the implementation of objectives. The INFFER analysis identified the appropriate mix of policy tools required and ensured that the best estimate of costs to achieve specified water quality objectives and to protect the values of the Corner Inlet Ramsar Site was made.

6.2 How the objectives were developed

Using available catchment modelling as the baseline information, the SMART objectives were developed based on the total maximum load of pollutant/s to be achieved. (Anon., 2002). The WQIP Technical Panel decided to base the development of water quality objectives on the link between sediment and nutrient (N, P) and seagrass condition and extent. As described in section 6.1 and Appendix 1, seagrass is central to the ecology of the Corner Inlet Ramsar Site, and plays a critical role in commercial and recreational fisheries (Kirkman, 2013; Poore, 1978). Many water birds, including migratory waders, forage in intertidal seagrass beds.

Development of the initial (called 'aspirational') water quality objectives by the Technical Panel involved a range of considerations, which were outlined in a discussion paper prepared by the WGCMA (Dickson, 2012, unpublished). They include:

- Acknowledgement of differences in catchment characteristics and embayment hydrodynamics and their potential impacts on seagrass beds. This made it sensible to have different objectives for each of the Nooramunga and Corner Inlet catchment areas of the Ramsar site. Nutrients are likely to be of most concern in Corner Inlet (elevated TP concentrations near seagrass beds in particular), whereas excessive sediment is believed to be of greater concern in Nooramunga.
- Uncertainty about location-specific thresholds and relationships between nutrient and sediment load reduction and extent and condition of seagrass beds for Corner Inlet and Nooramunga. Whilst there are well-documented relationships between nutrients and seagrass for other sites in Australia and overseas, the Technical Panel felt that such results could not be extrapolated sufficiently well for the Corner Inlet Ramsar Site due to the particular conditions in the embayment and the particular seagrass species present.
- Reference to other Water Quality Improvement Plans where nutrient reduction objectives are commonly set above 30% and with limited consideration of feasibility or cost to achieve targets.

- Previous INFFER work done in the Gippsland Lakes which showed that 40% P load reduction involved economically, socially and politically unacceptable land use changes (Roberts et. al., 2012).
- Knowledge that the environmental condition of Corner Inlet is better than that of the Gippsland Lakes, with the Corner Inlet Ramsar Site better flushed through tidal exchange. This suggests that lower nutrient reduction objectives than for the Gippsland Lakes are likely to be acceptable for the Corner Inlet Ramsar Site in order to maintain ecological values.

Based on this, the Technical Panel initially set 20-year 'aspirational' objectives for each of the Corner Inlet and Nooramunga catchments. The aspirational objectives were revised to 'Implementation Plan' objectives following bioeconomic modelling and INFFER analysis that estimated that large-scale changes to the composition of land uses would be required to achieve the aspirational objectives.

The results were deemed to be not feasible due to the social and political impacts this would cause and uncertainty around the water quality requirements of the Corner Inlet part of the Ramsar site. Both sets of objectives are shown below. Objectives have been set as the % reduction required from baseline loads. They are expressed in terms of Total Nitrogen (TN), Total Phosphorus (TP) or Total Suspended Sediment (TSS) estimated from the available catchment modelling using the E2 model (Water Technology, 2008).

1) **Aspirational objectives**
   Corner Inlet – 30% TN, 30% TP, 10% TSS; Nooramunga – 20% TN, 20% TP, 20% TSS by 2033.
2) **Implementation Plan objectives**
   Corner Inlet – 15% TN, 15% TP, 10% TSS; Nooramunga – 10% TN, 10% TP, 10% TSS[a] by 2033.

   [a] Note that following prioritisation and bioeconomic modelling (see Section 7 Prioritisation and Cost Benefit results) the Implementation Plan TSS target able to be achieved for Nooramunga was only 5% – all other objectives were predicted to be achievable with the costs outlined.

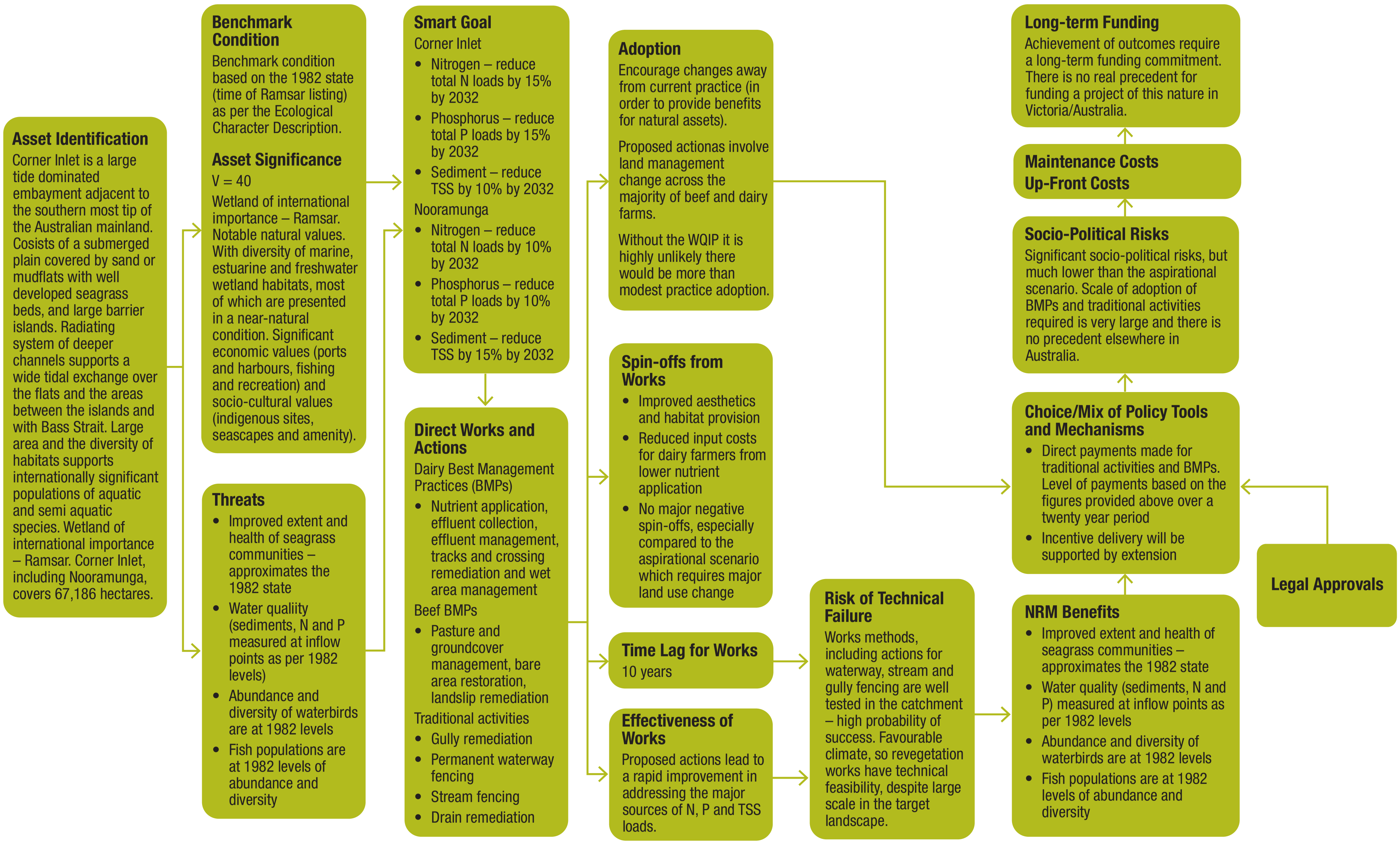
6.3 The link between values, water quality objectives and program logic

As outlined earlier, central to the Program Logic for the Corner Inlet WQIP is a focus on reducing sediment and nutrient delivery to the Corner Inlet Ramsar Site in order to maintain and improve the extent and condition of seagrass communities. The SMART objectives and the available underpinning science and knowledge base provide the basis for developing a sound and costed project for the Corner Inlet WQIP.

INFFER was used to assess how to achieve objectives that aim to protect the values of the Corner Inlet Ramsar Site from deterioration due to sediment and nutrient loads, primarily from agricultural land use. In addition to the simplified Program Logic diagram (Figure 6.1.1), the detailed Program Logic (figure 6.3.1) sets out the links between the values and objectives, along with all other important factors, that need to be considered in the development of a robust project. Unlike many Program Logic approaches where the causal links are loose and unquantified, the relationships between various factors in INFFER are explicit and quantified where appropriate.

Left: Seagrass meadows are a vital part of the Corner Inlet Ramsar Site. Photo – WGCMA.

Right: Six-spined Leatherjacket. Photo – Parks Victoria.



Documentation and assessment knowledge gaps: comprehensive ecological baseline condition for seagrass, role of sediment re-suspension on turbidity levels and seagrass health, ecological thresholds for key habitats i.e: seagrass, mangroves, saltmarsh and intertidal mud and sandflats. There is an assumption that reducing sediment and nutrient loads will result in an improvement in the ecological condition of key attributes of the asset eg: seagrass. The basis for this assumption is weak. There is a need for additional finer scale modelling to better account for spatial heterogeneity within the catchment. Impact of climate change on asset values and catchment dynamics is poorly understood.

Figure 6.3.1 Detailed Program Logic based on the INFFER analysis

7. Prioritisation and Cost Benefit Results

7.1 Load contributions and gains from the catchment

The prioritisation and cost benefit results in this section are underpinned by the modelled contributions of major land uses to overall catchment loads to Corner Inlet and Nooramunga and the improvements to water quality that could be achieved through the implementation of actions. The process also explicitly considers feasibility and costs as fundamental components of the prioritisation process.

Agricultural land uses (beef/sheep which occupies over 40% catchment area and dairy which occupies approximately 10%) contribute most of the nutrient and sediment loads to the Corner Inlet Ramsar Site. Accordingly, it is with the improved management of these lands that the largest gains in nutrient and sediment reduction are likely to be made. The distribution of dairy and beef/sheep farms across the catchment is shown in figure 7.1.1.

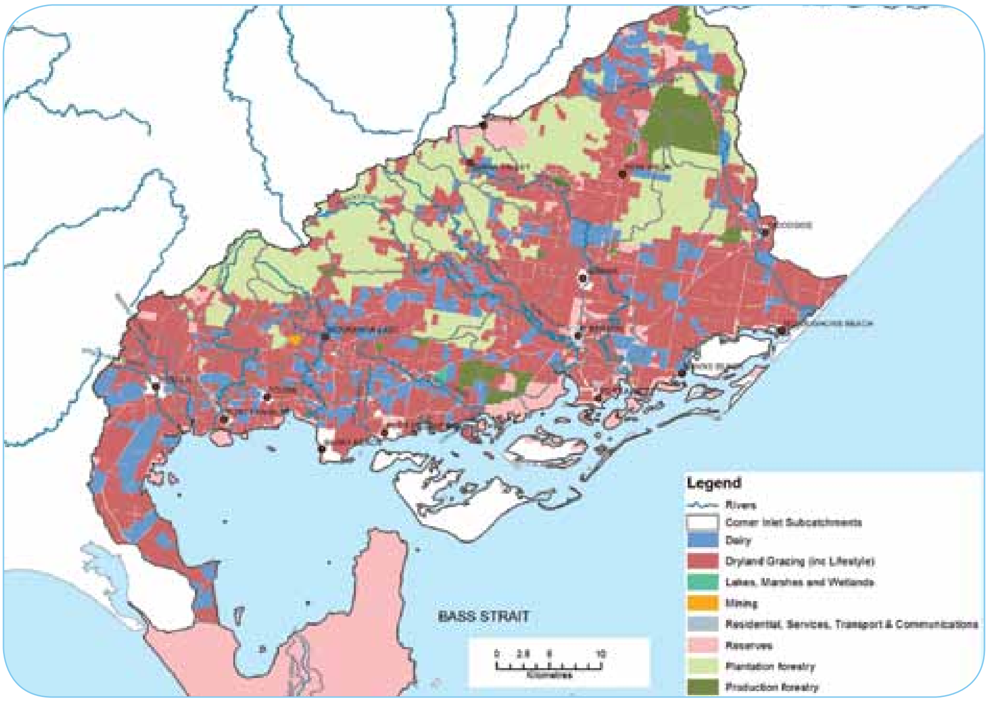


Figure 7.1.1 Land uses in the Corner Inlet and Nooramunga catchments

Plantation forestry is also an important land use across the area, mostly located in upper catchments as shown in figure 7.1.1. Initial catchment modelling indicated surprisingly high levels of sediment and nitrate-N loads generated from plantation forestry land. Both Hancock Victorian Plantations (HVP) and the Technical Panel are doubtful of these results. In view of this uncertainty, and the fact that this plan could not evaluate the effectiveness and costs and benefits of forestry management practices, the WQIP works program has been developed on the basis of load reduction targets being met solely from agricultural land management BMPs and fencing activities.

With respect to urban nutrient pollution, contributions from treatment plant outfalls are of concern. Whilst these need to be managed, their contribution to sediment and nutrient load in the Corner Inlet Ramsar Site is low overall.

Although there is uncertainty about the contribution of forestry to total loads and the contributions from urban areas is very small, local stakeholders and the Technical Panel have agreed it is important to identify actions relating to water quality from both these sectors and include them in the WQIP works program.

The loads of TN, TP and TSS from agricultural land uses are shown in the following graphs and figures.

Figures 7.1.2, 7.1.3 and 7.1.4 show the modelled agricultural loads of TN, TP and TSS from the major catchments in Corner Inlet and Nooramunga. The graphs show current (before WQIP) loads and the modelled improvements that will result (after WQIP) from implementation (assuming full implementation of all management actions). The approach for the development of the works program, namely the bioeconomic modelling and INFFER work, is outlined below in Sections 7.2 and 7.3.

Although load reductions are projected to come from all river basins, the largest reductions are predicted from the Western Tributaries (TN, TP, figures 7.1.2 and 7.1.3), the Jack and Albert River catchments (TN, TSS, figures 7.1.2 and 7.1.4), and the Franklin River and Bennison Creek catchments (TSS, figure 7.1.4).

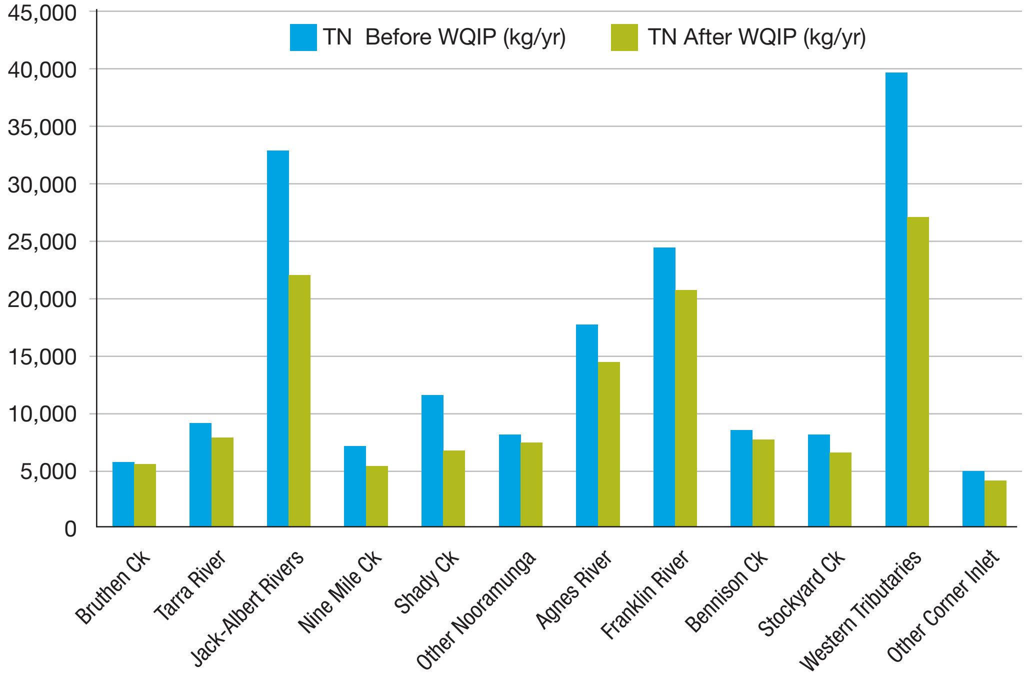


Figure 7.1.2 Total Nitrogen loads (TN kg/year) from agricultural land uses from major catchments before and after WQIP implementation

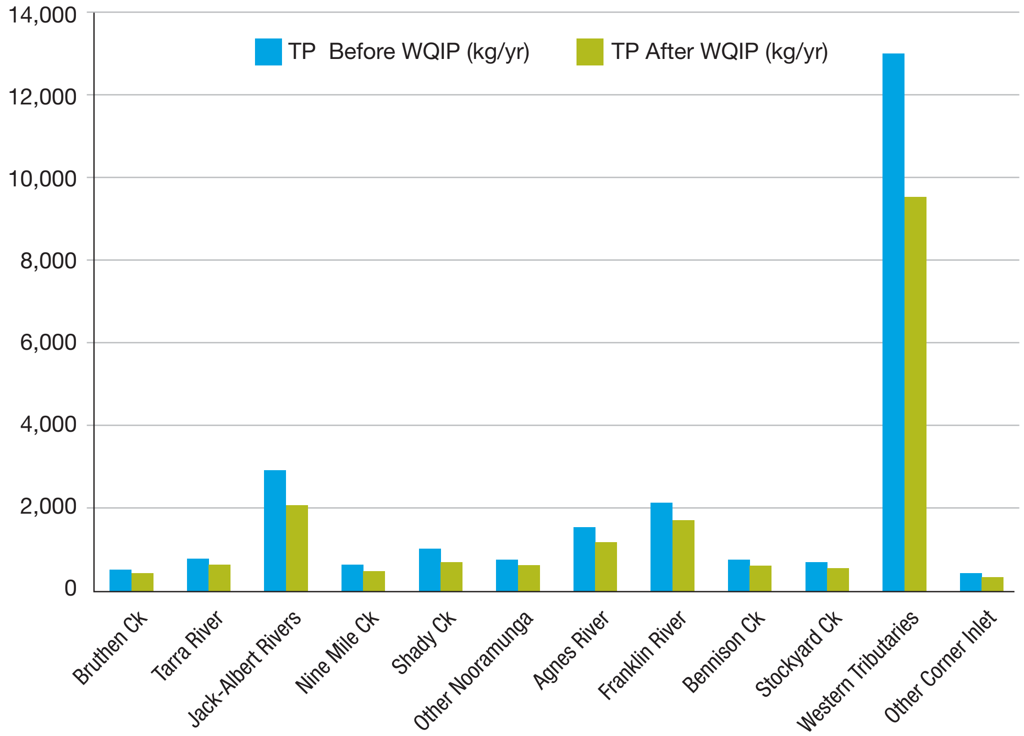


Figure 7.1.3 Total Phosphorus loads (TP kg/year) from agricultural land uses from major catchments before and after WQIP implementation

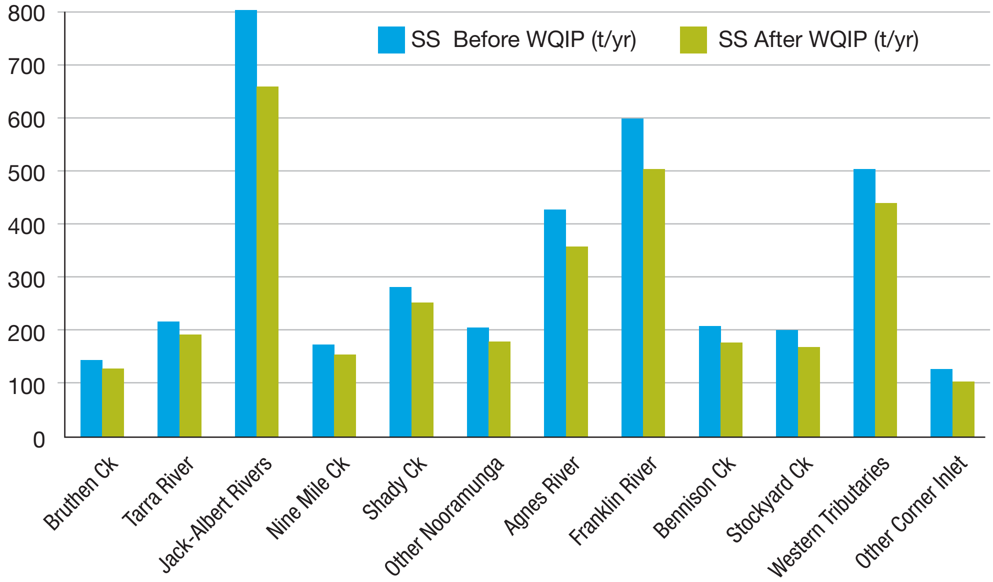


Figure 7.1.4 Total Suspended Sediment loads (TSS t/year) from agricultural land uses from major catchments before and after WQIP implementation

Figures 7.1.5 to 7.1.10 show a more detailed picture of nutrient and sediment loads associated with agricultural land management changes.

Figures 7.1.5, 7.1.7 and 7.1.9 depict the subcatchment loads for each of TN, TP and TSS prior to WQIP implementation.

Figures 7.1.6, 7.1.8 and 7.1.10 depict the change in load for each TN, TP and TSS after the WQIP is implemented.

Note that the southern end of the Western Tributaries catchment (E2 subcatchments 64 and 65) (figure 7.1.1) are not shown in figures 7.1.5 - 7.1.10. This is because the E2 modelling on which the loads are based did not cover these subcatchments. Given that both subcatchments contain agricultural land use, we would expect future implementation programs to extend to both of these subcatchments. The area omitted is 5% of the total catchment area.

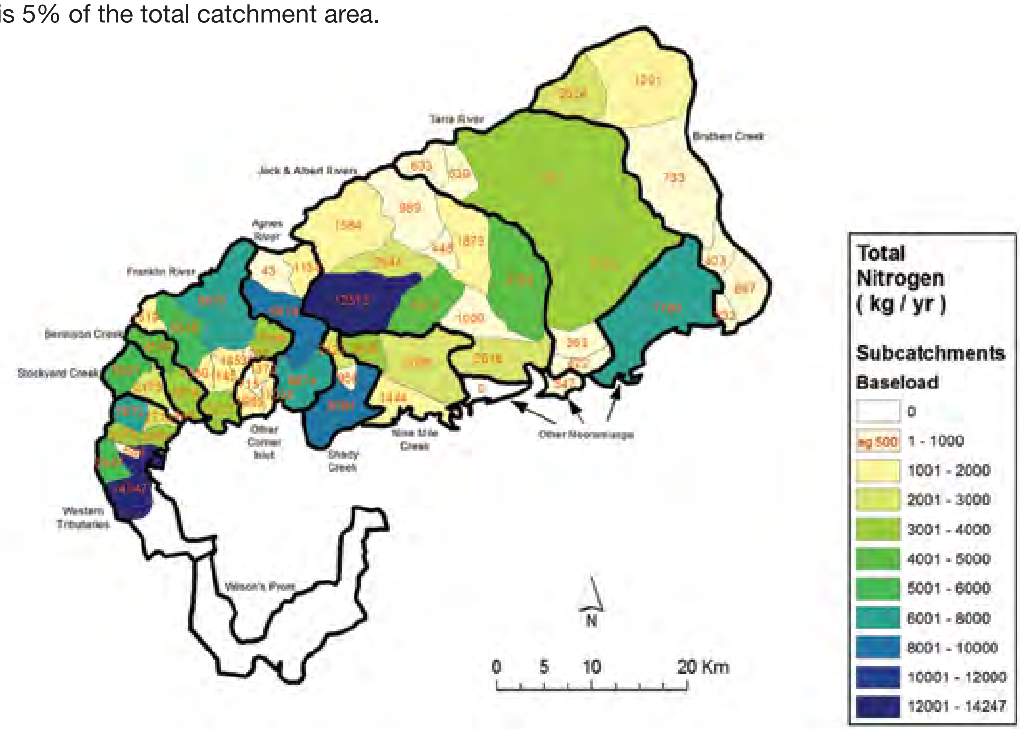


Figure 7.1.5 Total Nitrogen loads (TN kg/year) from agricultural land uses before WQIP implementation

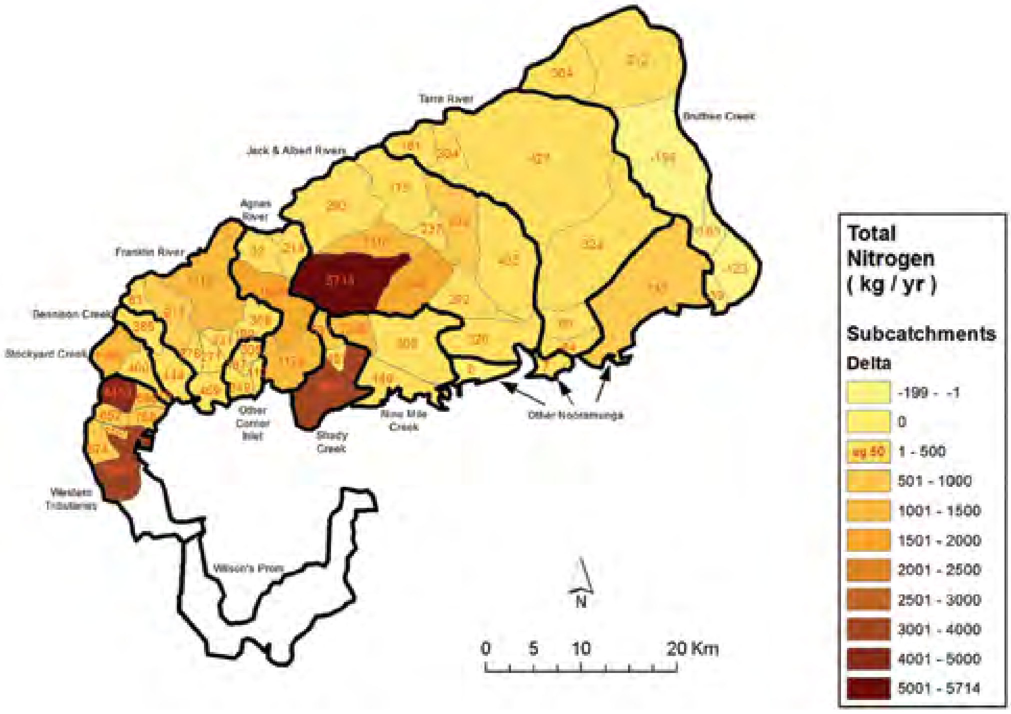


Figure 7.1.6 Change in Total Nitrogen loads (TN kg/year) from agricultural land uses assuming full implementation of the WQIP

Maps in figures 7.1.5 to 7.1.9 illustrate the spatial patterns of Nitrogen, Phosphorus and sediment loss.

Overall, there are high N losses from the Corner Inlet subcatchments and in parts of the Jack, Albert and Tarra catchments (figure 7.1.5). Whilst implementation of management actions needs to occur over most subcatchments, most TN load reduction is predicted to come from the Jack and Albert Rivers, Shady Creek, and the Western Tributaries (figure 7.1.6).

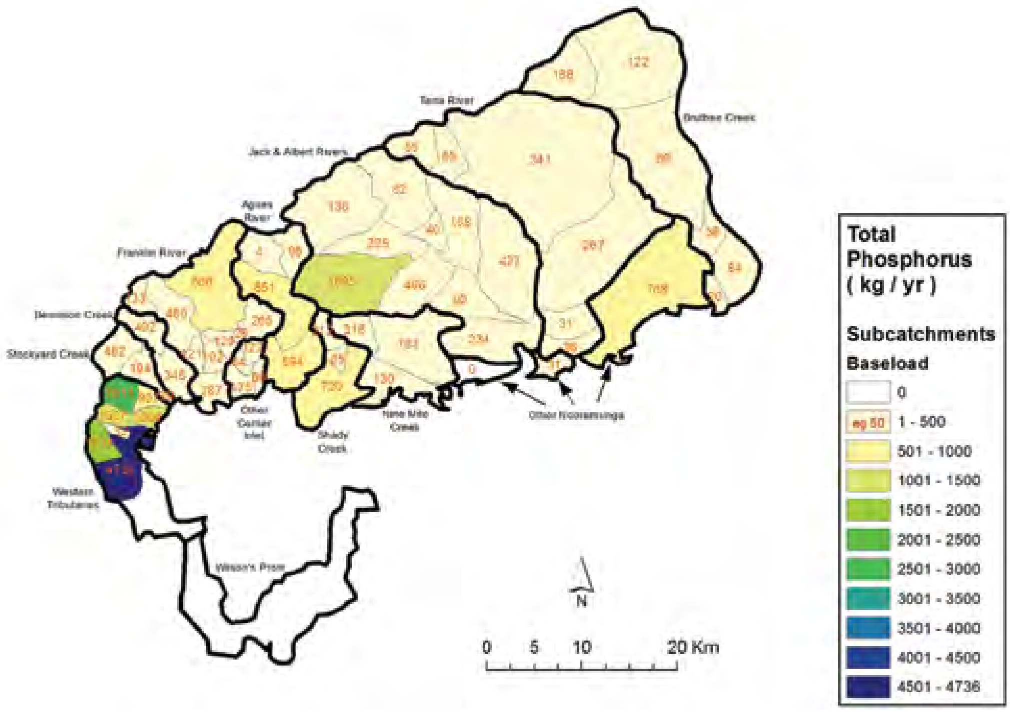


Figure 7.1.7 Total Phosphorus loads (TP kg/year) from agricultural land uses before WQIP implementation

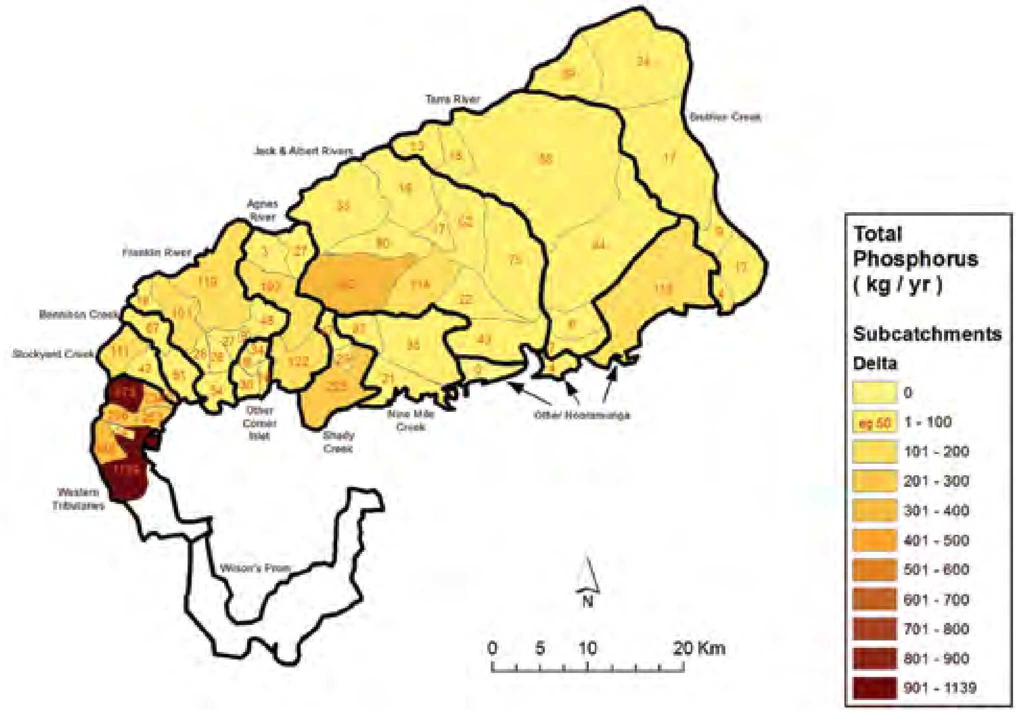


Figure 7.1.8 Change in Total Phosphorus loads (TP kg/year) from agricultural land uses assuming full implementation of the WQIP

The TP loads from agriculture are highest in the Western Tributaries of Corner Inlet (figure 7.1.7). The Jack and Albert catchment is also an important source of TP. The Western Tributaries, the Jack and Albert catchment, and Shady Creek are where the largest TP load reductions are predicted to occur as a result of the implementation of the Corner Inlet WQIP.

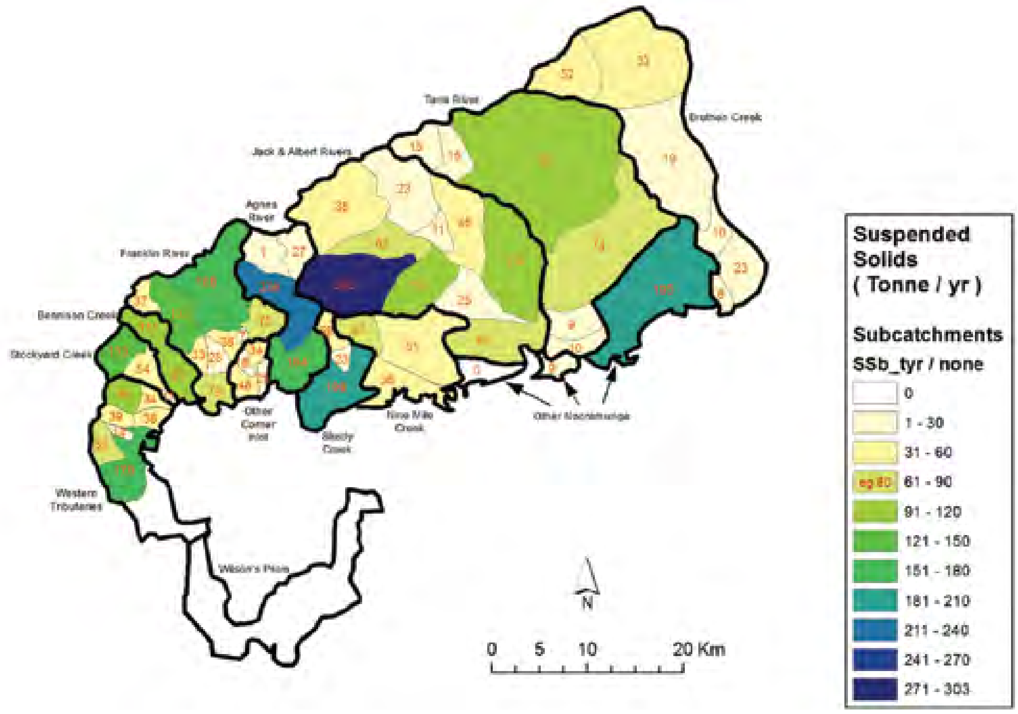


Figure 7.1.9 Total Suspended Sediment loads (TSS t/year) from agricultural land uses before WQIP implementation

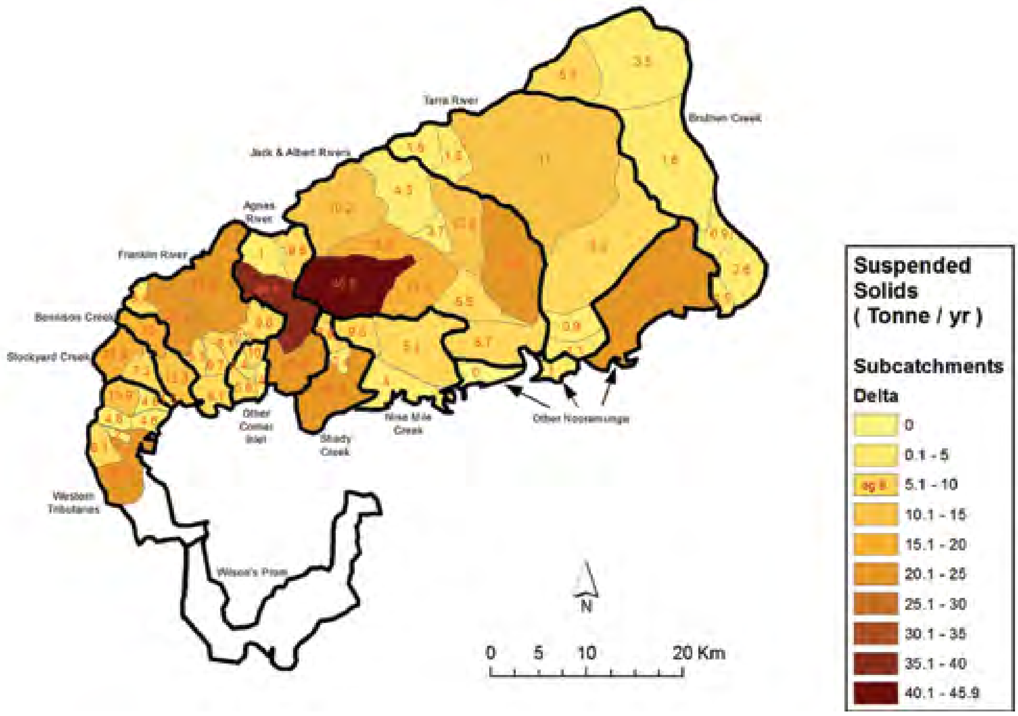


Figure 7.1.10 Change in total Suspended Sediment loads (TSS t/year) from agricultural land uses assuming full implementation of the WQIP

Compared with TN and TP, sediment load reduction is somewhat less targeted, with load reduction of over 10t/year needing to occur in a number of subcatchments, but especially in the Jack and Albert catchment and the Agnes River catchment.

7.2 Costs and implications of achieving targets (bioeconomic modelling)

Bioeconomic modelling was used to assess the feasibility and costs of management actions to achieve the water quality targets outlined in Section 6.2. A summary of the approach is outlined in Appendix 2 along with assumptions about the effectiveness of farm management actions and costs.

Over 20 scenarios were analysed in response to WGCMA and Technical Panel discussions. Scenario testing enabled increased understanding of predicted land use/management change implications associated with achieving differing load reduction targets. Three scenarios are presented (see table 7.2.1) to illustrate the costs and implications of achieving different targets.

The three scenarios (A, B and C) include one for higher aspirational targets (A) and two (B and C) for the revised targets that were chosen to be examined for implementation. Out of the three scenarios, the third (C) was selected for use in the implementation of the Corner Inlet WQIP. This scenario was arrived at through an iterative process that included consultation with the Technical Panel on two occasions and additional discussion with the WQIP Project Managers.

The logic behind the final implementation scenario is as follows:

- The Technical Panel agreed to the revised implementation targets outlined in Section 6.2.
- Whilst the least-cost solution (B) is predicted to be $8.58M/year (table 7.2.1), the results predict large-scale land use changes and this is not an acceptable outcome for the socio-economic viability of the local community. Best Management Practices (BMPs) and traditional activities were judged to be much more acceptable to the local community. The cost from the selected scenario (C) is only slightly greater $8.95M/year for a much more politically acceptable outcome (no land retirement). The trade-off however is that the sediment reduction target met in Nooramunga is only 5% in scenario C rather than 10% in scenario B. Apart from this, scenario C meets the same targets as scenario B.
- Due to its greater catchment size and the importance of sediment, it is much more costly to achieve targets in Nooramunga than in Corner Inlet. The Jack and Albert Rivers (subcatchments 17-26) are major contributors of sediment from agricultural areas within the Nooramunga catchment and these subcatchments provide a logical focus for traditional activities (fencing of waterways and erosion control) to reduce sediment loads.

Table 7.2.1 Costs and management implications of achieving load reduction targets for the Corner Inlet and Nooramunga catchments

Scenario	% load reduction estimated as achievable TN:TP:TSS	Cost $million (M)/year	Summary of management actions required to achieve targets[e]
A. Aspirational targets at least cost	CI[a] 30:30:11[c] N[b] 20:22[c]:20	$30.15M (CI $6.55M, N $23.60M)	• 46% dairy retirement to beef/ sheep (16%CI, 66%N) • dairy BMPs in some of both catchments • 28% beef land retirement to native vegetation • BMPs in beef/sheep in remainder and traditional activities
B. Implementation targets at least financial cost	CI[a]15:19[c]:10 N[b]12[c]:17[c]:15[c]	$8.58M (CI $0.95M, N $7.63M)	• 59% dairy retired to beef/sheep (11% CI, 83%N) • small amount of dairy intensification in several subcatchments • 2% beef retirement to native vegetation. Dairy BMPs in some of both catchments • extensive beef BMPs • range of traditional activities
C. Implementation targets using BMPs across both catchments and focus on sediment reduction in the Jack and Albert River catchments	CI[a]15:20[c]:10 N[b]10:11[c]:5[d]	$8.95M (CI $3.78M, N $5.17M)	• extensive dairy and beef/sheep BMPs in both catchments, including small amount of dairy intensification in several subcatchments (2-6 in Bruthen Creek) and extensification in others in the Franklin River (44,47), Bennison Creek (52) and the Western Tributaries (57,63,64 and 65) subcatchements • traditional activity focus in Jack and Albert River catchments (17-26) and much of Corner Inlet

CI[a] Corner Inlet
N[b] Nooramunga
[c] *In seeking to achieve all three targets, some targets can be over-achieved at no additional cost*
[d] *Confining TSS activities to the Albert and Jack catchments does not achieve 10% TSS reduction*
[e] *More detailed results are available, it is only possible to list summary results here*

Modelling results indicate that the scale of adoption and funding would need to be significantly increased compared with current program allocations for the WQIP targets to be achieved. With the exception of one BMP (nutrient application), all BMPS and traditional fencing activities cost farmers money. This financial impost to farmers, combined with the predominantly public benefit from the activities, means that it is unrealistic to expect sustained practice-adoption without investment in long-term stewardship payments that achieve outcomes for the public good.

Voluntary one-off or short-term incentive type programs, as have been commonly used in Australia, will not be sufficient. Regional agencies have successfully led BMP adoption programs such as CORE4 in West and South Gippsland, however catchment-wide adoption is likely require to a broad spectrum of approaches, including long-term incentives in the form of stewardship that are backed up by compliance for regulated activities across agricultural, forestry and urban land uses.


Left: Binginwarri Landcare group members learning about the native vegetation of the Corner Inlet catchment. Photo – Yarram Yarram Landcare Network.

Right: Weed management work on Macks Creek helped reveal a stand of rare warm temperate rainforest vegetation. Photo – HVP.

Fencing programs have the most impact on sediment reduction whereas many BMPs offer greater potential for nutrient reduction. Maintaining riparian and gully fencing programs whilst increasing other BMP programs requires a shift in emphasis. There is also increased risk in moving to BMP programs due to less experience in implementation and less tested confidence in terms of their effectiveness. In contrast, there is both more experience in waterway and erosion control programs and it is also much easier to assess whether works are maintained than to determine whether BMP programs will be effective.

BMP programs, whilst potentially cost-effective in reducing nutrients, present social and financial challenges not faced previously. Public funding of long-term stewardship payments needs to be underpinned by contracts, appropriate farm-level metrics and auditing of performance. There will also be a need for increased emphasis on assessing compliance for regulated activities both for initial implementation and for ongoing management. To be credible in the long-term, auditing of BMPs should be conducted by an independent third party and regulated activities audited by either a third party or the EPA.

It is acknowledged that the current knowledge base is inadequate to provide a high level of confidence regarding the level of catchment load reduction needed to maintain seagrass condition and extent. Until model confidence is improved the implementation targets should be considered as interim.

Development of robust water quality targets should also be guided by:

- improved catchment modelling that simulates the contributions of all major land uses with a high degree of confidence
- finer scale farm heterogeneity and cost information
- updated BMP and traditional waterway and erosion control activity effectiveness estimates.

Regardless of the scale of targets required to maintain seagrass and other water quality dependent values relating to the Corner Inlet Ramsar Site, it will be critical to further investigate the feasibility of reducing loads from the catchment through BMPs (across all major land uses) and through on-ground actions.

If aspirational load reduction targets are required to maintain the ecological character of the Ramsar site, BMPs and waterway and erosion control actions alone will not be sufficient. If so, other options will need to be investigated in partnership with industry and the community. This could include targeting land use in the catchment to minimise impact from intensive activities and/or formally setting nutrient caps and implementing nutrient trading schemes, drawing on models from New Zealand, the United States of America and Europe. Beginning a conversation about the possible need for targeted land use change should be contemplated.

The acknowledgment that the values of the Corner Inlet Ramsar Site may be threatened by catchment water quality, and that aspirational level water quality targets may not be able to be met through BMPs is an important factor for the community and public funders to understand and discuss. This will better ensure that active decisions can be made about what to do and will provide the community with information and time to think about the trade-offs involved.

7.3 INFFER analysis and cost effectiveness

INFFER (Investment Framework for Environmental Resources (Pannell et. al., 2011)) was used to assess the relative cost-effectiveness for each scenario and was based on the logic of Benefit:Cost Analysis (Boardman et. al., 2010). The scenarios were assessed for relative cost-effectiveness using the INFFER Project Assessment Form. The assessments calculated a Benefit:Cost ratio (BCR) for each scenario (see table 7.3.1).

Undertaking the analysis required collection of the following information:

- Clear identification of the environmental asset, including spatial location and extent.
- Significance or value of the asset.
- Threats that are affecting or are likely to affect the environmental asset.
- Specific, measurable, time-bound goals.
- Works and actions that are proposed to be undertaken to achieve the goals.
- Time lag between undertaking the project and the generation of benefits.
- Future degree of environmental damage with and without the proposed works and actions.
- Risk of technical failure of the project.
- Positive and negative spin-offs from the project (e.g. impacts on other environmental assets).
- Likely extent of adoption by private landholders of the works and actions that would be required to achieve the stated goals.
- Risk that, despite new public investment, private landholders will adopt new works and actions that would further degrade the environmental asset.
- Legal approvals required to undertake the works and actions.
- Policy mechanisms/delivery mechanisms to be used to encourage and facilitate uptake of the required works and actions.
- Socio-political risks.
- Costs of the current project.
- Annual maintenance costs required to maintain benefits after the current project is complete.
- Risk of not obtaining those essential maintenance costs, such that project benefits are lost.

The variables that feed into calculation of the Benefit:Cost Ratio (Pannell, 2012) are mostly specified as proportions, and are included in the index multiplicatively.

$$BCR = \frac{V \times W \times A \times F \times B \times P \times G \times DF \times 20}{C + PV(M + E) \times G}$$

Within this approach, there is no need to provide weights for each variable (as one would do in a multi-criteria analysis).

The variables that feed into calculation of the BCR are:

- V = value of the asset
- W = multiplier for impact of works
- F = multiplier for technical feasibility risk
- A = multiplier for adoption
- B = multiplier for adverse adoption
- P = multiplier for socio-political risk
- G = multiplier for long-term funding risk
- DFB = discount factor function for benefits, which depends on L
- L = lag until benefits occur (years)
- C = short-term cost of project
- PV = present value function
- M = annual cost of maintaining outcomes from the project in the longer term
- E = compliance costs for private citizens, if the project involves enforcement of regulations.

Using this approach a BCR was estimated for several scenarios that are summarised in table 7.3.1.

As well as the three scenarios (A, B and C) presented earlier, table 7.3.1 presents a new ‘future’ scenario (labeled D). Under this scenario it is envisaged that the on-ground cost of reducing nutrient and sediment loads entering the Corner Inlet Ramsar Site could be reduced from $8.95M/year (scenario C) to $6M/year.

Reducing costs could be possible with both finer scale modelling (enabling stronger targeting of nutrient reduction activities) and a market-like mechanism such as a nutrient trading scheme, whereby farm heterogeneity can be much better utilised. Stewardship payments could then be targeted to individual farms based both on the capacity for nutrient reduction (from the finer scale modelling) and the amount farmers would need to be paid for sustained practice-adoption (through farmer bids and competition in the market).

Left: River restoration work has been well supported by landholders on Corner Inlet’s Western Tributaries. Photo – WGCMA.

Top right: Off-stream watering points for cattle reduces bank erosion on waterways and improves water quality. Photo – WGCMA.

Lower right: Fencing to exclude stock and planting of riparian vegetation on the creeks and tributaries flowing through dairy and mixed grazing properties. Photo – WGCMA.

Table 7.3.1 Summarised INFFER analysis results

Scenario with % load reduction estimated as achieved TN:TP:TSS	Direct costs for works $M/year	In-direct costs $M (over 5 years)	Maintenance costs $M/year (after 5 years)	Benefit:Cost Ratio (BCR)	BCR parameter values		Comment
A. Aspirational targets at least cost CI[a] 30:30:11[c] N[b] 20:22[c]:20	$30.15M (CI $6.55M, N $23.60M)	$6.0M	$0.5M	0.003	V = 50 L =10 F = 0.92 B = 1 C = 151 E = 0	W = 0.45 DFb (L) = 0.61 A = 0.4 P = 0.05 M = 30.15 G = 0.1	Large-scale landscape change increases works effectiveness but with very high socio-political risk (P=0.05) and likelihood of future funding is very low (G=0.1).
B. Implementation targets at financial least cost CI[a]15:19[c]:10 N[b]12[c]:17[c]:15	$8.58M (CI $0.95M, N $7.63M)	$5.7M	$0.45M	0.047	V = 50 L = 10 F = 0.87 B = 1 C = 42.9 E = 0	W = 0.30 DFb (L) = 0.61 A = 0.4 P = 0.2 M = 8.58 G = 0.2	Requires some land use change to high socio-political risk (P=0.2), likelihood of funding still very low (G=0.2).
C. Chosen implementation targets. BMPs across both catchments, sediment reduction in Jack and Albert CI[a]15:20[c]:10 N[b]10:11[c]:5[d]	$8.95M (CI $3.78M, N $5.17M)	$6.0M	$0.45M	0.229	V = 50 L =10 F = 0.87 B = 1 C = 44.75 E = 0	W = 0.28 DFb (L) = 0.61 A = 0.5 P = 0.75 M = 8.95 G = 0.3	Much lower socio- political risk (P=0.75) associated with no land use change.
D. Possible future implementation scenario	$6.00M	$6.0M	$0.5M	0.366	V = 50 L =10 F = 0.87 B = 1 C =30 E = 0	W = 0.30 DFb (L) = 0.61 A = 0.5 P = 0.75 M = 6 G = 0.3	Lower costs and similar socio-political risks as WQIP Implementation Plan scenario C. Increased BCR as a result of the reduced on-ground costs.

CI[a] Corner Inlet
N[b] Nooramunga
[c] *In seeking to achieve all three targets, some targets can be over-achieved at no additional cost*
[d] *Confining TSS activities to the Albert and Jack catchments cannot achieve10% TSS load reduction*

The four scenarios outlined in table 7.3.1 are different in terms of the scale of the nutrient and sediment reduction target, overall cost, and ultimate cost-effectiveness. Achieving the aspirational target (scenario A) is very costly ($30.15M/year in direct works costs and additional indirect costs). The scenario requires large-scale landscape change, along with a range of traditional on-ground actions, such as waterway fencing and stewardship payments for dairy and beef farmers to adopt BMPs in some subcatchments. As well as the large costs, scenario A is likely to be viewed as unacceptable from a socio-political perspective (P value of 0.05 indicates very high socio-political risk). The BCR for this scenario at 0.003 indicates that it is 75 times less cost-effective than WQIP Implementation Plan scenario C (BMPs plus traditional activities).

Scenario B achieves only half the nutrient and sediment target of scenario A, however at $8.58M/year (in direct costs), it is less than a quarter of the cost of scenario A. Land use changes are still amongst the selected options, which means that the socio-political risks (P=0.2) remain high. As a result the BCR is still very low (0.047).

The chosen WQIP Implementation Plan scenario C, requires no agricultural land use change and thus is estimated to have much lower socio-political risks (P value 0.75). Water quality targets are achieved at only slightly higher costs ($8.95M/year direct costs) compared to scenario B. This scenario will still require unprecedented levels of investment, in both traditional on-ground fencing actions and stewardship BMP payments to landholders. With the exception of not achieving the sediment target in Nooramunga, similar levels of nutrient and sediment reduction are achieved to those of scenario B.

Lower socio-political risks are the main reason for scenario C having a higher BCR (0.229) than scenarios A and B. Under the future scenario D, the BCR is increased to 0.366 due to the lower on-ground costs which are projected to be achieved through the use of a market-based mechanism such as a well-designed nutrient trading scheme underpinned by finer scale modelling.

In calculating the BCR for each scenario the best available estimates and judgment for parameter values have been used, but there is uncertainty with parameters. To illustrate this, a basic sensitivity analysis was conducted by varying parameter values based on pessimistic, realistic and optimistic assessments for each value within the four scenarios for the chosen implementation scenario C (see table 7.3.2). Adjustment of values was restricted to factors including works effectiveness, technical feasibility, lag times, adoption and socio-political risks. Costs were unchanged for the sensitivity analysis as there is no basis for suggesting these would differ markedly from the base case costing already developed. The likelihood of future funding (G – long-term funding risk), rated as low for both pessimistic and realistic scenarios, has been assigned a value of 1 for the optimistic scenario.

Table 7.3.2 Benefit:Cost ratios for pessimistic, realistic, optimistic assessments for 4 water quality scenarios

Scenario	Pessimistic	Realistic	Optimistic
A. Aspirational targets	0.001	0.003	0.091
B. Implementation (least cost)	0.009	0.047	0.561
C. Chosen implementation (BMPs + traditional)	0.042	0.229	0.904
D. Future scenario with nutrient trading scheme	0.063	0.366	1.461

Table 7.3.2 shows a wide range of BCRs, from extremely cost-ineffective to potentially cost-effective (where a BCR score of 1 = cost-effective). The current political constraints (lack of guaranteed long-term funding and socio-political risks) are commonly the major reasons for poor BCR values. Even the most optimistic assessment of parameter values suggests that the aspirational and least financial costs WQIP targets (scenarios A and B) are not cost effective (BCR values less than 1).

The BCR for the chosen implementation target (0.229) could become close to cost-effective (0.904) with several BCR constraints lessened. Furthermore, the future scenario with lower costs due to a nutrient trading scheme could potentially be cost-effective (BCR 1.46) in reaching the WQIP nutrient reduction targets.

For a project of this scale and complexity, achieving a BCR of greater than 1 is a very good result. It highlights that reducing nutrient and sediment loads to the Corner Inlet Ramsar Site is much more cost-effective than for a previous analysis on the Gippsland Lakes, where only P was able to be considered and the assumptions used at the time about practice effectiveness were over optimistic.

8. Delivery Mechanisms

Implementation of the WQIP will require actions across a range of land uses including agriculture, forestry and urban areas.

In particular, actions on agricultural land to improve water quality are required across the majority of subcatchments. To select appropriate delivery mechanisms for implementation it is important to consider the relative levels of public (external) and private (internal) net benefits from the proposed actions. Depending on relative levels, it may be appropriate to use positive incentives, negative incentives, extension, technology development, or no action. To guide the choice of policy tools relating to private land the Public:Private Benefits Framework (Pannell, 2008) has been used. Under this approach policy mechanisms are grouped into one of five categories:

1. Positive incentives (financial or regulatory instruments to encourage change)
2. Negative incentives (financial or regulatory instruments to inhibit change)
3. Extension (technology transfer, education, communication, demonstrations, support for community network)
4. Technology change (development of improved land management options such as through strategic research and design (R&D), participatory R&D with landholders, provision of infrastructure to support a new management option)
5. No action.

The framework highlights the importance of targeting funds for environmental programs to selected areas, based on the levels of public and private net benefits. In particular, the framework indicates that mechanisms should be used as follows:

- Positive incentives – where public net benefits are highly positive and private net benefits are close to zero
- Negative incentives – where public net benefits are highly negative and private net benefits are slightly positive
- Extension – where public net benefits are highly positive and private net benefits are slightly positive
- Technology development – where private net benefits are negative (but not too negative) and public net benefits are positive
- No action – where private net benefits outweigh public net costs, where public and private net benefits are both negative, where private net benefits are sufficiently positive to prompt rapid adoption of environmentally beneficial activities, or where private net costs outweigh public net benefits (provided that technology development is not sufficiently attractive).

To date, a range of programs have been used successfully in the Corner Inlet catchment to encourage adoption of best management practices (BMPs) in order to reduce sediment and nutrient loads entering the Corner Inlet Ramsar Site. Below in table 8.1.1 the major delivery mechanisms used in recent programs are categorised.

Table 8.1.1 Programs used in Corner Inlet to improve water quality and associated main delivery mechanisms

Program	Primary Delivery Mechanism	Comment
Beef Cheque, BetterBeef and BestLamb	Extension	Beef Cheque – Delivered by regional TAFEs in collaboration with DEPI and Meat and Livestock Australia (MLA). BetterBeef and BestLamb – DEPI in partnership with MLA. These state-wide networks provide opportunities for producers to access the latest research messages and participate in courses that increase skills and knowledge.
Fert $mart	Extension	Dairy Australia initiative being developed to improve the efficiency and profitability of fertiliser use.
Core 4	Extension and positive incentives (differential incentives based on farmer expressions of interest)	Australian Government funded through the Caring for Our Country initiative. It was originally developed for the Gippsland Lakes catchments and has been trialled in the Agnes, Franklin and Stockyard Creek sub-catchments of Corner Inlet in 2012-13.
Direct grants/ devolved grants – waterway and erosion control incentives	Positive incentives	The WGCMA, South Gippsland Landcare Network and Yarram Yarram Landcare Network currently have grant programs in place for landholders within the Corner Inlet and Nooramunga catchments.
Market based instruments (MBI)	Positive incentives	The Corner Inlet Ramsar Site was included in a recent Saltmarsh Protection Project, which used a tender style market based instrument to achieve protection of habitat. However, such mechanisms have not used for catchment-scale water quality actions to date.
EPA compliance activities	Negative incentive/regulation	Auditing of dairy effluent systems and intensive animal licences in line with regulations.
Forestry Timber Code of Practice	Negative incentive/regulation	Forestry operators comply with a Code of Practice. Compliance is assessed through inspection by local councils and some independent auditors.
Wastewater treatment plant upgrades	Negative incentive/regulation	EPA inspections.
Domestic waste water treatment	Negative incentives/regulation	Council inspections.

Landholders, community groups, contractors and agency staff are an effective combination. Photos – Top left: WGCMA, Centre left: Yarram Yarram Landcare Network, Bottom left: Parks Victoria. Right by Sharyn Allott, courtesy South Gippsland Landcare Network.

Extension, positive incentives and regulation compliance activities have all been used in the Corner Inlet and Nooramunga catchments. For agricultural land activities, most programs have been focused on incentive and extension activities to influence the implementation of actions and the adoption of BMPs. Some of these programs operate in tandem; for example, extension activities often identify on-ground works, such as waterway fencing, which are then implemented through direct grant programs. Likewise incentive delivery is generally coupled with extension information for landholders outlining appropriate maintenance activities.

These programs have been successful in engaging landholders in the implementation of actions and the adoption of BMPs, and have been delivered in a collaborative way across agencies. Current programs and partnerships can be used as a foundation for a scaled-up delivery program, subject to available funding. However, bioeconomic modelling results indicate that the level of payments and scale of current programs are not sufficient to achieve the required reduction in nutrient and sediment entering the Corner Inlet Ramsar Site.

Achieving the implementation objectives (outlined in Section 7) will require a mix of incentive, extension and regulatory mechanisms, albeit at a much-increased scale compared to the current situation. This approach, with an appropriately designed and robust metric tied to water quality objectives and an adequate funding pool, has a high likelihood of success.

Overall delivery mechanisms are constrained by the level of funding available and the types of mechanisms funders are willing to support. There is community willingness to support programs at the current scale of investment. Continued willingness to participate in markedly scaled-up programs with actions at much greater levels than is currently the case would need to be assessed should funding become available. A further limitation of current programs is that there is no mechanism to ensure BMP implementation is maintained over the long-term.

9. Implementation Programs

Implementation programs include direct on-ground actions and enabling activities. The activities that need to be undertaken in the WQIP Works Program are described below.

9.1 Direct works

9.1.1 Agriculture – dairy, beef and sheep

Grazing industries (dairy, beef and sheep) contribute the majority of the nutrient and sediment load to the Corner Inlet Ramsar Site, and thus a major focus is on these land uses and their management in reducing these loads. The agricultural BMPs and waterway and erosion control management actions, along with their assumed levels of effectiveness in nutrient and sediment reduction, are outlined in Appendix 2 (table A2.2 for dairy, table A2.3 for beef).

The effectiveness estimates and assumptions that underpin the actions are based on a local understanding of current practice and recognise that there are differences in the level of adoption of BMPs across the two major agricultural land uses (dairy and dryland grazing – sheep/beef). For example, for dairy it is assumed that there is currently a high proportion of permanent waterways already fenced to exclude stock. This assumption is based on dairy industry data captured through the Dairying for Tomorrow Survey completed in 2012. Whilst for beef and sheep the proportion of waterways already fenced is assumed to be much lower. This assumption was developed from the knowledge of local experts. More comprehensive details are outlined in Stott and Roberts (2013).

The management actions identified in the WQIP Works Program (Section 10) have been modelled to achieve the plan's water quality objectives for Phosphorus, Nitrogen and sediment. The selection of actions through the modelling process draws on a combination of factors including modelled nutrient loads from subcatchments, type of land use, and the effectiveness and costs of management actions.

Note that with the exception of nutrient application, all other activities, whilst giving a benefit to the public, are at a cost to farmers. Implementation at the scale required to reduce nutrient loads entering the Corner Inlet Ramsar Site will require long-term incentive payments, referred to as stewardship payments.

Although the best available information has been used to underpin the WQIP Works Program (including BMP effectiveness and costs information), considerable uncertainties remain (see Section 12 Reasonable Assurance Statement). Further research and investigation in terms of updated integrated modelling is required to better assess the potential for management actions to reduce nutrient and sediment loads, in particular, from agriculture and forestry.

The implementation of BMP programs at a larger scale than has occurred previously will need careful consultation, partnership and design with agricultural and forestry industries prior to implementation.

9.1.2 Forestry

Production forestry is the second largest category of land use in the catchments of the Corner Inlet Ramsar Site, covering approximately 22 percent of the catchment area. Forestry activities are governed by the Code of Practice for Timber Production. The Code outlines a range of standards that must be used to protect water quality and environmental values from the impacts of forestry.

The Code provides a series of rules and guidance covering a number of activities. It concentrates on protecting soil, water quality, flora and fauna. The Code covers the following items: plantation planning and design; environmental values; the establishment and management of plantations; plantation roading; and timber harvesting. Advice from HVP Victoria is that the Code is being fully implemented across the land they manage.

HVP has voluntarily developed BMPs which are over and above that required by the Code. Forestry BMPs are grouped under the following headings:

- Protection of riparian vegetation around streams and drainage lines (buffers and filters)
- Slope limitations to harvesting
- Location, use and drainage of snig tracks and log landings
- Wet weather restrictions to forest operations
- Rehabilitation of harvested areas
- Careful planning, design, location, construction, drainage and maintenance of roads
- Design and construction of stream and drainage line crossings.

Due to the significance of the values in the Corner Inlet and Nooramunga catchments the WQIP Works Program aims to ensure that the Code of Practice is adhered to and routinely audited, that BMPs go beyond the requirements of the code and innovation in practice continues. An example of this would be to minimise the time between clearing and rehabilitation to reduce the likelihood of severe sediment loss from large rainfall events and bare ground exposure.

The available catchment modelling estimated that forestry sediment and nitrogen loads were predicted to be surprisingly high. In view of the uncertainties in the catchment modelling, and on the advice from HVP that the Code is being fully implemented, no additional on-ground management actions for forestry have been identified. Confirmation of the contribution of production forestry (through improved monitoring and modelling) to the overall loads of sediment and nutrient to the Corner Inlet Ramsar Site is an important research priority for the WQIP.

9.1.3 Urban

Approximately one percent of land in the catchments surrounding the Ramsar site is under urban use. The urban population has remained stable for the last 30 years and this is predicted to continue at this level over the next 30 years. The majority of towns with over 100 residents are sewered and include Foster, Toora, Welshpool, Port Welshpool and Port Albert. Smaller towns are serviced by septic tanks; however, Alberton is scheduled to be sewered in 2014.

Left: Corner Inlet's attractions and lifestyle make it popular with residents, visitors and holiday makers. Photo – InDetail Comms & PR.

Right: Production forestry is the second largest land use in the catchment. Photo – WGCMA.

South Gippsland Water's urban wastewater program focuses on:

- impacts from unsewered towns
- the upgrade of waste water treatment plants to land reuse schemes
- minimising impact of development through use of water sensitive urban design
- minimising impacts from any industrial developments.

9.1.4 Wetland protection

Wetland protection activities aim to provide a continuous buffer of protected frontage to the Corner Inlet Ramsar Site. These activities will involve the fencing and management of fringing wetland vegetation for conservation. Control of invasive weeds will be required to assist with protection and re-establishment of salt marsh and swamp scrub vegetation communities. Primarily, the program will aim to ensure that all fringing coastal land (Crown or freehold) is managed for conservation purposes and that fences are appropriately located.

Note that fringing wetland protection costs have not been included in the bioeconomic modelling or INFFER analysis as the costs and benefits of these activities cannot be assessed using current information.

9.2 Enabling Actions

In addition to direct works, a number of enabling actions are crucial in order to build on existing networks and the progress already made within the community, as outlined below.

9.2.1 Leadership and partnerships – Corner Inlet Steering Committee

The West Gippsland Catchment Management Authority (WGCMA) will lead and co-ordinate implementation of the Corner Inlet WQIP. The WGCMA will continue to deliver on-ground waterway management works at priority sites across the Corner Inlet and Nooramunga catchments as part of existing programs and activities, subject to available funding. These works include the construction of waterway stability structures, willow and weed management, and other waterway works such as fencing and revegetation. The WGCMA also leads key investigations regarding waterway management and the health of the Corner Inlet Ramsar Site and its surrounding catchments.

Partnerships are crucial to the success of the WQIP. The WGCMA has strong relationships with government, industry, non-government organisations and landholders in the Corner Inlet and Nooramunga catchments. The Corner Inlet Steering Committee (CISC) is the enabling partnership mechanism. The formation of the partnership in 2007 marked an important step in the region's history of stewardship and reinforced a commitment to a productive and healthy Corner Inlet. The partnership continues to facilitate or provide:

- a catchment wide approach to addressing water quality issues in the Corner Inlet Ramsar Site and in its surrounding catchments
- the sharing of expertise between organisations, groups and individuals
- a strong base for more competitive funding applications, showing support from a broad range of stakeholders
- increased efficiency and better return on investment
- the sharing of the costs, risks and rewards between partners
- the opportunity for more people to become actively involved and supportive of programs for Corner Inlet
- access to new ideas, information, equipment and resources
- an effective platform and mechanism for targeted and coordinated communication and engagement.

Input and discussion with local stakeholders during the development of the WQIP. Photo – WGCMA.

9.2.2 Governance

The CISC, made up of representatives from natural resource management agencies, local industry and community groups such as Landcare, will oversee the implementation of the Corner Inlet WQIP and will develop the associated engagement and reporting outputs required for the WQIP.

9.2.3 Communication and engagement

Clear communication and effective engagement with landholders, industry groups, government and the wider community is central to the successful implementation of the WQIP.

There is a strong foundation of existing networks within the Corner Inlet and Nooramunga catchments (e.g. South Gippsland Landcare Network, Yarram Yarram Landcare Network), industry representation (GippsDairy, SeaNet) and established programs (e.g. Gip Rip, Core4, Fert$mart, Beef Cheque). These provide a platform on which to build an understanding of the ongoing actions required for the implementation of the WQIP.

The development of the Corner Inlet WQIP has led to an improved understanding of the:

- technical effectiveness of BMPs and traditional activities, such as waterway and gully fencing, in reducing sediment and nutrient transport from agricultural land to the Corner Inlet Ramsar Site
- current level of adoption of BMPs and traditional activities by landholders
- barriers to increased adoption (largely constrained by financial factors).

Existing extension programs have developed clear messaging in relation to the appropriate management practices required to reduce sediment and nutrient run-off. These programs should be seen as the basis for a scaled-up communication and engagement effort, especially with beef, sheep and dairy farmers within the catchment. Some areas, for example the catchments of the Jack and Albert Rivers, have been identified as requiring targeted effort for land management actions and should therefore be supported by additional extension effort.

9.2.4 Lifestyle properties

Whilst urban settlements are predicted to remain relatively stable, an increase in the number of lifestyle properties can be expected. Due to both an ageing farm population and the proximity of Corner Inlet to Melbourne, there has been a significant reduction in the number of commercial farms in the catchments of Corner Inlet and Nooramunga. In 2006 there were 499 dairy farms in the catchment and 468 beef properties, whereas by 2010 it was estimated that only 240 dairy and 270 beef farms would remain. Some of the reduction in numbers will be due to the consolidation of smaller farms into larger enterprises particularly in the dairy industry, whilst some land has been retired from commercial production.

Lifestyle properties may be owned by absentee landholders or may be occupied. With the exception of appropriate septic tank management, the recommended actions to minimise sediment and nutrient runoff from these properties is the same as for other agricultural properties (maintaining groundcover as for beef and sheep farms is important).

There is a need to offer specifically targeted programs for these properties to ensure that best practice is followed. Education and engagement will be a key focus of in the WQIP Works Program. Social research into the barriers and drivers for the adoption of BMPs is also required to determine the likely level of landholder uptake, both with and without incentives

Overall, assuming appropriate septic tank management and groundcover is maintained, an increase in lifestyle properties has positive potential for the reduction of nutrient loads. Furthermore, if smaller or no incentive payments are required to encourage adoption of practices then the on ground costs associated with the WQIP could be considerably reduced.

9.2.5 Stewardship payments, agreements and auditing

Land stewardship payments (long-term incentive payments to off-set loss of production) for beef, sheep and dairy farms are required to ensure that the benefits of BMPs are achieved and maintained. Given the significance of long-term payments there is need for greater accountability of public spending than is required for current programs.

Long-term stewardship payments will need to be underpinned by:

- contracts
- appropriate farm-level metrics
- performance auditing
- assessment to ensure that the conditions of continued stewardship payments are adhered to.

To be credible in the long-term, auditing of BMPs should be conducted by an independent third party, as occurs in other parts of the world such as in the Chesapeake Bay region of the United States of America.

Left: Landcare engages with the community and provides advice and support for onground projects. Photo – South Gippsland Landcare Network.

Right: Land stewardship is a priority for local landholders and for the health of the catchment. Photo – South Gippsland Landcare Network.

9.2.6 Compliance of regulated activities

There will also be a need for increased emphasis on assessing compliance for regulated activities, including effluent collection and management and urban waste water and domestic waste water systems, both for initial implementation and for ongoing management. Compliance auditing could be conducted by the EPA or, potentially, by an independent third party auditor. Where necessary, enforcement may need to be undertaken by the EPA.

For plantation forestry, the Code of Practice needs to be adhered to and routinely audited by local government and independent auditors as appropriate. BMPs that go beyond the requirements of the code such as those implemented by HVP are also strongly encouraged as they contribute to improvements in water quality in the catchment.

9.2.7 Knowledge Gaps – research and investigations

As outlined in a number of parts of this WQIP, particularly in the Reasonable Assurance Statement (Section 12) and in the detailed INFFER analyses conducted, there remain a number of knowledge gaps. The most important knowledge gaps that need to be addressed to enable increased confidence in achieving water quality outcomes for the Corner Inlet Ramsar Site are:

- **Improved quantification**, based on empirical data, of the links between sediment and nutrient loads from all sources and their impacts on seagrass (including re-suspension of sediments) and other components of the marine ecosystem.
- **Finer scale and recalibrated catchment modelling** to address the knowledge gaps identified in the WQIP. The modelling approach should be based on a review of the current model and learnings from the development of the WQIP and those from other regions.
- **Improved catchment water quality monitoring**, particularly to systematically capture more of the high flow events in the region. Enhanced water quality monitoring programs should be designed in consultation with catchment modellers; this will ensure that the additional monitoring information collected can be used in an updated modelling approach.
- **Social research** to ascertain drivers and barriers to the uptake of BMPs, with segmentation incorporating the range of agricultural enterprises in the catchments (dairy, beef, sheep, lifestyle).

Additional research and investigations required to improve confidence regarding the link between land use, management practices and water quality impacts are listed below. These have not been costed within this WQIP.

- **Updated estimates of management practices** and their effectiveness for dairy and beef/sheep production. Field studies are prohibitively expensive, thus expert and modelling approaches (possibly Bayesian networks and/or linked catchment-farm 'treatment train' based approaches) would be worth exploring.
- **Improved accounting for farm heterogeneity in modelling** (dryland grazing and dairy farms), building on work completed for dairy in this WQIP (Stott and Roberts, 2013; Stott et. al., 2013).
- **Updated soil and land use information**. An updated land use layer was developed for the WQIP to provide greater resolution for agricultural land uses. In the longer term, an updateable approach based on the Victorian Land Use Information System would be useful (Morse-McNabb, 2013).
- **Improved gully length estimates** using a rapid assessment approach based on Whitford et. al. (2011).
- **Updated bioeconomic modelling and INFFER analyses** once improved catchment modelling, effectiveness estimates and heterogeneity information is developed.

9.2.8 Reinstating hydrology

Artificial drains and earthen seawalls are features of the farming infrastructure in the low-lying land areas within the Corner Inlet and Nooramunga catchments. The infrastructure allows farming in areas that would generally be inundated with water for much of the year. A pilot program will investigate the extent of landholder interest in reinstating some of the natural hydrology through the removal of artificial drainage and seawalls.

Activities could include:

- reducing the frequency of drain clearing
- ceasing drain-clearing activities.

An additional action for consideration is the removal of small sections of the sea wall from along the coastline, encouraging the re-establishment of swamp scrub and other floodplain and estuarine wetland vegetation, thus reinstating natural wetlands. This activity in particular requires a detailed feasibility investigation undertaken in consultation with relevant stakeholders including landholders and councils and would require exploration of issues associated with ownership, maintenance and benefits of the current structures and an alternate arrangement.

Note that fringing wetland protection costs have not been included in the bioeconomic modelling or INFFER analysis for reasons outlined earlier (9.1.4).

It should also be noted that sea level rise resulting from climate change is expected to increase the frequency and extent of coastal flooding; this needs to be considered in the planning and implementation activities around hydrological reinstatement.

9.2.9 Monitoring and evaluation

A detailed monitoring and evaluation (MERI) plan has been developed for the Corner Inlet WQIP. Its purpose is to demonstrate the process for monitoring and evaluating progress towards the agreed targets of the WQIP. The MERI plan:

- documents the program logic
- identifies assumptions and their associated risks
- identifies management measures to address those risks
- identifies and addresses evaluation questions
- identifies and addresses monitoring requirements
- enables reporting on progress toward, and achievement of, targets
- enables the adaptation of activities to ensure these targets are achieved and activities remain relevant over the implementation period of the WQIP.

Left: Australian Grayling a nationally threatened species is found in Corner Inlet's rivers and estuaries. Photo – Tarmo A Raadik.

Right: Corner Inlet is an important resting and feeding ground for migratory bird species such as the Red Knot which flies from the Northern Hemisphere. Photo – Parks Victoria.

10. Works Program

This section outlines the Implementation Programs and Management Actions required to achieve the water quality objectives set for the Corner Inlet WQIP over the period 2013-2021. The quantities required to be delivered have been derived from the bio-economic modelling results described in Section 7.

The WQIP Works Program has been set out as three tables, one for each of the Corner Inlet and Nooramunga catchments and one for the associated catchment-wide enabling activities. The tables identify actions at a range of scales including whole-of-river catchment and specific locations such as townships. The modelling sub-catchments have also been used to identify the location of specific actions. A map depicting river catchments and modelling subcatchment numbers is provided below for reference (figure 10.1.1 and table 10.1.1).

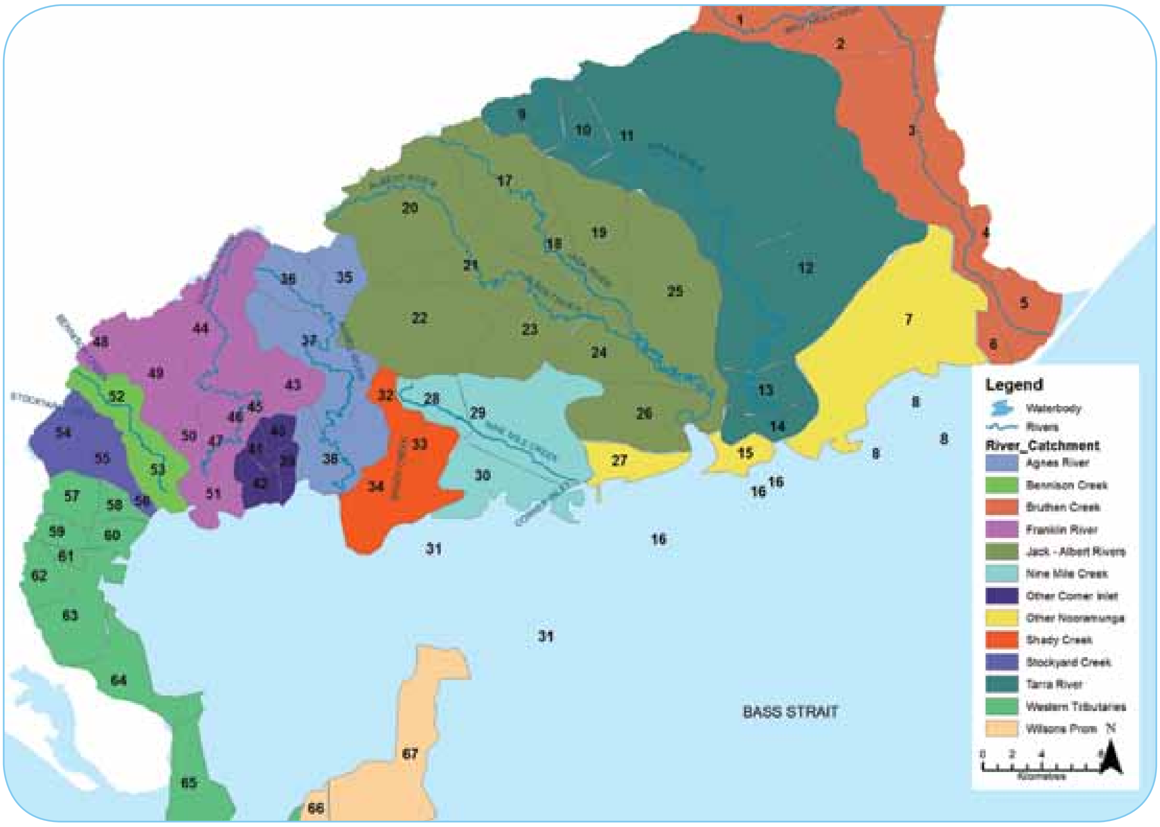


Figure 10.1.1. Corner Inlet and Nooramunga river catchments and modelling subcatchments

Table 10.1.1 Corner Inlet and Nooramunga river catchments and modelling subcatchments

Nooramunga		Corner Inlet	
River Catchment	Subcatchment	River Catchment	Subcatchment
Bruthen Creek	1	Agnes River	35
	2		36
	3		37
	4		38
	5	Other Corner Inlet	39
	6		40
Other Nooramunga	7		41
Island	8		42
Tarra River	9	Franklin River	43
	10		44
	11		45
	12		46
	13		47
	14		48
Other Nooramunga	15		49
Island	16		50
Jack - Albert Rivers	17		51
	18	Bennison Creek	52
	19		53
	20	Stockyard Creek	54
	21		55
	22		56
	23	Western Tributaries	57
	24		58
	25		59
	26		60
Other Nooramunga	27		61
Nine Mile Creek	28		62
	29		63
	30		64
Island	31		65
Shady Creek	32	Wilsons Promontory	66
	33		67
	34		

Table 10.1.2 Corner Inlet Catchment Works Program[1]

Works Program	Management Actions /BMPs	River Catchments, Towns or Location	Total Area (ha), Length (km) or Quantity	Cost ($/year[a] or total[b])	Lead Agency	Main Supporting Partners
Agriculture – Dairy	• Nutrient application rates • Effluent collection • Effluent management • Tracks and crossings • Wet area management	Agnes River, Buckland Drain, Muddy Creek, Franklin River, Bennison and Stockyard Creeks and Western Tributaries	BMPs required on 97% of dairy land (6447ha of total 6631ha in Corner Inlet) and in all subcatchments containing dairy	$559,000/year	DEPI Industry based organisations WGCMA	Dairy companies
Agriculture – Dryland Grazing	• Tracks and crossings • Pasture management (groundcover) • Restoring bare areas • Restoring landslips (fencing and revegetation)	Agnes River, Buckland Drain, Muddy Creek, Franklin River, Bennison and Stockyard Creeks and the Western Tributaries BMPs effectively needed in all subcatchments	BMPs required on 97% beef land (19351ha of 19887ha)	$1,388,000/year	DEPI Industry based organisations WGCMA	Landcare
Permanent Waterways	• Fencing to exclude/ manage stock grazing	Some works estimated in all subcatchments, except for 42 (Muddy Creek), 43,48, 51, 56 (Franklin River), 64, 65 (Western Tributaries)	107km	$525,000/year	WGCMA	DEPI Landcare
Streams	• Fencing to exclude/ manage stock grazing	Some works in most subcatchments, except for 39 (Buckland Drain), 64,65 (Western Tributaries)	173km	$550,000/year	WGCMA	DEPI Landcare
Gullies	• Fencing and remediation	Some gully work in all subcatchments	181km	$721,000/year	DEPI Industry based organisations WGCMA	Dairy companies
Drains	• Fence and encourage grass buffer establishment around constructed drains	Some drain work in all subcatchments	71km	$37,000/year	DEPI Industry based organisations WGCMA	Landcare

Continued from page 74... Table 10.1.2 Corner Inlet Catchment Works Program[1]

Works Program	Management Actions /BMPs	River Catchments, Towns or Location	Total Area (ha), Length (km) or Quantity	Cost ($/year[a] or total[b])	Lead Agency	Main Supporting Partners
Forestry	• Code of Practice and HVP BMPs implemented for timber production: 1) protection of riparian vegetation around stream and drainage lines 2) slope limitations for harvesting 3) location, use and drainage of snig tracks and log landings 4) wet weather restrictions to forest operations 5) rehabilitation of harvested area 6) planning, design, location, construction, drainage and maintenance of roads 7) design and construction of stream and drainage line crossings	All subcatchments containing plantation forestry as indicated in the land use map – subcatchments 35-37, 43, 44, 49, and 54.			Forestry operators	Wellington Shire Council South Gippsland Shire Council DEPI
Urban	• Waste water programs for unsewered towns	Yanakie – audit of wastewater management systems	Audits undertaken in line with revised Municipal Domestic Wastewater Management Plan		South Gippsland Shire Council	Department of Health
Urban	• Upgrade Wastewater Treatment Plant	Foster		$11million (total)	South Gippsland Water	EPA
Wetland protection	• Fencing of coastal fringe to protect remnant vegetation, salt marsh, swamp scrub, mangrove			$60,000	WGCMA DEPI	Landcare Parks Victoria

[a] *These are costs for stewardship payments. To maintain benefits, stewardship payments require on-going annual payments.*
[b] *One-off cost.*
[1] *Areas and lengths were based on the best available information available regarding land use, waterway, stream, gully and drain information. It is possible that there will be some inconsistencies between modelled predictions and local knowledge that can only be resolved in the future.*

Table 10.1.3 Nooramunga Catchment Works Program[1]

Works Program	Management Actions/BMPs	River Catchments, Towns or Location	Total Area (ha), Length (km) or Quantity	Cost ($/year[a] or total[b])	Lead Agency	Main Supporting Partners
Agriculture - Dairy	• Nutrient application rates • Effluent collection • Effluent management • Tracks and crossings • Wet area management	Bruthen, Manns, Gelliondale, Nine Mile and Shady Creeks, Tarra, Jack and Albert Rivers The only subcatchments without BMPs are those not containing dairy (8,15,27,31)	BMPs required on 99% of dairy land (9333 of 9462ha in Nooramunga) and in all subcatchments containing dairy	$1,004,000/year[a]	DEPI Industry based organisations WGCMA	Dairy companies
Agriculture – Dryland Grazing	• Tracks and crossings • Pasture management (groundcover) • Restoring bare areas • Restoring landslips (fencing and revegetation)	Bruthen, Manns, Gelliondale, Nine Mile and Shady Creeks, Tarra, Jack and Albert Rivers BMPs needed in all subcatchments containing beef	BMPs required on 99% beef/sheep land (39201 of 39719ha in Nooramunga)	$2,398,000/year[a]	DEPI Industry based organisations WGCMA	Landcare
Permanent Waterways	• Fencing to exclude/ manage stock grazing	Works required in all Jack and Albert River subcatchments (17-26)	123km	$617,000/year[a]	WGCMA	DEPI Landcare
Streams	• Fencing to exclude/ manage stock grazing	Works required in all Jack and Albert River subcatchments (17-26)	172km	$569,000/year[a]	WGCMA	DEPI Landcare
Gullies	• Fencing and remediation	Works required in all Jack and Albert River subcatchments (17-26)	141km	$567,000/year[a]	WGCMA Landcare	DEPI
Avulsion Works	• Works between the Jack and Albert Rivers (Pound Rd West to Jack River confluence) to minimise risks			Not costed	WGCMA	DEPI
Drains	• Fence and encourage grass buffer establishment around constructed drains	Works required in all Jack and Albert subcatchments (17-26)	29km	$18,000/year[a]	WGCMA Landcare	DEPI

Continued from page 76... Table 10.1.3 Nooramunga Catchment Works Program[1]

Works Program	Management Actions/BMPs	River Catchments, Towns or Location	Total Area (ha), Length (km) or Quantity	Cost (\$/year[a] or total[b])	Lead Agency	Main Supporting Partners
Forestry	• Code of Practice for Timber Production (details in table 10.1)	As indicated in land use map – subcatchments 1-4, 9-12, 17-25, 29		Not costed	Forestry operations	Wellington Shire Council
Urban	• Alberton sewering	Alberton		\$2.2M (project underway and set for completion in May 2014)	South Gippsland Water	Wellington Shire Council
Urban	• Waste water program for unsewered towns and settlements (e.g. continue to implement actions as per Domestic Waster Water Management Plans)			Not costed	Wellington and South Gippsland Shire Councils	Department of Health
Wetland Protection	• Fencing of frontage and exploration of covenants			\$33,500[b]	WGCMA	Landcare
Waterway Management	• Willow management (Gelliondale Rd to Pound Rd West) • Undertake stabilisation works (Gelliondale Rd to Pound Rd West)			To be determined based on site survey and designs	WGCMA	Landholders

[a] *These are costs for stewardship payments. To maintain benefits, stewardship payments require on-going annual payments.*
[b] *One-off cost.*
[1] *Areas and lengths were based on the best available information available regarding land use, waterway, stream, gully and drain information. It is possible that there will be some inconsistencies between modelled predictions and local knowledge which can only be resolved in future.*

Table 10.1.4 Enabling actions

Enabling Actions	Description	Cost ($m/year[a] or total[b])	Lead Agency	Main Supporting Partners
Leadership	• Overall responsibility for oversight of WQIP implementation • Undertake mid-term review of the WQIP in 2017 • Undertaken final review of the WQIP in 2021	0.4 FTE $68,000/year	WGCMA	Corner Inlet Steering Committee (CISC)
Governance	• In partnership with the WGCMA, will ensure implementation of the WQIP Works Program and strategic engagement with the local community is well coordinated between partners	4 x 0.5 day meetings per annum Assume 10 organisations attend	CISC	WGCMA
Project Management	• 3 full-time positions to design and implement the program of stewardship payments program @ $170,000/FTE including expenses	$540,000/year[a]		
Communication	• Communication activities including catchment health report card every two years including summary of Waterwatch, EstuaryWatch and continuous monitoring water quality data, research results and works completed • Signage • Community awareness campaign for compliance with onsite waste water management focussing on Yanakie	$40,000/year[a]	WGCMA	CISC

Continued from page 78... Table 10.1.4 Enabling actions

Enabling Actions	Description	Cost ($m/year[a] or total[b])	Lead Agency	Main Supporting Partners
Engagement	• Develop a strategic engagement plan for the implementation of the Corner Inlet WQIP • Develop annual engagement activity work plan • Encourage community participation in activities e.g. Waterwatch, EstuaryWatch, seminars to educate the community • Hold seminars such as the Estuaries Unmasked series to discuss the values of Corner Inlet and Nooramunga and their catchments • Hold stakeholder tours to highlight work sites, project outcomes and best management practices • Undertake field days of demonstration sites aimed at encouraging BMP use on lifestyle properties	$50,000/year[a]	WGCMA	CISC
Compliance and Enforcement – effluent collection	• Inspections on dairy properties to assess effluent storage facilities and adequacy of distribution to ensure no effluent leaves the farm • Issuing of notices and enforcement if required	$100,000/year[a]	EPA	DEPI Dairy companies Dairy Foodsafe Victoria
Compliance and Auditing – stewardship payments	• Farm visits and assessment of performance against management agreements for BMP implementation and stewardship payments	$100,000/year[a]	WGCMA or DEPI *Dependant on delivery mechanism	Independent third party auditor dependent on delivery mechanism
Research to Fill Knowledge Gaps	• Finer scale and recalibrated catchment modelling, updated BMP information, design of market-mechanism (e.g. nutrient trading program)	$400,000/year for 5 years	WGCMA	DEPI or research contractor
Research to Fill Knowledge Gaps	• Monitoring of seagrass condition • Improved quantification of the links between nutrient and sediment loads from all sources and their impacts on seagrass condition and extent including resuspension aspects	$390,000[b] (total)	Parks Victoria WGCMA	Research contractor

Continued from page 79... Table 10.1.4 Enabling actions

Enabling Actions	Description	Cost ($m/year[a] or total[b])	Lead Agency	Main Supporting Partners
Research to Fill Knowledge Gaps	• Improved understanding of the impacts of predicted climate change on the environmental values of Corner Inlet, water quality impacts and proposed actions (e.g. hydrological reinstatement)	Not costed, look for other government funding sources	WGCMA	Research contractor
Research to Fill Knowledge Gaps	• Social research regarding lifestyle property adoption of BMPs	$75,000[b]	WGCMA	DEPI or research contractor
Research to Fill Knowledge Gaps	• Undertake geomorphological investigation (potential for avulsions) between the Jack River and Albert River (Pound Rd West to Jack River confluence) • Investigate options for re-engaging the lower Albert River with the floodplain	$100,000[b] $50,000[b]	WGCMA	Research contractor
Research to Fill Knowledge Gaps	• Undertake detailed sediment and nutrient monitoring associated with forestry operations - including runoff from tracks and roads	$40,000[b]		Forestry operator
Research to Fill Knowledge Gaps	• Investigate relationship between water quality and flow including the synergies and risks to inform future water and natural resource management planning decisions	$50,000[b]	WGCMA	DEPI
Biophysical Monitoring	• Enhanced water quality monitoring to capture high flow events • Install/maintain continuous water quality and flow monitoring stations at appropriate locations • Waterwatch monitoring of key waterways • Marine water quality monitoring	$205,000 for catchment monitoring based on one year of event based sampling $80,000 for marine water quality based on one year of event-based sampling $20,000/year[a] Waterwatch	WGCMA Parks Victoria	

Continued from page 80... Table 10.1.4 Enabling actions

Enabling Actions	Description	Cost ($m/year[a] or total[b])	Lead Agency	Main Supporting Partners
Performance Monitoring and Evaluation	• Monitoring and evaluation will focus on the level of uptake of BMPs and fencing activities	0.5 FTE $85,000/year[a]	WGCMA	DEPI
MERI Program	• Implement the requirements of the Corner Inlet WQIP – Monitoring, Evaluation, Reporting and Improvement Plan (MERI Plan)	0.5 FTE $85,000/year[a]	WGCMA	
Assessments	• Undertake assessment to determine if there are areas where the boundaries of Crown land are compromised through historical management or lack of fencing and survey	3 @ $5000 each	DEPI	WGCMA Parks Victoria DEPI
Planning	• Ensure future developments recognise the values of the Corner Inlet Ramsar Site and its catchments and that appropriate protection is put in place through the use of statutory planning mechanisms, i.e. environmental significance overlays, reference to regional strategies, etc. • Continue to ensure that clear policy and standards for waste water management on new subdivisions is applied at the planning permit stage, and appropriate auditing of compliance is undertaken following development	Not costed	Wellington and South Gippsland Shire Councils	WGCMA DEPI

[a] *These are costs for stewardship payments. To maintain benefits, stewardship payments require on-going annual payments.*
[b] *One-off cost.*

11. Future Challenges to Water Quality Improvement

11.1 Background

The Corner Inlet Ramsar Site is one of Victoria's most important environmental assets. Both the Australian and Victorian governments have obligations to protect its unique values and maintain its ecological character. The Corner Inlet WQIP focuses on the protection and maintenance of water quality in its role in supporting the aquatic ecosystem values and critical wetland habitats of Corner Inlet.

The Corner Inlet WQIP brings together the experience and knowledge gained from almost ten years of research, monitoring, investigations and on-ground action. The work completed during the development of the WQIP has shown that, notwithstanding future impacts of climate change, the site is in relatively good condition. It is hoped that the water quality targets that have been set in the WQIP are sufficient to maintain this good condition.

The WQIP Works Program (Section 10) sets out the core activities that are the immediate focus for protecting water quality. These are:

- agricultural BMPs
- waterway fencing
- remediating gully erosion
- actions for forestry and urban land uses.

As outlined previously (Section 7.2), a marked increase in the scale of adoption and funding from existing levels is required to achieve the Corner Inlet WQIP targets. Furthermore, if it is found that aspirational load reduction targets are required to maintain the health of Corner Inlet, then current levels of BMPs and fencing activities are unlikely to be sufficient.

Once implemented, the WQIP Works Program will deliver significant benefits in terms of nutrient and sediment reductions to the Ramsar site. While these benefits are expected to occur in the short to medium term, future pressures from climate change, land use intensification and/or change, as well as demographic changes, pose a challenge to protecting the values of Corner Inlet in the longer term.

11.2 Future challenges and policy directions

Based on current knowledge, the key future challenges within the catchment, from a water quality perspective, will include:

- *Managing changes in the scale and area of highly productive land uses that bring in significant amounts of nutrients from external sources such as horticulture, dairy and feedlots*

  By 2050 we might expect to see fewer but larger dairy farms in the catchment as well as an increase in horticulture production and intensive animal operations such as feedlots.

  Increased areas of horticulture production and increased feed lotting of beef cattle in the Corner Inlet and Nooramunga are possible as water security and urban expansion around Melbourne displaces these land uses from their current locations.

  For dairy, the past few decades have seen a decline in the number of dairy farms, offset by an increase in average farm size, an increase in cows per farm and an increase in milk production per cow (Stott et. al., 2013). The adoption of feedpad use to capture and control effluent and increased substitution of fertiliser nitrogen for bought-in feed, have potential to increase profitability without markedly increasing nutrient losses compared to continued trends in high fertiliser use.

- *Increasing adoption of BMPs across extensive grazing (beef and sheep)*

  Large scale BMP programs that aim to reduce nutrient and sediment losses from agriculture have historically largely focussed on working with the dairy industry. However, dryland grazing (beef/sheep) is the predominant land use in the Corner Inlet and Nooramunga catchments (40%) and, as such, the WQIP Works Program identifies that in addition to focus on dairy, significant focus on BMPs for the beef/sheep industry is required. Unlike dairy, beef and sheep producers are not as well linked to a major supplier network (such as a milk factory). This poses additional challenges for engaging with landholders, encouraging industry peer support and ensuring adoption of BMPs at the required levels.

- *Engaging with and influencing NRM practice across lifestyle properties*

  The ageing farmer population and Corner Inlet's proximity to Melbourne will continue to put pressure on land use change away from dairying and commercial beef production. Lifestyle properties can have positive and/or negative impacts on the environment. On the positive side, fertiliser applications are often low or nil and environmental revegetation can be less constrained by financial concerns. On the negative side, disposal of household septic waste poses a challenge as does potential for overgrazing (and hence potential for increased sediment loss), particularly by close-grazing animals such as horses and sheep. By 2050, an increase in lifestyle properties is expected – this trend is already evident.

These challenges, as well as the possibility that nutrient and sediment load reduction targets may need to increase in the future, have implications for the long-term protection of the Corner Inlet Ramsar Site. Funding also places significant constraints to the implementation of the WQIP and adoption of BMPs. For these reasons, it is suggested that a staged approach be implemented over the next decade to improve knowledge and develop appropriate policy tools where required.

Stage 1. Continuing to build knowledge

- **Assembling the evidence base**
  An improved evidence base is required to inform the monitoring and evaluation of the implementation of the WQIP. This will ensure that nutrient reduction resulting from the WQIP can be assessed and measured.

  An improved modelling approach underpinned by robust water quality monitoring (including event-based sampling) that simulates the contributions of all the major land uses with confidence is recommended. This should be hydrologically-based modelling which links rural and urban sources, uses finer spatial resolution (to enable greater targeting), can be updated as land uses change, and which can be used to inform future bioeconomic modelling. Whether groundwater contributions need to be included is also important to consider.

  The development of linked farm-catchment scale metrics (such as those developed in the USA and New Zealand) to assess nutrient load reductions from farms is required to inform future policy approaches.

  The future impacts of climate change on catchment dynamics will also need to be considered in future modelling research and investigation.

- **Addressing critical knowledge gaps**
  A critical knowledge gap for this WQIP has been the lack of site-specific thresholds for water quality and seagrass. Under the Ramsar Convention the Australian Government is required to monitor ecological character and understand if there is human induced change to the ecological character of a Ramsar site over time. Seagrass health has a number of drivers, including many that will be influenced by climate change or cannot be addressed through catchment-based actions.

  Understanding the acceptable water quality conditions in Corner Inlet is fundamental to setting revised water quality improvement targets to protect ecosystem values, including seagrass. Targets need to continue to be specific, measurable, attainable and time-bound. Constructive engagement with the whole community and targeted research to quantitatively establish the thresholds and links between nutrient and sediment loads on water quality dependant values are required.

- **Actively valuing Corner Inlet**
  The above steps may reveal that the condition of Corner Inlet cannot be maintained through the current suite of management actions outlined in this plan. If this is the case, the community and government need to examine alternate policy tools and institutional arrangements, explore the trade-offs of implementing/not implementing these, and potentially make difficult decisions related to the long term protection of Corner Inlet.

Stage 2. Identification of alternate policy tools and institutional arrangements

- **Active land use planning decisions**
  Finer scale modelling and land use changes provide opportunities for more targeted land use planning. For example, in nutrient 'hot-spot' areas, moving from nutrient intensive to lower intensity land uses would be desirable. Restrictions on phosphorus (P) application above threshold soil P concentrations, as occurs in the USA and Europe, would be useful. A shared commitment and active collaboration between the WGCMA, industry, local and state governments will be required.

- **Institutional arrangements**
  As has been reviewed recently (Roberts and Craig, 2013), current Victorian regulations on diffuse-source pollution need improving. There is a lack of clarity of institutional responsibilities particularly between state and regional levels as well as a lack of resources and clarity around regulatory enforcement. Adoption of a source-based approach (e.g. as outlined by Beverly, Roberts and Stott, 2013), creation of a legal mechanism for linking point and diffuse sources, and increased government accountability are all crucial for the WGCMA, and local and Victorian governments to protect environmental assets such as the Corner Inlet Ramsar Site.

Stage 3. Finalising a policy approach

- **Developing a targeted, cost-effective and efficient policy approach**
  The costs for achieving a given set of water quality objectives are driven by two key factors; the scale of the water quality objectives being aimed for and the range of management actions used in order to achieve the objectives. Efficient and effective policy programs seek to achieve outcomes at least cost and that are socially and politically acceptable to communities.

  Nutrient trading schemes, such as that developed by the Waikato Regional Council in New Zealand's North Island to protect Lake Taupo (Anon., 2011), offer significant promise for achieving outcomes at a lower cost than current incentive programs used in Australia. Although the hydrology of Lake Taupo is different to that of Gippsland, the principles underpinning the approach are relevant and innovative on a global scale. The institutional settings (importance of both grazing industries and tourism, deregulated agricultural markets, small tax payer base) are sufficiently similar to Australia to render the policy experiences more directly applicable to this country than those of Europe and the USA where agriculture is highly subsidised.

  Institutional reform takes time, as does assembling a sufficiently strong, transparent and evidence-based approach to underpin programs where some level of land use/management restrictions and regulations are required. There is likely to be a significant (20+ year) time lag between implementing actions and measuring improved environmental condition. Given this, if the issues outlined in under Stages 1 and 2 (above) are not addressed in the coming decade it is possible that implementation programs to protect the values of Corner Inlet will not provide successful outcomes by 2050.

  Future effects of climate change are predicted to be significant for Corner Inlet and have the potential to have a major influence on the effectiveness of the actions proposed in this WQIP. Improved understanding of these impacts will be required to support an adaptive management approach to the implementation of the Corner Inlet WQIP.

12. Reasonable Assurance Statement

The science that underpins this WQIP is the best available and has been undertaken in good faith. Listed below are the major components of work that underpin the plan.

Seagrass Studies

The Technical Panel acknowledged that the location-specific information to link catchment nutrient and sediment reduction to seagrass condition and extent was inadequate to allow definitive conclusions to be drawn. The interaction of a number of different factors is believed to be responsible for loss of seagrass in the Corner Inlet Ramsar Site rather than one single factor. Increased sediments and nutrients are believed to be legitimate contributing factors, amongst others, to seagrass decline in the Ramsar site. The range of factors believed to contribute to seagrass decline in Corner Inlet is described in Appendix 1.

Overall uncertainty – moderate to high

Available Catchment Modelling (a previously calibrated E2 model) (Law et. al., 2008)

The Corner Inlet E2 catchment model used a relatively limited amount of water quality data (spatial and temporal) for calibration. It needs to be noted that the model was calibrated in a relatively dry period (1997-2006) and there was acknowledgement that data relating to high flow (and hence high load) events could not be captured. As such the loads from the calibrated model are likely to be conservative.

The E2 modelling suggested that urban source loads of nutrient and sediment are low and likely to remain so. Whilst treatment plant outfall concentrations are of most concern, in relation to urban land use, and need to be managed, they provide low load overall and their operations are in the process of being upgraded.

Modelled forestry sediment and Nitrogen loads were predicted to be surprisingly high, and a review of literature and expert knowledge from other catchments within Australia suggest this is highly uncertain, an opinion also shared by HVP.

Whilst dryland agriculture was estimated to contributed the greatest load to the catchments of Corner Inlet and Nooramunga, the impact and management practices relating to different agricultural land uses (dairy, beef and sheep production), could not be estimated using the original modelling and information had to retro-fitted accordingly. Finer scale hydrologically-based modelling is recommended to improve confidence in the modelled estimates of nutrient and sediment loads and to assess management impacts.

Overall uncertainty – moderate

Decision Support System

A simple integration of modelling results based on the E2 modelling and Mike21 Hydrodynamic model (Water Technology, 2008) was used to inform the likely zone of influence of catchment nutrient loads on seagrass beds.

Overall uncertainty – moderate

Literature Review and Workshops

To define and estimate the effectiveness of agricultural best-management practices (BMPs) for the dairy and beef industries literature reviews and workshops were undertaken. This information is the best available and in line with limited literature but remains subject to considerable uncertainty.

Overall uncertainty – moderate

DPI's Accountable Dairy Project (Stott and Roberts, 2013; Stott et. al., 2013)

This project was used as the basis for defining representative dairy and beef farms and the costs associated with management practices. This used available local knowledge and expert opinion and, for the time, is the best available knowledge at hand. The true heterogeneity of farms and costs is likely to be under-estimated and thus costs associated with achieving water quality targets may be over-estimated.

Overall uncertainty – low

Land Use Mapping

The WGCMA developed a new land use map to delineate dairy and dryland grazing (beef/sheep) farms within the catchments of the Corner Inlet Ramsar Site. Loads from dairy farms were assumed to be three times larger than those from dryland grazing farms, which is reasonable given the difference in management intensity and results of modelling undertaken in DPI's Accountable Dairying project in a nearby catchment. Given the local input used, there is a high degree of confidence in the land use layer used. For the WQIP, nutrient and sediment losses from lifestyle properties were assumed to be similar to beef farms.

Overall uncertainty – low

Field Surveys

Gully erosion estimates were based on available field surveys (Dudley, unpublished), local knowledge and modelling work conducted in the neighbouring Latrobe catchment (Vigiak et. al., 2011).

Overall uncertainty – moderate

Waterway Data

Waterway and streambank lengths were estimated using available waterway mapping, aerial photographs, assessment of mapped existing fencing activities and local knowledge.

Overall uncertainty – low

Bioeconomic Modelling

Using GAMs (General Algebraic Modelling System), bioeconomic modelling was based on catchment nutrient loads from E2, the land use mapping layer, BMP estimates and costs information as outlined in Section 6. This is a 'state of the art' technique.

Overall uncertainty – moderate to high (given the uncertainties of almost inputs)

INFFER Analysis

The INFFER analysis was used to assess the cost-effectiveness of actions to achieve targets. INFFER is based on theoretically sound Benefit:Cost analysis principles (Pannell et. al., 2011; Roberts et. al., 2012). The Corner Inlet Ramsar analysis has been based on the above information and considerable local knowledge. Despite the uncertainties of the inputs, there is confidence that the overall conclusions and implications of the results are consistent with previous work.

Overall uncertainty – low

Despite the considerable uncertainties outlined in this section, the scientific information used in the development of this plan is the best available and similar to that used to underpin many other WQIPs. The Benefit:Cost analysis and bioeconomic modelling is 'state-of-the art' and information has been used in a highly integrated and logical way.

The WGCMA is reasonably certain that the scenarios outlined in this WQIP, if implemented at the scale at which they are required, will achieve a measurable impact on the sediment and nutrient reduction targets described in this document. The WGCMA has a high degree of confidence that these impacts will be sufficient to move catchment loads much closer to being able to maintain the Corner Inlet Ramsar Site in an acceptable ecological condition.

At this stage the WGCMA has not included climate change impacts in the WQIP. As climate change is likely to have significant effects on the environmental values, catchment hydrology and ecological responses of the inlet and its surrounding catchment, improved understanding of these issues is a priority to support an adaptive management approach to the implementation of the Corner Inlet WQIP.

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Appendix 1

Conceptual model for seagrass health underlying the program logic

Underlying the program logic for Corner Inlet is the conceptual understanding of factors affecting seagrass condition and extent. A review of existing literature relating to seagrass health and Corner Inlet proposed that the conceptual model presented in Ball et. al. (2009) adapted and presented in figure 1, reasonably represented the factors likely to adversely affect seagrass health in the Corner Inlet Ramsar Site. These factors, including evidence to support these, are presented below.

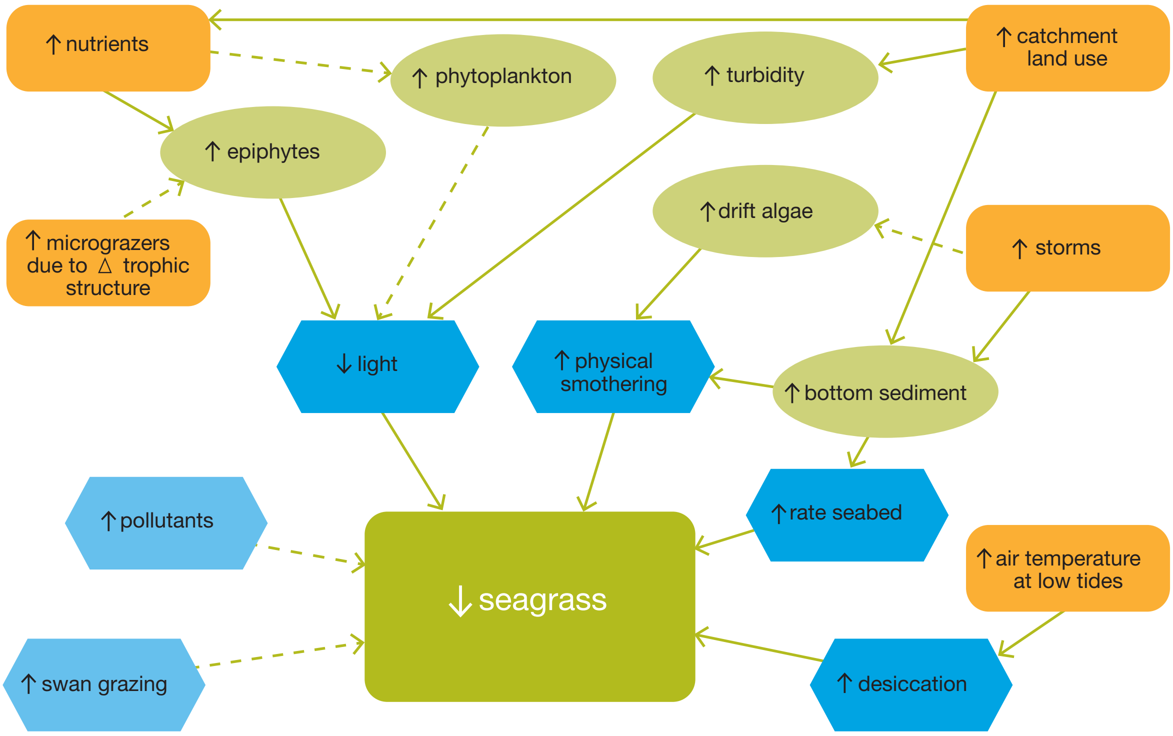

Figure 1. Conceptual model of factors affecting seagrass health in southern Australia (modified from review by Ball et. al., 2009). The four most commonly cited proximate causes of widespread seagrass decline are depicted in dark blue, two other localised proximate causes are in light blue. The primary environmental drivers of the often interconnected pathways are depicted in orange and the secondary drivers in yellow.

There has been substantial loss of seagrass cover in Corner Inlet and Nooramunga (Poore, 1978; Roob et. al., 1998; Hindell et. al., 2009; Ball et. al., 2010). Seagrass decline in Corner Inlet was first noticed by professional fisherman operating from Port Franklin who related it to a decline in the fishery of rock flathead, flounder, whiting and garfish (Poore,1978). The *Posidonia australis* decline was wide spread and particularly noticeable from 1972 into the late 1970s, at the same time a similar decline was reported from Flinders Island in Bass Strait (Poore,1978). However, comparison of aerial photography from 1965, 1972 and 1978 showed no change in cover (Poore,1978).

Comparison of seagrass cover in Corner Inlet only from aerial mapping done in 1998 and 2006 indicated highest losses at the Franklin River Channel and Stockyard Channel in the northwest of Corner Inlet (Ball et. al., 2010). An expansion in cover, thought to be an expansion of the *Zosteraceae* into areas previously vegetated with *Posidonia*, was observed in aerial mapping between 2006 and 2007, but without ground truthing this could not be confirmed (Ball et. al., 2010). It is difficult to quantify the area and species lost in this previous mapping due to no or minimal ground truthing and lack of error calculations (Monk et. al., 2011; Pope et. al., 2013). There is evidence that there was a high degree of misclassification of seagrass in the 1998 mapping (Monk et. al., 2011). The mapping of Pope et. al. (2013) is currently the best mapping available due to its small pixel size, extensive ground truthing and automated classification with error calculation. In a review of evidence of historical changes in seagrass extent and condition in Corner Inlet and Nooramunga, Kirkman (2013) concluded that historical extent and loss could not be quantified.

Seagrass cover in Corner Inlet Ramsar Site is variable (Hindell et.al., 2009; Ball et. al., 2010; Stevenson and Pocklington, 2011). Loss of *Posidonia* beds is of greatest concern because it can take many decades to re-establish vegetatively in eastern Australia, if at all (Fox et. al., 2007; Warry and Hindell, 2009; Kirkman, 2013). In a three year study in Corner Inlet in the mid-2000s no seeds of *P. australis* were observed (Ball et. al., 2010). *Zosteraceae* cover is known to be particularly variable and may have expanded during the drought (Pope, 2006; Monk et. al., 2011). Coring by Poore (1978) and CEC (2008) established that there were seagrass rhizomes in areas that were bare when sampled.

The cause of a putative anthropogenic decline of seagrass beds in Corner Inlet and Nooramunga has not been established. Ball et. al. (2010) summarised the known causes of seagrass bed decline in a conceptual model. This forms the bases of examining the assumptions and knowledge gaps of seagrass loss in Corner Inlet and Nooramunga. The Ball et. al. (2010) conceptual model of the processes that affect seagrass in southern Australia shows the often interconnected pathways by which the causes of seagrass decline are manifested. No single factor is thought to be responsible for seagrass decline, rather, a number of different factors interact (Fox et.al., 2007; Ball et. al., 2010).

The experience of past declines in seagrasses in Australia and other parts of the world suggest numerous potential causes for the suggested dieback in Corner Inlet and Nooramunga (Poore,1978). There can be long time lags between nutrient loading increases and seagrass losses (Fox et. al., 2007). Ball et. al. (2010) in the mid-2000s tested some parts of the conceptual model by measuring epiphyte and drift algal abundance and micro-grazer community composition; and indirectly inferred heat/desiccation stress by measuring changes in the percentage of brown seagrass leaves at intertidal sites over three years. Experimental results from a major study by the South Australian government investigating causes of seagrass loss, including *Posidonia* spp., off the coast of Adelaide were not able to conclusively establish that compromised light climate alone could have caused the loss of seagrass, although this remains a possibility (Fox et. al., 2007). They did unambiguously prove that chronic, yet minor, increases in water nutrients (as might be associated with waste water treatment plant and industrial inputs) could have caused the slow decline of *Amphibolis* and *Posidonia* in shallow, previously nutrient poor, coastal waters (Fox et. al., 2007). Further research is required to better understand the complex interactions between light availability, suspended sediment concentrations, nutrient enrichment, and seagrass/epiphyte response (Fox et. al., 2007).

At a recent workshop (December 2012) an expert panel established by the West Gippsland Catchment Management Authority considered the potential drivers for seagrass loss in Corner Inlet and Nooramunga and concluded that these could include:

- increased nutrients leading to increased epiphyte growth and or algal growth resulting in reduced light availability for seagrass
- increased sediments in the water column from flood flows combined with increased wind/wave action (re-suspension) from storms resulting in reduced light availability for seagrass
- exposure of seagrass at low tide leading to desiccation of exposed plants, of particular concern in intertidal seagrass beds and includes Nooramunga
- sediment instability causing suspension of sediments resulting in reduced light availability for seagrass
- increased turbidity.

It is often difficult to distinguish impacts associated with elevated turbidity in the water from those attributable to increased sedimentation on the seagrass bed (Ball et. al., 2010). Loss of seagrass beds can also lead to higher turbidity as bare mudflats are subject to wave, wind and tide resuspension (Warry and Hindell, 2009; Ball et. al., 2010). Wind generated suspension of seabed sediments occurs on the intertidal and shallower subtidal flats (< 1m) of Corner Inlet and Nooramunga and occurs under typical wind conditions particularly near the shore (CEC, 2008).

Tidal river channels and the area of their immediate discharge are important nutrient sources (CEC, 2008). The sediments of the upper beaches and in the immediate neighbourhood of river mouths contain small but significant amounts of finer sand and silt, with the content of these materials tapering off within a couple of kilometres of the shoreline (CEC, 2008). Terrestrial silts settle out in the quieter sections of the tidal river channels and backwater drainage channels (CEC, 2008). The lower and mid estuarine regions undergo considerable reworking of the sedimentary deposits resulting in the clay materials either being washed into the upper estuarine reaches or being flushed out of the system onto the marine shelf (CEC, 2008). Modelling of hydrodynamics (WT, 2008) showed that numerous seagrass beds near the mouth of rivers would be influenced by the river discharge even with the low flow and high tidal flushing in Corner Inlet and Nooramunga. The rates of deposition of sediment on seagrass beds located within a few hundred metres of a river mouth may also be impacted by sediments carried by large floods (>10yr) (CEC, 2008).

Reductions in light (sediment)

Seagrass can be affected by a reduction in light due to increased turbidity and suspended sediments (Ball et. al., 2010). Advice from ecologists for modelling the hydrodynamics indicated that high suspended solids over a period of two weeks is considered to have an impact on seagrass as it affects the available light, and hence the ability for the plant to photosynthesise (WT, 2008). Poore (1978) thought that the breaks in seagrass beds at the river mouths and ports could be due to the effects of turbidity and lowered light levels. However he did discuss that *Posidonia* in Corner Inlet grows in particularly shallow depth (occasionally exposed at low tide) so light limitations seemed unlikely. From the coring carried out and predicted sediment surface velocities it was concluded that there was limited fine sediment available and accessible and that typical wind stirring would not generate high sediment concentrations and transports in Corner Inlet and Nooramunga (CEC, 2008). However, the study did not take many cores in the near shore or in the north-west section of Corner Inlet. An onshore wind may trap flood water inshore or at the water surface, making the turbid water more visible for a longer period (CEC, 2008). Local residents at McLoughlins Beach observe turbid water persisting for about a week following flood events (CEC, 2008).

Increased rates of seabed erosion

Seagrasses are sensitive to seabed erosion driven by changes in bottom sediment transport (Ball et. al., 2010). Near-shore sediment transport may be influenced by long term climatic variation such as changes in wind speed and direction (Ball et. al., 2010). Storms can tear out seagrass plants, although *Posidonia* can directly resist wave action by producing deeply rooted rhizomes that form dense mats within the sediment (Ball et. al., 2010). Storm intensity and frequency is predicted to alter with climate change. Seagrass beds can become fragmented by mudflat ‘blow outs’ but it is unknown if this is a major factor in Corner Inlet and Nooramunga.

Increased seabed height

Increased sediment can increase seagrass bed height potentially making them more vulnerable to desiccation (Poore, 1978; Ball et. al., 2010). Poore (1978) found no recent records of increased turbidity from the catchment and observed that the sediment load from rivers is largely deposited in the mangrove and shallow seagrass (*Zosteraceae*) zones close to the mouths. The presence of *Posidonia* fibres deep in the sediments of Corner Inlet indicates the possibility of gradual elevation of the seagrass beds (Poore, 1978). This process may have been accelerated by clearing of forest for agriculture but no evidence of this was apparent (Poore, 1978).

Physical smothering and burial

Seagrasses are sensitive to burial driven by changes in bottom sediment transport (Fox et. al., 2007; Ball et. al., 2010). Sediment movement can prevent seagrass bed regrowth (Fox et. al., 2007). A crude estimate of total sediment inflow based on Malloy et. al. (2005) is in the order of 14,000 tonnes/yr (CEC, 2008). An average sediment inflow of 2500 tonnes/yr is equivalent to a deposition of a 3mm layer over an area of less than half a kilometre of sea bed (CEC, 2008). Thus catchment sediment is unlikely to form significant deposits except within the tidal river channels and their immediate point of discharge into the inlets, although there may be widespread turbidity and very minor deposition following a flood (CEC, 2008).

Despite the stability of the channels and mudflats, there has been coastal erosion due to waves at Foster and, by implication, Port Albert and other locations (CEC, 2008). Sea walls have been constructed to protect against erosion and levees to exclude seawater from land now used for agriculture (CEC, 2008). There is no evidence to suggest that the sedimentation rates on the major sand bodies and channels has been accelerated to any observable degree through impact by human activities in Corner Inlet and Nooramunga, and any increase in sediment supply from the catchments, resulting from recent human activities, is likely to be minor in comparison with the large sediment storage within Corner Inlet and Nooramunga (CEC, 2008).

Poore (1978) found little evidence to suggest massive sand movements in Corner Inlet, nor any measurable changes in levels of meadows. He also found no evidence of storm erosion or of more gradual erosion of seagrass beds and thought that the shallow depth and relatively short fetch of the inlet ruled out this possibility. Aerial photographs and local observation do not support the hypothesis that *Posidonia* banks have become higher in recent time or that the plants have died as a result of desiccation or heat stress (Poore, 1978). Physical damage by fishing equipment did not seem to be a probable cause either (Poore, 1978), although this is contested by O'Hara et. al. (2002).

Seagrass beds can also be smothered by drift algae or wrack (Ball et. al., 2010). They found that drift algae in both the intertidal and subtidal did not exceed 30% and was usually <10%.

Increased nutrients

Increased nutrients from the catchment are thought to be one of the factors influencing seagrass beds in Corner Inlet and Nooramunga (Hindell et. al., 2009). It seems likely that Nitrogen, rather than Phosphorus, plays a key role in the degradation of marine (and seagrass) systems (Fox et. al., 2007). Poore (1978) found no spatial trend in water nutrients across Corner Inlet, levels were low and basically similar to those in Western Port, with slightly higher organic Phosphorus (Poore, 1978). Hindell et. al. (2009) found nutrient concentrations in Corner Inlet often exceeded SEPP, and were significantly higher than those of Port Phillip Bay but less than those of the Gippsland Lakes. Auditing of farms in Corner Inlet and Nooramunga found that a large percentage of farms had nutrient runoff issues, particularly in the Yanakie region (WT, 2008). Targeted sampling found that Golden Creek had particularly high nutrient concentrations (WT, 2008).

South Gippsland Water intend to cease sewage discharge into Corner Inlet and Nooramunga as soon as budget and planning approvals allow upgrade projects to proceed, removing this source of nutrient input from the Corner Inlet Ramsar Site (Dickson, 2012). The rivers draining into Corner Inlet and Nooramunga are relatively small and direct rainfall on Corner Inlet and Nooramunga is about four times river inflow (CEC, 2008). Tidal flows dominate river flows and direct rainfall, on average, by a factor of about 1000 (CEC, 2008). The tides still exceed the freshwater inflows from flooding rains and associated river flows by a factor of 10 and 35 respectively (CEC, 2008). WT (2008) concluded that short residence times of freshwater in Corner Inlet indicate it has significant capacity to accept runoff from the catchment and exchange these waters with Bass Strait. Accordingly, poor water quality in the streams/rivers discharging into Corner Inlet may not be resulting in impacts as severe as might be observed in other less well-flushed Inlets. In contrast, Nooramunga receiving waters, with a lower flushing rate, were potentially at higher risk of suffering under nutrient and sediment discharges (WT, 2008).

Water quality data in the catchment and particularly in the inlets is sparse. Two studies that have tried to address this, WT (2008) in the catchment and Hindell et. al. (2009) in Corner Inlet, were both conducted during a major drought, so it is unclear how well their sampling represents wetter, more normal years. WT (2008) found that water quality data from Waterwatch and Hindell et. al. (2007) indicated that Corner Inlet had elevated Nitrogen concentrations, most likely from river discharge. Phosphorus loadings also appear to be elevated, but this is not reflected in elevated Phosphate in Corner Inlet, suggesting the system is phosphorus limited. Western streams, Foster WWTP, Franklin River, Agnes River and Albert River were producing loads significant enough to influence nearby seagrass beds (WT, 2008). Very high nutrients can create toxic conditions in sediments and inhibit seagrass growth (Fox et. al., 2007).

Reductions in light (biotic)

Seagrass can be affected by decreased light due to increased epiphyte growth stimulated by increased nutrients (Ball et. al., 2010). In a three-year study, epiphyte biomass on seagrass beds in Corner Inlet was found to be very variable across the embayment (Ball et. al., 2010). Episodes of large amounts of filamentous algae growth on seagrass or 'slub' over large areas of Corner Inlet have been reported in the last few decades (Michelle Dickson, pers. comm.)

Seagrass can be affected by decreased light due to increased phytoplankton growth stimulated by increased nutrients (Ball et. al., 2010). Hindell et. al. (2009) did not find significantly elevated water chlorophyll levels indicating large amounts phytoplankton or blooms.

Large numbers of the small bivalve *Electroma georgiana* (Wing Shell or Butterfly Shell) smothered *Posidonia* beds in Corner Inlet in May 2011. The reasons for their large increase in density are not known (Kirkman, 2013).

Desiccation

Temperature extremes coinciding with low tides can lead to the desiccation of seagrass beds. This has been documented as causing major seagrass dieback in the Spencer Gulf and Western Port Bay (as stated in Ball et. al., 2010). Examination of air temperatures for the Corner Inlet region did not suggest that this was associated with the 1970s seagrass loss (Poore, 1978).

Desiccation events may have a greater impact where the heights of intertidal flats have increased through the accrual of sediments (Ball et. al., 2010). Higher temperatures for longer durations as part of extreme events are predicted with climate change. Climatic changes as a causative factor on seagrass condition and extent cannot be ruled out even though no evidence of major temperature changes has been found (Poore, 1978). *Posidonia* in Corner Inlet is near its southern most limit of distribution, possibly close to its low temperature tolerance, and its intertidal position subjects it to considerable temperature stress in mid-summer or mid-winter (Poore, 1978).

Increased pollutants

Ball et. al. (2010) regarded pollutants as a more localised proximate cause of seagrass loss. Biocides, petroleum hydrocarbons and heavy metals from the catchment can cause seagrass loss (Poore, 1978; Fox et. al., 2007). Water quality sampling in Corner Inlet and Nooramunga has not found toxicants to be of concern (Poore 1978; Hindell et al 2009). Aerial spraying of the herbicide Fusilade Forte occurs in Corner Inlet and Nooramunga as part of *Spartina* control, but this is not thought to impact on seagrass beds. Pollutant loads associated with the ports within the inlets has not been assessed.

Increased swan grazing

Ball et. al. (2010) regarded swan grazing as a more localised proximate cause of seagrass loss. Corner Inlet and Nooramunga are listed as a Ramsar site, due to their large number of wader birds. The impact of direct bird grazing on the seagrass beds in Corner Inlet and Nooramunga has not been specifically assessed.

As discussed in Ball et. al. (2010) there are many factors cited as causes of major seagrass loss and a wide acceptance that there are complex interactions and feedback loops between the factors. From the investigations undertaken in Corner Inlet and Nooramunga there is no one or two particular factors that stand out. The major land use change (from native vegetation to cleared, agricultural, urban and production forestry land uses), since European settlement, in the catchments does imply that catchment sediment and nutrient supply to Corner Inlet and Nooramunga has increased although direct causative links to seagrass loss have not been established.

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Appendix 2

Outline of the bioeconomic modelling approach used to underpin the INFFER analysis

An essential component of INFFER is to assess the technical feasibility of achieving set targets. This requires the estimation of the effectiveness of available land management options in reducing catchment nutrient loads. A bioeconomic modelling approach was used to assess the technical feasibility and associated costs of management interventions to achieve defined environmental targets. The approach used is outlined in Beverly et al. (2013) and summarized below.

1. Adaptation of a previously calibrated catchment model (E2 model, Argent et al. 2006) which included updated mapped land use data on dairy and beef systems and gully risk mapping based on aerial photos and survey data which was correlated to streambank and gully erosion estimates derived in nearby catchments (Vigiak et al., 2011). The revised E2 modelling provided subcatchment load estimates of TN, TP and TSS from each of 67 subcatchments (33 in Corner Inlet and 34 in Nooramunga).
2. Estimation of the % effectiveness of alternative management practices. In the absence of locally relevant field and published information, two workshops of technical experts were held to identify meaningful so-called 'best management practices' (BMPs) for reducing nutrient and sediment losses. Details are outlined in Stott and Roberts (2013). BMPs were identified, some relevant to either beef or dairy, with some relevant to both. Effectiveness estimates in terms of percentage reduction for TN, TP and TSS were assigned to each BMP compared to the current practice. The effectiveness of some practices on dairy farms was assessed as lower than for beef farms (for example sediment reduction effectiveness for gully erosion, all constituents for drains) due to current practice on dairy farms being higher (more gullies and drains already fenced) than on beef farms.
3. Construction of representative farming systems. Three land-use enterprises were considered, namely dairy, beef and revegetation. Within the dairy systems, 4 levels of intensity (extensive, moderately extensive, moderately intensive, intensive – see Table below) were constructed which covered the range of intensity of dairy farming currently. The four representative farming systems were constructed using a combination of available data (Gilmour et al., 2012), field surveys in the neighbouring Moe River catchment and discussion with local extension staff. Details of the current systems are outlined in Stott et al. (2013).
4. Estimation of the costs of implementing management practices on farm types. The annual net private benefit (+) or cost (-) of implementing each BMP on each dairy or beef representative farm was calculated relative to a baseline, this being the annual 'Operating Profit' for each system. The operating profit was calculated as gross income minus costs (including variable costs and fixed costs or overheads). Full calculation details are outlined in Stott and Roberts (2013) and the costs assumed for dairy and beef farms are outlined in Table A2.1 below.
5. Development of a bio-economic optimisation model using the General Algebraic Modelling System (GAMS, Brooke et al. 2008). The optimisation model maximises total net benefits expressed as the difference between producer profit and regulatory costs for a given nutrient target. This cost-effectiveness approach, where emissions goals are sought at least cost (e.g. Doole, 2012; Doole and Pannell, 2012) avoids the difficulty and cost of assessing the benefits associated with improved water quality.
6. Development of scenarios to assess changes in profit and land management implications associated with achieving sediment and nutrient reduction targets. Following the initial aspirational and revised target setting with the Technical Panel, CMA *staff and modellers worked through a range of scenarios to assess implications on profit, land use and management changes required to achieve targets*. CMA staff also worked with the Steering Committee who provided feedback as to the economic and political acceptability of some of the management implications, which then led to additional scenarios being tested. Because there was no information regarding current distribution of dairy farm intensity in the catchment, under the 'base case' (before optimisation) all land under dairy farming was assumed to be in the 'moderately intensive' system under current practice conditions. This farm type was believed to best represent an average dairy farm in the catchments. Under optimisation, any of the 4 dairy farm systems and single beef system and associated best management practices could be selected as could traditional activities. Land retirement could also be selected if this was less costly than management practice change.

Table A2.1 Assumptions about farming system intensity underpinning the Corner Inlet analysis

	Total area (ha)	Milking area (ha)	Operating profit ($/ha)	Fert. N (kg/ha)	Fert. P (kg/ha)	Concentrates fed (tDM/cow)	Cows (no. per farm)	Stocking rate (cows/ha)	Milk (kg MS/ha)
Beef	175	-	397	0	7	0	204	1.3	-
Dairy – extensive	150	95	565	35	16	1.0	180	1.3	418
Dairy – mod extensive	150	95	810	70	16	1.2	210	1.5	600
Dairy – mod intensive	175	110	1,057	140	16	1.5	275	1.8	783
Dairy – intensive	175	110	1,332	210	16	1.7	330	2.1	987

Table A2.2 Assumed effectiveness estimates and costs/ha for dairy BMPs and traditional activities

	Assumed effectiveness at reducing load			Cost[a] (profit) $/ha	Notes/assumptions about farm area to which the BMP is applied
	%TN	%TP	%TSS		
Best management practices ($ are on a per ha basis)					
Nutrient application rates	5	2	0	(26.23)	100% farm area
Effluent collection	90	90	0	23.93	10% farm area
Effluent management	20	20	0	2.11	50% farm area
Tracks and crossings[b]	50	50	50	199.11	2% farm area
Wet area management	90	90	90	58.14	10% farm area
Traditional fencing activities ($ are on a per km basis)					
Gullies	5	5	20	4513	Differing lengths assumed per farm based on spatial information (hydro layer, % dairy farms in each subcatchment
Permanent waterways	15	20	40	6367	
Streams	10	13	25	3976	
Constructed drainage lines	2	2	5	312	1500 m drainage lines assumed per farm, already fenced

a Note that costs have been calculated on a per hectare basis assuming a moderately intensive dairy farm (see Table A.2.1 in Appendix) of 150 ha in size.

b Length of tracks and crossings was not possible to gain from available spatial information, therefore a simple proportion of farm area was assumed

Table A2.3 Assumed effectiveness estimates and costs/ha for beef and sheep BMPs and traditional activities

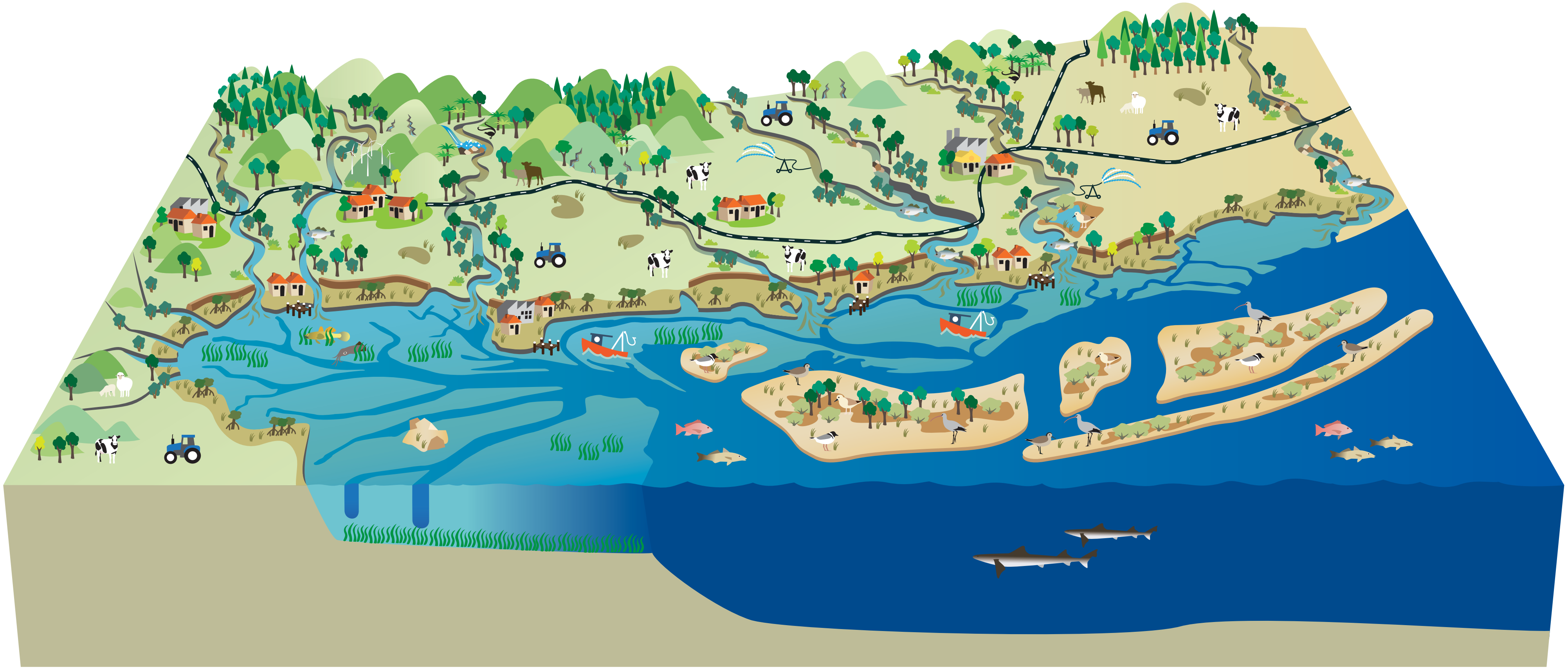
	Assumed effectiveness at reducing load			Cost (profit) $[a]	Notes/assumptions about farm area to which the BMP is applied
	%TN	%TP	%TSS		
Best management practices ($ are on a per ha basis)					
Tracks and crossings	50	50	50	21.7	0.5% farm area
Pasture management (groundcover)	0	5	5	66.53	100% farm area
Restoring bare areas	20	80	20	7.68	10% farm area
Restoring landslips	50	70	90	10.48	1% farm area
Traditional fencing activities ($ are on a per km basis)					
Gullies[a]	5	5	50	4513	Differing lengths assumed per farm based on spatial information (hydro layer, % dairy farms in each subcatchment
Permanent waterways	15	20	40	5438	
Streams	10	13	25	3697	
Constructed drainage lines	2	2	5	2065	125m drainage lines assumed on beef farms, all unfenced

a *The effectiveness in sediment reduction by gully fencing was assessed as higher (50%) on beef farms than on dairy farms (20%). More gullies have already been fenced on dairy farms compared with beef and sheep farms and thus the ability to further reduce sediment loads was estimated to be lower on dairy farms.*

Acronyms

ANZECC	Australian and New Zealand Environment Conservation Council
BCR	Benefit : Cost Ratio
BMPs	Best Management Practice
CISC	Corner Inlet Steering Committee
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEPI	Department of Environment and Primary Industries
DEWHA	Department of the Environment, Water, Heritage and the Arts
DWC	Dry Weather Concentration
ECD	Ecological Character Description
EMC	Event Mean Concentration
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GAMs	General Algebraic Modelling System
GLaWAC	Gunaikurnai Land and Waters Aboriginal Corporation
Giffard GMA	Giffard Groundwater Management Area
GRSWS	Gippsland Region Sustainable Water Strategy
HVP	Hancock Victorian Plantations
INFFER	Investment Framework for Environmental Resources
LGA	Latrobe Group Aquifer
MBI	Market Based Instruments
MERI	Monitoring, Evaluation Reporting and Improvement
MLA	Meat and Livestock Australia
R&D	Research and Development
SEPP	State Environment and Protection Policy
SGW	South Gippsland Water
SMART	Specific, Measurable, Attainable, Realistic and Time-bound
SRW	Southern Rural Water
TN	Total Nitrogen consisting of Total Kjeldahl Nitrogen plus Nitrate and Nitrite
TP	Total Phosphorus
TSS	Total Suspended Solids
WGCMA	West Gippsland Catchment Management Authority or West Gippsland CMA
WQIP	Water Quality Improvement Plan
WSPA	Water Supply Protection Area
WWTP	Waste Water Treatment Plant

Corner Inlet Catchment – conceptual map



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Cover: View of Corner Inlet from Silcocks Hill. Photo – InDetail Comms & PR.

Above: Seagulls at Corner Inlet. Photo – WGCMA.