Corner Inlet **Water Quality Improvement Plan** 2013

CornerInletConnections
Committed to a Healthy Corner Inlet

Acknowledgements

The development of this report has involved the collective effort of a number of departments and individuals. In particular:

- Primary authors
  - Michelle Dickson (WGCMA)
  - Geoff Park and Anna Roberts (Natural Decisions)
- Contributing authors
  - Craig Beverly (DEPI)
  - Tracey Jones and Eleisha Keogh (WGCMA)
  - Simone Wilkie and Greg Peters (Riverness Consulting)
  - Jan Barton (Deakin University)
- Technical support from DEPI staff Kerry Stott, Olga Vigiak, Jane McInnes, Terry McLean, Nick Dudley, David Shambrook and Greg O'Brien
- Technical Panel members Llew Vale (independent chair and local landholder), Dr Paul Boon, Dr Jon Hinwood, Dr Craig Beverly, Dr Ian Rutherford, Tim Allen and Kylie Debono
- Organisations represented on the Corner Inlet Steering Committee Gippsland Ports, South Gippsland Water, HVP Plantations, Yarram Yarram Landcare Network, South Gippsland Landcare Network, Department of Environment and Primary Industries, Gippsland Coastal Board, South Gippsland Shire Council, Wellington Shire Council, Environmental Protection Authority, GippsDairy and Parks Victoria
- Editing and graphic design
  - Vanessa Facey (InDetail Comms & PR)
  - Wendy Schlipalius (Italicherry Design Studio)
- Photography with thanks to:
  - 1st Foster Cub Group
  - Hancock Victorian Plantations
  - InDetail Comms & PR – Vanessa Facey
  - Jonathon Stevenson
  - Parks Victoria – Roger Fenwick, Jonathon Stevenson
  - Sally-Anne Henderson
  - Sharyn Allott
  - South Gippsland Landcare Network
  - South Gippsland Water
  - Tarmo A Raadick
  - WGCMA - Michelle Dickson, Vanessa Facey, Mandy Leggett, Peter Newgreen
    - Aerial photos, Michael Malone
    - Corner Inlet Connections photos, David Fletcher
  - Yarram Yarram Landcare Network

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

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The level of government investment in this strategy will depend upon budgets and Government priorities.

Accessibility

This document is also available in pdf format on the WGCMA website www.wgcma.vic.gov.au

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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.

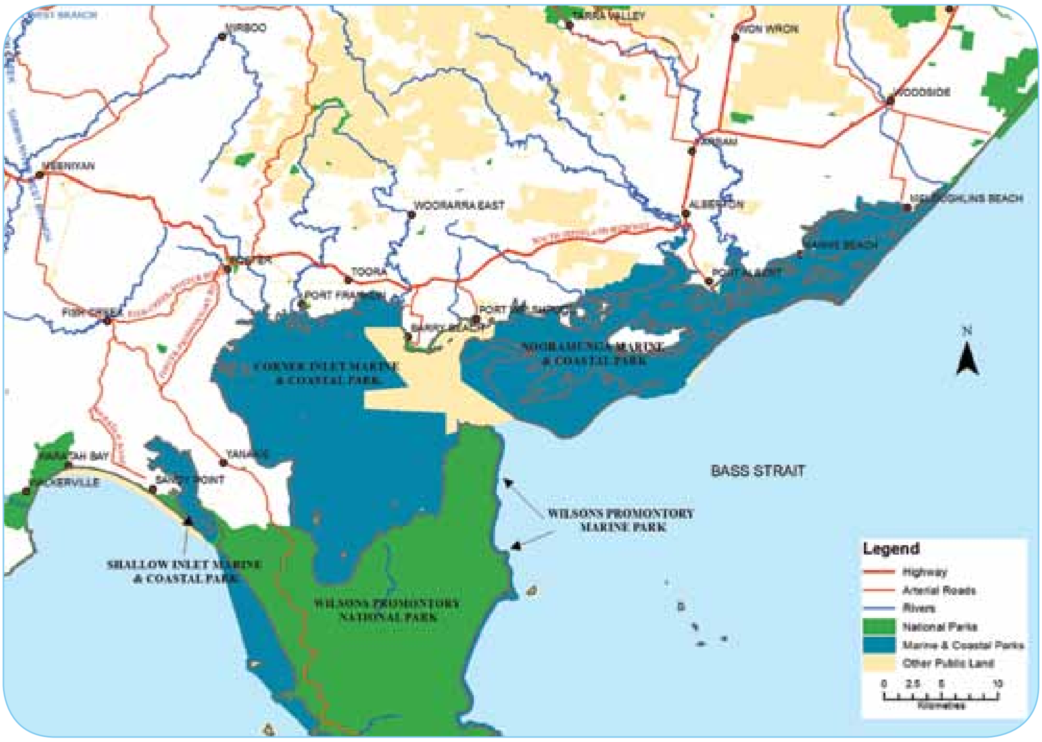


Figure 1.1.1 Corner Inlet Ramsar Site (including coastal and marine park boundaries and surrounding catchment)

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.

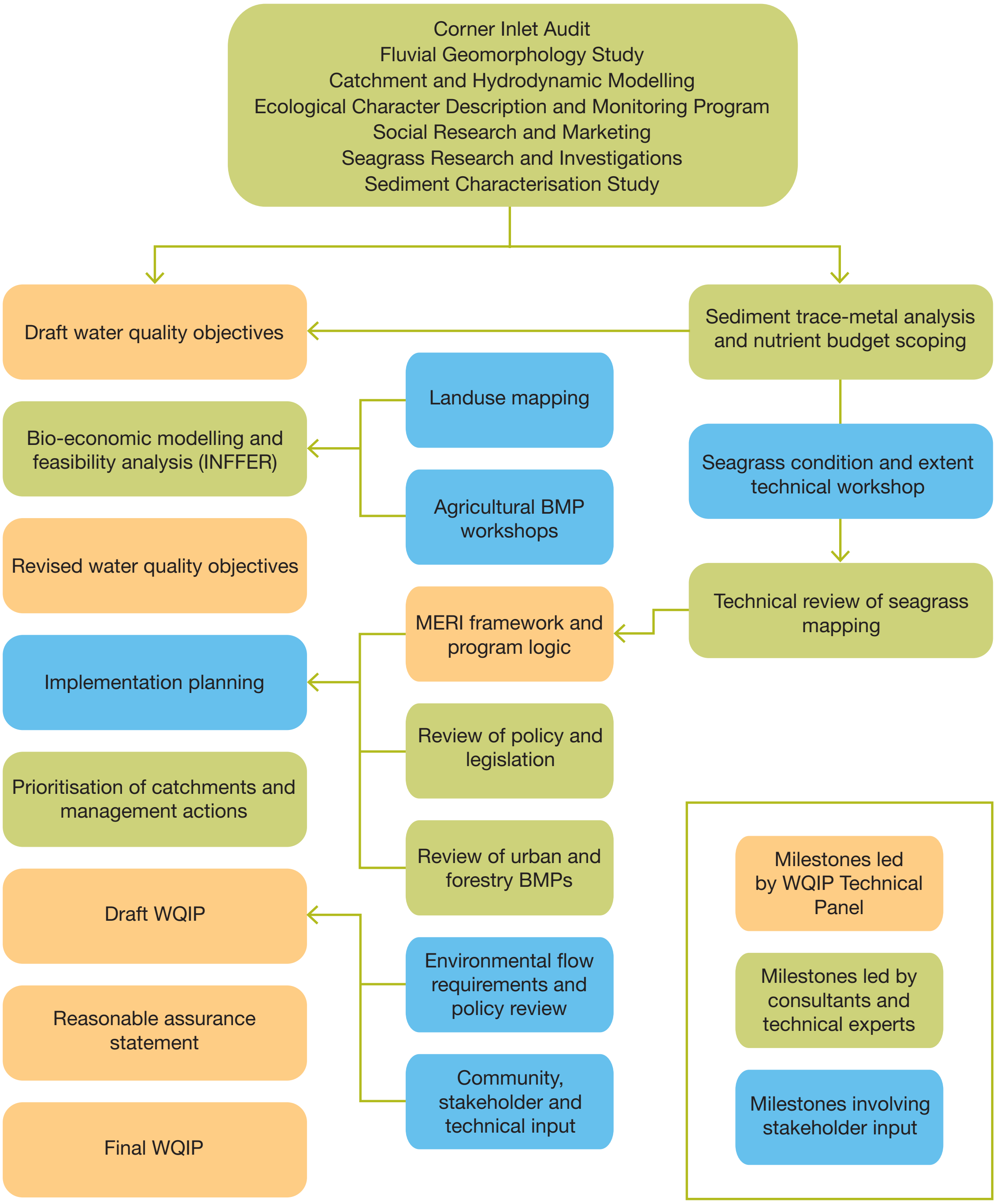


Figure 1.4.1 Key stages for developing the Corner Inlet WQIP

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.

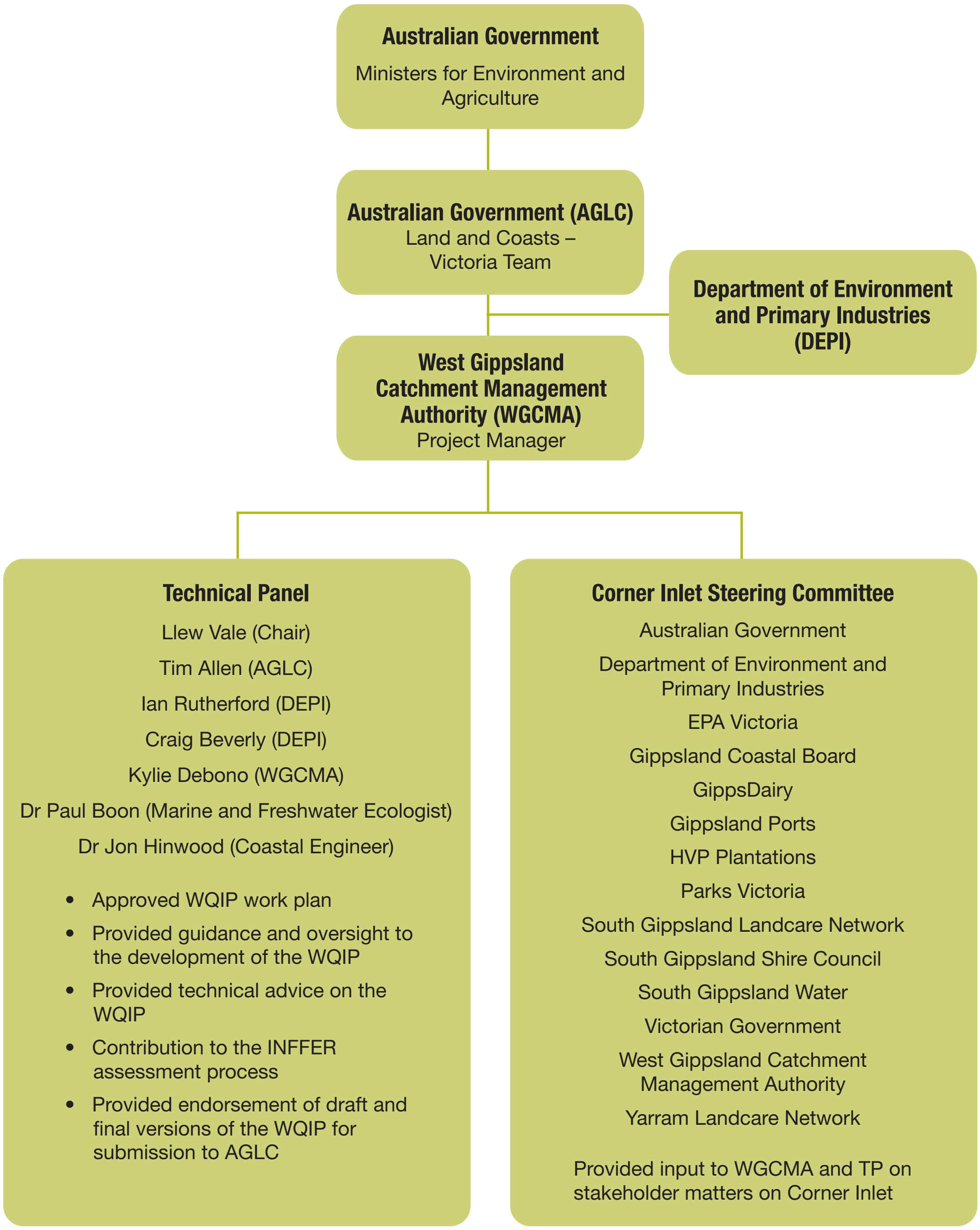


Figure 1.5.1 Water Quality Improvement Plan Governance and Engagement Structure

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

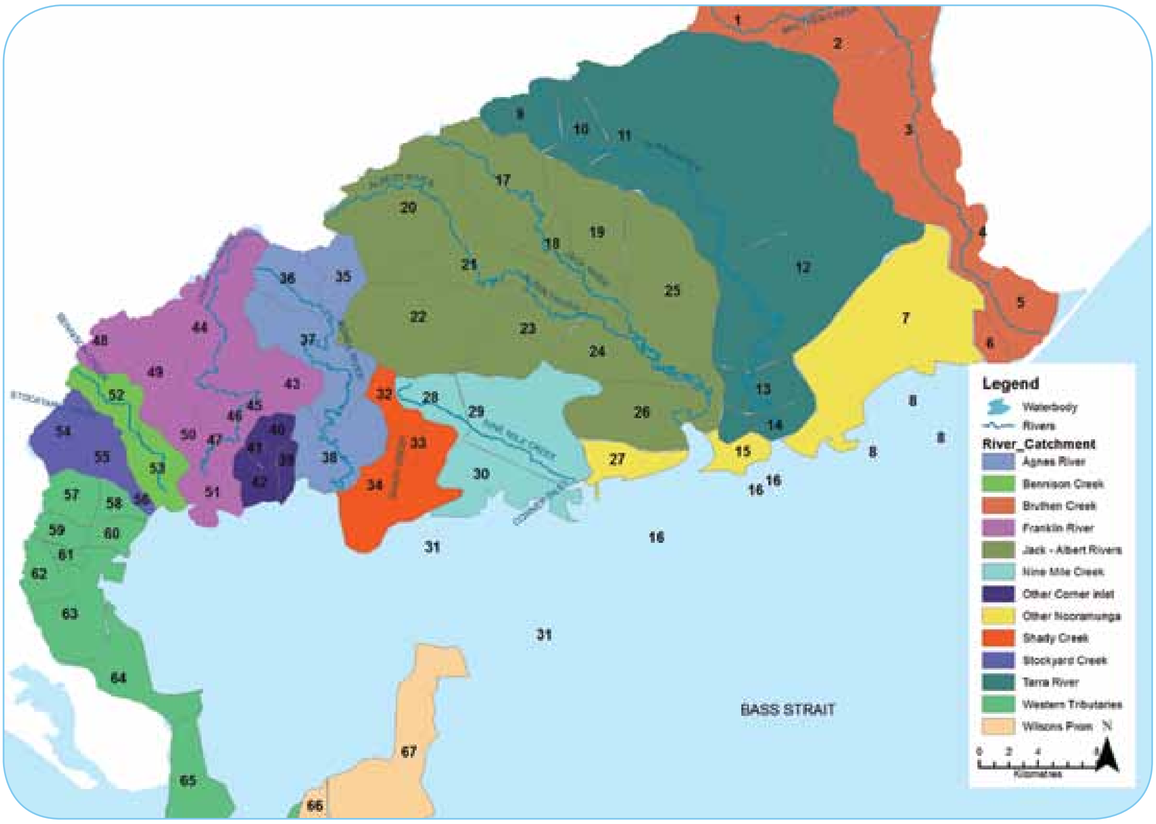


Figure 2.1.2 River Catchments of Corner Inlet and Nooramunga

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).

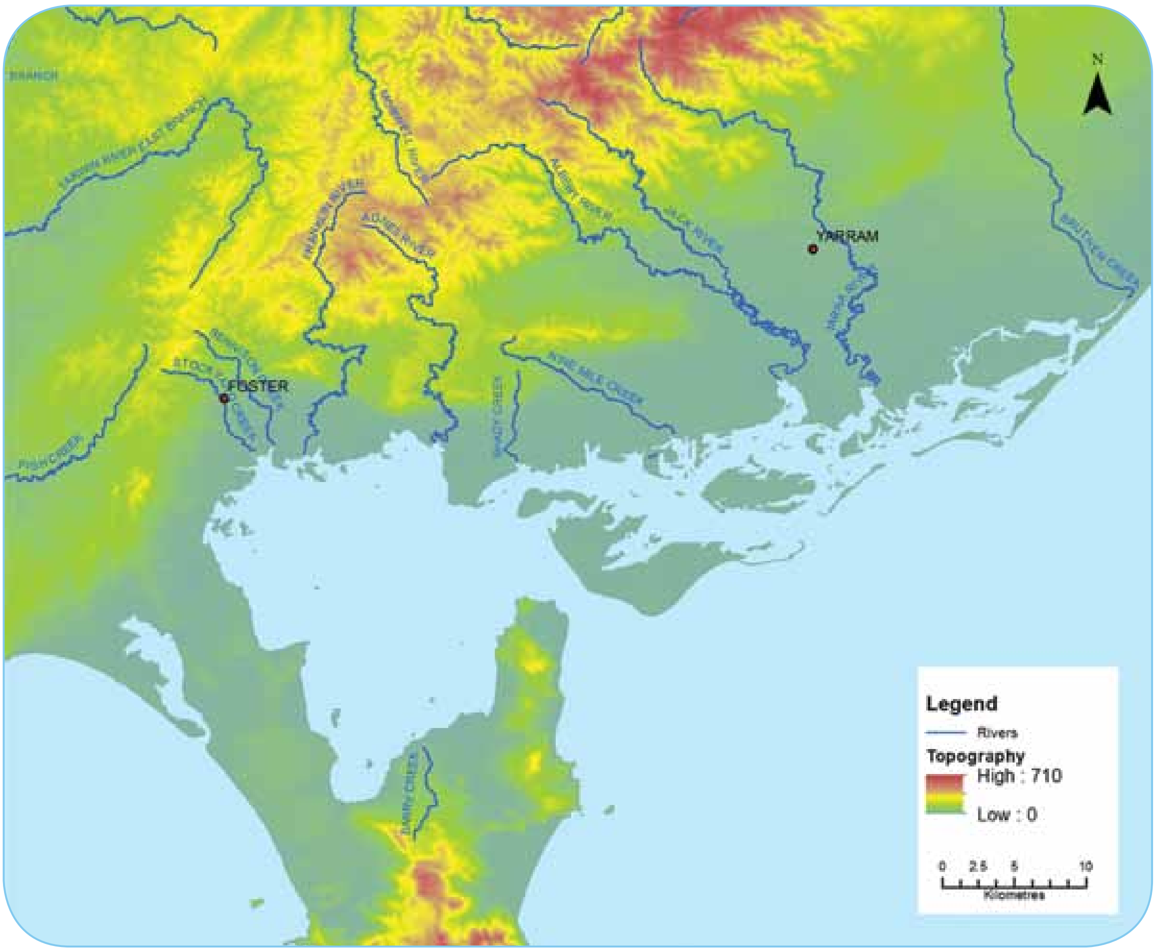


Figure 2.2.1 Topography within the Corner Inlet and Nooramunga catchment

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.

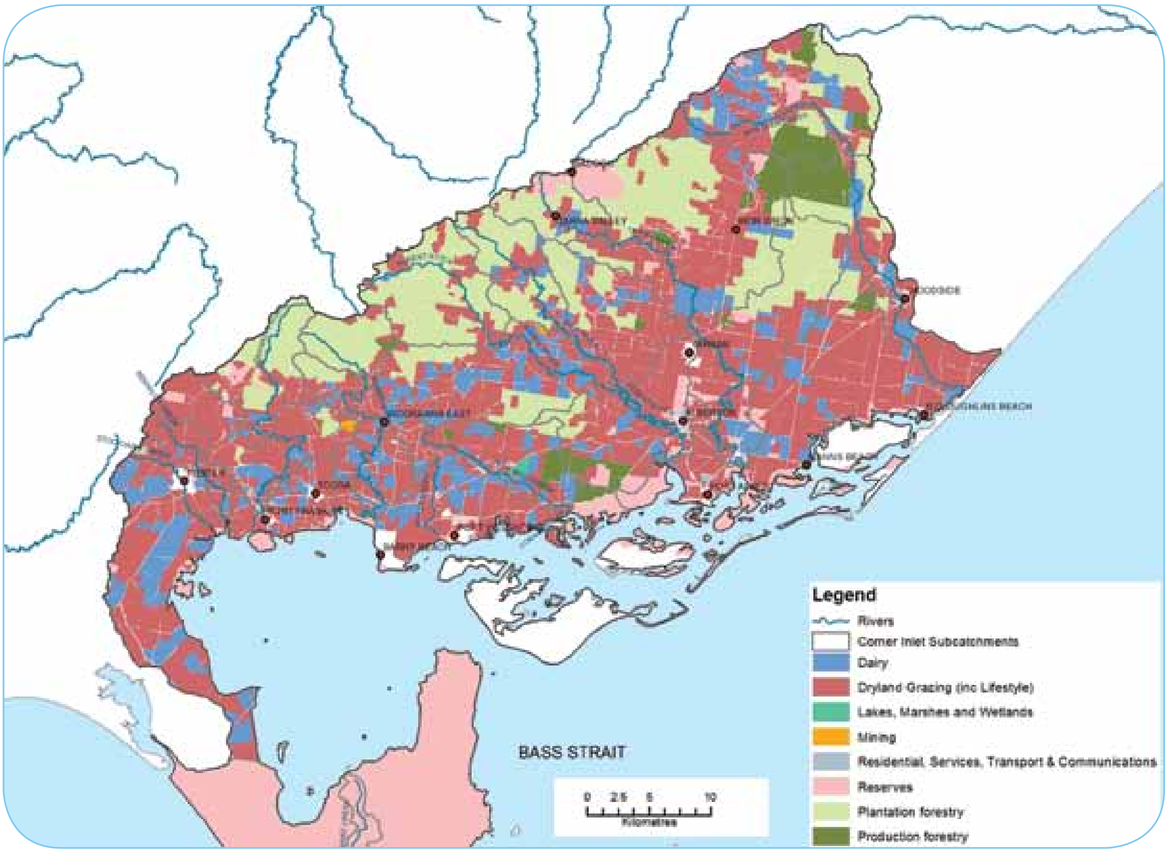


Figure 2.3.1 Current land use

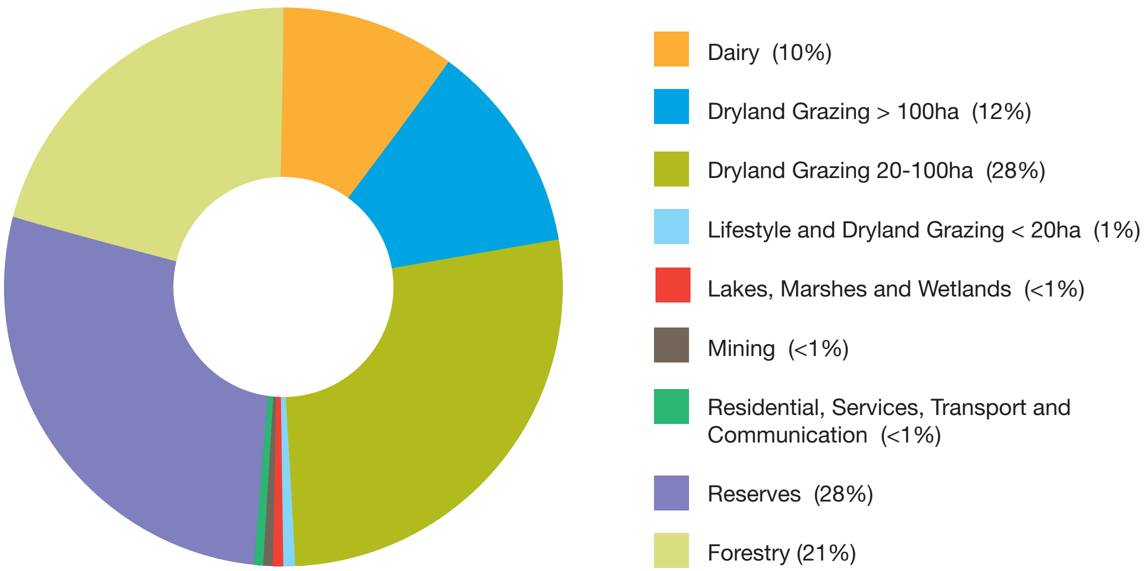


Figure 2.3.2 Proportion of each land use in the Corner Inlet catchment

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)

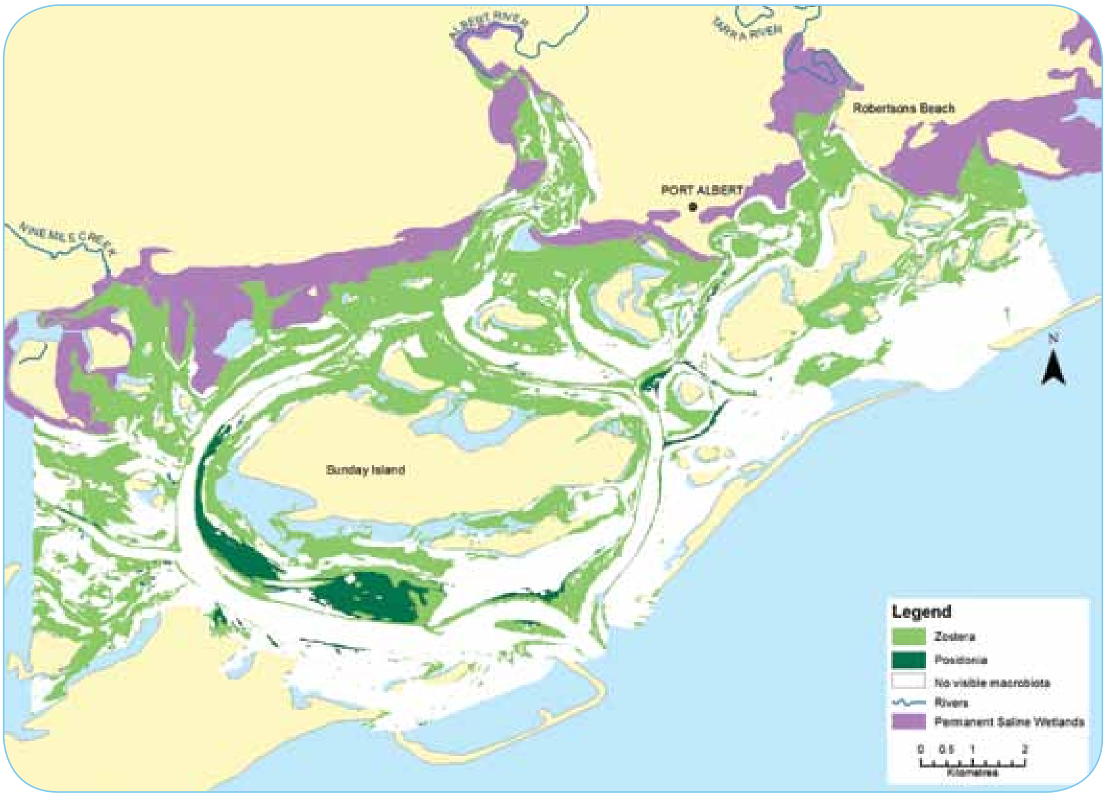


Figure 3.1.2 Nooramunga seagrass mapping (Monk et. al., 2011)

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.

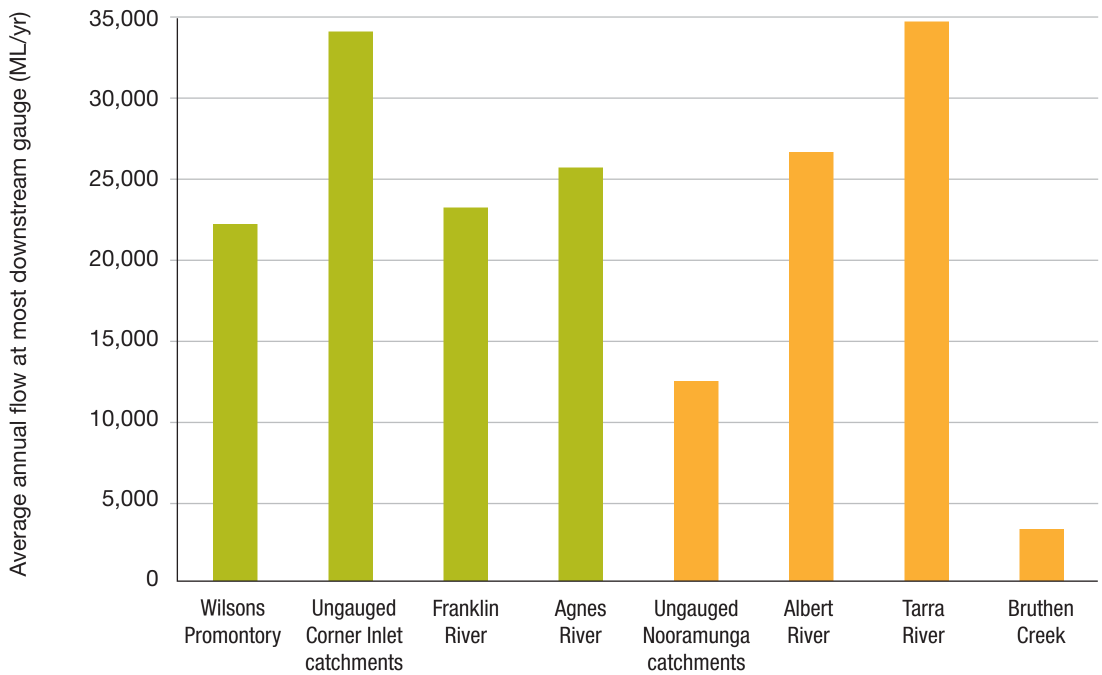


Figure 4.1.1 Average annual flow in tributary streams

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.

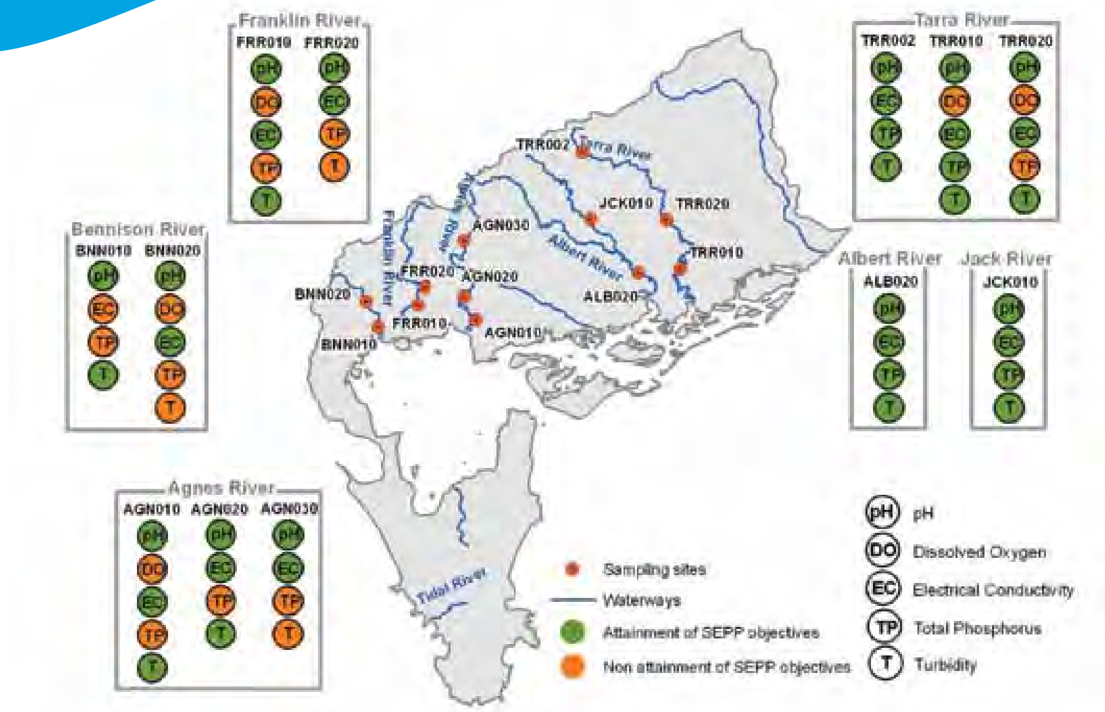


Figure 4.5.1 Attainment of SEPP water quality objectives for selected sites in the Corner Inlet catchment (WGCMA and Hyder, 2010)

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.

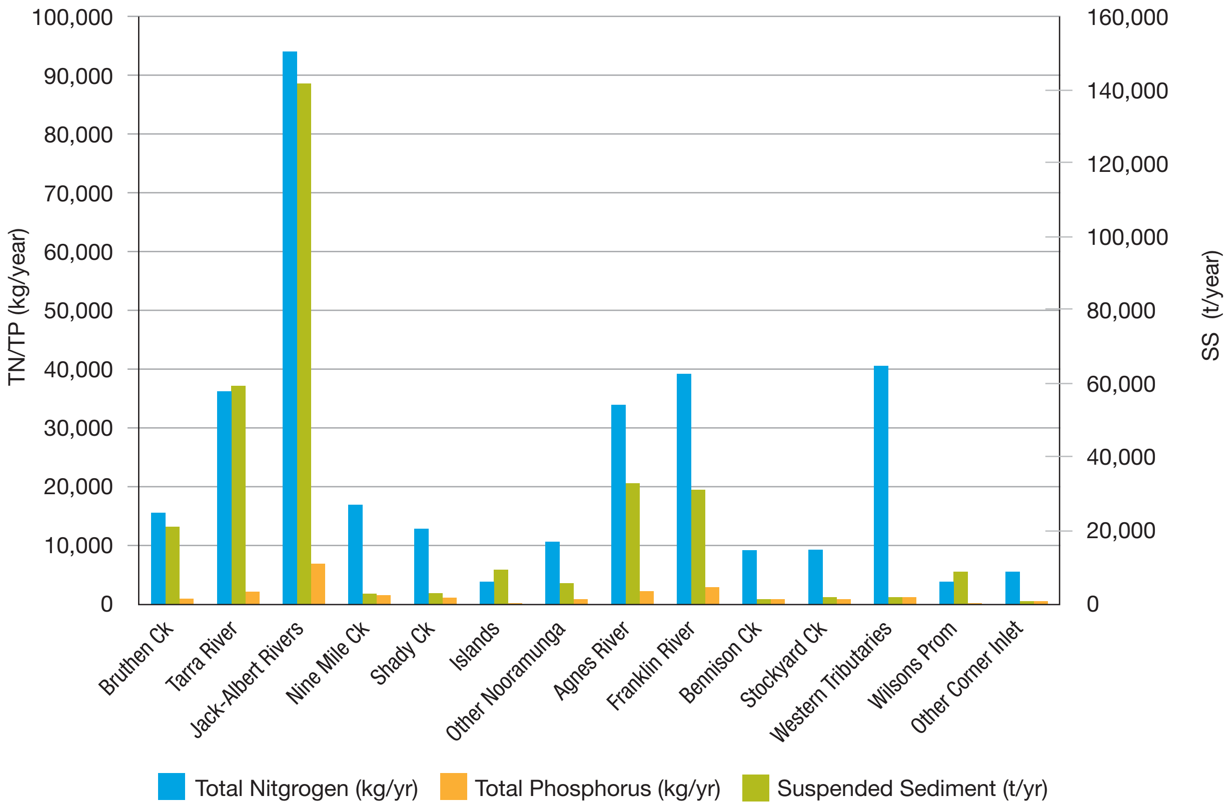


Figure 4.7.1 Modelled suspended sediment (tonnes/year), Total Nitrogen and Total Phosphorus (kg/year)

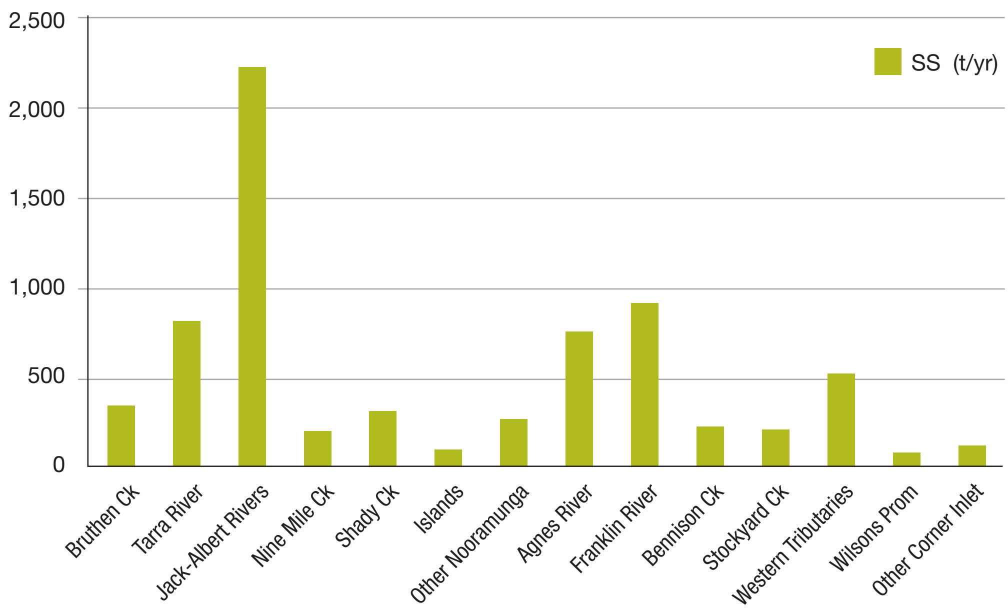


Figure 4.7.2 Modelled suspended sediment load in tonnes/year

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.

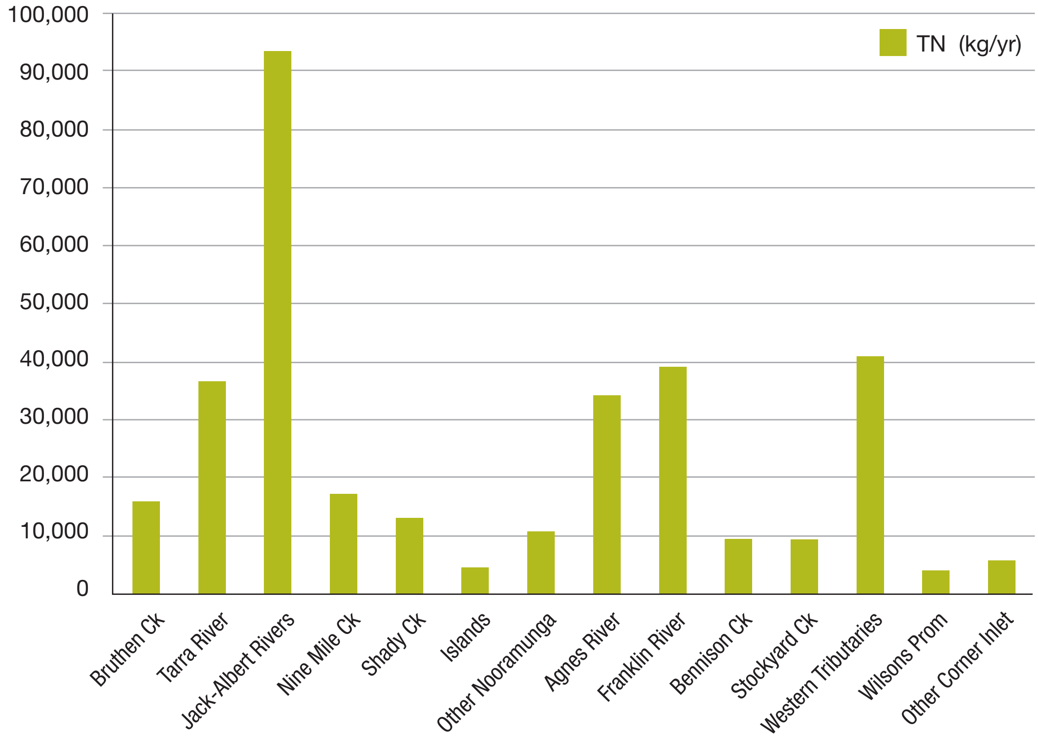


Figure 4.7.3 Modelled Total Nitrogen load in kg/year

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.

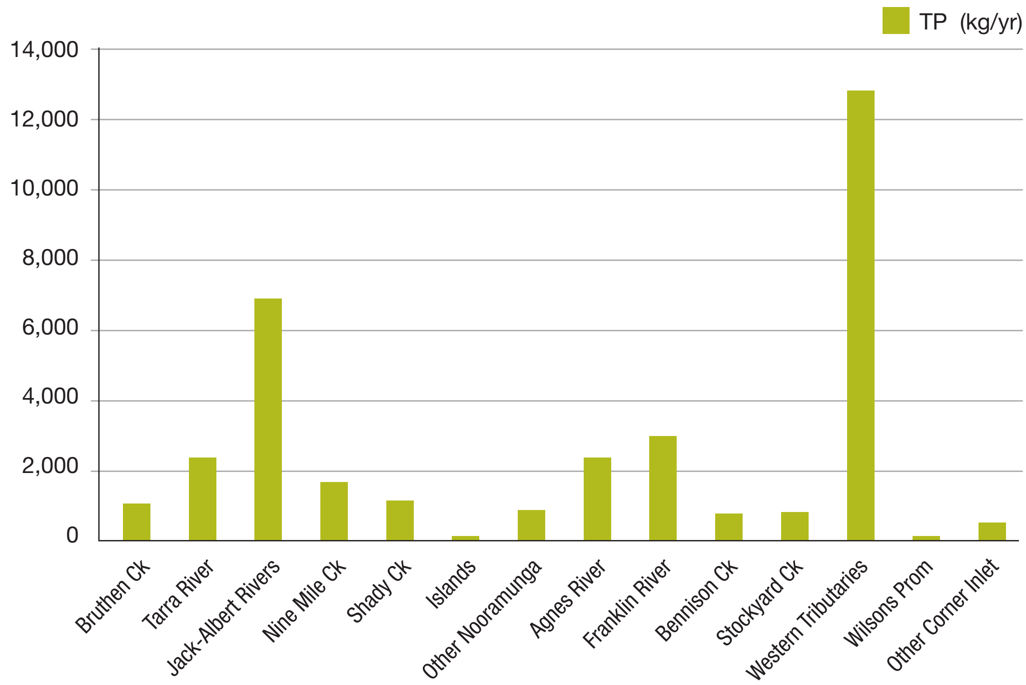


Figure 4.7.4 Modelled Total Phosphorus load in kg/year

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.

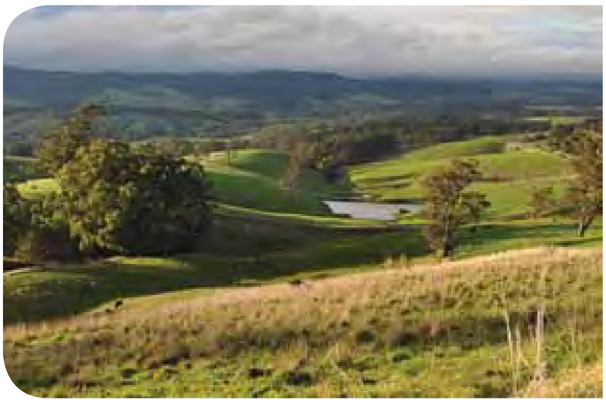
Table 5.2.1 Implications of Victorian water management legislation and policy for the Corner Inlet WQIP

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).

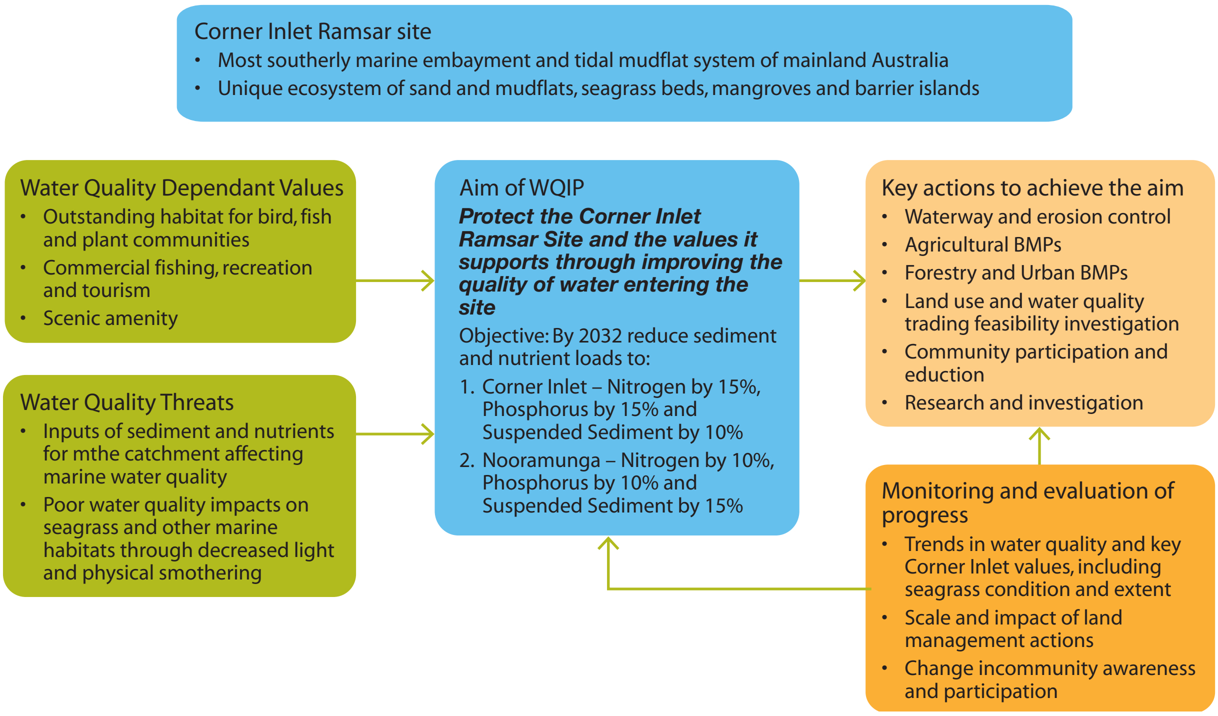


Figure 6.1.1 Simplified Program Logic for Corner Inlet WQIP

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.

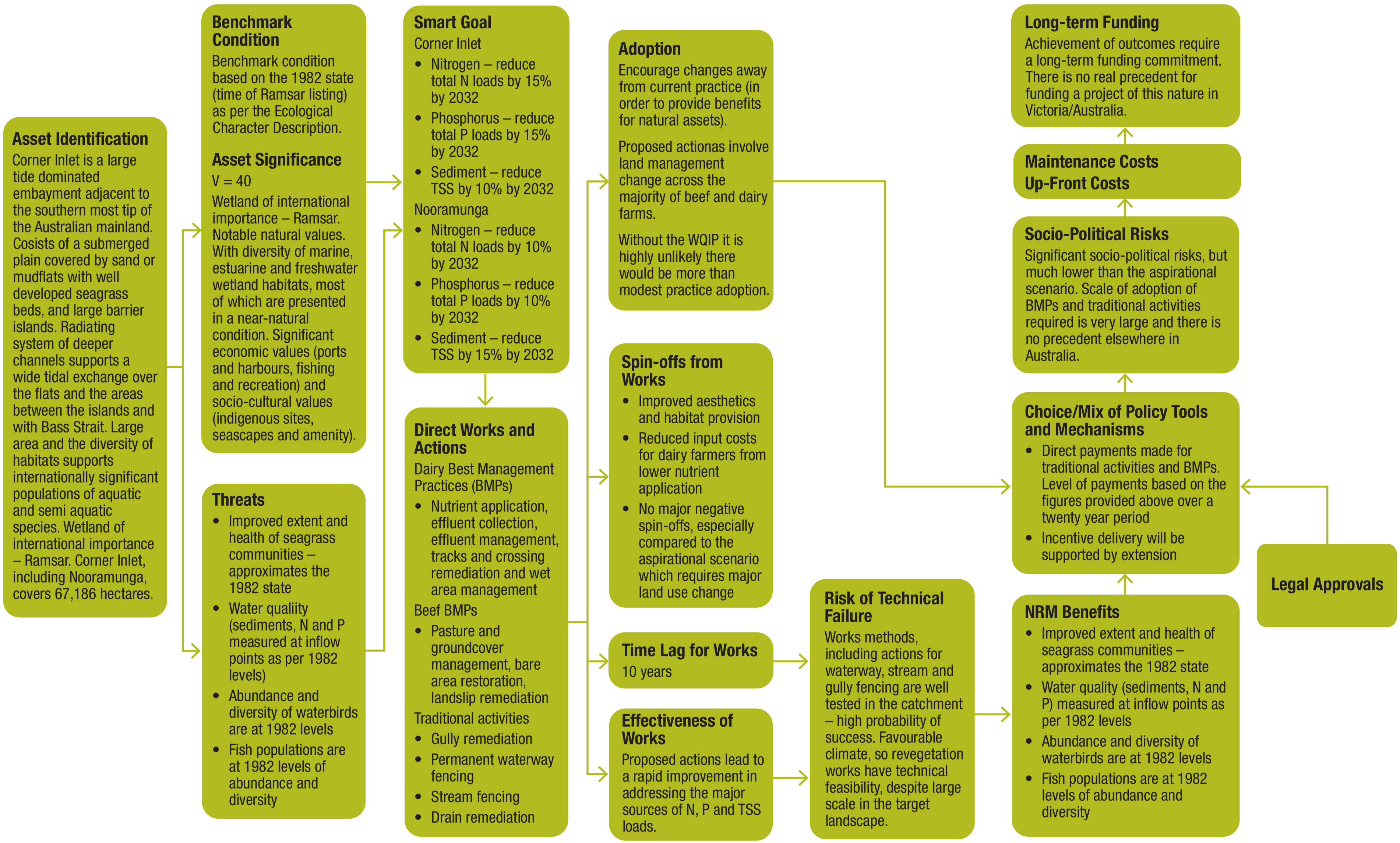
6.3 The link between values, water quality objectives and program logic

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