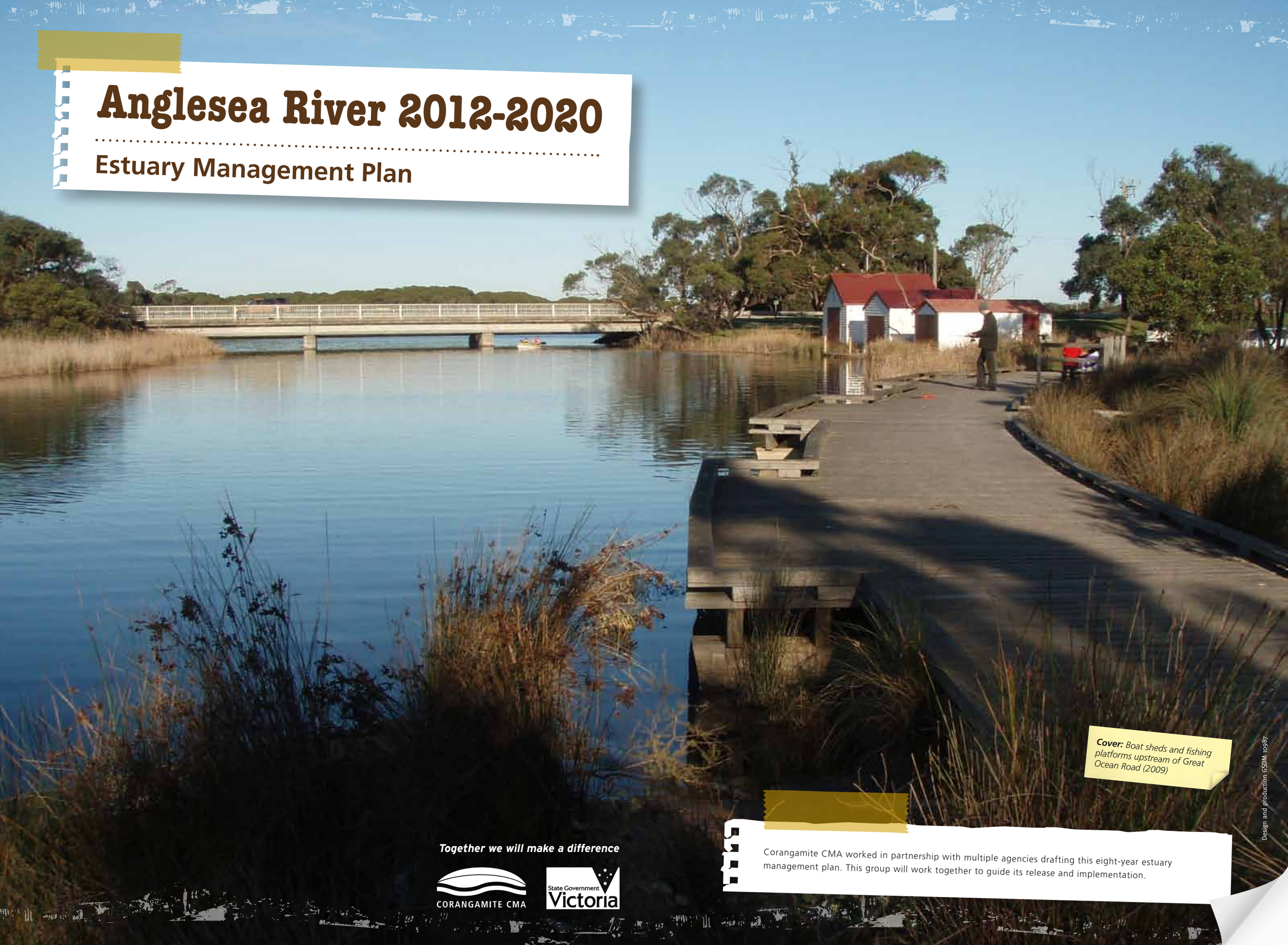
Anglesea River 2012-2020

Estuary Management Plan



Cover: *Boat sheds and fishing platforms upstream of Great Ocean Road (2009)*

Together we will make a difference

CORANGAMITE CMA

State Government Victoria

Corangamite CMA worked in partnership with multiple agencies drafting this eight-year estuary management plan. This group will work together to guide its release and implementation.

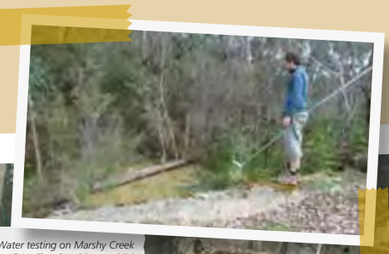
Design and production GSDM 10987

Anglesea River Catchment

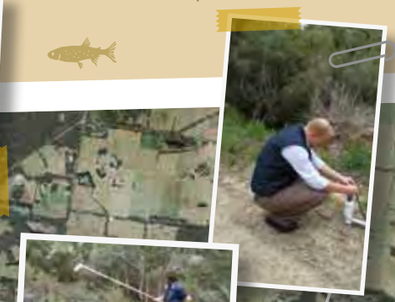
Total Catchment: 885 Ha
River Length: 20.5 km
Estuary Length: 2.6 km
Location: 144°11'28.8015" E
38°24'53.0069" S

CORANGAMITE CMA

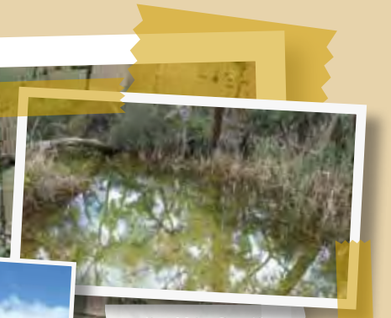
Scale: 1:50,000



Water testing on Marshy Creek at Gum Flats Road (non-acidic)

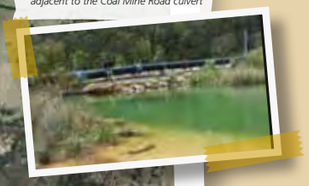


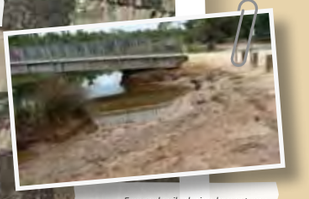
Water testing on lower Marshy Creek just upstream of Alcoa on the Boundary Track (acidic)



Above & Below: Clear acidic water adjacent to the Coal Mine Road culvert

Looking downstream from Coal Mine Road toward Coogoorah Park





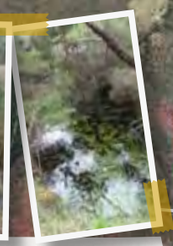
Exposed soils during low estuary water level at Wray Street footbridge

Flow gauging weir on Breakfast Creek, a western tributary flowing to Salt Creek (non acidic)

Marshy Creek (Anglesea River)

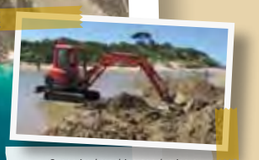
Breakfast Creek

Salt Creek



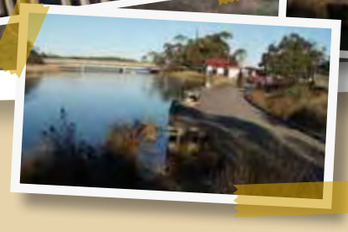
Above: Water pooled around road culverts on Salt Creek (acidic)
Below: Salt Creek in high flow

Installation of a constant 24 hour water quality logger on the river bank within the estuary



Supervised machine conducting a permitted estuary mouth opening

Aerial shot of estuary mouth



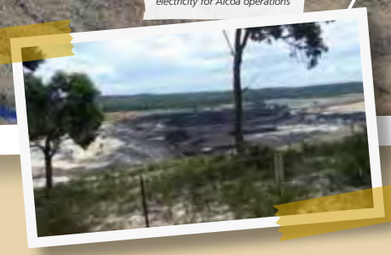
Active and passive recreation in the lower estuary

Gauge board surveyed to AHD on the northern side of the Great Ocean Road

Exposed sea grass during low estuary water level

Measuring pH at the estuary mouth

Open cut coal mine supplying electricity for Alcoa operations



Executive summary

The Anglesea River Estuary Management Plan is an eight-year action plan aimed to improve the environmental condition of the Anglesea River estuary. Protection and improvement of the estuary will ensure the estuary is able to continue to support the variety of social, economic and cultural values identified by the community during the development of this plan.

In recent times the condition of the Anglesea River has been the subject of much community concern. Poor water quality events during 2010 and 2011 resulted in fish deaths throughout the estuary. An independent review by Professor William Maher, commissioned by the Victorian Government, indicated that the events were the result of acidic or low pH waters from natural processes in the catchment (and accelerated processes) and the estuary. He also concluded that similar events were likely to occur due to, but not limited to, prolonged periods of low rainfall followed by soaking rains.

A government response to the review recommended that the Anglesea River Estuary Management Plan should be updated, with a focus on improved knowledge about these events, ensuring that the estuary becomes more resilient to such events over time and that community values, particularly recreational values are maintained.

The development of this estuary management plan follows an extensive community engagement process, including the release of a draft for public comment and a broad community survey. The plan contains a list of priority actions which contribute to four broad directions.

These directions are:

1. Amenity and recreation (including fishing)
2. Biodiversity
3. Information and knowledge
4. Integrated management.

The Anglesea Estuary Management Plan implementation will involve many agencies and groups. The Corangamite CMA will manage its implementation under the direction of an implementation committee, consisting of representatives of agencies and groups with responsibilities for actions in this plan. Regular reviews of the plan's progress of implementation will be undertaken and reports provided to the community.

Anglesea River mouth (2008)

This document was written and prepared by the Corangamite CMA during 2012-2013. An independent external review and edit of the document took place in July and August 2013 prior to the release of the final document. Key stakeholders were informed during this process as to the progress of the plan.

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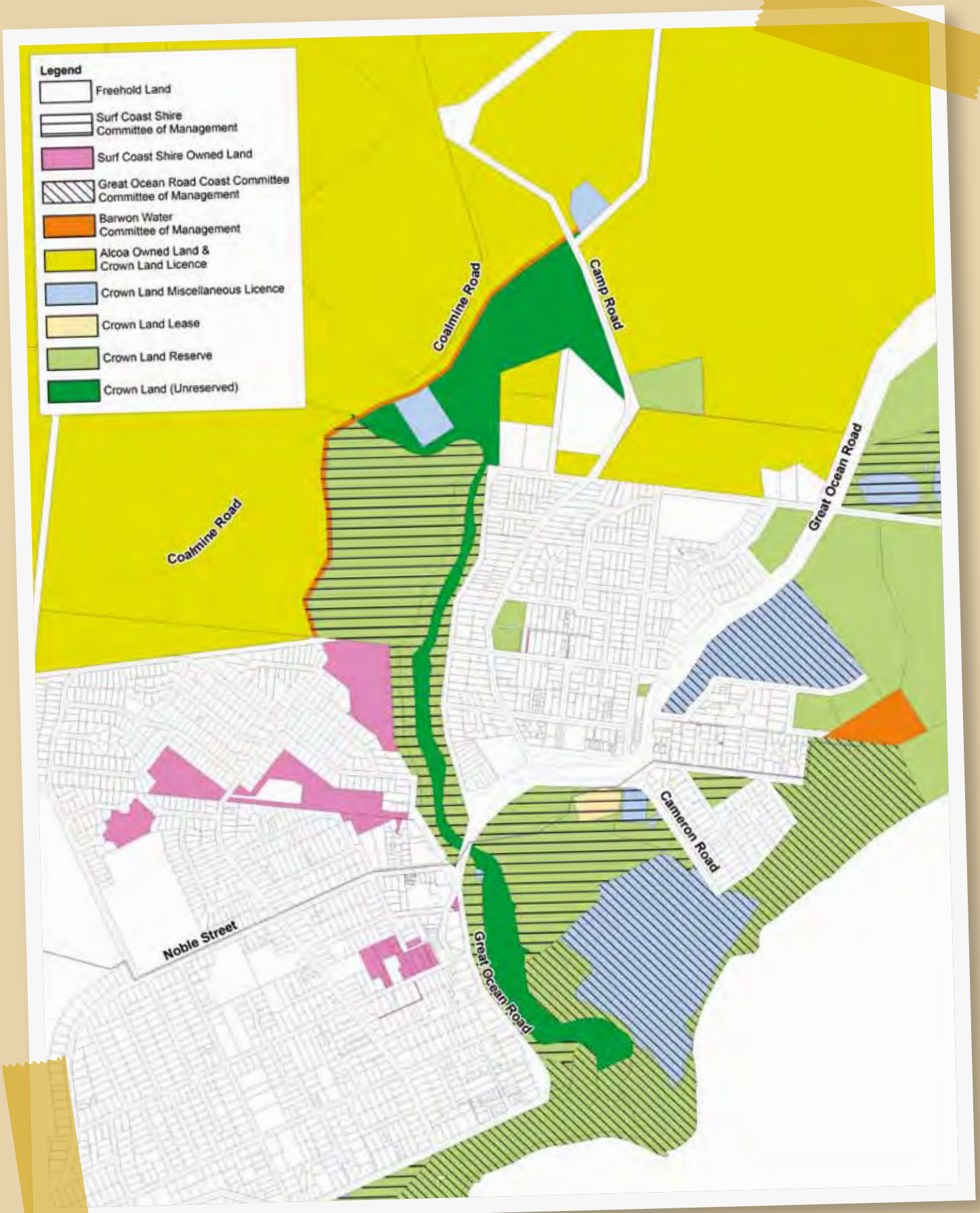
Acknowledgment of support
Key documents used in this plan from Water Technology Pty Ltd and the Centre for Aquatic Pollution Identification and Management (CAPIM). Drafting and support from DEPI and Surf Coast Shire and assistance from Anglesea and District Historical Society.

Anglesea River estuary land managers map



Partners and their roles and responsibilities in waterway management

The diversity of habitats, land use and land tenure surrounding estuaries typically results in the involvement of many groups undertaking management roles. This is the case for the Anglesea River.

Details of the partners roles and responsibilities in estuary management at a state and local level can be found in the table below.

The map on the preceding page identifies the complex land tenure divisions surrounding the estuary. Land tenure is a result of development history, and current town planning.

Group or Agency	Regional responsibility
Corangamite Catchment Management Authority (CMA)	Regional caretaker of water health, including the development of the Corangamite waterway strategy and Estuary Management Plan; implementation of waterway work programs; authorisation of works on waterways, including estuary mouth openings, responding to natural disasters and incidents affecting waterways.
Local Government (Surf Coast Shire)	Planning authority, management of stormwater drainage and on-site domestic wastewater systems, land management, emergency management.
Department of Environment and Primary Industries (DEPI)	Development of waterway policy, coordination of regional delivery and prioritisation of government investment in waterways; management of fisheries, including recreational fishing.
Environment Protection Authority (EPA)	Responsible for the protection and improvement of Victoria's environment by establishing environmental standards, regulating and working with organisations to meet these standards.
Parks Victoria (PV)	Management of the Greater Otway National Park and the Anglesea Heath.
Great Ocean Road Coast Committee (GORCC)	Management of the coastal land at and adjacent to the estuary mouth and foreshore to east and west.
Western Coastal Board	Strategic coastal and marine planning and preparation of regional coastal plans.
Traditional Owners (TOs)	Recognised native title rights; collaboration in the development and implementation of plans.

Coogoorah Park Wetlands, Winter 2009

Connection to place: Wadawurrung and the Anglesea River estuary

The Anglesea River estuary is located on the traditional lands of the Wadawurrung. The Wadawurrung name for the Anglesea River is knarka-dorla which means sandy stream.

The entire Wadawurrung country was a mosaic of clan estates, of which there were 25, through which intermarriage, and other alliances, people were able to access land and resources far beyond their own estates. Access to land and resources was negotiated through discussion, marriage, ceremony and adherence to traditional law.

Wadawurrung country extends from Fiery Creek west of Beaufort in the north-west, the Great Dividing Range in the north, the Werribee River in the east and the coastline from the Werribee River to Painkalac Creek at Aireys Inlet to the south, the eastern boundary being located near to the towns of Cressy, Darlington and Skipton encompassing the modern-day districts of Geelong and Ballarat.

Three Wadawurrung clans are associated with the Anglesea region; the Bengalat balug associated with Indented Head, the Wadawurrung balug associated with the Barrabool Hills and Geelong but are also reported to have frequented and camped at Indented Head, around the Werribee River and on the Barwon River (Clark 1990, pp.330-331) and the Gerarlture balug associated with the area west of Lake Modewarre (Clark 1990, p.322).

Wadawurrung people have lived, hunted and foraged along the shores of Anglesea and the banks of the Anglesea River estuary for thousands of years. The archaeological record tells us that the Anglesea River estuary was regularly occupied by Wadawurrung people. There are a large number of stone artefact scatters located near to the Anglesea River Estuary as well as a smaller number of shell middens.

The Anglesea River Estuary would have been occupied by Wadawurrung people owing to its proximity to the coastline, freshwater and the abundance of plant and animal resources. William Buckley who lived and travelled with the Wadawurrung, particularly the Bengalat balug, across the Bellarine Peninsula and along the Surf Coast is known to have said that the Anglesea River was a good place to catch mullet. The Anglesea River Estuary would also have been of particular importance for its abundance of shellfish species.

The Wathaurung Aboriginal Corporation, trading as Wadawurrung, representing Wadawurrung Traditional Owners, are continuing the tradition of caring for country through their role as a Registered Aboriginal Party under the *Aboriginal Heritage Act 2006*.

The Wathaurung Aboriginal Corporation is appreciative of the opportunity provided by the Corangamite Catchment Management Authority to contribute to the Anglesea River Estuary Management Plan.

Commissioned by Corangamite CMA from Wathaurung Aboriginal Corporation. Please note that neither text or artwork can be reproduced without permission of the author or artist.

ANGLESEA RIVER

Medium: Acrylic on canvas
Artist: Albert Fagan
Tribe: Wadawurrung
Nation: Kulin

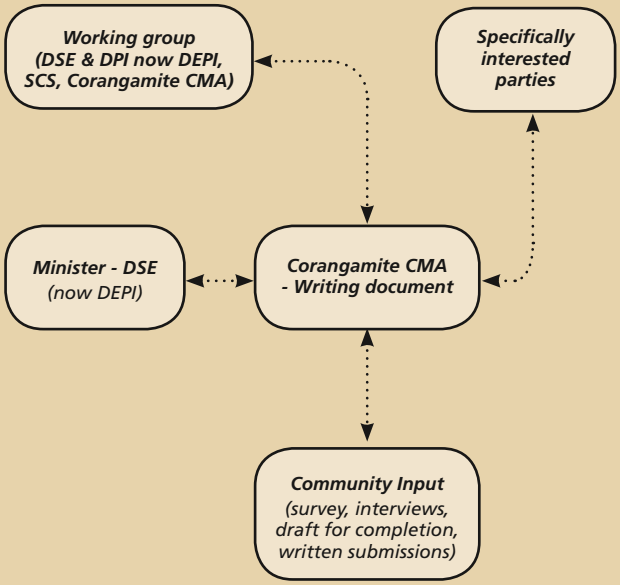
Albert Fagan

Development of this plan

This plan builds on the outcomes and actions listed in the Anglesea Estuary Management Plan (2004). The need to review that plan was identified by Surf Coast Shire, and was reinforced as an action by government, identified in the response to the Water Quality Review (Maher 2011). The development and implementation of any management plan requires substantial input from government agencies, the community and interest groups.

A working group comprising staff from the then Department of Sustainability and Environment, Surf Coast Shire, the then Department of Primary Industries (Fisheries Victoria) and Corangamite CMA met several times during the drafting of this plan to discuss progress, structure and content.

The draft plan was released in September 2012, and submissions and comments on the draft were accepted until December 2012. Many existing documents and plans were considered in the development of this plan, all relevant to ecosystem health and the social and economic assets of the estuary. Much of this requires substantial background reading and therefore this plan includes several appendices with further reading and a facility for fact sheets at the rear of the document. Management actions for implementation are tabulated for easy reference on page 12.



The process of drafting and completing the Estuary Management Plan involved interaction between the Corangamite CMA and various groups and individuals.

Consultation

The Anglesea community and visitors to the area have long been interested in the health of the estuary. This was highlighted by the large number of concerned people who attended public meetings, wrote to local media and contacted agencies following the water quality events of 2010-2011.

As a result of this, consultation for this plan aimed at allowing individuals, groups and agencies in the local area and beyond to share their thoughts about estuary management and values. This occurred through one-on-one interviews and an online survey.

Corangamite CMA staff were available during May and June 2012 for these interviews. Meeting times were advertised through local newspapers, public notice spaces and circulars to business houses and places of interest. Ten people arranged interviews.

The online survey consisted of 37 questions aimed at identifying community concerns, aspirations, knowledge and interests. There were 67 surveys completed. The draft plan was released for public comment and seven submissions were received. Feedback from the submissions was incorporated into the final plan.

PLANNING PROCESS

1. Identify values > Rate value
2. Identify threats > Rate threats
3. Assess risks to values via likelihood association and consequence
4. Develop management actions
5. Implement actions
6. Review success

Planning context - Asset based approach

The Victorian Government use an asset-based approach to natural resources management. An asset is a spatially defined component of the environment that provides values to the community e.g. a river reach, an estuary reach, an individual wetland or a wetland complex. An asset may provide social, environmental, cultural and economic values. Action planning to manage these assets, includes identifying any threats to the values, and following this, the risk of the threat affecting the values.

There is a complex mix of policy and planning relevant to the management of the Anglesea River estuary. As shown below, the *Water Act* and the *Catchment and Land Protection Act*, and *Coastal Management Act*, guide the management of waterways in Victoria. This legislation requires the development of regional strategies for waterways and coastal areas. In certain circumstances local plans may be required to address areas of interest. The Anglesea estuary is one such case, due to the complex water quality events of recent years. Local waterway planning allows for detailed community engagement and specific local planning. From a regional level, local planning is then well informed and aligned with both state level strategies and legislation.

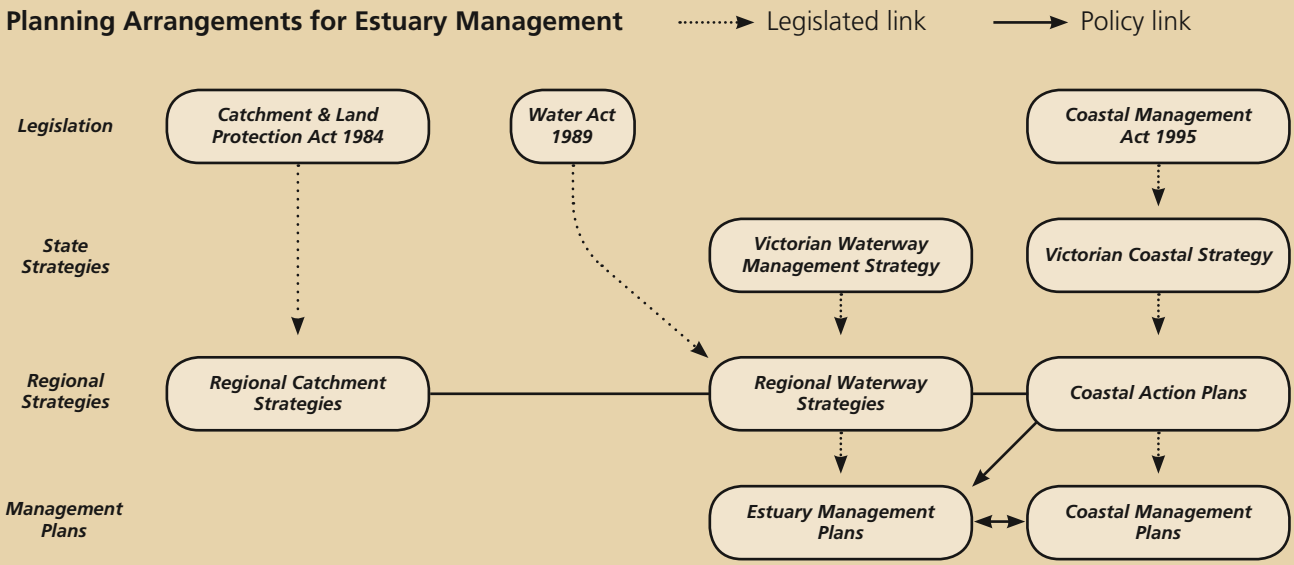
In addition to the planning outlined above, there are many other planning processes which can benefit and protect the health of the Anglesea estuary.

Local government planning through the township Structure Plan and the Anglesea Riverbank Masterplan, Emergency Management Plans (fire and flood), Western Coastal Board planning, such as the 2005 Estuaries Coastal Action Plan, GORCC Weed identification and management plan or Fisheries plans.

The Corangamite Regional Catchment Strategy (RCS) 2013-2019 is a region-wide planning framework for managing the region's land, water and biodiversity across public and private land. It is prepared under the provisions of the *Catchment and Land Protection Act (CaLP Act)*. The RCS provides 20-year objectives and six year actions at a broad level for the region's natural resources.

A draft Corangamite Waterway Strategy will be developed by early 2014. The Waterway Strategy is a sub strategy of the RCS and identifies actions to improve or maintain the health of waterways (rivers, estuaries and wetlands). The Corangamite Waterway Strategy will be developed under guidelines and policy developed through the Victorian Waterway Management Strategy.

Planning Arrangements for Estuary Management



Influencing: *Other relevant State legislation eg. Flora & Fauna Guarantee Act 1988, Environment Protection Act 1970. Other relevant State strategies eg. Victorian Biodiversity Strategy , SEPP (WoV).*

Source: Victorian Waterway Strategy (2013)

Values, threats and management actions

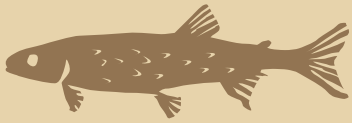
Management actions have been developed in consultation with agencies responsible for management of the Anglesea River estuary and consider comments received on the draft document. Many documents have been reviewed to ensure that the actions collate all previous work and discussions. Surveys of community interest have also helped shape the priorities.

The actions outlined have been devised to address threats impacting on the estuary's broader community values (social, economic or environmental).

Values of Anglesea River estuary

Anglesea, as a seaside holiday resort, is both a permanent home for residents and a great coastal escape for holiday makers, day visitors and those on weekends away. Tourism is the primary driver of the town and the seasonal use of the estuary reflects this, with peak use periods in the summer months. There is a variety of access points for recreational anglers, and on-water activities such as canoeing and kayaking, bank based activity such as walking, jogging and bike riding, and for those looking to enjoy the peaceful surrounding that the estuary offers. There is also a great deal of infrastructure to support activities, such as trails and paths, fishing platforms and jetties, public open space, toilet facilities, barbeques and weather shelters, a skate park and playgrounds.

The Department of Environment and Primary Industries (formerly DSE) has developed a tool for the collection of data on the values, threats and risks to Victoria's waterways, known as AVIRA. It is being applied for use during the development of regional Waterway Strategies such as the Corangamite Waterway Strategy. To assist with the development of the Anglesea EMP, AVIRA has been used. AVIRA collates data in categories and scores them according to a standard system. Each value and threat score may consider many measures.



Values for Anglesea have been entered into AVIRA, scored using a rating system ranging from 5 (very high value) to 1 (very low value). Of the twenty six values collated within AVIRA, some of the critical ones for Anglesea include (in no specific order): recreational fishing, non-motor boating, motor boating, camping, swimming, beside water activities (tracks), beside water activities (sightseeing), beside water activities (picnics and BBQs), landscape, community groups, use of flagship species.

Threats to values and risk assessment

Most comments and observations regarding the range of threats to Anglesea estuary relate to visual impact of the consequence of the threat. Threats such as litter, impacts to water quality like low pH level, stormwater pollution, nutrients from septics, sediment from building sites and unsealed roads and paths, loss of native vegetation and air pollution all cause concern. A method of capturing threats and how they impact on the identified values in Anglesea is undertaken via AVIRA.

To complete the risk assessment process in AVIRA the waterway threats to the 26 values identified for AVIRA are grouped under seven categories. For Anglesea, asterix indicates the highest risk threats e.g. greater than 4 out of 5.

1. Altered water regimes*
2. Altered physical form
3. Poor water quality
4. Acid sulfate soils*
5. Degraded habitats
6. Invasive flora and fauna*
7. Reduced connectivity*

Risk in AVIRA is measured in terms of likelihood and consequence and is the chance of something happening that will have an impact on the values of the Anglesea River estuary. This process has been considered when prioritising actions within the management action table. The highest risk threat in the Anglesea River estuary was identified as acid sulfate soils.

Key issues and objectives:

To incorporate key areas of community interest and values.

1. Amenity and recreation (including fishing) - Ensure management considers the high aspirations and goals of estuary users; management considers both passive and active users and maintains estuary health to allow recreational values to continue.
2. Biodiversity - Protect and enhance the natural features and living components of the estuary.
3. Information and knowledge - Continue to gather new information on the values and threats of the estuary and use this to inform management , share and utilise the best knowledge and practice in management.
4. Integrated management - Clear roles and responsibilities undertaken and clearly communicated.

Prioritising actions

Actions have been prioritised based on the criteria presented below:

1. Action already underway.
2. High priority due to high risk and high community interest/concern/involvement identified through consultation.
3. Unplanned or unbudgeted item(s) identified within the risk assessment and not identified within the community consultation as of highest concern.
4. Unbudgeted or unplanned items of lowest priority, low cost-benefit ratio, or actions resulting from lower percentage of community interest.*

**These actions were not included in the plan.*

Implementation, monitoring, evaluation and reporting of the EMP

It is the intention of those present at the working group developing this plan that an Implementation Committee be established to meet twice annually and develop a clear communication plan. The meetings will consider the actions within the management action table and report on the progress of the actions.

Conveying progress and information to the community is considered of the highest importance for the plan to be successful and is likely through avenues selected as desirable within the survey.

The progress of actions within the plan will be monitored against the timeline as per the management action table. Completed actions will be communicated to the community as deemed necessary by the Implementation Committee.

MANAGEMENT ACTIONS TABLE

Management actions have been developed with management agencies responsible for managing the Anglesea River estuary. Many documents have been reviewed to ensure the actions collate all previous work. Discussions and a survey of community interest have also shaped the priorities.

OPEN HERE →

	Action	Detail of Action	Who leads implementation	Partners	When to complete	Success measure and outputs
Priority 1	1	Develop an implementation committee to oversee plan implementation and report on plan progress annually.	CCMA	All	2013	Relevant agencies appoint representative
	2	Manage the estuary mouth opening using a risk based approach which protects community values- social, economic and environmental.	CCMA	SCS	Ongoing	EEMSS is used at Anglesea
	3	Develop an estuary mouth opening management plan and ensure that the plan is applied by agencies and available to the community.	CCMA	SCS, DEPI, Vic Roads	2013	Plan complete and adopted by all within Committee of Implementation
	4	Continue the Corangamite EstuaryWatch program in the Anglesea River catchment.	CCMA	All	Ongoing	Data to be stored and available to public
	5	Construct structural habitat in priority habitat areas which support fish species reliant on this habitat component, particularly Black Bream.	CCMA	DEPI, ARI	2014	Survey fish presence around structures
	6	Continue to actively encourage Anglesea River visitors and wider community to use the appropriate rubbish and recycling bins to reduce litter within the river and environs.	SCS, GORCC	EPA	Ongoing	Clean and healthy river and environs
	7	Finalise potential remediation options resulting from the Maher report for periods of acidity.	CCMA	DEPI	2013	Options ranked and awaiting volume data
	8	Undertake study to identify sources of acid within the estuary and (more detail), i.e. map Potential and Actual Acid Sulphate Soils (PASS and ASS and pursue inclusion of this data in the planning scheme through an overlay.	DEPI	SCS, CCMA	2015	Management plan available for planners
Priority 2	9	Through the Anglesea Riverbank Precinct Masterplan, continue to identify and implement appropriate access points and pathways to and along the river and estuary with suitable infrastructure/ signage to guide movement.	SCS		2018 ongoing	
	10	Implement the new Victorian Government Public Land Tour Operator and Activity Provider Licence system.	SCS	DEPI	2013	
	11	Develop an annual communication plan for the Anglesea EMP.	CCMA	Implementation Committee	2013	Clarity within community as to management roles and responsibilities
	12	Detail key agency management responsibilities and contacts for the Anglesea River and its estuary.	CCMA/SCS	All	2013	Clarity within community as to management roles and responsibilities
	13	Put in place land subject to inundation and floodway overlays which consider inundation associated with estuary mouth closures and storm surges, as well as catchment based events.	CCMA		Ongoing	Reduced risk to infrastructure
	14	Continue to develop and use the best available information relating to climate change and sea level rise and its impact on coastal vulnerability.	DEPI	SCS, GORCC, CCMA	Ongoing	Maps and overlays are available to Shire Planners and CCMA floodplain managers
	15	Implement the new Guidelines for Coastal Catchment Management Authorities: assessing development in relation to sea level rise.	CCMA, DEPI	SCS	2014/15	Overlays are within the planning scheme
	16	Review land subject to inundation layers (LSIOs) and flood overlays as significant information on climate change and sea level rise becomes available.	CCMA, SCS	DEPI	Ongoing	Map produced shows assets, heights and tide/ flood levels
	17	Investigate opportunities to upgrade infrastructure, including Great Ocean Road, Bingley Parade, River Reserve Road and Coogoorah Park pathways to remove the need to artificially open the Anglesea River estuary mouth in response to flooding of these assets, and to minimise damage associated with high stormwater flows or storm surge.	VicRoads SCS, CCMA	DEPI	2015	Map produced shows assets, heights and tide/ flood levels
	18	Continue to monitor and store estuary water quality conditions for a continuous long term record in accordance with agreed roles and responsibilities and/or obligations.	CCMA	SCS, EPA	Ongoing	Data to be stored and accessible to managers
	19	Ensure Fish Death Response Plan, Blue Green Algal Response Plan and Municipal Emergency Management Plan (including Flood Plan) are up to date and reviewed annually.	EPA, SCS, VicRoads, SES	CCMA	Ongoing	Documents complete and managed by SCS
	20	Continue to implement a range of best management practices, to protect associated Ecological Vegetation Classes (EVCs), including but not limited to, Estuarine Wetland, Coastal Alkaline Scrub and Riparian Scrub / Swampy Riparian Woodland Complex. Aim to maintain or increase extent and maintain or improve the condition of EVCs associated with the estuary with the following key methods: • Existing indigenous vegetation should be protected, and where required, fencing or other methods to secure their health may be required • Vegetation in riparian zones to be protected and replaced as required • Protect and enhance remnant stands of Melaleuca lanceolata (Moonah), particularly within Fairyland and isolated remnant areas west of the Anglesea River downstream of Great Ocean Road • Continue ongoing programs to control blackberry, sallow wattle hybrid, boneseed, broom and mirror bush, focussing on areas that threaten high value vegetation as a priority.	Land manager (ie GORCC, SCS, PV, DEPI)	CCMA	Ongoing	Net habitat stability or gains within period of plan
	21	Review the Surf Coast Shire Stormwater Management Plan for the Anglesea estuary, and or develop a specific stormwater management strategy to reduce sediments and pollutants from the local urban and industrial sources.	SCS	CCMA	2015	Reduced point source sediment loads entering the river
	22	Develop education and interpretation material on the sources of acid within the catchment; complexity of estuarine water chemistry; potential impacts of climate change; estuary function; and estuary mouth opening processes.	CCMA	SCS, DEPI	2014	Mapping, posters, interpretive material and the like
	23	Develop an acid sulfate soil management plan for the Anglesea estuary.	DEPI	SCS, CCMA	2015	Management plan available for planners
	24	Seek funding opportunities to improve vegetation cover of priority areas within Coogoorah Park which are affected by Active Acid Sulfate Soils.	SCS	CCMA DEPI	2008	Improvement in vegetation cover
	25	Report on estuary condition in 2019 using the Index of Estuary Condition.	CCMA	All	2019	
Priority 3	26	Review and update the existing Anglesea Riverbank Precinct Masterplan Stage 3 (Wray St to Coal Mine Rd, west and east side of River including Coogoorah Park.	SCS		2015	
	27	Report on water quality annually using data collected from the various monitoring sources.	CCMA		2015	Trial use of IEC measures for Anglesea in 2015
	28	Install flow meters within tributaries to enhance knowledge of catchment flows and determine the role of water inputs to estuarine condition.	CCMA		2014	Able to quantify water volumes
	29	Repeat survey for EVCs in 2018 as part of continual monitoring of estuary vegetation across the region.	CCMA	SCS, GORCC, DEPI	2018	Mapping and reporting completed and layers updated
	30	Investigate cost effective ways to stabilise previously walled river bank sections downstream of Great Ocean road. Continue to stabilise river banks where erosion or structural collapse risks occur.	Land manager	CCMA		Not specified
	31	Consider remediation plans for Active Acid Sulfate Soils identified in the Acid Sulphate Soil Management Plan, at priority locations containing high community values.	DEPI	SCS, CCMA	Ongoing	On site-by-site basis
	32	Identify opportunities to work with research institutions to address key knowledge gaps identified in Maher report, including: • A more detailed assessment to determine the relative contributions of trace metals during high and low flows • Research on the flocculation process within the estuary • Consider the settling of metals and the risk of boron to Anglesea River freshwater ecosystems downstream of the effluent discharge point • The measurement of flow and trace metals concentrations above, below and at the Alcoa discharge.	CCMA, DEPI	Research institutions, SCS	Ongoing	Various relating to water quality improvements and integrated management

Estuarine processes and characteristics

Landscape evolution and geological history as part of Otway Coast

The factors contributing to physical change and landscape evolution are important concepts to grasp, they establish estuary functions and background to the complex interrelations between biotic and abiotic components, and provide clues as to how Anglesea River came to look the way it does today. Much of this is on a larger scale both physically and temporally.

The things you would see today at Anglesea River include the current physical characteristics like the shape and form of the estuary, the bottom contours (bathymetry), drainage and accumulated sediments, near shore marine processes and the state of the estuary mouth, and the structures and constructed components of the river.

The geological history of the Anglesea River catchment as part of the Otway Coast and the current geomorphology are significant when considering the current day catchment chemistry. Much of the material available for the evolution of the area is quite broad scale. However, summaries offer further detail relative to Anglesea in recent thesis work by Tutt 2008, and Pope 2002, water quality review by Maher 2011 and in *Geology Victoria*. There is also a lot of information sources online, particularly for those interested in paleontology.

There are additional appendices and fact sheets included in this plan that go into more detail. For further detail explore some of the referenced materials, visit websites or ask staff at one of the management agencies.

Near shore marine processes. Reference: Anglesea River estuary mouth dynamics (2010), Water Technology

Physical characteristics, catchment and estuary

The Anglesea River estuary is 2.6km long and a variable 110 metres wide near the mouth, narrowing to 40 metres one kilometre upstream and approximately 15 metres in the upper reaches just upstream of Coal Mine Road. Recent surveys estimate a total surface area of 15 hectares when the banks are full, which is tiny in comparison with interstate estuaries in NSW, rivers such as Myall, Clarence, Hawkesbury, and Lake Macquarie, Jervis and Batemans Bay, which are all well over 10,000 hectares (Roper *et al.* 2010). Regionally however, with the exception of the Barwon River, there are a lot of very small estuaries similar to Anglesea on the Victorian coast between Cape Otway and Queenscliff.

The Anglesea estuary broadly exhibits the salt wedge character trait familiar to most of Victoria's intermittently open or closed estuaries with stratification more measurable upstream of the Great Ocean Road. Freshwater inputs and wind driven mixing result in a less marked stratification than other systems. The river, when open, flows out to sea across a flat extent of beach that appears, anecdotally and through survey, to have extended somewhat since the 1960s.

Upstream of the estuarine extent are extensive low lying lands with a total catchment area of 885 hectares encompassing Marshy and Salt creeks. Much of the catchment is Crown land managed as the Anglesea Heath Flora and Fauna Reserve, including the Alcoa open cut coal mine and power station. The open cut mine has resulted in the lowest section of Salt Creek being diverted to a purpose built trapezoidal channel.

Hydraulic modelling-creating a virtual estuary

The condition of the estuary entrance is one of the most critical variables controlling the hydrodynamics and broader environmental processes of the estuary (Water Technology 2010). The opening, and closure, of the estuary also provides very challenging management situations, the most pressing the inundation of land and roads.

The six key aspects implementing river mouth dynamics for Anglesea are:

1. The net eastward longshore transport of sand which traps sand in the mouth of the river (Water Technology 2010; Pope 2006; Nelson 1981) is the dominant process in shaping the estuary mouth.

2. A typical December/January wave climate yielded an average longshore sand transport rate in the order of 183 m^3/day (equivalent to 67,000 m^3/year) (Water Technology 2011).

3. The influence of the river flows is not significant, resulting in regular closures of the river mouth. After the river opens it can close in remarkably short periods of time (Water Technology 2010).

4. Research into closure/opening ratios has shown: closed for approximately 44% of the time, and tidal for the 27%. For the remaining 29% of the duration of the study period it was perched i.e. not quite open, but not really closed (Pope 2006).

5. Flooding can occur in low lying areas when the estuary is either closed or open, via heavy rain fall, high tides and large seas.

6. There is no trigger height for opening the river, however threats to public and private assets in the system, like inundation of the Great Ocean Road, has historically lead to openings when water levels exceed 1.7m AHD.

To assist estuary management, a detailed three dimensional model (MIKE3 FM) was created in 2010 (Water Technology 2010) allowing the ability to predict changes in salinity and mixing of water during river openings of different depths. To populate the model an estuary bathymetry survey was completed to build a terrain model. More detail on bathymetry and modelling is in a fact sheet in the back of this document.

The model has the ability to predict the effects of stratification between freshwater inflows and sea water, further allowing representation of either an artificial or natural opening of the estuary entrance. After the model was completed the Corangamite CMA required the model to predict the salinity response of the estuary to openings of 0.75, 0 and -1 metres AHD.

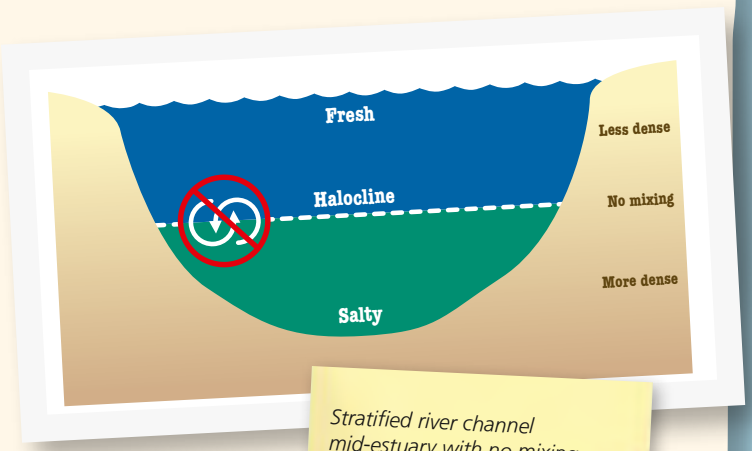
The hydraulic model simulated the 0m and -1m scenarios over a three-day period (six tidal cycles) and the shallower 0.75m AHD scenario over a longer seven day period (14 tidal cycles) to determine the extent of saline intrusion into the estuary and the mixing of saline waters through the estuary.

In addition to the artificial opening scenarios, the model was asked to provide an alteration to the hydrology of the river by providing sea water to the bottom of the river channel, pumping sea water into the estuary in the vicinity of the Great Ocean Road Bridge over a period of approximately three weeks. At a rate of 100 litres per second, the salinity increased gradually until after three weeks salinity ranged from 15 to 18 parts per thousand.

Stratified estuary

Slight density variation between sea and freshwater allows many estuaries to develop clearly separate surface and bottom waters based upon salinity differences. High acidic freshwater inflow may rest above the saltier bottom water without mixing.

These two diagrams show stratification of the estuary. Many estuaries develop clearly separate surface and bottom waters based upon slight density variations between sea and freshwater. This is shown as a long section (below) and a cross section (right).

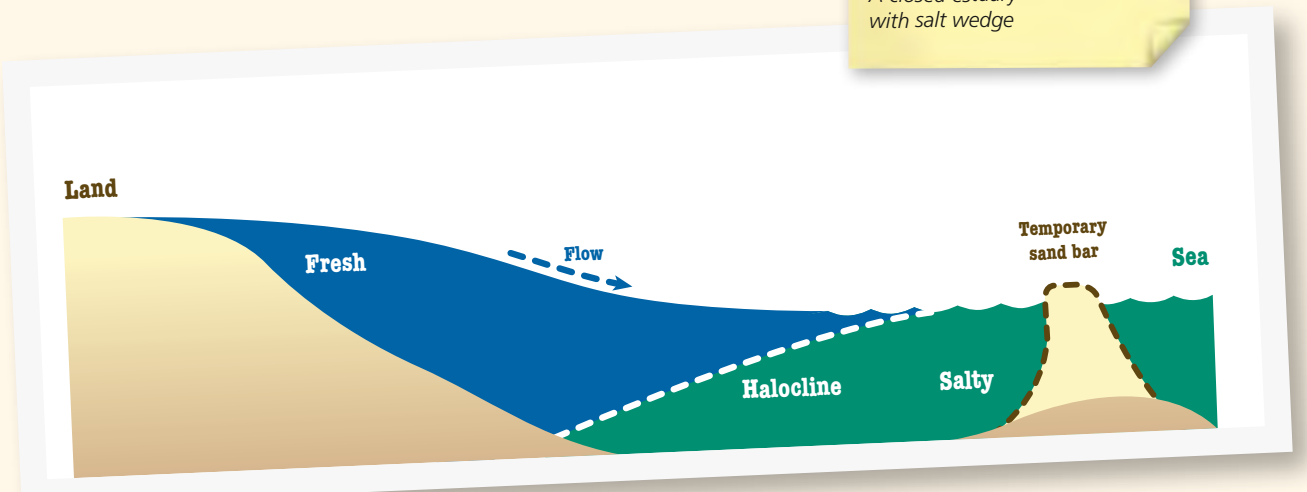


Stratified river channel mid-estuary with no mixing

Without significant mixing these water bodies can exhibit very different physical and chemical properties both when the estuary is either closed or open to the sea. Due to the wind driven mixing and shallow lagoon downstream of the Great Ocean road, the stratification in Anglesea is mostly in the upper estuary.

During periods of highly acidic freshwater streamflow, the two separate bodies of water may not only alter in salinity, but also pH. The more alkaline sea water can often buffer lower pH streamflow, but only on the boundary layer between the two layers, or where they are mixed together. This can produce a bright blue colour as a flocculant forms (detailed in Appendix 3, page 32).

A closed estuary with salt wedge



Measuring pH at the estuary mouth

Gauge board surveyed to AHD on the northern side of the Great Ocean Road

The Estuary Entrance Management Support System EEMSS

The EEMSS provides information to assist estuary managers on decision making in regard to estuary opening. Information on estuary assets (Ecological, Social and Economic) are stored in the EEMSS. A scoring system of asset value and threat level at various water heights provides considerations on why the estuary should or should not be opened at a given height. Water quality monitoring can provide additional information to assist in decision making. The EEMSS does not provide the decision, merely information on the impact of high and low water levels.

The EEMSS database was sufficiently populated with data through detailed digital terrain models, field measurements, survey, Surf Coast Shire records and anecdotal accounts of previous water levels. A community workshop was conducted in 2009 to both ground truth the data and explain the EEMSS system and how it is used to assist decision making.

Many of the infrastructure and structural assets are shown in the map in the fact sheets along with asset heights in the estuary.

Installation of a constant 24 hour water quality logger on the river bank within the estuary

Water quality and conditioning reporting

Several water quality parameters are regularly measured in the Anglesea River estuary to give an indication of the water quality. A brief summary is provided below, including extra measures not normally included in a regular suite. For more information on quality parameters and what they reveal the Interpreting Estuary Health Data-EstuaryWatch Victoria (Corangamite CMA 2012) can be downloaded from the Corangamite CMA website.

Typical or regular parameters	Additional parameters not often measured
• depth	• flow
• temperature	• colour
• dissolved oxygen	• redox
• turbidity	• heavy (or other) metals
• salinity and/or conductivity	• nutrients (ie N and P compounds, chlorophyll A)
• pH	• sediment (size/type)

NB: EstuaryWatch members have been actively monitoring Anglesea River since 2007.
See glossary for explanation of terms.

As is their nature, being the end point of the catchment, estuaries tend to accumulate metals within their sediments. This occurs at Anglesea, and most other estuaries in Victoria. Though not tested routinely in the Anglesea estuary, there is clear evidence of high concentrations of aluminium, iron, manganese and associated trace elements particularly after rainfall, as well as evidence of aluminium and iron floccating (building up) on seagrasses (Maher 2011). Maher states that this is expected, with flows from acidic soils with underlying coal deposits, acid sulphate soils and marshes rich in these elements. Some of these metals do reside within estuarine sediments and are likely in forms not readily soluble or biologically available.

During the review on water quality in Anglesea River, Maher stated that trace metals in the estuary were likely to be sourced either naturally, or from either activities associated with coal mining and power generation or storm water runoff from the Anglesea township.

The impacts on aquatic life of metals in solution and suspended in the estuary water column are discussed in several studies (Maher 2011, Pope 2011, Sharley *et al.* 2012). All evidence suggests Aluminium becomes more toxic to fish as pH decreases and high concentrations of aluminium in fish tissues, particularly the gills, is a potential cause of fish death events in the Anglesea River estuary. Sharley goes further to detail impacts of acid on the fish, sea grass and macroinvertebrates of Anglesea River and this has been included as Appendix 4.

Rainfall impacts water quality in the estuary. Rainfall information for Anglesea can be found on the Bureau of Meterology website which includes forecasts, recorded rainfall and historical rainfall data. There are current condition from Aireys Inlet and the historical data is from Aireys Inlet, Wensleydale and Winchelsea. Apart from rainfall, Alcoa's discharge of approximately 4ML/day has a significant influence on the flow dynamics of the Anglesea River estuary. Alcoa has the only EPA licensed discharge in the catchment. The discharge is a controlled release from various uses within the operation and must meet stringent water quality limits set within their EPA licence.

Rainfall within the Anglesea catchment is the main factor which determines whether or not an acid flush occurs, i.e. rain in the catchment creates, collects and transports acid (Maher 2011). The general pattern of major fish deaths is for dry periods followed by flushing rains. Smaller fish death events, such as that of June 2012 (involving Flounder and Marble Fish) occur despite not having a dry period, but did not generate the concentration of acid of the event which followed the prolonged dry spell. EPA and Fisheries Victoria records suggest similar small fish death incidents reported over the last 10 years.

Maher describes the process of acid formation to stream flow as follows:

'Small and steady rain of 5mm per day in the week before estuary acidification (fish deaths 13 September 2010) may have been optimal for infiltration and are likely to have created a slow flush of acidic waters from the vadose zone (underground flow) and surface water aquifers to the streams and creeks, and ultimately into the estuary.'

Further technical information regarding the formation of acid is available in Appendix 3.

Condition reporting

It is important to have the ability to assess water quality against a standard set(s) of data in order to gauge condition. As all estuaries tend to behave quite differently and can have extreme variability in multiple facets, a range of measures have been developed and can be applied to Anglesea River.

The index of estuary condition is designed to complement the existing Index of Stream Condition (ISC) for estuaries, providing a consistent statewide assessment every six years of the environmental condition of estuaries. IEC has six themes water quality, physical form, hydrology, sediment, flora and fauna.

This will better enable estuarine condition of Anglesea to be reported at regional, state and national levels, prioritisation of resource allocation, and strategic evaluation of management interventions in estuaries.

Given that the IEC is essentially a snap shot of condition (with some parameters perhaps not being taken at the same time) it is important to have long term datasets to allow estuary conditions to be established under different hydrological states. The EstuaryWatch program collect data allowing comparison against IEC in regard to mouth condition monitoring and depth profiling.

The EPA water quality guidelines provide a framework and tools for assessing the environmental condition of riverine estuaries. The guideline values provided describe the condition or reference quality estuaries and these can be used as an indicator for assessment of other estuaries.

Current condition

The 2004 Index of Stream Condition (ISC) establishes the Anglesea River in very good condition. This is for the waterway reaches above the estuary within the freshwater reaches of Marshy and Salt creeks.

Anglesea estuary is predominately brackish-never as saline as sea water, but never entirely fresh. There is generally a salt wedge beyond the Great Ocean Road bridge with the water column exhibiting variable salinity depending on the volume of stream flow and the extent to which tides, winds and waves can push sea water into the estuary. Wind driven mixing and the shallow waters downstream of the bridge tend to prevent a salt wedge forming.

The pH varies quite a bit, and when stream flow from the mid catchment persists, can be below six for extended periods. Turbidity can vary too, with extremely clear water often an indicator of elevated acidity, and aqua discolouration when acid water mixes with saline water. High temperatures have been recorded in deeper parts of the estuary.

Streamside zone vegetation is quite good considering the level of use within these areas, and many projects have been completed over previous decades to protect and enhance remnant and revegetated sites.

Recent tests suggest, as is normal with estuaries, elevated levels of some metals are present within the sediment of the Anglesea River estuary. These are both catchment derived and as a result of human activities in the township and beyond.

Catchment vegetation is in varied condition. Breakfast Creek (far left), Anglesea River above Coal Mine Road (middle) and Salt Marsh in lower estuary (above)

Estuarine values

Socio-Economic values

Tourism

The primary role of Anglesea is as a seaside holiday resort and home for permanent residents. Tourism is the primary economic driver of the town (SCS structure plan 2012). The retail and hospitality industry is challenged by the highly seasonal nature of visitation and expenditure, with many businesses struggling to survive in the quieter months. More details are available regarding actions and planning for tourism and growth in the structure plan.

Recreation, amenity and education

Anglesea is a hotspot for both on and near water activity due to the extensive path networks and high variety of access points. Boating and canoeing are very popular and recreation camps and environmental education activities make excellent use of the estuary. Passive recreation activities are also very popular, as are short stay day visitors and picnickers. Many of the responses during the formal engagement for this plan remarked that the amenity of the river is the main attractant.

Recreational fishing

There is a high variety of fishing experiences along the Great Ocean Road and the Anglesea River estuary is a favourite both with highly skilled catch-and-release Bream fishers and children looking for easy access points. Generally people target bream, yellow eyed mullet, salmon, flounder or even mulloway. Fishing forums give a great insight into the use of Anglesea for fishing, with lots of posts regarding the near shore marine fishing too.

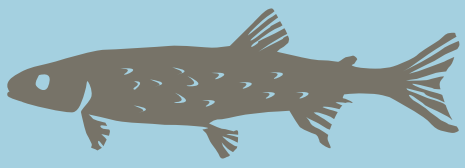
Facilities at Anglesea provide great access for all abilities, but there are limited facilities for cleaning fish or launching boats (as motor boating on the river is restricted).

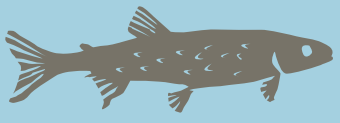
For more information on fish examine the fact sheet.

Infrastructure within the estuary

Many and varied infrastructure appears within the estuary landscape. This includes a variety of public and private infrastructure such as public open space, playgrounds, toilets, car parks and roads, shared trails for walking and riding, picnic tables, skate park, jetties, fishing platforms and boat ramps, boat sheds, houses, retail premises, and community buildings. Public land managers manage the majority of these assets along with the large crown land leased occupied by the Anglesea Foreshore Caravan Park. The land ownership is represented by the map on page 4.

In the back of this plan is a fold out map showing landscape features. The map has lines linking modelled areas of similar height above sea level to give an indication of terrain. Similar map are used to plan to ensure assets are not constructed in sites subject to inundation.





Birds

While populating the EEMSS database in 2010 the Corangamite CMA commissioned a survey of the region's estuaries, where bird occurrence data could assist management. The purpose was "to obtain information on the distribution and abundance of birds, focussing on waterbirds and other estuarine specialists, in order to make an assessment of bird use in the context of estuary entrance openings" (Hansen 2010), with species classified into lists according to those pre-determined in the EEMSS. Surveys were conducted in Anglesea between 18 and 22 July 2010. Anglesea was surveyed over half a day from a vessel.

The method of survey for Anglesea was as follows:

- estuary broken in lower, middle and upper
- bird counts of the channel and riparian zone were conducted by two observers, either from a vessel or on foot, by traversing the estuary from the lower reaches to the upper reaches
- sections were divided into sequential 200 metre transects (recorded using a hand held GPS unit) and birds were counted separately in each transect
- all bird species were recorded, including waterbirds, riparian passerines, raptors, parrots and introduced species
- the only species not recorded during surveys were seabirds e.g. Australasian Gannet, shearwaters and albatross.

Due to the seasonality of the survey, many species were absent, particularly trans-equatorial migratory waders. Waders are a specialist group of waterbirds that use intertidal areas of south-eastern Australia during their non-breeding season (Bamford *et al.* 2008). Other notable absences were seasonally-transient species like Hardhead, Pink-eared duck, Whiskered Tern and Australian Reed-Warbler. Some resident shorebird species like oyster catchers were under-represented. There was also a notable absence of a number of waterbirds, most likely due to inland water availability during the winter months, which attracts birds away from the coast. Surveys conducted during mid-late summer would be informative in determining waterbird habitat use in these estuaries.

Rare and threatened species that were absent were Orange-bellied Parrot, Ground Parrot, Freckled Duck and Australian Painted Snipe. Their absence from surveys is more likely to be due to their general rarity which is reflected in their national conservation status rather than a false absence failure to detect them when they are actually present.

Superb Wren

Rufous Bristle Bird

Australian Painted Snipe

Seagrass

Seagrass cover in Victoria only accounts for 0.2% of the national seagrass extent (Kirkman 1997), and much of this occurs in large bays such as Westernport, Port Phillip and Corner Inlet. That suggests that the ecosystem service provided by seagrass in smaller location such as Anglesea are critical in supporting a regionally diverse estuarine aquatic community.

The extensive seagrass beds on the eastern and western margins of the estuary are critical for regional ecosystem health and play some role in the long term sustainability of Australia's coastal zone. Nationally, meadows contribute to cycling of nutrients, baffling of flow and sediments, rhizomes stabilise sediments, provide food sources to grazers and herbivores and are the nursery grounds for recreational and commercial fisheries (1997).

Seagrass in the lower estuary, downstream of the Great Ocean road

Many young Bream are found in the Anglesea River. Seagrass beds are highly valued by estuary managers and are always considered when artificial estuary openings are requested. Threats to seagrass include desiccation from prolonged low water levels, the scour associated with openings and potentially high flow rates that may impact on area covered by seagrass (sea bathymetry fact sheet for land areas affected by deep openings).

Fish species

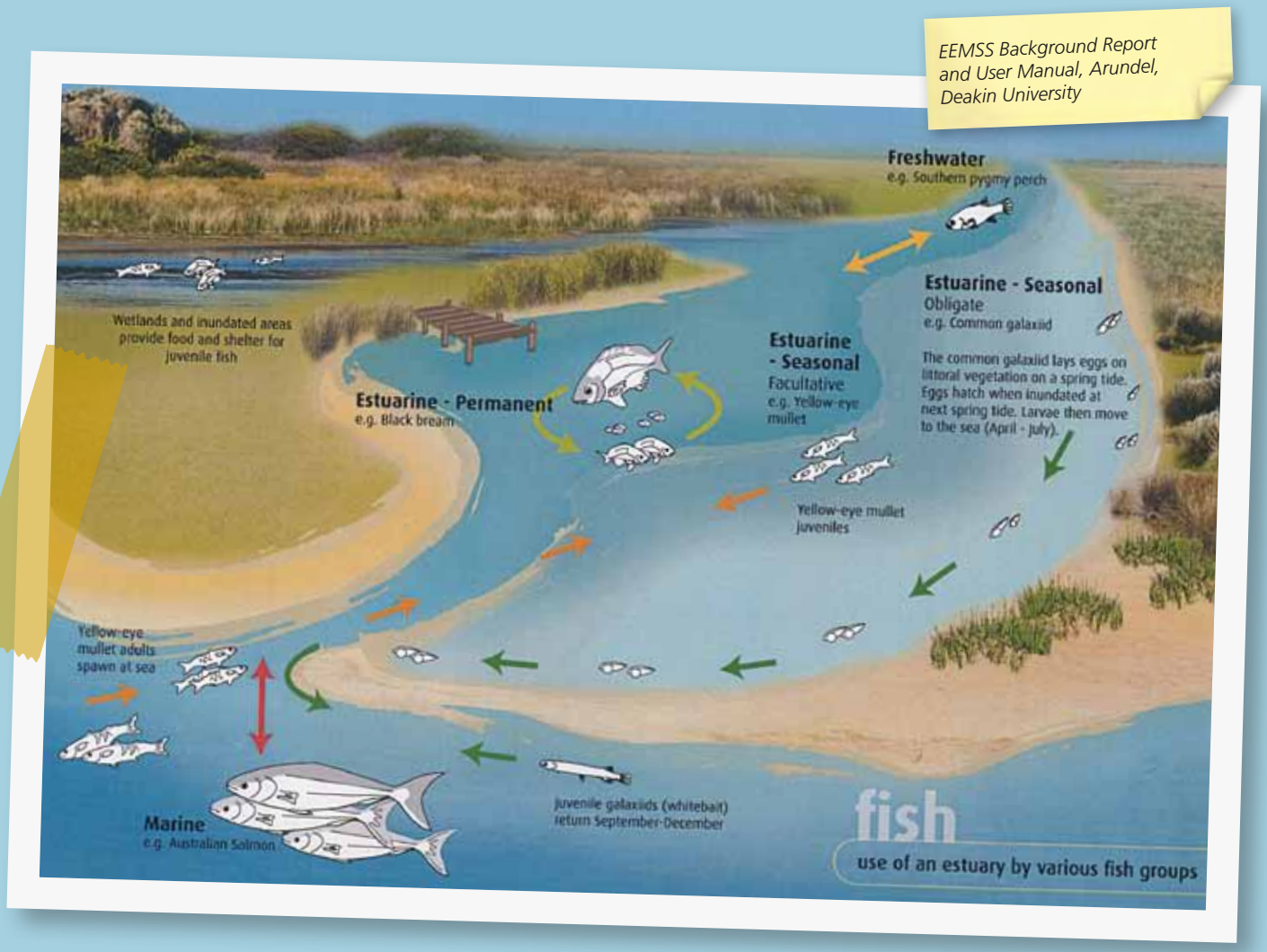
Fish are managed throughout Victoria for various reasons. Broadly speaking the Victorian guide to native fish management prioritises the following:

- Freshwater and estuarine species recognised as threatened (listed under *EPBC Act*, *FFG Act,* or recognised under the DEPI Advisory Lists (DEPI 2007a, 2008a)
- Freshwater and estuarine species that are targeted by recreational fishers (information derived from DEPI resources and the Scientific Advisory Panel) or are of cultural significance
- Remaining freshwater species for which we have good knowledge.

Beyond these three priority groups, estuarine fish are prioritised according to their level of dependence on estuarine environments with greater emphasis placed on species heavily reliant on estuarine environments to complete life cycles. Native fish that occur in estuaries are divided into three groups:

- Freshwater species
- Estuarine species usually further divided into permanent or seasonal
- Marine stragglers visitors to the estuary environments.

Black Bream



Large numbers of dead fish have been noted, observed and recorded in the Anglesea River in periodic events. Fish survey information for Anglesea is up to date and is included in the fact sheet. There have been four surveys since the events of Sept-Oct 2010, where low fish numbers were recorded. The results show high species richness, higher than any other estuary of the Corangamite region during the 2011 Index of Estuary Condition survey. The wide variety of fish within the estuary and give a good indication of the recovery of the system to acidic water flushes and the resilience of the aquatic life within the Anglesea River estuary.

Other terrestrial fauna or aquatic fauna

Victorian Government records identify 16 species protected within the *Victorian Flora and Fauna Guarantee Act* as Near Threatened or Vulnerable known to occur at Anglesea. Of these 15 were birds and one mammal, the Swamp Antechinus , which was observed on the Southern side of the Great Ocean Road, an area not necessarily intimately associated with the estuary.

Other observations of the non-listed species noted in Water Technology 2010 was the lack of amphibians, with only the Common Froglet recorded. Multiple targeted amphibian searches have been undertaken returning no significant findings.

Vegetation

Ecological Vegetation Classes have been used to map and record vegetation for Anglesea River estuary. This process is consistent across Victoria.

An Ecological Vegetation Class (EVC) is a component of a vegetation classification system, grouping vegetation communities based on floristic, structural, and ecological features.

Individual EVCs within a bioregion can be assigned a conservation status or significance, to indicate its degree of alteration since European settlement in Australia. To assist with the assessment of an EVC within a bioregion, benchmarks have been established to ensure that assessments are carried out in a standard fashion across Victoria.

Information about Anglesea vegetation is sourced from studies in 2009/10 (Cook and Osler) and the Great Ocean Road Coast Committee Native Vegetation and Weed Action Plan.

Twelve EVCs were used to describe the estuary vegetation at Anglesea River.

They are:

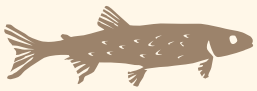
- Brackish Sedgeland
- Coastal Alkaline Scrub
- Coastal Dune Scrub
- Estuarine Flats Grassland
- Estuarine Reed Bed
- Estuarine Scrub
- Estuarine Wetland
- Heathy Woodland
- Saline Aquatic Meadow
- Swamp Scrub
- Swampy Woodland
- Wet Saltmarsh Herbland
- Coastal Tussock Grassland
- Coastal Tussock Grassland/Estuarine Flats Mosaic.

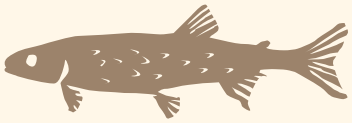
The condition was generally recorded as poor reflecting a high level of disturbance with scores showed in the table within the attached fact sheet.

Lawrencia spicata (Salt Lawrencia) is known to occur within the estuary (ie below 2.5m AHD). It is the only species listed as rare or threatened. Fairyland area contains a regionally significant stand of estuarine Swampy Woodland which is dominated by an over storey of the iconic Moonah (Melalueca lancealata) and contains Salt Marsh. All possible means should be taken to protect and enhance the condition of this area to conserve its unique value.

During the mapping of Anglesea in 2009, ARI were asked to assess the reasons and implications of dieback in the Coogoorah Park precinct as per action Action 9 in Objective 2 of the 2004 Estuary Management Plan. There was inconclusive evidence as to the cause of the dieback but it appears to be either the result of water logging (pers. comm. Matt White 2009) or acid sulfate soils (pers. comm. Doug Crawford DPI 2011). The notion of water logging is sound and may be reflective of the changing hydrology since the creation of the channel system in the 1980s. Surf Coast Shire staff also report that estuary opening frequency has reduced and the duration of high EWLs has increased since 2001 when permitting of the openings became more strict.

List of references and further reading





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Glossary

Acid Water with a pH lower than 7.

AHD Australian Height Datum is the standard measure for height with zero being a mean sea level.

Alkaline Water with a pH higher than 7.

Anaerobic Living or active in an environment where oxygen is absent.

Anoxic Areas of marine or freshwater that are depleted of dissolved oxygen.

Asset Values Identification and Risk Assessment (AVIRA) A spatial tool for assessing the values and threats to river reaches, wetlands and estuaries.

Bathymetry The terrain beneath the water's surface, which could be marine, riverine or wetland.

Berm The sand accumulated at the mouth of a waterway (river or creek).

Catchment An extent of land where water from precipitation drains into a of water way.

Dissolved oxygen (DO) Oxygen dissolved in water. Usually measured in milligrams per litre (mg/l or ppm) but can also be presented as per cent saturation.

Drought prolonged A place within an ecosystem that provides refuge during dry times. Estuaries as the end point of river systems often still have water in times of drought.

Electrical conductivity (EC) A measure of how well a material accommodates the transport of electrical charge. EC is used to estimate the concentration of dissolved salts.

Estuary Semi-enclosed body of water where salt from the sea mixes with freshwater flowing from the land.

Estuary Entrance Management Support System (EEMSS) A decision support database tool to inform artificial estuary mouth openings by considering the risks to social, environmental and economic assets or values.

EVC An Ecological Vegetation Class (EVC) is a component of a vegetation classification system, grouping vegetation communities based on floristic, structural, and ecological features.

EWL The Estuary Water Level refers to the surface height of water within the estuary.

Flocculation The process where a soluble metal leaves solution and forms a solid. This is relevant to the Aluminium Oxyhydroxide which dissolves in acidic water with salinity lower than 8 ppt.

Freshwater Looking at estuaries, water with a low salinity. Not necessarily potable or clear.

Future Coasts Victorian Government program investigating the impact of climatic variability on Victoria's coastline through modelling and mapping.

Halocline An area of transition from lower to higher salinity with increasing depth.

Hydraulic Operated by, moved by, or employing water or other liquids in motion. Studying the hydraulics of the estuary will explain where the water moves and the way it does within the estuary.

Hydrodynamics The branch of science concerned with the hydraulic properties of water and in this context, how the water within the estuary moves based upon the physical boundaries within the system such as bank steepness and roughness, depth (bathymetry) and bank width.

Hydroxide Forms when water splits into two radicals. The hydroxide has a single negative charge and is written OH- (the other part of water is the single positive charge Hydrogen H+).

Index of Stream condition (ISC) Standard measure of river health in Victoria reported every six years.

Index of Estuary Condition (IEC) Still in pilot phase, the estuary index has been trialled across the state with the aim to having a similar state-wide measure of estuary health as that for wetlands (IWC) and rivers (ISC).

Land Subject to Inundation Overlay (LSIO) A flood related town planning control.

Longshore sediment transport The general direction of sand and sediment transport along the Victorian coastline is west to east.

Macroinvertebrate Small invertebrate animal which is visible with naked eye. Often used as a surrogate measure of water quality based upon species tolerance levels.

Microinvertebrates Very small invertebrate animal which requires visual aid such as a microscope to identify.

Marine Of or pertaining to the sea; existing in or produced by the sea.

Parameters The different types of qualities that estuary water is tested for can be termed parameters.

pH A measure of how many H+ and OH- ions are in solution giving us a measure of acidity or alkalinity on a scale of 1-14, where less than 7 is acid, 7 is neutral, and greater than 7 is alkaline.

Pyrite Iron and sulphur combined in a simple compound FeS_2. Also called Iron disulfide.

Terrestrial Belonging to the land rather than the sea or air living or growing on land: living or growing on land rather than in the sea or the air.

Rock groyne Artificial structure placed to prevent erosion or control water flow and/or direction.

Saline Water containing significant content of salt.

Salt wedge The physical separation of marine and riverine water within an estuary with the denser salty marine water sitting beneath the riverine water and forming a wedge.

Stormwater Water that originates during rainfall events. Rain water within an urban environment like Anglesea can often be confused with river water in low lying areas.

Stratification Water stratification occurs when water masses with different properties such as salinity (halocline), oxygen (chemocline), density (pycnocline) temperature (thermocline) form layers that act as barriers to water mixing.

Sulphuric acid This acid forms within the Anglesea catchment by the dissolution of iron pyrites with the subsurface.

Threats Something which may do harm to a value or assets.

Turbidity Visible cloudiness due to suspended material in water causing a reduction in the transmission of light.

Tributary A stream that flows to a larger stream or other body of water.

Vadose zone In the region above the water table- relevant to the position of pyrites and their wetting drying cycles during changing position of the water table.

Values Things important to the community and stakeholders.

List of figures, maps and images

Appendix 1 - Summary of recent events - acidity, fish deaths and river closures

In the summer of 2010-11, a series of acidification events occurred in the Anglesea River estuary causing fish death events and closure of the estuary for recreational users for several months. The Anglesea community demanded action, concerned about the threat to estuarine health and potential ecological damage, impact on recreation and amenity values and consequent effects on tourism.

On September 13 2010, the Environment Protection Authority (EPA) responded to a fish death event in the Anglesea River estuary. The EPA found the estuary waters were pH 4 and found similar or lower pH measurements in upstream tributaries. At this time, the EPA-licensed discharge into the river from the nearby Alcoa power station and mine site was within required limits, with a pH level just above 7.

A subsequent EPA investigation found the probable cause of fish deaths was a combination of pH stress (acidic water), aluminium toxicity, and suffocation through smothering of the gills by precipitated aluminium compounds (Pope 2010). The investigation concluded that the source of both the acidic water and the elevated concentrations of aluminium were likely generated from acid sulphate soils and coal seams (both generating sulphuric acid) and peats swamps (generating humic acids), within the catchment. A fourth potential source, the licensed discharge from the Alcoa open cut coal mine, was also suggested (Pope 2010).

A government review was commissioned in response to community concern. The investigation by Professor William Maher (University of Canberra) reviewed the factors affecting water quality in the Anglesea River. He found that low pH waters result from natural processes in the catchment, in which sulphides in coal and other pyritic materials are oxidised. There was no evidence of any significant input of acid from oxidation of sulphur dioxide from Alcoa's coal-fired power plant. Maher concluded that a flush of acid water occurs after prolonged periods of low rainfall, followed by soaking rain. Large amounts of aluminium, iron, boron and probably associated trace metals are generated and transported naturally during acid formation.

Professor Maher suggested a more detailed assessment was necessary to determine the relative contributions of trace metals during high and low flows. This will require measuring the flow and concentrations of trace metals above, below and at the Alcoa discharge. Given the large amounts of boron being discharged from the ash ponds, he suggested paying particular attention to assessing the risk of boron downstream of the effluent discharge point. There is also clear evidence flocculation occurs when low pH water encounters higher pH sea water in the estuary, but where this occurs will depend on the flow of freshwater into the estuary. This process must be better understood to determine whether it is necessary to act to minimise trace metals or flocculation.

There were many suggested actions from the Maher report which are likely to appear within the action list within this estuary management plan, including a number of options for acidity management. But each needs further investigation before any meaningful recommendation can be made. Further investigation would involve assessing the viability, appropriateness and cost effectiveness of each option as well as the potential social impacts.

Deceased bream within estuary during September 2010

Appendix 2 - Community values and aspirations

Through the survey data we can establish that people value the estuary highly and have a great level of knowledge of estuary health and function. Most people also state they are interested in involving themselves in making the estuary healthier and learning more about the estuary. They also stated that they generally trusted information provided regarding the river.

Survey participants were asked to suggest what should be done to protect the Anglesea River in the future. Responses were collated and generally met one of these key areas of interest:*

1. Amenity and recreation
2. Biodiversity protection
3. Information and knowledge
4. Integrated management.

**These four key areas became the basis for the aims and objectives within the Management Action Plan detailed on pages 9-14.*

When asked what things had been done well in the past in relation to the management of the river, answers included recent responses to fish death incidents, fewer sewage leaks and response to recent leaks, the creation of boardwalks, paths, parks and walkways, removal of rock walls and construction of rock walls, revegetation and weed control, and strong positive response to the creation and support of the EstuaryWatch Program.

INTERESTING STATISTICS

Some interesting statistics from the survey:

- 90% of respondents were aged 25-70
- 58.5% were male
- 33.8% lived outside the Surf Coast Shire and 38.5% were Anglesea residents
- 7.7% had more than 50-year association with Anglesea, while 90% were associated for more than five years.

When asked what people used the river and its environs for, responses were dominated by active uses, with over 75 per cent of respondents cycling, running or walking, (50 of the 67). The five top responses were chosen by almost one in three people and recreational fishing about one in four. Of the fourteen options, the thirteenth lowest responses still managed 12.3% of responses indicating people use and value the river for a great variety of reasons.

The survey confirms the health of the river is very important to respondents, with 82.8 per cent indicating they had a responsibility to keep the Anglesea River estuary healthy. The respondents had excellent knowledge of estuary functions. Over 90 per cent of people have improved knowledge in the last 5 years and 10.8 per cent of people claim themselves experts and 43.1 per cent of people claimed a very good knowledge. Responses showed 68.8 per cent had heard of the EstuaryWatch Program, with 50 per cent having viewed the online data and a further 10 people having at one stage tested water with the EstuaryWatch program.

Knowledge of estuary openings and closures was of interest to management agencies. Responses showed 56.3 per cent said they were aware of the procedure for mechanical opening of the estuary, but 54.7 per cent thought the estuary openings took place too often or often enough. There were 20.3 per cent who thought it should be open more often. Thoughts of who should have most responsibility in estuary management varied but Corangamite CMA identified at number one, with the Department of Environment and Primary Industries second and Surf Coast Shire third highest.

Within the survey, respondents were asked "What are the two most important things that could be done to protect the Anglesea River in the next couple of years?"

- Get all Anglesea residents to become custodians of the river and its welfare
- Management of ALL threatening processes
- Leave the river alone
- Open the river earlier
- Better opening regime
- Keep monitoring
- Water quality monitoring
- Stop inflow of urban pollution
- Storm water abatement
- Management and control of pollution
- Control of acid sulphate oils, peat, etc.
- No more bank modification or groynes
- Restrict fishing to certain areas
- Prevent coalmine activities impacting flows and groundwater
- Better retaining walls to be built to stop random access to estuary
- Education to combat ignorance around the natural cycles of the estuary
- Accurate public availability of water quality analysis and impacts on ecology
- Better coordination of management and decision making in relation to the opening of the estuary taking into consideration environmental values - as a priority not an after thought
- Make access tracks safe - currently unsafe and often flooded (e.g. 4 bridges area near Coogorah Park)
- Platforms to allow commercial users to access river and of estuary with minimal impact to banks and riparian vegetation
- Communicate with local Aboriginal organisations
- Put back the landmass that was destroyed by the US Airforce in the 40's and let mother nature do her thing
- Protect and manage streamside ecology stop the negative press re fish kills and pollution
- More State Government environmental funding and support
- Increase funding to the relevant management agencies to provide better support for estuary watch personnel.

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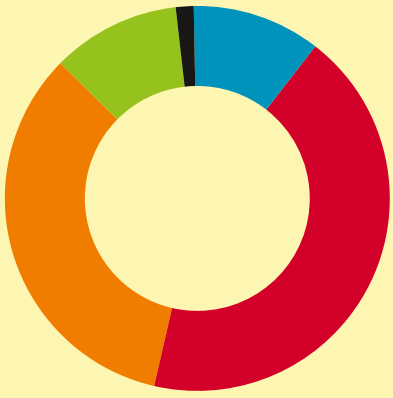
Estuaries are places where waterways meet the sea. How would you describe your level of knowledge of how estuaries function?



- Expert (I could detail estuary functions and processes to other using scientific terminology)
- Very good (I can confidently explain functions and processes to others)
- Good (I could discuss some things about the estuary)
- Average (I don't know much about the function of estuaries)
- Not so good (I have no knowledge of estuary functions)

Appendix 3 - Formation of acid from pyrites

Formation of acid from pyrites, coal and sediment

It has been established through much research that pyrites ((FeS$_2$) or iron disulphide) within soil, in particular the sulphur mineral, are usually responsible for acid generation.

Acid generation can be represented by the chemical equation (in Maher and explained in detail within Sharley 2012);

$FeS_2 + 15/4O_2 + 7/2\ H_20$ » $Fe(OH)_3 + 2\ H_2SO_4$

(iron disulphide plus oxygen plus water gives iron hydroxide and sulphuric acid)

Estimating the ability to produce acid is explained within the "Manual of techniques to quantify processes associated with contaminated effluent from sulfidic mine waste" (Garvie and Taylor 2000). To use this manual we first establish via Holdgate (2001), who reported coal sulphur contents for Anglesea at 3.8% but notes variations across the seam with peaks over 5%. The manual states that every 1 per cent of sulphur present per one tonne of material such as coal, has the potential to generate 30.6 kg of sulphuric acid, based on the stoichiometry of equation above. So given the coal layers thicknesses summarised in the table opposite from Tutt 2008 some estimations can begin of the potential to produce acid. Further work mapping the coal extents (at considerable cost) would be required to provide detailed estimates for the catchment.

The transportation of 'acid' from its geological sources to water courses is the infiltration of water (typically precipitation, i.e. rain) into the strata, then its discharge to surface waters. A similar process can occur if marshes in the catchment had 'dried out'.

Before reduced sulphides (such as pyrites) can generate acid, oxygen and water must be present. Typically, infiltration that reaches a water table has low dissolved oxygen and groundwater itself tends to have low to zero dissolved oxygen. This creates an anaerobic (no oxygen) environment.

Pyrites typically are therefore stable or non-acid generating when they are below the water table.

Thickness of coal or heterogenous units mentioning coal

Bore No.	Metres (m)	Bore No.	Metres (m)
B113002	24	B116458	42
B113003	18	B116460	40
B113004	18	B119347	3
B113470	51	B119349	0
B115867	12	B121768	70
B115868	37.4		

Further investigation is required using available data on climate, rainfall, water flow and water quality for up to 10 years after the fire to fully understand the influence of fire and implications of any fire management plan using controlled burns. Also, if fish are in the low pH water, flocculation may well occur on the gills of fish.

Formation of flocculants

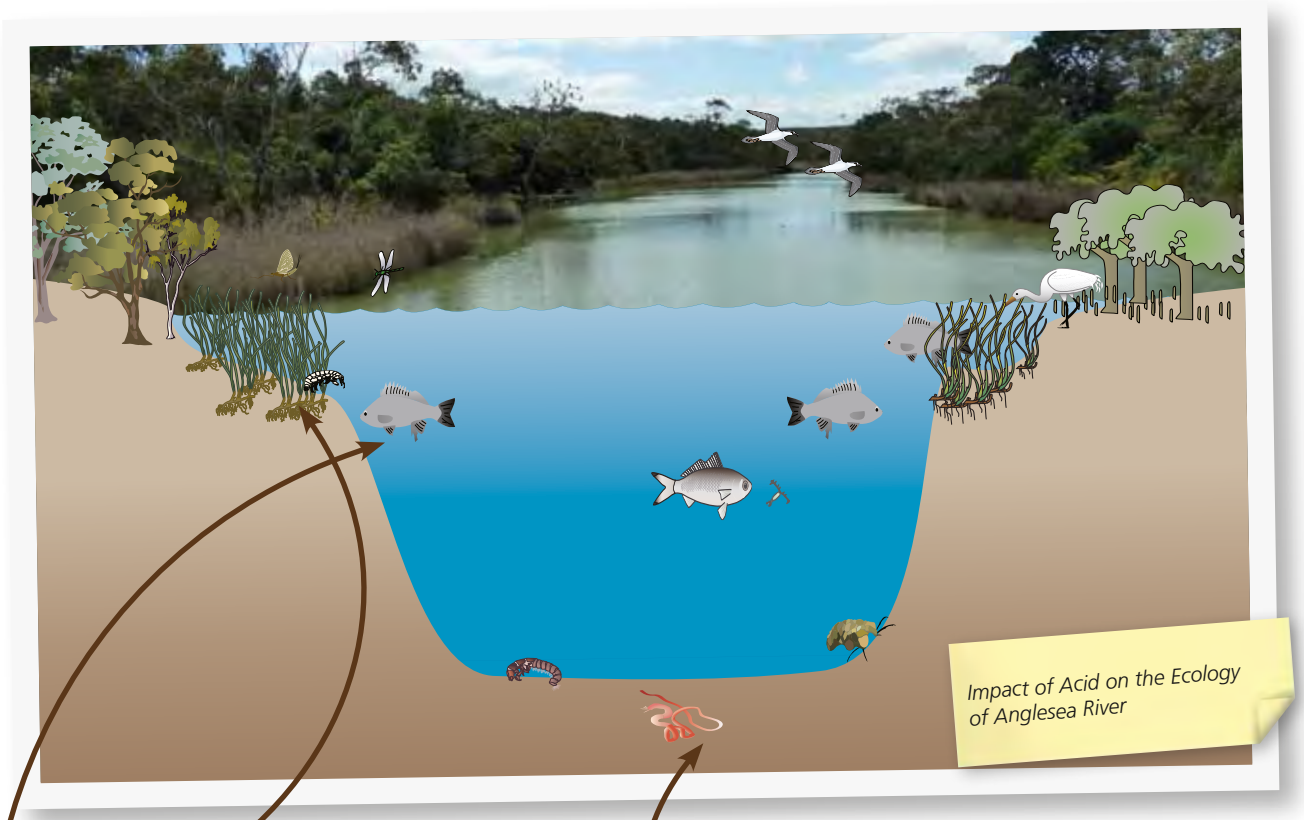
Estuarine mixing of freshwater and saline water is likely to flocculate most of the dissolved aluminium, iron and manganese and other associated trace metals. In particular, aluminium is removed by the time a salinity level of 8 parts per thousand (ppt) is reached. It is expected that some of this material would be re-solubilised during floods as the pH and salinity drop. Where this occurs will depend on the flow of freshwater into the estuary. During low flow, flocculation will occur at Coal Mine Rd at the head of the estuary. During high flow, if a layer of freshwater exists over the more saline estuarine water, flocculation will occur at the boundary where freshwater and sea water meet, and will continue as far as the layer of freshwater extends into the estuary. It may also occur on the gills of fish in this section of water.

Aluminium oxy-hydroxide flocculant formed near river mouth (October, 2010)

Appendix 4

Extract from 'factors affecting the ecology of Anglesea River estuary' 2012

Reference: Centre for Aquatic Pollution Identification and Management



Seagrass

- Seagrass is a marine flowering angiosperm found on sandy substrates or in estuaries submerged or partially floating
- This vegetation type is located throughout the world and is found in specific regions of the Victorian coastline that suit this ecotype including the Anglesea River estuary
- The Anglesea River estuary usually contains two different species of seagrass, Zostera spp and Ruppia spp.

Fish

- Waters impacted by low pH and high acidity can effect fish in numerous ways, including physiological and behavioral changes and if severe enough, can lead to fish deat
- Variation in pH levels can cause stress to fish populations. Often pH stress can be seen by changes to a species reproduction, respiration rates and an increase the likelihood of dermal lesions. In particular, this damage to the epithelium layer of fish can leave individuals vulnerable to attack by pathogens and other diseases such as red spot disease
- As the pH is reduced, the likelihood of fish death increases. Below a pH of 5.0, fish mortality across some life stages can occur. The severity of pH stress on fish populations depend on the strength of acidity and the buffering potential of an estuary to acid.

Macroinvertebrates

- Macroscopic invertebrates play an important part of all ecosystems
- The variation in functional feeding groups across the 200 macroinvertebrate families form an important part of aquatic food webs, and are essential to the proper functioning of aquatic ecosystems
- Following an acidic input into freshwater and/or estuarine environments it is likely that macroinvertebrate diversity will change in response
- If this becomes repetitive it has been shown that species sensitive to change in pH are removed from the system, resulting in local extinction of these species. Conversely, other more tolerant species will become more abundant. This has the effect of changing entire food webs and can result in the collapse of these systems if the stress is severe enough.

Appendix 5 - Alcoa operation at Anglesea

Since 1963, Alcoa of Australia has operated the 160 MW Anglesea Power Station. Alcoa's water usage is monitored and controlled under the power station's EPA licence and Alcoa actively seeks to improve water management and conservation on site.

The station receives process water from three sources – town water, bore water and recycled water from the mine. Since 2000, Alcoa Anglesea has achieved a greater than 60% reduction in town water consumption.

Water is primarily used at the power station to cool the return steam from the turbine. Other processes that use water include boiler water feed, auxiliary cooling systems and dust suppression for conveyor belts and coal surfaces.

Process water and storm water from the site is discharged from ash ponds. The EPA licensed discharge flows through a natural wetland mixing zone prior to entering the estuarine section of the Anglesea River. Alcoa Anglesea's EPA licence has parameters set for flow, pH, suspended solids, colour, aluminium, boron, iron and zinc.

Discharge from the site is monitored using on-line instrumentation. Daily inspections and monthly sampling are conducted for water quality compliance.

Text supplied by Kate Betts, Alcoa of Australia.

View to the north over the open cut mine, power plant in background

Appendix 6

Partners and their roles and responsibilities in waterway management

Group or Agency	Statewide responsibility
Corangamite Catchment Management Authority (CCMA)	The Corangamite CMA was established in 1997 by the Victorian Government, under the *Catchment and Land Protection Act 1994*. The primary goal - 'to ensure the protection and restoration of land and water resources, the sustainable development of natural resources-based industries and the conservation of our natural and cultural heritage. Under Part 10 of the *Water Act 1989*, CMAs are designated with specific responsibility for the management of waterways, rural drainage and floodplains. The range of functions that CMAs undertake include: • development of a regional Waterway Strategy and associated plans and delivery of waterway work programs • authorisation of works on waterways and a referral body for planning applications, licences to take and use water to construct dams • coordination of regional floodplain management plans, as appropriate • responding to natural disasters and incidents affecting waterways such as bushfires, floods and algal blooms • community participation and awareness programs.
Local Government (Surf Coast Shire)	Councils are involved in the management of waterways in Victoria through their roles as responsible planning authorities, managers of stormwater drainage and onsite domestic wastewater systems, users of integrated water systems, land managers, emergency management bodies, and supporters of community groups. Specifically with regard to waterways, local government have the following roles and responsibilities: • incorporate waterway restoration and catchment management objectives, priorities and actions into planning processes • undertake floodplain management and flood warning in accordance with the Victorian Flood Management Strategy • develop and implement urban stormwater plans • manage on-site domestic wastewater systems • manage adjoining waterways under Committees of Management • manage rural drainage schemes where appropriate.
Department of Environment and Primary Industries (DEPI)	DEPI is the lead agency for waterway management. It is responsible for the development of waterway policy, co-ordination of regional delivery and prioritisation of government investment in waterways. DEPI is also responsible for other aspects of natural resource management that are of relevance to waterways, including: • sustainable management of water resources including catchment planning to promote integrated catchment management • management of biodiversity and of public land, including waterways and bushfire management on public land • delivery of sustainability and environment services at regional level • management of fisheries and recreational fishing in waterways in waterways to optimise economic and social value while ensuring the sustainability of resources.
Environment Protection Authority (EPA)	The EPA Victoria is an independent body responsible for the protection and improvement of Victoria's environment by establishing environmental standards, regulating and working with organisations to meet these standards. Their roles and responsibilities include: • identifying the beneficial uses of water environments and the level of environmental quality needed to protect them through the State Environmental Protection Policy (Waters of Victoria) • setting statutory standards for acceptable water quality and indicators of water quality • investigating water quality incident classified as 'pollution' • using mandatory and regulatory mechanisms, such as licensing and other discretionary tools to assist in the achievement of water quality objectives • acting in partnership with DEPI and regional bodies to monitor water quality and waterway health, and enables problem solving approaches and independent audits of impacts on the environment and the protection of beneficial uses.
Parks Victoria (PV)	Parks Victoria manages parks and conservation reserves in which many waterways are located. They create, manage and maintain visitor sites and manage a range of assets, including visitor facilities and access points, piers and jetties, sporting facilities and navigation aids, many of which are associated with waterways.
Great Ocean Road Coast Committee (GORCC)	Appointed by DEPI to manage *Crown Land (Reserves) Act 1978*. Responsibilities stipulated through the *Crown Land (Reserves) Act 1978*. Manage the coastal land at and adjacent to the estuary mouth and foreshore to east and west. Also manage a small parcel within the estuary. Former managers of Beach Front Caravan site which is now leased from the Crown and managed independently.
Western Coastal Board	The Western Coastal Board is one of three regional coastal boards formed under the *Coastal Management Act 1995* reporting to the Minister for the Environment and Climate Change. Their role is to implement the Victorian Coastal Strategy, provide advice to the minister and the Victorian Coastal Council, and prepare and implement regional coastal plans.
Traditional Owners (TOs)	TOs with recognised native title rights or formal agreements with the State are important in land and water management and are collaborated with in development and implementation of plans.