Draft Coastal Zone Management Plan for Wooloweyah Lagoon

PART 1: BACKGROUND AND PLAN

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Wooloweyah Lagoon, from Radial No. 1

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Executive Summary

Wooloweyah Lagoon is a tidal barrier estuarine lagoon on the lower Clarence River floodplain on the north coast of New South Wales. The lagoon is approximately 12 km from the mouth of the Clarence River and forms part of the broader Clarence River estuary. It is connected to the main estuary by three channels: Palmers, Micalo/Shallow and Oyster Channels. The catchment area of the lagoon and adjoining channels is approximately 206 km^2 (including the lagoon, which has a surface area of 24.5 km^2). Land use immediately adjacent to the lagoon and channels includes Yuraygir National Park to the south-east, urban development to the east (Wooloweyah township) and north-east (Yamba), and agriculture (predominantly sugar cane and grazing) to the west and south. More than 70% of runoff is estimated to enter the lagoon via the extensive drainage network on the western flats.

The Wooloweyah Lagoon catchment and waterway has high ecological values, and is listed on the 'Directory of Important Wetlands in Australia'. The lagoon is fringed by SEPP 14 wetlands and contains areas of seagrass, which provides important nursery habitat for many fish and school prawns. A range of migratory wader (waterbird) species have also been observed within the catchment.

A number of key management issues were identified from a range of sources, including the previous *Wooloweyah Lagoon Management Strategy* (Woodhouse 2001), a condition assessment of the lagoon and catchment, and consultation with government and non-government agencies and the community. The key issues identified were: future development/land use change; erosion and sedimentation; environmental flows; navigation; fishing (commercial, recreational and aquaculture); on-site sewage management; water quality; acid sulfate soils; bank condition and riparian vegetation; sugar cane; non-sustainable grazing; clearing; cane toads and climate change.

The long-term aim of the Coastal Zone Management Plan for Wooloweyah Lagoon is to protect and enhance environmental, economic and social values. To achieve this aim, a number of management objectives were determined:

- improve water quality to reduce sediment, nutrient and oxygen demand loads, and to meet performance targets;
- maintain and improve ecosystem health and biodiversity of the lagoon, estuary, riparian zone and subcatchment;
- ensure future development and land use change has minimal impact on ecosystem health and sustainability of the lagoon;
- stabilise degraded channels to rehabilitate their natural values, improve downstream health and reduce infilling of the lagoon;
- raise community awareness of, and protect areas important to, Aboriginal cultural heritage; and,
- manage potential impacts of climate change.

The management objectives will be addressed through twenty management strategies, each of which contains a number of actions. These include bank stabilisation, riparian rehabilitation, upgrading the Yamba STP and improving management of on-site waste facilities, dredging of Palmers Channel for safe navigation and to improve environmental flows, encouraging sustainable use of the land and waterways, and planning provisions to protect natural ecosystem processes. The relative timeframe, responsible agencies and indicative costs have been provided for each management strategy.

Acknowledgements

The Coastal Zone Management Plan for Wooloweyah Lagoon was jointly funded by Clarence Valley Council and the Department of Environment, Climate Change and Water through its Estuary Management Program.

The Steering Committee established to oversee the progress of the Wooloweyah Lagoon Condition Assessment, and the development of the management plan, was comprised of representatives from Clarence Valley Council, Department of Environment, Climate Change and Water, NSW Department of Primary Industries (Fisheries), Department of Lands and the Northern Rivers Catchment Management Authority.

Input from the community and key stakeholders is also greatly appreciated in the development of this Management Plan.

1 About the Plan

1.1 Management Area

The management area relevant to the Coastal Zone Management Plan for Wooloweyah Lagoon (CZMP) covers the Wooloweyah Lagoon catchment (Figure 1.1). The area includes the tidal waters, foreshores, drains and adjacent lands of Wooloweyah Lagoon and Palmers, Micalo, Shallow and Oyster Channels.

The floodplain to the west and north-west of the lagoon has been classified into six discrete management areas in the *Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems* report (Foley & White 2007; Figure 1.2). These areas were determined based on drainage, landform, land use and management issues.

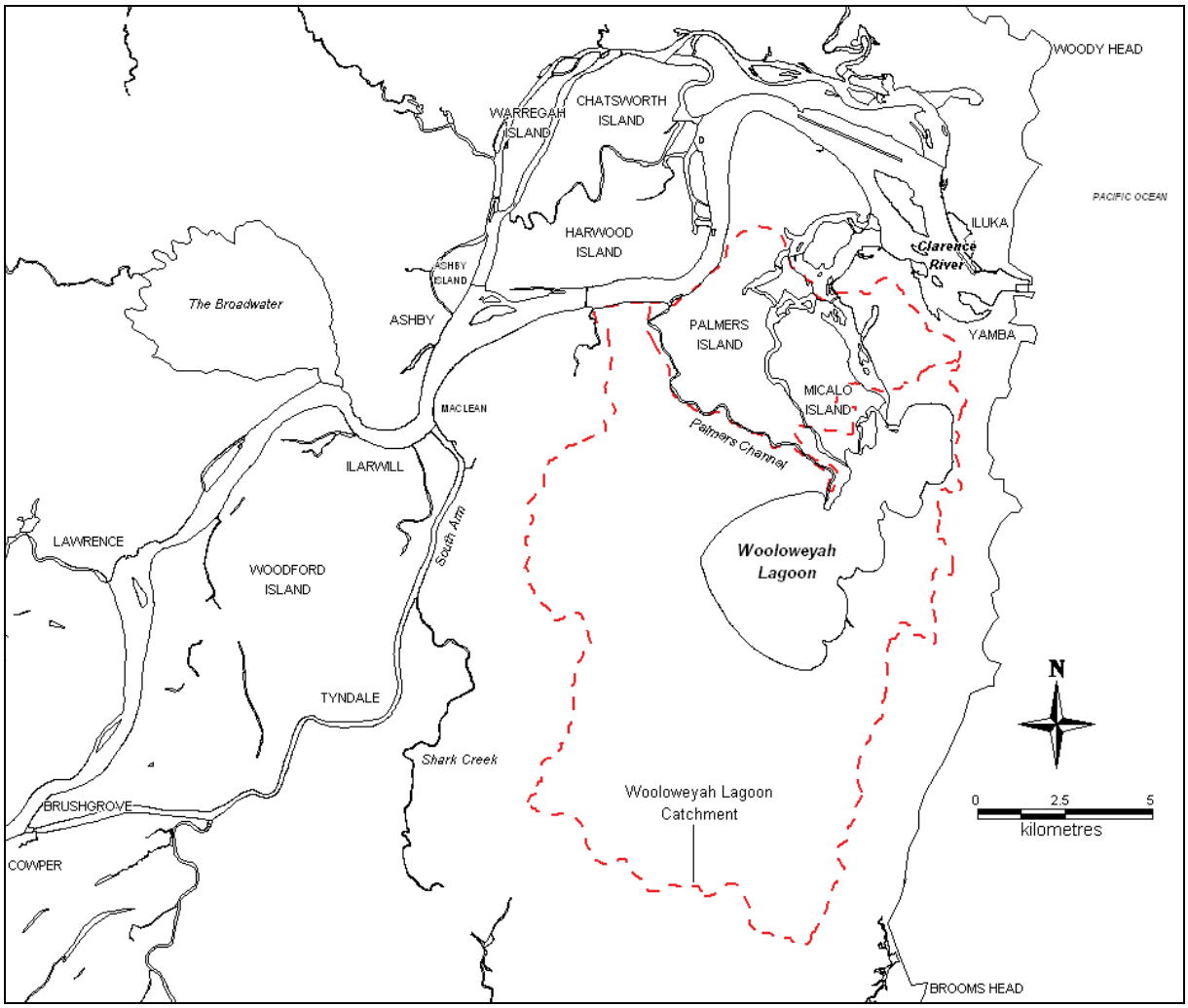

Figure 1.1: Location of Wooloweyah Lagoon and its catchment on the Lower Clarence River floodplain.

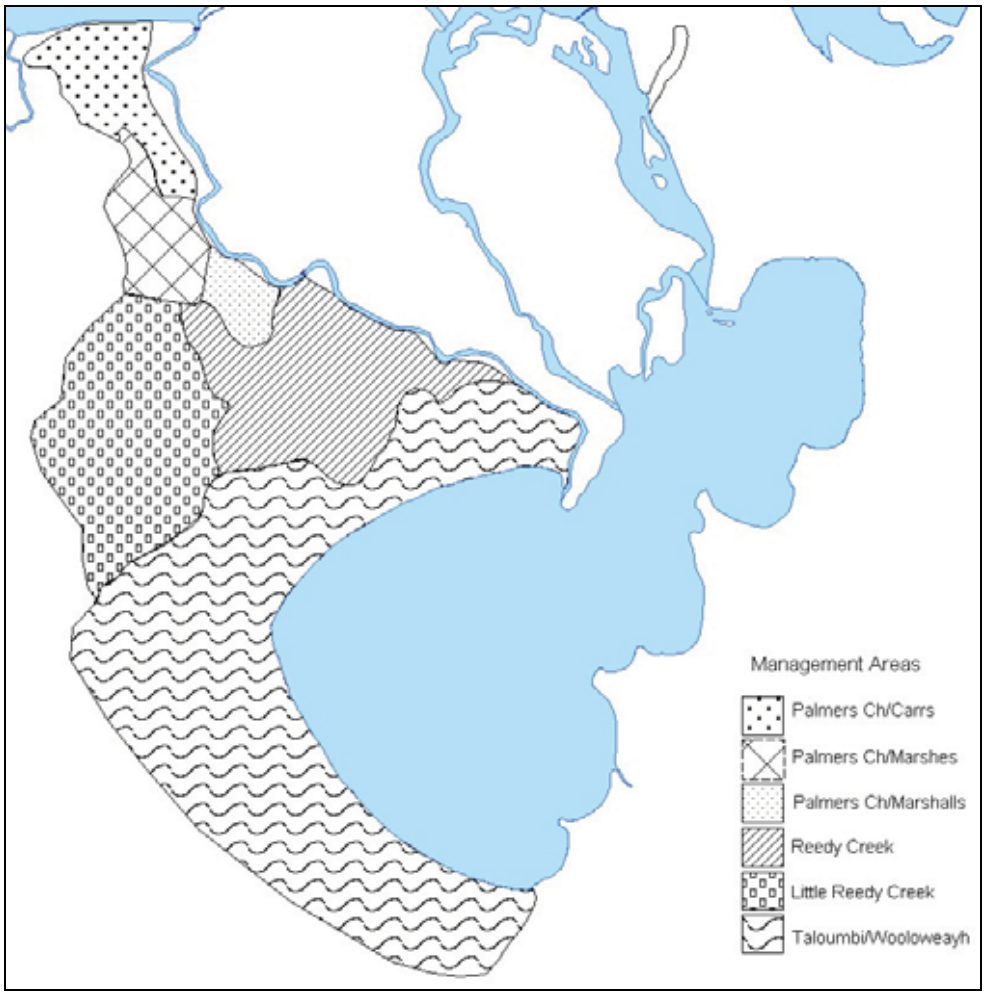

Figure 1.2: Management areas identified and discussed in the *Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems*.

1.2 Purpose of the Plan

The purpose of the CZMP is to develop policies and strategies to guide long-term management of the lagoon and subcatchment. The Plan utilises previous processes and management studies, information from a condition assessment and stakeholder consultation to develop objectives for achieving this aim. A secondary purpose of the CZMP is to update the previous management plan, *Wooloweyah Lagoon Yamba, NSW Management Strategy* (Woodhouse 2001).

The Coastal Zone Management Plan for Wooloweyah Lagoon provides a description of the management area, including natural and cultural significance, the current condition and current uses. Management issues, objectives and targets are listed, along with a detailed action plan to achieve the objectives. Management principals, reporting mechanisms, performance evaluation and review of the Plan are also described.

1.3 Strategic Vision and Goals of the Plan

The strategic vision that the plan seeks to promote is to manage Wooloweyah Lagoon to protect its environmental values and provide for long-term sustainable use of its waterways and catchment. To

achieve this, the Plan will endeavour to ensure that the social, economic and environmental values relating to water quality, habitat, biodiversity and commercial enterprise are maintained.
The following goals set the direction of the Plan, and help to define long-term management of the lagoon.

1. Wooloweyah Lagoon and its surrounding catchment will retain their environmental values
2. The social, commercial and recreational values of the lagoon and its catchment will be retained without compromising the natural values
3. Maintain and develop new partnerships between stakeholder groups to achieve best management of the natural environment and economic, recreational and social resources.

1.4 Management Agencies

Clarence Valley Council is the primary agency responsible for implementation of the CZMP, in consultation with the Clarence Floodplain and Estuary Partnership (CF&EP). A number of agencies hold implementation responsibilities for various issues related to the CZMP (Table 1.1), including Industry and Investment NSW (previously NSW Department of Primary Industries), Department of Environment, Climate Change and Water (DECCW), Northern Rivers Catchment Management Authority (NRCMA) and Land and Property Management Authority (previously Department of Lands).

Table 1.1: Management agencies and the responsibilities each has under the management plan.

Agency	Responsibilities/Issues
Clarence Valley Council	Water pollution, noxious weeds, public land management, assess development, local infrastructure (including STP), natural resource management, land use planning and regulation, floodgate management.
Land and Property Management Authority	Management of Crown land and property under the *Crowns Lands Act 1989* (including the bed of most State waterways and the ocean to a distance of 5.5 km from the land), approval of activities on Crown land, co-ordination of dredging.
Industry and Investment NSW	Marine vegetation, threatened species (aquatic), endangered ecological communities, dredging and reclamation, fish passage, commercial and recreational fisheries, aquaculture.
DECCW	Natural resource management including biodiversity, threatened species and endangered ecological communities (EECs), natural and cultural heritage, climate change, regulating activities to protect the environment (e.g. water pollution and clearing of native vegetation), water licensing and control of activities in or adjacent to waterways, activities in coastal areas, soils (including acid sulfate soils), land management (e.g. areas reserved under the *National Parks and Wildlife Act 1974* such as Clarence Estuary Nature Reserve and Yuraygir National Park).
NRCMA	Coordinate natural resource management.
NSW Maritime	Recreational and commercial boating.

Other agencies which may have responsibilities under the management plan include the Department of Environment, Water, Heritage and the Arts (Federal) and the Department of Planning. A summary of environmental and land use legislation administered by the above government agencies is provided in Table 1.2. Commonwealth legislation relevant to the Plan is also listed. The large number of relevant Acts indicates the difficulty in implementation of Total Catchment Management (TCM) principles.

Table 1.2: Legislation which may be relevant under the Coastal Zone Management Plan for Wooloweyah Lagoon.

Legislation	Level of Government
Australian Heritage Council Act 2003	Commonwealth
Catchment Management Authorities Act 2003	State
Coastal Protection Act 1979	State
Conveyancing Act 1919	State
Crown Lands Act 1989	State
Environmental Planning and Assessment Act 1979	State
Environment Protection and Biodiversity Conservation Act 1999 ▪ Japan-Australia Migratory Bird Agreement (JAMBA) 1974 ▪ China-Australia Migratory Bird Agreement (CAMBA) 1986 ▪ Republic of Korea-Australia Migratory Bird Agreement (RoKAMBA) 2006 ▪ Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)	Commonwealth
Heritage Act 1977	State
Local Government Act 1993	Local
Local Government Amendment (Ecologically Sustainable Development) Act 1997	Local
National Parks and Wildlife Act 1974	State
Native Vegetation Act 2003	State
Native Vegetation Conservation Act 1997	State
Noxious Weeds Act 1993	State
NSW Fisheries Management Act 1994	State
Protection of the Environment Operations Act 1997	State
Roads Act 1993	State
Rural Fires Act 1997	State and Local
Rural Lands Protection Act 1989	State
Soil Conservation Act 1938	State
Threatened Species Conservation Act 1995, including schedules for threatened species and Endangered Ecological Communities (EEC) (e.g. Coastal Saltmarsh, Swamp Oak Floodplain Forest)	State
Water Management Act 2000	State
Water Act 1912	State

1.5 Relationships to other Plans and Policies

The Wooloweyah Lagoon management area is subject to a range of State and local government plans and policies, the context of which has been incorporated into the development of the CZMP. At a State Government level the most significant is the Northern Rivers Catchment Action Plan, and at a local government level it is the Clarence Estuary Management Plan. A full list of all relevant plans and policies is provided below.

- Clarence Estuary Management Plan 2003
- Clarence Estuary Nature Reserve Draft Plan of Management 2007
- Clarence Valley Council Development Control Plans (DCPs)
    - Development in Rural Zones
    - Development in Rural Residential Zones
    - Development in Residential Zones
    - Development in Environment Protection, Open Space and Special Use Zones
- Clarence Valley Council Drain Management Plans within the Wooloweyah Lagoon catchment
    - Palmers Channel/Carrs
    - Palmers Channel/Marsh
    - Palmers Island/McKenzie/Castle
    - Palmers Island/ Hansens
    - Palmers Island/Levee Dr South
    - Palmers Island/Middle Rd
    - Palmers Island/Notts
    - Taloumbi Radial 5
- Clarence Valley Local Environmental Plan (LEP) (Draft)
- Coastal Lakes Strategy 2002
- Commonwealth Coastal Policy
- Fish Habitat Protection Plan No. 2 (Seagrasses)
- Grafton and Lower Clarence Flood Risk Management Plan 2007
- Independent Inquiry into the Clarence River System (Healthy Rivers Commission) 1999
- Independent Inquiry into the North Coast Rivers (Healthy Rivers Commission) 2003
- Maclean LEP 2001
- Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems 2007
- Management Plan for Micalo Island, Lower Clarence Estuary, NSW 2006
- Mid North Coast Regional Strategy 2009
- North Coast Regional Environmental Plan 1999
- Northern Rivers Catchment Action Plan 2006
- NSW Coastal Policy 1997
- NSW Estuary Management Policy
- NSW Fisheries Policy and Guidelines
- NSW Sea Level Rise Policy Statement 2009
- NSW State Rivers and Estuaries Policy 1993
- NSW Wetlands Management Policy 1996
- NSW Wetlands Policy (Draft)
- State Environmental Planning Policies (SEPPs)
    - SEPP No. 14 – Coastal Wetlands
    - SEPP No. 62 – Sustainable Aquaculture
    - SEPP No. 71 – Coastal Protection
    - SEPP (Infrastructure) 2007

- Yuraygir National Park and Yuraygir State Conservation Area Plan of Management 2003
- Wooloweyah Foreshore Reserve Plan of Management 1999
- Wooloweyah Lagoon Yamba, NSW: Management Strategy 2001
- Wetlands Policy of the Commonwealth

1.6 Supporting Documents

A number of documents have been reviewed and collated to provide the background information on which this management plan is based.

- *Physicochemical Conditions and Seasonal Changes in Wooloweyah Lagoon, Yamba, NSW 1990* – provides baseline data regarding water quality and recommendations on land use and drainage, aquaculture, future agricultural development and further research.

- *Independent Inquiry into the Clarence River System 1999, Healthy Rivers Commission of NSW* – the purpose was to recommend river health objectives and ways of improving river health; progress the resolution of long-standing river health problems; and, add value to current work on river health improvement.

- *Clarence River Estuary Processes Study 2000* – the third stage of the Estuary Management Policy. Defines the baseline conditions of the Clarence estuary processes and interactions between them.

- *Wooloweyah Lagoon Yamba, NSW Management Strategy 2001* – provides a description of the site and identifies and assesses impacts on the lagoon. A number of options are provided for management of the lagoon, and recommendations for studies and works are made.

- *Independent Inquiry into Coastal Lakes 2002, Healthy Rivers Commission of NSW* – provided a number of recommendations for decisions on management, resources and priorities. The pilot application of the Coastal Lakes Assessment and Management (CLAM) tool was also presented.

- *Palmers Channel Comparative Acid Neutralisation Demonstration 2003* – trialled different water exchange devices to determine the effectiveness of promoting saline exchange for acid neutralisation and drain weed control.

- *Ensuring Sustainable Development in Coastal Lake Catchments of NSW Northern Rivers: Coastal Lakes Assessment and Management (CLAM) Tool 2006* – assists in planning and management decisions in the Wooloweyah Lagoon catchment through an integrative model which explores the potential impacts of management scenarios on ecosystems, communities and economies that depend on the lagoon.

- *Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems 2007* – provides a description of the site and recommendations for improved management of the western drainage systems.

- *Wooloweyah Lagoon Condition Assessment 2009* – provides information on baseline conditions of water quality, sediment nutrient load and the general riparian condition of Wooloweyah Lagoon and the associated channels. Recommendations are made for revision of the water quality objectives for the management area. Management issues for inclusion in the CZMP are identified based on the results of the assessment.

2 About the Management Area

2.1 Location and Setting

Wooloweyah Lagoon is a tidal barrier estuarine lagoon on the Clarence River floodplain, North Coast of New South Wales (latitudes 29° 27' S to 29° 32' S and longitudes 153° 16' E to 153° 21' E) (Figure 1.1). The lagoon is approximately 12 km from the mouth of the Clarence River and is connected to the main estuary by three channels: Palmers, Micalo/Shallow and Oyster Channels (Figure 2.1). Land use immediately adjacent to the lagoon and channels includes Yuraygir National Park to the south-east, urban development to the east (Wooloweyah township) and north-east (Yamba), and agriculture (predominantly sugar cane and grazing) to the west and south. The lowlands and floodplain have a slope of less than 5% (Lancaster 1990).

Wooloweyah Lagoon has a depth range of 0-2 m (average approximately 1.3 m), a surface area of 24 km^2, a volume of 32.5 million m^3, a length of approximately 9 km and a width of 1-4.5 km (Lancaster 1990; MHL 2000). The catchment has an area of 206 km^2 (Foley & White 2007), including the lagoon (24.5 km^2) and an area of 32 km^2 which drains into Palmers Channel, Micalo/Shallow Channel and Oyster Channel. The catchment is bounded by several ranges along the southern border, including The Coast, Bees Nest and Shark Creek ranges. The catchment extends mostly west and south from the lagoon and these areas are therefore, the dominant source of land drainage (Lancaster 1990). It is estimated that more than 70% of runoff enters the lagoon through the Taloumbi Ring and Radial Drainage system due to the extensive drainage network on the western flats (Foley & White 2007).

Areas of seagrass, mangrove and saltmarsh habitats within and around the lagoon and channels provide important nursery habitat for prawns and fish (Woodhouse 2001). Migratory wader (waterbird) species also utilise the lagoon, which is fringed by SEPP 14 Wetlands (*EP&A Act 1979*). Due to these high ecological values, Wooloweyah Lagoon is listed on the 'Directory of Important Wetlands in Australia' (Environment Australia 2001).

The lagoon developed due to infilling of a deeper river valley which formed during periods of lower sea level, and formation of a barrier dune against the eastern bedrock exposures separated the lagoon from the coast (Woodhouse 2001). The lagoon then became separated from the main river channel due to continual infilling of the lower floodplain by land drainage. Wooloweyah Lagoon is a sediment settling basin, with marine sand continuing to be deposited as a flood-tide delta in the northern end of the lagoon and sediments and fine silts deposited during floods are trapped (Hashimoto & Hudson 1999; Woodhouse 2001). Recent dating of sediment cores from the lagoon indicate the sedimentation rate is between 0.4-3.0 cm yr^{-1} (ANSTO 2009). A higher rate of accretion in the southeastern and western regions of the lagoon in comparison to the northeast region supports the theory that the lagoon is becoming smaller rather than shallower (Hashimoto pers. comm. 6/10/00 cited in Woodhouse 2001: 16). Air photos of the flats west of the lagoon reveal relict shorelines (Figure 2.2), consisting of a series of at least 50 closely spaced concentric ridges which extend inland by more than 2 km in some areas (Tulau 1999). These indicate the previous varying extents of the lagoon system (Woodhouse 2001), and remain as geomorphically significant features which are of interest for scientific research on changes in sea level and sea chemistry (Australian Heritage Commission 1999; Tulau 1999). Accretion rates in the southeastern region of Wooloweyah Lagoon are at the higher range of those reported in other studies of lagoons and coastal lakes. For example, sedimentation rates in Lake Illawarra (south coast of NSW) are reported as 0.7-1.6 cm yr^{-1} (Chenhall 1994), The Coorong in South Australia is infilling at a rate of more than 1.5 cm yr^{-1} (Diatoma 2005), and Ryan *et al.* (2003) states that infilling rates of wave-dominated estuaries and coastal lagoons can be as high as 2 cm yr^{-1}.

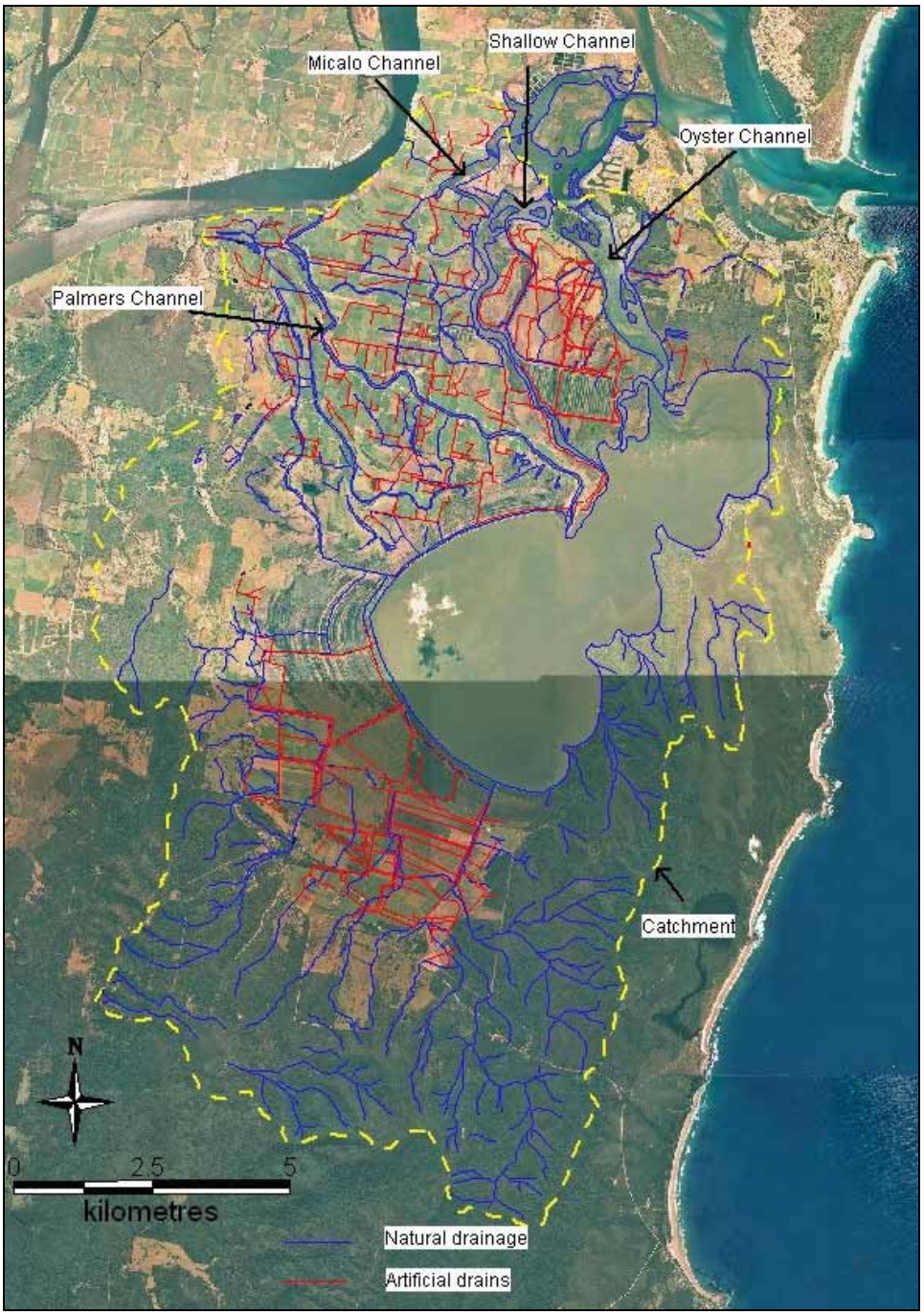

Figure 2.1: Wooloweyah Lagoon Management Area, indicated by the catchment boundary. Drainage lines are indicating, and include natural and artificial drainage.

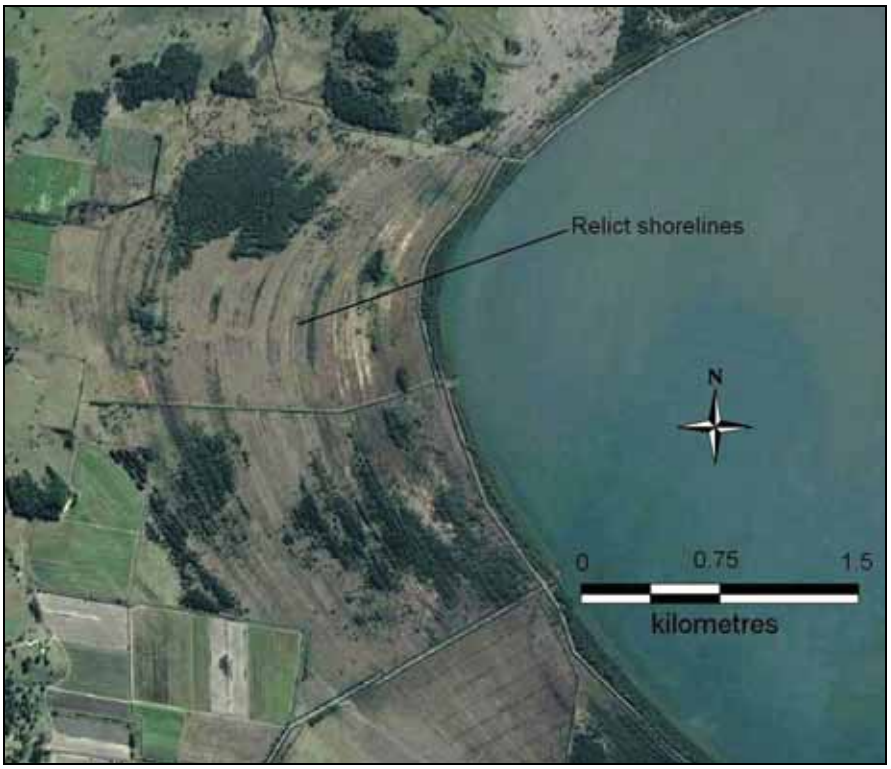

Figure 2.2: Relict shorelines of Wooloweyah Lagoon, indicated by concentric circles on the western flats.

Quaternary beach sand and dune deposits run in a narrow band parallel with the coast and broaden south of Yamba to extend inland to the edge of Wooloweyah Lagoon (Woodhouse 2001). Behind the coastal zone are Quaternary alluvium deposits from the Clarence River, and outcrops of the underlying Triassic-Jurassic sandstone (upper member of the Bundamba Group) forms a high headland behind the town and smaller hills at various locations east of the lagoon (Geological Survey of NSW 1970; Galloway *et al.* 1984; MHL 1999).

Soils in the drainage basin are predominantly yellow and grey-brown podzolics, with the eastern and southern shores mainly sands and sandy lithosols (Lancaster 1990). Acid sulfate soils (ASS), which formed during the last sea level rise less than 10,000 years ago (Dent 1986; Sammut *et al.* 1996), have been identified in the area. The lower estuary floodplain and islands of the Clarence River (which includes Wooloweyah Lagoon, Oyster Channel, Palmers Channel and Micalo/Shallow Channel) has been identified as an ASS priority management area (Tulau 1999).

Groundwater quality is reasonable in the upper 10 m of alluvium due to the extensive unconsolidated deposits of the floodplain (Woodhouse 2001). Below 10 m are black muds and silt with groundwater quality ranging from brackish to highly saline. The groundwater contribution to Wooloweyah Lagoon is approximately 50 m^3 day^{-1} (Woodhouse 2001). The hydraulic conductivity of the silty sand aquifer to the north-east of the lagoon ranges from 1.1-11 m day^{-1}, with an average of approximately 3 m day^{-1} (MHL 1999).

The region has a coastal subtropical climate with warm, wet summers and cool, dry winters (Woodhouse 2001). The climate is influenced by the subtropical high pressure belt during winter and spring, and easterly monsoonal trade winds and northern tropical cyclones during summer and autumn (MHL 2000). The warmest month is February with a mean daily temperature range of 20.3 °C to

26.7 °C and the coldest month is July with a mean daily range of 9.7 °C to 19.0 °C (ABM 2008; Figure 2.3). Mean annual rainfall at Yamba is 1454 mm, although Wooloweyah Lagoon and its catchment may receive a higher annual precipitation due to orographic rainfall caused by the range to the south-west of the lagoon and moist sea air (Lancaster 1990). The dry season is from August to November and the wet period from January to May. On average September is the driest month and March is the wettest (Figure 2.3).

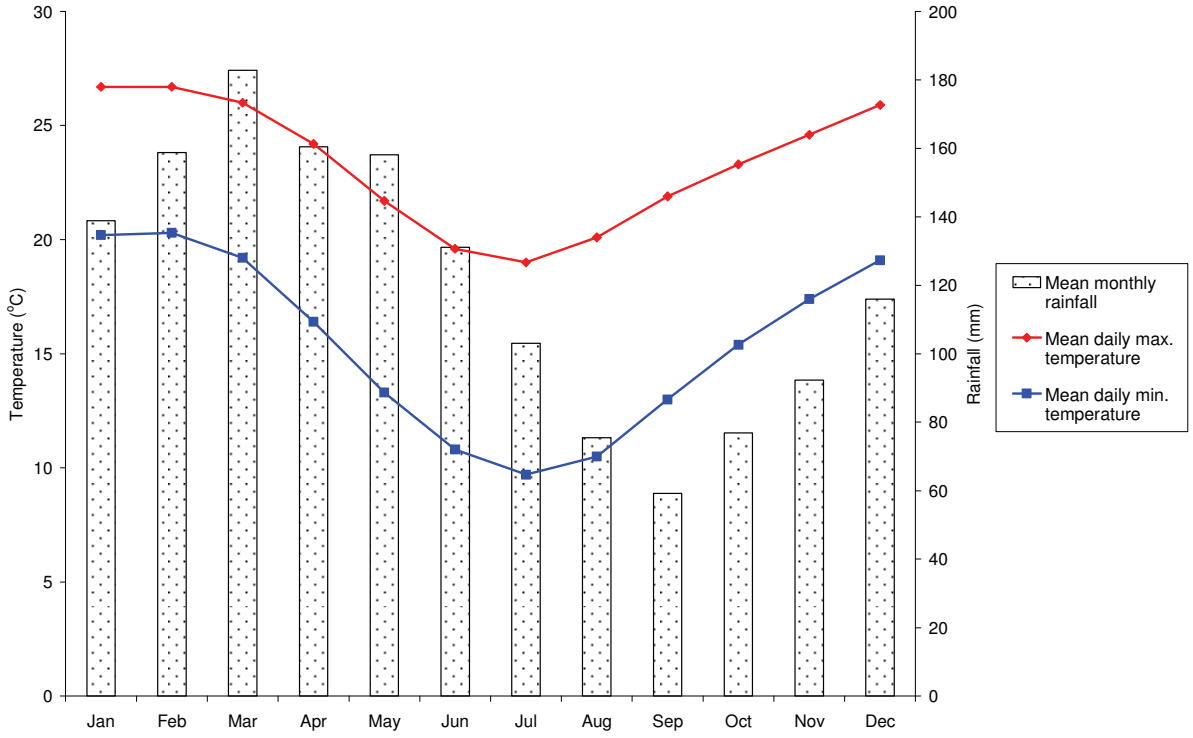

Figure 2.3: Climate averages for Yamba (Yamba Pilot Station #058012) (ABM 2008).

Winds are variable, with summer months dominated by northeasterlies and southeasterlies, and south to southeasterlies predominant during autumn. Winter months are characterised by west to southwesterlies strongest in the morning (Lancaster 1990), becoming more southerly during early spring. Strong winds (greater than 15 knots) are mainly onshore and from the south and southeast (Woodhouse 2001).

2.2 History

Wooloweyah Lagoon is located within the traditional boundaries of the Yaegl and Birrigan Gargle Aboriginal people tribal country. Matthew Flinders first landed in the Clarence River mouth in 1799, however, there was no significant European population in the Lower Clarence until the 1860s. European settlement and agriculture through the 1800s displaced the local Aboriginal people from their traditional lands, sometimes violently. The increase of agriculture with the availability of cheap land in the 1860s destroyed hunting grounds and the culture of the native inhabitants (McSwan & Switzer 2006).

Cedar harvesting began on the Clarence River in the late 1830s and peaked in the 1840s, however, by the 1850s the quantity of red cedar available had severely declined. Pastoralists (squatters) followed the

cedar cutters and then small-scale farmers (free selectors) arrived in the 1860s (Bawden 1979; McFarlane 1980; McSwan 1992).

In 1854 a pilot station was established on the present-day Yamba town site to aid boats in crossing the dangerous river bar, and in 1862 the construction of the breakwater at the mouth of the river began (Anon. 2008a, b). The influx of construction workers and their families led to the growth of services in the town, including a post office and the Wooli Hotel (1862), a school (1868), Church of England (1871), lighthouse (replaced in 1956) and police station (1879) (Anon. 2008a, b).

In 1885 the name Yamba was officially gazetted for the town and by the early 1890s tourism began to emerge. The population continued to increase and further works were carried out on the breakwater between 1893 and 1903, while tourism continued to grow when the Sydney railway arrived at South Grafton in 1923 (Anon. 2008a, b). Growth and development of Yamba slowed during the Depression and World War II, however, further harbour works from 1952 to 1971 helped with infrastructural development and a growth in population. In 2006 the population of Yamba was 5513 (ABS 2008), compared to just 35 people in 1876, with numbers increasing considerably during the holiday periods.

Commercial fishing has long been an important industry on the Clarence River, with the first shipment of fish to Sydney in 1884. Prawn trawling commenced in 1946 and Clarence River oysters have been shipped since the 1880s (Anon. 2008b). Between 1934 and 1943, and again in the early 1970s, sand mining was also a major industry in the area.

Flood mitigation works have been carried out since the early 1900s, although the majority of works around Wooloweyah were carried out in 1966/67 by Clarence River County Council. These works included a major drain and levee (Taloumbi Ring Drain) along the western perimeter of the lagoon. The purpose of the works was to protect agricultural land from flooding and improve grazing productivity by decreasing drainage time (Woodhouse 2001; Foley & White 2007). Many kilometres of private drains and levees have been constructed and linked to existing creeks and the council drains (Foley & White 2007). See Section 2.4.6 for further details about the flood mitigation works.

2.2.1 Management History

There are a range of studies conducted and plans written in the past which are relevant to management of Wooloweyah Lagoon and its subcatchment. These studies and plans provide recommendations for management of the Clarence Estuary and some specifically refer to the lagoon. The majority of recommendations have arisen from the Healthy Rivers Commission (HRC) Inquiry into the Clarence River (HRC 1999), the Wooloweyah Lagoon Management Strategy (Woodhouse 2001), and the Environmental Impact Statements and resulting Fishery Management Strategies for the Estuary General and Estuary Prawn Trawl Fisheries (NSW Fisheries 2003a, b) (see Section 1.6 for other relevant documents).

In 1999 the HRC conducted an *Independent Inquiry into the Clarence River System*, which was designed to recognise and assess all interests in the river (HRC 1999). A number of recommendations were made for management of the Clarence River, several of which are relevant to the management of Wooloweyah Lagoon and adjacent channels and drains (Table 2.1).

The *Wooloweyah Lagoon Management Strategy* (Woodhouse 2001) was developed to improve the management of Wooloweyah Lagoon and it's catchment based on recommendations from previous studies and management plans, including the *Clarence River Estuary Processes Study* (NSW DPWS 1999a), *Clarence River Estuary Management Plan* (Umwelt 2003), *Independent Inquiry into the*

Clarence River System (HRC 1999), and *Assessment of Floodgated Watercourses and Drains for Management Improvements – Clarence River Coastal Floodplain* (Williams 2000). A total of 26 structural and management options were discussed in the 2001 Management Strategy, a number of which have been completed (Table 2.2).

Table 2.1 (continued overleaf): Recommendations from the HRC (1999) Independent Inquiry into the Clarence River, relating to the Wooloweyah Lagoon catchment.

Theme	Recommendation	Status
Sustainable use of coastal floodplains and adjacent estuaries	A 'Partnership Agreement' approach for managing coastal floodplains should be developed	The Clarence Floodplain and Estuary Partnership was formed in 2003. The committee comprises of members who represent landholders, the cane industry, the fishing industry, community groups, Clarence Valley Council (CVC), the NRCMA, the University of New England, WetlandCare Australia and NSW Government agencies with a role in resource management on the floodplain (Industry and Investment NSW, DECCW, Land and Property Management Authority).
Wastewater	Review the need to meet the 'Sensitive Waters' criteria for an upgraded Yamba sewage treatment plant within the context of other wastewater priorities in the catchment	The upgrade of the Yamba STP is in progress.
	Wastewater related to boats	Untreated sewage from boats is not permitted to be discharged into any NSW waterway under the *Marine Pollution Amendment (Waste Discharge and Oil Spill Response Plans) Regulation* 2003. Wooloweyah Lagoon does not fulfil the criteria for a 'no discharge zone', and therefore treated sewage may be discharged.
	Agricultural runoff: policy developments and determination of funding eligibility criteria in all parts of Government should aim to establish incentives for farmers in the Clarence catchment to adopt best practice techniques, such as controlling soil erosion, rehabilitating riverine vegetation, minimising the use of chemicals and managing stock access to rivers	Landholders are encouraged to adopt best practice techniques. The cane industry has adopted a farming code of practice which lists a number of ways to manage nutrient and fertiliser use. A number of projects have been implemented through various agencies to rehabilitate riparian zones and managing livestock access to riparian areas.
Water quality	Environmental values listed in the report should be endorsed as realistic targets	Implemented.
	Water quality objectives – ANZECC (1992) guidelines should be adopted as water quality objectives	The ANZECC (2000) guidelines have been adopted, and the results of the condition assessment from 2008/2009 will aid in revision of the water quality objectives for the lagoon.
	Nutrient criteria specified in the report should be adopted as indicative water quality objectives for nitrogen and phosphorus throughout the catchment	Adopted, but will be revised as new data becomes available.
Canal estates, road causeways	Work on the Shallow Channel road causeway should be expedited as a high priority river health measure	The Shallow Channel causeway was replaced with two culverts in June 2008, allowing tidal flushing of the channel.

Theme	Recommendation	Status
and dredging		
	The *Fisheries Management Act, 1994* should be amended to provide for greater rigour in the assessments of dredging proposals by public authorities, so that adequate safeguards for river health/fisheries are established. Operations involving the restoration and maintenance of existing navigation channels should require the concurrence of the Minister for Fisheries	The permit application for dredging under Part 7 of the *Fisheries Management Act 1994* is regularly revised. Approvals for dredging are required from the Minister for Fisheries.
	Dredging in Oyster Channel should cease immediately to protect the estuarine ecosystem. If dredging is permitted to continue in Oyster Channel, it is critical that the Department of Land and Water Conservation ensure that rigorous monitoring is undertaken, under the supervision of NSW Fisheries and the Department, and subject to full public disclosure, to assess the impact of the activity on the estuarine ecosystem. Operations should be ceased immediately, if it is confirmed that the operation is having a detrimental river health impact	Dredging has ceased in Oyster Channel, and has not occurred in Palmers Channel since the HRC (1999) report was prepared. In 2002 the Statement of Intent was issued, with no further dredging permitted in Oyster Chanel, except under the licences current at the time.
Fishing	An investigation should be undertaken to determine the impact of trawling operations and other factors that may adversely affect seagrass beds and associated ecosystem processes in Lake Wooloweyah. Appropriate responses should then be developed and implemented to protect these ecosystems	Trawling has been prohibited over seagrass beds under the *Fisheries Management Act 1994*. A study on seagrass and the impact of threats such as climate change and trawling is included as an action in the CZMP (Strategy B7). Research on the potential impacts of prawn trawling on estuarine benthic assemblages has also been conducted in the Clarence River (Underwood 2007).
	Fishing entitlements and obligations of Aboriginal communities should be recognised in an integrated fisheries management plan	The Resource Assessment System administered by Industry and Investment NSW is used to monitor fish stocks across all harvest sectors and the NSW Government is currently considering amendments to the *Fisheries Management Act 1994* to recognise cultural fishing activities. The *NSW Indigenous Fisheries Strategy* was also developed in 2002 and implemented, and the *Clarence River Estuary Management Plan* considered interactions between commercial, recreational and indigenous fishers.
	The impacts on river health of recreational fishing should be monitored to support assessments of the need for greater regulation of them	Projects such as 'Fishers for Fish Habitat' recognise the involvement of recreational fishers in habitat improvement initiatives and provide examples of what can be done to protect these areas. Industry and Investment NSW is conducting a number of research projects which are examining ways to modify recreational fishing gear and maximising the survival of species released by recreational fishers.

Theme	Recommendation	Status
Vegetation	Revegetation of riverbanks through incentives for best practice and public funding	Implemented along some sections of the channels, through projects such as the' Palmers Island Wetland Biodiversity Project', and the 'Banrock Station Oyster Channel Project'.
	Weed management strategies should be incorporated into regional vegetation management strategies	Implemented. Also development of the Northern Rivers Invasive Plants Action Strategy 2009-2013.
	Weeds audit to identify current and potential instances of weeds adversely affecting river health in sensitive/stressed environments	The Noxious Weeds Compliance Audit Program has been developed and pilot audits were conducted in 2008. The process will be refined and randomly selected Local Control Authorities (LCAs) will be audited each year.

Table 2.2 (continued overleaf): The status of structural and management options recommended in the 2001 Wooloweyah Lagoon management strategy (Woodhouse 2001).

Option	Status
1. No change in current management of flood mitigation structures	Not recommended and not implemented.
2. Managed operation of floodgates for water exchange/fish passage	Drain management plans have been signed and endorsed for the major drains in the catchment.
3. Improvement to the Taloumbi drainage scheme	Initial consultation with landholders resulted in no changes being made to the drainage network. However, recent work and consultation with landholders has resulted in works going ahead which will improve water quality and habitat within the drainage system.
4. ASSPRO Wooloweyah Acid Wetland management project	Unsuccessful implementation.
5. Wetland Care Australia's Palmers Island Wetland Biodiversity Project	Completed.
6. Palmers Channel wash protection and bank revegetation project	No work has been done.
7. CASSP Palmer Channel Acid Neutralisation Project	Completed (see Davison & Wilson 2003).
8. Clarence River Estuary Management Plan and Study	Completed (see Umwelt 2003).
9. Healthy Rivers Commission Coastal Lakes Inquiry	Completed (see HRC 2002).
10. More stringent development control in wetland areas	Implemented.
11. Implementation of Maclean Shire Council's Biodiversity Strategy	Implemented, and a new Biodiversity Strategy is currently under review.
12. Improve the monitoring of water quality in the lagoon and connecting drains and channels	Landholders have been provided with handheld TPS to monitor pH and salinity of drain water. Lack of funding resulted in no regular monitoring of water quality by Council staff until 2006, when regular monthly monitoring was conducted in the Taloumbi Ring and Radial Drains over a 5 month period. Further funding from DECCW and Council enabled a 12-month condition assessment of the Wooloweyah Lagoon catchment to be conducted. The assessment has involved regular monitoring of water quality in the lagoon and channels, and event-based monitoring in the drains and natural creeks.
13. Yuraygir National Park Draft Plan	Plan finalised/adopted in 2003 and currently being implemented.

Option	Status
of Management	
14. Improved commercial fisheries management	The Estuary General and Estuary Prawn Trawl Fisheries have been environmentally assessed under both State and Commonwealth law, and management strategies have been developed and are being implemented.
15. Improved recreational fisheries management	Fish bag and size limits and a review of recreational fishing gear was conducted in 2007 and changes have been implemented. Numerous other improvements to recreational fisheries management have also been made.
16. Sustainable aquaculture	The NSW North Coast Sustainable Aquaculture Industry Development Plan was implemented in 2000. Monitoring/ongoing review of the strategy should ensure that development or re-establishment of aquaculture in the Wooloweyah Lagoon catchment in the future is environmentally and economically sustainable.
17. Improved indigenous fisheries management	The Resource Assessment System administered by Industry and Investment NSW is used to monitor fish stocks across all harvest sectors and the NSW Government is currently considering amendments to the *Fisheries Management Act 1994* to recognise cultural fishing activities. The *NSW Indigenous Fisheries Strategy* was also developed in 2002 and implemented, and the *Clarence River Estuary Management Plan* considered interactions between commercial, recreational and indigenous fishers.
18. Improved tourism/recreation management	The area has not been developed or promoted as a recreational site. The *Plan of Management for the Wooloweyah Foreshore Reserve* was adopted by Maclean Shire Council in 1999, and the Wooloweyah Parks and Reserves Management Committee has been established.
19. Improved stormwater management	The *Urban Stormwater Management Plan* was adopted by Maclean Shire Council in 2000, with strategies relevant to Wooloweyah Lagoon implemented.
20. Improved sewage management	The Yamba STP is in the planning stage of augmentation, and will cease discharging into a wetland which ultimately flows into Wooloweyah Lagoon (see Section 2.4.5). Untreated sewage from boats is not permitted to be discharge into any NSW waterway under the *Marine Pollution Amendment (Waste Discharge and Oil Spill Response Plans) Regulation* 2003. Furthermore, the *Clarence Estuary Management Plan* recommended that Wooloweyah Lagoon, and Shallow, Oyster and Palmers Channels be designated 'no discharge zones' for sewage (both treated and untreated) from boats.
21. Expedite work on Micalo/Shallow Channel causeway	The Shallow Channel causeway was replaced by two culverts in June 2008, to allow tidal exchange between the Channel and main river. See Section 2.4.1 for more detail.
22. Dredging (implement recommendations from the Clarence Estuary Management Plan (Umwelt 2003)	No further dredging has been carried out in any of the channels or the lagoon since the strategy was prepared.
23. Improved agricultural practices	Implementation of best practice farming techniques has been implemented along some drainage lines, however, this is an ongoing management action.
24. Aboriginal heritage management	Ongoing – see Strategy C1, Section 4.
25. Control of urban growth	Ongoing – see Strategy D1, Section 4.
26. Improved ecological management	See Clarence Estuary Management Plan. The preparation of the Clarence Valley Riparian Strategy is in progress. Seagrass beds have been mapped as part of an estuarine macrophyte study (NSW DPI 2006a), however, no specific study has been conducted looking at factors affecting seagrass within Wooloweyah Lagoon. Prawn trawling is prohibited over seagrass and trawlers are generally unable to access the shallow areas where seagrass beds currently exist. Ongoing works and consultation with landholders is resulting in fish passage being restored to drains.

Both the HRC (1999) Inquiry and the 2001 Wooloweyah Lagoon management strategy listed a number management recommendations relating to the commercial fishing industry (Tables 2.1 and 2.2). In 2003 the *Fishery Management Strategy for the Estuary General Fishery* and the *Fishery Management Strategy for the Estuary Prawn Trawl Fishery* (NSW Fisheries 2003a, b) were published, and incorporated some of the recommendations from the previous reports. A recent study by Ives *et al*. (2009) indicates that current management of the Estuary Prawn Trawl Fishery is sustainable (i.e. the stock is not at serious risk of recruitment-overfishing), and that alternative management strategies such as extending the period of closure would not significantly increase stock. Current management controls for the fisheries include:

- limited entry to the fishery;
- limits on the size of boats used;
- controls on fishing gear
    - mandatory use of square-mesh codends on prawn trawl nets;
    - mandatory use of Bycatch Reduction Devices (BRDs) in prawn trawl nets;
    - restriction on the species that may be taken in certain fishing gear;
- restricted seasons (e.g. Wooloweyah Lagoon is only open to trawling between the first Tuesday nearest 1st October and the Friday nearest 31st May, excluding weekends and public holidays, and may be extended up to 15 working days subject to the availability of prawns);
- numerous other spatial and temporal closures to various or all commercial fishing methods;
- prohibition of trawling (and other methods) over beds of *Zostera* and *Posidonia* seagrass;
- codes of practice, which include guidelines for operating near environmentally sensitive areas (i.e. riverbanks, seagrass, saltmarsh, mangroves), operating in the vicinity of Ramsar wetlands or known JAMBA and CAMBA habitat; and,
- a Resource Assessment System which involves ongoing monitoring the quantity length, age and sex composition of target and bycatch species to maintain species at sustainable levels.

A management plan for Micalo Island was developed in 2006, and provides comprehensive background on recent and current land use, site rehabilitation history, and monitoring works (NSW DPI 2006b). A range of generic actions were listed, along with specific actions for Shallow Channel (installing the culvert under the road crossing) and West Micalo. Many of these actions have been implemented, and the generic actions have been incorporated into the Coastal Zone Management Plan for Wooloweyah Lagoon.

Past management within the Wooloweyah Lagoon catchment has also been implemented by the sugar cane industry, including active drain management, developing and adopting best practice techniques (e.g. *The NSW Sugar Industry Best Practice Guidelines for Acid Sulfate Soils*, *NSW Sugar Industry Farming Code of Practice*), water quality monitoring, and riparian rehabilitation. Furthermore, Clarence Valley Council, through the Clarence Floodplain Project, has been involved in establishing and encouraging active management of flood mitigation structures to improve water quality, increase fish access, improve habitat, and reduce the impact of drainage on acid sulfate soils.

2.3 Natural and Cultural Significance

Archaeological and ethnographic evidence suggests that the Lower Clarence was intensively used by the Aboriginal people for thousands of years preceding European settlement of the area (Woodhouse 2001). A number of Aboriginal sites of archaeological and contemporary Aboriginal significance have been reported near Wooloweyah Lagoon, including bora rings, canoe and shield trees (Bell & Edwards 1980). Willoughby (1999) reports a midden near the shores of the lagoon as well as middens and a burial site on Micalo Island, a midden on Joss Island and an open camp site in the Taloumbi area. There is also a contact camp near the Crystal Water development at Yamba (Maclean Shire Council

2000). The Birrigan Gargle Local Aborigianl Land Council has been granted native title ownership to a culturally significant area of land to the north of Wooloweyah Lagoon (Figure 2.4)

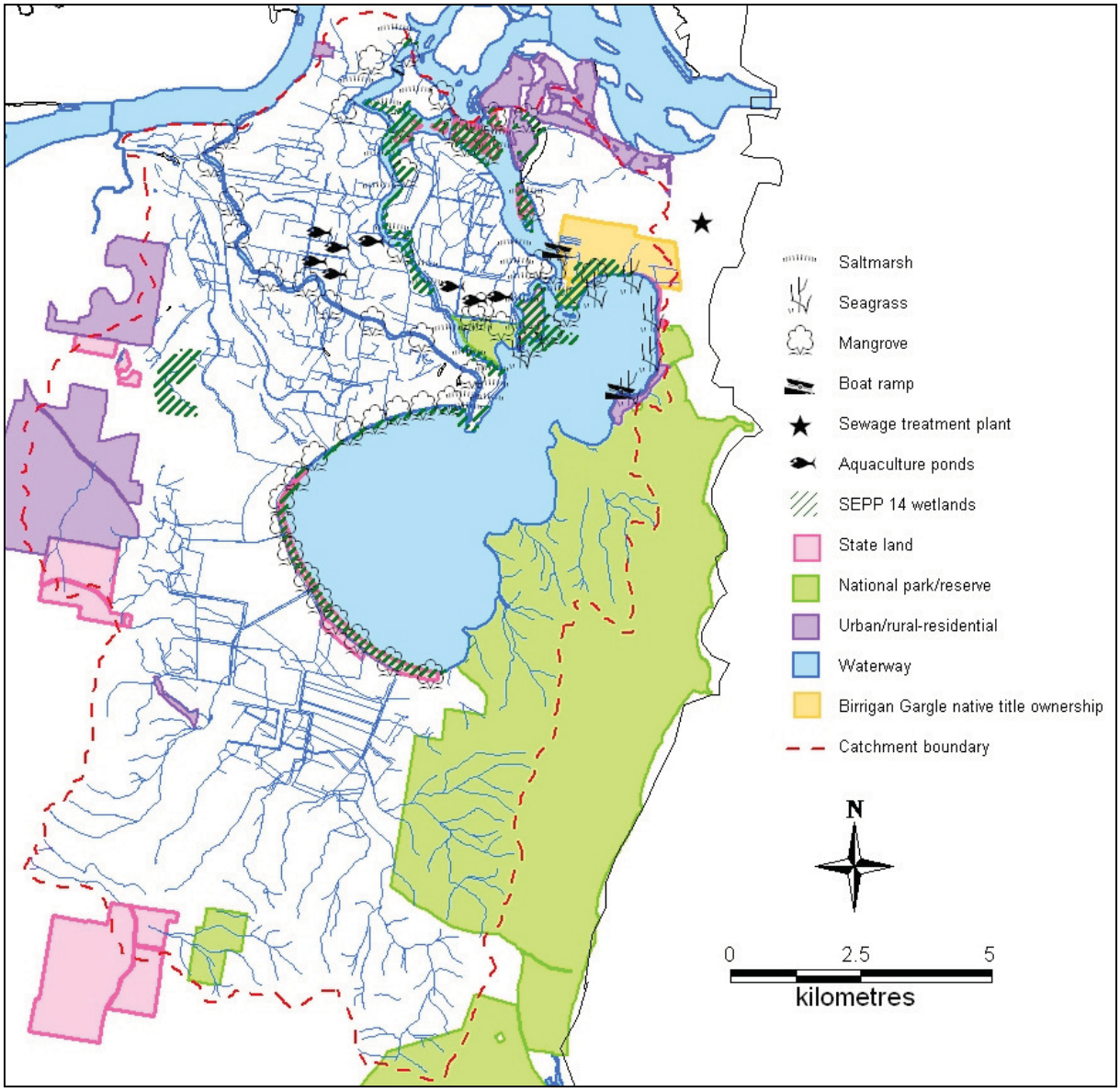

Figure 2.4: Wooloweyah Lagoon catchment indicating significant features, including residential land use, national parks, SEPP 14 wetlands and state land. Features located outside the catchment area are not indicated. N.B. macrophyte mapping was conducted by NSW DPI (2006), and the distribution of habitat such as seagrass may have since changed.

The Clarence Estuary wetland cluster, including Micalo Island and the west bank of Micalo Channel, has been classified as very high conservation value with very high level of threats (Eco Logical Australia 2008). Oyster, Micalo/Shallow and Romiaka Channels, and Wooloweyah Lagoon have been identified as the most important ecological areas of the Lower Clarence River (Soros-Longworth & McKenzie Pty Ltd 1978). The lagoon is an important habitat for migratory waders and commercial fish species (NSW DNR n.d.). The wetlands to the south and west of the lagoon have been noted as "wetlands of outstanding value" by Pressey (1987) due to the occurrence of a perennial herb (*Maundia triglochinoides*) which is listed as a vulnerable species under the *Threatened Species Conservation Act*

1995 (*TSC Act 1995*). Furthermore, the Wooloweyah Lagoon subcatchment has been identified as high conservation value by NSW NPWS and NSW Fisheries (now Department Industry and Investment) due to the very high diversity of wet forest types, very high species diversity among endangered and vulnerable species listed on the *TSC Act 1995*, and high aquatic species diversity (NSW DLWC 1999).

The southern, eastern and north-western foreshore of Wooloweyah Lagoon is designated as a SEPP 14 Wetland (*EP&A Act 1979*; NSW DLWC 1999; Tulau 1999) (Figure 2.4) and the lagoon is listed on the 'Directory of Important Wetlands in Australia' (Environment Australia 2001) as it fulfils the following criteria:

- it is a good example of a wetland type occurring within a biogeographic region in Australia;
- it is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides refuge when adverse conditions, such as drought, prevail and;
- the wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.

Environment Australia (2001) classifies the lagoon as having the following environs:

- Subtidal aquatic beds – includes kelp beds, seagrass and tropical marine meadows.
- Estuarine waters – permanent waters of estuaries and estuarine systems of deltas.
- Intertidal marshes – includes saltmarshes, salt meadows, saltings, raised saltmarshes and tidal brackish and freshwater marshes.
- Intertidal forested wetlands – includes mangrove swamps, nipa swamps and tidal freshwater swamp forests.

The Wooloweyah Lagoon catchment contains a number of habitats listed as threatened ecological communities under the *TSC Act 1995* and the *Environment Protection and Biodiversity Conservation* (*EP&BC*) *Act 1999*. This includes coastal saltmarsh (Figure 2.4), swamp oak floodplain forest, freshwater wetlands on coastal floodplains, swamp sclerophyll forest on coastal floodplains, sub-tropical eucalypt forest on coastal floodplains, coastal vine thicket, stands of coastal cypress pine, and littoral rainforest and coastal vine thickets of eastern Australia. Seagrass (eelgrass (*Zostera* spp.) and paddleweed (*Halophila* spp.) has been mapped in the north-eastern shallows of Wooloweyah Lagoon and in isolated stands in Oyster and Shallow Channel (NSW DPI 2006a) (Figure 2.4), and is protected under the *Fisheries Management Act 1994*. Mangroves (predominantly Grey Mangrove *Avicennia marina* and River Mangrove *Aegiceras corniculatum*) have been mapped along the western and southern shores of the lagoon and also along Palmers, Micalo/Shallow and Oyster Channels (Figure 2.4), and are protected under the *Fisheries Management Act 1994*. The northern and western areas of the Wooloweyah Lagoon catchment have been identified by DECCW (2009) as a regional corridor linking Yuraygir National Park in the east to vegetated areas around Gulmarrad. This area is also currently being investigated as a corridor link as part of CVC's draft Biodiversity Management Plan (in prep.).

The Lower Clarence River estuary is significant waterbird habitat, it is the third most important wader habitat in NSW and has the highest known species diversity (Australian Heritage Commission 1999; Woodhouse 2001). Priority roost and foraging sites within the Wooloweyah Lagoon catchment are Joss Island, Oyster Channel/Wooloweyah Entrance (medium priority), Palmers Island at the Palmers Channel/Wooloweyah entrance (low priority), Micalo Island North (medium priority) and the Micalo Island prawn farm (high priority) (Rohweder 2006; Rohweder in prep.). A number of species listed on the *TSC Act 1995* and under the *EP&BC Act 1999* (the international bilateral Migratory Bird Agreements of JAMBA, CAMBA and RoKAMBA) have been recorded within the Wooloweyah Lagoon catchment, and some of the species are listed below (Environment Australia 2001).

Threatened Species Conservation Act 1995

- Black-necked Stork (*Ephippiorhynchus asiaticus*)
- Osprey (*Pandion haliaetus*)
- Brolga (*Grus rubicundus*)
- Great Knot (*Calidris tenuirostris*)
- Broad-billed Sandpiper (*Limicolu falcinellus*)
- Black-tailed Godwit (*Limosa limosa*)
- Terek Sandpiper (*Xenus cinereus*)
- Pied Oystercatcher (*Haematopus longirostris*)
- Lesser Sand plover (*Charadrius mongolus*)
- Glossy Black Cockatoo (*Calyptorhynchus lathami*)

JAMBA, CAMBA and RoKAMBA (under the *EP&BC Act 1999*)

- Great Egret (*Ardea alba*)
- Glossy Ibis (*Plegadis falcinellus*)
- White-bellied Sea-eagle (*Haliaeetus leucogaster*)
- Sharp-tailed Sandpiper (*Calidris acuminata*)
- Red Knot (*Calidris canutus*)
- Curlew Sandpiper (*Calidris ferruginea*)
- Red-necked Stint (*Calidris ruficollis*)
- Grey-tailed Tattler (*Heteroscelus brevipes*)
- Bar-tailed Godwit (*Limosa lapponica*)
- Eastern Curlew (*Numenius madagascariensis*)
- Whimbrel (*Numenius phaeopus*)
- Common Greenshank (*Tringa nebularia*)
- Marsh Sandpiper (*Tringa stagnatilis*)
- Black-winged Stilt (*Himanotopus himanotopus*)
- White-winged Black Tern (*Chlidonias leucopterus*)
- Caspian Tern (*Sterna caspia*)
- Common Tern (*Sterna nilotica*)

2.4 Current Condition

2.4.1 Tidal Hydraulics

Due to the morphology, length and storage of the adjoining channels, the tidal hydraulics of Wooloweyah Lagoon is often independent of the Clarence River (Lancaster 1990). The tidal prism of the lagoon is about 7% of the total tidal prism entering the Clarence River estuary, of which 85% is supplied by Oyster Channel and 15% by Palmers Channel (Soros-Longworth & McKenzie Pty Ltd 1978). Shallow Channel was re-opened to tidal flows in June 2008 and may have increased the percentage of the total river tidal prism which the lagoon receives. The causeway was replaced with a double-cell box culvert, with each culvert measuring 4200 x 900 mm. This structure allows the greatest volume of tidal exchange and maximum fish passage without requiring the road height to be raised.

The lagoon is flushed predominantly via Oyster Channel, although the longer ebb tide of Palmers Channel is an important means of water release and thus flushing of the lagoon (Winders, Barlow & Morrison Pty Ltd 1987; Lancaster 1990). There is a 1.2 hour delay in flood tide from Oyster Channel to Palmers Channel which results in inflow at Oyster Channel, changing the direction of currents in the lagoon towards Palmers Channel and thus increasing its outflow (Lancaster 1990). Hydrological studies conducted prior to the re-opening of Shallow Channel determined that Micalo/Shallow Channel had a

three hour flood tide and nine hour ebb tide, and flows were considered negligible in the flushing of the lagoon (Dawson 1997). No hydraulic studies have been undertaken since the re-opening of Shallow Channel and therefore, it is unknown if flows through Micalo/Shallow Channel are still considered negligible in the flushing of the lagoon.

The flushing rate of Wooloweyah Lagoon has been estimated at 16.3% per tidal cycle, and would take 11-20 days (22-40 tidal cycles) to remove 99% of a potential pollutant (Lancaster 1990). Flushing would be greatest in the lagoon near the three channels and poorest in parts of the lagoon furthest from the channels (Soros-Longworth & McKenzie Pty Ltd 1978). The lagoon is rarely completely flushed due to its morphology and smaller freshwater inflows in comparison to tidal flows (MHL 2000). The reduced flushing of the southern part of the lagoon has the potential to increase the effect of runoff from agriculture, with the major source being via the Taloumbi Drainage network.

An investigation of sedimentation rates within the lagoon, in combination with anecdotal evidence, indicates that Wooloweyah Lagoon is gradually infilling. Previous estimates of the rate of infill were approximately 0.1 cm yr^{-1} (NSW DPWS 1999a), although current evidence indicates the rate could be between 0.4 cm yr^{-1} (in the northeast) and 3 cm yr^{-1} (in the south) (ANSTO 2009). Associated with the higher sedimentation rate is the possibility of reduced flushing potential of the lagoon, and therefore increased nutrient loads within the southern region. Reduced environmental flows can have a significant impact on seagrass habitats, fish and prawns, and thus have flow-on effects to the fishing industry.

2.4.2 Water Quality

As part of a 12-month condition assessment of the Wooloweyah Lagoon catchment, water quality within the lagoon, channels, drains and creeks was monitored (see Appendix A). This was to provide comprehensive information on water quality during 2008/2009, and also to examine the quality of runoff from the catchment after rainfall events. Monthly water samples were collected from a number of sites within the lagoon, Palmers Channel, Micalo/Shallow Channel and Oyster Channel. Rainfall event-based monitoring locations were also established in the major drains and creeks in the north and along the eastern shore of the lagoon. Sediment nutrient analysis at all monitoring locations was also conducted every 3 months. The most significant water quality issues were found to be turbidity and nutrients. Below is a summary of the key findings of the condition assessment (White 2009a). See Appendix A for the full report on the assessment.

Turbidity within the lagoon is a function of many factors, including wind speed and direction, wave action, sediment type, and runoff. Continuous monitoring of turbidity did not show any evidence of trawling significantly increasing long-term turbidity loads within the lagoon. However, a water sample collected from behind a working trawler indicated that there may be short-term increases in turbidity. Wind appeared to have more of an impact on lagoon turbidity, maintaining increased turbidity of the water column over periods of hours to days. Turbidity in runoff water was similar between National Park creeks and cane drains during low-rainfall periods, indicating that some areas of the Wooloweyah Lagoon catchment may have increased erosion potential, and thus broad statements about the contribution of different land uses to turbidity in the lagoon system cannot be made.

Nutrient concentrations were generally highest in Palmers Channel, Carrs Drain and Middle Road Drain (which discharge into Palmers Channel). Within the lagoon itself, concentrations of nutrients were variable. Total phosphorus, orthophosphate and nitrate predominantly below the HRC (1999) guideline, in contrast to total nitrogen, ammonia and nitrite which were often above the HRC (1999) guideline (see Section 3.2). Chlorophyll-*a* concentrations at the majority of sites were predominantly above the HRC (1999) guideline, with the highest concentrations also generally in the southern region of the lagoon.

However, no algal blooms were observed during the condition assessment. Increased concentrations of nutrients in Palmers Channel and the southern region of Wooloweyah Lagoon may be related to poorer flushing of these areas.

Nutrient concentrations in the northern creek, which is believed to be a surface water overflow path from the wetland which Yamba STP pumps treated sewage into, were often higher than those recorded in the National Park creeks. However, the amount of water discharge from this creek, in comparison to the size of the lagoon, and the increased tidal flushing of the northern region of the lagoon (relative to other regions within the catchment), suggests that the nutrient contributions from the northern creek are negligible. Turbidity values exceeding the recommended HRC (1999) maximum of 25 NTU were often recorded in Carrs Drain and creeks located within Yuraygir National Park.

Sediment nutrient concentrations were variable between sites, although the drains generally had the highest average concentrations. Sediment total nutrients were also high within Palmers Channel, Shallow Channel and the southern region of the lagoon. In Palmers Channel, increased turbidity may be associated with bank erosion, which is an ongoing problem in the channel, although the elevated turbidity of Middle Road Drain and Carrs Drain may also have been contributing to the high levels in Palmers Channel. The correspondence between higher concentrations of nutrients in sediments and the water column within the southern region of the lagoon and Palmers Channel, suggests that at least some of the nutrient load in the water is related to the high nutrient sediment load. However, there was no correlation between turbidity and nutrient concentrations during either high-runoff periods or normal conditions.

2.4.3 Habitats and Ecology

As previously discussed, the management area supports saltmarsh, swamp oak floodplain forest, and freshwater wetlands on coastal floodplains, which are all listed as EECs. Furthermore, the management area also contains stands of mangroves and areas of seagrass. While extensive areas of mangrove and saltmarsh have been mapped throughout the catchment, field observations found that the density of the vegetation is often quite sparse and not indicative of a healthy habitat. This is especially the case for the mangroves along the western shore of the lagoon, between Palmers Channel and Radial Drain #2. As a result of the lack of riparian vegetation, there has been considerable erosion of the western shore. To reduce erosion and encourage sedimentation and re-establishment of mangroves, a series of rock fillets have been placed along the shoreline. These appear to be working well, with a large amount of sediment built up behind the fillets.

Seagrass has also been mapped within Wooloweyah Lagoon, providing an important habitat for prawns and many finfish species. While the cover is quite low in the lagoon (0.15 km^2, or 0.7% of the total cover in the Clarence Estuary), prawns and swans have been observed within the seagrass areas. It is estimated that there was up to an 80% decline in seagrass cover within the Clarence estuary between 1940 and 1986 (Umwelt 2003), and a decline of 46-52% between 1983 and 2004 (Williams *et al.* 2006). Changes in seagrass distribution (location and extent) within Wooloweyah Lagoon are unknown. If any changes in seagrass cover within Wooloweyah Lagoon have occurred, these are most likely due to a combination of factors, including natural growth cycles, (historic) prawn trawling, increased turbidity (HRC 1999), or potentially reduced flushing of the lagoon (and the associated increase in nutrient concentrations; see Section 2.4.2).

The majority of the eastern side of the management area is designated as national park, and therefore is managed by DECCW (National Parks and Wildlife Service) under the *Yuraygir National Park and Yuraygir State Conservation Area Plan of Management 2003*. The national park is predominantly dry

sclerophyll forest and woodland, wet and dry heathland (Lancaster 1990), graminoid clay heathland, swamp sclerophyll forest and sedgeland (Griffith 1984).

2.4.4 Economic Resources

There are number of industries which are valuable economic resources within the management area. The main industries are commercial fishing, sugar cane farming and cattle grazing. The value of these resources is discussed below, and the potential impacts to the environmental values of the management area are discussed in Section 2.5.

2.4.4.1 Commercial Fishing

The Clarence River Fishery accounts for approximately 23% of the total estuarine commercial catch for NSW and is the leading district in terms of catch value (NSW Fisheries 2001). The lagoon is the most significant fishery nursery ground within the whole Clarence River system (Planners North 1991; WetlandCare Australia 2002) and is one of the more important sources of Eastern School Prawn (*Metapenaeus macleayi*) (NSW PWD 1985) and the Eastern King Prawn (*Penaeus plebejus*) (Soros-Longworth & McKenzie Pty Ltd 1980). Approximately 40% of the estuary school prawn catch from the Clarence River comes directly from Wooloweyah Lagoon (J. Harrison pers. comm. July 2009 [1]). Other major species which are commercially fished from the lagoon include finfish (e.g. mullet, flathead, whiting, bream; approximately 40% of total catch is from the lagoon [2]) blue swimmer crabs, mud crabs (approximately 60% of the total catch) and eels.

There are currently 104 endorsements issued by NSW Fisheries for the Clarence River Estuary Prawn Trawl Fishery (J. Harrison pers. comm. July 2009). However, not all licenced fishing boats (LFBs) actually trawl in the lagoon due to restricted access through Palmers Channel caused by sedimentation (see Section 3.1, Table 3.1). Recent data provided by Industry and Investment NSW indicates that between 40 and 50 trawlers operate in Wooloweyah Lagoon over the trawling season. Wooloweyah Lagoon is open for trawling from the first Tuesday nearest 1st October to the Friday nearest 31st May excluding weekends and public holidays, and the season may be extended by up to 15 working days subject to the availability of prawns. The Clarence River is not open to trawling until December, and as such Wooloweyah Lagoon is of considerable economic importance to the commercial fishing industry, particularly during the months of October and November.

The worth of the commercial fishing industry on Wooloweyah Lagoon is variable, depending on where the data is sourced and literature cited (Woodhouse 2001). This is generally due to catch values being calculated with different techniques. Data provided by Industry and Investment NSW reports the value at first point of sale, while information from the Clarence River Fishermen's Cooperative (CRFC) is the result of a formula to calculate a value to better represent the worth of the fishery. The total catch and catch value (at first point of sale) of the commercial fishery (Estuary General and Estuary Prawn Trawl, Wooloweyah Lagoon) has generally been increasing since 2002/03 (Table 2.3). In 2006/07 and 2007/08 the fishery was valued at more than $1.2 million (Table 2.3). This equates to a worth of approximately $3.5 million per annum (school prawn fishery at $2.2 million, finfish fishery at $700 000, mud crab fishery at $600 000) (J. Harrison pers. comm. July 2009, reported by the CRFC). It is important to note, however, that catch tonnage and value varies annually due to a number of factors including floods, droughts, and the economic climate.

[1] Data sourced from Clarence River Fishermen's Cooperative (CRFC) and commercial fishers.
[2] Excludes catch from the lagoon weighed in at the CRFC Iluka factory and also catch from non-CRFC members.

Table 2.3: Total crustacean and finfish catch from Wooloweyah Lagoon, with catch value (at first point of sale) for each financial year also indicated. Values in parenthesis are for crustacean species only. Data sourced from Industry and Investment NSW.

Financial Year	Catch (tonnes)	Estimated Value (at first point of sale) in $'000
1999/00	66.2 (60.2)	$447 ($435)
2000/01	94.5 (70.7)	$617 ($569)
2001/02	123.9 (115.8)	$922 ($899)
2002/03	69.6 (57.9)	$674 ($625)
2003/04	92.6 (80.9)	$697 ($660)
2004/05	130.8 (98.6)	$672 ($578)
2005/06	149.7 (93.0)	$971 ($742)
2006/07	195.7 (162.6)	$1,404 ($1,252)
2007/08	207.0 (154.2)	$1,213 ($977)

The commercial fishing industry is also a valuable economic resource in terms of income and employment in the region. The commercial fishing industry (for the whole Clarence Estuary) supports 370 jobs directly and many more indirectly, and generates approximately $27 million each year (CVC 2006).

2.4.4.2 Sugar Cane

Sugar cane is the most important land use on the Clarence River floodplain (Soros-Longworth & McKenzie Pty Ltd *et al.* 1980) and contributes $103 million to the local economy per annum, while the industry supports approximately 1000 jobs (CVC 2008). The Harwood mill crushed 623 662 tonnes of cane in 2008, 791 811 tonnes in 2007, and 887 735 tonnes in 2006. The number of tonnes of cane crushed in the 2008 was lower than average due to severe frosts and floods prior to the season starting (www.nswsugar.com.au). On average, the Harwood mill crushes 780 000 tonnes of cane harvested from 12 000 ha, producing 92 000 tonnes of raw sugar (www.nswsugar.com.au). Based on these values and estimated raw sugar prices (www.canegrowers.com.au), the 2008 harvest could be valued at approximately $23.9 million.

The value of the cane industry for the Wooloweyah Lagoon catchment was calculated by Woodhouse (2001) based on various data sources. It was estimated that there is 2700 ha of sugar cane plantations in the Wooloweyah Lagoon catchment, worth approximately $2.7 million to the local economy (plus flow-on effects).

2.4.4.3 Grazing

In 2000 there was approximately 4000 ha of grazing and grassland in the Wooloweyah Lagoon catchment (Woodhouse 2001). This was valued at approximately $273 600 in beef cattle production to the local economy (plus flow-on effects). However, there has been a decline in the beef cattle industry over the last few years, at both the local and industry scales (CVC 2008). This is attributed to a number

of factors, including increased transport costs, changing use of land and stagnant sale prices (CVC 2008).

2.4.5 Wastewater Management

The Yamba Sewage Treatment Plant (STP), which serves Yamba, West Yamba, Angourie and Wooloweyah village, has discharged tertiary treated sewage effluent into a 50 ha wetland (dunal swamp forest), located south of Yamba and immediately north-east of Wooloweyah Lagoon, since 1970 (Woodhouse 2001). During periods of overflow effluent may reach the lagoon via surface and groundwater flows (NSW PWD 1991; NSW DPWS 1998). The MHL (1999) noted mounding of groundwater at the Yamba STP and during wet periods treated effluent entering the groundwater system may also become surface water flows which can flow at a greater capacity than groundwater to the lagoon.

The primary pollutants in the treated effluent include nutrients (phosphorus and nitrogen) and biological contaminants, although other contaminants such as heavy metals and organic compounds are also present (MHL 1999). It is difficult to estimate the load actually reaching the lagoon as the surface flow paths are not well defined and detailed nutrient measurements are not available (Woodhouse 2001). However, it has been suggested that this is not a significant source to the lagoon because the flows only occur during wet weather when there would be considerable dilution, and nutrient uptake by the macrophytes within the wetland would also substantially reduce the nutrient concentration (MHL 1999). The apparent low permeability (31 mm day^{-1}) of the subsurface silty-clayey soils also suggests that subsurface flow is minimal (MHL 1999). Given these factors, Woodhouse (2001) assumed that the STP contribution to Wooloweyah Lagoon was negligible. The condition assessment of the lagoon (White in prep.) indicated that there were higher than recommended (ANZECC 2000) nutrient loads entering the lagoon via an identified surface water flow path from the STP (NSW DPWS 1999b).

While the current disposal method was deemed satisfactory in 1991, population growth within the area would have increased outflow levels to the wetland since the NSW PWD (1991), NSW DPWS (1998) and MHL (1999) studies. The elevated soil moisture and nutrients are encouraging the growth of ground cover species not normally associated with the undergrowth of dunal swamp forests, and there is a decline in health of mature *Melaleuca quinquinervia* trees in the north-west corner of the wetland (Shortland Wetland Centre 1999).

Future impacts from sewage will most likely be reduced with augmentation of the STP. The augmentation will involve increasing the use of recycled water for irrigation, and recycled water which cannot be used will be released through ebb tide discharge into the Clarence River (Sinclair Knight Merz 2005). The disposal of recycled water into the woodlands/wetlands will also cease. Planned completion date for the Yamba STP augmentation is late 2010/early 2011 (Greg Mashiah, pers. comm. 30 June 2008). Final designs for the ebb-tide release are still being finalised at present.

On-site wastewater systems may also have impacts to the surrounding environment, through seepage into groundwater or runoff into surface water, which may then affect vegetation and/or water quality in nearby creeks/drains and/or the lagoon. Seepage into waterways also presents a potential risk to public health. A number of constraints to sustainable management of effluent on-site have been identified and include: poor design, poor maintenance, and small lot sizes in poor soil (CVC 2005). Future development in areas that are not connected to sewer increases the risk of environmental pollution through potential leakage of on-site waste systems.

2.4.6 Flood Mitigation Works

The Taloumbi Ring Levee extends along the western edge of Wooloweyah Lagoon from Palmers Channel to high ground at the south-eastern corner (Soros-Longworth & McKenzie Pty Ltd 1978; NSW PWD 1991). Immediately to the west of the levee is a major perimeter drain, the Taloumbi Ring Drain, which is approximately 8.5 km long. The Ring drain receives drainage from four major radial drains (Taloumbi Radial Drains #1-4) and discharges into Palmers Channel at its northern end and into Wooloweyah Lagoon at the intersection with each Radial drain. Taloumbi Radial Drain #5 is not linked to the Ring drain and discharges directly into Wooloweyah Lagoon.

The northern end of Palmers Channel also receives drainage water from two other floodgated drainage systems on the western flats. On Palmers Island there are nine major floodgated drains, including a number of major drainage lines which have been 'improved' and floodgates (Woodhouse 2001). A levee and drainage system extends along the western margin of Micalo/Shallow Channel.

Flood mitigation works have provided a number of benefits for agriculture, mainly increasing available land and increased removal of floodwaters. However, associated with this have been a number of impacts on the environment, including:

- increasing the quantity and rate of runoff;
- draining of wetlands and loss of habitat, including saltmarsh;
- conversion of brackish wetlands to freshwater wetlands;
- alienation of estuarine habitat;
- change/reduction of habitat and associated fauna assemblages;
- barriers to fish passage and habitat migration (due to sea level rise); and,
- a lowering of the water table which has exposed and may potentially expose more acid sulfate soils, contributing to poor discharge water quality.

The conversion of floodplain vegetation from species able to tolerate inundation in floods, to primarily dryland species, has resulted in poor quality discharge water after high rainfall (due to low dissolved oxygen concentrations from decaying vegetation).

2.4.7 Urban/Tourism Development

As the population continues to grow in the lagoon catchment area, pressures increase on all natural resources. Some of these pressures include increased demand for land and recreational areas, and increased clearing and waste generation (Woodhouse 2001).

Urban development in the Wooloweyah Lagoon catchment has had, and continues to impact the lagoon. Urban stormwater pollution to the lagoon includes nutrient and heavy metals, sourced from rooves, paved areas, streets, house gardens, nature strips and parks. However, it is difficult to estimate diffuse loads as there is a lack of data in the inflow drains (MHL 2000).

The Wooloweyah Foreshore Reserve Plan of Management (Smyth, Maher & Associates Pty Ltd 1999) noted that there is a need to improve existing stormwater drainage from Wooloweyah village into the Wooloweyah Foreshore Reserve. The recommendation included the installation of gross pollutant traps at the outlets of all stormwater drains located in the reserve.

There are four main canal developments in Yamba – Crystal Waters, Oyster Cove, Yamba Keys and Yamba Shores. These were all approved prior to 1997 when SEPP No. 50 (Canal Estates) was

introduced, which bans new canal estates to assist in protecting aquatic environments. Canal estates can impact on the health of the channels adjoining the lagoon through:

- direct loss of wetland habitats and other sensitive aquatic systems;
- poor water quality and sedimentation due to inadequate hydraulic flushing of some canals, exacerbated by stormwater runoff from residential areas and foreshore erosion caused by boat wash; and,
- discharge of acidic water due to disturbance of acid sulfate soils (HRC 1999).

There is potential for development of West Yamba in the near future, which would increase residential pressures to the Wooloweyah Lagoon catchment. The Draft LEP went on public exhibition in 2006 and has not been implemented as yet, and it is still uncertain whether the development will proceed (Webb, McKeown & Associates Pty Ltd 2009). Council has recommended the rezoning of West Yamba to proceed, and is currently being reviewed by the Minister of Planning. Approximately 150 ha of the land is proposed for development (SMH 2009), however, a significant amount of fill will be required to ensure housing is above projected maximum flood level. This suburb has a projected population of 2000-2500 (Maclean LEP 2001, West Yamba Amendment). Impacts of development in West Yamba include increased stormwater, nutrient and sediment inputs to Oyster Channel, and potentially increased recreational pressure on fisheries.

Other impacts of urban and tourism development include recreational impacts (e.g. trampling or siltation of seagrass) and increased runoff due to clearing (Lancaster 1990). Yamba is very dependent on the seasonal tourism industry, however, the lagoon itself is not a major tourism destination and has limited recreational potential due to the shallow depth and navigational hazards (Lancaster 1990). The main form of recreation is fishing, but may also include, canoeing, boating and sailing, while sightseeing, bird watching, bushwalking and picnicking regularly occur on the foreshore (Lancaster 1990).

2.4.8 Acid Sulfate Soils

Acid sulfate soils (ASS) occur naturally throughout many coastal and inland areas, with coastal ASS forming during the last sea level rise (10 000 years before present). The lower estuary floodplain and islands of the Clarence River (including Wooloweyah Lagoon and Oyster, Micalo and Palmers Channels) were identified by Tulau (1999) as a Priority ASS Management Area. While some actual ASS (AASS) has been indentified in the Wooloweyah Lagoon catchment, potential ASS (PASS) material is more dominant and is generally present 1-2 m below the surface. Widespread exposure and oxidation of ASS on western Micalo Island has been reported (Tulau 1999). Acid sulfate soils were exposed on Palmers Island and in the Taloumbi drainage network during the 2002 drought, however, no significant acid discharge was recorded during subsequent rainfall (Davison & Wilson 2003). Similarly, the recent condition assessment of Wooloweyah Lagoon (White 2009a; Appendix) did not record any significant acid discharge over a 12-month period in 2008/2009 (pH of all waterways monitored remaining above 5) and a study by White (2009b) only recorded a minimum pH of 6.5 within the Taloumbi Drainage network. The decrease in pH after rainfall did indicate that some acidic water was entering the system, and the study by White (2009b) indicated that concentrations of aluminium, iron and manganese (products of ASS oxidation) were high within the groundwater on the western flats of the lagoon. However, both Davison and Wilson (2003) and White (2009b) determined that drain water pH was not affected by the mildly acidic groundwater.

The main risk associated with ASS in the management area is the potential disturbance of PASS. This may result in acidification of soils and water, decreased water quality (relating to increased metal concentrations), a reduction in agricultural productivity, loss of habitat and a degradation of vegetation (Tulau 1999). Active management of floodgates (i.e. opening gates during non-flood periods and neap

tides) on drainage systems in agricultural areas can help to reduce the potential exposure of ASS and reduce acidification of groundwater and drain water (Davison & Wilson 2003) by maintaining the water level above maximum low tide. Furthermore, opening the floodgates and/or installing tidal gates improve water quality by flushing the drains and reducing the build-up of nutrients, improve fish passage, reduce weeds (Johnston et al. 2003). Increased active management over recent years is most likely contributing to reduced ASS oxidation and the improvement in water quality in contrast to that reported in studies from the early 1990's (see Warren 1991, Bowman 1991, and Planners North 1991 cited in Woodhouse 2001: 54-55). While many of the management strategies implemented since the Tulau (1999) report, current evidence of ASS oxidation products still being transported into drains and groundwater suggests that on-going management is required to maintain and/or improve water quality.

2.5 Current Uses

2.5.1 Land Use

Based on percent area of land, the major land uses are: cattle grazing (55%); sugar cane growing (24%), national parks and reserves (19%); and urban development (3%) (Foley & White 2007). While aquaculture facilities take up a small proportion of land within the catchment, it has not been included in the above figures. Accordingly, the majority of the Wooloweyah Lagoon catchment is zoned as rural under the Maclean LEP (Figure 2.5). Under the draft Clarence Valley LEP (CV LEP) zoning of Wooloweyah Lagoon will be revised from '1 (w) Rural Waterway' (Maclean LEP) to 'W1 Natural Waterway'. This zoning acknowledges the lagoon's ecological, scenic and recreational value and will assist in protection of aquatic habitat and regulate commercial and recreational activities to prevent adverse effects on the natural value of the waterway. National park and environmental protection LEP zones cover the second largest area of land in the catchment, and the environmental protection zoning of the southwestern lagoon foreshore has been maintained in the draft Clarence Valley LEP.

The village of Wooloweyah is the closest town to the lagoon, and Angourie Rainforest Resort, an eco-tourist resort, is located to the east of the lagoon. The northern end of Oyster Channel is affected by increasing housing and tourism development, particularly relating to the potential development of West Yamba (see Section 2.4.7). During peak holiday periods the total population of Yamba may increase three-fold (Soros-Longworth & McKenzie Pty Ltd 1978). The shallow depth of the lagoon and general inaccessibility by boat reduces the potential for this area to become a significant recreational site, and thereby protects the lagoon's valuable habitats (Lancaster 1990). However, increased housing development within the catchment increases the potential amount and effect of stormwater runoff on the lagoon. Other development pressures include rural-residential properties in the Gulmarrad region, in the southwest of the catchment. The pressures associated with development within the catchment are different between development types, i.e. increased stormwater is associated with town urbanisation and on-site sewage management is associated with rural-residential development.

The agricultural development within the catchment has had a number of impacts on the management area. Extensive clearing has occurred throughout the catchment for sugar cane production and grazing, and associated with this is increased erosion and sedimentation. Impacts of cattle grazing may include the introduction of exotic grasses, increased nutrients in drainage waters due to increased manure, loss of estuarine habitat, and trampling/pugging which severely impacts upon saltmarsh and provides ideal habitat for midge and mosquito breeding (McPherson 1992). Sugar cane farming may increase nutrients in drainage waters through fertiliser use, and drainage due to flood mitigation works (drains, levees, floodgates) has increased the rate of runoff and can lead to oxidation of ASS. The impacts of these flood mitigation works are listed in Section 2.4.6 and discussed in detail in Woodhouse (2001), while the issues of ASS are discussed in Section 2.4.8.

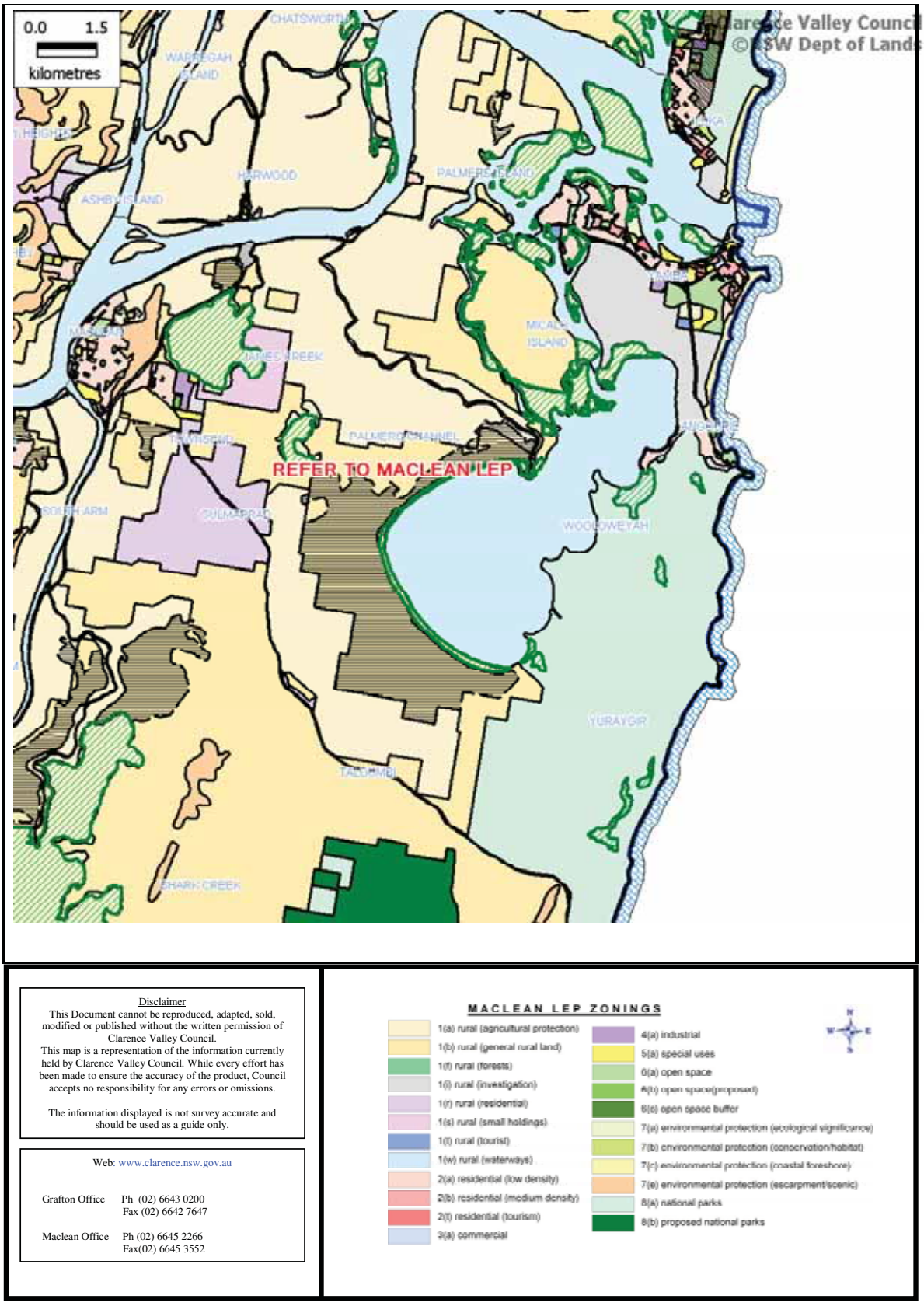

Figure 2.5: Maclean LEP zoning map of Wooloweyah Lagoon catchment.

2.5.1.1 Erosion and sediment transport

Soil loss from the catchment is a function of a number of factors, and is highly dependent on land use and soil type. Average annual soil loss from sheet and rill erosion can be predicted with the Revised Universal Soil Loss Equation (RUSLE) (Wischmeier & Smith 1978):

$$A = R * K * LS * P * C$$

where A = computed soil loss in tonnes ha^{-1} yr^{-1}
R = rainfall erosivity factor
K = soil erodibility factor
LS = slope length/gradient factor
P = erosion control practice
C = ground cover and management factor

The rainfall erosivity factor (R) is a measure of the ability of rainfall to cause erosion, and in the Wooloweyah catchment is between 3500 and 4000 (Landcom 2004). The soil erodibility factor (K) is affected by soil texture, structure and organic matter and ranges from very low (≤ 0.01) to very high (≥ 0.06) (Simms *et al.* 2003).

The LS factor represents the topography of the land, with ratios defined as (Landcom 2004):

- Low – undisturbed grazing/pasture lands with good cover.
- Moderate – moderately consolidated crop lands with little to moderate cover.
- High – highly disturbed lands with little or no cover.

The erosion control practice factor (P) is usually applied to disturbed lands, and is the ratio of soil loss with a specified surface condition ploughed up and down the slope (Simms *et al.* 2003; Landcom 2004). The C factor is the ratio of soil loss from land maintained under specified crop or mulch conditions to the corresponding loss from continuously tilled bare soil (Landcom 2004). This factor effectively measures the combined effect of all interrelated vegetative cover and management variables (Simms *et al.* 2003).

While the RUSLE predicts annual soil loss, it does not indicate the seasonal variability associated with crops. Sediment transport would potentially be greatest after harvest when the land is clear of vegetation. Different types of vegetation will also have different stabilisation abilities in terms of absorbing raindrop impact, reducing the volume and velocity of runoff, soil binding capabilities, and protection from wind erosion (Landcom 2004). Based on land use, forests have the least amount of soil loss, followed by pasture and then cultivation (Landcom 2004). Evidence from the Wooloweyah Lagoon Condition Assessment suggests that the types of sediments found in the catchment may have a strong influence on the erosion potential, and also the potential turbidity of runoff and receiving waters. For example, nutrients bind more readily to fine sediments, and fine sediments also remain suspended in water for longer than larger particles, thus increasing turbidity (Landcom 2004). Monitoring of creeks in the National Park showed that runoff water during small rainfall events had a turbidity which was comparable to that recorded in Carrs Drain and Middle Road Drain (agricultural areas).

2.5.1.2 Nutrients

Excess nutrients are available from a number of sources within the Wooloweyah Lagoon catchment, including surface runoff and sediments. Monitoring of water quality within the catchment (see White 2009a; Appendix A) indicated that the drains had higher nutrient concentrations than the creeks in the National Park. The creek at the northern end of the lagoon (a surface overflow pathway for sewage from

Yamba STP) also had higher concentrations of nutrients than the National Park. The major point source of nutrients (total phosphorous and total nitrogen) to Wooloweyah Lagoon and adjacent waterways was Carrs Drain and Middle Road Drain (White 2009a; Appendix A). Within the lagoon and channels, total nutrients were generally highest in the southern region of the lagoon. Therefore, evidence of high nutrient concentrations in 'pristine' waterways, along with very high concentrations within the sediments, indicates that Wooloweyah Lagoon may naturally have increased nutrient concentrations. The size of the water body in comparison to the amount of freshwater inflow may mean that the nutrient inputs from the drains and creeks is negligible in comparison to the potential available nutrients from sediment resuspension via wind/wave action. However, the poor flushing of the lagoon and the higher total nutrient loads of the southern region may increase the susceptibility of eutrophication and degradation.

2.5.2 Fishing

The school prawn is the dominant prawn species caught in Wooloweyah Lagoon. A seasonal restriction has been placed on trawling in the lagoon during the winter months (see Section 2.4.4.1), as the prawns are generally small and low in abundance, and thus this aids in protecting stocks and maintaining the sustainability of the fishery (Lancaster 1990). Generally, only the southern region of the lagoon is trawled (an estimated 80-90% of the lagoon) as the northern portion is too shallow (Woodhouse 2001).

While trawling is a valuable industry, there are environmental impacts associated with the industry, primarily sediment disturbance and potential flow-on effects. Trawling is not carried out over seagrass beds in Wooloweyah Lagoon, as the fishermen recognise that this is valuable prawn habitat (J. Harrison pers. comm. 19 Jan 2009), and because of the prohibition of trawling over beds of *Zostera* and *Posidonia* seagrass. However, trawling could still impact seagrass through the localised disturbance of sediments and changes in light attenuation and potential smothering of seagrass, if trawling is conducted near these areas. While there is no evidence of long-term increases in turbidity due to trawling in the lagoon (previously discussed in Section 2.4.2), trawling still results in a significant increase in turbidity at least in the short-term. The disturbance caused by trawling is clearly evident in an aerial photograph of the lagoon (Figure 2.6), and recently a turbidity value of 170 NTU was recorded from the path behind a trawler, at least four times higher than elsewhere in the lagoon during the same sample period. Nevertheless, wind disturbance of sediments in the lagoon can result in a turbidity of more than 200 NTU (see White 2009a; Appendix A). Further research is required to determine the effect of trawling near seagrass habitat, and the relative impact of natural (e.g. wind, climate change) and anthropogenic processes (e.g. trawling, increased sediment and nutrient runoff).

Other forms of commercial fishing within Wooloweyah Lagoon include meshing, crabbing and eeling. Local fishermen have reported that the number of blue swimmer crabs caught over the past two years has been very low. However, the fishery has high annual variability as the success of annual recruitment may be influenced by environmental factors such as water temperature, wind and current conditions, or the amount and timing of rainfall (Sumpton *et al.* 2003; Department of Fisheries 2007). Blue swimmer crab larvae also have a high death rate and are susceptible to predation from fish and jellyfish (Department of Fisheries 2007). Anecdotal evidence from a local resident(J. Mousley pers. comm. 10 June 2009), and from observation in the field, indicates that jellyfish numbers within the lagoon can be high at times, and therefore may be contributing to the fluctuations in numbers of blue swimmer crabs within the lagoon.

Recreational fishing is also a popular pastime within Wooloweyah Lagoon and adjoining channels. Flathead, bream, flounder, mud crab and blue swimmer crab are popular species caught.

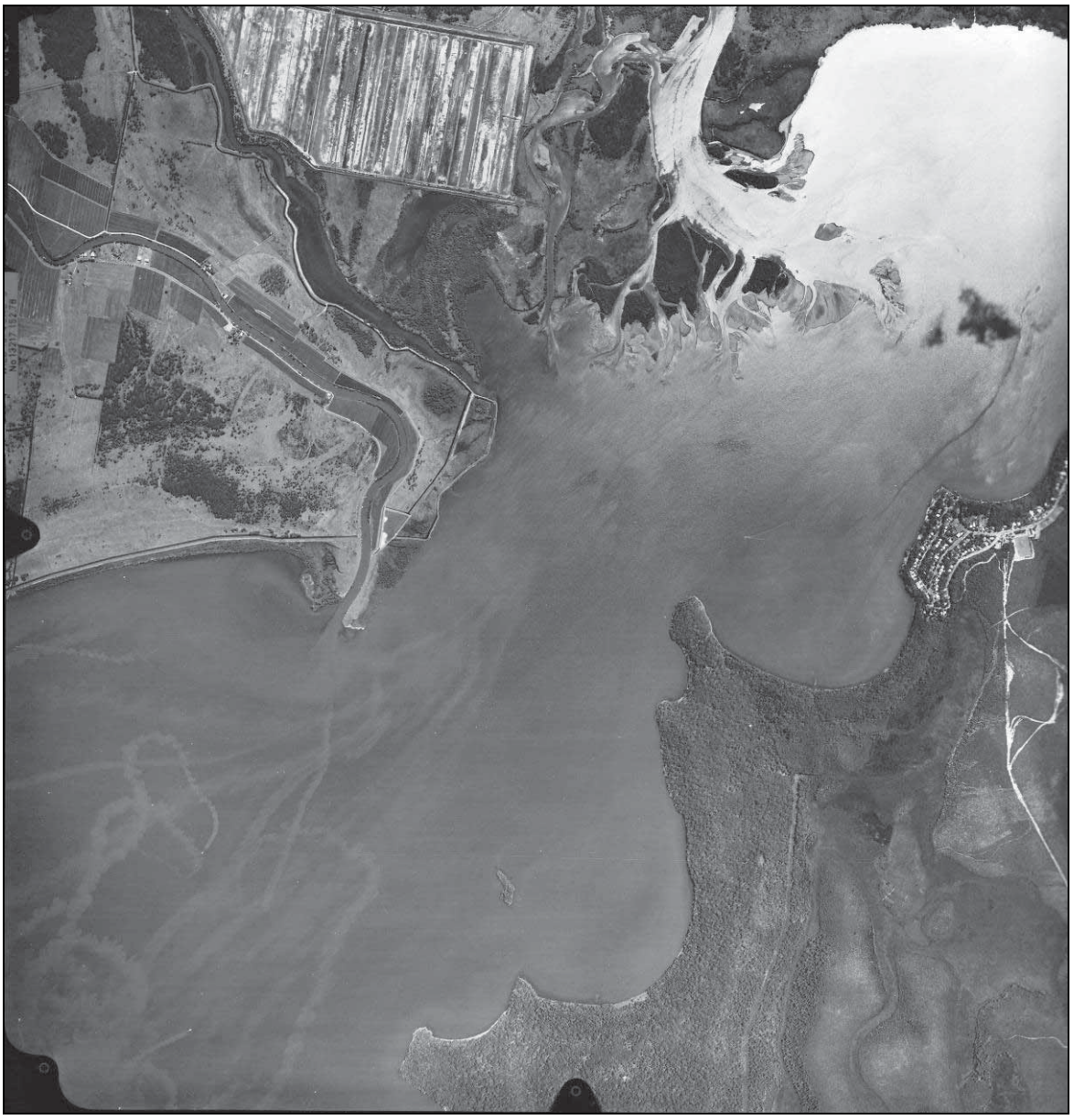

Figure 2.6: Trawlers disturb sediment and may contribute to short-term and isolated increases in turbidity within the lagoon. Trawler tracks can be clearly seen in the lower left corner of the aerial photograph (March 1998).

2.5.3 Recreation

Recreational activities within the Wooloweyah Lagoon catchment are limited to recreational fishing, bushwalking, picnicking, bird watching, and canoeing. Windsurfing was once a popular pastime on the lagoon, however, shallowing of the northeastern region and increased jellyfish numbers have discouraged people from continuing this activity.

3 Strategic Framework

3.1 Management Issues

Key management issues were identified from the *Wooloweyah Lagoon Management Strategy* (Woodhouse 2001), and additional issues were identified through the *Wooloweyah Lagoon Condition Assessment* (White 2009a. Appendix A). The initial list of key management issues was presented to a steering committee, consisting of representatives from local and state government, in December 2008 and other management issues were included. The steering committee met again in March 2009 and June 2009, where additional key management issues were identified and included in the Draft Coastal Zone Management Plan for Wooloweyah Lagoon. The Draft CZMP was also discussed at a meeting of the CF&EP in March 2009.

A number of management issues were identified by Foley and White (2007) relating to the six discrete drainage network management zones on the western flats of the lagoon (Figure 1.1). These issues were mainly related to water quality, reduced fish access and potential overtopping of banks, and are incorporated in Table 3.1.

Further issues/threats relating to the Wooloweyah Lagoon management area were identified by Eco Logical Australia (2008). These issues include urban and rural residential development, increased nutrient and sediment loads, and non-sustainable fishing practices (both recreational and commercial). There are also a number of potential issues relating to climate change. The adopted key management issues in the Wooloweyah Lagoon management area are described in Table 3.1.

Table 3.1 (continued overleaf): Current management issues in the Wooloweyah Lagoon management area.

Management Issue	Description
Future development/land use change	Urban growth, primarily in terms of rural-residential development and sub-divisions at Gulmarrad, and the potential development of West Yamba, may have a number of impacts on the Wooloweyah Lagoon catchment and waterway. Issues include increased clearing and increased sediment, nutrient and pollutant inputs to waterways. Changes in land use from agricultural to rural-residential can change patterns of water flows. There could also be some additional impacts, primarily on native fauna, through increased numbers of domestic pets if there is lack of compliance with the *Companion Animals Act 1998*. Council manages development through the LEP, clearing controls, and on-site sewage plans, among other legislation.
Erosion and sedimentation	Sedimentation of the channels and lagoon is a combination of marine and fluvial deposition, and bank erosion. The large number of flood mitigation drains in the catchment may also be increasing fluvial sedimentation of the waterways. There is anecdotal evidence that the entrances to Palmers and Oyster Channels from Wooloweyah Lagoon are infilling. The sedimentation may be a natural process or could be exacerbated by increased drainage and clearing within the southern and eastern catchment. The main areas with significant bank erosion are Palmers Channel, Oyster Channel and Micalo Channel. It is unclear whether erosion in the channels is caused by boat wake (especially Palmers Channel), wind-wave action, land use (i.e. cattle), natural processes, or a combination of factors. While bank erosion in these channels may be contributing to sedimentation of the channel entrances, sediment cores collected in 2008 indicate that Wooloweyah Lagoon is also infilling from the south (sedimentation rate of 2-3 cm yr^{-1} in comparison to 0.4-0.6 cm yr^{-1} in the north) (ANSTO 2009).
Environmental flows	Sedimentation of Palmers Channel and Oyster Channel may be causing considerable changes to environmental flows in the lagoon system. Restriction of both incoming and out-flowing water could, in the long-term, lead to reduced flushing of the lagoon, and contribute to increased nutrient concentrations in the southern region. The reduced exchange could potentially increase the risk of algal blooms. The issue of environmental flows also relates to floodgates and drains. Restoring environmental flows is mainly achieved by actively managing floodgates (i.e. opening during non-flood periods and neap tides) and installing tidal gates and fish gates, to allow flushing to promote good water quality and fish access.
Navigation	Due to sedimentation of the Palmers Channel entrance to the lagoon, navigation is becoming difficult for commercial trawlers. The

Management Issue	Description
	Palmers Channel delta was dredged regularly in the past which allowed for safe navigation. However, major dredging has not occurred since 1992 (A. Ling pers. comm. 1 July 2008). If trawlers are unable to safely enter the lagoon, then the Estuary Prawn trawl fishery on the Clarence will be impacted.
Fishing	A number of strategies have been implemented by Industry and Investment NSW and the commercial fishing industry to reduce by-catch and the impact of trawling on seagrass communities (see NSW Fisheries 2003a, b). Sedimentation and dredging are closely tied with this issue, as restricted access to the lagoon due to sedimentation of Palmers Channel may force a closure of the lagoon to commercial trawlers. Fishing (commercial and recreational) can have a number of impacts on the environment, including: catching undersize fish; over-harvesting of species; waste such as discarding fishing equipment; contributing to riverbank erosion by motoring at high speeds through narrow channels; motoring through seagrass beds (OceanWatch Australia 2008), and disturbance of shorebirds. A number of regulations are in place to reduce the impacts of fishing however there are still issues associated with fishing within the catchment. Aquaculture does not pose a significant threat to the catchment. Two aquaculture facilities are located within the Wooloweyah Lagoon catchment – Palmers Island (operational but not commercially) and Micalo Island. The Micalo Island ponds have not been operational since 1991, although the licence is still current, and now provide significant wetland habitat.
On-site sewage management	A large area of the catchment still has on-site wastewater management. There is the potential for leakage into groundwater and/or runoff via surface water, which may result in the death of vegetation, pollution to natural waterways, and public health issues.
Water quality	Increased runoff from the catchment due to the large drainage network may be contributing higher amounts of sediment, nutrients and other pollutants to the channels and lagoon. The large agricultural land use of the catchment may also be increasing nutrient loads from the catchment. It is unclear though if increased turbidity of the lagoon is due to trawling, increased sediment inputs, or if it is a naturally highly turbid system due to the long fetch and strong winds. Water quality issues within the drains is mainly related to low DO and increased nutrients, which may lead to algal blooms and growth of aquatic weeds. In some drains saline intrusion to freshwater reaches of drains/modified creeks is also an issue (primarily the Taloumbi Ring Drain and connecting Radial Drains). Acid water discharge is also a potential issue, although active management

Management Issue	Description
	of the floodgates has been shown to reduce acid discharge in this region (Davison & Wilson 2003). The main water quality issues in the lagoon are increased turbidity and nutrients.
Acid sulfate soils	Much of the potential ASS does not pose a significant risk to wetlands or water quality in the management area, unless disturbed. Actual ASS poses a substantial threat, although much of the high risk ASS is under active management via NRCMA, CVC and DECCW funded programs (Eco Logical Australia 2008), or through drain management plans. Active management has appeared to improve drain water quality, although products of ASS oxidation are still present within the area, especially after high rainfall.
Bank condition and riparian vegetation	Land use such as grazing can contribute to bank erosion and degrade riparian vegetation. Other activities which remove riparian vegetation also contribute to bank erosion. The issue of erosion along the north-western shore of Wooloweyah Lagoon has been partially addressed with the placement of rock fillets and rock revetment in 2008 along 850 m of eroding bank. These works also aim to protect and increase existing saltmarsh and mangrove communities. Older rock protections works are present along the northern bank of Palmers Channel near the entrance to the lagoon, although there is little riparian vegetation. Palmers Channel is also a designated 'no wash zone', however, erosion of the banks is still evident and widely thought to be due to boats, although natural processes such as wind-wave action may also be contributing to the erosion. It has been estimated that the replacement/repair cost of bank erosion along Palmers Channel is approximately $20.42 per m^3 of sediment (Zvirbulis 1994 cited in DECC 2004). The replacement/repair cost is the cost to landowners and industry for repair and replacement of the banks.
Sugar cane	A number of improvements in cane growing practices have been implemented within the management area including active drain management, developing and adopting best practice techniques (e.g. *The NSW Sugar Industry Best Practice Guidelines for Acid Sulfate Soils*, *NSW Sugar Industry Farming Code of Practice*), water quality monitoring, and riparian rehabilitation. However, impacts of the industry still include nutrient and sediment runoff, and the associated loss of wetlands due to drainage.
Non-sustainable grazing	Sustainable grazing is an important issue, as overgrazing can compact soils, disturb sediments, increase bank erosion (and thus increase sedimentation of drains, channels and lagoon), contributes to increased nutrient loads through erosion and faecal matter, and pugging can expose acid sulfate soils and reduce the effectiveness of scald rehabilitation. Furthermore, many valuable wetland habitats have been degraded due to drainage for grazing, and areas such as saltmarsh and mangrove forests have reduced revegetation potential due to grazing and trampling of seedlings.

Management Issue	Description
Clearing	Clearing within the catchment reduces biodiversity and can contribute sediments to the waterways, and ultimately contribute to increased sedimentation of the lagoon. The primary contributor is clearing in residential and rural-residential areas, including a number of alleged incidences of illegal clearing in the Gulmarrad area. A range of legislation is enforced by Council, DECCW and NRCMA for clearing, including the *Native Vegetation Act 2003*, tree preservation orders, and erosion and sediment control plans.
Cane toads	Cane toads have recently entered the management area. The cane toad is poisonous at all stages of their lifecycle. The biological effects, including lethal toxic ingestion, caused by cane toads is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*. Under the *Threatened Species Conservation Act* 1995, invasion and establishment of cane toad is listed as a key threatening process. Native animals are impacted through predation and lethal ingestion of cane toad toxin. Declines in faunal biodiversity due to competition with other carnivores for food resources are also a likely impact of cane toads (DEH 2005 cited in NRCMA 2008). The DECC (2008) considers the coastal region from Yamba to Port Macquarie most vulnerable to colonisation by the cane toad.
Climate change	Climate change could potentially reduce the extent of seagrass habitat due to increasing sea level (decreasing potential habitat) and storm intensity (increasing turbidity within the lagoon). A rise in sea level (predicted rise of 40 cm by 2050 and 90 cm by 2100; DECC 2009) would result in inundation of low level land adjacent to the lagoon, and thus a shift in vegetation community structure with a potential loss of saltmarsh (an EEC) and inundation of cane land. Associated with this will be shoreline recession. Changes in rainfall patterns, particularly a decrease in rainfall, may lead to an accumulation of pollutants (i.e. nutrients) in the southern end of the lagoon, which could then lead to an increased frequency of algal blooms. Extended droughts may lower the watertable in the catchment, threatening the viability of wetlands and oxidising potential ASS. A change in prevailing wind direction due to changing weather patterns may also result in erosion along different parts of the Wooloweyah Lagoon shoreline, due to wind-waves.

3.2 Management Objectives

The long-term aim of the Coastal Zone Management Plan for Wooloweyah Lagoon is to protect and enhance environmental, economic and social values. The management objectives which will help to achieve this aim are:

- improve water quality to reduce sediment, nutrient and oxygen demand loads, and to meet performance targets;
- maintain and improve ecosystem health and biodiversity of the lagoon, estuary, riparian zone and subcatchment;
- ensure future development and land use change has minimal impact on ecosystem health and sustainability of the lagoon;
- stabilise degraded channels to rehabilitate their natural values, improve downstream health and reduce infilling of the lagoon;
- raise community awareness of, and protect areas important to, Aboriginal cultural heritage; and,
- manage potential impacts of climate change.

Trigger values for water quality indicators within the Wooloweyah Lagoon catchment are currently based on the HRC (1999) recommendations for the Clarence estuary (including Wooloweyah Lagoon), and have been updated with the ANZECC (2000) guidelines where applicable. The exception is turbidity, which has been increased for the lagoon based on the results of the recent condition assessment (White 2009a; Appendix A), and the indication by earlier studies that the higher lagoon turbidity is most likely due to natural process of wind-wave sediment resuspension. The trigger values for the management area are:

- pH: 7.0-8.5
- Dissolved oxygen: 80-100% saturation
- Turbidity: 5-30 NTU (lagoon); 5-25 NTU elsewhere in catchment
- Total nitrogen: < 400 µg L^{-1}
- Total phosphorus: < 50 µg L^{-1}
- Nitrate, nitrite, ammonia: < 15 µg L^{-1}
- Phosphate: < 5 µg L^{-1}
- Chlorophyll-*a*: < 4 µg L^{-1}

3.3 Management Principles

A range of management principles will be applied when implementing actions and making decisions, the main being adaptive management (see NRM MERI Framework in Section 5). Adaptive management is defined as “learning to manage by managing to learn” (Bormann *et al.* 1993) and involves: clearly specifying the management objective; defining hypotheses of how the ecosystem may work and ranking them according to plausibility; monitoring how the ecosystem reacts to management; and, adjusting hypotheses and adapting management accordingly (Hauser 2008). Other management principles incorporated into the development and implementation of the management plan are:

- community and stakeholder involvement;
- address cultural sensitivities through DCPs;
- provide assistance for management of weeds;
- acknowledge sea level rise and the impacts of climate change;
- use scientific knowledge as the basis for decision making and setting hypotheses; and,
- clearly define roles and responsibilities of relevant agencies prior to implementation of actions.

4 Management Strategy

Twenty management strategies have been determined to address the management objectives for the Wooloweyah Lagoon management area. The strategies aim to protect and enhance the natural environment while also protecting existing land and waterway uses. The management strategies were developed through consultation with stakeholder organisations and the Clarence Floodplain and Estuary Partnership. These strategies are summarised in Table 4.2 and described within Section 4.1 (high priority), Section 4.2 (medium priority) and Section 4.3 (low priority).

Each strategy has been prioritised independently of the relative timeframe, with priorities classified as:

- High: important strategies that should take precedence over lower order strategies.
- Medium: should be implemented as funding and resources become available.
- Low: these strategies are less urgent and can be built into other investigations or activities, and should be implemented as funding and resources become available.

The relative timeframes for strategies are given below, although implementation is dependent on the availability of funds and resources:

- Immediate: within 12-18 months.
- Short: within 1-3 years.
- Medium: within 3-5 years.
- Long: some time 5-10 years from now.

Costs for implementation of each strategy are categorised in Table 4.1.

Table 4.1: Categories of costs for the management strategies.

Category	Capital costs	Maintenance and extension costs
Low	less than $100,000	less than $10,000
Medium	$100,000 to $500,000	$10,000 to $100,000
High	more than $500,000	more than $100,000

It is strongly recommended that the Management Plan be reviewed five to ten years after being adopted. This will allow for the identification of new issues, the incorporation of new management strategies and updated scientific information, and a review of the responsibilities of government departments. Furthermore, a review of the Plan partially fulfils the evaluation stage of the NSW MERI framework (see Section 5).

Table 4.2: Summary of management strategies for the Wooloweyah Lagoon management area.

Strategy		Relative Priority	Relative Timeframe
Water quality			
WQ1.	Reduce nutrient loads of runoff and receiving waters within the catchment	High	Short-Medium
WQ2.	Implement regular water quality and condition assessment monitoring for the lagoon, channels, drains and creeks	Low	Medium-Long
WQ3.	Implement water quality improvement actions for priority drains and their catchments	Medium	Medium
WQ4.	Reduce sewage impacts on waterways	High	Medium
Biodiversity			
B1.	Identify and prioritise riparian areas for regeneration and rehabilitation	High	Medium-Long
B2.	Encourage cane toad control	Medium	Short
B3.	Identify and prioritise wetland/floodplain habitats for rehabilitation	Medium	Short
B4.	Implement and encourage uptake of best management practice actions for agricultural activities in the catchment	High	Short-Long
B5.	Develop and implement a shorebird management plan for the Clarence Estuary	High	Immediate-Short
B6.	Decommission the Taloumbi Ring Drain and Levee	Low	Long
B7.	Seagrass management and protection	High	Short-Medium
Erosion and sedimentation			
ES1.	Reduce bank erosion along Palmers, Micalo and Oyster Channels	High	Medium
ES2.	Improve navigability of Palmers Channel	High	Short
ES3.	Improve environmental flows	Medium	Medium
Floodgates and drains			
FD1.	Improve water quality, fish passage and habitat in drains	High	Medium
Development			
D1.	Control of urban growth areas	High	Ongoing
Planning			
P1.	Zone Wooloweyah Lagoon as 'W1 Natural Waterway' in the revised Clarence Valley LEP in accordance with the NSW Planning Reforms LEP Standard Template	High	Short
P2.	Incorporate a foreshore buffer around Wooloweyah Lagoon to allow for ecosystem processes and expected response to future environmental change	High	Medium
Cultural			
C1.	Aboriginal heritage management	High	Ongoing
Climate Change			
SL1.	Incorporate and make provision for potential impacts of climate change in planning instruments, development controls and environmental assessments	Medium	Immediate-Short

4.1 High Priority Strategies

WQ1. REDUCE NUTRIENT LOADS OF RUNOFF AND RECEIVING WATERS WITHIN THE CATCHMENT

Relative Timeframe: Short-Medium

Actions Required:

- Quantify nutrient loads from drains and channels by measuring nutrient concentrations and discharge rates.
- Encourage landholders to provide off-stream watering points and fence riparian areas to reduce the impact of stock.
- Ensure implementation of nutrient and fertiliser reduction strategies as listed in the *NSW Sugar Industry Farming Code of Practice.*
- Promote riparian rehabilitation as preferred practice for bank stabilisation along drains, creeks, channels and the lagoon.
- Ensure treated sewage discharge from the Yamba STP is diverted within 1-3 years, in line with augmentation of the plant.
- Ensure compliance with West Yamba REF in terms of stormwater management.
- Ensure ongoing implementation of the *Maclean Shire Council Urban Stormwater Management Plan*.
- Continue schools and community stormwater awareness program.

Key Responsibility: Landholders, CVC

Other Partners: NRCMA, DECCW

Indicative Cost: Capital – medium; Maintenance or extension – medium. Capital costs exclude the augmentation of the Yamba STP, as this is already budgeted under existing programs.

Comments: Increased nutrient concentrations were identified in several drains and the southern region of Wooloweyah Lagoon. In the future there may be issues of eutrophication and algal blooms if adequate flushing of the lagoons and drains is not maintained, and nutrient loads are not reduced/maintained. Trigger values for water quality indicators are given in Section 3.2.

A range of funding is periodically available for individual landholders to undertake NRM projects on their property (e.g. cattle exclusion fencing, revegetation) are available through the NRCMA and other bodies. Council also regularly seeks funding from various government agencies to undertake works on private lands, in consultation with landholders.

Related to Strategies WQ2, WQ3, WQ4, B4, ES1 and ES3.

WQ4. REDUCE SEWAGE IMPACTS ON WATERWAYS

Relative Timeframe: Medium

Actions Required:

- Ensure treated sewage discharge from the Yamba STP is diverted within 1-3 years, in line with augmentation of the plant.
- Audit on-site sewage systems.

- Continued implementation and review of CVC's On-Site Management Strategy.

Key Responsibility: CVC

Other Partners: Landholders

Indicative Cost: Capital – nil; Maintenance or extension – low. There are no associated capital costs as augmentation of the Yamba STP is already budgeted under existing programs.

Comments: The majority of the management area is serviced by on-site sewage systems, which are a potential source of nutrients, bacteria and pathogens.

Related to Strategy WQ1.

B1. IDENTIFY AND PRIORITISE RIPARIAN AREAS FOR REGENERATION AND REHABILITATION

Relative Timeframe: Medium-Long

Actions Required:

- Implement priority actions listed in *Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems*, specifically those in relation to revegetation of Reedy Creek and Little Reedy Creek (see Appendix B).
- Implement recommendations from the Clarence Valley Council *Riparian Action Strategy* (in prep.).
- Investigate expanding the Palmers Island Wetland Biodiversity Project.
- Support landholders to establish and/or manage riparian vegetation through strategies such as fencing off areas from cattle and providing information on individual funding available through government departments.

Key Responsibility: CVC

Other Partners: Landholders, DECCW, NRCMA, WetlandCare Australia, Landcare

Indicative Cost: Capital – low/medium; Maintenance or extension – medium

Comments: Improving riparian vegetation helps to stabilise banks and thus reduce sedimentation of drains and channels, and also increases the habitat value of drainage networks for aquatic animals and birds.

Related to Strategies WQ3, B4, B6 and ES1.

B4: IMPLEMENT AND ENCOURAGE UPTAKE OF BEST MANAGEMENT PRACTICE ACTIONS FOR AGRICULTURAL ACTIVITIES IN THE CATCHMENT

Relative Timeframe: Short-Long

Actions Required:

- Undertake a review of current best management practice for cane and grazing, in conjunction with industry/user group representatives.
- Encourage graziers to fence off saltmarsh, mangrove and other riparian areas from cattle to promote bank stabilisation and riparian rehabilitation.
- Coordinate with industry representatives to discuss relevant changes in best management practice.
- Encourage Land and Property Management Authority to implement new grazing licence conditions consistent with current best practices.

Key Responsibility: Cane industry, graziers, CVC, Industry and Investment NSW, Land and Property Management Authority

Other Partners: NRCMA, DECCW

Indicative Cost: Capital – medium; Maintenance or extension – medium

Comments: The sugarcane industry has a number of guidelines in place for best management practice (e.g. *The NSW Sugar Industry Best Practice Guidelines for Acid Sulfate Soils*, *NSW Sugar Industry Farming Code of Practice*). These will be reviewed and updated where applicable.

A number of common goals for graziers to improve sustainable management of biodiversity, which are linked to best management practice, are given in Purcell (2009), *Developing Best Practice Biodiversity Management – A Framework for Northern Rivers Graziers*.

Related to Strategies WQ1, WQ2, WQ3, B1, B6 and ES1.
Related to Strategies WQ1, WQ4 and ES1.

B5. DEVELOP AND IMPLEMENT A SHOREBIRD MANAGEMENT PLAN FOR THE CLARENCE ESTUARY

Relative Timeframe: Immediate-Short

Actions Required:

- Prioritise management actions listed in the *Shorebird Values and Threats in the Clarence Estuary* report (Rohweder 2006).
- Source funding for implementation of priority strategies.

Key Responsibility: CVC

Other Partners: DECCW, NRCMA, Land and Property Management Authority, WetlandCare Australia

Indicative Cost: Capital – dependent on identified actions; Maintenance or extension – low

Comments: The Clarence Estuary has been recognised as an important shorebird site since the early 1980s, and is the third most important site in NSW (Rohweder 2006). There are a number of priority roosts and foraging areas in the Wooloweyah Lagoon catchment, specifically Joss Island, Oyster Channel and the Micalo Island abandoned prawn farm. A recent *Shorebird Data Audit – Northern NSW* (Rohweder in prep.) identifies three medium-high priority shorebird sites in the Wooloweyah Lagoon catchment, being Oyster Channel/Wooloweyah Entrance, Prawn Farm (Micalo Island) and Micalo Island North.

Related to Strategies P1, P2 and SL1.

B7. SEAGRASS MANAGEMENT AND PROTECTION

Relative Timeframe: Short-Medium

Actions Required:

- Map significant seagrass areas within Wooloweyah Lagoon and implement buffer zones to minimise the potential impacts of commercial and recreational waterway activities, such as localised increased sediment loads and inadvertent physical damage, on or near seagrass beds, subject to consultation with the commercial fishing industry.
- Conduct a seagrass study examining the limiting factors on seagrass growth, impact of threats (both natural and anthropogenic) on seagrass in the lagoon, and the potential for rehabilitation and/or revegetation.
- Conduct a bathymetric survey of the lagoon to aid in identifying/determining potential areas suitable for seagrass regeneration.
- Investigate, in consultation with the commercial fishing industry, the concept of establishing 'no-go-zones' in areas identified as potentially viable for seagrass regeneration.
- Ongoing research into the modification of commercial fishing gear to minimise impacts on biodiversity, including species sustainability and reducing resuspension of sediments.

Key Responsibility: Industry and Investment NSW, DECCW (bathymetric survey)

Other Partners: Professional Fishermen's Association, CVC, NRCMA

Indicative Cost: Capital – medium; Maintenance or extension – medium

Comments: Both the HRC (1999) and Umwelt (2003) recommended a study be conducted on the impact of trawling on seagrass within Wooloweyah Lagoon. Although the environmental impact assessment of the Estuary Prawn Trawl Fishery (NSW Fisheries 2002) discussed the impact of trawling on seagrass, it was considered that the prohibition of trawling over seagrass beds was an effective management strategy to reduce the risk of damage to seagrass beds. Trawling can still be conducted near seagrass beds, which may result in localised increased turbidity, reduced light attenuation and potentially smothering of seagrass. Further studies are required to determine the extent to which trawling near seagrass can impact the habitat.

The seagrass study should document the location, distribution and density of seagrass species, where seagrass could potentially establish within the lagoon, limiting factors (e.g. turbidity and the associated depth-range) and threats (natural and anthropogenic). Much of this study could be completed based on existing data. Experimental trials for growth and establishment of seagrass could also be conducted as part of this study, depending on the determination of limiting factors within the lagoon. The seagrass

study would aid in expanding knowledge on the growth parameters of seagrasses in NSW, and would provide an opportunity to develop new techniques for seagrass restoration (as recommended by Ganassin & Gibbs 2008). Engaging university researchers (either as private consultant or as an internship/Honours/Masters/PhD research project) from a local university (University of New England or Southern Cross University) will help to reinforce existing ties between these institutions and CVC.

Related to Strategy ES2.

ES1. REDUCE BANK EROSION ALONG PALMERS, MICALO AND OYSTER CHANNELS

Relative Timeframe: Short-Medium

Actions Required:

- Investigate channels to determine where major erosion is occurring, the causative factors and what type of bank stabilisation works are suitable (i.e. hard or soft engineering, revegetation, etc.).
- Reduce anthropogenic impacts on the waterway and adjoining lands which cause erosion (e.g. clearing, grazing, boat wash) through partnerships with industry representatives.
- Liaise with landholders through workshops to promote/educate riparian rehabilitation.
- Implement recommendations from the Clarence Valley Council *Riparian Action Strategy* (in prep.).

Key Responsibility: CVC
Other Partners: Land and Property Management Authority, NRCMA, landholders, NSW Maritime, Professional Fishermen's Association, DECCW
Indicative Cost: Capital – low/medium (depending on type of works required); Maintenance or extension – medium

Comments: Issues relating to this strategy are loss of land, sedimentation of the lagoon, and smothering of seagrass. Some bank protection works have already been constructed along the northern side of Palmers Channel, near the entrance to Wooloweyah Lagoon, and the channel is a designated 'no wash' zone. However, more works are required to reduce erosion along other sections of Palmers Channel, and also Micalo and Oyster Channels. Previous concept plans for works were the washboard concept and the floating log concept (see Woodhouse 2001). Rock revetment and revegetation are other potential strategies to reduce bank erosion along Palmers Channel. Revegetation/rehabilitation of the banks also relates to the strategy regarding improving riparian vegetation and habitat, and is the preferred strategy if suitable. Costs will depend on the types of works.

Related to Strategies WQ1, WQ3, B1, ES2 and ES3.

ES2. IMPROVE NAVIGABILITY OF PALMERS CHANNEL

Relative Timeframe: Short

Action Required:

- Dredge the lagoon entrance to Palmers Channels.

Key Responsibility: Land and Property Management Authority (coordination of dredging)

Other Partners: Industry and Investment NSW, Professional Fishermen's Association, DECCW, Regional Development Australia

Indicative Cost: Capital – medium; Maintenance or extension – low

Comments: Due to siltation of the Palmers Channel delta, navigation to the lagoon is becoming unsafe. There were several incidents in March 2009 where trawlers became stuck trying to get through the delta. Furthermore, a reduced number of trawlers can access the lagoon, thus reducing viability of the fishery. Dredging of the channel entrance may also help to improve environmental flows (see Strategy ES3), which could benefit the fishing industry by improving water quality and thus habitat.

The Land and Property Management Authority will assist Industry and Investment NSW, the commercial fishing industry and other partners with the planning, investigations and approval for a small-scale dredging campaign. Any dredging at the entrance to Palmers Channel should be coordinated with actions to stabilise bank erosion along Palmers Channel to minimise any further infill.

Disturbance to shorebirds would be minimal. Palmers Island at the Palmers Channel/Wooloweyah Lagoon entrance has been identified as only a low priority roost area (Rohweder in prep.). Medium and high priority roost areas are located at the Micalo Island Prawn Farm and the Oyster Channel/Wooloweyah Entrance (Rohweder in prep.), and disturbance to these areas by the dredging activity at Palmers Channel would be nil to minimal.

Related to Strategies B7, ES1, ES3 and P1.

FD1. IMPROVE WATER QUALITY, FISH PASSAGE AND HABITAT IN DRAINS

Relative Timeframe: Medium

Actions Required:

- Implement priority actions listed in *Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems*, specifically those in relation to installing tidal gates and lightweight fish gates on existing floodgates.
- Identify priority drains and promote active management of floodgates.
- Ensure implementation of *NSW Sugar Industry Farming Code of Practice* strategies related to drainage (e.g. vegetation).

Key Responsibility: CVC

Other Partners: Industry and Investment NSW, DECCW, landholders
Indicative Cost: Capital – low/medium; Maintenance or extensions – medium

Comments: Related to Strategies WQ2, WQ3, B1, ES1 and ES3.

P1. ZONE WOOLOWEYAH LAGOON AS 'W1 NATURAL WATERWAYS' IN THE REVISED CLARENCE VALLEY LEP IN ACCORDANCE WITH THE NSW PLANNING REFORMS LEP STANDARD TEMPLATE

Relative Timeframe: Short

Action Required:

- Council planners in drafting the new Clarence Valley LEP (CV LEP) ensure that the Wooloweyah Lagoon and the connecting Oyster and Micalo Channels are zoned as 'W1 Natural Waterways', with the exception of the approximate area shown in Figure 4.1 which should be zoned as 'W2 Recreational Waterways'.

Key Responsibility: CVC

Other Partners: Nil

Indicative Cost: Capital – nil; Maintenance or extension – low

Figure 4.1: Approximate area of Wooloweyah Lagoon to be zoned 'W2 Recreational Waterways' to allow for dredging for safe navigation (Strategy ES2).

Comments: The intent of this zoning acknowledges the lagoon's ecological, scenic and recreational value. It will assist in protection of aquatic habitat, provide for sustainable commercial and recreational fishing, and prevent adverse effects on the natural value of the waterway.

Zoning a small proportion of Wooloweyah Lagoon as 'W2 Recreational Waterways' would allow dredging for safe navigation to be conducted, as recommended in Strategy ES2.

Related to Strategy ES2.

P2. INCORPORATE A FORESHORE BUFFER AROUND WOOLOWEYAH LAGOON TO ALLOW FOR ECOSYSTEM PROCESSES AND EXPECTED RESPONSE TO FUTURE ENVIRONMENTAL CHANGE

Relative Timeframe: Medium

Actions Required:

- Undertake an assessment to determine the width and extent of the required foreshore buffer considering existing land use zonings, vegetation communities, ecological functioning, flooding/inundation impacts and future sea level rise.
- Determine the appropriate mechanism to install the required foreshore buffer. Options could be as an Environmental Protection zone or a map overlay with development conditions within the CV LEP.

Key Responsibility: CVC
Other Partners: Land and Property Management Authority, landholders

Indicative Cost: Capital – nil; Maintenance or extension – medium

Comments: Development around the lagoon should be kept at a sufficient distance to allow and maintain natural functionality. The buffer would be beyond the natural range of water level conditions to allow for natural ecosystem processes and interaction between the estuarine and terrestrial environments. The buffer should also incorporate the predicted impacts of future sea level rise.

The buffer is partially addressed through the current Draft CV LEP, with only approximately 10-15% of the foreshore zoned as rural, 'RU2 Rural Landscape'. However, much of this rural area supports SEPP 14 wetlands (see Figure 2.4). The remainder of the foreshore is zoned as Environmental Protection ('E1 National Parks and Nature Reserves', and 'E2 Environmental Conservation'), and 'RE1 Public Recreation Zone' for the Wooloweyah Foreshore Reserve at Wooloweyah village.

Related to Strategies B6, D1 and SL1.

D1. CONTROL OF URBAN GROWTH AREAS

Relative Timeframe: Ongoing

Action Required:

- Ensure development is in accordance with the Mid-North Coast Regional Plan and any impacts on the lagoon and other waterways is considered

Key Responsibility: CVC

Other Partners: Department of Planning

Indicative Cost: Capital – nil; Maintenance or extension – low

Comments: Related to Strategies WQ3, WQ4 and C1.

C1. ABORIGINAL HERITAGE MANAGEMENT

Relative Timeframe: Ongoing

Action Required:

- Consult with the Yaegl and Birrigan Gargle Local Aboriginal Land Councils prior to development and ensure development complies with the Cultural Protocol (in prep.)

Key Responsibility: CVC

Other Partners: DECCW

Indicative Cost: Capital – nil; Maintenance or extension – low
Comments: Related to Strategy D1.

4.2 Medium Priority Strategies

WQ3. IMPLEMENT WATER QUALITY IMPROVEMENT ACTIONS FOR PRIORITY DRAINS AND THEIR CATCHMENTS

Relative Timeframe: Medium

Actions Required:

- Further investigation of drains identified in the Wooloweyah Lagoon Condition Assessment (Carrs Drain and Middle Road Drain) as primary sources of nutrients and turbid water.
- Work with the cane industry to ensure ongoing implementation and updating of the *NSW Sugar Industry Farming Code of Practice.*
- Quantify nutrient contributions from cattle.
- Identify other priority drains for active management of floodgates or installation of tidal gates.
- Investigate contributions of sediment and nutrients from Gulmarrad development to waterways.

Key Responsibility: CVC

Other Partners: NRCMA, cane industry, graziers

Indicative Cost: Capital – medium; Maintenance or extension – medium

Comments: Elevated concentrations of nutrients were identified in several drains which could potentially contribute to eutrophication of the lagoon. Trigger values for water quality indicators are given in Section 3.2.

Related to Strategies WQ1, WQ2, B4 and ES3.

B2: ENCOURAGE CANE TOAD CONTROL

Relative Timeframe: Short

Actions Required:

- Encourage community volunteer involvement in cane toad control through awareness programs such as *Trap That Toad* (DECCW) and Clarence Landcare's community cane toad control activities.
- Source funds for contractors for cane toad control.
- Discuss with the cane industry and graziers potential awareness programs/workshops for landholders.

Key Responsibility: DECCW

Other Partners: NRCMA, CVC, cane industry, graziers, landholders

Indicative Cost: Capital costs – low, Maintenance or extension – medium

Comments: Cane toads are a major threat to native animals on the North Coast. The Wooloweyah Catchment is the southern limit of cane toad migration in coastal Australia. Strategies to remove cane toads through community and contractor activities have proven to be an effective measure to slow population growth of this pest. Community efforts to slow the southern rate of migration of cane toads are important. Community volunteer involvement in cane toad control is proving to be effective at the local scale.

B3. IDENTIFY AND PRIORITISE WETLAND/FLOODPLAIN HABITATS FOR REHABILITATION

Relative Timeframe: Short-Medium

Actions Required:

- Implement priority actions listed in *Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems*, specifically those in relation to increasing and retaining water levels in previously drained freshwater wetlands, and installing a floodgate in Reedy Creek to prevent saline intrusion into freshwater sections of the creek.
- Investigate the potential for a wetland rehabilitation trial behind the Taloumbi Ring Levee on the western/southern shore of Wooloweyah Lagoon.
- Continue community and landholder education of ecologically sustainable land use and the benefits of strategies such as flushing drains and wet pasture management.

Key Responsibility: CVC

Other Partners: NRCMA, DECCW, Landcare, WetlandCare Australia, landholders, cane industry, graziers, Industry and Investment NSW

Indicative Cost: Capital – low/medium; Maintenance or extension – medium

Comments: There are significant areas of high conservation value vegetation in the catchment, including EECs (saltmarsh, floodplain forest and mangroves), and many of the islands in the channels contain remnant vegetation. Where this vegetation occurs on private land, the landholders could be encouraged to obtain financial and in-kind assistance for biodiversity management of these areas.

ES3. IMPROVE ENVIRONMENTAL FLOWS

Relative Timeframe: Medium

Actions Required:

- Investigate hydraulics of Palmers Channel and Oyster Channel in relation to flushing of the lagoon.
- Implement actions (e.g. dredging of Palmers Channel, see Strategy ES2) if proven will significantly improve flushing.
- Promote active management of floodgates.
- Implement priority actions listed in *Management Options for the Wooloweyah Ring Drain and Palmers Channel Drainage Systems*, specifically those in relation to installing tidal gates and lightweight fish gates on existing floodgates.
- Identify other priority drains for installation of tidal gates and fish flaps.

Key Responsibility: Land and Property Management Authority (coordination of dredging), CVC, DECCW
Other Partners: NRCMA, landholders, Professional Fishermen's Association, Regional Development Australia

Indicative Cost: Capital – medium; Maintenance or extension – medium

Comments: The most recent study of lagoon hydraulics was conducted in the late 1980s, when there was no exchange through Shallow Channel and regular dredging of Palmers and Oyster Channels was conducted. The re-opening of Shallow Channel, and anecdotal evidence of increased sedimentation of the entrance to Oyster Channel and Palmers Channel from the lagoon, indicates that there is a strong possibility that the flushing dynamics of the lagoon may have changed. Reduced flushing through Oyster and Palmers Channels may be contributing to increased concentrations of nutrients within the southern region of the lagoon. Associated with this is the increased risk of algal blooms, and high nutrients also impact on the fishery (i.e. increased algal growth can impact on seagrass and thus reduce nursery habitat). Dredging of Palmers Channel to improve navigation (Strategy ES2) may also aid in maintaining adequate flushing of the lagoon. The NSW Government does not permit any further dredging in Oyster Channel (NSW Government 2002).
Active management of floodgates and the installation of tidal gates and fish gates will improve water quality, allow fish passage into the drains and reduce the risk of fish kills due to low dissolved oxygen and/or acid discharge.

Related to Strategies ES1, ES2 and FD1.

SL1. INCORPORATE AND MAKE PROVISION FOR POTENTIAL IMPACTS OF CLIMATE CHANGE IN PLANNING INSTRUMENTS, DEVELOPMENT CONTROLS AND ENVIRONMENTAL ASSESSMENTS

Relative Timeframe: Immediate-Short

Actions Required:

- Vulnerability and risk-based assessments of land and identification of migration paths for intertidal and estuarine habitat.
- Coordinate with representatives from the cane industry to discuss how best to adapt to predicted sea level rise.
- Ensure works such as bank stabilisation take into account the predictions of sea level rise and select the type of works required accordingly.

Key Responsibility: CVC

Other Partners: DECCW, Land and Property Management Authority, cane industry, graziers, landholders

Indicative Cost: Capital – dependent on works required; Maintenance or extension – medium
Comments: Climate change poses a threat to the natural environment and also the agricultural and urban landscape. Cane land to the west of the lagoon is at high risk of saline inundation.

Related to Strategy ES1.

4.3 Low Priority Strategies

WQ2. IMPLEMENT REGULAR WATER QUALITY AND CONDITION ASSESSMENT MONITORING FOR THE LAGOON, CHANNELS, DRAINS AND CREEKS

Relative Timeframe: Medium-Long
Actions Required:

- Identify potential funding sources
- Repeat the condition assessment of Wooloweyah Lagoon and catchment every 2-3 years (dependent on funding)
- Ensure compliance with NSW MER strategy

Key Responsibility: CVC, DECCW

Other Partners: NRCMA, Landcare, UNE, SCU

Indicative Cost: Capital – low; Maintenance or extension – medium

Comments: The Wooloweyah Lagoon Condition Assessment (White 2009a; Appendix A), conducted during 2008/2009, indicated that turbidity and nutrient concentrations were of concern for long-term protection of the environmental values of the lagoon system. Continuing sedimentation (potentially reducing the flushing capacity) along with nutrient inputs from the catchment, could lead to poor conditions within the lagoon. Trigger values for water quality indicators are given in Section 3.2.

It is recommended that the condition assessment should be repeated every 2-3 years, however, funding constraints may restrict repetition to every 5-10 years. The NSW MER strategy should be used for monitoring to allow the data to be input into a state-wide database and comparisons to be drawn between catchments and/or coastal lakes.

Implementation of this strategy partially fulfils the monitoring stage of the Australian Government MERI Framework (see Section 5).

The local universities (University of New England and Southern Cross University) could be engaged to conduct the monitoring (as part of a research project), and could possibly be run in conjunction with a seagrass study.

Related to Strategies WQ1, WQ3, B3, ES1 and FD1.

B6. DECOMMISSION THE TALOUMBI RING DRAIN AND LEVEE

Relative Timeframe: Long

Actions Required:

- Discuss purchasing options with affected landholders.
- Investigate the potential for additional works to protect freshwater habitats and caneland.

Key Responsibility: CVC

Other Partners: DECCW, Industry and Investment NSW, Land and Property Management Authority, WetlandCare Australia, Landcare, graziers, cane industry, landholders

Indicative Cost: Capital – high; Maintenance or extension – medium

Comments: A similar strategy has been suggested in the past by Smith (2002), who explored the option of moving the Ring Levee inland by up to 1 km. While there would be benefits to the fishing industry and would provide clear migration paths for saltmarsh and mangrove communities in response to sea level rise, there are a number of problems and/or obstacles to achieving this, primarily being (Foley & White 2007):

i) Cost of purchasing land and moving/reconstructing the levee.
ii) The project could not proceed if one or more landholders do not want to sell their land.
iii) There is potential for more extensive regular tidal inundation than prior to levee construction due to extensive drainage. Some areas that were previously freshwater wetlands would become brackish.
iv) An increased potential for blackwater events.

As such, this strategy has been allocated a 'Long' relative timeframe for completion, due to the careful planning and consultation required with such a project.

Related to Strategies B1, B4 and P2.

5 Monitoring, Evaluation and Reporting

The development, monitoring, evaluation, reporting and review of the Coastal Zone Management Plan for Wooloweyah Lagoon are based on the Australian Governments Natural Resource Management Monitoring, Evaluation, Reporting and Improvement (NSW MERI) Framework (Figure 5.1). The first two stages have been achieved through the development of this Management Plan.

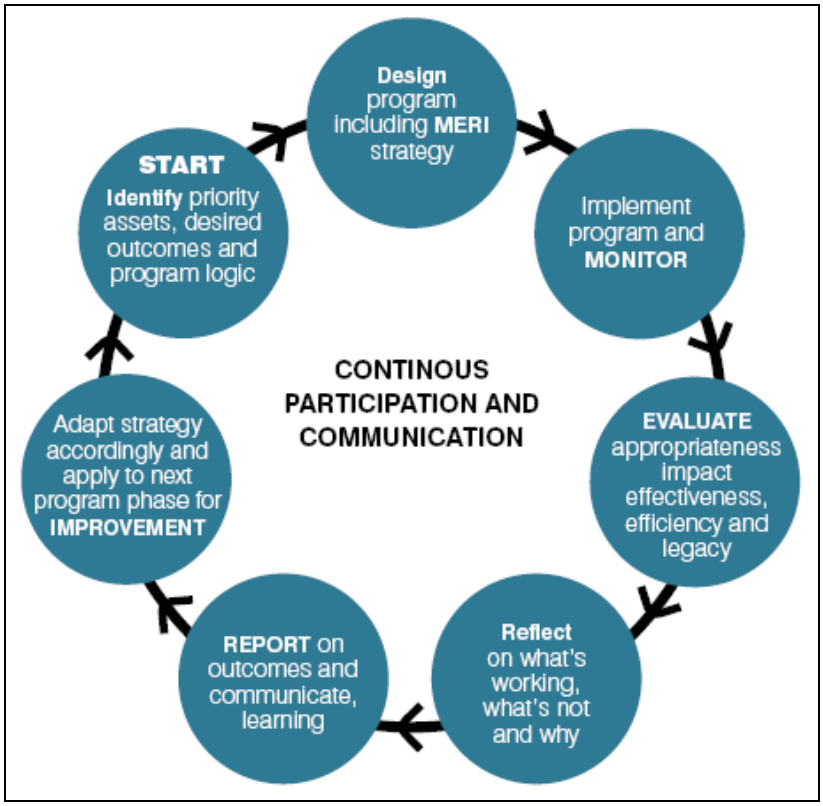

Figure 5.1: NRM MERI Framework (Australian Government 2009: 9).

Evaluation and monitoring will be undertaken as a routine part of the implementation of the Plan. The success of the Plan will be gauged through the ability to achieve the management objectives (Section 3.2). Indicators such as improvement in water quality (i.e. through the use of the trigger values given in Section 3.2) and the estuarine environment, and improvements in habitat will be used to monitor success. Evaluation measures will include determining if the strategies are being implemented, and reviewing the appropriateness of the strategy to help achieve the objectives.

The Management Plan will be reviewed every five to ten years to determine the progress and effectiveness of the management strategies. Outcomes will be discussed between key stakeholder agencies, and will aid in updating the management plan based on new knowledge and changing impacts.

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