Appendix 3: Existing environmental flow management systems

All of the rivers in the catchments of the Great Lakes CCI are unregulated. Unregulated rivers are classified as those rivers that do not have their flows regulated by major state-administered dams, i.e. licence holders cannot order water to be delivered from a dam through the river system. Most water users on unregulated rivers rely on natural flows for their water supply. Under the existing situation, three basic rights to access water are available to rural landholders in NSW. Water licences are not required for:

- domestic and stock rights [1]
- native title rights [2]
- harvestable rights [3].

The Water Quality Improvement Plan rrecognises that protecting environmental flows is essential for maintaining good water quality and healthy aquatic ecosystems – both within the river system and receiving waters such as a lake or estuary. As shown in Figure A3.1, an unregulated river experiences periods of floods to low flows, each occurring for different durations. The duration and nature of the flow event has an important role in the functioning of the aquatic ecosystem.

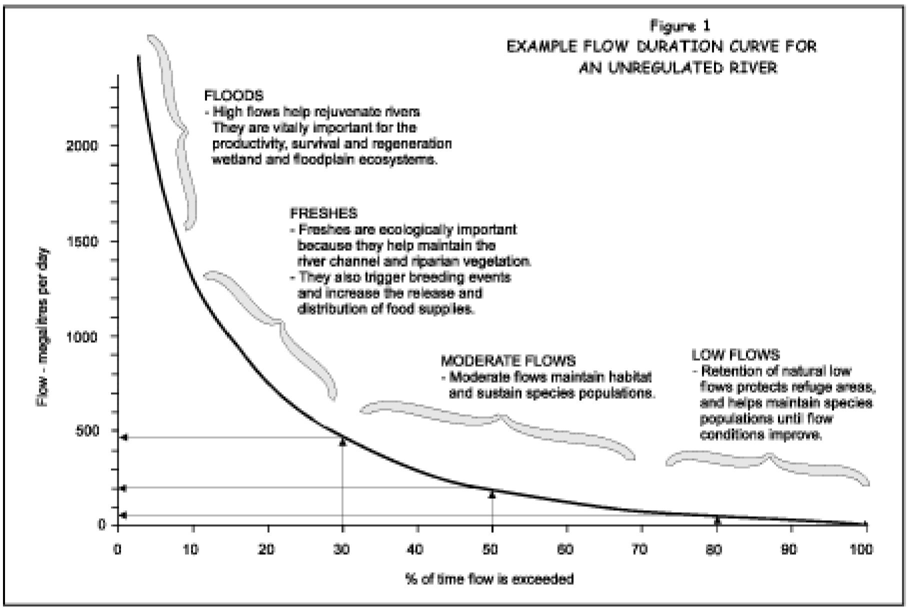

Figure A3.1. Example flow duration curve for an unregulated river
(Source: http://www.dnr.nsw.gov.au/water/rivers.shtml)

1 Domestic and stock rights. Landholders over an aquifer or with river or lake frontage can access water for domestic (household) purposes or to water stock.
2 Native Title rights. Anyone with native title to water as determined under the *Native Title Act 1993* (Cth) can access water for a number of personal, domestic and non-commercial purposes.
3 Harvestable rights (farm dams). Harvestable right water is intended for essential stock and household use, but can be used for any purpose. Harvestable right water allows for landholders in most rural areas to collect a proportion of the runoff on their property and store it in one or more farm dams up to a certain size.

While the importance of managing flows is recognised as part of the WQIP, the WQIP does not make recommendations relating directly to environmental flows. This is to be determined by a separate process through the development of Water Sharing Plans consistent with the *Water Management Act 2000*.

The Department of Water and Energy (formerly the Department of Natural Resources) has developed a Draft Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources. This water sharing plan is a legal document prepared under the *Water Management Act 2000*, which establishes rules for sharing water between the environmental needs of the river or aquifer and water users; and also between different types of water users such as town supply, rural domestic supply, stock watering, industry and irrigation.

The Water Sharing Plan includes the Lower North Coast unregulated rivers (which together with the previously endorsed Water Sharing Plan for the Karuah River) covers all rivers and tributaries in the area of the Great Lakes CCI, the highly connected alluvial groundwater (which is above the tidal limit) and the tidal pool areas.

The Lower North Coast Water Sharing Plan sets out rules for extraction, which govern the total volume of water that can be extracted annually from the water source or water management zone (long-term average annual extraction limit), the flow levels at which extraction is allowed and rules for trading water extraction. These rules were developed based on river flow objectives for the unregulated rivers for the Lower North Coast Water Sharing Plan area, which aim to:

- protect natural low flows
- protect natural water levels in pools of creeks, rivers and wetlands during periods of no flow
- protect a proportion of moderate flows, ‘freshes’ and high flows
- maintain or rehabilitate estuarine processes and habitats
- maintain groundwater within natural levels and variability, critical to surface flows or ecosystems.

For more information on how the Water Sharing Plan was developed please refer to the Draft Water Sharing Plan (Department of Natural Resources NSW 2006a, 2006b, 2006c).

To ensure the Lower North Coast Water Sharing Plan and the Water Quality Improvement Plan are complementary in their approach in protecting water and, ultimately, the aquatic ecosystems, a submission to the Draft Lower North Coast Water Sharing Plan has been made by the CCI. The submission recommended the inclusion of an additional clause in section 16 of the Draft Lower North Coast Water Sharing Plan, to allow for amendment of the Water Sharing Plan by the minister based on the findings of studies and modelling done through the Great Lakes CCI.

If accommodated, this clause will allow the reassessment of decisions made in the Water Sharing Plan on extraction limits, minimum ecological flow requirements and inflow sensitivities through the consideration of additional information collected during the CCI, such as:

- movements of salinity and pollutants through the lake systems during different rainfall events
- how different rainfall conditions affect ecological sensitivity indicators, such as seagrass distribution and algal abundance
- ecological sensitivity of Wallis and Myall lakes

It is expected that the Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources will commence in 2008/09.

Appendix 4: Issues identified by the community

The following tables (Tables A4.1 to A4.3) show issues that were collated during discussions with community groups and individuals that were engaged through the process described in Appendix 1. The tables list the water quality issues suggested by the community against the areas that were being discussed. The footnotes show which groups suggested which issues. The tables then show if the issue has been dealt with in the WQIP and, if so, which section of the Plan people can go to in order to find more information. Where the issue is not dealt with in the WQIP, the last column of the tables explains the reason for the omission.

Table A4.1. Wallis Lake issues.

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Boating Impacts [2, 3, 6, 11, 15]	Wallamba River, Wallis Lake Estuary	Yes	See Section 2.2.2 for a description of the issues and Section 3.5 for the reccomended management actions.	
Climate Change [2, 3, 4, 11]	Wallis Lake Estuary	Partially	The decision support system allows users to test estimates of the effects of management decisions against different climate situations (e.g. 'current', 'dry' and 'wet' climates) The models are not capable of predicting the full effect of climate change (e.g. sea level rise, increased frequency of storms). However, the risks associated with climate change and the need to adaptively manage for climate change are discussed in the Adaptive Management Strategy (Section 3.9).	
Decline in fish numbers / fish stock and recruitment pressures [4]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Partially	The WQIP identifies actions to improve water quality in terms of reducing nutrient and sediment loads. It identifies how these catchment loads impact on lake ecology. By protecting the ecology of the lakes through water quality management, there are likely to be flow-on effects within the ecosystem – increasing the viability of fish stocks (i.e. management actions described in Part 3, such as reducing sediment inputs from the catchment and protecting seagrass beds, will help protect fish breeding grounds).	

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Development and population pressures (including land use change and subdivisions) [3, 4, 6, 9, 11, 12]	Wang Wauk River, Wallis Lake Estuary	Yes	See Section 3.4.2.	
Entrance management (tidal flush maintenance through channel network) [6]	Wallis Lake Estuary	No		Dredging and navigational issues, therefore tidal flushing, are identified and actions are outlined in the Wallis Lake Estuary Management Plan.
Erosion and sedimentation (stream bed and stream bank; sheet, rill, tunnel, gully and mass slump erosion; sand and gravel bar movement or expansion) [3, 4, 6, 9, 11, 12, 15]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Partially	See Section 3.3.2. Recommendations for groundcover management and riparian management cover some of these issues.	Sand and gravel bar movement or expansion is not covered in the WQIP. However, the Wallis Lake Estuary Management Plan outlines strategies for mobile marine sands, and its dredging and management.
Fertiliser and agricultural chemical usage [3, 6]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Fertiliser – yes Chemicals – no	See Section 3.3.2. Recommendations for fertiliser management are outlined in this section.	Chemical usage is not covered by the WQIP. The use of chemicals is governed by relevant standards and legislation, and requires appropriate training on use, storage and handling.
Government decision-making [4, 9]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	See Section 3.6. Also see Section 3.2.	

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Groundcover [14]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	See Section 3.3.2. Recommendations for groundcover management are outlined in this section.	
Habitat degradation / loss of vegetation (seagrass, saltmarsh, wetlands and fringing buffer areas, catchment clearing, endangered plant protection, large woody debris replacement) [3, 11, 12]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Partially	See Section 3.3.2. Recommendations for riparian and wetland management on farms are outlined in this section. Section 2.7 outlines actions that are required to protect wetland and riparian areas. The WQIP identifies actions to improve water quality in terms of reducing nutrient and sediment loads that will protect the lake's ecology (including seagrass health).	No recommendations are made for managing woody debris. However, design guidelines for the reintroduction of wood in Australian streams is available from Land and Water Australia (Brooks *et al.* 2006). The removal of debris from streams is listed as a key threatening process under the *Fisheries Management Act*, and a Threat Abatement Plan (NSW DPI 2007) has been prepared to identify appropriate management.
Highway construction (sedimentation and oil) [9, 15]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	No	The plan does outline recommendations for managing unsealed roads and the construction phase of development (which includes road construction). However, it does not specifically deal with highway construction.	The environmental assessment conducted for highway upgrades recognised and considered these issues. It is also addressed in operational environmental management plans for highway upgrades adopted by the Road Traffic Authority.

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Inappropriate construction on farms (dams, roads) [12, 15]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	See Section 3.3.2. Recommendations for dam management and construction are outlined in the section on farm infrastructure management, and recommendations for improved land use planning regarding dams are also included in this section.	
Irrigation [4]	Wallamba River	No		The Water Sharing Plan, described in WQIP Appendix 3 Existing Environmental Flow Management Systems, provides the process for maintaining environmental flows and addresses issues regarding irrigation.
Landfill (Coolongolook tyre dump, Minimbah landfill) [4, 9]	Coolongolook River, Wallis Lake Estuary	Partially	The impact of the Coolongolook tyre dump is identified for future investigation in Appendix 7.	The impact of the Minimbah land fill on water quality is conditioned by Development Application conditions, EPA licence conditions and a detailed risk assessment undertaken by senior GLC and MCW staff. As a result of the above, the impact on groundwater quality and surface water quality of the surrounding areas is expected to be nil.
Management of large woody debris (including in-stream snags) [12]	Wallingat River, Coolongolook River, Wang Wauk River Wallamba River	No		No recommendations are made for managing woody debris. However, design guidelines for the reintroduction of wood in Australian streams is available from Land and Water Australia (Brooks *et. al* 2006) The removal of debris from streams is listed as a key threatening process under the *Fisheries Management Act*, and a Threat Abatement Plan (NSW DPI 2007) has been prepared to identify

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
				appropriate management.
Over-stocking [12]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	See Section 3.3.2. The section on groundcover management identifies the need to match stocking densities to feed availability.	
Professional fishing impacts [3, 4, 11]	Wallamba River, Wallis Lake Estuary	Partially	See Sections 2.2.2 and 3.5. Note that Section 3.5 did not comprehensively review strategies to manage professional fishing impacts.	The Estuary Management Plan makes recommendations for the adoption of sustainable commercial fishing practices in Wallis Lake.
Riparian vegetation (maintenance – prevent stock damage, thinning, degrading, weed infestations) [3, 13, 15]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Partially	See Section 3.3.2. Recommendations are outlined in the section on riparian management (Table 3.3.2).	The WQIP does not specifically deal with the issue of weeds in riparian areas. However, it was flagged by landholders as an issue to deal with when undertaking riparian rehabilitation projects. This issue is covered by the Wallis Lake Catchment Plan.
Rubbish / litter [2, 3, 4, 11]	Wallamba River, Wallis Lake Estuary	No	The focus of the CCI project was on the management of land-based activities to reduce sediments and nutrients entering the waterways	The need for gross pollutant traps and education is identified in the Wallis Lake Estuary Management Plan.
Rural road construction and maintenance (both public and private) [12]	Wallamba River	Yes	See Sections 3.3.2, 3.3.3 and 3.7.4.	
Septic systems improved [15]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	See Section 3.7.3.	

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Sewage discharge [6]	Wallis Lake Estuary	Yes	See Section 3.7.3.	
Stock Access to Waterways [12, 13]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	See Section 3.3.2. Recommendations are outlined in the sections on Riparian management and Wetland management (Table 3.3.2).	
Surrounding land use [2, 3]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	Part 3 of the WQIP contains action plans that aim to reduce the impacts on water quality from surrounding land use, such as farming and urban development.	
Tourism impacts [12, 3]	Wallamba River, Wallis Lake Estuary	Yes	See Section 3.5.	
Water extraction volumes (stock water, crop irrigation and domestic water supply) [11]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	No		The Water Sharing Plan, described in Appendix 3 'Existing Environmental Flow Management Systems', provides the process for maintaining environmental flows.
Water quality decline (faecal contamination, suspended soils, nutrients, acid sulfate leachate, chemical spills) [2, 3, 6, 9, 11, 12]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	The whole focus of the Water Quality Improvement Plan is to reduce the impacts from pollutants such as sediments, nutrients and faecal coliforms. See Section 2.2 for more details on these pollutants. Through the wetland protection actions identified in Section 2.7, acid sulfate leachate is covered. The Plan does not cover issues such as chemical spills.	Chemical spills are covered by the existing management systems, which are either set up as individual organisations (e.g. Road Traffic Authority), or the system of State Emergency Response is used in major spills.

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Waterway usage (professional and recreational fishing, recreational boating, swimming, foreshore picnicking, camping) [2, 3, 12]	Wallingat River, Coolongolook River, Wang Wauk River, Wallamba River, Wallis Lake Estuary	Yes	See Section 3.5.	

Table A4.2. Smiths Lake issues.

Issue	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Agricultural industry impacts [2, 3]	Yes	See Section 3.3.2.	
Boating impacts [1, 2, 3]	Yes	See Section 3.5.	
Climate change [2, 3]	Partially	The decision support system allows users to test estimates of the effects of management decisions against different climate situations (e.g. 'current', 'dry' and 'wet' climates[DG1]). The models are not capable of predicting the effect of climate change however the risks associated with climate change and the need to adaptively manage for climate change are discussed in the Adaptive Management Strategy (Section 3.9).	
Decline in fish numbers [4]	Partly	The WQIP looks at improving water quality in terms of reducing catchment loads and impacts to lake ecology. This will have a flow-on effect of increasing the viability of fish stocks (i.e. management actions described in Part 3, such as reducing sediment inputs from the catchment and protecting seagrass beds, will help protect fish breeding grounds)	
Development and population pressures [3, 12]	Yes	See Section 3.4.2.	
Drag net and professional fishing [3, 4]	Yes	See Sections 2.2.2 and 3.5. Note that Section 3.5 did not comprehensively review strategies to manage professional fishing impacts.	
Erosion and sedimentation (catchment erosion, entrance / foreshore erosion, increased stormwater) [1, 2, 3, 4]	Yes	See Section 3.3.2. Also see Section 3.4.2.7 and associated implementation strategy (Section 3.4.2.12), and Section 3.7.4.	

Issue	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Government decision-making [4]	Yes	See Section 3.6. Also see Section 3.2.	
Highway construction (sedimentation and oil) [15]	No		The environmental assessment conducted for highway upgrades recognised and considered these issues. It is also addressed in operational environmental management plans for highway upgrades adopted by the Road Traffic Authority.
Inappropriate construction on farms (dams, roads) [15]	Yes	Recommendations for dam management and construction are outlined in [DG2]Table 3.3.2. Recommendations for improved land use planning regarding dams are included in Section 3.3.2.4 .	
Loss of vegetation (and pervious surfaces) [1]	Yes	See Sections 3.3 and 3.4.	
Riparian vegetation (maintenance – prevent stock damage, thinning, degrading, weed infestations) [15]	Yes	See Section 3.3.2. Wetland management on farms is outlined in this section (Table 3.3.2). Section 2.11 outlines actions that are required to protect wetland and riparian areas.	
Rubbish / litter [2, 3]	No	The focus of the CCI project was on the management of land-based activities to reduce sediments and nutrients entering the waterways.	
Rural road construction and maintenance (both public and private) [12]	Yes	See Sections 3.3.2, 3.3.3 and 3.7.4.	
Septics systems improved [15]	Yes	See Section 3.7.3.	
Stock access to waterways [15]	Yes	See Section 3.3.2.	
Tourism impacts [3]	Yes	See Section 3.5.	
Weeds [3, 4]	No		Noxious weed management is

Issue	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
			directed by the *Noxious Weeds Act 1993* and Council's Noxious Weed Officer. Volunteers work with Council staff in this area to rehabilitate natural areas and foreshores, which involves weed removal.

Table A4.3. Myall Lakes issues.

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Algal growth and aquatic weeds [8, 12]	Myall Lakes, Myall River, Crawford River	Algal growth – Yes Aquatic weeds – No	The problems and causes of algal growth are summarised in Section 2.2. For each lake particular levels of chlorophyll-a – an indicator of algal growth – have been chosen as ecological condition targets (Sections 2.6, 2.10 and 2.14), so that we can monitor stress to the lakes from algal growth and aim to reduce this stress through various management actions (Sections 2.7, 2.11 and 2.15)	Although aquatic weeds have an impact on the ecological health of waterways, they do not impact on the water quality parameters that have been addressed through the CCI project.
Boating impacts [2, 7, 8]	Myall Lakes	Yes	See Section 3.5.	
Climate change [2, 7]	Myall Lakes	Partly	The decision support system allows users to test estimates of the effects of management decisions against different climate situations (e.g. 'current', 'dry' and 'wet' climates[DG3]). The models are not capable of predicting the effect of climate change. However, the risks associated with climate change, and the need to adaptively manage for climate change, are discussed in the Adaptive Management Strategy (Section 3.9).	
Development and population pressures [5, 7, 15]	Myall Lakes	Yes	See Section 3.4.2.	
Effluent upgrade [13]	Myall River	Yes	See Section 3.3.2. Recommendations to upgrade effluent management systems are outlined in the Nutrient management section (Table 3.3.2).	

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Erosion and sedimentation (stream bed and stream bank; sheet, rill, tunnel, gully and mass slump erosion; sand and gravel bar movement or expansion) [5, 7, 13, 15]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.3.2. Recommendations for groundcover management and riparian management (Table 3.3.2) cover some of these issues.	
Fertiliser and agricultural chemical usage [2, 7, 13]	Myall River, Crawford River, Myall Lakes	Fertiliser use – Yes Chemical use – No	See Section 3.3.2. Recommendations are outlined in the section Nutrient management (Table 3.3.2).	Chemical usage is not covered by the WQIP. The use of chemicals is governed by relevant standards and legislation, and requires appropriate training on use, storage and handling.
Government decision-making [4, 5, 7]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.6. Also see Section 3.2.	
Groundcover [14]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.3.2. Recommendations are outlined in the section Groundcover management (Table 3.3.2).	

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Habitat degradation or loss (seagrass, saltmarsh, wetlands and fringing buffer areas, catchment clearing, loss of vegetation, endangered plant protection, large woody debris replacement) [7]	Myall River, Crawford River, Myall Lakes	Partially	See Section 3.3.2. Recommendations for riparian management and wetland management on farms are outlined in this section (Table 3.3.2). Section 2.15 outlines actions that are required to protect wetland and riparian areas. The WQIP identifies actions to improve water quality in terms of reducing nutrient and sediment loads that will protect the lakes ecology (including seagrass health).	No recommendations are made for managing woody debris. However, design guidelines for the reintroduction of wood in Australian streams is available from Land and Water Australia (Brooks *et al*. 2006). The removal of debris from streams is listed as a key threatening process under the *Fisheries Management Act*, and a Threat Abatement Plan (DPI NSW 2007) has been prepared to identify appropriate management.
Highway construction (sedimentation and oil) [15]	Myall River, Crawford River, Myall Lakes	No	The plan does outline recommendations for managing unsealed roads and the construction phase of development (which includes road construction). However, it does not specifically deal with highway construction.	The environmental assessment conducted for highway upgrades recognised and considered these issues. It is also addressed in operational environmental management plans for highway upgrades adopted by the Road Traffic Authority.
Inappropriate construction on farms (dams, roads) [15]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.3.2. Recommendations for dam management and construction are outlined in the section on farm infrastructure management (Table 3.3.2) and recommendations for improved land use planning regarding dams is also included in this section.	

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Management of large woody debris [12]	Myall River, Crawford River	No		No recommendations are made for managing woody debris. However, design guidelines for the reintroduction of wood in Australian streams is available from Land and Water Australia (Brooks *et al*. 2006). The removal of debris from streams is listed as a key threatening process under the *Fisheries Management Act*, and a Threat Abatement Plan (NSW DPI 2007) has been prepared to identify appropriate management.
Over-stocking [12]	Myall River, Crawford River	Yes	See Section 3.3.2. The section on groundcover management (Table 3.3.2) identifies the need to match stocking densities to feed availability.	
Riparian vegetation (maintenance – prevent stock damage, thinning, degrading, weed infestations) [13, 15]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.3.2. Recommendations are outlined in the section on riparian management (Table 3.3.2).	The WQIP does not specifically deal with the issue of weeds in riparian areas. However, it was flagged by landholders as an issue to deal with when undertaking riparian rehabilitation projects.
Rubbish / litter [8, 15]	Myall Lakes	No	The focus of the CCI project was on the management of land-based activities to reduce sediments and nutrients entering the waterways.	For the areas of the catchment in national park, the National Parks and Wildlife Service regulation prohibits littering.
Rural land runoff [7]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.3.	
Rural road construction and maintenance (both public and private) [12]	Myall River	Yes	See Sections 3.3.2, 3.3.3 and 3.7.4.	

Issue	Where	Is this dealt with in the Plan?	If so, where?	If not, why or where is the information found?
Septic systems improved [15]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.7.3.	
Stock access to waterways [7, 12, 13, 15]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.3.2. Recommendations are outlined in the sections on riparian management and wetland management (Table 3.3.2).	
Surrounding land use [2, 7]	Myall Lakes	Yes	Part 3 of the WQIP contains action plans that aim to reduce the impacts on water quality from surrounding land use, such as farming and urban development.	
Tourism impacts [2, 5, 7]	Myall Lakes	Yes	See Section 3.5.	
Urban runoff [2]	Myall River, Crawford River, Myall Lakes	Yes	See Section 3.4.	

1 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Smiths Lake Landcare group report** (2007), Great Lakes Council.

2 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Hunter-Central Rivers Aboriginal Cultural and Environmental Network (ACEN) – CMA Partnership Committee report** (2007), Great Lakes Council.

3 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Great Lakes Coastal Land Managers Network group report** (2007), Great Lakes Council.

4 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Karuah / Great Lakes, Nabiac and Dyers Crossing Landcare groups report** (2007), Great Lakes Council.

5 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Pindimar / Bundabar Community Association and residents group report** (2007), Great Lakes Council.

6 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Wallis Lake Oyster Growers group report** (2007), Great Lakes Council.

7 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Hawks Nest Progress Association and the Myall Koala and Environment Support groups report** (2007), Great Lakes Council.

8 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Getaway Luxury Houseboats group report** (2007), Great Lakes Council.

9 **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Wang Wauk Landcare group report** (2007), Great Lakes Council.

[10] **Sanitary Survey Report for the Cape Hawke, Long Island and Wallis Lake Shellfish Harvesting Areas at Wallis Lake, Volume 1 & 2** (2002), SafeFood New South Wales, New South Wales Shellfish Program.

[11] **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Forster U3A group report** (2007), Great Lakes Council.

[12] **Workshopping community uses, values, concerns and ideas surrounding the water quality of our local waterways: Landholder Reference Group** (2008), Great Lakes Council.

[13] **Dairy Advancement Group meeting notes: 15 0ctober 2007** (2008), Great Lakes Council.

[14] **Landholder workshop meeting notes: Krambach 29 0ctober 2007** (2008), Great Lakes Council.

[15] **Coastal Catchments Initiative Landholder Survey** (2008), K Billingham, NSW Department of Primary Industries.

Appendix 5: Estimates of model reliability and modelling limitations

To further understand how actions in catchments impact ecological conditions in the Great Lakes, models of the catchment and estuary processes were built. Outputs from these models were used to build a decision support system (DSS) that has been used to support the development of this Plan. The key components and outcomes from this work are listed in Table A5.1.

Table A5.1. Model development for the Great Lakes CCI project.

Component work	Outputs
AnnAGNPS	• Catchment water quality models for dominant sub-catchments in the Great Lakes area have been developed, tested and refined with local data (where available). The models are capable of examining the potential effects of local management practices aimed at reducing catchment loads • Revised and updated land use maps for the catchment areas • Improved information on the contribution of sub-catchments to total pollutant exports into the studied estuaries
MUSIC	• Models of nutrient and sediment export from existing urban land • Models of the treatment train effectiveness of water-sensitive urban design (WSUD) devices • Predicted impacts of the partial redevelopment of existing urban land in selected sub-catchments in Forster • Predicted impacts of adoption of rainwater tanks in selected sub-catchments in Forster
Estuary mixing and ecological response	• Hydrodynamic / hydrologic models of the lakes • Prognosis software to explore the relationship between catchment inputs and ecological response
Decision support system	• A DSS that integrates available data, modelling results, estuary prognosis software and expert knowledge into a framework that facilitates transparent and defensible decision-making for improved environmental outcomes

As with all modelling projects, there is considerable uncertainty and error associated with the outputs from each model and the DSS. Uncertainty and errors arise from many sources, including model structure, input data and scenario development.

Models represent our understanding of real processes and, to some degree, all models simplify the ‘real world’. Uncertainties can arise due to imperfect knowledge about the processes at play (and their relative importance). Input data for the models can be difficult to measure and collate, particularly across large catchments and water bodies.

The Great Lakes catchments, like most Australian catchments, have incomplete climate and water quality records and limited catchment datasets (e.g. soils, land management practices). This is a potentially large source of uncertainty in the model results. Related to both model structure and data availability is the issue of limited knowledge of the catchment-scale impacts of different land management practices – including their effectiveness, and any temporal lags in impacts and of in-stream processes.

Integrated models of this nature have been demonstrated to be accurate in terms of the direction and magnitude of impacts, but are not assured as predictive models in the sense of accurately predicting precise future loads or concentrations.

This appendix describes in detail each of the modelling components that was used to estimate the effectiveness of the Plan, the data and calibration procedures used for these models, the sources of uncertainty in this modelling, and general model limitations.

AnnAGNPS

AnnAGNPS is a water quality model that can be used to simulate sediment and chemical (pesticide and nutrient) transport from agricultural catchments. The model can be used to provide estimates of runoff water quality, including soluble and particulate forms of nitrogen (N) and phosphorus (P) as well as sediments. Version 4.0 of AnnAGNPS was used to develop models for the Myall, Smiths and Wallis lakes catchments.

AnnAGNPS was developed by the Agricultural Research Service, Minnesota Pollution Control Agency, and the Natural Resource Conservation Service. It has been widely applied in the US and other countries under a variety of climate and topographic conditions. Past applications of the model in Australia have been limited to small catchments (<3 km^2) with relatively few land cover and soil types (e.g. Baginska, Milne-Home & Cornish 2003). The suitability of use of AnnAGNPS for the Great Lakes CCI was based on a review of the capabilities of available models in consideration of the goals of the project (Baginska 2000). Australian-based models, and in particular the (now) widely used E2 Catchment Modelling Software (http://www.toolkit.net.au), were unavailable at the time of model selection.

The model has four main modules: hydrology, sediment, nutrient and pesticide transport. Component modules in AnnAGNPS are summarised in Table A5.2. The representation of these components varies in detail and this has implications for the types of scenarios or management actions that can be considered using AnnAGNPS. The representation of groundcover processes is reasonably detailed, and scenarios looking at impacts of land management on hydrology and hillslope erosion processes can be readily constructed. In contrast, stream bed and stream bank erosion components are represented in a simplistic manner and cannot easily be used to examine alternative management scenarios for these sites. Groundwater processes are not considered in the model.

Table A5.2. Summary of AnnAGNPS model components.*

Component	Description
Hydrology	• Surface runoff (using the SCS curve number approach) and routing of overland flow • Subsurface flows (using Darcy's equation) • Irrigation component that can model dissolved chemicals and sediments with attached pollutants • Discharge from point sources
Sediment	• Sheet and rill erosion (using RUSLE technology) • Gully erosion (sediment and attached pollutants) • Stream bed and stream bank erosion • Sediment transport and deposition (Hydro-geomorphic Universal Soil Loss Equation [DG4] technology) • Impoundments (mass balance calculations)
Nutrients	• Dissolved and particulate nitrogen, phosphorus, and organic carbon (mass balance calculations, as used in CREAMS) • Dissolved nutrients from feedlots • Dissolved nutrient from point sources
Pesticides #	• Dissolved and particulate pesticides

* For more information on specific algorithms visit: http://www.wsi.nrcs.usda.gov/products/w2q/h&h/tools_models/agnps/index.html

\# Not used in the CCI project.

Model outputs – the model outputs considered in the Great Lakes application of AnnAGNPS are the total annual sub-catchment exports of total nitrogen, total phosphorus, suspended solids and runoff. Total nitrogen and phosphorus are comprised of the dissolved inorganic form (DIN and DIP) as well as the particulate form. Organic forms were not included due to the lack of adequate data on organic nitrogen and phosphorus concentrations in soils.

Input data – AnnAGNPS requires a large amount of input data to drive the model. The data used to develop, calibrate and test the models is summarised in Table A5.3.

Table A5.3. Summary of data used to develop and test the AnnAGNPS models for the Great Lakes catchments.

Attribute	Data	Source
Terrain	25 m digital elevation model (slope, elevation, aspect and reach length)	Land and Property Information Centre, NSW
Climate	1. Daily records of temperature, sky cover and wind speed and direction 2. SILO data drill	1. Bureau of Meteorology automatic weather stations 2. Queensland Department of Natural Resources and Mines
Soil properties	1. Local soil hydraulic properties were extracted from the Soil and Landscape Information System (SALIS), and the associated Soil Profile Attribute Data Environment Professional (SPADE Pro) data base 2. Measures of bulk density and saturated hydraulic conductivity were extracted from data contained in the Australian Soil Resource Information System (ASRIS) 3. Local field measurements	1. The former NSW Department of Natural Resources (now DECC). 2. Jointly developed by the Commonwealth Scientific Industrial Research Organisation, the Australian Collaborative Land Evaluation Program, National Heritage Trust and the Natural Land and Water Resources Audit 3. Landcare, DPI and DECC soil tests
Land use and soil – landscape maps	1. Digital land use map updated using 2005 SPOT imagery and local (Great Lakes Council) knowledge to account for recent developments in the area. Land use classifications were adopted to align with the Australian Land Use and Management (ALUM) Classification system (BRS 2006).[DG5] 2. Digital soil landscape map for Bulahdelah and Port Stephens. The map was simplified by reducing the number of classes using the Great Soil Group classification system	1 & 2. The former NSW Department of Natural Resources (now DECC)
Vegetation / land condition	1. Landholder and habitat surveys	1. Undertaken as part of the CCI project by staff from DECC and landcare
Reach geometry	1. Field surveys	1. Undertaken as part of the CCI project by staff from DECC
Model calibration	1. Daily maximum water height measurements at gauging stations in Bulahdelah (Upper Myall River), Nabiac (Wallamba River), Wang Wauk and Coolongolook (converted to discharge) 2. In-stream nutrient and sediment concentration at gauging stations in Bulahdelah, Nabiac, Wang Wauk and Coolongolook for runoff events	1, 2 & 3. [DG6]Collected as part of the CCI project by staff from DECC

Attribute	Data	Source
Model testing	1. Response and baseline sampling (grab samples) at 30 locations in the main sub-catchments (Wallamba, Wang Wauk, Coolongolook and Bulahdelah) 2. Plot scale rainfall simulations	1. Collected as part of the CCI project by staff from DECC 2. Collected as part of the CCI project by the University of Sydney in collaboration with staff from DECC

Spatial representation – the model is spatially explicit and represents a catchment as a number of cells, each of which reflects an area of land that behaves in the same way. Each cell type reflects hydrological boundaries (which way water flows) – as well as the dominant land use and the dominant soil type – both of which influence the amount of runoff and pollutant exported from a cell. Each cell may also have point sources (e.g. septic systems), gullies or feedlots in them. Runoff and pollutants from each cell are routed through reaches (the stream network) and may be transported out of the catchment, or deposited somewhere in the stream network or in impoundments (or storages).

The size of the cells were controlled in the model through adjustments in the critical source area (CSA) and minimum source channel length (MSCL) parameters, which define the minimum area required to support a permanent channel and the minimum length of a channel. The final set of parameters reflect a compromise between model accuracy and model effort, and capture the dominant land use in the Wallis and Myall catchments.

Model calibration and parameterisation – AnnAGNPS was originally developed for application to ungauged North American catchments for which there is no time-series data of flow and pollutants at the catchment outlet. For the Great Lakes CCI, the model was calibrated using local water height data (converted to discharge data) collected from the four gauged sub-catchments in the Great Lakes catchments between 1 January 2000 and 31 December 2006 (Figure A5.1).

Modelled runoff was calibrated against the major (>1000 ML) runoff events that occurred in the main sub-catchments over the seven-year period. The calibration process was based on an initial sensitivity analysis, which showed parameters to which modelled runoff volumes at the sub-catchment outlets were sensitive. Initial parameter values were iteratively adjusted until good model fits to the calibration data were obtained.

Calibration data for modelling nutrient and sediment exports from the main sub-catchments was based on collections of water samples during runoff events that occurred only in 2006. The limited calibration period is reflective of the lack of long-term nutrient and sediment load data for the Great Lakes area, a characteristic of the majority of catchments along the NSW coast. Similar to the process for calibrating runoff, calibration of sediment and nutrient parameters were based on sensitivity analysis. The analysis demonstrated that many parameters may influence the modelled estimates of sediment and nutrient export from the main sub-catchments. Initial values for all parameters were based on the means of the local data and information. Good modelled estimates of nutrient and sediment exports were obtained through iterative adjustments of the parameter values within the range given by the local data and information.

The points below summarise the main issues encountered during model calibration, and should be considered when interpreting model outputs:

- default parameters for runoff and nutrients reflect North American catchments. In order to calibrate the model, extreme values were used for some parameters (e.g. runoff curve numbers) and extreme ranges for some input data (e.g. soil nutrient concentrations)
- the model was insensitive to adjustment of many of the model parameters, even those that are dominant controls for runoff (e.g. rainfall distribution, parameters that affect time to concentration) which increased the difficulty in obtaining good hydrographs
- there is no groundwater component, which appears important for the Great Lakes area (according to baseflows estimated for that area)
- when examining the final parameter set used for the modelling, the parameters were partly chosen to apply to other sub-catchments (i.e. generalised)
- a large degree of uncertainty is introduced by the lack of spatial resolution in the soil and land use layers
- the following parameters and variables required considerable adjustment: runoff curve numbers, K-factor (soil erodibility), soil moisture steps, number of initialisation years, initialisation method, annual root mass, soil nutrient ratios, reach nutrient half-life
- it was not feasible to incorporate sources such as gullies and stream bank erosion, dams and feedlots given the lack of data at the sub-catchment scale.

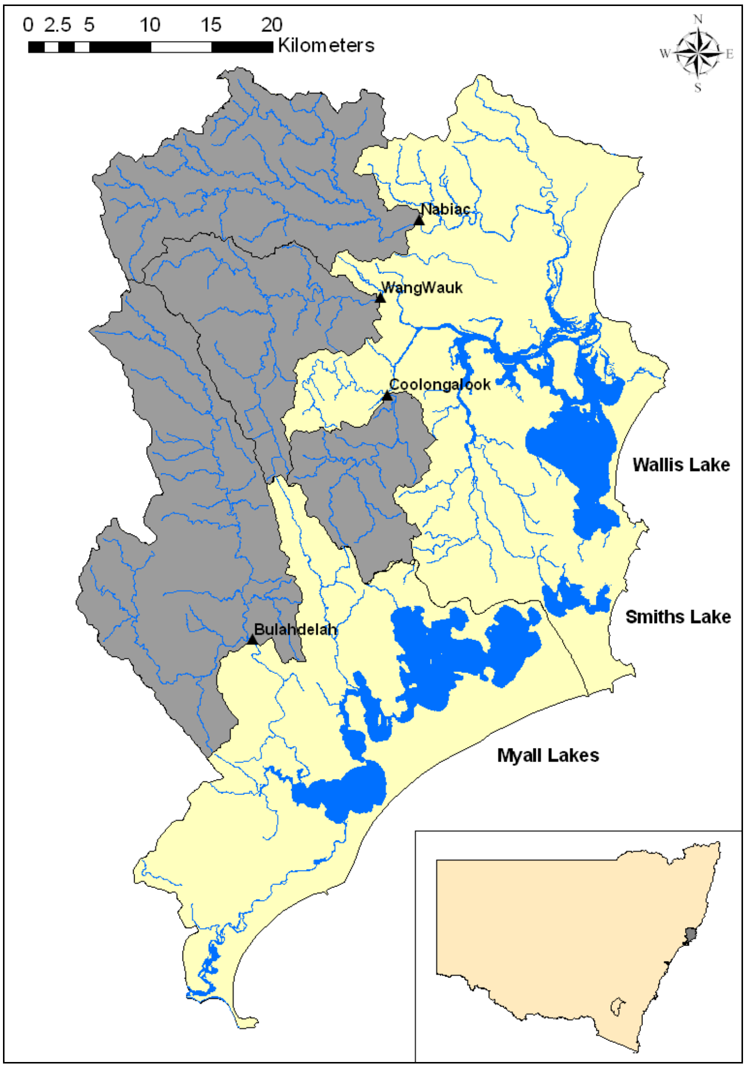

Figure A5.1. Calibration points within the Myall Lakes and Wallis Lake catchments.

Model outputs – AnnAGNPS model outputs are best used at a strategic level for managing nutrient and sediment exports (e.g. prioritisation at sub-catchment scale). Using outputs at a finer scale needs to be assessed case by case, and it may be more appropriate to undertake detailed modelling (e.g. MUSIC modelling for urban areas; farm-scale models).

Model performance – Predictive capabilities of AnnAGNPS may be summarised by an R^2 value, which describes the relationship between the modelled outputs and the field data. R^2 values close to 1 indicate good model performance or predictive capability. As shown in Figure A5.2, AnnAGNPS is able to adequately predict runoff volumes in the Bombah Broadwater, Wang Wauk and Wallamba sub-catchments. Each 'dot' in the graphs denotes a runoff event in the period between the start of 2000 or 2001 and the end of 2006. Hence AnnAGNPS was calibrated using runoff volumes from 15 events in the Bombah Broadwater sub-catchment, 14 events in the Coolongolook sub-catchment, 19 events in the Wallamba sub-catchment and 22 events in the Wang Wauk sub-catchment.[pt7]

The precision of the model predictions were examined through the coefficient of efficiency proposed by Nash and Sutcliffe (1970). The coefficient examines the difference between modelled and measured values. If the coefficient is <0, then the predictive precision of the model is lower than when the mean of the measured values is used. If the coefficient = 1, the model has precisely predicted the measured value. According to previous modelling efforts on river discharges in over 100 catchments in Australia, coefficient values greater than or equal to 0.6 are considered acceptable (Chiew, Stewardson & McMahon 1993). For runoff volumes, the coefficients are: Bombah Broadwater (0.63), Coolongolook (0.61), Wallamba (0.79) and Wang Wauk (0.61) sub-catchments; therefore, they indicate relatively adequate precision.

Model performance statistics for the other outputs of the model, such as the total sediment and nutrient loads, are shown in Table A5.4. Calibration of AnnAGNPS for these variables was determined by the number of runoff events that occurred in 2006. On average, two or three events could be used for calibration for each catchment.

Comparison with Australian catchment models – Since completion of the Great Lakes CCI, the NSW Department of Environment and Climate Change has applied the E2 modelling approach to all coastal catchments along the NSW coast, including the Wallis, Myall and Smiths lakes catchments. The runoff modelling was based on two unsaturated zone models – PERFECT and HYDRUS 2D (Littleboy *et al*. 1992) – and the event mean concentrations were based on best available information in the current literature. The unsaturated zone models have been successfully applied to range of catchments in east Australia (e.g. Abbs & Littleboy 1998). This modelling showed that the AnnAGNPS nutrient and sediment exports largely fall within the values produced using the Australian-based models (Table A5.6), which are also subject to a large degree of variability.

Table A5.4. A comparison of observed (O) and modelled (M) estimates of total event runoff volume, total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) between July and December 2006.

Sub-catchment	Event date		Total runoff volume (hm^3) [DG8] *	TN (tonnes)	TP (tonnes)	TSS (tonnes)
Bulahdelah	09.09.06 to 30.09.06	O	11.1	2.8	1.1	340.5
		M	11.4	2.4	0.8	340.2
Bulahdelah	03.11.06 to 17.11.06	O	4.4	0.6	0.3	47.7
		M	4.6	1.0	0.4	55.5
Coolongolook	04.08.06 to 13.08.06	O	1.1	0.4	0.1	25.5
		M	0.5	0.6	0.1	21.5
Coolongolook	29.08.06 to 05.09.06	O	0.9	0.2	0.02	16.1
		M	0.3	0.2	0.04	14.2
Coolongolook	08.09.06 to 15.09.06	O	5.1	1.1	0.2	114.2
		M	2.6	0.9	0.2	126.1
Wallamba	04.08.06 to 17.08.06	O	3.0	0.8	0.1	59.3
		M	1.9	2.1	0.4	242.0
Wallamba	28.08.06 to 07.09.06	O	5.5	3.5	0.6	392.4
		M	1.5	1.8	0.4	257.0
Wallamba	09.09.06 to 18.09.06	O	12.0	7.3	1.4	1,112.8
		M	7.2	6.4	1.1	1,498.8
Wallamba	04.11.06 to 07.11.06	O	0.5	0.3	0.1	60.7
		M	0.5	0.6	0.1	39.3
Wang Wauk	04.08.06 to 11.08.06	O	1.8	0.5	0.1	67.8
		M	1.2	1.4	0.2	116.0
Wang Wauk	28.08.06 to 05.09.06	O	1.6	0.5	0.1	51.7
		M	0.6	0.7	0.1	75.6
Wang Wauk	07.09.06 to 20.09.06	O	9.2	3.5	0.6	544.3
		M	5.5	2.5	0.3	482.0

* hm^3 = cubic hectometres

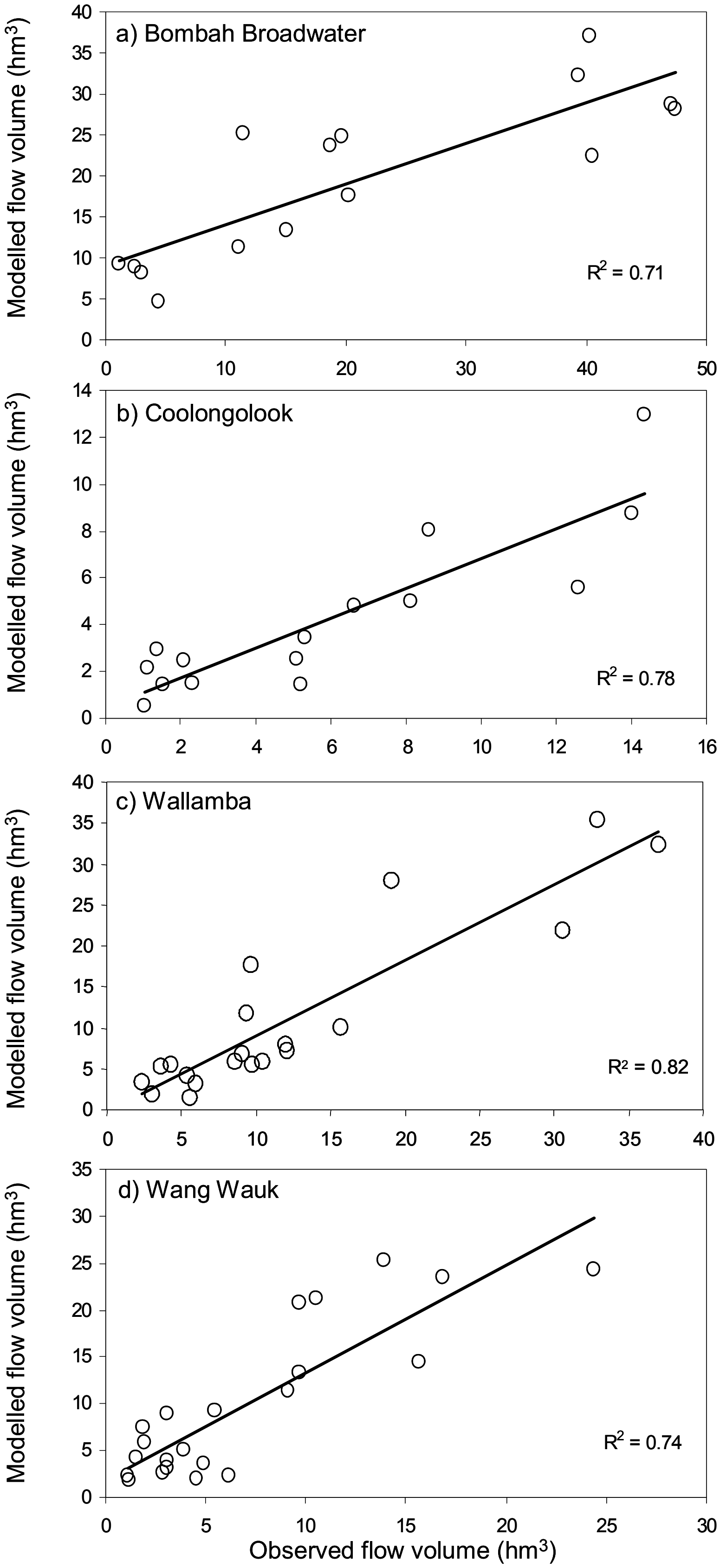

Figure A5.2. Observed vs modelled estimates of runoff from the Bombah Broadwater, Coolongolook, Wallamba and Wang Wauk. [pt9][DG10]**R^2 values close to 1 indicate good model performance or predictive capability.**

Table A5.5. Precision of model predictions given by the coefficients of efficiency proposed by Nash and Futcliffe (1970). The coefficient examines the difference between modelled and measured values. Coefficient values greater than or equal to 0.6 are considered acceptable.

Sub-catchment		Total volume (hm^3)	TN (tonnes)	TP (tonnes)	TSS (tonnes)
Bulahdelah	% difference	8.5	1.7	16.2	-2.0
	NS coefficient	0.63	0.96	1.17	1.00
Coolongolook	% difference	29.0	-8.1	-9.0	-3.9
	NS coefficient	0.61	0.97	0.99	0.97
Wallamba	% difference	9.9	8.3	9.3	-25.3
	NS coefficient	0.79	0.98	0.98	0.73
Wang Wauk	% difference	28.3	-2.2	15.1	-1.5
	NS coefficient	0.61	0.95	0.94	0.96

Table A5.6. A comparison of annual nutrient and sediment exports generated by AnnAGNPS and an Australian-based model (E2).

System	Land use	TSS (t/ha/y)		TP (kg/ha/y)		TN (kg/ha/y)	
		E2 approach	AnnAGNPS	E2 approach	AnnAGNPS	E2 approach	AnnAGNPS
Wallis Lake							
	National park	0.02	0.01 ± 0.01	0.06	0.02 ± 0.03	1.03	0.39 ± 0.34
	Urban residential	0.14	5.79 ± 5.99	0.84	1.31 ± 0.96	4.59	17.56 ± 17.92
	Native / exotic pasture	0.03	0.07 ± 0.65	0.38	0.19 ± 0.20	2.86	2.54 ± 2.24
Myall Lakes							
	Cleared land	17.77	71.93	21.64	18.63	240.38	200.66
	National park	0.02	0.01 ± 0.01	0.04	0.04 ± 0.05	0.73	0.3 ± 0.3
	Urban residential	0.09	2.08 ± 2.47	0.52	0.73 ± 0.65	2.84	7.95 ± 7.79
	Native / exotic pasture	0.03	0.3 ± 0.3	0.33	0.15 ± 0.15	2.45	1.14 ± 1.03
Smiths Lake							
	National park	0.01	0.00 ± 0.01	0.04	0.13 ± 0.12	0.65	0.48 ± 0.46

Note: AnnAGNPS outputs are presented as the average ± standard deviation. The standard deviation reflects variability associated with varying soil types, groundcover condition, topography and rainfall.

MUSIC

The urban modelling component of the CCI project was undertaken using the MUSIC modelling software developed by the Cooperative Research Centre for Catchment Hydrology. This software is widely adopted within Australia and is endorsed by many local government and state agencies (e.g. Gold Coast City Council, Brisbane City Council, Melbourne Water) as being the most appropriate tool to make predictions about the impacts of implementation of WSUD and other water quality management strategies.

No detailed calculation of uncertainty with this model has been undertaken for this project. The uncertainty, variations and assumptions associated with how a stormwater treatment strategy (or scenario) is constructed in MUSIC is usually significant compared to the actions that are actually delivered on the ground. Assuming that model representation exactly represents the final adopted strategies, a value representing model accuracy of 10% has been suggested as being a reasonable value when preparing stormwater treatment curves (Fletcher, Duncan, Poelsma & Lloyd 2004[DG11]).

The developer of the MUSIC models for the Great Lakes CCI suggests that the uncertainty of MUSIC model results be considered to be at least ±10% (BMT WBM 2008).

Estuary mixing and ecological response

The many processes that operate concurrently in an estuary make it difficult to quantify in a rigorous scientific sense where material from a catchment moves within a water body, any changes to the form of that material and exactly how the ecology of the estuary changes in response to catchment inputs. Available theory and local (site-specific) measurements enable an assessment of some important estuarine characteristics as they relate to catchment inputs.

The modelling component of the estuary project involved development of:

- hydrodynamic models that calculate the transport of material within the estuary
- models of estuarine ecology that relate the ecological response of the estuary to material from the catchment.

For each of the Great Lakes systems, a Catchment Estuary Management System was developed by Brian Sanderson (affiliated to DECC) for the CCI project (the ‘prognosis’ software). Users can examine the impacts of changes in sub-catchment load and flow volume inputs to the estuary, on concentrations of nutrients and sediment in the water column, and ecological response to these changes. Ecological response is related to changes in chlorophyll-a concentrations and the area of seagrass (Smiths Lake and Wallis Lake) or charophytes (Myall Lakes) communities.

Hydrodynamic models – hydrodynamic models are based, for the most part, on well-known and broadly applicable physical theory that can be formulated and described mathematically. This means that the models have relatively few constants that need to be determined empirically. Hydrodynamic models are forced by catchment runoff and measurements of: wind, rainfall, nutrient concentrations in rainfall, and offshore water level (tides).

Hydrodynamic models were developed for the Myall and Wallis lakes that simulate the movement of water (and water-borne, catchment-derived pollutants). The pollutants were assumed to be 'conservative', meaning that there was no loss or gain of material in the lake itself. A sink or source term was then used to account for any non-conservative behaviour (i.e. loss or gain of material) observed in the lake. Unit tracers for each sub-catchment, direct rainfall (Wallis Lake only) and salinity were used to model the transport of material from (respectively) runoff, rainfall and the ocean, as well as the redistribution of the material in the lake. Concentration of any particular nutrient at a point in time in any location in the estuary is calculated as a linear combination of the tracers.

Comparison of modelled and measured TN concentrations showed similar spatial trends for the Myall Lake, although modelled concentrations were less than measured. These model calculations were made before rainfall data was available, and adding in the effects of rainfall almost exactly accounted for the TN discrepancy (Brian Sanderson, pers. comm.). Both the model and the measurements give a down-lake gradient of TN concentrations (higher in Myall Lake and lower in Bombah Broadwater). The model developer concluded that the agreement between modelled and measured concentrations was reasonable, given uncertainties in catchment runoff, hydrodynamic modelling and measurement variability (Sanderson 2007a).

Initial model runs gave TP concentrations that ranged from 0.03 to 0.35 g/m^3 through most of Myall Lakes, whereas observations reported by Sanderson & Baginska[DG12] (2007) [cited in Sanderson (2007a)] suggest TP is about 0.3 g/m^3 in Bombah Broadwater and 0.12 g/m^3 in Myall Lake. To account for this, Sanderson (2007a) introduced a 'sink', which amounts to a burial of phosphorus with a magnitude equivalent to 93% of the P load entering the Myall Lake from its surrounding catchment.

Table A5.4 shows a comparison of the modelled and observed TN for segments of Wallis Lake. Modelled TN is the result considering sub-catchment inputs, as well as inputs from rainfall and ocean sources. Observed TN are estimates based on measured TN concentrations in the lake. Differences can be attributed to errors in the hydrodynamic model, omission of biological fluxes, measurement errors, errors in the catchment modelling, and omission of sedimentation and resuspension processes (Sanderson 2007b). The table illustrates the importance of more extensive measurements required to extend our knowledge of the dominant mechanisms in the catchment.

Table A5.7. Summary of lake estuary models (Proportion = modelled concentration divided by the observed concentrations).

Proportion	Possible cause of discrepancies
Wallamba River Estuary (HS1 to HS3)	
1.954	• In-lake sink somewhere in the path taken by material entering Wallis Lake via Wallamba River • Over-estimation of loads entering Wallamba River • Hydrodynamic model underestimates the extent to which runoff from Wallamba River is directly flushed to the ocean • Few measurements of total dissolved N were made in this part of Wallis Lake relative to the spatial variability – possible under-sampling
Wang Wauk, Coolongolook and Wallingat river estuaries (HS4 to HS11)	
0.507	• In-lake sources or errors in measurements or predictions
Southern and western catchments entering Wallis Lake (HS12 to HS15)	
0.391	• In-lake sources or errors in measurements or predictions
Eastern catchments entering Wallis Lake (HS16 to HS12)	
0.878	• In-lake sources or errors in measurements or predictions

A different approach was utilised for Smiths Lake, as the lake is mostly closed and not influenced by tidal induced fluxes of oceanic water or inputs from large catchments and large streams. Hence the transport and mixing dynamics are different and much simpler than for either Wallis or Myall Lakes. Smiths Lake can be considered well-mixed because the timescale for mixing in the lake is short compared to the timescale between entrance opening or major rainfall events. This meant that Smiths Lake could be modelled as a single reservoir into which all catchment runoff and rainfall enters.

Ecological response models – Ecosystems are highly complex and variable from one estuary to the next, and there is no general theoretical formulation that describes estuary ecology at a detailed level. There are, however, some principles that are broadly applicable but require measurements for site-specific formulation and calibration. Estuary response models developed for the CCI project relate the abundance of valuable plants (seagrass, charophytes) and nuisance plants (e.g. planktonic algae and epiphytic macroalgae) to the input nutrient loads and other characteristics of the water body.

The ecological responses to catchment inputs are modelled based on the concept of the potential for eutrophication (PE) within each system. PE describes the potential for excessive plant growth to occur in a water body. It provides a measure of the risk of negative outcomes such as nuisance algal blooms, transition to phytoplankton dominance, diminished light penetration, more turbid waters and muddy foreshores.

For each of the Great Lakes systems, relationships have been established between:

- potential for eutrophication and light attenuation
- potential for eutrophication and chlorophyll-a
- light attenuation and seagrass distributions (for Smiths and Wallis lakes) or charophytes (Myall Lakes).

These relationships relate loads from the catchment to the expansion and contraction of nuisance aquatic plants (represented by chlorophyll-a levels), and plants representative of healthy ecosystems (seagrass and charophytes). Given water clarity, hypsometry and knowledge of the organisms light requirements, the maximum area within the lake that can sustain seagrass (or charophytes and *Najas marina* in Myall Lakes) can be estimated.

Key evidence and assumptions used to derive these relationships are defined in Table A5.5.

Prognosis software – The tracers defined for the dynamic model can be scaled by the sub-catchment input loads to look at changes in concentrations in the lake in response to changes in the catchment. This approach is used in the prognosis software for the Myall Lakes and Wallis Lake, and was used for computational efficiency.

The system has been designed to capture 'key ecosystem functionalities' in a simple manner. A more complex biogeochemical modelling approach may not necessarily improve a prognosis and, even if it did, it would be hard to work out why there was an improvement or where things are going wrong (http://users.eastlink.ca/~bxs/LAYMAN/node21.html, accessed 28 May 2008).

The single reservoir model for Smiths Lake is much less computationally demanding than the hydrodynamic models developed for the other lakes. It was thus directly included in the prognosis software developed for Smiths Lake (http://users.eastlink.ca/~bxs/LAYMAN/node9.html, accessed 28 May 2008). This allows changes over time to be viewed.

Model outputs – The outputs from the prognosis software are best used at a strategic level for identifying the likely direction and magnitude of change in indicator values in the estuaries. To examine temporal responses, users need to refer back to the dynamic models constructed for each lake. For areas of the estuary that are at a small scale (e.g. the Forster Keys area), the use of outputs from both the dynamic models and the prognosis software need to be assessed on a case-by-case situation, and it may be appropriate to undertake more detailed modelling (e.g. finer-resolution modelling of some areas of the lake).

Specific considerations when using outputs from the dynamic models and the prognosis software are:

- the model for Smiths Lake has been calibrated and simulated on data that is several years old. Since this data was collected, the entrance has been in an open state for an unusually prolonged period. This is likely to have had substantial impacts on the state of Smiths Lake that has not been accounted for in the modelling
- the estuary model relies on inputs of flows and pollutants from the catchment models. Pollutant concentrations entering from sub-catchments are created using estimates of flow and pollutant loads modelled from the catchment modelling components. These concentrations are thus strongly affected by the flow estimates from the catchment model.

The model developer has noted that the "available theory may be crude, but it has been calibrated relative to site-specific information and packaged into a form that enables a prognosis of ecological response in the estuary to some specified catchment degradation" (http://users.eastlink.ca/~bxs/LAYMAN/node20.html, accessed 28 May 2008). Some issues exist if the package is used to examine improved catchment management (see 'seagrass' example in Table A5.8).

Table A5.8. Defining ecological response in the Great Lakes.

System	Ecological response
Myall Lakes	
Potential for eutrophication	Experimental evidence shows that water clarity and the potential for eutrophication is related to total phosphorus in Myall Lake. Total nitrogen is high in the lake, although is in a dissolved organic form that does not block light.
Smiths Lake	
Water clarity	Few measurements are available for Smiths Lake. The relationship between water clarity and total nitrogen that was obtained for Wallis Lake was recalibrated to fit available data in Smiths Lake and then used to diagnose water clarity in Smiths Lake.
Potential for eutrophication	An empirical relationship relating the coefficient of light attenuation to PE was defined for Wallis Lake. Wallis Lake is, on average, shallower than Smiths Lake and its lake bottom is subject to a greater bottom stress. This would result in greater levels of particulate resuspension in Wallis Lake. For the same PE, the model developer expects that the light attenuation will be less in Smiths Lake than in Wallis Lake. This means that light can penetrate further into a water column in Smiths Lake, thus allowing seagrass to grow to greater depths. This is reflected in the light–depth relationships used for Smiths Lake and detailed in Sanderson (2007a).

System	Ecological response
Wallis Lake	
Potential for eutrophication	Water clarity and the potential for eutrophication are strongly correlated with total nitrogen concentration in Wallis Lake.
Seagrass [a]	Other factors apart from bottom light intensity affect the distribution of seagrasses (e.g. mechanical stress on the bottom): • seagrasses are not observed to grow, for example, in dynamic channels or on shallow sand flats that are subject to wave action • in the modelling approach, substrate instability is accounted for empirically by matching modelled seagrass distributions to the present-day observed distributions • the areas of mismatch – where seagrass would be expected because of the light regime but is actually absent – were diagnosed to be the areas of mechanical exclusion. By implication, a modelled improvement in light attenuation will not show an increase in seagrass distribution in these areas.

a: Note that the intention of the Great Lakes CCI is to achieve water quality improvement through the promotion of better catchment management. By limiting the extent of seagrass under any light availability conditions to the areas where seagrass currently occurs, the approach is, by definition, limited in its capacity to model increases in seagrass due to modelled improvements in water quality and light availability.

Decision Support System

The DSS model base consists of a number of sub-models that link the impacts of urban and non-urban land management to catchment exports and estuary response. The models are coded in the Integrated Component Modelling System (ICMS) – a software platform developed by at CSIRO Land and Water.

AnnAGNPS and MUSIC model results were used to generate the data bases in the DSS. In the case of AnnAGNPS results, this means that results used in the DSS are simpler than those present in the original model. However, the DSS has been tested to ensure that it accurately reproduces the AnnAGNPS estimates of catchment load to minimise these potential errors. The estuary model in the Myall Lakes and Wallis Lakes DSS exactly replicates the prognosis software developed in MATLAB by Brian Sanderson, which enables quantification of how an estuary changes in response to management actions on the catchment that drains into that estuary. The prognosis software developed for Smiths Lake has also been replicated in the Smiths Lake DSS application, although the temporal aspects cannot be viewed in the DSS. To look at temporal aspects requires the MATLAB version of the software.

Non-urban catchment data base – outputs of the AnnAGNPS model representing current catchment conditions (climate as well as land condition, management and use) were used to develop mean 'export' rates for TN (kg/ha/year), TP (kg/ha/year), TSS (tonnes/ha/year) and runoff volumes (ML/ha/year) for different land use classes in a sub-catchment. These export rates were calculated for erodible and non-erodible soils, and by slope class. Not all land use types were present on each combination of sub-catchment, erodibility class and slope class. However, the DSS requires a value for each combination. A set of 'rules of thumb' was developed for selecting an appropriate rate based on similar land uses and slope classes. There is a higher level of uncertainty associated with these combinations.

The impact of catchment actions and climate conditions on non-urban exports calculated in the DSS are captured mainly through parameters developed from AnnAGNPS scenarios developed by Jocelyn Dela-Cruz (from DECC) or from other sources (e.g. literature). These parameters act as multipliers on the basic generation rates – that is, the new load generated after the catchment action or change in climate condition is a scalar multiple of the original generation rate-based load. Literature-based rates were implemented due to limitations identified with the model (e.g. limited capacity to model stream banks) and could be considered more uncertain, given their reliance on untested literature-based data or assumptions. In all cases, the best available literature was used and this was cross-checked against alternative sources of information where available.

Urban catchment data base – results from MUSIC models representing current catchment conditions (climate as well as land condition, management and use) were used to develop mean 'export' rates for TN (kg/ha/year), TP (kg/ha/year), TSS (tonnes/ha/year) and runoff volumes (ML/ha/year) for urban lands in the Great Lakes catchment. These generation rates replace those calculated for urban land using AnnAGNPS.

The impact of urban catchment actions and climate conditions on urban exports calculated in the DSS are mainly captured through 'multipliers' (similar to those used on non-urban lands) developed from MUSIC scenarios developed by Tony Weber (from BMT WBM).

Scenario development and costs

Appendices 14, 17 and 20 describe in detail the scenario and cost assumptions that underlie the Plan. As this section demonstrates, the Plan relies on a substantial set of scenario and cost assumptions. Major assumptions underlying these scenarios can be summarised as the:

- level of uptake and consequent on-ground change following rural programs
- resources required to create and maintain uptake of programs into the future
- extent and location of deteriorated stream banks as well as the costs, extent and effectiveness of actions to remediate them
- level of population growth and subsequent redevelopment
- rates of uptake for rainwater tanks and urban programs
- timing and nature of new developments, and retrofitting of existing developments

- costs of urban retrofit and WSUD devices.

All assumptions have been developed in consultation with relevant community members and Council staff. Where possible, assumptions have been tested against existing information (e.g. historical rates of population growth). Scenario and cost assumptions remain a significant source of uncertainty in the Plan.

Model accuracy and uncertainty

As with all modelling projects, there is considerable uncertainty and error associated with the outputs from each model and the DSS. Uncertainty and errors arise from many sources, including model structure, input data and scenario development. Table A5.9 give examples of key sources of uncertainty for the component models.

Table A5.9. Sources of uncertainty in the outputs from the DSS, and the catchment export and estuary models.

Source	Model structure	Input data	Scenario development
AnnAGNPS	*Source(s):* Imperfect knowledge of the mechanisms driving nutrient cycling (such as resuspension, settling, denitrification and burial), and sources or sinks in the estuary *Implication:* Inability to construct detailed scenarios relating to some erosion processes (e.g. gullies, stream banks).	*Source(s):* Climate records, water level measurements, land use mapping, the range of soil data, landscape characterisation and field measurements (nutrients, TSS). *Implication:* Increased need to calibrate model parameters	Difficulties in relating 'real-world' characteristics to model parameters (e.g. groundcover is described in AnnAGNPS using several parameters that are quite difficult to relate to on-ground conditions due to limited capacity to survey lands on a catchment scale).
MUSIC	*Source(s):* Assumption that urban processes are similar for all parts of the catchment, dependent only on % imperviousness differences. No in-channel processing of pollutants passing down the network *Implication:* May not represent the specifics of urban land uses within GLC, although is consistent with other urban areas in Australia. In-channel processing may lead to overestimation of pollutant contribution to receiving waters (but this is a conservative approach, i.e. we will be	*Source(s):* Rainfall data, evapotranspiration data, flow data for calibration, pollutant export data for the region. *Implication:* Reliance on default parameters or values from literature. May underestimate the importance of sandy soils in allowing infiltration (but this is a conservative approach, i.e. we will be overpredicting rather than underpredicting pollutant loads, consistent with the precautionary principle)	*Source(s):* Uncertainties associated with the ability to fully implement proposed treatment strategies (e.g. practical limitations that could not be modelled / forseen). Uncertainties also on the adoption rates of rainwater tanks and the performance of treatment measures in the GLC region specifically *Implication:* Potential overestimation of reductions possible by implementation of strategies

Source	Model structure	Input data	Scenario development
	overpredicting rather than underpredicting pollutant loads, consistent with the precautionary principle)		
Estuary	*Source(s):* Imperfect knowledge of the mechanisms driving nutrient cycling (such as resuspension, settling, denitrification and burial), and sources or sinks in the estuary *Implication:* The prognosis tool can be used to look at ecological response in the estuary from catchment degradation. Limiting the extent of seagrass to the current seagrass extent, also limits the ability to model increases in seagrass due to modelled improvements in the catchment. Note that incorporating more detailed process representation will increase model complexity with no guarantee of improved prognosis.	*Source(s):* Errors in the modelled catchment runoff and loads, uncertainty in climate inputs, limited measurements in the estuary (esp. for Smiths).	*Source(s):* Prohibitive computational resources required to examine temporal scenarios in Myall and Wallis lakes
DSS	*Source(s):* Aggregation of spatial data from catchment models *Implication:* Risk of oversimplifying processes and results	*Source(s):* Uncertainties from estuary and catchment models flow through to development of DSS data base *Implication :*Risk of accumulating errors from various models	*Source:* Scenario assumptions and costings (see Appendices 14, 17 and 20) *Implication:* These assumptions need to be re-evaluated regularly throughout the implementation of the Plan

[DG13]

Model limitations

The modelled impacts of riparian remediation actions in Sections 2.7 (Wallis Lake), 2.11 (Smiths Lake) and 2.15 (Myall Lakes) of the WQIP (e.g. riparian fencing and off-stream watering) are nutrient and sediment loads at the sub-catchment scale, and the response of chlorophyll-a and seagrass or charophytes in the estuary to these load changes. The benefits of healthy riparian zones on water quality and ecology in streams and rivers cannot be shown with the CCI models. Monitoring by DECC, undertaken as part of the

CCI project, demonstrated the benefits of riparian vegetation on streams and rivers, showing distinct differences (Haine, Dela-Cruz & Scanes in prep). Where healthy riparian vegetation exists there is greater abundance and diversity of macroinvertebrates and fish species in the streams compared to streams with no (or limited) riparian vegetation.

The DSS considers only average annual conditions, so cannot be used to consider temporal aspects such as seasonal variability or events. The original models (AnnAGNPS, MUSIC and the hydrodynamic models) can consider finer temporal scales, although to integrate the outputs from these models into a user-friendly decision support tool requires some aggregation in both time and space.

Not all catchment and estuary processes could be modelled in detail due primarily to data and resource limitations. For example, to represent detailed biogeochemical processes in the estuaries requires extensive temporal and spatial datasets. Such datasets are not available in the Great Lakes estuaries. The implication of this for the development of hydrodynamic models for Myall and Wallis lakes is that these processes cannot be modelled directly. Pollutant movement through the estuary was modelled conservatively, meaning that sinks and sources of pollutant were not considered. The model was then calibrated to local data to account for any sinks and sources. Areas of further research have been identified for the Great Lakes catchments and estuaries as part of the Plan's Adaptive Management Strategy (Section 3.9 of the WQIP).

A summary of those scales and processes that were and were not modelled as part of the CCI processes is given in Table A5.10.

Table A5.10. Representing scales and processes in the Great Lakes CCI modelling.

	Modelled	Not modelled
Scale	*Catchment* • Sub-catchment TN, TP and TSS export loads and flow volumes (sub-catchments in the Great Lakes range from 87 to 23,956 hectares) *Estuary* • *Myall:* 250 m × 250 m grid of light attenuation, constituent concentrations and charophyte extent • *Wallis:* 250 m × 250 m grid of light attenuation, constituent concentrations and seagrass extent • *Smiths:* light attenuation, constituent concentrations and seagrass extent	*Catchment* • Water quality and ecological health of streams and rivers (e.g. in-stream benefits of riparian protection) *Estuary* • No spatial representation in Smiths Lake • River estuaries not modelled • No temporal resolution in Myall and Wallis lakes [a]
Processes	*Catchment* • Sub-catchment TN, TP and TSS export loads and flow volumes (sub-catchments in the Great Lake range in size from 87 to 23,956 hectares) • Limited differentiation of erosion types [b] *Estuary* • 'Conservative' mixing of pollutant concentrations in response to catchment inflows, oceanic tides and wind	*Catchment* • In-stream attenuation processes *Estuary* • Nutrient cycling and settling processes (these are accounted for through calibration) • Indicators of ecological condition other than chlorophyll-a concentration and bottom-dwelling plants like seagrass and charophytes (e.g. aquatic fauna)

a: The hydrodynamic models developed for the CCI project do operate on a daily time-step. However, average conditions were considered in the prognosis software developed from these models (by DECC) and the DSS to aid interpretation of outputs.

b: There is limited information on the extent of gully erosion in the Great Lakes catchments, so gullies could not be modelled directly by AnnAGNPS. However, the model was calibrated to local data, and the export rates developed from AnnAGNPS model runs include the input from gullies.

[DG14]

Appendix 6: Contributions of pollutants by land use in individual sub-catchments, Wallis Lake

This appendix provides details on the contribution of pollutants by land use for the seven sub-catchment groups considered in this Plan, as well as for all sub-catchments defined for, and modelled using, the Wallis Lake Decision Support System (DSS).

1. Sub-catchments and sub-catchment reporting groups

A total of 143 sub-catchments were defined and grouped according to where the sub-catchments enter the lake or estuarine rivers. The 20 groups identified are shown in Figure A6.1 and Table A6.1. For implementation of the Decision Support System, the large Upper Wallamba, Wang Wauk and Coolongolook sub-catchments were split into smaller sub-catchments. To facilitate interpretation of this plan, the catchment export summaries in Sections 2.5.6 and 2.7 of the WQIP are grouped into the seven regions indicated in Table A6.1.

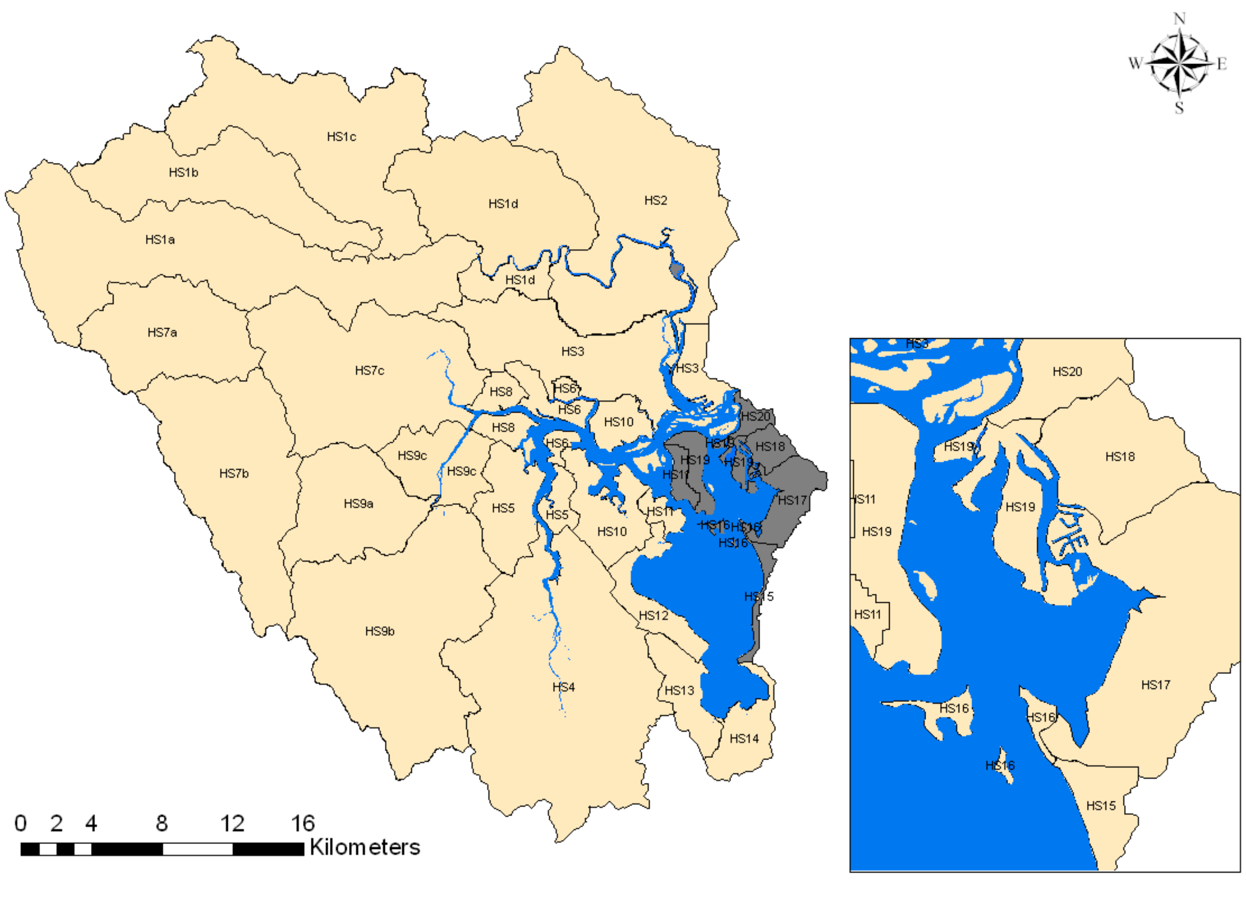

Figure A6.1. Location of sub-catchments of Wallis Lake.

Table A6.1. Sub-catchments of Wallis Lake.

Code	DSS sub-catchments
Wallamba River sub-catchments	
HS1a	Upper Wallamba River
HS1b	Firefly River
HS1c	Khoribakh Creek
HS1d	Candoormakh and Pipeclay creeks
HS2	Bungwahl and Darawakh creeks
Lower River Estuary sub-catchments	
HS3	Minimbah and Tuncurry
HS6	Duck Gully
HS8	Coolongolook Estuary Reach
HS10	Beaky Bay
Wallingat River sub-catchments	
HS4	Wallingat River
HS5	Coomba Creek
Wang Wauk River sub-catchments	
HS7a	Bunyah Creek
HS7b	Upper Wang Wauk River
HS7c	Lower Wang Wauk River
Coolongolook River sub-catchments	
HS9a	Cureeki Creek
HS9b	Upper Coolongolook River
HS9c	Lower Coolongolook River
Wallis Lake – southern and western sub-catchments	
HS11	Coomba / Wallis Island
HS12	Coomba Bay
HS13	Whoota / Yarric
HS14	Pacific Palms
HS15	Booti Booti
HS16	Green Point
Wallis Lake – Forster sub-catchments	
HS17	Pipers Bay (Cape Hawke)
HS18	Pipers Creek (South Forster)
HS19	Big Island
HS20	Forster

2. Land use groups

In undertaking analysis for this Plan, detailed land uses have been grouped into several broader classifications. These classes are based on similar generation rates. Groupings used in the analysis are shown in Table A6.2.

Table A6.2. Land use classes represented in the Great Lakes CCI DSS.

Simplified DSS land use class	Land use description	AnnAGNPS model classes	Australian Land Use and Management (ALUM) classification [a]
Protected Vegetation	Protected Vegetation: This group is comprised of: (1) National parks, which are protected areas managed mainly for ecosystem conservation and recreation; and (2) Strict nature reserves, which are protected areas managed mainly for science.	• National park • Strict nature reserves	• ALUM 1.1.3 • ALUM 1.1.1
Forestry	Forestry: This group is comprised of: (1) Hardwood production, which is land managed for hardwood sawlogs or pulpwood; (2) Production forestry, which involves commercial production from native forests, and related activities on public and private land; and (3) State forest.	• Hardwood production • Production forestry • State forest	• ALUM 3.1.1 • ALUM 2.2.0 • n/a
Native Vegetation	Native Vegetation: This group is comprised of: (1) Remnant native cover, which is land under native cover that is mainly unused (no prime use), or used for non-production or environmental purposes; and (2) Riparian vegetation.	• Remnant native cover • Riparian vegetation	• ALUM 1.3.3 • n/a
Unimproved Pasture	Unimproved Pasture: This land use type is native / exotic pasture mosaic, which is pasture with a substantial native species component despite extensive active modification or replacement of native vegetation (BRS 2006).	• Native / exotic pasture mosaic	• ALUM 3.2.1
Improved Pasture	Improved Pasture: This group is comprised of: (1) Pasture legume / grass mixture; (2) Irrigated sown grasses; and (3) Irrigated legume / grass mixture.	• Pasture legume / grass mixture • Irrigated sown grasses • Irrigated legume / grass mixture	• ALUM 3.2.4 • ALUM 4.2.4 • ALUM 4.2.3

Simplified DSS land use class	Land use description	AnnAGNPS model classes	Australian Land Use and Management (ALUM) classification [a]
Roads	Unpaved Roads: All unpaved roads mapped for the Great Lakes catchments.	• Roads	• ALUM 5.7.2
Rural Residential	Rural Residential: This land use is “characterised by agriculture in a peri-urban setting, where agriculture does not provide the primary source of income” (BRS 2006).	• Rural residential	• ALUM 5.4.2
Urban Residential [b]	Urban Residential: This group is comprised of: (1) Urban residential (e.g. houses, flats, hotels); and (2) Recreation, which include parks, sports grounds, camping grounds, swimming pools, museums and places of worship (BRS 2006).	• Urban residential • Recreation	• ALUM 5.4.1 • ALUM 5.5.3
Manufacturing		• Manufacturing	• ALUM 5.3.0
Quarries		• Quarries	• ALUM 5.8.2
Cleared Land	• Cleared land	• Cleared land	• n/a

n/a = not applicable.
a: Bureau of Rural Sciences (2006).
b: Export rates for urban residential land were determined from MUSIC model results for urban sub-catchments in the Great Lakes.

The groups and their ALUM classification (BRS 2006) are listed above. More details on features of these land uses can be accessed from http://adl.brs.gov.au/mapserv/landuse/alum_classification.html, accessed 24 July 2008.

3. Overview of contributions by major sub-catchment areas

All land areas contribute some sediment and nutrients to the lake, even protected vegetation. In a management sense we are most interested in where human activities have caused elevated pollutant loads to the lake, as these are areas where intervention may act to decrease loads. This means, for example, that while protected vegetation may contribute pollutants to the lake, if no human activities (such as changes to the fire regime or provision of tracks) have caused this to be higher than what would be expected to naturally occur then these pollutants are not of management concern. Descriptions below of sources of pollutants by land use should be read with this in mind. Figures showing the area and pollutant split by land use for individual sub-catchments are given in the following section.

The land use classes that are targeted in modelling presented in Section 2.7 of the WQIP are: agriculture, urban residential, rural residential and (only in the Wallamba River sub-catchments) unpaved roads. The modelled actions in this Plan do not address the management of forestry, protected vegetation or native vegetation, although these land uses are considered by some of the non-modelled actions in this Plan. The management of forestry and protected vegetation areas should be accounted for by other planning and legislative processes (e.g. DECC licensing agreements).

Wallamba River

The Wallamba River sub-catchments are shown in Figure A6.2.

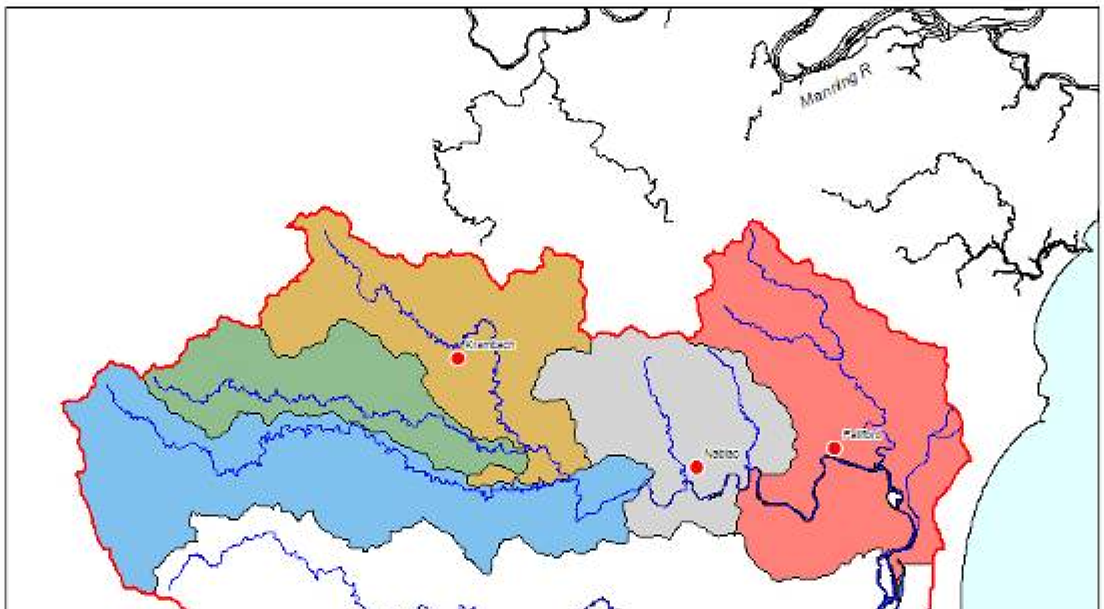

Figure A6.2. The Wallamba River sub-catchments.

Much of the nutrient and sediment sourced from the Wallamba River sub-catchments are from the Upper Wallamba River sub-catchment (Table A6.3), with the remaining contributions dominated by the remaining upper sub-catchment areas. The Lower

Wallamba sub-catchments – Bungwahl and Darawakh creeks – do not contribute much of the total sub-catchment load even though they are a substantial part of the total area.

The relative contribution of different land use activities and sources of pollutants compared to their area in the sub-catchment is shown in Figure A6.3 for the Wallamba River sub-catchments.

All lands in the Wallamba River sub-catchments are on soils classed as being prone to erosion ('erodible'). All of the improved pasture, 90% of unpaved roads and 60% of the unimproved pasture land occur on low sloping lands (<20%). In the Upper Wallamba sub-catchments (HS1a, HS1b, HS1c, HS1d), much of the forest vegetation remains on high slope land, although 70% of the protected vegetation class in the sub-catchments is on low slope land. In Bungwahl and Darawakh creeks (HS2), much of the remnant native cover remains on high slope land, although 70% of the protected vegetation and forestry activities occur on low slope land.

Most of the nutrient (TN – 85%; TP – 75%) and sediment (85%) exports from the Wallamba River sub-catchments come from the unimproved pasture lands that cover 53% of the land area (Figure A6.3). The next largest contributor of TP (11%) is from native vegetation, although this reflects the large area of the land use (27%) rather than an elevated generation. Unpaved roads contribute disproportionately to their areal extent.

Table A6.4 lists the percentage area of target (agriculture, rural and urban residential lands, and unpaved roads) and non-target land (forestry, protected vegetation or native vegetation), and the amount of total loads sourced from these lands. While 34% of the land is not targeted by the actions modelled in Section 2.7 of the WQIP, the remaining land contributes over 85% of the nutrient exports and nearly all of the sediment exports modelled for theWallamba River sub-catchments.

Table A6.3. Area and pollutant exports from the Wallamba River sub-catchments. The table shows absolute values as well as the percentage contribution of the sub-catchment to the sub-catchment group (% Group) and catchment (% Wallis) total.

Sub-catchment	Area			TN			TP			TSS		
	ha	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	tonnes	% (Group)	% (Wallis)
Upper Wallamba River sub-catchments												
Upper Wallamba River (HS1a)	12,050	27	10	32,934	41	22	3,295	43	25	12,831	46	32
Firefly Creek (HS1b)	5,562	12	5	11,921	15	8	1,160	15	9	4,382	15	11
Khoribakh Creek (HS1c)	8,861	20	8	17,973	22	12	1,767	23	14	6,792	24	17
Candoormakh and Pipeclay creeks (HS1d)	6,796	15	6	10,222	13	7	981	13	8	3,674	13	9
Lower Wallamba River sub-catchments												
Bungwahl and Darawakh creeks (HS2)	11,467	26	10	7,289	9	5	439	6	3	646	2	2

Table A6.4. Percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation or native vegetation) in the Wallamba River sub-catchments, and the amount of total loads sourced from these lands.

	Area	TN	TP	TSS
Target land	64	93	87	99
Non-target land	36	7	13	1

Subcatchment	***Area***		***TN***		***TP***		***TSS***	
	Ha	**%**	**kg**	**%**	**kg**	**%**	**tonnes**	%
Wallamba River	44,736	38	80,339	53	7,642	59	28,325	**70**
Catchment Total	**117,585**		**151,690**		**13,001**		**40,233**	

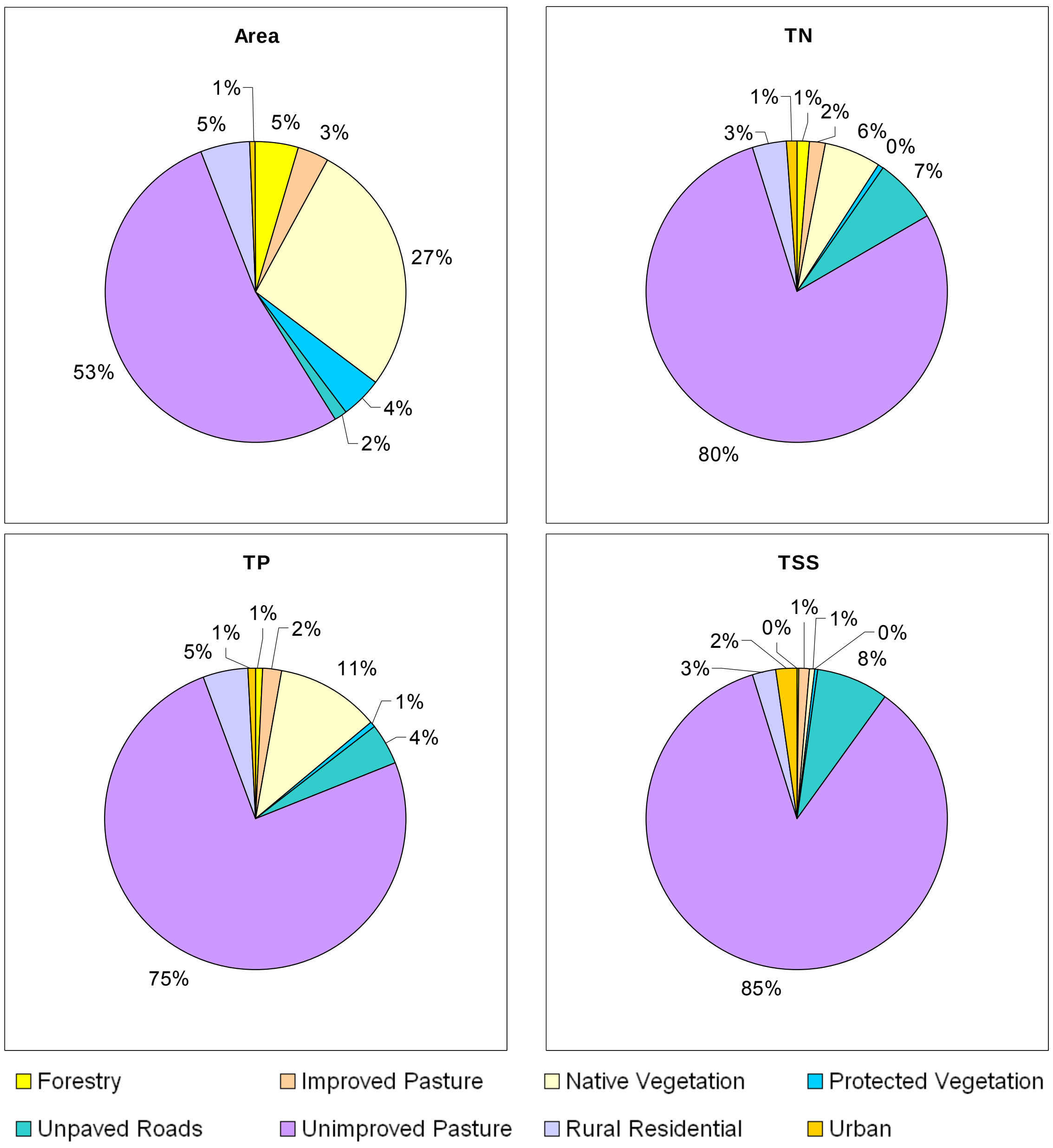

Figure A6.3. Relative contribution of land use activities to pollutants and area in the Wallamba River sub-catchments. For reference, the contributions of the Wallamba sub-catchment group to catchment totals are listed. [4]

4 A description of land use groups is given in Table A6.2 of Appendix 6.

Wang Wauk River

The Wang Wauk River sub-catchments are shown in Figure A6.4.

The Bunyah Creek sub-catchment contributes nutrients and sediment more than the sub-catchment area would suggest (Table A6.5). The Upper Wang Wauk River sub-catchment has a higher forest cover and thus contributes a smaller proportion of pollutants.

The relative contribution of different land use activities and sources of pollutants compared to their area in the sub-catchment is shown in Figure A6.5.

All lands in the Wang Wauk sub-catchments are on erodible soils. Approximately 90% of the improved pasture and unpaved roads, as well as 80% of the unimproved pasture land, occur on low sloping lands (<20%). Also, 80% of the protected vegetation and forestry activities occur on low slope land, although the remaining forest cover is evenly split between the two slope classes reported on.

Unimproved pasture constitutes nearly half the area, although these lands contribute much of the pollutant exports (61% of TN, 64% of TP and 77% of TSS). Unpaved roads are the next largest component of total loads for TN (15%) and TSS (17%), and contribute disproportionately to their areal extent (1%). Native vegetation comprises 23% of the sub-catchment area and, although not a large contributor on a unit area basis, is the second largest component of TP loads (16%).

Figures showing the area and pollutant split by land use for individual sub-catchments are given in Section 4 of Appendix 6.

Table A6.5 lists the percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation, native vegetation and unpaved roads), and the amount of total loads sourced from these lands. While 44% of the land is not targeted by the actions modelled in Section 2.7 of the WQIP, the remaining land contributes over 60% of the nutrient exports and 77% of the sediment exports modelled for the Wang Wauk River sub-catchments.

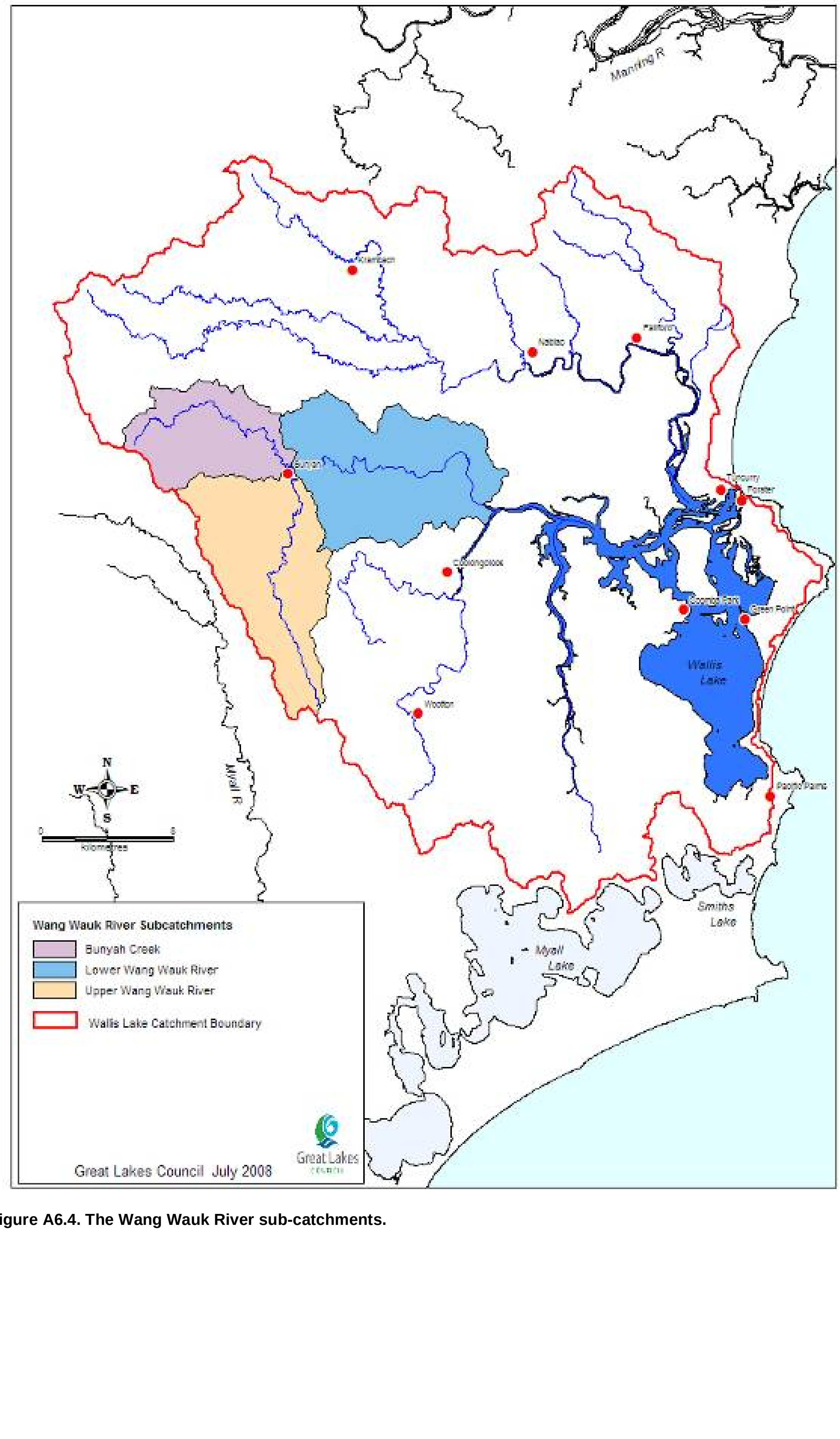

Figure A6.4. The Wang Wauk River sub-catchments.

Table A6.5. Area and pollutant exports from the Wang Wauk River sub-catchments. The table shows absolute values as well as the percentage contribution of the sub-catchment to the sub-catchment group (% Group) and catchment (% Wallis) total.

Sub-catchment	Area			TN			TP			TSS		
	ha	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	tonnes	% (Group)	% (Wallis)
Bunyah Creek (HS7a)	4,700	22	4	7,651	30	5	515	37	4	1,557	34	4
Upper Wang Wauk River (HS7b)	7,912	38	7	7,784	30	5	369	27	3	1,081	23	3
Lower Wang Wauk River (HS7c)	8,417	40	7	10,367	40	7	504	36	4	1,965	43	5

Table A6.6. Percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation or native vegetation) in the Wang Wauk River sub-catchments, and the amount of total loads sourced from these lands.

	Area	TN	TP	TSS
Target land	56	67	71	81
Non-target land	44	33	29	19

Subcatchment	*Area*		*TN*		*TP*		*TSS*	
	Ha	**%**	**kg**	**%**	**kg**	**%**	**tonnes**	%
Wang Wauk River	21,029	18	25,802	17	1,388	11	4,603	**11**
Catchment Total	**117,585**		**151,690**		**13,001**		**40,233**	

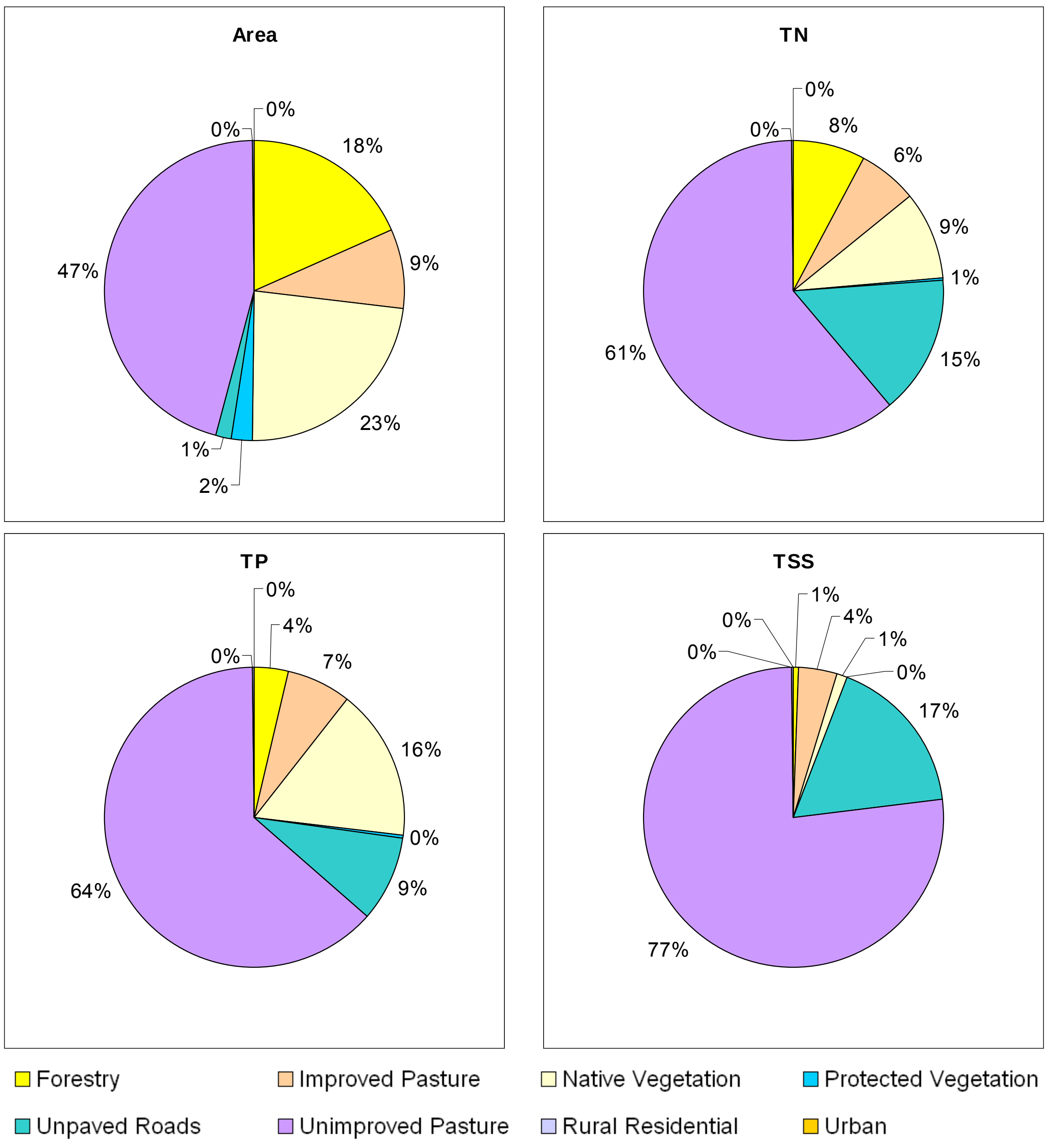

Figure A6.5. Relative contribution of land use activities to pollutants and area in the Wang Wauk River sub-catchments. For reference, the contributions of the Wang Wauk River sub-catchment group to catchment totals are listed. [5]

5 A description of land use groups is given in Table A6.2 of Appendix 6.

Coolongolook River

The Coolongolook River sub-catchments are shown in Figure A6.6.

The Coolongolook River sub-catchments contribute to the nutrient and sediment loads proportionally with their areal extent (Table A6.7).

The relative contribution of different land use activities and sources of pollutants compared to their area in the sub-catchment is shown in Figure A6.7.

All lands in the Coolongolook sub-catchments are on erodible soils. Approximately 90% of the improved, as well as 80% of the unimproved, pasture land occur on low sloping lands (<20%). Also, 80% of the protected vegetation and forestry activities occur on low slope land, although the remaining forest cover is evenly split between the two slope classes reported on. All native vegetation types are evenly split across the two slope classes reported on.

Unimproved pasture constitutes nearly one-quarter of the area but contributes a large proportion of TN (38%), TP (52%) and TSS (49%) loads. Unpaved roads contribute disproportionately to their areal extent (2%) for both nutrients (~25%) and TSS (39%). Forest cover (i.e. forestry, native vegetation and protected vegetation) is the next largest component of loads followed by improved pasture (≤5%). Figures showing the area and pollutant split by land use for individual sub-catchments are given in the next section of this appendix.

Table A6.8 lists the percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation, native vegetation and unpaved roads), and the amount of total loads sourced from these lands. While 68% of the land is not targeted by the actions modelled in Section 2.7 of the WQIP, the remaining land contributes over 44% of the nutrient exports and 54% of the sediment exports modelled for the Coolongolook River sub-catchment.

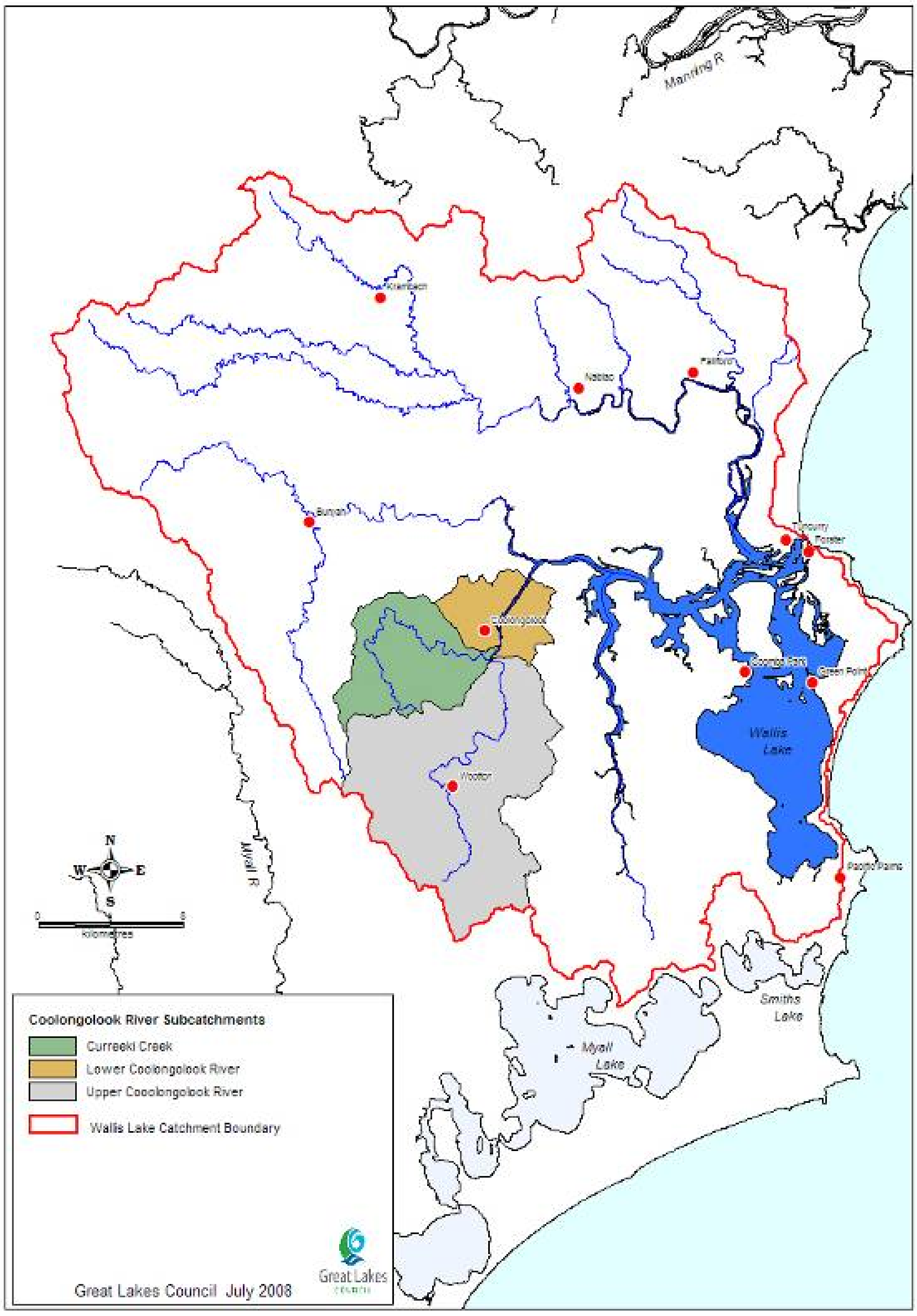

Figure A6.6. The Coolongolook River sub-catchments.

Table A6.7. Area and pollutant exports from the Coolongolook River sub-catchments. The table shows absolute values as well as the percentage contribution of the sub-catchment to the sub-catchment group (% Group) and catchment (% Wallis) total.

Sub-catchment	Area			TN			TP			TSS		
	ha	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	tonnes	% (Group)	% (Wallis)
Cureeki Creek (HS9a)	3,972	23	3	3,493	23	2	178	22	1	486	21	1
Upper Coolongolook River (HS9b)	10,890	65	9	10,140	66	7	530	66	4	1,557	67	4
Lower Coolongolook River (HS9c)	2,113	12	2	1,759	11	1	93	12	1	288	12	1

Table A6.8. Percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation or native vegetation) in the Coolongolook River sub-catchments, and the amount of total loads sourced from these lands.

	Area	TN	TP	TSS
Target land	32	45	57	54
Non-target land	68	55	43	46

Subcatchment	***Area***		***TN***		***TP***		***TSS***	
	Ha	**%**	**kg**	**%**	**kg**	**%**	**tonnes**	%
Coolongolook River	16,975	14	15,392	10	801	6	2,331	**6**
Catchment Total	**117,585**		**151,690**		**13,001**		**40,233**	

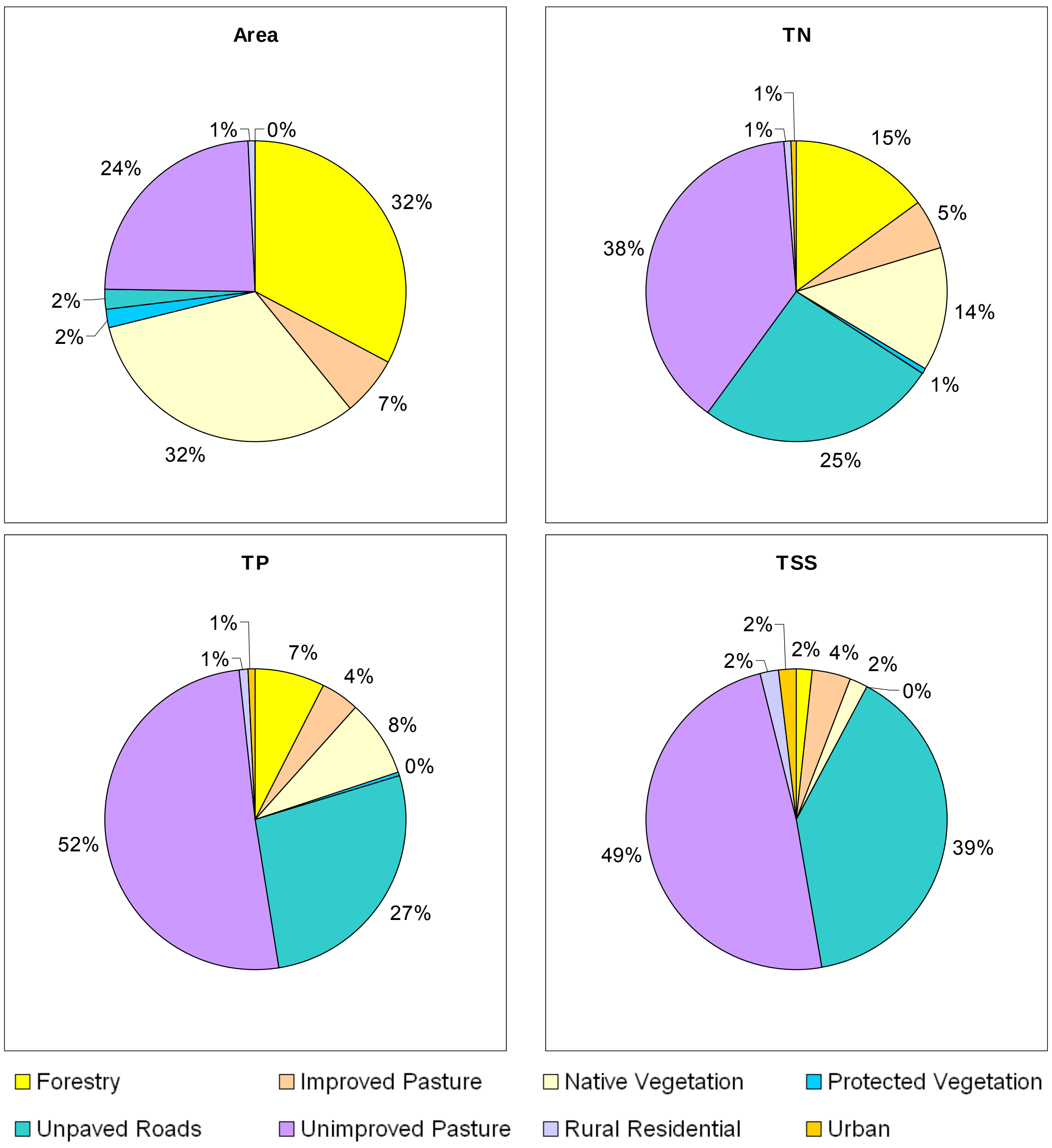

Figure A6.7. Relative contribution of land use activities to pollutants and area in the Coolongolook River sub-catchments. For reference, the contributions of the Coolongolook River sub-catchment group to catchment totals are listed. [6]

6 A description of land use groups is given in Table A6.2 of Appendix 6.

Wallingat River

The Wallingat River sub-catchments are shown in Figure A6.8.

Over 80% of the Wallingat River sub-catchments are forested, with the remaining land comprised of unimproved pasture (17%), unpaved roads (2%) and small areas (<1%) of improved pasture and rural residential land. Due to their areal extent, forests (i.e. forestry, native vegetation and protected vegetation) account for >40% of the TP and TN loads from the sub-catchment, and 6% of the TSS (Figure A6.9). Unpaved roads and unimproved pasture contribute most of the nutrients (>50%) and TSS (90%).

Figures showing the area and pollutant split by land use for individual sub-catchments are given in the next section of this appendix.

Table A6.9 lists the percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation, native vegetation and unpaved roads), and the amount of total loads sourced from these lands. While 83% of the land is not targeted by the actions modelled in Section 2.7 of the WQIP, the remaining land contributes 30% or more of the nutrient exports and 47% of the sediment exports modelled for the Wallingat River sub-catchment.

Table A6.9. Percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation or native vegetation) in the Wallingat River sub-catchments, and the amount of total loads sourced from these lands.

	Area	TN	TP	TSS
Target land	17	33	30	47
Non-target land	83	67	70	51

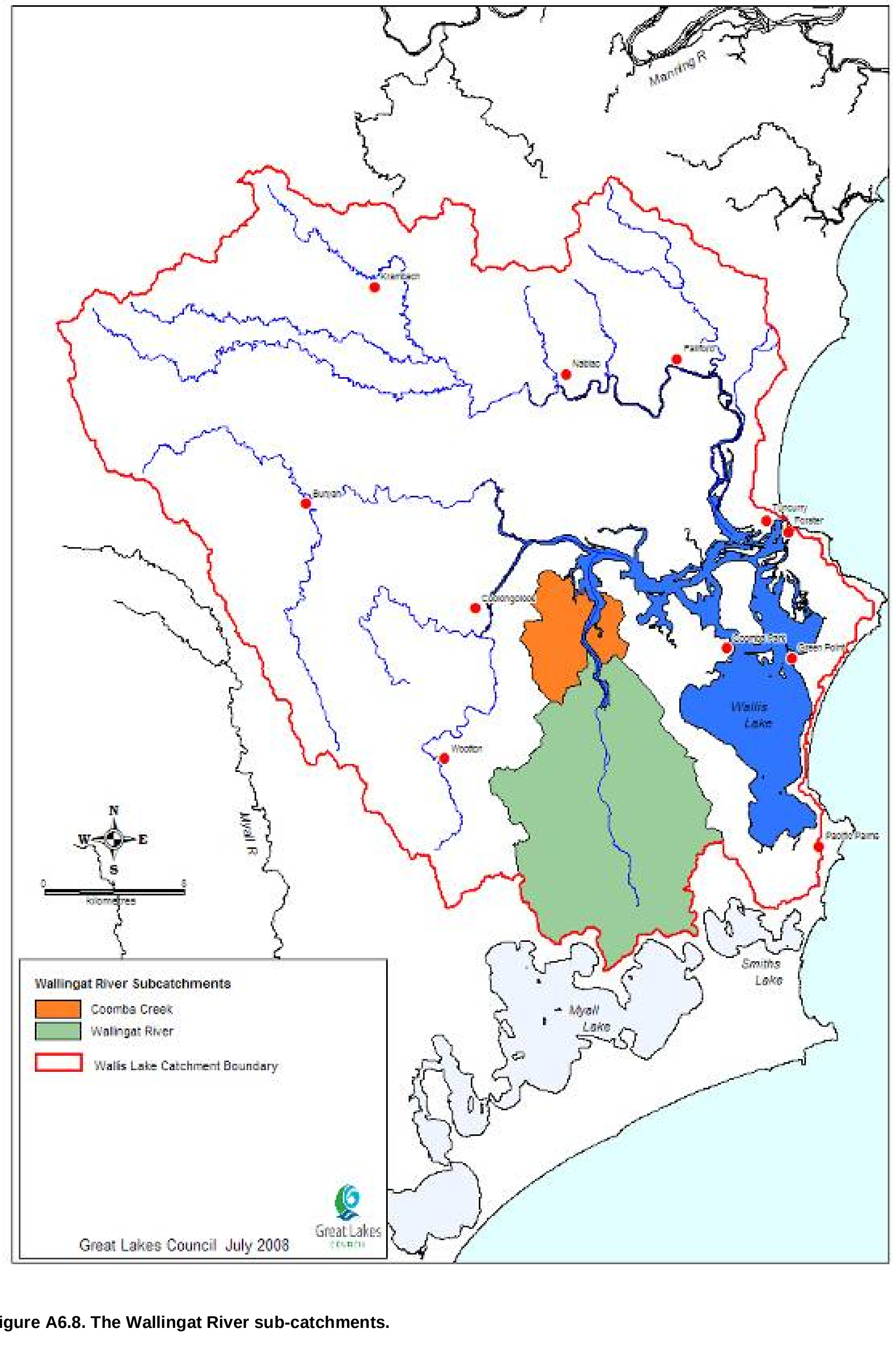

Figure A6.8. The Wallingat River sub-catchments.

Subcatchment	***Area***		***TN***		***TP***		***TSS***	
	Ha	**%**	**kg**	**%**	**kg**	**%**	**tonnes**	%
Wallingat River	16,359	14	11,106	7	454	3	964	**2**
Catchment Total	**117,585**		**151,690**		**13,001**		**40,233**	

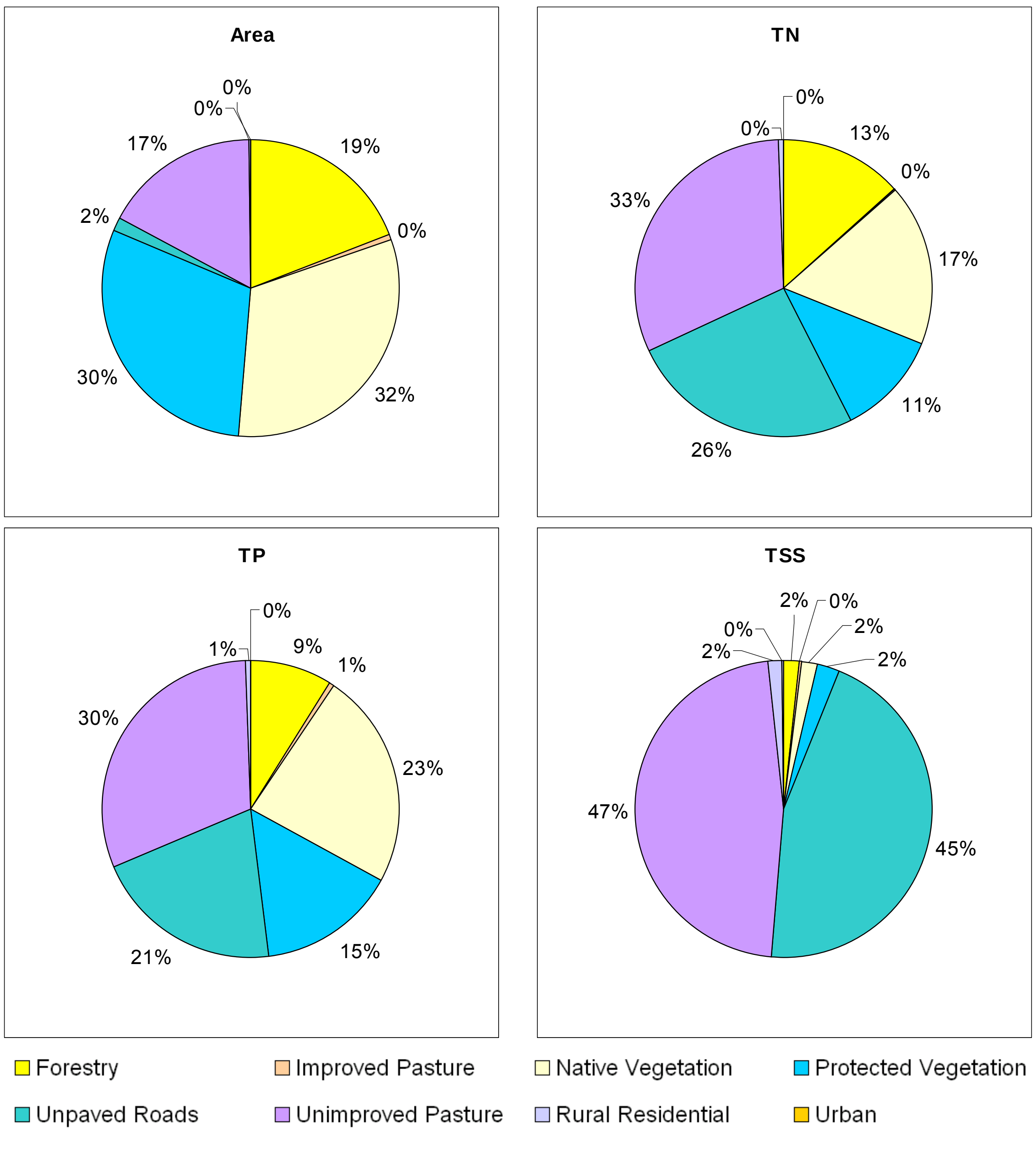

Figure A6.9. Relative contribution of land use activities to pollutants and area in the Wallingat River sub-catchments. For reference, the contributions of the Wallingat River sub-catchment group to catchment totals are listed. [7]

7 A description of land use groups is given in Table A6.2 of Appendix 6.

Lower River Estuary sub-catchments

The Lower River Estuary sub-catchments are shown in Figure A6.10.

The Minimbah Aquifer and Tuncurry sub-catchment dominates the TP and, to a lesser extent, TSS loads from the Lower River Estuary sub-catchments (Table A6.6).

The relative contribution of different land use activities and sources of pollutants compared to their area in the sub-catchment is shown in Figure A6.11.

All lands in the Lower River Estuary sub-catchments are on slopes less than 20%. Areas of non-erodible soils exist in the sub-catchments. Land use on these areas include 30% of improved pasture cover, 20% of unimproved pasture cover and 20% of forest cover.

Native vegetation (53%) and unimproved pasture (27%) are the dominant land uses in the Lower River Estuary sub-catchments. This is reflected in the breakdown of pollutant land use source for TN and TP and, for unimproved pasture, TSS. Rural residential land, urban lands and unpaved roads – with 8%, 4% and 1% of the sub-catchment area, respectively – contribute more pollutants than area alone would suggest. These three land use types are predicted to supply 80% of the sub-catchment's TSS loads.

Figures showing the area and pollutant split by land use for individual sub-catchments are given in the next section of this appendix.

Table A6.11 lists the percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation, native vegetation and unpaved roads), and the amount of total loads sourced from these lands. While 60% of the land is not targeted by the actions modelled in Section 2.7 of the WQIP, the remaining land contributes 61% of the nitrogen exports and 91% of the sediment exports modelled for the Lower Estuary sub-catchments.

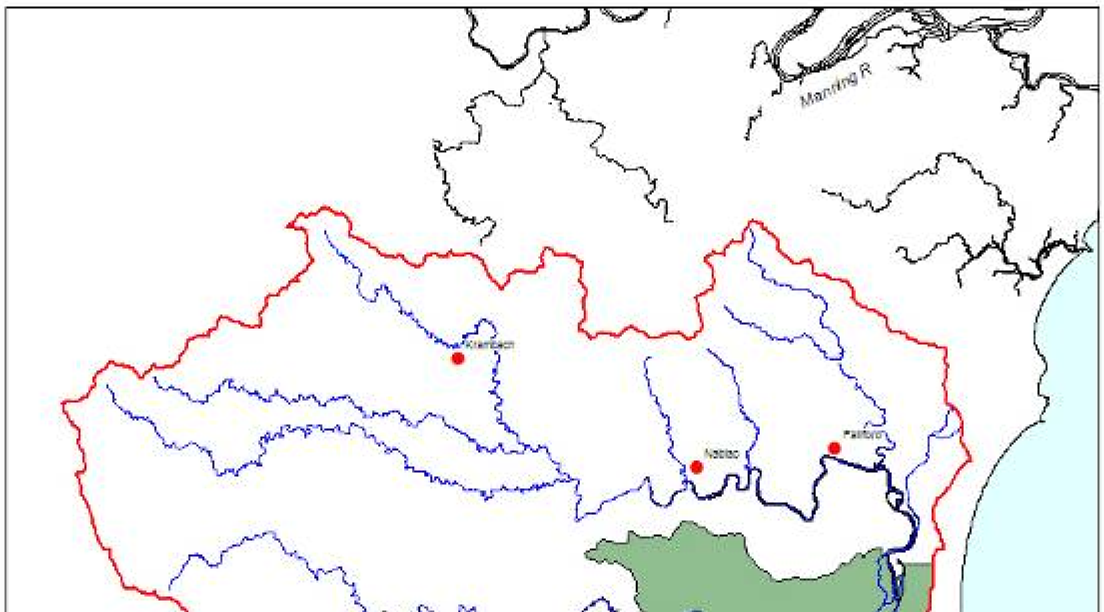

Figure A6.10. The Lower Estuary sub-catchments.

Table A6.10. Area and pollutant exports from the Lower River Estuary sub-catchments. The table shows absolute values as well as the percentage contribution of the sub-catchment to the sub-catchment group (% Group) and catchment (% Wallis) total.

Sub-catchment	Area			TN			TP			TSS		
	ha	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	tonnes	% (Group)	% (Wallis)
Minimbah / Tuncurry (HS3)	5,728	56	5	4,001	57	3	757	72	0	1,030	69	3
Duck Gully (HS6)	1,061	10	1	1,080	15	1	100	10	1	183	12	0
Coolongolook Estuary (HS8)	961	9	1	562	8	0	25	2	0	81	5	0
Beaky Bay (HS10)	2,585	25	2	1,401	20	1	167	16	1	209	14	1

Table A6.11. Percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation or native vegetation) in the Lower Estuary sub-catchments, and the amount of total loads sourced from these lands.

	Area	TN	TP	TSS
Target land	40	61	36	91
Non-target land	60	39	64	9

Subcatchment	***Area***		***TN***		***TP***		***TSS***	
	Ha	**%**	**kg**	**%**	**kg**	**%**	**tonnes**	%
Lower River Estuaries	10,335	9	7,044	5	1,049	8	1,503	**4**
Catchment Total	**117,585**		**151,690**		**13,001**		**40,233**	

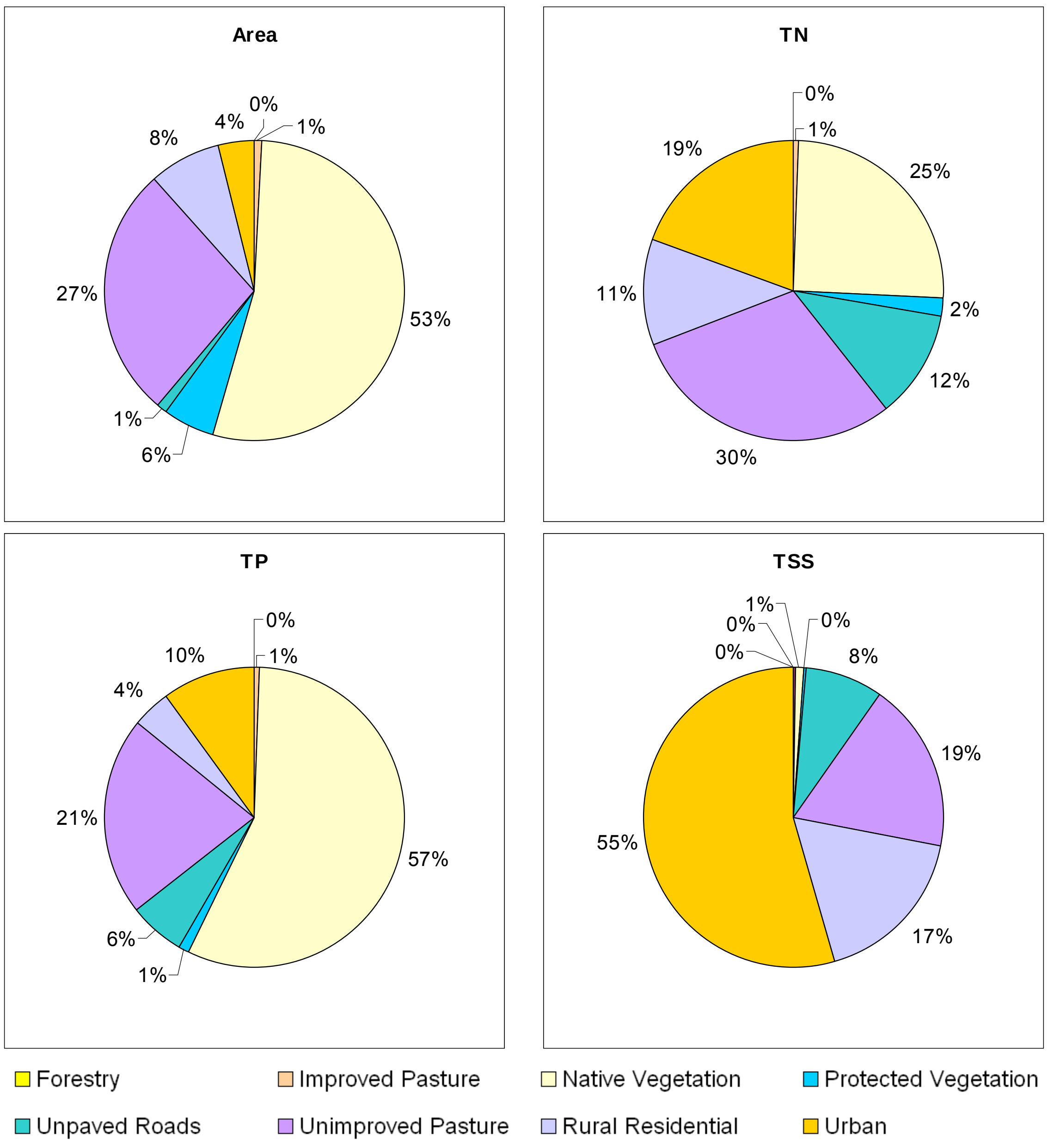

Figure A6.11 Relative contribution of land use activities to pollutants and area in the Lower River Estuary sub-catchments. For reference, the contributions of the Lower Estuary sub-catchment group to catchment totals are listed. [8]

8 A description of land use groups is given in Table A6.2 of Appendix 6.

Wallis Lake – Southern and western sub-catchments

The southern and western sub-catchments Wallis Lake are shown in Figure A6.12.

Much of the nutrient and sediment sourced from the southern and western sub-catchments of Wallis Lake are from more urbanised sub-catchments – Coomba / Wallis Island, Coomba Bay and Pacific Palms – although the latter two are proportionate with their area (Table A6.12). Coomba / Wallis Island constitutes 14% of the sub-catchment area and up to 53% of the total loads. The Green Point sub-catchment (HS16) contributes three times more TSS than could be expected based on area alone.

All of the improved pasture and 60% of the unimproved pasture occurs on land with low slopes and erodible soils (<20%). The remaining unimproved pasture is on land with high slopes and erodible soils. Also, 80% of unpaved roads are on low sloping land with erodible soils. Native vegetation types are split between low slope and erodible land (≥50%), high slope and erodible land (≥40%), and low slope non-erodible land (10%).

Forest cover dominates the sub-catchments (68%), with significant areas of rural residential (21%) and unimproved pasture (6%) lands (Figure A6.13). Roads and urban lands both constitute 2% of the area, but contribute disproportionately to nutrient and sediment exports. The major components of TN and TP loads are sourced from unpaved roads, forest cover (i.e. forestry, native vegetation and protected vegetation), and rural and urban residential lands. Forest cover does not contribute much TSS to the total loads. Its contribution to all pollutants is smaller than would be expected based on the area it contributes to the sub-catchments, illustrating it does not have problematic, elevated pollutant levels.

Figures showing the area and pollutant split by land use for individual sub-catchments are given in the next section of this appendix.

Table A6.13 lists the percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation, native vegetation and unpaved roads), and the amount of total loads sourced from these lands. While about 70% of the land is not targeted by the actions modelled in Section 2.7 of the WQIP, the remaining land contributes over 45% of the nutrient exports and 69% of the sediment exports modelled for the Wallis Lake – Southern and western sub-catchments.

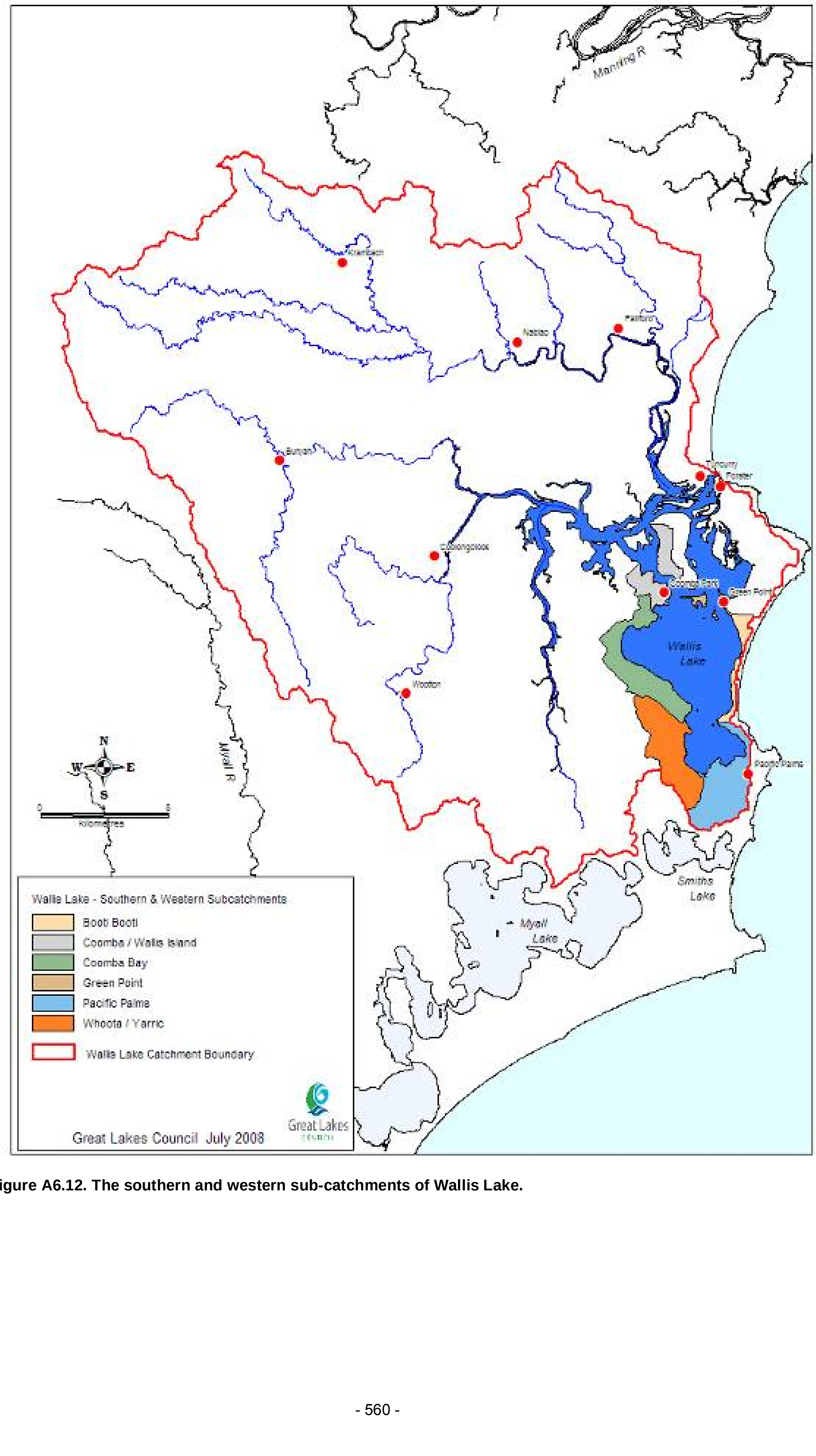

Figure A6.12. The southern and western sub-catchments of Wallis Lake.

Table A6.12. Area and pollutant exports from the southern and western sub-catchments of Wallis Lake. The table shows absolute values as well as the percentage contribution of the sub-catchment to the sub-catchment group (% Group) and catchment (% Wallis) total.

Sub-catchment	Area			TN			TP			TSS		
	ha	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	tonnes	% (Group)	% (Wallis)
Coomba / Wallis Island (HS11)	701	14	1	1,453	29	1	213	53	2	149	22	0
Coomba Bay (HS12)	1,215	23	1	1,046	21	1	30	7	0	182	26	0
Whoota / Yarric (HS13)	1,391	27	1	783	16	1	36	9	0	117	17	0
Pacific Palms (HS14)	1,454	28	1	1,351	28	1	82	20	1	189	27	0
Booti Booti (HS15)	328	6	0	194	4	0	36	9	0	13	2	0
Green Point (HS16)	87	2	0	85	2	0	7	2	0	39	6	0

Table A6.13. Percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation or native vegetation) in the southern and western sub-catchments of Wallis Lake, and the amount of total loads sourced from these lands.

	Area	TN	TP	TSS
Target land	29	47	58	69
Non-target land	71	53	42	31

Subcatchment	***Area***		***TN***		***TP***		***TSS***	
	Ha	**%**	**kg**	**%**	**kg**	**%**	**tonnes**	%
Wallis Lake – Southern and Western Subcatchments	5176	4	4912	3	404	3	689	**2**
Catchment Total	**117,585**		**151,690**		**13,001**		**40,233**	

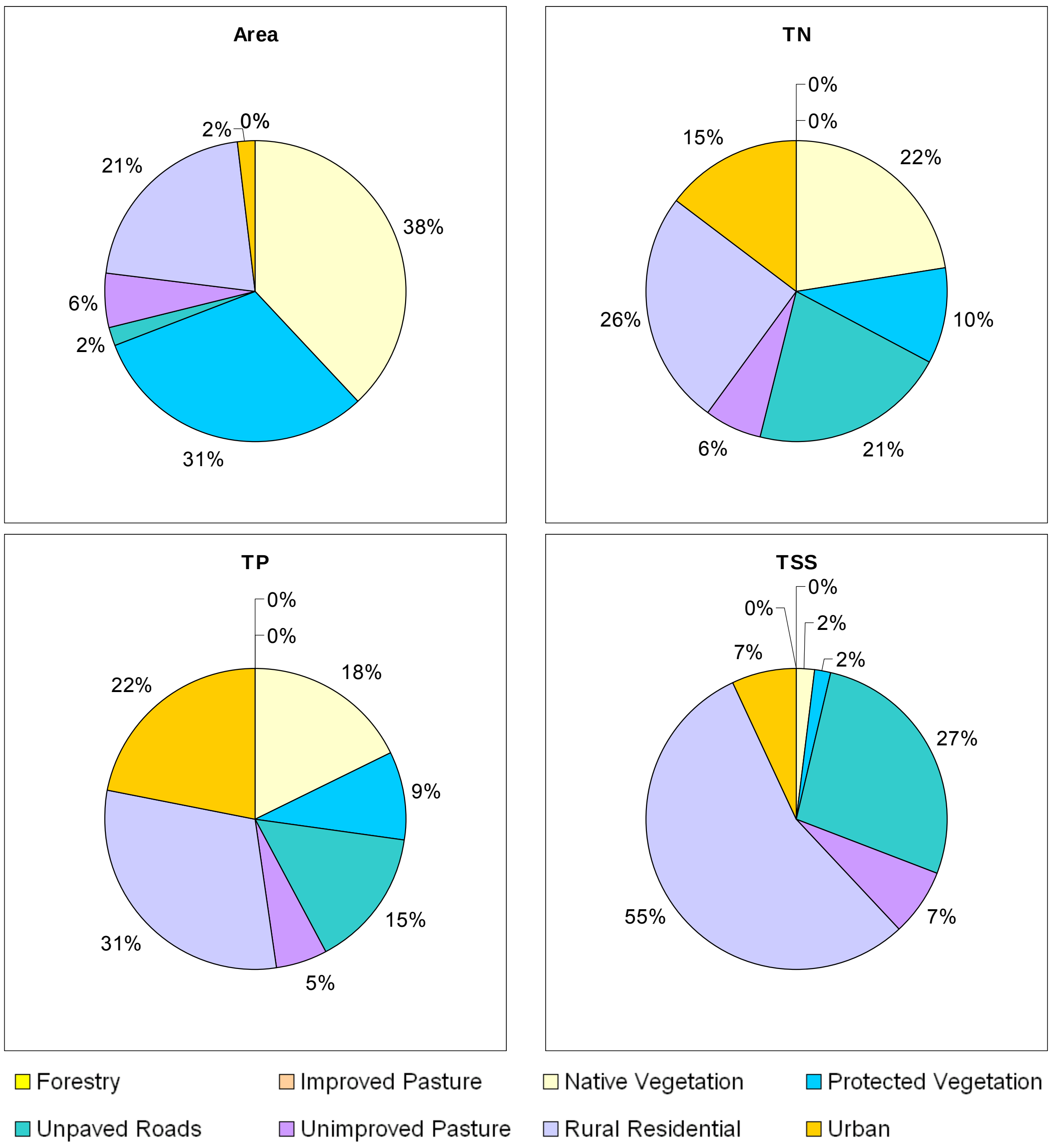

Figure A6.13. Relative contribution of land use activities to pollutants and area in the southern and western sub-catchments of Wallis Lake. For reference, the contributions of the southern and western sub-catchments of Wallis Lake to catchment totals are listed. [9]

9 A description of land use groups is given in Table A6.2 of Appendix 6.

Wallis Lake – Forster sub-catchments

The Wallis Lake – Forster Sub-catchments are shown in Figure A6.14.

Much of the nutrient sourced from the Forster sub-catchments of Wallis Lake sub-catchments is from the Pipers Bay and Pipers Creek sub-catchments (Table A6.13). In contrast, 70% of the TSS is sourced from the Forster sub-catchments.

Pasture in the Forster sub-catchments is split quite evenly between low sloping erodible and non-erodible lands. Approximately 70% of native vegetation and 90% of unpaved roads occur on low-sloping erodible lands.

Forest cover dominates the sub-catchment land use (47%), with significant areas of urban residential (23%) and unimproved pasture (6%) lands, and the remaining land use split between pasture, rural residential and unpaved roads. The major components of TN and TSS loads (>75%) are sourced from urban residential lands, which also account for ~50% of the TP loads from the Forster sub-catchments. Pasture (14%), unpaved roads (14%) and forest (i.e. forestry, native vegetation and protected vegetation) (17%) also contribute significant amounts of total TP loads.

Figures showing the area and pollutant split by land use for individual sub-catchments are given in Section 4 of this appendix.

Table A6.15 lists the percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation, native vegetation and unpaved roads), and the amount of total loads sourced from these lands. While about 70% of the land is not targeted by the actions modelled in Section 2.7 of the WQIP, the remaining land contributes 87% of the nitrogen exports and 93% of the sediment exports modelled for the Wallis Lake – Forster sub-catchments.

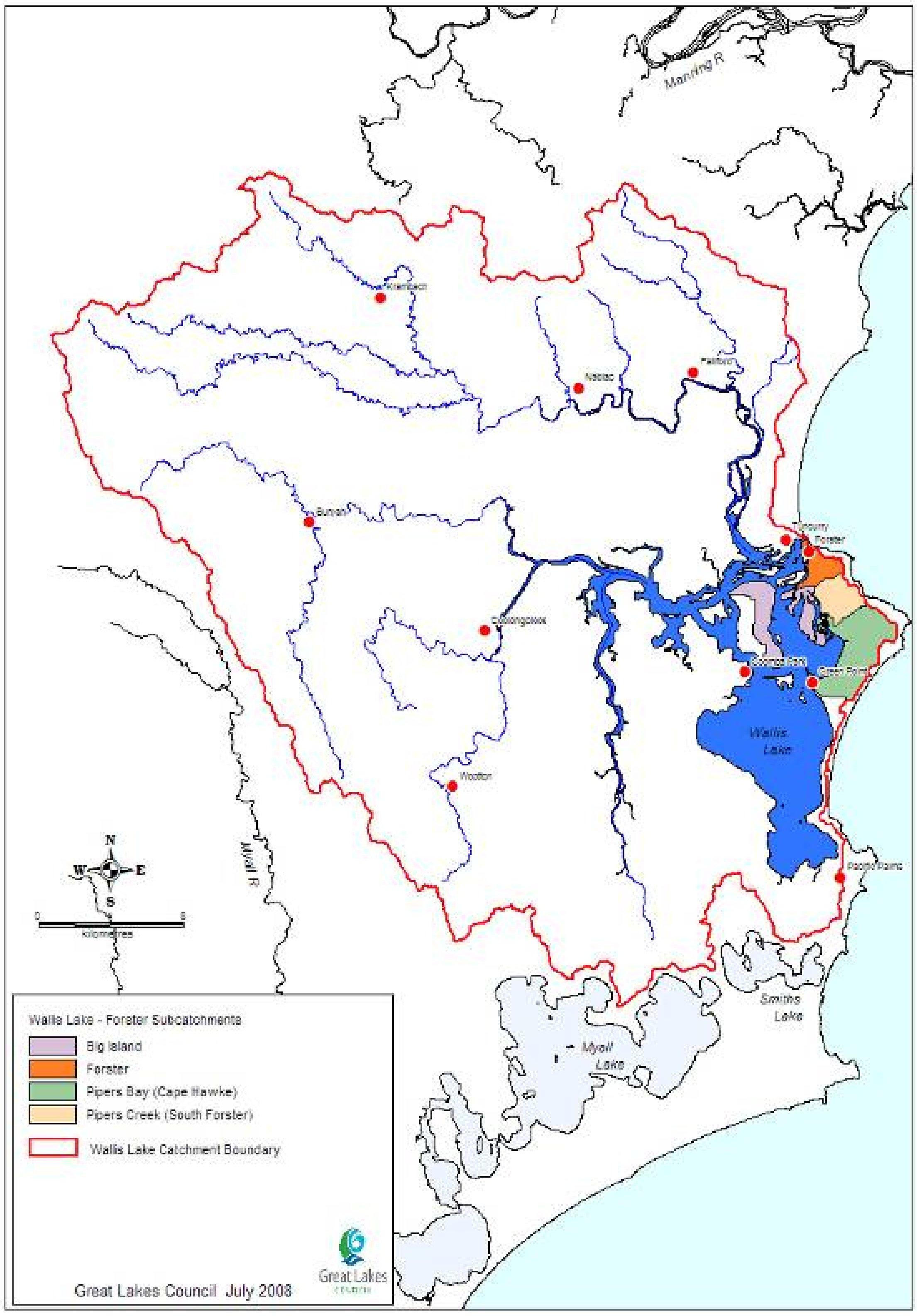

Figure A6.14. The Wallis Lake–Forster sub-catchments.

Table A6.14. Area and pollutant exports from the Forster sub-catchments of Wallis Lake. The table shows absolute values as well as the percentage contribution of the sub-catchment to the sub-catchment group (% Group) and catchment (% Wallis) total.

Sub-catchment	Area			TN			TP			TSS		
	ha	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	kg	% (Group)	% (Wallis)	tonnes	% (Group)	% (Wallis)
Pipers Bay (HS17)	1,318	45	1	2,401	34	2	579	46	4	292	16	1
Pipers Creek (HS18)	542	18	0	2,789	40	2	334	26	3	213	12	1
Big Island (HS19)	811	27	1	315	4	0	175	14	1	35	2	0
Forster (HS20)	304	10	0	1,590	22	1	175	14	1	1,278	70	3

Table A6.15. Percentage area of target (agriculture, rural residential and urban residential lands) and non-target land (forestry, protected vegetation or native vegetation) in the Forster sub-catchments of Wallis Lake, and the amount of total loads sourced from these lands.

	Area	TN	TP	TSS
Target land	69	87	69	93
Non-target land	31	13	31	7

Subcatchment	***Area***		***TN***		***TP***		***TSS***	
	Ha	**%**	**kg**	**%**	**kg**	**%**	**tonnes**	%
Wallis Lake – Forster Subcatchments	2,975	3	7,095	5	1,263	10	1,818	**5**
Catchment Total	**117,585**		**151,690**		**13,001**		**40,233**	

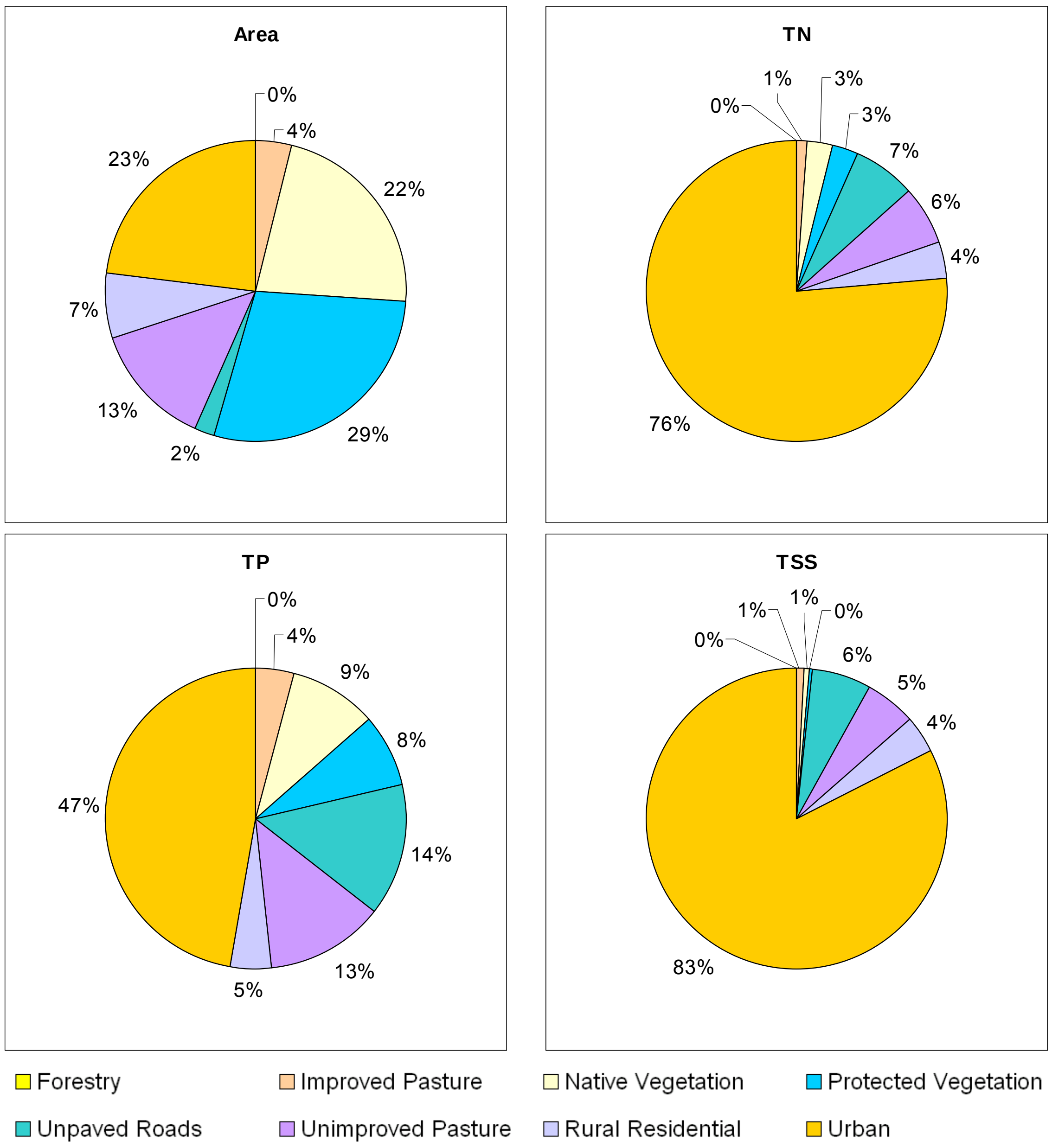

Figure A6.15. Relative contribution of land use activities to pollutants and area in the Forster sub-catchments of Wallis Lake. For reference, the contributions of the Forster sub-catchments of Wallis Lake to catchment totals are listed. [10]

10 A description of land use groups is given in Table A6.2 of Appendix 6.

4. Detailed information on split of pollutants and areas by land use for all individual sub-catchments

This section provides pie charts summarising the split of pollutants and area by land use for all 27 sub-catchments represented in the DSS (Figures A6.16 to A6.42). This information is provided to aid land managers in their decision-making and management activities. As such, no discussion is provided of the results. Readers should refer to Section 3 of this appendix for a summarised analysis of pollutant contributions by land use.

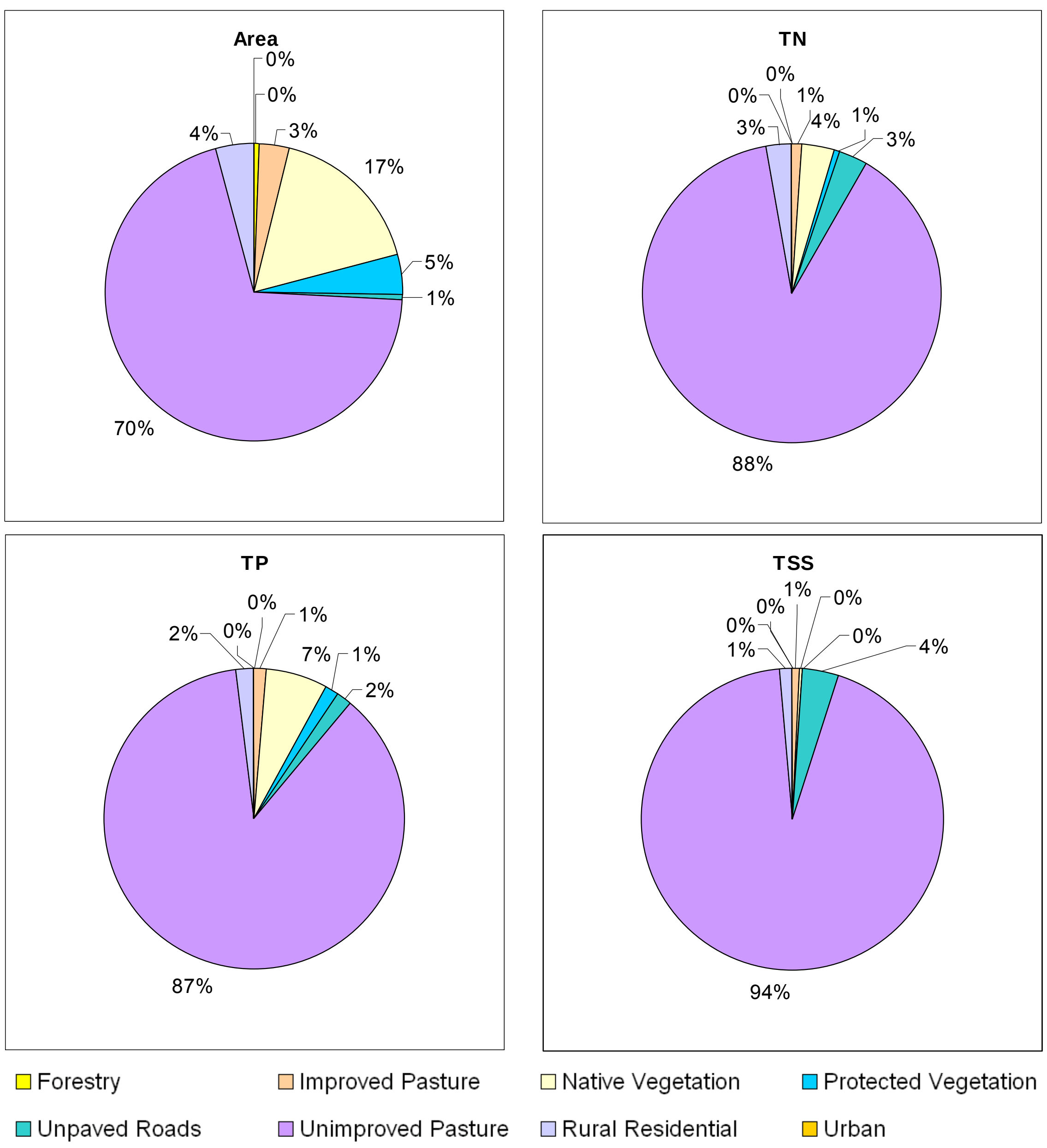

Figure A6.16. Pollutants and areas by land use, Upper Wallamba River (HS1a).

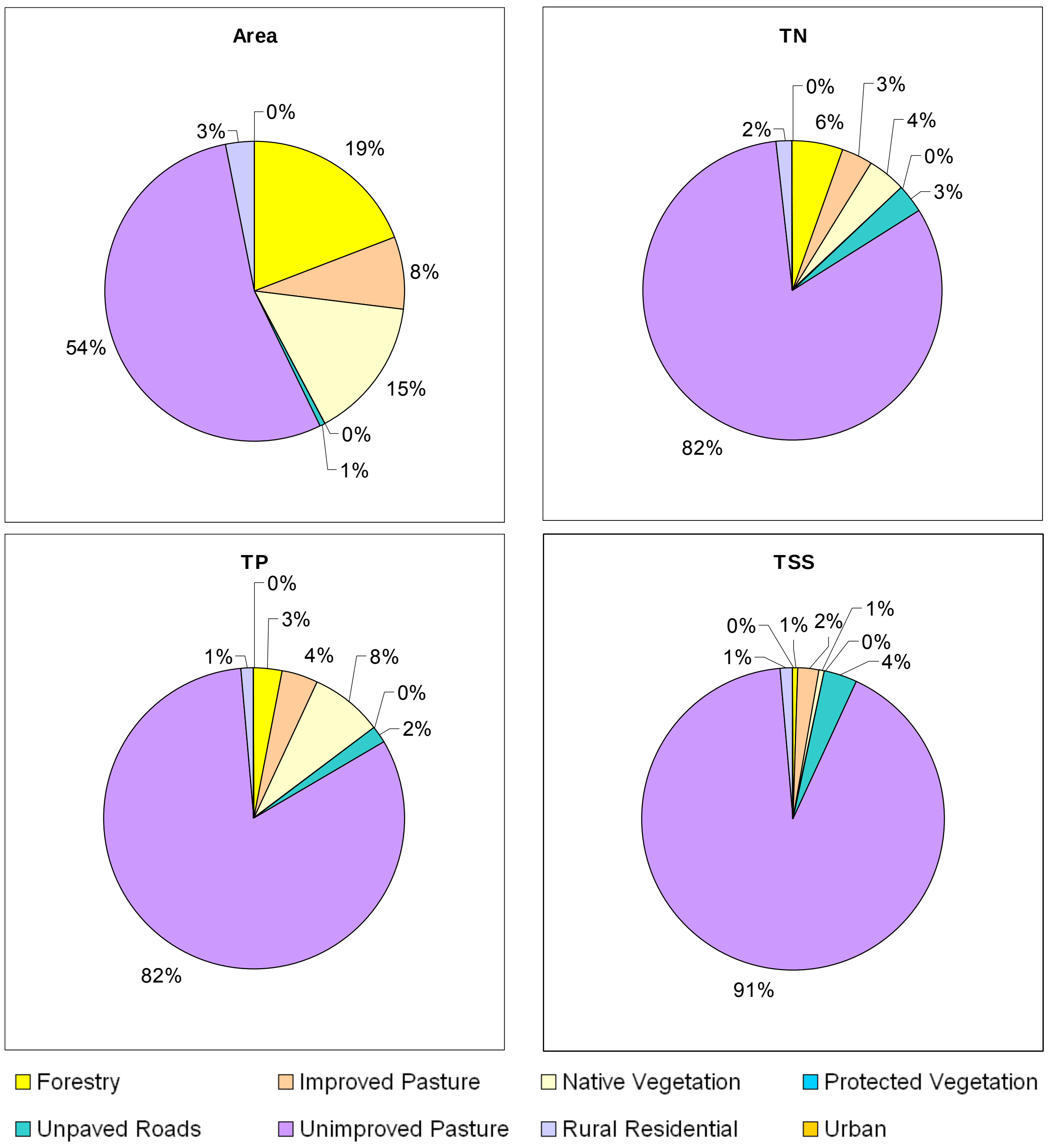

Figure A6.17. Pollutants and areas by land use, Firefly River (HS1b).

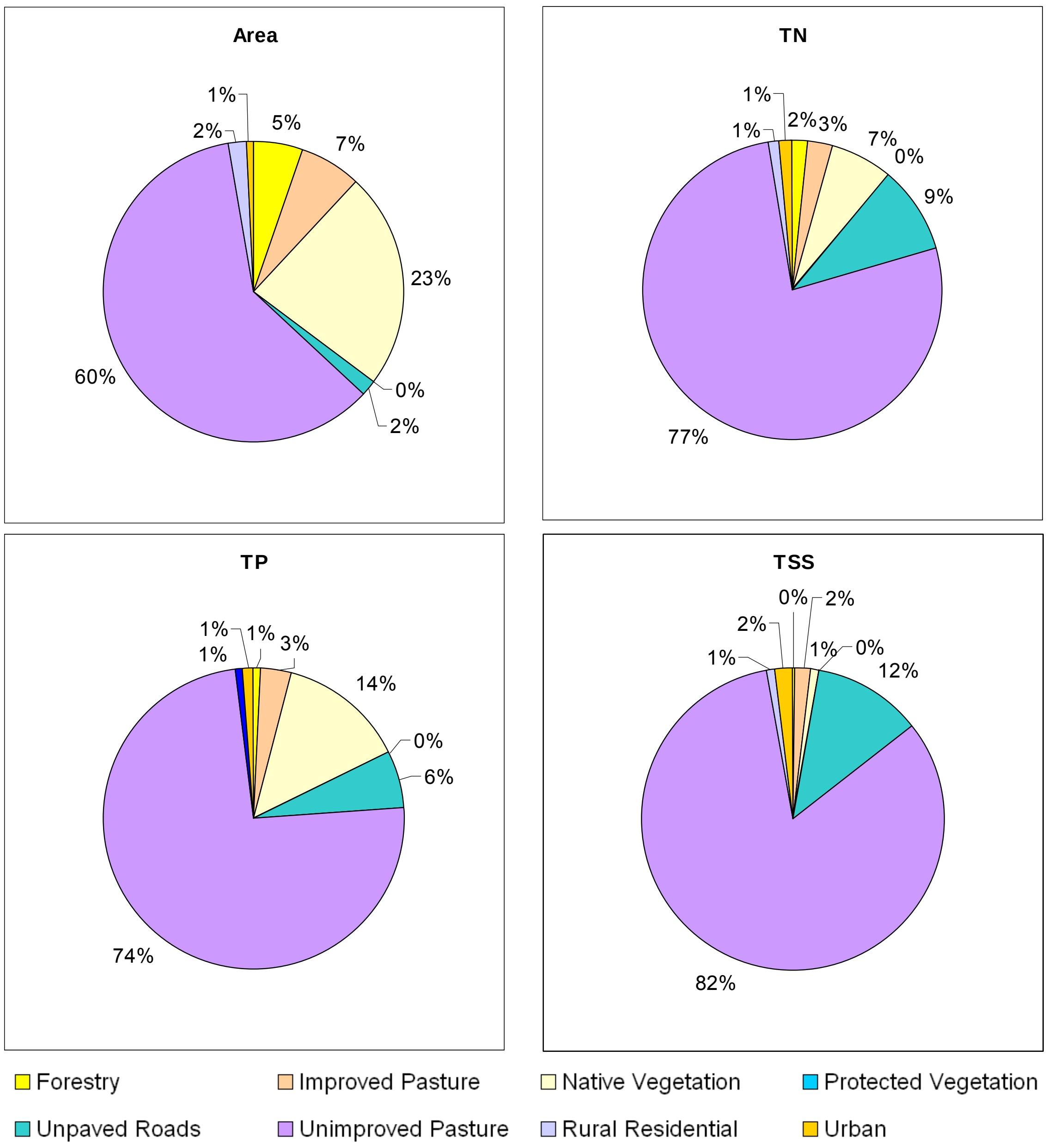

Figure A6.18. Pollutants and areas by land use, Khoribakh Creek (HS1c).

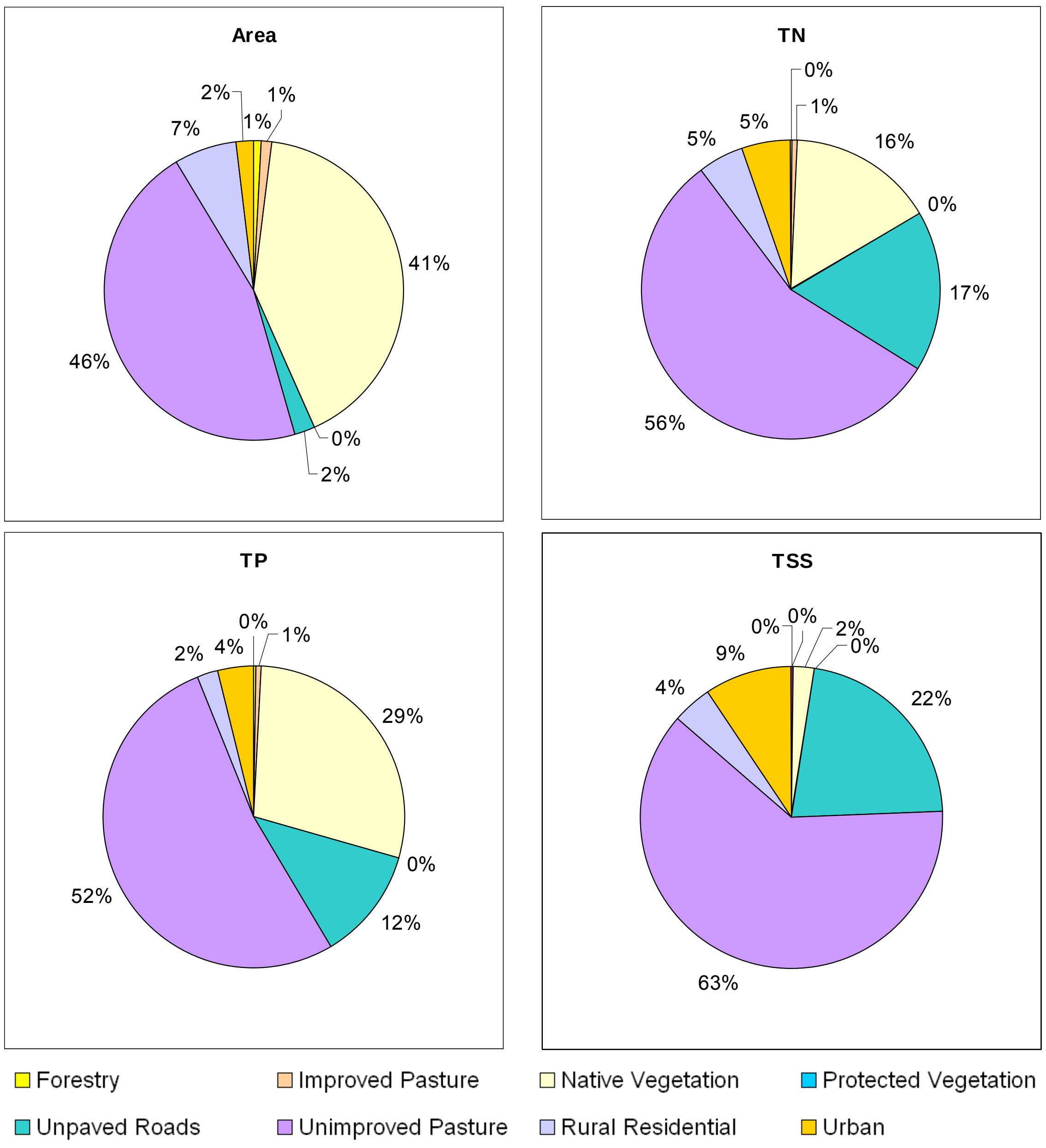

Figure A6.19. Pollutants and areas by land use, Candoormakh and Pipeclay Creeks (HS1d).

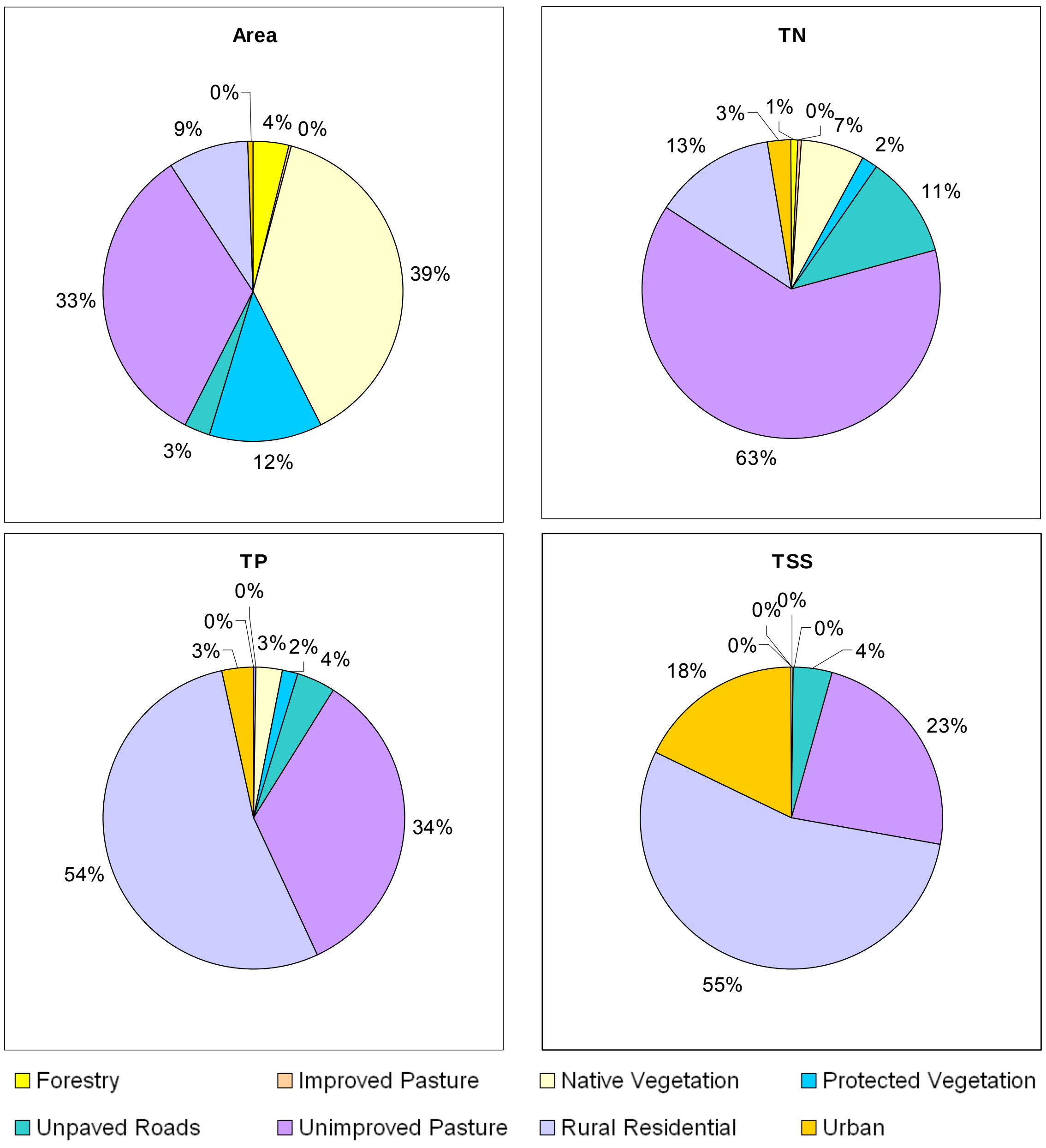

Figure A6.20. Pollutants and areas by land use, Bungwahl and Darawakh Creeks (HS2).

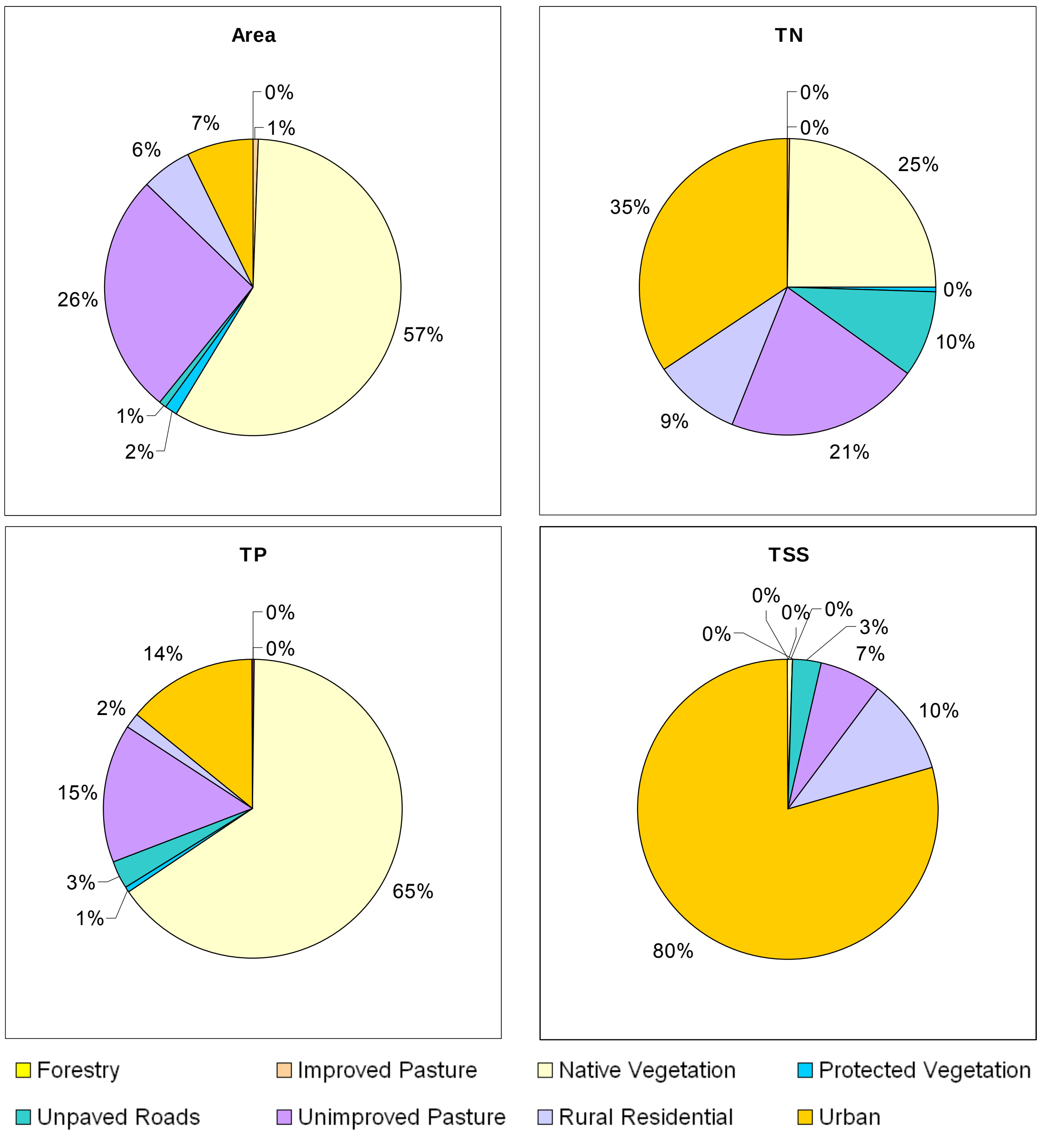

Figure A6.21. Pollutants and areas by land use, Minimbah and Tuncurry (HS3).

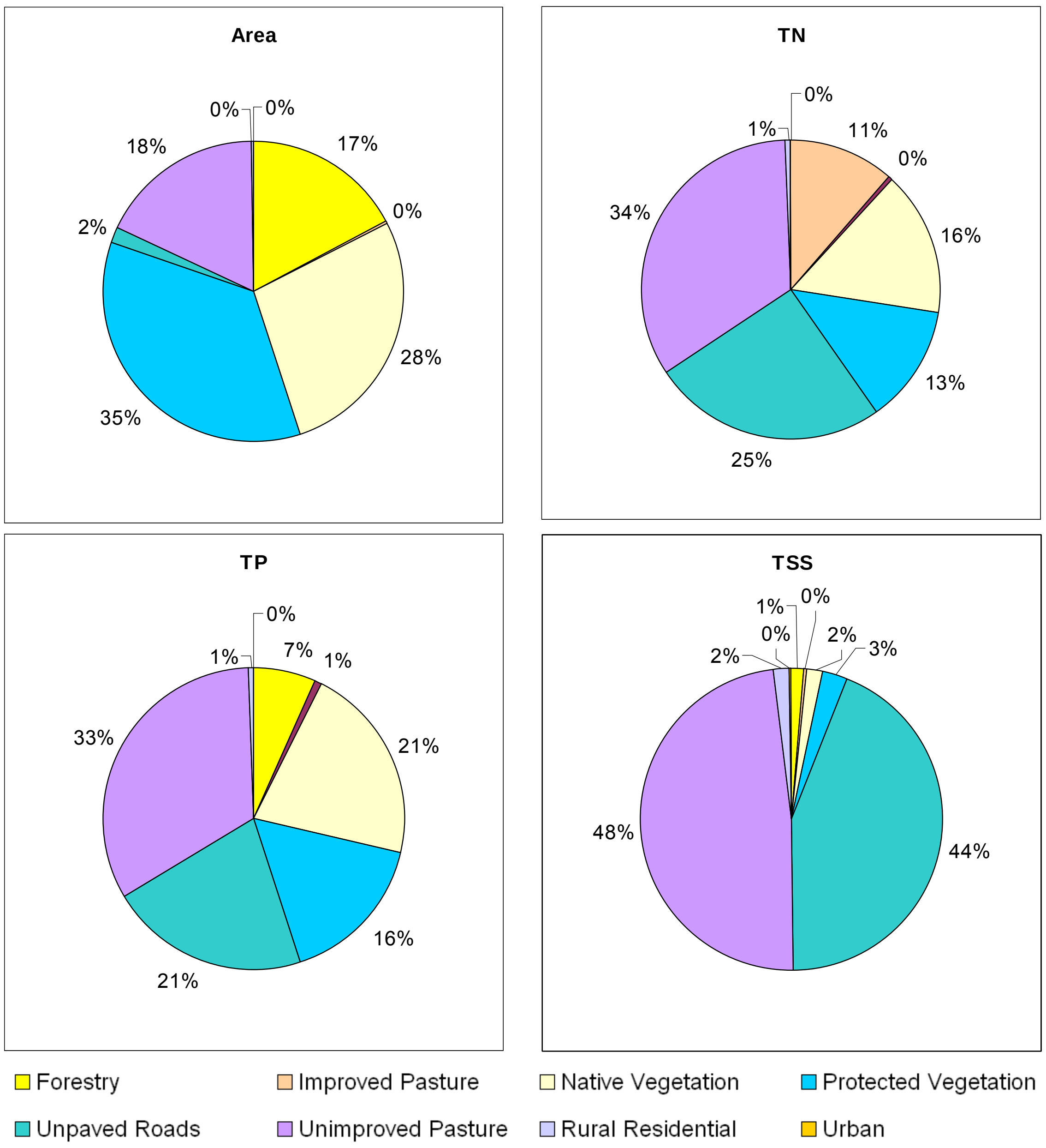

Figure A6.22. Pollutants and areas by land use, Wallingat River (HS4).

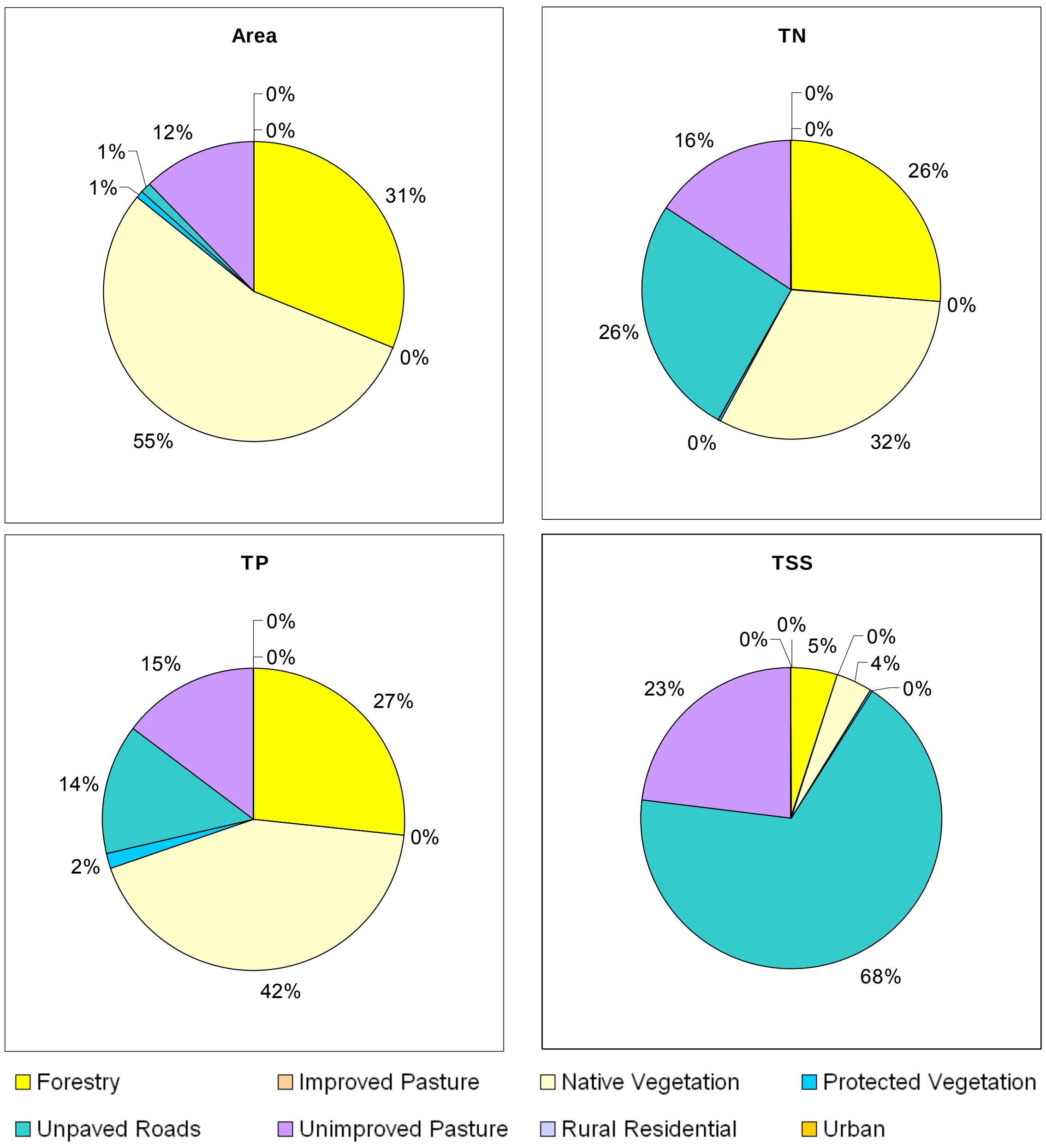

Figure A6.23. Pollutants and areas by land use, Coomba Creek (HS5).

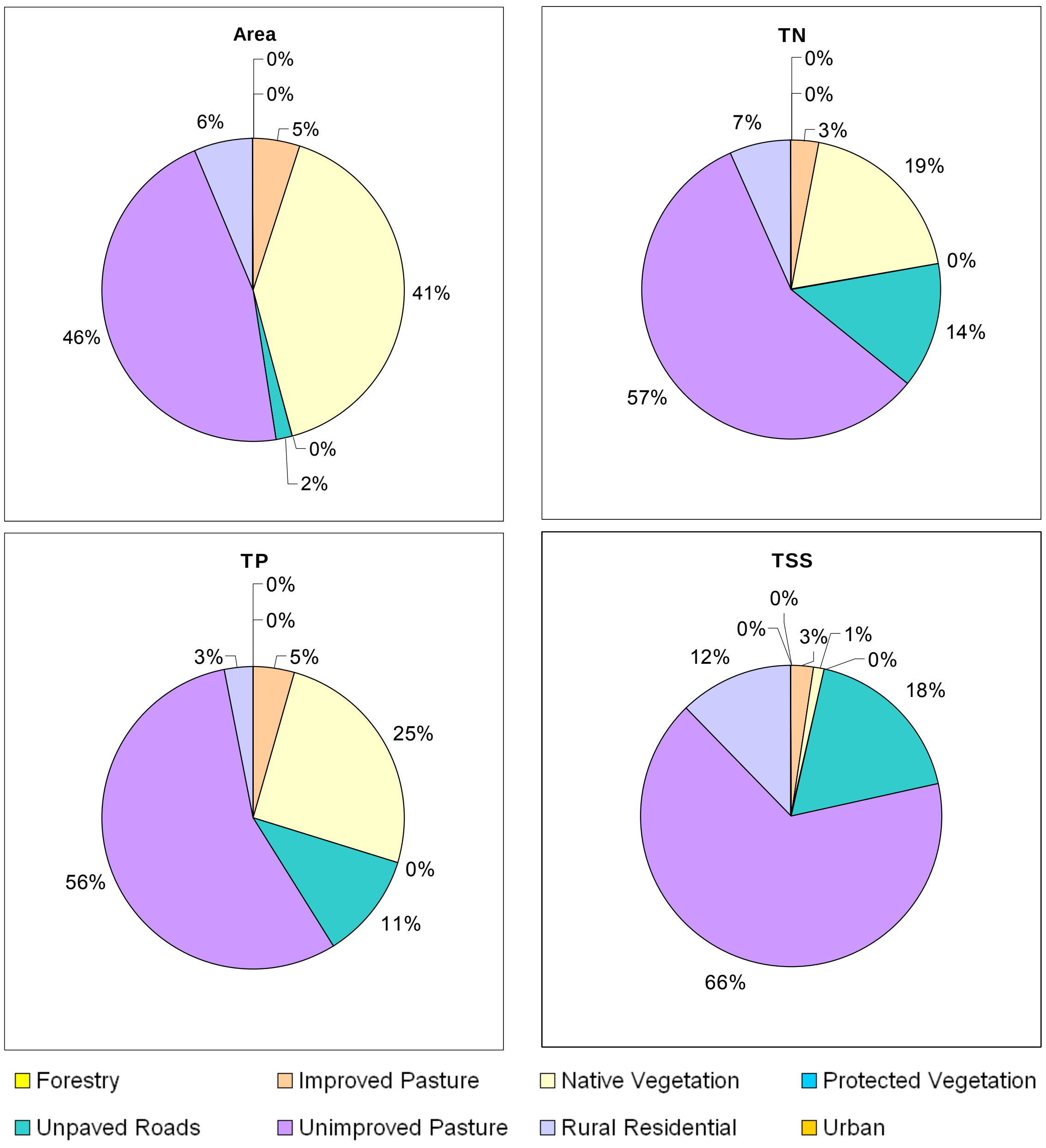

Figure A6.24. Pollutants and areas by land use, Duck Creek (HS6).

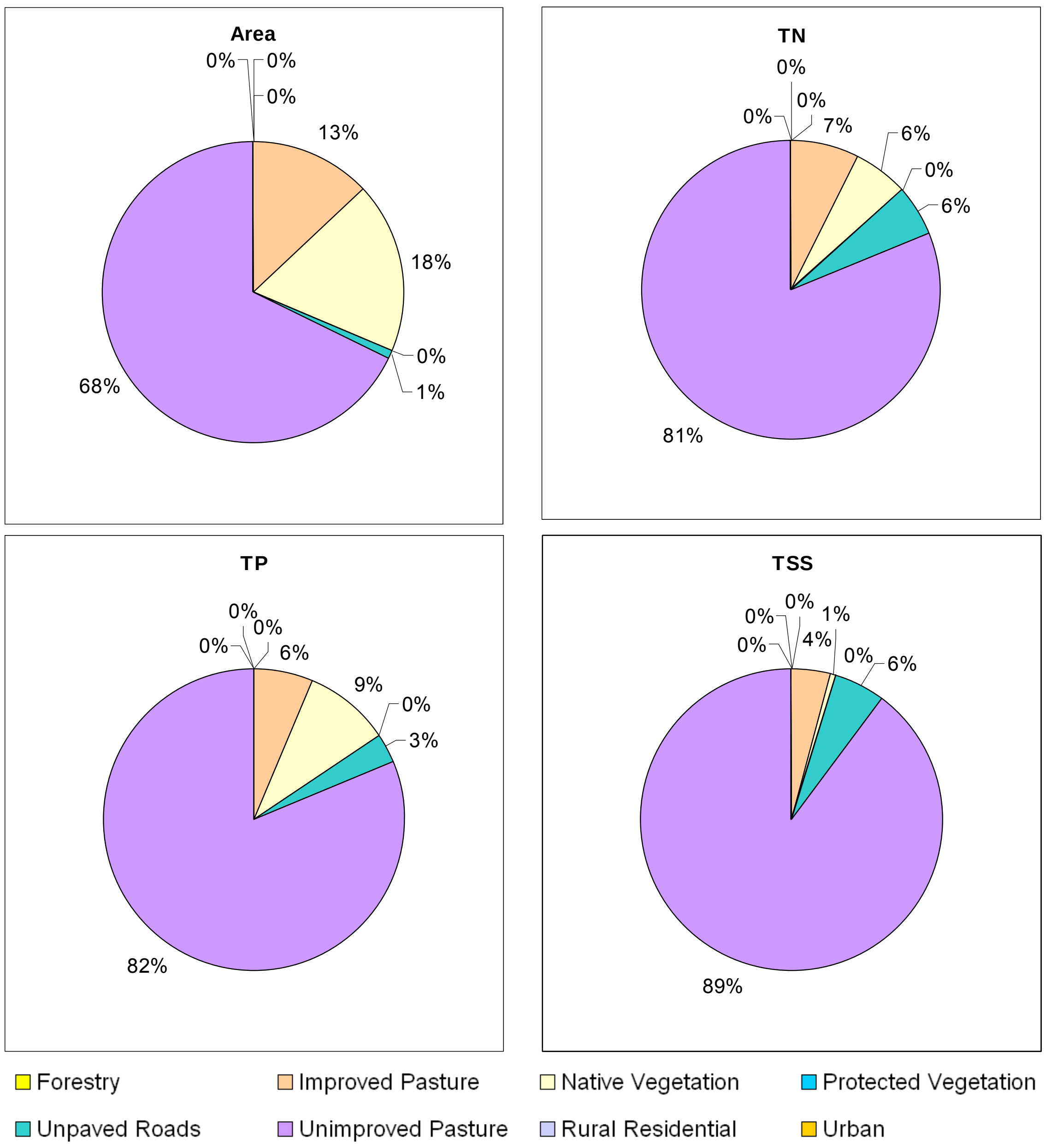

Figure A6.25. Pollutants and areas by land use, Bunyah Creek (HS7a).

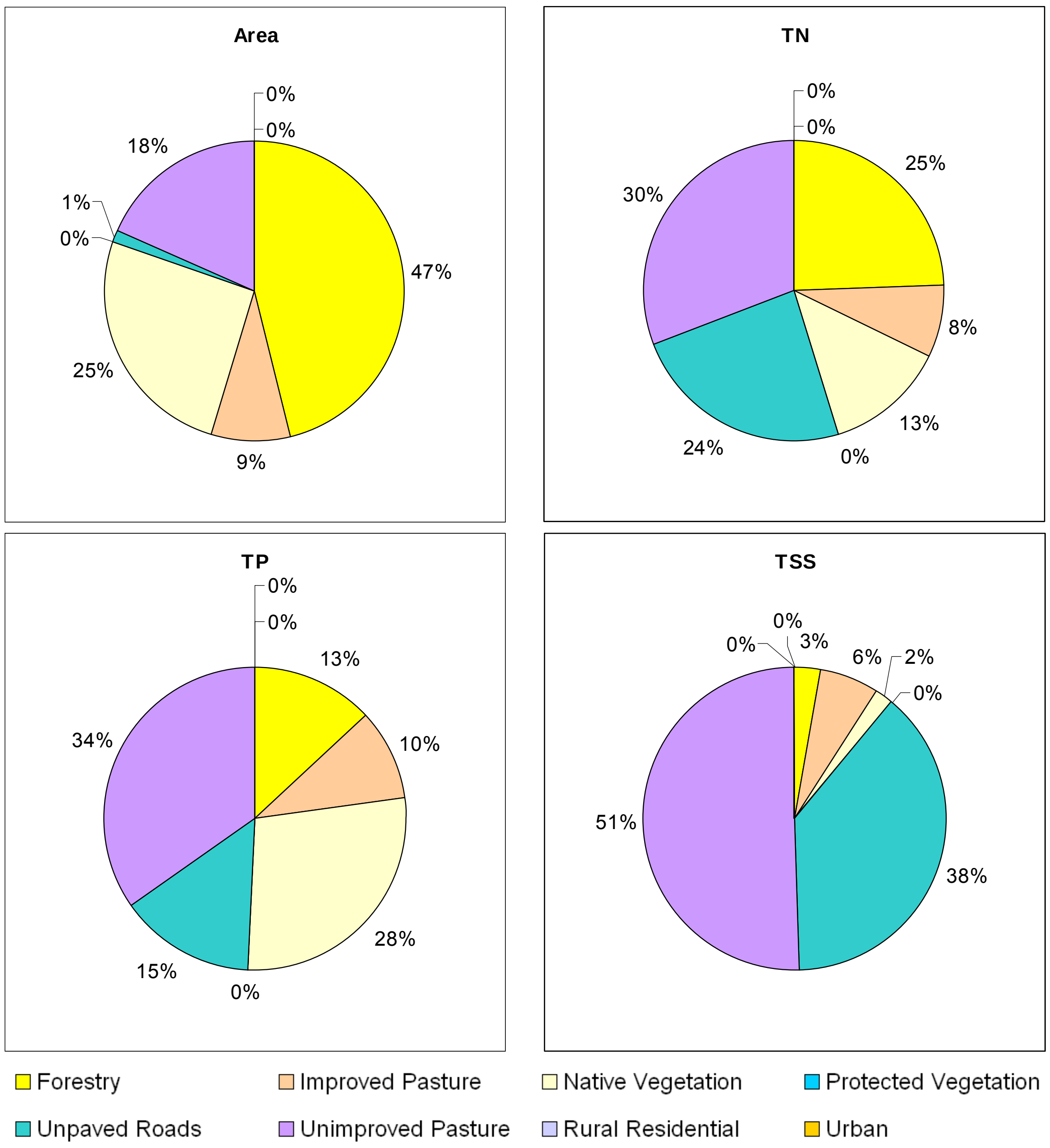

Figure A6.26. Pollutants and areas by land use, Upper Wang Wauk River (HS7b).

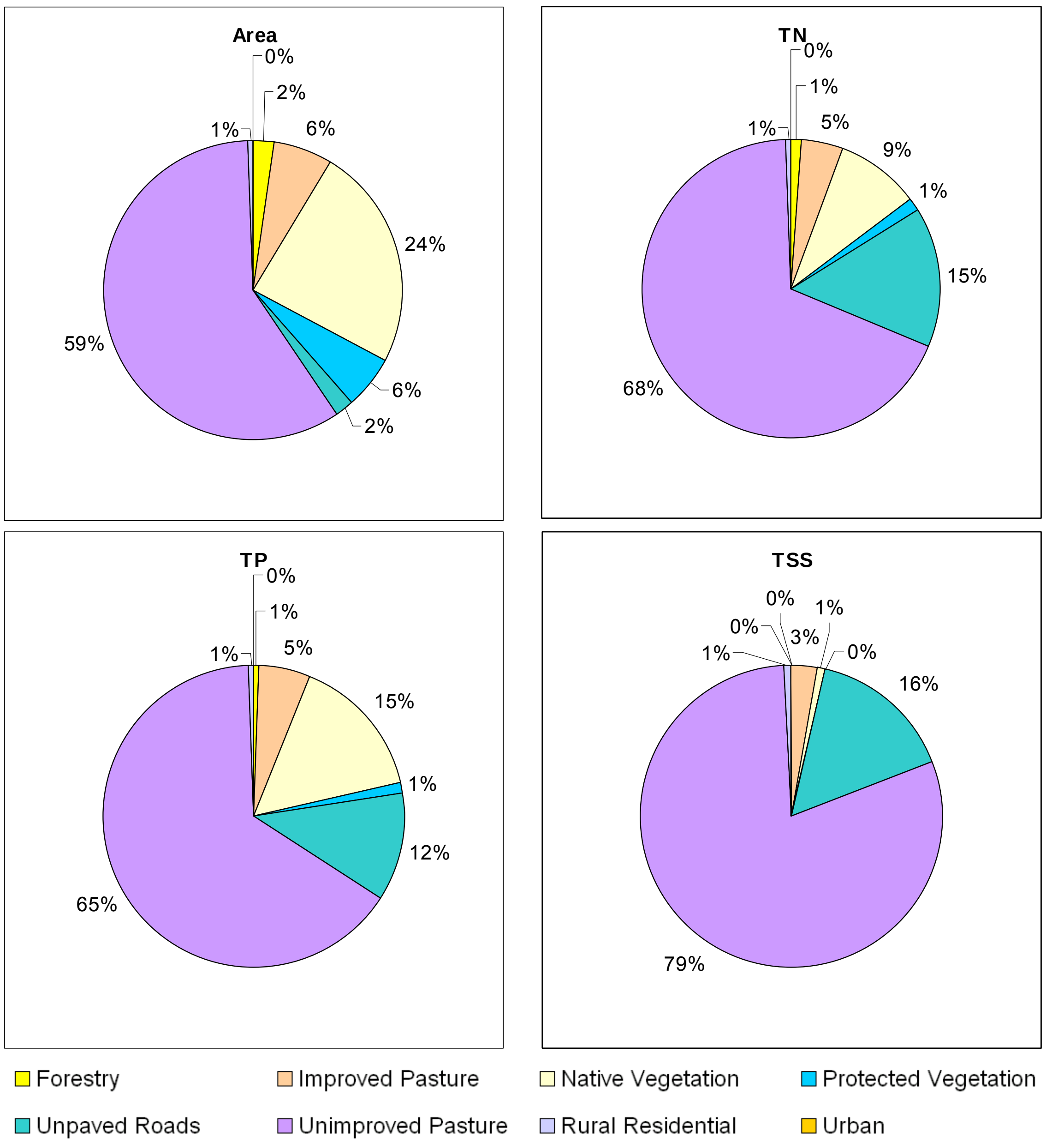

Figure A6.27. Pollutants and areas by land use, Lower Wang Wauk River (HS7c).

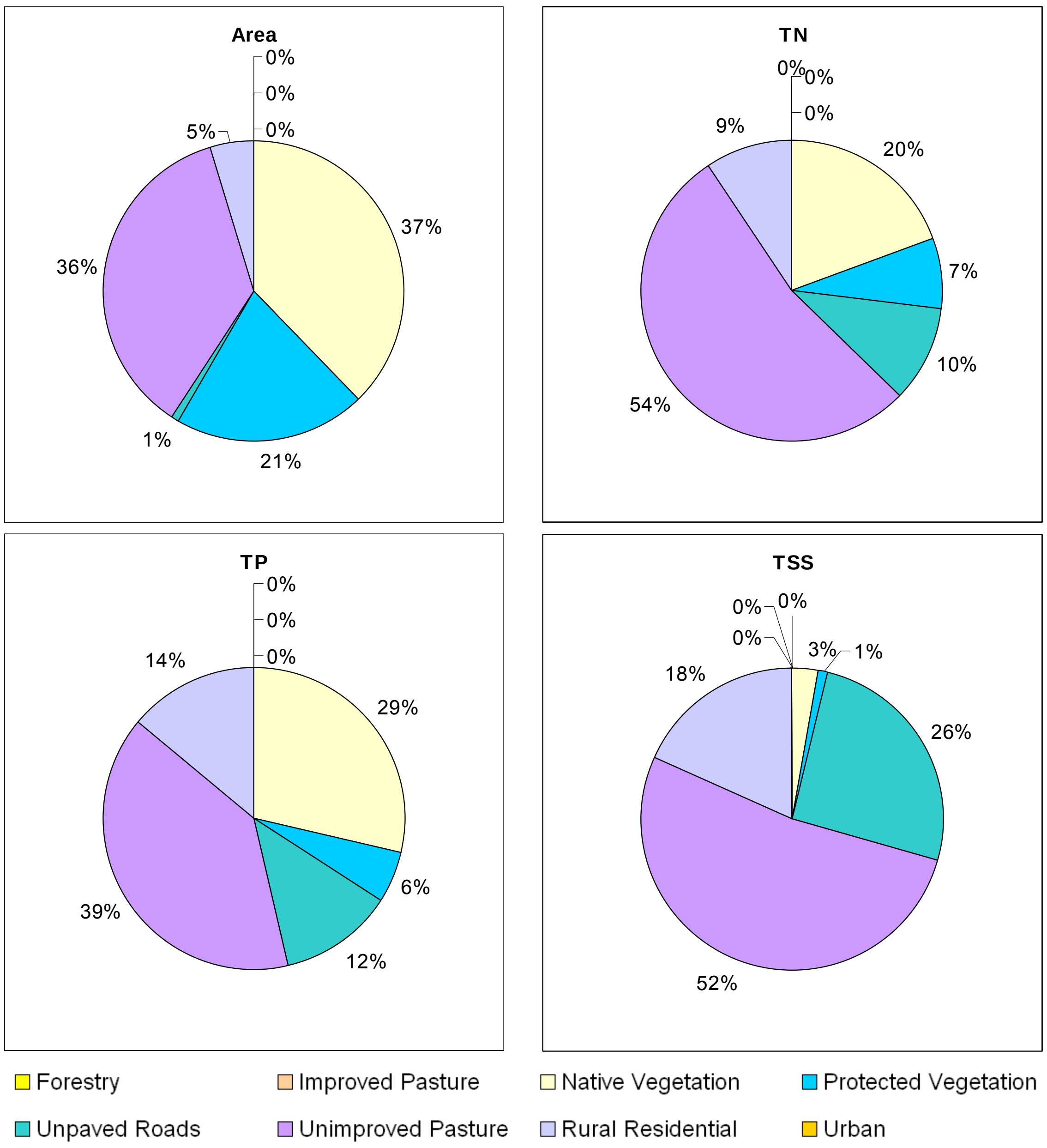

Figure A6.28. Pollutants and areas by land use, Coolongolook Estuary Reach (HS8).

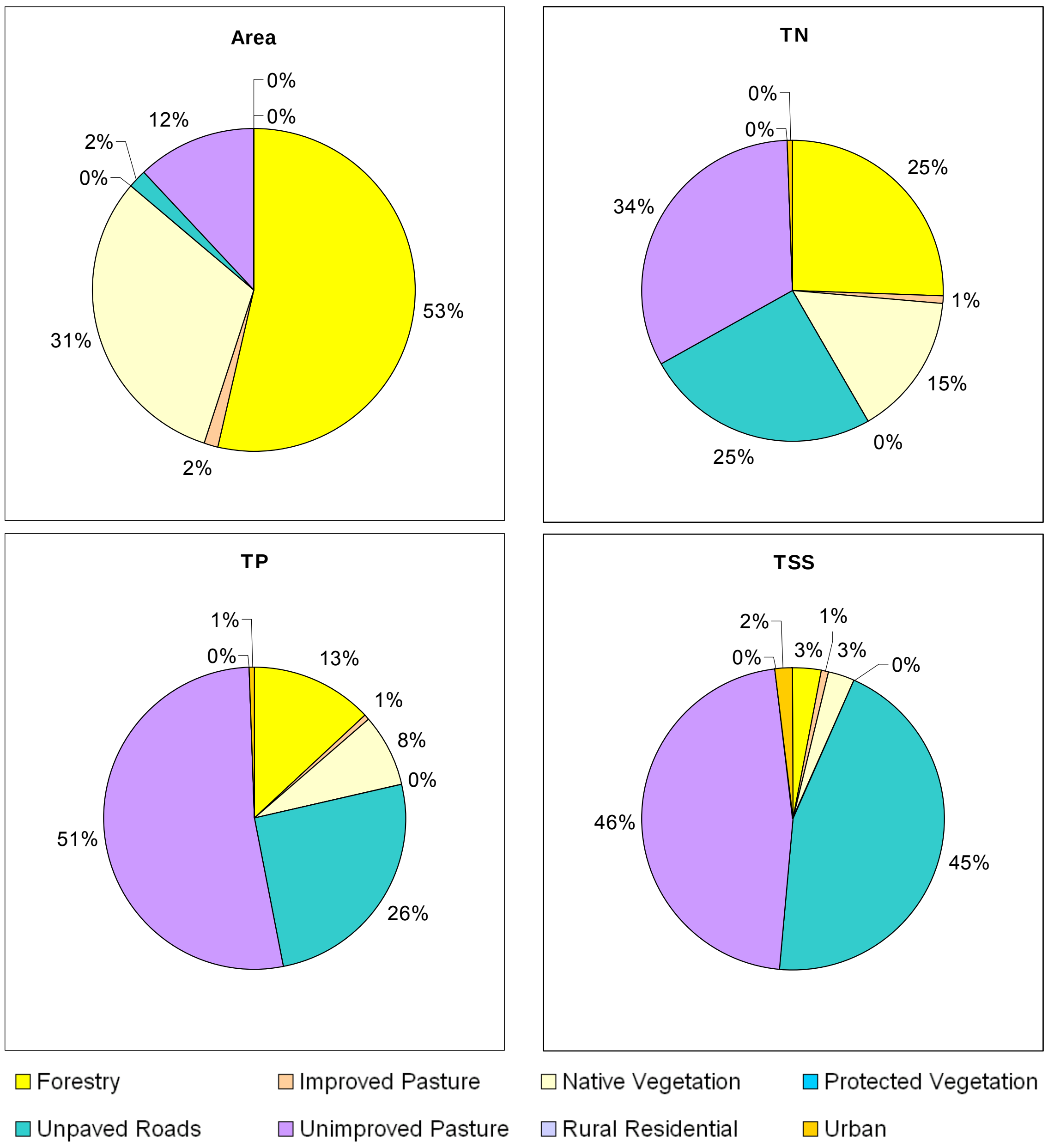

Figure A6.29. Pollutants and areas by land use, Cureeki Creek (HS9a).

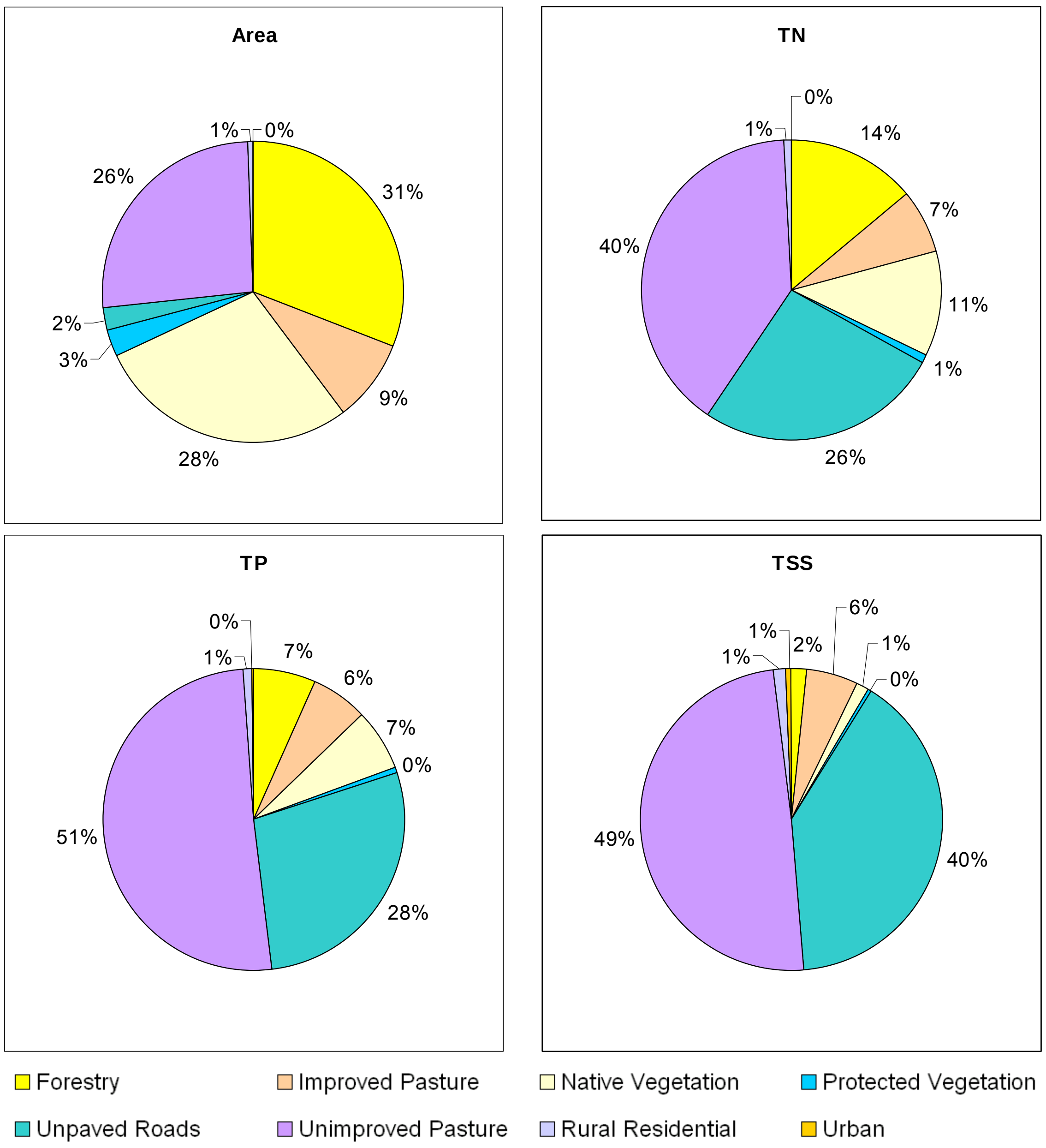

Figure A6.30. Pollutants and areas by land use, Upper Coolongolook River (HS9b).

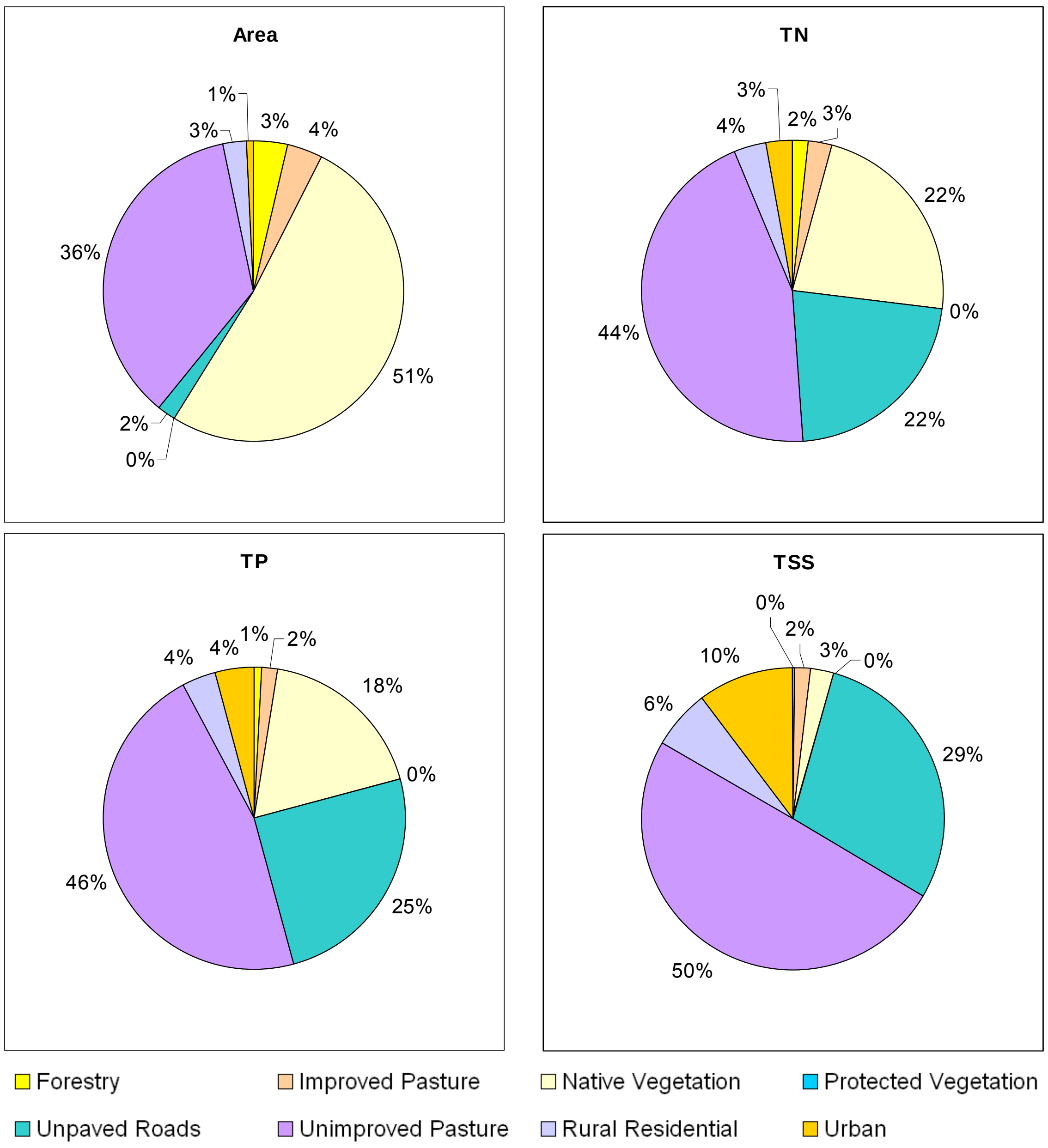

Figure A6.31. Pollutants and areas by land use, Lower Coolongolook River (HS9c).

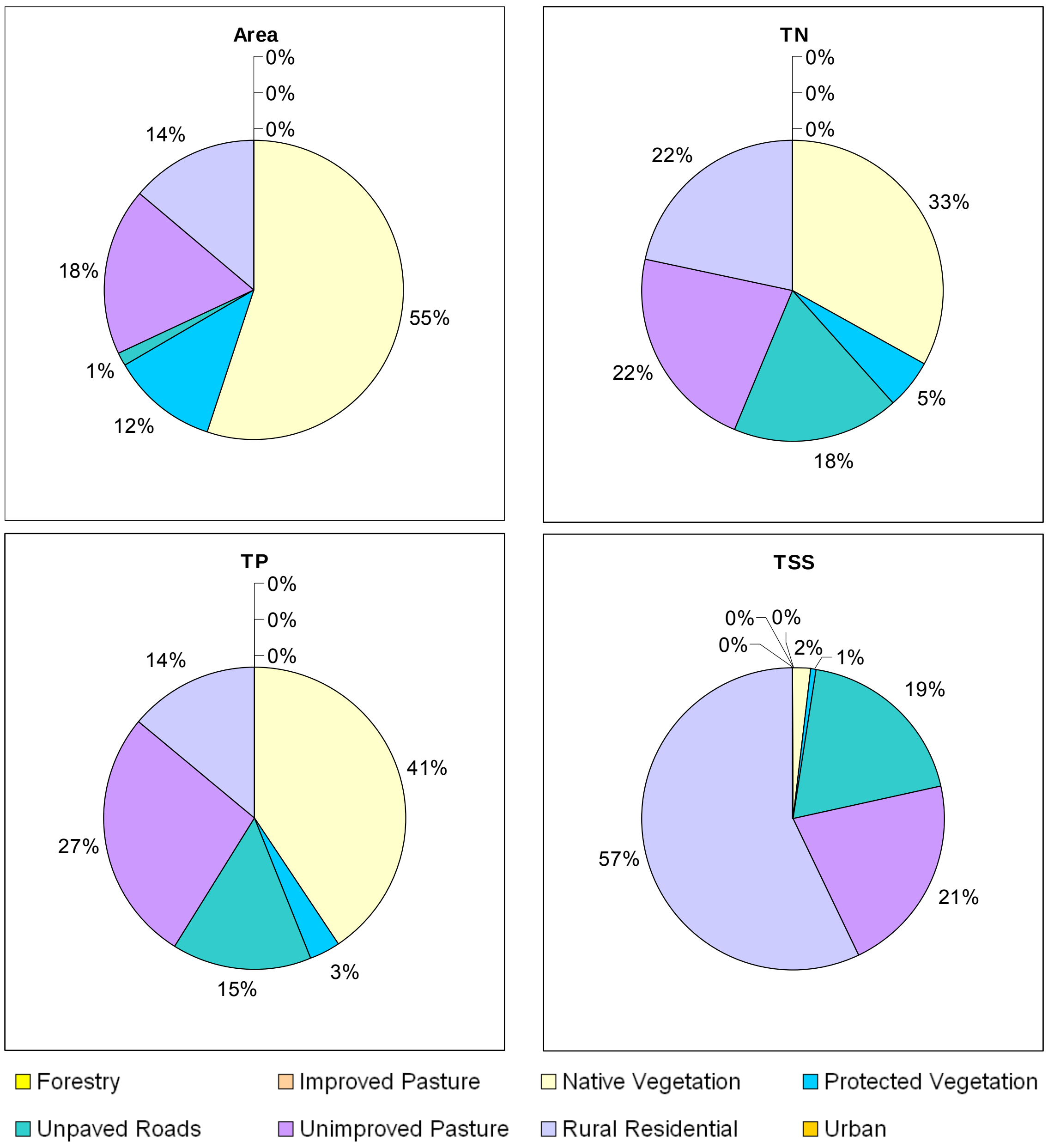

Figure A6.32. Pollutants and areas by land use, Beaky Bay (HS10).

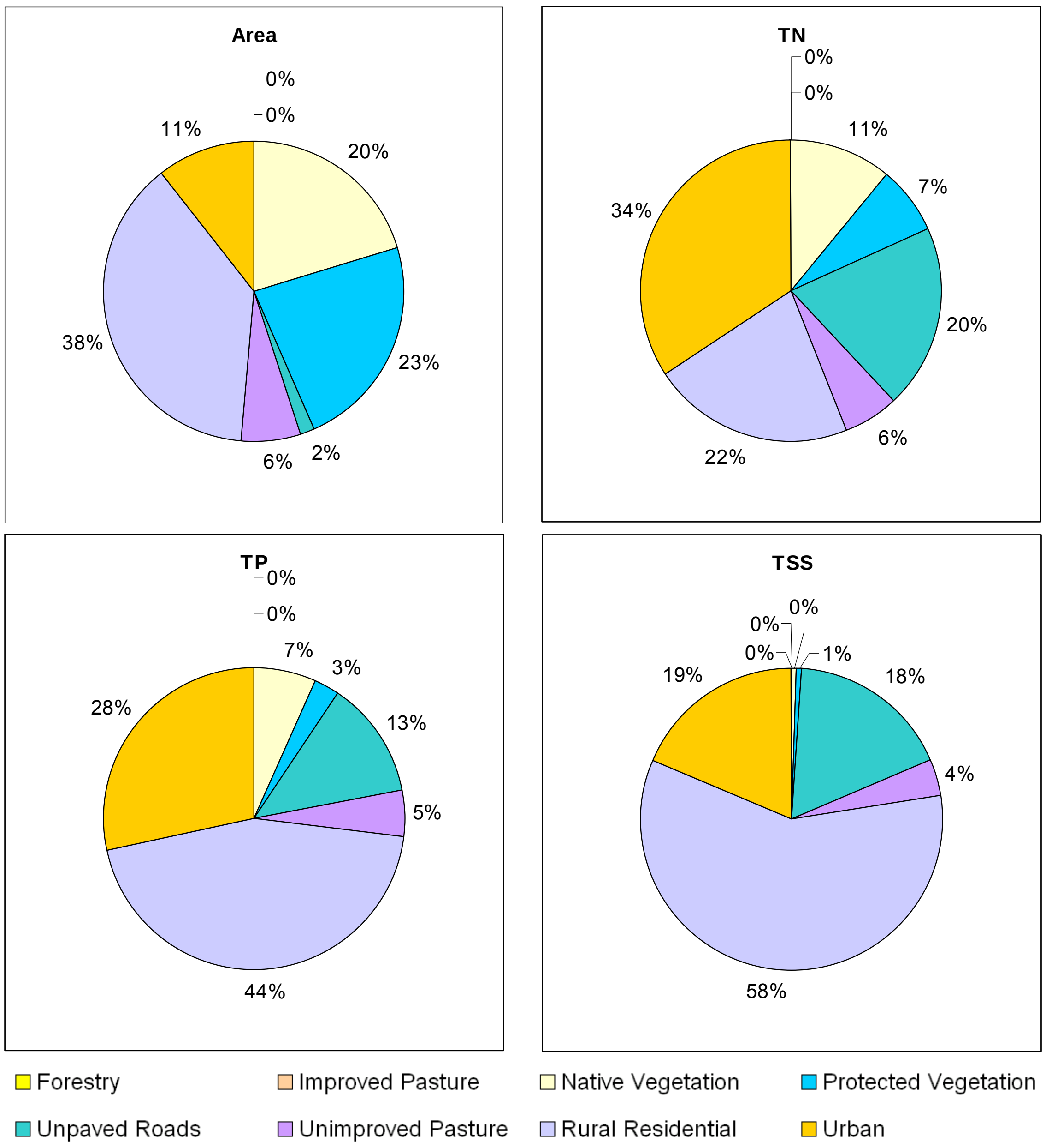

Figure A6.33. Pollutants and areas by land use, Coomba / Wallis Island (HS11).

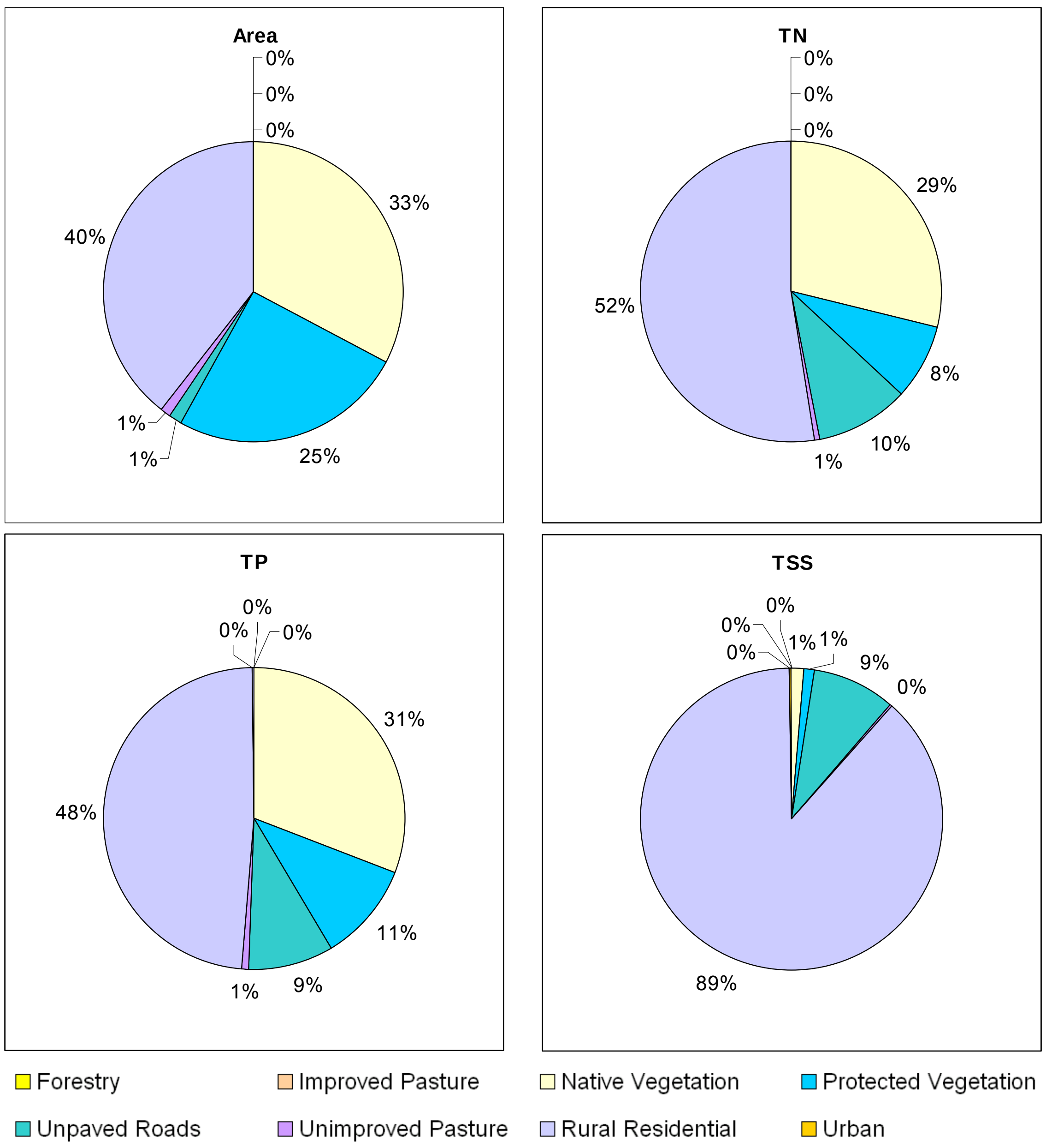

Figure A6.34. Pollutants and areas by land use, Coomba Bay (HS12).

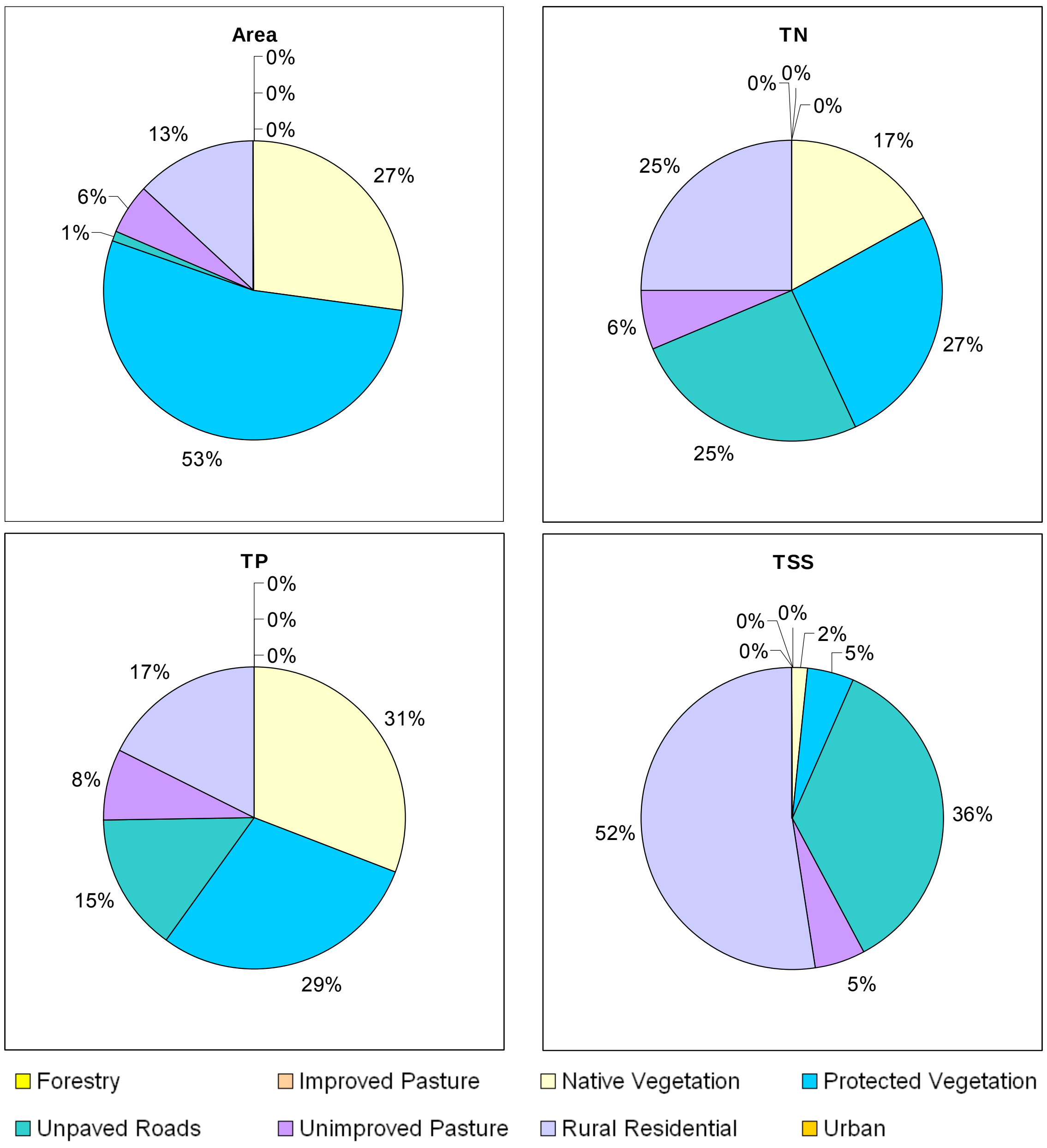

Figure A6.35. Pollutants and areas by land use, Whoota / Yarric (HS13).

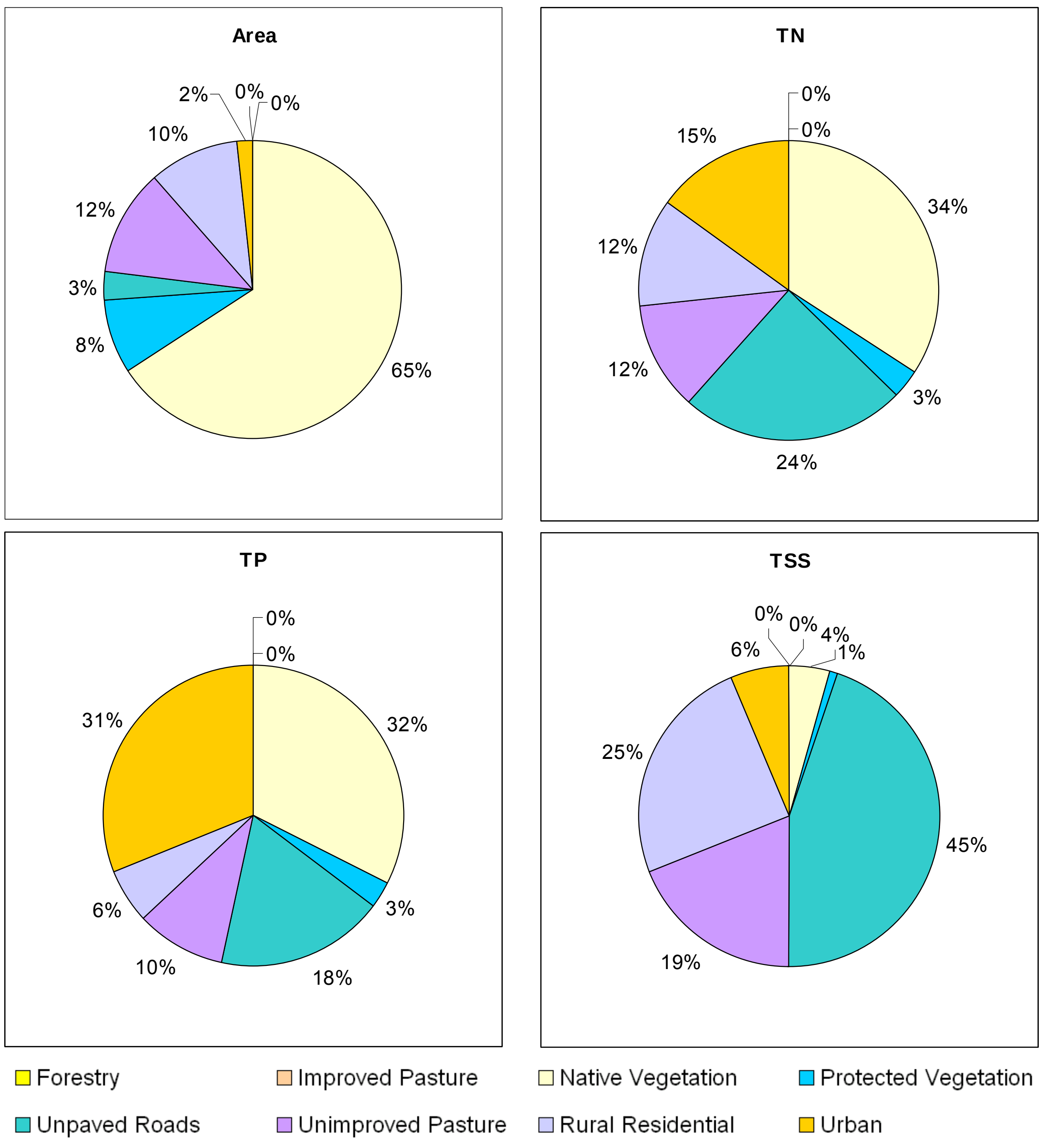

Figure A6.36. Pollutants and areas by land use, Pacific Palms (HS14).

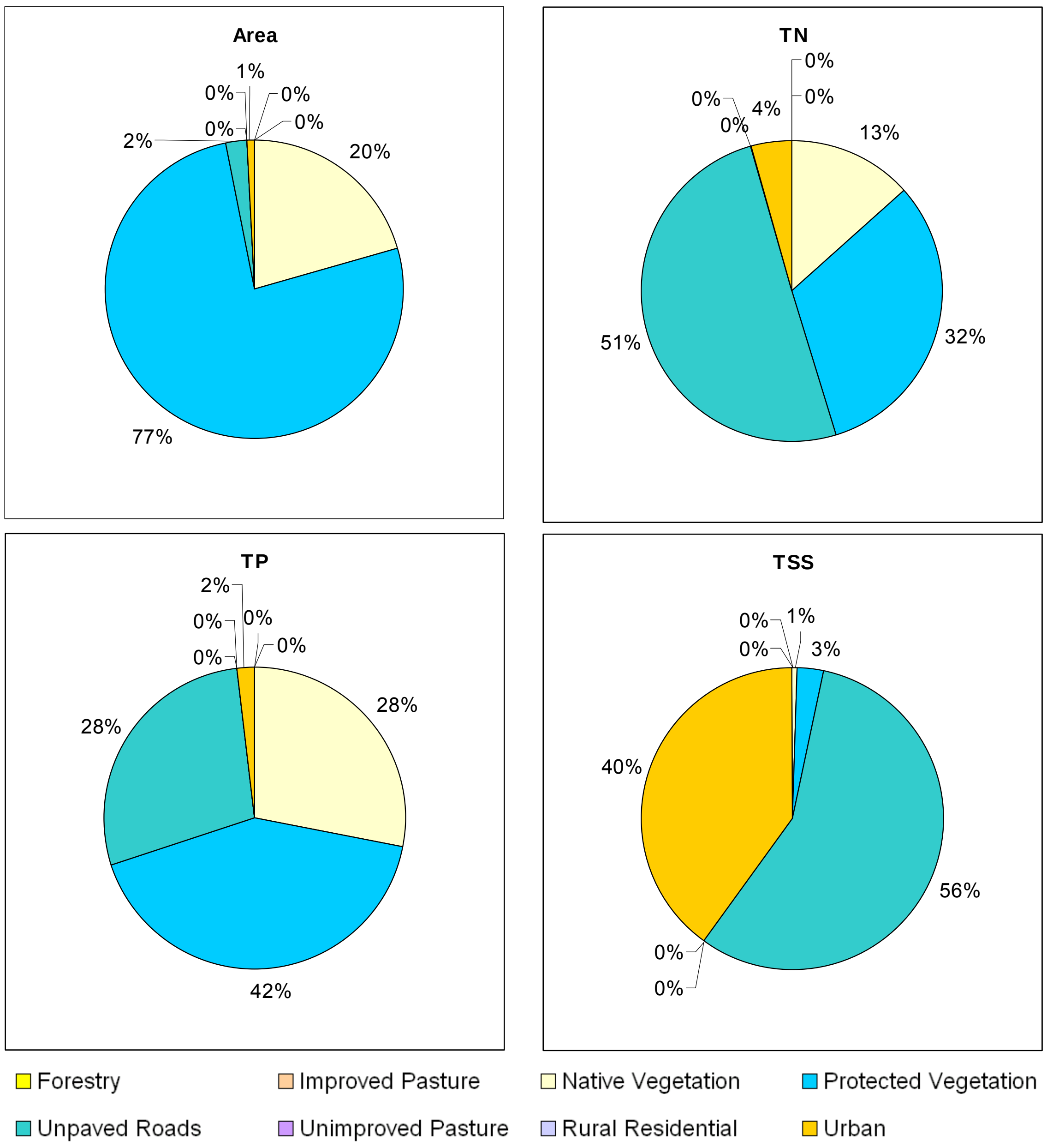

Figure A6.37. Pollutants and areas by land use, Booti Booti (HS15).

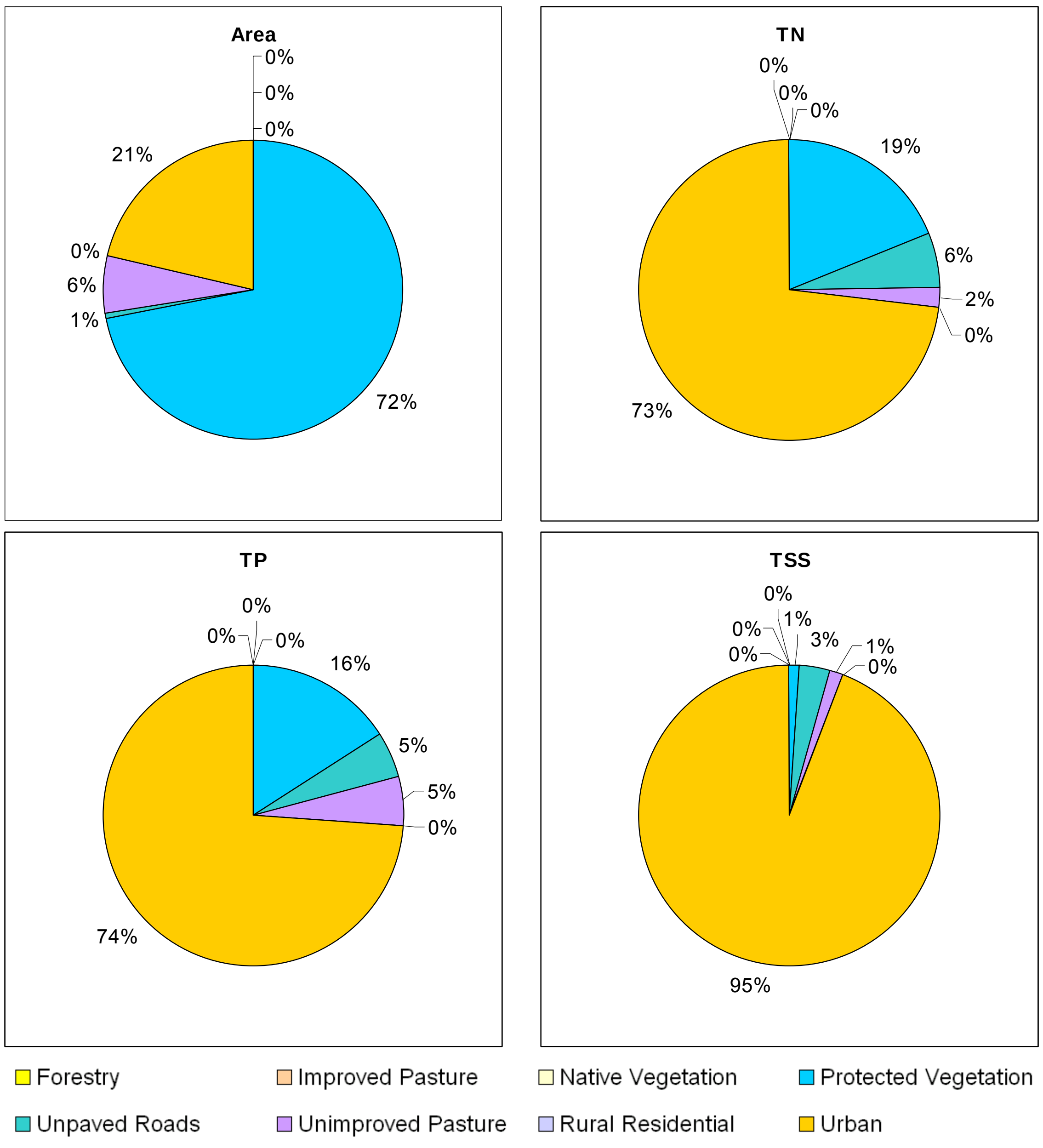

Figure A6.38. Pollutants and areas by land use, Green Point (HS16).

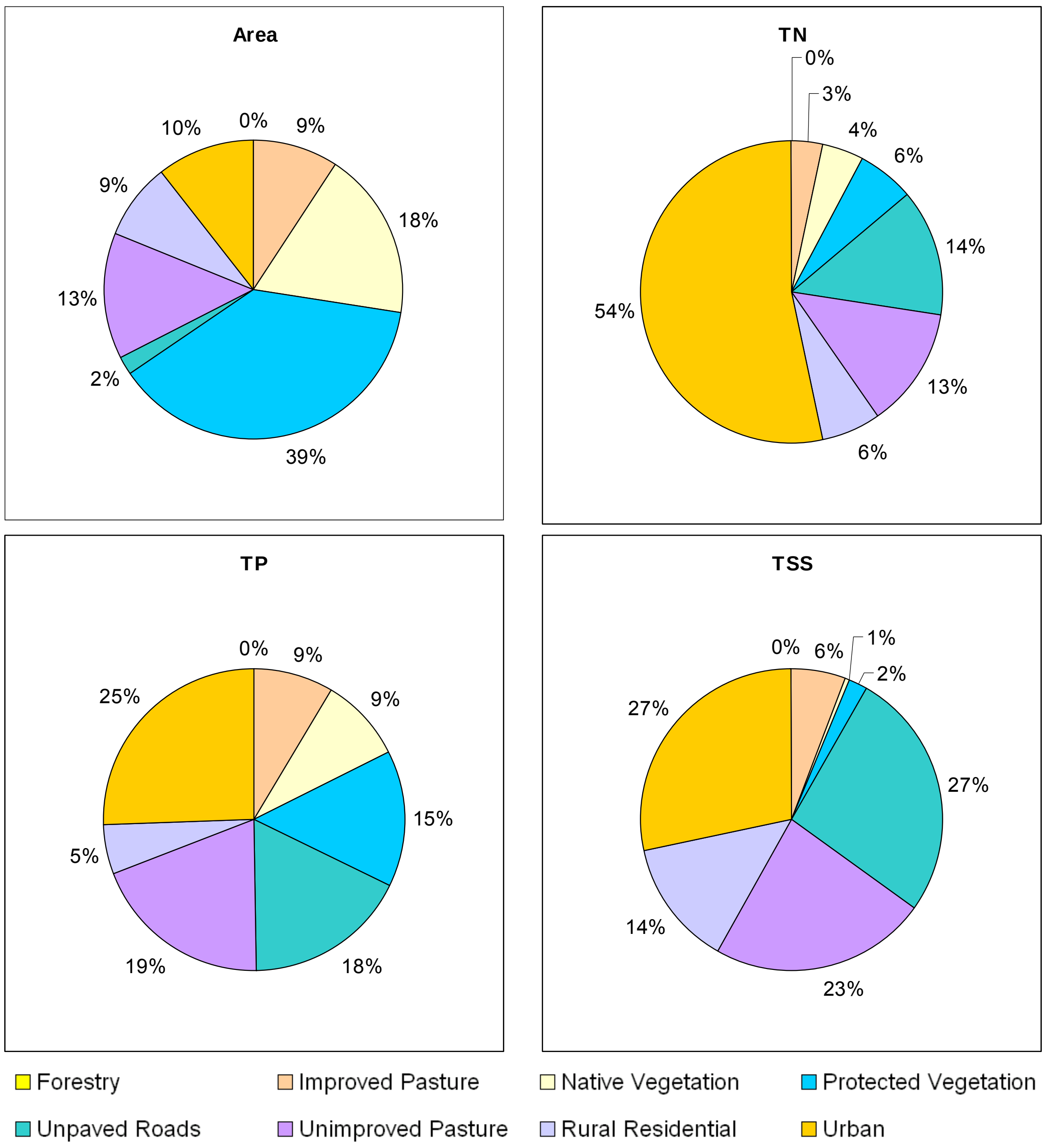

Figure A6.39. Pollutants and areas by land use, Pipers Bay (Cape Hawke) (HS17).

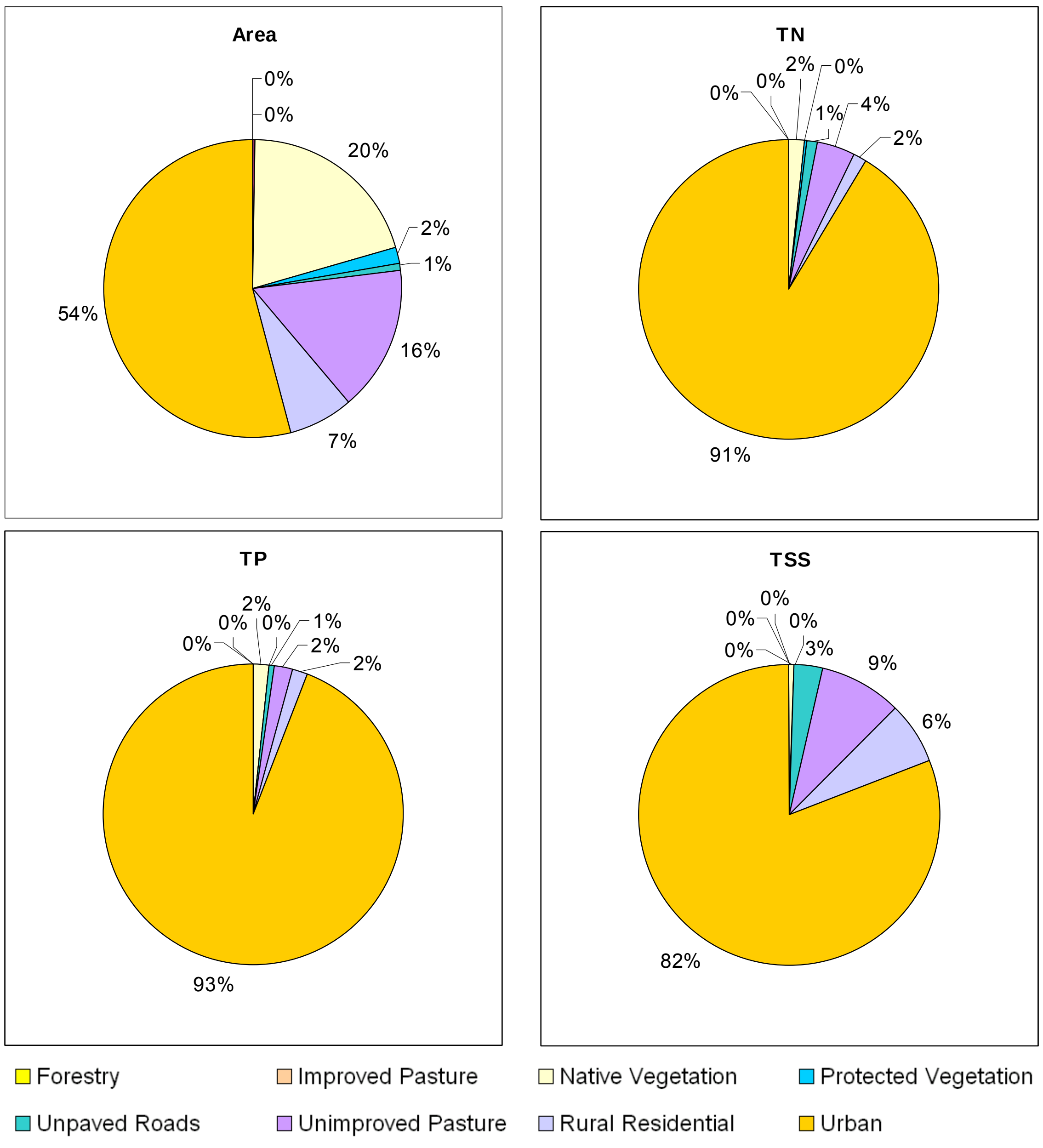

Figure A6.40. Pollutants and areas by land use, Pipers Creek (South Forster) (HS18).

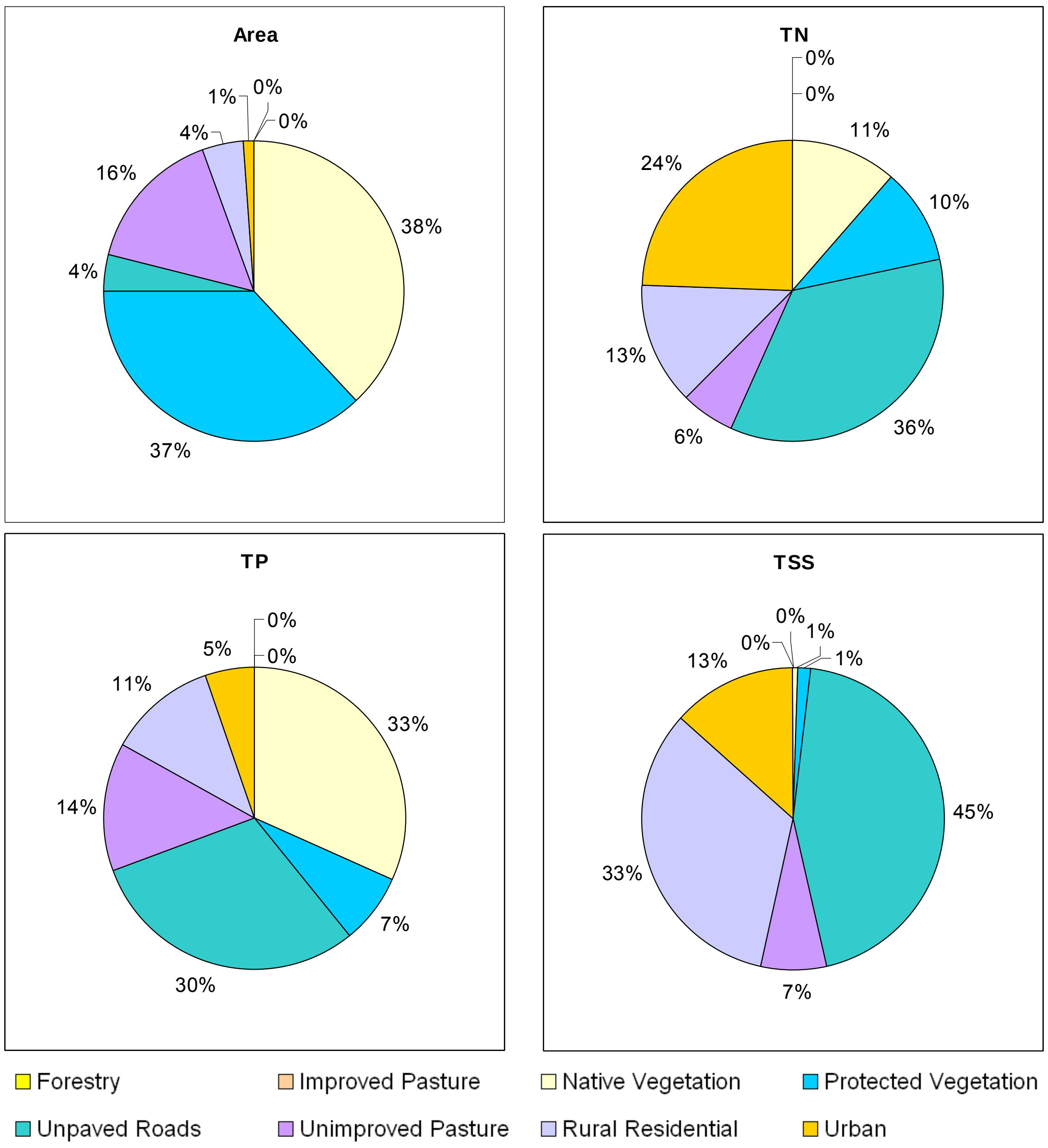

Figure A6.41. Pollutants and areas by land use, Big Island (HS19).

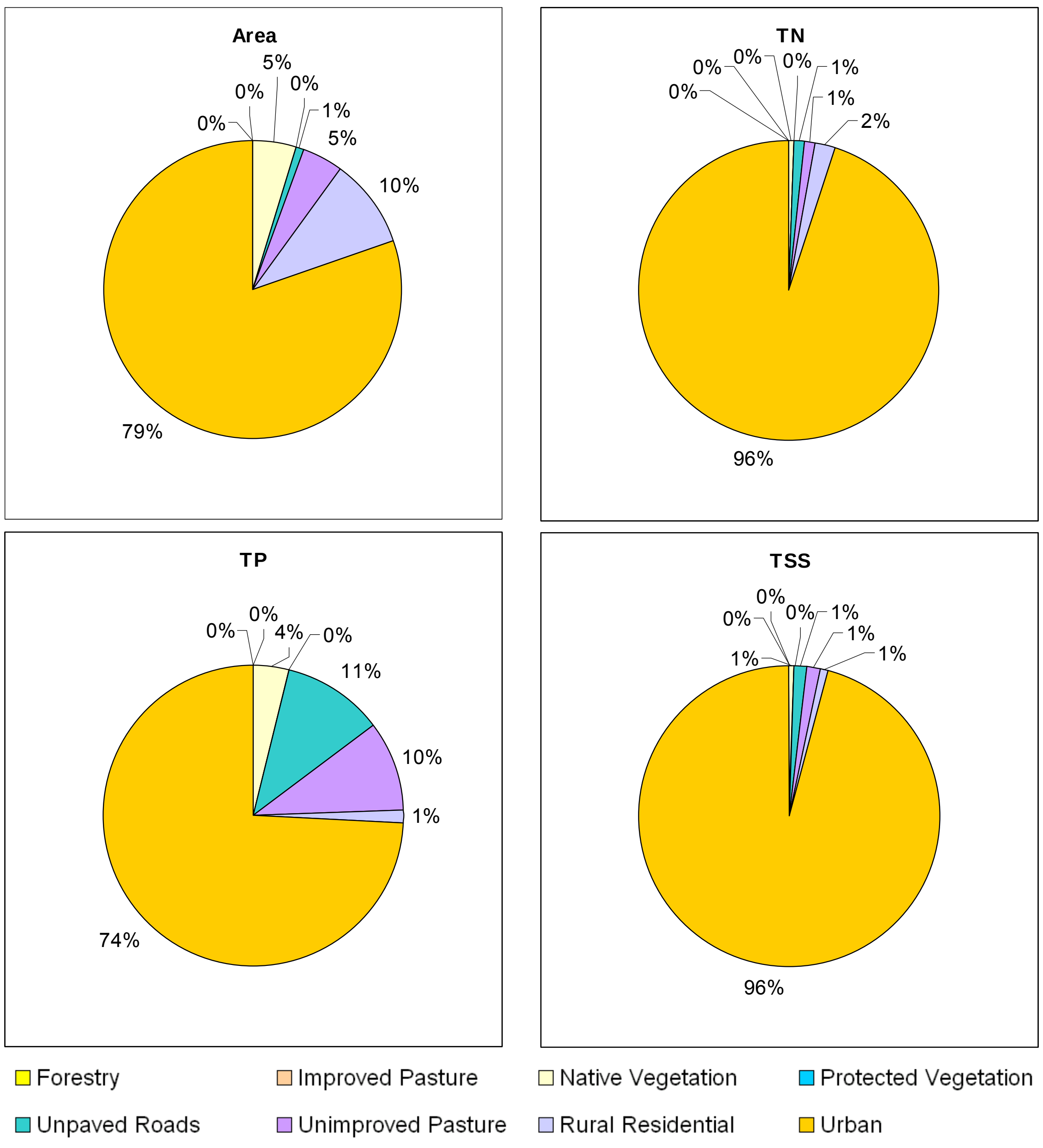

Figure A6.42. Pollutants and areas by land use, Forster (HS20).

Appendix 7: Priority research and development activities

1. Catchment modelling

The integration of catchment and estuary response models to examine how land-based activities affect the water quality and ecological health of receiving waters is now a common approach for sustainability assessments. However, a large part of the uncertainty in the estimates of input loads for the estuary models is a lack of accounting of the transformation and attenuation of nutrients within a river system. Previous work in the northern hemisphere has shown that these processes reduce the concentration of inorganic nutrients during transport and alter the timing of delivery of nutrients to downstream water bodies. Up to 76% of nitrogen exported from upland catchments may be lost via denitrification or biotic sequestration. The amount attenuated, however, may depend on season and flow conditions, with greatest retentions occurring during slow or baseflow conditions. An investigation of in-stream processes was beyond the time and resources allocated for our modelling activities for the CCI, but is recognised as a priority area for future research.

More research is also needed into the effectiveness of rural management practices in general, given the lack of data in the Australia. Our monitoring was conducted in two seasons, but nonetheless showed distinctions between properties that had implemented a rural management practice and those that had not. Ideally, as done for previous rapid assessment programs (e.g. AUSRIVAS), future work could be focussed on identifying sensitive indicator species (of macroinvertebrates and / or fish).

Improvements in the models will come about largely through increasing the sizes of the datasets available for calibration and verification. The monitoring suggested in the Monitoring Strategy will provide suitable data. It is suggested that after five years, the performance of the models should be assessed against the new data and the need for changes assessed.

The catchment models used in this study were the best available, but it has become apparent that they still had shortcomings. The majority of catchment models available for use have their origins in North America, and many of the parameters and relationships required substantial reworking for Australian conditions. The development of new catchment modelling tools that better reflect Australian conditions (particularly hydrology and nutrient mobilisation) would be a great step forward.

Table A7.1. Key areas of future research and development for non-urban catchment modelling (based on DECC documentation).

Aim	Research / Development	Work type
Improve representation of sediment source	• Map location and extent of gullies in catchments (including size, stability, connectivity to streams, where they occur in the landscape) • Local rates of stream bank erosion	• Data collection • Data collection
In-stream processes	• Local rates of in-stream erosion • In-stream attenuation process	• Data collection
Characterisation of point sources	• Location of septic systems • Concentration of effluent and flow from all septic types present in catchment	• Data collection • Data collection / Literature

2. Estuary modelling

The ecological response components of the estuarine model relied heavily on empirical relationships in existing data. This was because process understanding does not exist at a level that allows confident parameterisation of an estuarine response model. As our understanding of ecological processes increases through appropriate research, inclusion of that process knowledge in the response model has the potential to improve its spatial and temporal resolution.

"Any program to improve the prognostic system should be prioritized in terms of considering processes that have big effects and which might be calculated with sufficient accuracy. The prognostic system might be improved by [Estuary model – sourced from Brian Sanderson's website: http://users.eastlink.ca/~bxs/LAYMAN/node22.html, accessed 28 May 2008]:"

Table A7.2. Key areas of future research and development for estuarine response modelling (Source: http://users.eastlink.ca/~bxs/LAYMAN/node22.html, accessed 28 May 2008).

Aim	Research / Development
Improving our knowledge of mechanisms presently used within the software	*Smiths Lake* More chlorophyll and water column measurements (so that chlorophyll response does not have to be modelled on the assumption of similarity with Wallis Lake) *Myall Lakes* More chlorophyll and water column measurements *All lakes* • Improving our knowledge of how light attenuation in the water column varies according to concentrations of total nitrogen, total phosphorus, total suspended solids and dissolved organic material that colours the water. This work has been begun as part of the CCI project, but more extensive measurements are required to bring it to fruition. • Considering distribution of benthic 'plants' availability of specific wavelengths of light. Explicit, rather than implicit, treatment of sediment suitability for benthic plants.

Aim	Research / Development
Adding mechanisms that have large effects and might, with additional work, be calculated with reasonable accuracy	*All lakes* • Bottom stresses impose constrain benthic habitat. Consideration of bottom stresses, which can be calculated from wave and current models -- with a requirement for some field work for empirical calibration. • Resuspension and settling mechanisms are major determinants of the properties of the water column and sediment–water exchange. Addition of resuspension and settling mechanisms. Lake-specific measurements are required for calibration of semi-empirical models. Such measurements must be done in conjunction with measurements of light attenuation in the water column -- discussed above.
Adding functionality by calculating ecological measures that provide additional insight without affecting existing calculations	*Wallis Lake* • Diagnose fluxes of particulates and dissolved inorganic material associated with aquaculture within Wallis Lake. *All lakes* • Diagnose distributions of benthic microalgae[a] production by consideration of light, water depth, etc.

a: Benthic microalgae – microscopic plants found on the lake bottom. They are considered a functionally important part of the estuarine system (http://users.eastlink.ca/~bxs/LAYMAN/node15.html, accessed 28 May 2008).

Additional recommendations from the Advisory[DG15] Committee on Estuary Modelling included improving modelling of Smiths Lake to take into account the alternative opening regime (open all of the time rather than every 1–2 years).

Table A7.3. Non-urban catchment modelling (from iCAM and based on DECC documentation)

Aim	Research / Development	Work type
Improve representation of sediment source	• Map location and extent of gullies in catchments (including size, stability, connectivity to streams, where they occur in the landscape) • Local rates of stream bank erosion	• Data collection • Data collection
In-stream processes	• Local rates of in-stream erosion • In-stream attenuation process	• Data collection
Characterisation of point sources	• Location of septic systems • Concentration of effluent and flow from all septic types present in catchment	• Data collection • Data collection / Literature

3. Decision Support System

Recommendations for improving the performance of the DSS include:

- running a more extensive set of AnnAGNPS models (e.g. land use change scenarios, a broader range of management scenario) to make the data tables in the DSS even more robust
- exploring options for presenting duration curve information (more capacity to show variability)
- undertaking research to get supporting information to help verify model results on the effectiveness of management actions (e.g. those modelled as part of the WQIP)

- obtaining local catchment information to help think more clearly about local benefits (i.e. river health), so as to look at trade-offs between localised and catchment / estuary scales
- improving the capacity to consider different climates using the DSS (e.g climate change impacts on catchment exports, etc.)
- implementing point sources into the DSS interface (currently the capacity is in the underlying model, but was not implemented in the final DSS due to data limitations).

Recommendations for expanding the capabilities of the DSS include:

- considering the impacts of fire management and fauna on water quality
- including a pathogens model that can identify how changing catchment management actions impacts on faecal coliforms
- improving the model to assess the impact of different road management actions.

4. New models

Recommendations for other types of models that would add value to the models developed as part of the CCI project include:

- a pathogen model to identify how changing catchment management actions impacts on faecal coliforms (noted above – this could be incorporated into the DSS)
- a trophic model that identifies how oysters and fish are impacted by changes in nutrients and sediment concentrations.

5. Other recommended research

5.1 Catchment issues and water quality risk

Other research specifically aimed at gaining a better understanding of the catchment and the water quality risks are outlined below:

- identifying where there is high risk of gullies developing in the Smiths Lake catchment
- better quantifying the risk of large pollution events in Pipers Creek area in Wallis Lake
- identifying the water quality risk associated with developing the floodplain areas between Pipers Bay and Dunes Creek, particularly in relation to loss of water detention
- undertaking risk analysis on unpaved roads, and identifying priorities for remediation
- researching the impacts of burning off native grasses on water quality, in particular sediments and erosion
- investigating the role of eucalypt plantations in water quality management (and associated benefits of being a carbon sink)
- investigating the impact of the Coolongolook tyre dump on water quality, specifically burning during bushfire, pollution of air and the flow-on pollution of water.

- gaining a better understanding of the distribution and use of chicken litter in the Myall Lakes catchment.

5.2 Understanding the impact of management actions on water quality

A number of areas for future investigation are identified in the Farm Scale Action Plan. While the specific recommendations are not repeated here, some additional research into the impact of management practices include:

- researching the benefits of dung beetles in relation to water quality.

Appendix 8: Background information on Wallis Lake and catchment

This appendix has two purposes: to provide a background to the Wallis Lake system and catchment, and to provide the context and history to the catchment management actions and approach to catchment management. The first section on Wallis Lake and its catchment includes descriptions of the key sub-catchments, catchment topography, history, land uses and ecology. The second section on catchment management includes discussion of land use planning, focussing on further expansion of urban and rural residential areas, and the development and implementation of catchment and estuary management plans.

1. Wallis Lake and its catchment

Situated on the New South Wales Lower Mid North Coast (152°30'E, 32°10'S), the Wallis Lake catchment covers 1,292.2 km^2, and a total waterway area of the lake and its tributaries to the tidal limit of 91.24 km^2 (Wallis Lake Estuary Management Committee 2005). Wallis Lake is a large, relatively shallow coastal estuary with an average depth of 1.8 m and the lake entrance is trained open permanently (Wallis Lake Estuary Management Committee 2005). The Wallis Lake catchment can be divided into seven primary sub-catchments based on the major drainage networks: Wallamba River, Lower Wallamba River, Wang Wauk, Coolongolook, Wallingat, Wallis and Minimbah (Figure Figure A8.1).

The four major river networks of the Wallamba, Coolongolook, Wang Wauk and Wallingat rivers together drain a total catchment area of approximately 1,292.2 km^2. The Wallamba River and Lower Wallamba River sub-catchments, totalling some 429.5 km^2, drain the northern most third of the Wallis Lake catchment and are the most modified for agricultural purposes. The Wang Wauk and Coolongolook river catchments, also significantly modified for agricultural activity, drain a further 389.6 km^2 (30%) of the catchment. The Wallingat River catchment, draining approximately 173.1 km^2 (13%), remains the least modified sub-catchment. More than 124 km^2 (72%) of the Wallingat catchment is private native forest, state forest or conservation estate. The lake body and its immediate foreshore areas drain a further 177.8 km^2 (15%), while the Minimbah sand bed aquifer collects water from the remaining 122.1 km^2 (9%) of the catchment area.

The catchment extends over three local government boundaries: the Great Lakes Council (65%), the Greater Taree City Council (30%) and the Gloucester Shire Council (5%). Wallis Lake and the Minimbah sand beds – as well as the Coolongolook, Wallingat and most of the Wang Wauk sub-catchments – lie within the Great Lakes local government area. The northern third – including the Wallamba River, Lower Wallamba River and parts of the Wang Wauk River sub-catchments – falls within the Greater Taree City local government area. The Gloucester Shire local government area covers grazing lands in the west of the catchment.

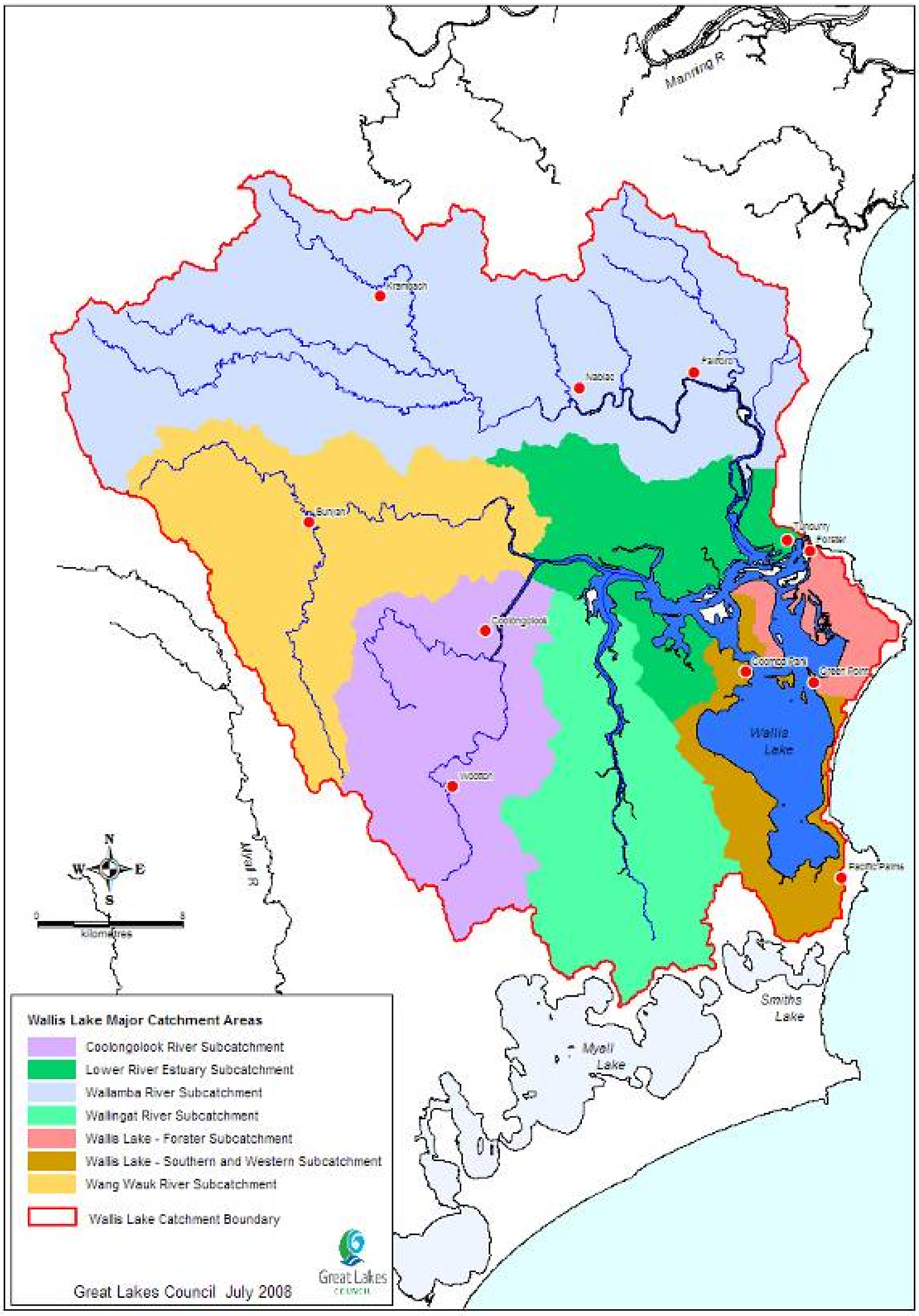

Figure A8.1. Location of Wallis Lake within the Great Lakes in the Hunter-Central Rivers region, just north of the Myall Lakes and Smiths Lake catchments. The various sub-catchments of Wallis Lake catchment are also shown.

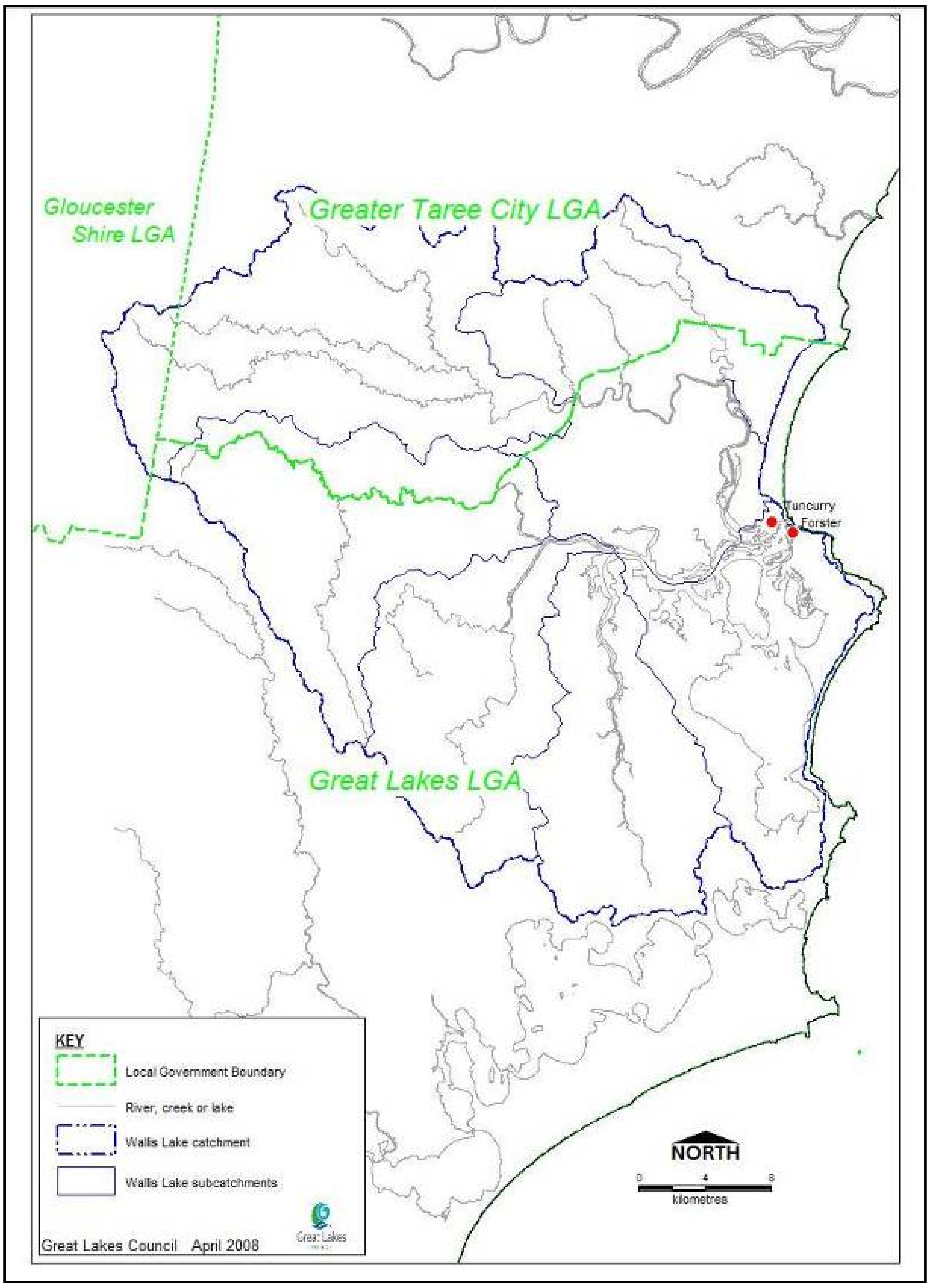

Figure A8.2. Local government jurisdictions within the Wallis Lake catchment: Great Lakes local government area, Greater Taree City local government area and Gloucester Shire local government area.

2. Catchment topography

The Wallis Lake catchment can be subdivided into two broad topographical units: the predominantly sand barrier-formed coastal plain, and the sedimentary / metamorphic origin inland ridges and valleys (Wallis Lake Catchment Plan Steering Committee 2003a[DG16]; Wallis Lake Estuary Management Committee 2005; Webb, McKeown & Associates 1999).

The coastal plain, generally less than 10 m in elevation, extends up to 10 km inland and is formed by a series of parallel Quaternary barrier dunes and a small sedimentary origin floodplain to the west of the barrier dune system. Wallis Lake is situated in a shallow depression between the barrier dune system and the floodplain (Wallis Lake Catchment Plan Steering Committee 2003a[DG17]; Webb, McKeown & Associates 1999).

The inland ridges and valleys form the largest part of the Wallis Lake catchment. Both the Wallamba and Wang Wauk River sub-catchments consist of broken sedimentary rock hills bisected by valleys. In both sub-catchments, the upper valley depositional zones consist of loamy yellow earths and podsols, while the lower valley depositional areas are primarily dune, fluvial or swamp deposits. The Coolongolook and Wallingat River valleys both cut down through sedimentary rock ridges to form relatively steep narrow valleys, and each terminates in a drowned river valley. The highest elevations within the Wallis Lake catchment are found in the north-western areas and exceed 600 m above sea level (Wallis Lake Catchment Plan Steering Committee 2003a).

3. Catchment soils

Having developed from predominantly volcanic / sedimentary parent material, Wallis Lake catchment soils are generally low in fertility. Colluvial and erosional soil landscapes are the most common within the catchment (Table A8.1), and these soil landscapes dominate the inland ridges and undulating grazing lands of the western catchment area.

Table A8.1. Soil landscape types of the Wallis Lake catchment.

Soil landscape group	Area (ha)	Proportion of catchment (%)
Aeolian	7,097.65	5.50
Alluvial	8,205.16	6.35
Colluvial	42,636.10	32.99
Disturbed	978.48	0.70
Erosional	38,574.59	29.85
Estuarine	6,280.95	4.86
Residual	9,711.72	7.52
Swamp	453.19	0.35
Transferral	6,016.98	4.66
Water	9,109.85	7.10
Data unavailable	159.76	0.12
Total	**129,224.43**	**100.00**

Colluvial landscapes develop from the downslope mass movement of parent material; these landscapes typify the soils of the steeper catchment ridgelines. Soils of this type are generally shallow yellow earths and, being weakly aggregated, are easily detached when the vegetative cover is disturbed or removed (Wallis Lake Catchment Plan Steering Committee 2003a; Webb, McKeown & Associates 1999).

Erosional soil landscapes are products of the erosive action of running water and are typically found on the mid to lower catchment slopes. Here, soils are generally classed as yellow podsolic duplex soils, exhibiting strong differences between the upper and lower levels (Webb, McKeown & Associates 1999). Erosional landscape soils are poorly aggregated and during wet weather are subject to severe sheet erosion in exposed situations. Contiguous vegetative cover can significantly reduce the rate of erosion in this soil landscape.

The river floodplains and coastal plains are dominated by alluvial, residual, estuarine and aeolian soil landscapes. These soils are generally highly permeable and of low fertility and are therefore of limited value for agricultural activity. Significant areas of the aeolian landscapes have been mined for heavy minerals, such as rutile and zircon. Soil types in these landscapes are generally podsols or peaty podsols; these soils are highly susceptible to wind and water erosion once the vegetative cover has been removed. Low-lying estuarine and aeolian landscapes are often underlain with clays and have organic acid peat deposits. Acid sulfate soils have developed in many low-lying coastal plain areas (Wallis Lake Catchment Plan Steering Committee 2003a; Webb, McKeown & Associates 1999).

4. Historical land use

The cultural heritage of Wallis Lake and its catchment includes a rich Aboriginal heritage and significant landuse changes under European Settlement. The extent of vegetation and ecosystem modification attributable to Aboriginal land use within the Wallis Lake Catchment is difficult to quantify. However, the arrival of European settlement defines a major alteration in catchment land use.

Early European records indicate that prior to settlement, the catchment was thickly vegetated: extensive stands of riverine rainforest lined most of the catchment’s waterways, while old-growth eucalypt forest and woodland covered much of the remaining lowland slopes and ridge landscapes. Early settlers and pastoral companies, pushing further out from the established settlements, identified and exploited valuable timber resources and pastoral lands. The Wallis Lakes catchment was one of the earliest catchments exploited in this manner. The earliest European arrivals were timber cutters targeting red cedar, rosewood, coachwood and other rainforest species. Effort was then focussed on clearing the riverine floodplains and lowland slopes of the “thick impenetrable bush” to accommodate the expansion of agricultural activities (Thom 2002; Wallis Lake Catchment Plan Steering Committee 2003a).

The earliest attempts at agricultural activity on lands cleared of their native timber were by the Australian Agricultural Company (AA Company). Sheep and wheat production met with little success due to the humid coastal conditions encountered in the region. However poultry, dairy and beef cattle production met with greater success, as did vegetable cropping (Wallis Lake Catchment Plan Steering Committee 2003a). By the mid-1800s, the AA Company had surrendered its claim on the Wallis Lake catchment and the adjacent coastal strip, in return for inland areas more favourable toward the greater profitability of sheep and wheat production. In 1855, the first private land grants within the catchment were awarded in the Nabiac and Coolongolook areas, and timber felling and milling began in earnest. Between 1856 and 1875, the awarding of land grants in the Forster and Tuncurry area saw the start of the earliest fishing and shipbuilding enterprises as well as a further expansion of timber milling – forming the basis of industry in early Forster and Tuncurry.

By the mid 1970s, native vegetation cover had been removed from approximately 44% of the Wallis Lakes catchment (Wallis Lake Catchment Plan Steering Committee 2003a; Webb, McKeown & Associates 1999). Such landscape modification included the clearing of riparian corridors and steep hillslope areas, as well as the draining, infilling and mining of substantial areas of coastal wetland and the barrier dune system.

Upon Wallis Lake itself, dredge harvesting and the cultivation of natural oyster beds began in the early 1880s. The formal introduction of oyster production leases in 1884 led to 700 applications covering approximately 5.5 km of the Wallis Lake foreshore.

Several European historical sites remain in the Great Lakes district, particularly in the settlements of Bungwahl, Bulahdelah and Stroud.

5. Land use and economic activities

Dominant land use types and economic activities in the Wallis Lake catchment and upon the lake itself include agriculture, aquaculture, conservation and commercial forestry, urban and rural residential development, and the tourism and coastal retirement sectors.

The proportions and locations of the land use areas within the Wallis Lake Catchment are detailed in Figure A8.3 and Table A8.2. The most extensive land use type within the catchment is grazing (volunteer, naturalised, native or improved pasture) at 32.16% followed by tree cover on private and unreserved lands at 30%. Privately-held native forest is often deemed to have multiple uses, and some of this tree cover is under commercial forestry operation. Further tree cover is accounted for as state forest (10%) and some also under conservation area (8%). Urban and rural residential development now occupies a significant and expanding portion of the catchment, while small-scale horticultural activity, such as vegetable and wine production, occurs at isolated locations within the catchment. The major urban settlements in the Wallis Lake catchment include Forster / Tuncurry, Green Point, Coomba Park, Coolongolook and Nabiac (Figure ~~Figure~~ A8.1).

Wallis Lake itself is widely used for recreational and commercial purposes. Recreational uses include fishing, swimming, paddling, picnicking, power boating and jet-skiing, while key lake-based economic industries include tourism, oyster production, commercial fishing and commercial cruise boats.

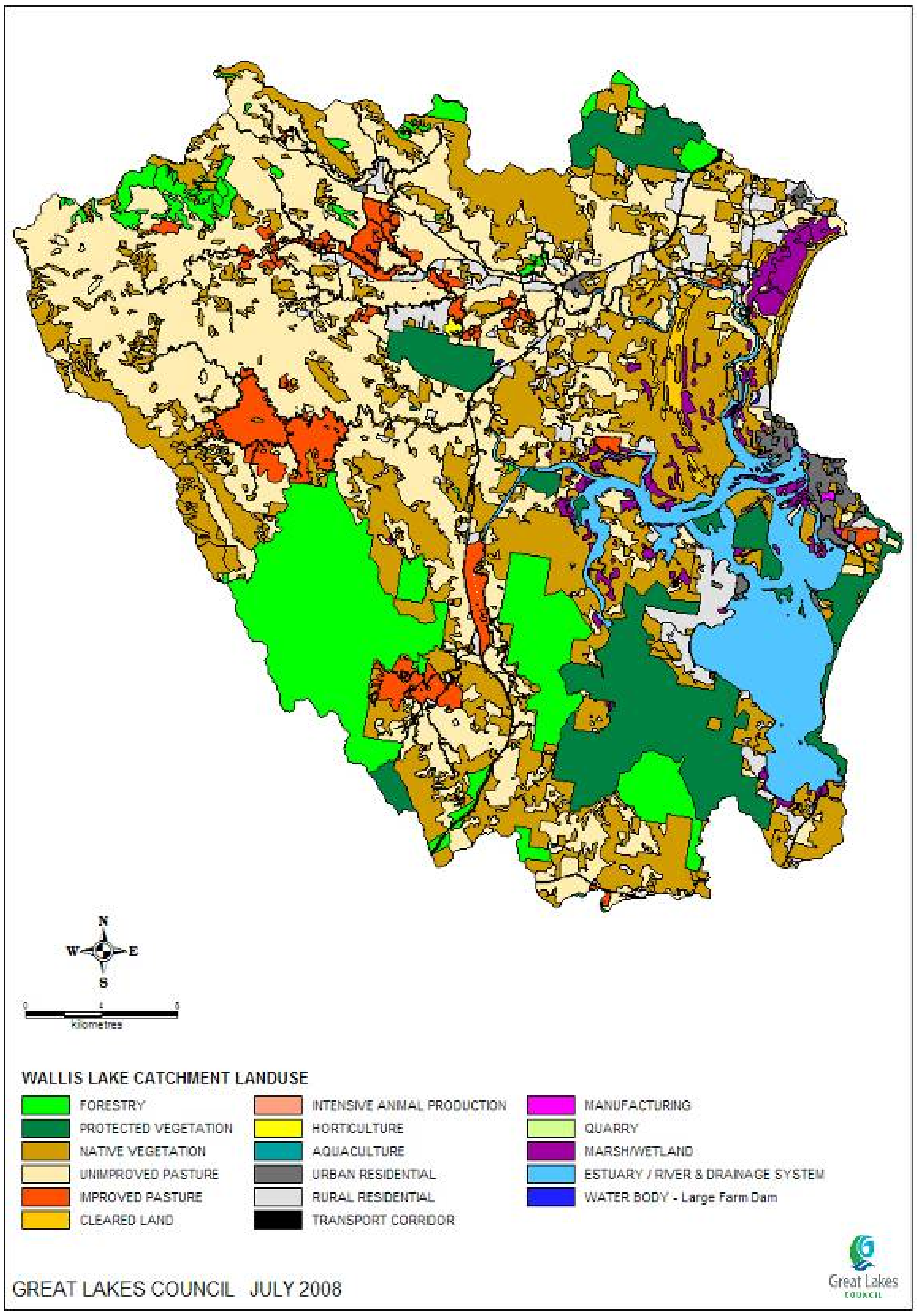

Figure A8.3. Land uses in the Wallis Lake catchment.

Table A8.2. Percentage land use in the Wallis Lake catchment.

Wallis Lake catchment land use – Mapped classes		**Area (ha)**	**Area (%)**
AQUACULTURE	Oyster, fish, prawn, yabbie or beach worm farm infrastructure	22.19	0.02
CONSERVATION AREA	National park or nature reserve	11,261.42	8.73
GRAZING	Irrigated or improved perennial pasture	4,690.34	3.63
	Volunteer, naturalised, native or improved pasture	41,503.13	32.16
HORTICULTURE	Orchard, vegetable or turf production	76.32	0.06
INTENSIVE ANIMAL PRODUCTION	Dairy shed	10.32	0.01
MINING & QUARRYING	Construction sand or gravel quarry	106.25	0.08
	Restored sand mining area	786.80	0.61
RIVER & DRAINAGE SYSTEM	Major river, creek or other incised drainage feature	2,595.25	2.01
STATE FOREST		13,411.76	10.39
TRANSPORT & OTHER CORRIDORS	Road or road reserve	639.51	0.50
TREE COVER	On Private or unreserved lands	38,712.54	30.00
URBAN	Residential and urban infrastructure	1,746.56	1.35
	Rural residential / Small rural landholdings	4,907.02	3.80
WATER BODY	Coastal lake, sand spit or estuarine feature	6,581.54	5.10
	Large farm dam	63.93	0.05
WETLAND	Coastal marsh, mangrove, mudflat or swamp	1,936.22	1.50
Total mapped area		**129,051.10**	**100.00**

In monetary terms, tourism, oyster production, commercial fishing and agriculture are the most valuable industries within the Wallis Lake catchment (Wallis Lake Catchment Plan Steering Committee 2003[DG18]a[DG19]). As of 2001, the local commercial fishing industry was valued at $2 million per annum, oyster aquaculture industry at $8 million per annum, the dairy industry at $3 million per annum, beef production at $1.5 million per annum and the tourism industry in excess of $124 million per annum (Great Lakes Business 2007; Wallis Lake Estuary Management Committee 2005). While agriculture remains an important contributor to local economic activity, the region has moved towards being a 'lifestyle region' with increased retiree and 'sea-changer' populations. Economic activity sectors in the Great Lakes region include tourism and retail (accommodation, shops, cafes and restaurants), social (education, health and community services), agriculture, aquaculture (oyster and fisheries) and construction.

Aquaculture

Oyster production and commercial fishing are essentially aquatic-based activities and, as such, are conducted primarily on Wallis Lake, the estuarine sections of the catchments' rivers and in the open oceanic waters surrounding the lake entrance. The catchment waterways and their associated wetland occupy less than 10% of the catchment area.

Figures released by NSW Department of Primary Industries (Fisheries) indicate that for the financial year 2005/06, oyster production in Wallis Lake stood at 2,013,355 dozen oysters at a total value of $9,656,176 (Sakker 2006). In 2001, the local commercial fishing industry was valued at approximately $2 million per annum (Wallis Lake Estuary Management Committee 2005). Precise estimations of the current total value of Wallis Lake's commercial fishery are not readily obtainable. However, available literature suggests that the fishery is in a state of gradual decline in the total volume of harvested resource (Stephens 2005; Wallis Lake Catchment Plan Steering Committee 2003[DG20]a).

In addition to producing a third of NSW's oysters and a commercial fishing industry, Wallis Lake is considered the largest NSW crustacean producer, at approximately 20% of the NSW estuarine total (*Estuaries of NSW: Wallis Lake* 2007[DG21]).

Agriculture

Dairy and beef grazing, the main agricultural activity within the catchment, utilises approximately 466.3 km^2 (36%) of the Wallis Lake catchment. Grazing is located predominantly in the Wallamba, Wang Wauk and Coolongolook sub-catchments.

The trend of reduced dairy production activity noted in the Wallis Lake Catchment Management Plan is continuing. The plan noted that in 1999, 48 dairies were operating within the Wallis Lake catchment, and that by 2001 that number had fallen to 29 operational dairies. Based on field surveys, current GIS layers and personal communication with catchment landholders, only nine dairies remain operational in the Wallis Lake catchment today. Estimates undertaken for the Coastal Catchment Initiative project indicate that approximately 13.3 km^2 (2.85%) of the catchment's grazing lands are currently supporting dairy production. However, it should be noted here that access arrangements to neighbouring grazing pasture is a common method of increasing the carrying capacity – and therefore milk output – of many of the catchment's remaining dairy operations. Many of those leaving the dairy industry are converting their properties to beef cattle grazing.

Horticultural activity within the catchment remains small-scale, being primarily restricted to wine grape, vegetable, cut flowers and lawn turf production. These activities occupy less than 0.1% of the catchment.

More detailed information on the agricultural land uses that occur in the Great Lakes can be found in Appendix 9 of the WQIP.

Forested land

Together, privately-owned native forest and state forest (NSW Forests estate) cover approximately 518.69 km^2 (40.2%) of the catchment. The larger proportion of this, 384.59 km^2, is under private ownership.

In the north-western parts of the Wallamba River catchment, substantial areas of private native forest are being managed as commercial timber plantations. It is also evident that previously grazed land is being converted to native hardwood timber plantations. An increasing area of privately-owned native forest is being managed for conservation purposes under formal agreements with conservation agencies.

Privately-owned forests frequently support concurrent land use activities, such as grazing cattle in the understorey, low-volume timber harvesting, firewood collection, seed and flower collection, private conservation, as well as numerous recreational activities.

Conservation

Approximately 112.60 km^2 (8.73%) of the catchment is utilised for conservation purposes. This land is under the ownership and management of the NSW National Parks and Wildlife Service. The largest proportion of conservation estate is located within the Wallingat and catchments immediately surrounding Wallis Lake. These areas are managed as national park (Wallingat and Booti Booti national parks), and provide recreation and tourism opportunities as well as high-value conservation. Smaller conservation areas, managed as nature reserves, are located on the northern edge of the catchment and along the boundary between the Wallamba and Wang Wauk sub-catchments. Much of the current conservation estate is located on steeper timbered hillslopes and ridgetop landscapes within the catchment. Riverine and riparian rainforest and valley lowland habitats are poorly represented within the current Wallis Lake catchment conservation estate. More information on the ecological significance of the Wallis Lake catchment is found in Section 6 of this appendix.

Urban / Rural residential development

Urban and rural residential development and its associated infrastructure cover approximately 70.87 km^2 (5.5%) of the Wallis Lake catchment and support a total population of approximately 26,229 (Greater Taree City Council 2007; Great Lakes Council 2007). The townships of Forster and Tuncurry, with a combined population of 18,810, are located on the north-eastern shore of Wallis Lake and are the largest urbanised areas within the catchment (Great Lakes Council 2007[DG22]c). Additional coastal population centres include the villages of Hallidays Point, Coomba Park and Pacific Palms. Smaller urban centres in western parts of the catchment include the villages of Nabiac, Coolongolook, Wootton and Krambach.

Figure A8.4. Aerial image of the Wallis Lake entrance, showing the major urban settlements of Forster and Tuncurry (Source: Google Maps 2008).

Since the mid-1950s, tourism and the coastal retirement industries have grown to be two of the more dominant industries (Wallis Lake Catchment Plan Steering Committee 2003[DG23]a). Population numbers within the Hallidays Point, Pacific Palms and Forster / Tuncurry townships increase significantly during the summer holiday season. The Wallis Lake area is well-developed in terms of active and passive recreational activities – primarily fishing, powerboating and picnicking.

Approximately 44.10 km^2 (3.4%) of the catchment is developed for rural residential purposes. Much of this land is located in the Wallamba River catchment surrounding Nabiac, and in the Lower Wallamba River catchment surrounding the Failford / Darawank areas. The western and south-western shores of Wallis Lake, in the Coomba and Charlotte Bay areas, also support significant areas of rural residential development.

Wallis Lake catchment supports a diverse range of settlement types in both size and function. Some of the smaller settlements and outlying rural areas are somewhat limited in the services offered to residents yet larger rural centres, such as Coolongolook and Krambach, do offer a range of community services to its residents.

Reticulated effluent treatment systems service the larger urban areas of Forster / Tuncurry, Pacific Palms, Green Point, Failford and Nabiac. On-site effluent disposal systems service the remaining rural and rural residential areas. The main unsewered villages are Coomba Park and Coolongolook. Following the 1997 contamination crisis in Wallis Lake oysters, problems of sewage point-source pollution from failed septic tanks were vigorously addressed through the Septic Safe Program. The program is described in Section 3.7.3 of the WQIP.

6. Ecological significance

The Wallis Lakes catchment is an important ecological system for many reasons. It has the largest area of estuarine seagrass in NSW (33.203 km^2, an increase of 2.418 km^2 from 1985 estimates) in addition to 5.9 km^2 of the total area of NSW saltmarsh communities (an increase of 1.895 km^2 from 1985 estimates) (Department of Planning NSW 2006). The lake is listed as a Wetland of National Importance and its margins contain a number of gazetted SEPP 14 coastal wetlands. The lake and its catchment are inhabited by over 30 JAMBA and CAMBA-listed international migratory bird species, as well as a range of threatened species listed on the *Threatened Species Conservation Act 1995*. The catchment has two national parks located within its boundary:

- Wallingat National Park – located on the western side of Wallis Lake and covering much of the Wallingat River sub-catchment
- Booti Booti National Park – covering 1,500 ha south of Forster on the coastal strip east of Wallis Lake.

These two parks support a diverse range of vegetation communities including littoral rainforest, coastal heath, coastal forests, cabbage palm forests and moist eucalypt forests.

In addition, national reserves exist on the Wallis Lake islands and at the mouth of the Coolongolook River:

- Coolongolook Nature Reserve – a relatively small reserve located near the confluence of the Wang Wauk and Coolongolook rivers and protecting swamp sclerophyll forest types
- Wallamba Nature Reserve – preserving dry sclerophyll forests between the Wallamba and Wang Wauk rivers
- Talawahl Nature Reserve – mixed wet and dry sclerophyll forest within the Bungwahl Creek sub-catchment is conserved in this reserve
- Wallis Lake estuarine island nature reserves – comprising Wallis Island (part); and Regatta, Mills, Yahoo, Bandicoot, Flat and Durands islands – protect significant estuarine habitats including mangrove, saltmarsh and swamp sclerophyll forest.

These parks and reserves support a diverse range of vegetation communities including, but not limited to, littoral rainforest, coastal heath, cabbage palm forests, wetlands, dry eucalypt forests and moist eucalypt forests.

Vegetation communities

Aquatic vegetation

The most prominent aquatic vegetation communities in the Wallis Lake catchment are saltmarsh and seagrass (*Zostera* and *Posidonia australis*), with lesser areas of mangroves (Figure A8.5).

Freewater (2004[DG24]) found that the major subtidal communities in the Wallis Lake catchment are seagrass beds (30 km^2 in the area) and soft-bottom communities. The major intertidal communities include mangroves and saltmarshes – all of which play significant ecological roles, acting as structural habitats for aquatic fauna. The northern part of the lake – especially in the vicinity of Wallis Island, Yahoo Island and Big Island, and around Wallamba Island – is dominated by *Posidonia australis*, while the southern parts of the lake have extensive stands of *Zostera capricorni* and *Ruppia* spp. The major submerged aquatic plants in the catchment is the *Vallisneria gigantea* (Ribbonweed), while the dominant emergent plants are *Typha orientalis* (Cumbungi), *Lomandra* sp. (Mat rush), *Gahnia* sp. (Sawsedge), *Phragmites australis* (Common reed) and the introduced pest species *Myriophyllum aquaticum* (Parrots feather) (Freewater 2004).

Coastal saltmarsh has been listed as an endangered ecological community on the *Threatened Species Conservation Act 1995*. Mangrove and seagrass communities are specifically protected under the *Fisheries Management Act 1994*, largely due to their productivity and value as fishery habitat.

A number of areas within the Wallis Lake catchment are classified under the SEPP 14 Coastal Wetlands, designed to protect wetlands from ad hoc clearing, draining, filling and levee construction (Wallis Lake Estuary Management Committee 2005).

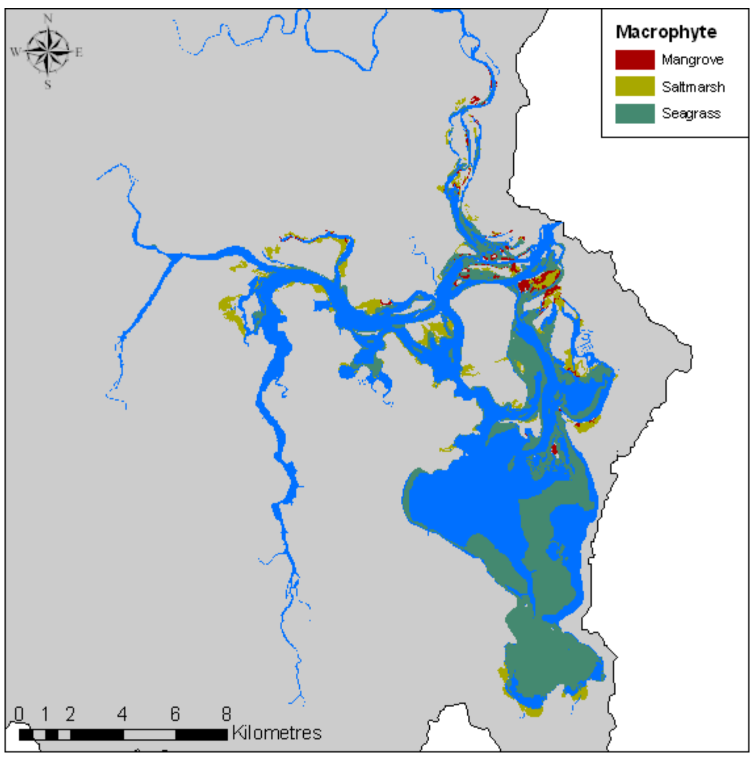

Figure A8.5. Macrophyte vegetation in Wallis Lake catchment (Source: Department of Planning NSW 2006).

Terrestrial vegetation

The Wallis Lake catchment contains a diverse assemblage of native terrestrial vegetation community types. This is a result of the location of the catchment near a region where two botanical biogeographic regions converge (the NSW North Coast and Sydney Basin biogeographic regions), and due to the variety of landscapes and soil types present. The landscapes include coasts, estuaries, river floodplains and coastal ranges.

There has never been a systematic assessment of the description and mapping of vegetation community types in the Wallis Lake catchment. However, Great Lakes Council (2003b) provided a survey and description of the privately-held and unreserved public lands (excluding state forest and national park / nature reserve) of the catchment. This was based on aerial photograph interpretation and some ground-truthing. More recently, Griffiths (2007) compiled a description of the wetland communities of the catchment. Furthermore, there has been prepared a range of site-specific or local-scale studies of terrestrial vegetation for individual development proposals, assessments of conservation reserves (i.e. Booti Booti National Park) and strategic planning.

The information available on terrestrial native vegetation confirms that the Wallis Lake catchment is diverse and significant. The major vegetation classes (Keith 2004) of the Wallis Lake catchment contains are shown in Table~~Table~~ A8.3.

Table A8.3. Broad vegetation classes of the Wallis Lake catchment.

Subtropical rainforests	Northern warm temperate rainforests
Dry rainforests	Littoral rainforests
North coast wet sclerophyll forests	Northern hinterland wet sclerophyll forests
Coastal valley grassy woodlands	Maritime grasslands
Hunter–Macleay dry sclerophyll forests	Coastal dune dry sclerophyll forests
Coastal headland heaths	Wallum sand heaths
Coastal heath swamps	Coastal freshwater lagoons
Coastal swamp forests	Coastal floodplain wetlands
Mangrove swamps	

Within these broad vegetation classes, there is a wide range of specific vegetation communities that are known to occur. The Wallis Lake catchment contains vegetation communities of state, regional and local conservation significance. Table A8.4 lists the endangered ecological communities that occur in the Wallis Lake catchment.

Table A8.4. Endangered ecological communities of the Wallis Lake catchment.

Freshwater wetlands on coastal floodplain	Littoral rainforest
Lowland rainforest on floodplain	Lowland rainforest
Subtropical coastal floodplain forest	Swamp oak floodplain forest
Swamp sclerophyll forest on coastal floodplain	*Themeda* grassland on sea cliffs and coastal headlands

The regional significance of native vegetation communities has been determined by the Comprehensive Regional Assessment for the NSW North Coast. Great Lakes Council (2003b) listed the native terrestrial vegetation communities that are considered to be regionally significant – due to the rarity, vulnerability, levels of depletion through clearing since European settlement and degree of representation in conservation reserves. The Wallis Lake catchment also contains a number of locally significant vegetation communities, i.e. represented by currently less than 100 ha extent in the Great Lakes local government area. Examples of regionally and locally significant native vegetation communities in the Wallis Lake catchment are provided in Table A8.5.

Table A8.5. Regionally and locally significant vegetation communities of the Wallis Lake catchment.

Brown myrtle dry rainforest	Cabbage tree palm rainforest
Tallowwood wet sclerophyll forest	Forest red gum dry sclerophyll forest
Coastal banksia low open forest / woodland	Spotted gum / ironbark/ mahogany dry sclerophyll forest
Brushbox wet sclerophyll forest	Swamp mahogany swamp sclerophyll forest
Wallum banksia / *Allocasuarina* dry heathland	*Baumea* sedgeland

Clearing, fragmentation and disturbance since European settlement has affected the extent and condition of native terrestrial vegetation across the Wallis Lake catchment. As part of the Great Lakes CCI Project, the vegetated and non-vegetated proportions of the sub-catchments of Wallis Lake have been determined. This has calculated that native vegetation is best represented in the Wallingat sub-catchment, with over 80% of the sub-catchment being covered with forest or wetland types. In declining proportion, the Coolongolook retains 34% forest / wetland cover, the Wallis Lake margin has 31% cover, while the Wang Wauk and the Wallamba sub-catchments contain 22% and 17% native vegetation cover, respectively. Clearing of native vegetation has been disproportionately focussed on the more productive agricultural landscapes, such as the riverine plains and adjoining low ranges. Clearing has also occurred due to sand mining, rural settlement, roads and, increasingly, urban development. The condition of native vegetation has also been affected as a consequence of land uses, such as grazing, logging, thinning, as well as altered fire regimes and the effects of exotic flora and fauna.

There is a need to recognise and address the risks and threats to the extent and integrity of native vegetation communities, and to implement programs and strategies to reverse such threats. There is also a requirement to increase endeavours that lead to the effective public and private conservation of native vegetation communities across the catchment, especially in riparian, floodplain and wetland landscapes.

Faunal communities

Aquatic fauna

The Wallis Lake and tributaries provide a habitat for a wide variety of aquatic fauna species, while also supporting aquaculture – an important commercial role in the Wallis Lakes economy.

In an assessment of aquatic fauna around Wallis Island, over 70 species of fish were recorded around this island alone (Power 2006). Among the species recorded were bream, luderick, flathead, as well as coral reef species of snapper, wrasse and butterfly fish. The assessment also noted the presence of protected fish species such as the estuarine cod – recording one individual that was more than 1 m long – as well as pipefish species.

The southern bays of Wallis Lake are in near-pristine condition with high biodiversity, including very rare brackish macrophyte and estuarine sponge communities (refer to Section 2.3 of the WQIP).

Terrestrial fauna

The Wallis Lake catchment (and the Great Lakes local government area generally) is a region of significant and characteristically high faunal species diversity. This is due to the diversity of vegetation community types (coastal, estuarine, rainforest, forest, woodland, heath and wetland habitats), the relative intactness of habitat units (when compared to other regions), and the location of the region in a zone where it receives influences from both tropical and temperate faunal groups. Due to this zone of overlap of major faunal assemblages, the region contains a number of species at or near the limit of their natural distribution, such as the eastern blossom-bat (*Syconycteris australis*).

There has never been a systematic and representative inventory of the faunal species of the Wallis Lake catchment. Nor have the results of specific fauna studies on lands within the catchment, particularly for environmental assessments of development proposals, been collated. A current program to catalogue the faunal species diversity of the wider Great Lakes local government area has identified that 67 native mammal species, 38 frog species, 59 reptile species and 303 native bird species have been recorded in the region. Within these faunal groups, the local government area in which the Wallis Lake catchment occurs contains habitats for 26 threatened mammal species, six threatened frogs, one threatened reptile and 39 threatened birds (as listed on the *Threatened Species Conservation Act 1995*). Characteristic threatened species in the Wallis Lake catchment are listed in Table A8.6.

Table A8.6. Examples of threatened terrestrial faunal species within the Wallis Lake catchment.

Common name	Scientific name
Koala	*Petaurus norfolcensis*
Squirrel glider	*Phascolarctos cinereus*
Brush-tailed phascogale	*Phascogale tapoatafa*
Greater broad-nosed bat	*Scoteanax rueppellii*
Grey-headed flying-fox	*Pteropus poliocephalus*
Wallum froglet	*Crinia tinnula*
Stephen's banded snake	*Hoplocephalus stephensii*
Osprey	*Pandion haliaetus*
Pied oystercatcher	*Haematopus longirostris*
Jabiru	*Ephippiorhynchus asiaticus*
Glossy black cockatoo	*Calyptorhynchus lathami*
Masked owl	*Tyto novaehollandiae*

The terrestrial faunal assemblages of the Wallis Lake catchment are under significant pressure from a range of threats. Such threats include, but are not limited to, clearing, modification or fragmentation of habitat, pollution, inappropriate fire regimes, effects of exotic fauna and flora, altered drainage patterns, disease, road kills, and effects of climate change. Such threats must be recognised, managed and reversed in order to protect and enhance the biodiversity of the Wallis Lake catchment.

International conservation agreements

Australia has two international agreements for the protection of migratory birds that have implications for the management of the Wallis Lakes system:

- JAMBA: Australian Treaty Series 1981, No. 6 – The agreement between the government of Australia and the government of Japan for the protection of migratory birds and birds in danger of extinction, and their environment
- CAMBA: Australian Treaty Series 1988, No. 22 – The agreement between the government of Australia and the government of the People's Republic of China for the protection of migratory birds and their environment.

These agreements list terrestrial, water and shore bird species that migrate between Australia and the respective countries, the majority of which are shorebirds. They require both parties to "protect migratory birds from take or trade except under limited circumstances, protect and conserve habitats, exchange information, and build cooperative relationships" (*Bilateral Migratory Bird Agreements* 2007[DG25]). The JAMBA agreement also includes specific provisions for cooperation on conservation of threatened birds.

Wallis Lake is utilised by over 30 JAMBA and CAMBA-listed migratory bird species and threatened species (Wallis Lake Catchment Plan Steering Committee 2003[DG26]a). Wallingat State Forest and

Wallis Lake Islands (particularly Little Tern, Sand, Godwin, Miles, Sand and Pelican islands) are important areas of bird habitat requiring conservation (Wallis Lake Estuary Management Committee 2005). Significant threats are posed to JAMBA and CAMBA birds from introduced species, and the modification and degradation of their habitat.

7. Planning and management

Planning and management strategies developed for the Wallis Lake Catchment can be considered in terms of land use planning (strategic planning), and also catchment and estuary planning.

Land use planning

A key issue facing both the Great Lakes and Greater Taree City councils is that of future expansion of urban and rural residential land use, and the design of suitable planning instruments for future development strategies. The 2006 Australian census figures indicate the population of Forster / Tuncurry has grown from 17,819 to 18,810 over the past 10 years, an increase of 14.6%. In the Nabiac / Failford / Darawank area, the population has increased by more than 22% over the same 10-year period (Great Lakes Council 2007[DG27]c). If population growth of this magnitude continues over the next 20 years, it would be reasonable to expect the area to be supporting double the current population.

Great Lakes Council has not released land for residential or rural residential development since the late 1990s. In the intervening period, Great Lakes Council has directed its resources towards the development of a comprehensive strategic framework to guide future growth and development within the local government area. Both Great Lakes Council and Greater Taree City Council have adopted strategic plans that will guide future development within the local government areas. The adopted strategies ensure that such development proceeds in an efficient manner, and that effective and sustainable conservation measures are put in place to protect lands of environmental value to the community.

Future development strategies of particular relevance to the maintenance and enhancement of water quality within the Wallis Lake catchment are Greater Taree City's Rural Residential Strategy and Release Program (2002) and Great Lakes Council's Rural Living Strategy (Greater Taree City Council, 2002; Great Lakes Council 2004). These strategic frameworks are aimed at preserving the valued identities and character of the rural communities within the catchment. Both documents outline the extent of growth in rural residential development for the foreseeable future and the relationship of any future development to the surrounding agricultural activities. Both strategies have sought community input through consultation with the rural community and endeavour to translate that input into a strategic framework for actions that reflect the values expressed by the rural community.

The respective strategies have been prepared with the aim of ensuring a long-term sustainable future for those lands impacted by urban expansion within the Wallis Lake catchment. Both strategies consider the social, environmental and economic needs of the region's communities. While outlining a template for continued growth into the future, both documents also outline an appropriate framework that will ensure the critical elements of water quality and ecological integrity remain intact and continue to serve as assets to the catchment community.

Strategies and plans are discussed in more detail in Appendix 29.

Catchment and estuary planning

History of catchment management in the Wallis Lake catchment

Catchment management priorities within the Wallis Lake catchment today are a product of past catchment management approaches. By the late 1980s, evidence of worsening stream bank erosion, river and estuary sedimentation, eutrophication of waterways, and increasing levels acid sulfate runoff began to send clear signals that past land management practices were desperately in need of revision.

The recent catchment management approaches that have taken place in the Wallis Lake Catchment are summarised inTable A8.7. Some of these approaches have ongoing associated plans, strategies or programs, which are discussed in Appendix 29.

Table A8.7. Wallis Lake catchment management to date.

Program	History	Current operation
Landcare Coastcare Dunecare	The landcare concept was introduced to the Wallis Lake catchment in the early 1990s as a means of halting or reversing the effect of nearly two centuries of landscape clearing and modification (D Smith & K Smith 2007, pers. comm., 27 November). Early landcare groups, in partnership with the then NSW Department of Land and Water Conservation, focussed mainly on addressing site-specific issues affecting individual landholders. Within a few years of the introduction of landcare, active groups were operating at numerous rural locations – including Wang Wauk, Bunyah, Dyers Crossing and Nabiac – while Coastcare / Dunecare groups were operating at several coastal locations (D Smith 2007, pers. comm., 27 November). The Karuah Great Lakes Landcare Management Committee oversees the strategy, activities and funding of the landcare groups in the region. The committee is comprised of members of each landcare group within its management area (the Karuah River catchment, Myall Lakes catchment, Smiths Lake catchment and Wallis Lake catchment). The committee is voluntary and meets regularly. It oversees the activities of the various groups, attracts / sources project funding for their area of responsibility, and liaises with federal and state government departments associated with land and environmental management. The committee also engages a landcare officer to work with and offer advice to local landholders, to assist them in improving the sustainability of their farming operations. This officer also organises field days at various local properties to demonstrate property management techniques such as rotational grazing, dung beetle release and off-stream watering systems.	Landcare groups operating at Wang Wauk, Bunyah, Dyers Crossing and Nabiac Coastcare / Dunecare groups operating at several coastal locations Coordinated through Karuah Great Lakes Landcare Management Committee
Rivercare	Rivercare Plans have been prepared with the Hunter-Central Rivers Catchment Management Authority for both the Lower and Mid Wallamba River. The Rivercare Plans were produced to assist landholders in the management of the tributaries to the Wallamba River, focussing on stream conservation and rehabilitation strategies. The Plans provide recommendations for on-ground works to address existing problems, with the companion booklets to provide support information on stream management strategies and how to prevent stream problems.	Lower Wallamba Rivercare Plan and Companion Booklet (Skelton 2003[DG28]) and Mid Wallamba (Including lower Firefly Creek and lower Khoribakh Creek) Rivercare Plan and Companion Booklet (Schneider 2005)
Rural Programs	Several rural programs designed to improve catchment condition and water quality. These generally involved dairy effluent and management, and sustainable grazing programs ranging from 1998 to the present.	Ongoing participation within federal, state and regional programs to improve on-farm management

Program	History	Current operation
	Dairy Effluent Management Project: a National Heritage Trust-funded project running from 1998 to 2002, which involved auditing dairy effluent systems, preparing action plans to manage effluent and sourcing funding to carry out on-ground works. A total of 415 dairy farms were involved, of which approximately 40 were in the Great Lakes CCI area.	Completed program
	Cleaner Production on Dairy Farms project (2004): funded by the NSW Environment Protection Agency (now part of DECC), this project identified, documented and demonstrated solutions to NRM and production issues on dairy farms. Farmers put in stock water, effluent management systems, and improved feed pads and laneways. It featured workshops, field days and the development of various resources, such as fact sheets and a CD photo library. The program was commended by the Industry Partnership Program in the Best Cleaner Production Cluster Category.	Completed program
	Setting Targets for Change project (2003/04) / Farmers Targets for Change: Mid Coast Dairy Advancement Group (MCDAG) piloted program on behalf of Dairy Australia. It was promoted under the national 'Dairying for Tomorrow' banner. Farmers on one river sub-catchment (Landsdown) participated and worked as a group to prioritise local issues and provide solutions. Projects were linked to external funding from the Hunter-Central Rivers Catchment Management Authority. Since that time, Setting Targets for Change has expanded (Farmers Targets for Change) and has involved approximately 16 farms in the Wallamba sub-catchment of Wallis Lake.	Completed program
	PROfarm, including courses such as Prograze and LANDSCAN	Ongoing program
	Advancing for nutrients	Ongoing program
	Real farm planning	Ongoing program
	Milk Biz	Ongoing Program
	Dairying for tomorrow	Ongoing program
	National Landcare Program	Ongoing program
Wallis Lake Catchment Plan Steering Committee	Great Lakes Council and Greater Taree City Council initiated the Wallis Lake Catchment Plan Steering Committee in 2001 to develop a management plan as the primary vehicle for the implementation of proactive actions to promote and enhance catchment and water quality targets, including on-ground works, interagency cooperation and community empowerment. The committee was developed in response to a serious hepatitis A contamination event on the lake during late 1996 and early 1997. The hepatitis A viral agent was traced back to contaminated Wallis Lake oysters sourced from several locations within the lake. One person died and a further 443 people were variously affected by the virus. The Hepatitis A event served as a wake-up call, illustrating the fundamental role water quality plays in supporting the local economy, and highlighting the value of a healthy lake and catchment to the community. It provided the motivation to focus greater awareness and management efforts on the maintenance and improvement of catchment health, with an emphasis on maximising the catchment's water quality through the effective management of rural and urban effluent, nutrients and sediment loads.	Wallis Lake Catchment Management Plan (2002)

Program	History	Current operation
Wallis Lake Catchment Management Plan Implementation Program (WALI Group)	A committee of land managers was formed to oversee the development and administration of the implementation of the catchment management plan. An incentive program was developed – the Rural Incentives Scheme – with funding from NHT, Great Lakes Council and landholder contributions, and in-kind support from the Department of Land and Water Conservation, Greening Australia, Karuah / Great Lakes Landcare, and Greater Taree City Council. The program targets creek and stream bank management, erosion control, wetland management, and establishment of vegetation management agreements. The implementation program was commenced in October 2002 and following the setting of administrative protocols, the project rollout commenced. Interested landholders, who had assisted in the initial project development, were the first landholders engaged to develop and submit project applications for the initial incentive scheme works program. The project was then extended to identify interested landholders through targeted consultation (in priority areas), general promotion through mail-outs and local media, responding to general landholder enquiries, and interest generated through landcare workshops.	Incentive program is continuing. Successful on-ground works completed across 86 project sites
Wallis Lake Estuary Management Committee	The Wallis Lake EMC was established in 1995 to develop plans for the sustainable use of the estuary and its immediate catchment, bringing together representatives of local and state government authorities, estuary user groups, and community to ensure inclusion of a broad array of interests and values in the planning process. The EMC has representatives from Great Lakes Council, Greater Taree City Council, state government agencies (DECC, NPWS, DPI – Fisheries), MSB Waterways, industry (Oyster Farmers Association, Wallis Lake Commercial Fishing Cooperative), Forster Local Aboriginal Land Council, Great Lakes Environment Association, amateur and recreational anglers, and local community representatives.	Wallis Lake Estuary Management Plan 2005

Catchment management achievements

On-ground works have been successfully completed across 86 projects sites within the Wallis Lake catchment. The Great Lakes Council's Management Tracking System contains information on formally-funded projects (that is, by Council or the Hunter-Central Rivers CMA), include fencing, erosion control works, revegetation and dairy effluent management system repairs.

Protective fencing

Protective fencing is used as a means of controlling or preventing stock access to riparian margins. Currently a total of 80.5 km of protective fencing has been put in place to control stock access to the catchment's waterways, wetlands and vegetation management areas. These fences have been mapped and fall into the following categories:

- riparian protection – 28.0 km
- dam and gully protection – 37.2 km
- wetland protection – 5.4 km
- vegetation protection – 11.6 km.

In all cases, fencing has been used as a means of controlling or preventing stock access to riparian margins, water storage dams, ephemeral gullies or native vegetation management areas. State forest and conservation estate has been excluded from this figure, as grazing stock is generally excluded from forestry and conservation lands.

Restricting direct stock access to the catchments waterways has been given a high priority in efforts to improve water quality. Therefore, where protective riparian fencing is employed, it is considered more beneficial to restrict stock access from both sides of the watercourse. Where possible, riparian fencing projects have attempted to restrict stock access to both sides of a watercourse; achieving this can be a complex process, as it is common for a given length stream bank to be bordered by several landholders. Table A8.8 provides a summary of the length of catchment watercourses fenced on both sides and on one side only, compared to the total length of water course that potentially could be fenced (see Attachment 1 in this appendix for a detail summary by sub-catchment).

The riparian fencing has been implemented as follows across the main sub-catchments of the Wallis Lake Catchment:

- Wallamba River sub-catchment – 10.122 km
- Lower Wallamba sub-catchment – 3.203 km
- Wang Wauk River sub-catchment – 31.944 km
- Coolongolook River sub-catchment – 13.369 km

- Minimbah Sandbar sub-catchment – 3.12 km
- Wallingat River sub-catchment – 1.604 km
- Wallis Lake sub-catchment – 1.8 km

Table A8.8. Riparian fencing ratio summary for the watercourses within the Wallis Lake sub-catchments (excluding watercourses within state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Wallamba River	1,104.623	2.592	0.23	4.938	0.45
Lower Wallamba	572.174	0.317	0.06	2.569	0.45
Wang Wauk	635.104	10.165	1.60	11.614	1.83
Coolongolook	450.339	3.846	0.85	5.677	1.26
Minimbah Sandbed	290.053	0.466	0.16	2.188	0.07
Wallingat River	299.486	0.06	0.02	1.484	0.50
Wallis Lake body	188.868	0.559	0.30	0.682	0.02
Total Wallis Lake catchment	**3,540.647**	**18.005**	**0.51**	**29.152**	**0.82**

The above figures refer only to those fences put in place as part of the catchment management incentive schemes and formally mapped in the Great Lakes Catchment Management Tracking System. The potential does exist for considerably more fencing, put in place by landholders, to act as barriers to stock access to the catchment waterways. However, logistical difficulties and time constraints preclude the collation of such detailed data.

Off-stream stock watering systems

Off-stream stock watering systems utilise pump extraction of water from streams or storage dams to supply off-stream storage tanks and further distribution to outlying stock water troughs. This allows landholders to restrict direct stock access to the catchment's waterways. Currently, 25 off-stream water systems are in place with the Wallis Lake catchment, each designed with the specific purpose of removing or reducing the need to allow stock access into the catchment watercourse network.

Vegetation and erosion management

Approximately 561 ha of native vegetation have been placed under protective management and approximately 105,360 m^2 of erosion control measures are in place across the catchment.

Acid sulfate runoff management

Approximately 4.7 km^2 of wetland are under management to reduce acid sulfate leachate through the modification or removal of more than 16 km of excavated drainage channels.

Urban stormwater management

In 2001, Council established the diverse and wide-ranging Healthy Lakes Program to address urban water quality issues identified in the *Wallis Lake Stormwater Management Plan* (2000). [DG29]

As part of the Healthy Lakes Program, Council has constructed a number of structural solutions aimed at decreasing the amount of pollutants reaching local waterways. These structures include litter baskets, gross pollutant traps and constructed wetlands. Funding for structural solutions was initially gained through Stormwater Trust Grants and is now supplied through the Environmental Special Rate and Council budgets. In total, Great Lakes Council has installed or acquired the following structural solutions within the Wallis Lake catchment:

- 107 litter baskets (79 in Forster, five in Nabiac, 23 in Tuncurry)
- seven gross pollutant traps (four in Forster, three in Tuncurry)
- eight constructed wetlands (seven in Forster, one in Tuncurry).

The litter baskets are installed in areas of high traffic and / or pedestrian flows, which are predominantly the CBD areas of each town and village. The two largest gross pollutant traps are located in the Forster urban area. The Little Street gross pollutant trap treats the 42 ha Breckenridge catchment, which includes predominantly residential, tourist and light business land uses. The Condell Place gross pollutant trap treats an 18 ha catchment of varied land use including residential, commercial, light industrial, public space and bushland reserve areas. Each of the eight constructed wetlands installed has been retrofitted into residential catchments that previously lacked any stormwater treatment devices. Consequently, these wetlands are primary stormwater treatment systems, filtering out gross pollutants, as well as stripping and absorbing excess nutrients such as nitrogen.

Maintenance and cleaning of all stormwater treatment equipment is carried out on a periodic basis as resources permit. Litter baskets are cleaned out on a monthly basis; most gross pollutant traps and wetlands are cleaned out on a six-monthly basis. During the cleaning operation, Council staff records the composition of the captured material and its weight. The types of pollutants captured in each of the structural solutions are divided into three categories: litter, sediment and organics (leaf litter / grass, etc.). Analysis of these pollutant categories is an important monitoring and assessment tool for stormwater management, and can help identify and address locally unique stormwater issues.

Attachment 1. Summary of the ratio of riparian fencing on one or both sides of the Wallis Lake catchments waterways as compared to the total length of waterways (waterways falling within national park and state forest estate have been excluded, as stock access to these areas is generally prohibited).

Wallis Lake Drainage Basin

Table A8.9. Wallamba River catchment riparian fencing (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Wallamba River	50.070	0.000	0.00	3.089	6.17
Firefly Creek	28.480	0.516	1.81	0.978	3.43
Khoribakh Creek	29.670	0.000	0.00	0.000	0.00
Minor named creeks	85.303	0.000	0.00	0.320	0.38
Unnamed creeks and gullies	911.100	2.076	0.23	0.551	0.06

Table A8.10. Lower Wallamba River catchment riparian fencing (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Wallamba River	7.930	0.000	0.00	1.440	18.16
Candoormakh Creek	8.398	0.000	0.00	0.000	0.00
Pipeclay Creek	8.422	0.000	0.00	0.000	0.00
Bungwahl Creek	17.870	0.140	0.78	0.000	0.00
Darawakh Creek	6.580	0.000	0.00	0.000	0.00
Named creeks	31.594	0.000	0.00	0.000	0.00
Unnamed creeks and gullies	491.380	0.177	0.04	1.129	0.23

Table A8.11. Wang Wauk River catchment riparian fencing (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Wang Wauk River	31.270	0.583	1.86	6.081	19.45
Bunyah Creek	17.880	0.402	2.25	0.267	1.49
Named creeks	53.754	0.323	0.60	1.063	1.98
Unnamed creeks and gullies	532.200	8.857	1.66	4.203	0.79

Table A8.12. Coolongolook River catchment riparian fencing (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Coolongolook River	31.490	0.000	0.00	3.869	12.29
Cureeki Creek	10.950	0.000	0.00	1.808	16.51
Named creeks	39.889	0.000	0.00	0.000	0.00
Unnamed creeks and gullies	368.010	3.846	1.05	0.000	0.00

Table A8.13. Minimbah Sandbed catchment riparian fencing (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Wallamba River	33.540	0.000	0.00	1.448	4.30
Named creeks	21.113	0.000	0.00	0.000	0.00
Unnamed creeks and gullies	235.400	0.466	0.19	0.740	0.31

Table A8.14. Wallingat River catchment riparian fencing (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Wallingat River	24.010	0.000	0.00	0.804	3.30
Named creeks	33.476	0.000	0.00	0.000	0.00
Unnamed creeks and gullies	242.000	0.060	0.02	0.680	0.28

Table A8.15. Wallis Lake body catchment riparian fencing (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Named creeks	18.768	0.559	3.00	0.000	0.00
Unnamed creeks and gullies	170.100	0.000	0.00	0.682	0.40

Table A8.16. Summary of riparian fencing for all Wallis Lake catchment watercourses (excluding state forest and national park estate).

Watercourse	Length (km)	Length fenced both sides (km)	% fenced both sides	Length fenced single side (km)	% fenced single side
Named rivers	178.310	0.583	0.33	16.731	9.38
Named creeks	412.147	1.940	0.47	4.436	1.08
Unnamed creeks and gullies	2950.190	15.482	0.52	7.985	0.27

Agricultural landholdings within the Wallis Lake Drainage Basin

Table A8.17 includes those land parcels zoned Rural (1a) within the Great Lakes local government area; and 1A Rural General, 1B1 Rural Valley General and 1C2 Rural Farmlets within the Greater Taree City local government area. These zonings define areas within their respective local government areas where agricultural activities are permissible. This number excludes urban and other land zonings where agricultural activities are not permissible.

Table A8.17. Number of land parcels within each catchment where agricultural activities are permissible.

Catchment	Landholdings where agricultural activities are permissible
Wallamba River	1,050
Lower Wallamba River	769
Coolongolook River	421
Wang Wauk River	477
Minimbah Sandbed	375
Wallingat River	214
Wallis Lake body	203
Total	**3,509**

Appendix 9: Agricultural industry profiles

1. Dairy farming

The dairy industry has been a dominant feature of the Wallis and Myall Catchments for over 60 years, once occupying a high proportion of the grazing area. However, the number of producers and area under dairy has declined steadily since the 1970s. A further exit occurred after 2000 when deregulation of the industry led to the abolishment of quota and a decline in on-farm milk prices.

In 2000, in the Wallis Lakes Catchment there were 35 dairy farms with a milking herd of 3,500 (Great Lakes Council 2003[DG30]a). In the Myall Catchment there were seven herds in 2003 (Smith 2001). In 2007, the number had declined to 13 over both catchments – three in the Myall and ten in the Wallis Lakes catchments (Billingham 2007[DG31]), with an estimated milking herd of only 1,800 milking cows. These farms are estimated to utilise 1,200 to 2,000 ha of 85,868 ha of Rural 1A land, or only 1.7% of rural land and less than 1% of the 128,361 ha in the catchment area. In the Myall Lakes, seven farms in 2003 had declined to only three in 2007, with an estimated milking herd of fewer than 600. These farms are estimated to utilise 800 ha of land, or 3.3 % of the 24,000 ha of Rural 1A land, and less than 1% of the catchment area.

Even though the remaining farms have increased herd size to adapt to a changing price structure, it has not compensated for the overall decline in dairy farms in terms of cow numbers and land under production. The trend of decline is likely to continue as demand for land from lifestyle farmers has lifted the value well beyond an economic proposition for most dairy farmers. This has also caused a reduction in the availability of suitable land close to the original dairy that hampers the ability of farms to adapt to the structural changes of the industry. However, larger herd sizes and higher production per hectare in the remaining dairy farms magnify the risk of nutrient loss on individual farms, hence the need for ongoing management.

Pasture production is based on tropical perennial grasses (mainly kikuyu, but also paspalum) oversown each year with annual ryegrass for winter growth. Dry matter production can reach 18 to 30 t/ha dry matter from cut plots, with pasture utilisation under grazing conditions ranging between six and 12 tonnes dry matter per hectare. Seasonal conditions have a large impact on the pasture production figures.

Considerable research and extension has been undertaken to improve water quality outcomes for dairy catchments. The national dairy industry, now represented by Dairy Australia™, has adopted a proactive approach to achieve a sustainable industry with minimal impact to the environment. For example, dairy effluent management guidelines for the NSW dairy industry were developed in 1997 in response to pressure from the then EPA and the introduction of the *Protection of the Environment Operations Act 1997*.

Throughout Australia, each state government collaborates with Dairy Australia, Land and Water Development, the National Heritage Trust, and Department of Agriculture, Fisheries and Forestry through a range of programs. In particular, the dairy industry's 'Dairying for Tomorrow' has a stated philosophy to:

> "…actively encourage collaborative partnerships between the dairy industry and catchment managers to set on-farm targets for change that will contribute to healthy catchments and communities" (http://www.dairyingfortomorrow.com/aboutdft.php).

Within this framework, extensive research, extension and implementation on farms has been undertaken on nutrient and effluent management, riparian rehabilitation and farm planning to achieve sustainable catchment management.

Locally, the Dairy Industry Advancement Group has cooperated with NSW Department of Primary Industries (DPI) in a succession of natural resource management programs that have been recognised by the DECC with an award. The model, Setting Targets for Change, was developed in this region. This is now used as a model for the dairy industry in the remainder of the state, and has been adapted for beef farms by NSW DPI and the Hunter Rivers in the CCI area. More detail is given in Appendix 1.

2. Beef farming

Beef production is practised on the majority of the cleared land in both the Myall and Wallis lakes catchments in the order of 110,000 ha. However, a significant portion of land (10 to 20%) is left unused or is forest. Land holdings number 6,782 where agriculture is permissible in the CCI project area. Ownership of these farms is now dominated by lifestyle owners who derive only a small income from the farm. A large proportion of owners are based off-farm in surrounding towns, Newcastle or Sydney. This demographic mix brings a wide range of aspirations, knowledge and financial capability to implement practices that influence water quality.

A typical farm of 40 ha carrying 20 to 30 cows has a gross income from cattle sales in the order of $7,000 to $15,000. This leaves a very finite financial resource to fund environmental works unless it is supplemented by off-farm income.

Pasture production is based mainly on unfertilised carpet grass mixtures with annual dry-matter production below 5 t/ha. These pastures contribute 90% of the grazing land area. However, there are also improved also improved pastures with introduced species, such as kikuyu, that reach 10 to 20 t/ha dry matter and occupy 5 to 10% of the land area.

Stocking rates are inherently low in unfertilised pastures (200 to 350 kg LW / ha) but vary in intensification.

Using a stocking rate of 0.6 cows per hectare derived from the CCI Landholder Survey, Billingham and Beale (2007)[DG32], Rural Lands Protection Board data and Blackwood, Briggs, Christie, Davies & Griffiths (2006)[DG33], the size of the beef herd can be estimated at equivalent to 58,000 cows on 85,686 hectares of Rural 1 A land in the Wallis Lake catchment and 14,400 cows on 24,000 hectares of Rural 1 A land in the Myall Lake catchment. In practice, the herd is a mixture of cows, steers and calves, and actual numbers of cows would be much lower than these figures.

The beef industry, through the Meat and Livestock Association, has supported a range of research and extension programs to reduce water quality impacts. National programs, such as the Sustainable Grazing Systems Project and the Making Better Fertiliser Decision for Grazed Pasture Project have influenced this region. Locally, landcare and NSW Farmers have had a range of programs that promote sustainable grazing, improving riparian vegetation and reduced stream bank erosion.

3. Poultry industry

The poultry industry is located in the Myall catchment east of Bulahdelah. Production is focussed solely on broilers. Six farm owners have a total of 18 sheds with an estimated gross value of production in the order of $1.5 to $2.5 million. All poultry producers have land adjacent or nearby that is used for grazing livestock production. Three out of the five operators now use tunnel shed housing and this has allowed about 30% higher production per area shed through more reliable thermoregulation.

Poultry litter is brought into the catchment from areas such as Maitland, Stroud and Tamworth. The relative freight cost and the availability of supply are the major restriction to more widespread use of poultry litter in the region.

A review of the environmental concerns of the poultry industry of the Mid North Coast was conducted by Griffiths (1998[DG34]). At this time, both poultry producers and users of poultry litter cooperated in the sampling of poultry litter, fields with a history of poultry litter and storage sites. This identified a pattern of over usage of poultry litter as a fertiliser that led to elevated phosphorus levels well in excess of plant requirements. The tendency to use poultry litter as a source of nitrogen without accounting for phosphorus application leads to such over-usage. It is noted in many sources as a common concern world-wide with the use of animal litters [DG35].

An extension program developed best management practices and informed the industry of the issues. Since this time, considerable progress has been made in the use of poultry litter as a fertiliser. More recently, the chicken meat industry, through Rural Industries Research and Development Corporation, commissioned a review (Runge, Blackall & Casey 2007[DG36]) of the use of poultry litter with the aim of identifying areas for future research. The chicken meat industry has a clear desire to fulfil its obligations to the government and community to when poultry litter is used as a fertiliser (Runge, Blackall & Casey 2007). They outlined three key issues:

- rate applied to be based on crop removal of major nutrients and trace elements
- it will not pose a risk to the environment due to the accumulation of nutrients, salts or heavy metals
- it will not pose a risk to public health through application to edible crops.

These goals are consistent with the industry's commitment to produce safe food products, and ensure health and productivity of chickens. That is, there is a high level of synergism in maintaining disease-free conditions for young chickens, and the reduction in faecal pathogens that may contaminated food and water through using litter as a fertiliser. The industry also acknowledges that higher quality assurance could lead to greater acceptance of poultry litter as a product and, in turn, higher returns (Runge, Blackall & Casey 2007).

Among the existing poultry producers there is high level of awareness of the issues surrounding poultry litter and, in general, application rates are now tailored to plant demands. Improved spreading equipment has enabled lower rates to be applied. However, with the potential for change in ownership, new clients may enter the market without the experience in the use of litter. This suggests there will be a need for ongoing collaboration with industry in this region.

4. Forestry for plantations and conservation

Plantation forestry as an industry is a relatively small component of the farm land. Current plantations on farm land associated with future forest are in the order of 750 ha over both catchments; there may be more areas of private origin. In addition to this area, many farms have a significant portion of the farm as native forests. There is potential to add to this forest area with more plantations or conservation plantings targeted to riparian zones or perhaps steep erodible soils.

Currently, forest cover ranges from 25% of the Wallamba, 44% of the Wang Wauk and about 75% in the Coolongolook and Wallingat catchments, and 22% [DG37]in the Myall River catchment. Harris (2003) recommends afforestation to a benchmark level of 50% of the catchment to reduce nutrient loading in the Lakes. Plantations and conservation planting offer one strategy to achieve this.

While there are well-established benefits of afforestation, the target of 50% should only be seen as a general guide. Prosser (2001) stated that the vegetation in the riparian zone is of importance for protecting watercourses from channelisation and consequently the amount of sediments delivered to streams.

The attraction of forestry or conservation planting for water quality lies in the fact that forests utilise more rainfall for evapotranspiration and so generate less runoff than pastured lands (Lane, Best, Hickel & Zhang 2003[DG38]). This, in turn, should lead to less nutrient and sediment delivery to streams. A thorough review of the impacts of reafforestation on water quality is provided by Zhang *et al.* (2007[DG39]) as a summary of extensive research undertaken by the CRC for Catchment Hydrology and the eWater CRC.

There are requirements for plantation forestry [DG40]that will restrict the area used for this purpose. Plantation yields determine the economic return and foresters look for the more productive sites.

5. Other rural industries and practices

Smaller rural industries are emerging in the CCI catchment areas, including vineyards and wineries, turf farms, plant nurseries and tourism ventures such as farm stays. A number of alternative animal industries are also present. These include horse studs, deer farms, alpaca farms and free-range poultry. Horses are also a common feature on beef farms, numbering 2,000 to 3,000 over the project area. Thus, these industries combined can contribute up to 5% of the grazing pressure in the area. Overall, these industries are few in number and hence impact. Then, some industries have a low impact in any case. Turf farms have a high nutrient use but also good groundcover for most of the year.

Management practices recommended for other industries can mostly be transferred to these industries. Future research topics that could be assessed in relation to water quality include: chemical storage and use, equipment storage, scrap storage (old cars, farm machinery), rural roads (council), tree clearing and road management in forests, rural tourism including farm stays, alpaca farming, wineries, and free-range chicken farms.

6. Rural industries summary

On farms, there are a range of risks that could potentially contribute to reduced water quality. On any one farm there may be only one or two of these risks present, or there may a large problem in one area but minor problems in others. Therefore, programs that provide a process of assessing the whole farm's needs – ranking priorities and providing incentives for a range of issues, rather than just focussing on riparian fencing – have great merit in initiating change and creating momentum for future works.

In addition, the capacity of the rural industries to fund improvements in water quality is limited by overall profitability, and the continual pressures to adjust to market forces. A foundation to the success of Setting Targets for Change is the funding of projects that that delivers both economic gain and reduced risk of nutrient transport to streams. In many cases this has meant less focus on riparian fencing and more on developing farm infrastructure to better manage nutrients and livestock, e.g. improvements in laneways, off-stream water, creek crossings and effluent systems.

This does not minimise the importance of restoring riparian vegetation, which is essential for stream health and erosion protection, but it does increase the rate of change and assist farmers to the point where riparian fencing can be addressed in more detail.

Note: At the time of writing, details of some references could not be obtained. Consequently, full references may not appear in the bibliography.

Appendix 10: Establishing targets for indicators of ecological condition

This appendix is authored by Peter Scanes.

1. Setting and using targets

Ecological targets will be set for indicators relevant to each of the Great Lakes catchments. These targets should be considered as 'triggers to action', i.e. they suggest that the system is under stress and action needs to be taken – *not* that the system is immediately damaged once that value is exceeded.

Indicators are a small set of measures that are used to describe the ecological condition of an ecosystem. Based on DECC's research (Scanes, Dela-Cruz *et al*. 2007[DG41]), measures of algal abundance (chlorophyll-a) and water clarity (turbidity or Secchi depth) were chosen as appropriate triggers for ecosystem disturbance in NSW estuaries. They have therefore been directly adopted for the coastal lakes and estuaries in the Wallis and Smiths lakes systems. More care needed to be taken prior to adoption in the Myall Lakes system. Our conceptual understanding is that ecosystems of this type are threatened by increased turbidity (decreased light penetration leading to loss of macrophytes) and excessive nutrients (algal blooms, low phosphorus tolerance by charophytes). This leads to the belief by DECC that the indicators used in other coastal lakes (turbidity and chlorophyll) will still be suitable for the Myall Lakes system because they monitor the presence / consequence of the two primary threats, reduced light and nutrients.

To aid the development of catchment targets for the WQIP, DECC developed ecological target values that correspond to:

- high conservation value in coastal lake ecosystems
- slight to moderate disturbance in coastal lake ecosystems
- high conservation value in coastal river ecosystems
- slight to moderate disturbance in coastal river ecosystems.

2. Setting targets for indicators of ecological condition

Literature review

The setting of target values needs to be based on a transparent and reproducible process. A range of options has been used in national and international planning, although none have been adequately tested in NSW for the chosen indicators.

A review of the literature suggests four main approaches for determining targets (Table A10.1). Three of these are based on statistical analysis of existing data, defining percentiles values that we should aim for. A percentile is the value of a variable (here chlorophyll-a) below which a certain percent of observations fall. So, the 25th percentile is the value (or score) below which 25 percent of the observations may be found. The 25th percentile is also known as the first quartile; the 50th percentile as the median.

Table A10.1. Methods for defining Ecological Condition Targets.

Approach	Description
Biological effects data (e.g. seagrass decline)[DG42]	n/a
75th percentile for reference quality data (USEPA)	This approach aims for the value that only includes the smallest 75% of measurements. This acknowledges that there is natural variation above and below the average, and we really only need to be concerned if the values stay really high (higher than 75% of the reference data).
80th percentile of reference condition (ANZECC / Qld EPA)	This approach aims for the value that only includes the smallest 80% of measurements. This acknowledges that there is natural variation above and below the average, and we really only need to be concerned if the values stay really high (higher than 80% of the reference data).
25th percentile of all mixed quality data (USEPA)	This approach aims for the value that only includes the smallest 25% of measurements. This acknowledges that most of the values are higher than we would want. This approach comes from the US where the vast majority of estuaries are highly contaminated and few reference systems exist.

Short-term (immediate) and long-term targets

Determining whether the targets are being met will require collection of data and comparison of the median of those data with the target. Unfortunately, it takes quite a while to collect sufficient data to determine a meaningful median value, making this technique less suitable for immediate or short-term comparisons. In compiling the data for the target setting, it was quite clear that while the median value for estuaries with different ecological conditions did change, there was a far greater change in the range of the data, i.e. disturbed systems had a much greater range of values and the high values were much higher than estuaries in good condition (Figure A10.1). The highest values for both systems occur shortly after heavy rainfall and reflect system reaction to catchment inputs. These reactions are variable, but provide an opportunity for short-term or immediate tracking of system condition.

We can use this characteristic short-term response to derive targets for estuary condition following rainfall events that will be much more amenable to immediate assessment of whether we are achieving estuary condition targets. DECC therefore suggests that in addition to the long-term (median) targets that ANZECC recommends, the Plan also sets short-term ‘event targets’ based on the 95th percentile of reference data.

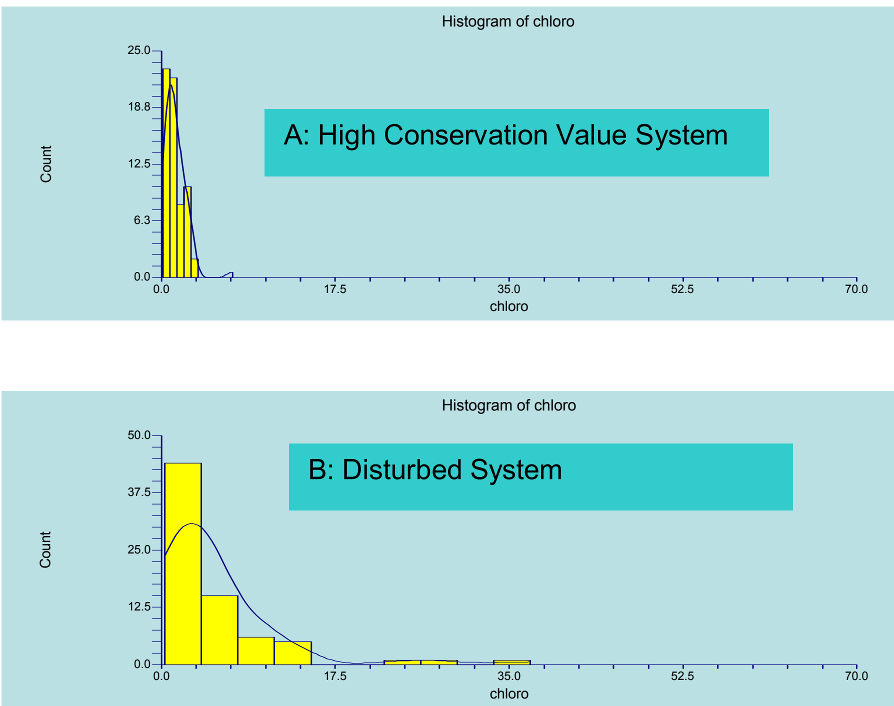

Figure A10.1. Range of data from a high conservation value system and a disturbed system. It is obvious that while the median value is slightly different, the range (about 6 for A, and 30 for B) is very different.

Statistical analysis of chlorophyll-a data

DECC statistically analysed chlorophyll-a data from a number of coastal lagoons and river estuaries in NSW to develop targets. There was limited data from the Myall, Smiths and Wallis lakes with which to draw conclusions about appropriate targets for *High conservation value* and *Slightly to moderately disturbed* conditions. DECC is confident that:

- Smiths and Wallis lakes can be compared with other coastal lagoons for this purpose
- the riverine estuaries are sufficiently similar to other riverine estuaries in NSW.

Myall Lakes system, however, will have to be treated differently. The lakes system is unique in NSW, in that there are no other systems of comparable size with similar salinity regimes. This means that targets will need to be set by inference from existing condition, conceptual understanding and modelling.

In preparation for target-setting for the coastal lakes and estuaries, available chlorophyll, turbidity and Secchi data for NSW were collated for:

- *lakes:* Coila, Corunna, Deep Creek, Durras, Illawarra, Macquarie, Merimbula, Narrabeen, Nelson, Pambula, Smiths, St George, Swan, Tuggerah, Tuross, Wallaga, Wallagoot, Wallis and Wapengo

- *rivers:* Wallamba, Wallingat, Manning and Bellinger rivers were separated into three sections by salinity (>30, 12–29, <12[DG43]).

Table A10.2 summarises the results from analyses undertaken for this project and includes some data from other similar analyses. The green cells in the table are ANZECC target guidelines for chlorophyll, which were derived from lakes / lower river estuaries. For the mixed data (blue cells), the trigger is recommended to be the 25th percentile – the values range from 0.9 across all lakes to 1.8 for all Sydney estuaries, and up to 3.56 for all NSW river estuaries.

Table A10.2. Percentile chlorophyll-a concentrations for NSW lakes and estuaries.

		Percentile					
	Mean	**25th**	**50th**	**80th**	**95th**	**99th**	**Max.**
ANZECC Triggers			**2.0**				
All sites – Wallis	3.7	**1.18**	2.3	3.8			60.04
All estuaries – Sydney	9.89	**1.80**	3.50	8.00			866.2
All River estuary (Wallis and Myall)	4.35	**1.5**	2.4	5.04	12.6	30	37.17
All NSW Rivers (middle)	4.6	**3.56**	**4.7**	6.6	9.1	14.2	
All NSW Lakes	3.0	**0.9**	**1.8**	4.9	9.25	15.6	
Wallis and upper entrance	1.42	0.70	1.20	**1.95**	7		7.2
South and Central Wallis	1.1	0.34	0.72	**1.80**	7		7.04
Two pristine and modified estuaries - Sydney	1.43	0.70	1.20	**1.70**			11.00
One pristine estuary- Sydney (Wattamolla)	1.23	0.42	0.90	**1.60**			10.00

Synthesis

The recommendation of 25th percentile for mixed data comes from the US where the vast majority of estuaries are highly contaminated. For Sydney data, where average impact is high, 25th percentile is 1.8, which is similar to 80th percentile data from reference sites (South and Central Wallis Lake [1.8], and Wattamolla Estuary [1.6]). For other NSW lakes, the 25th percentile lake value is 0.9, which is very low; and 3.6 for mid-zone river estuaries, which is also quite low. This indicates that, when using data from less stressed systems, the 25th percentile is too low. If the 50th percentile of all data is used for lakes, we get the same value as for the 80th percentile from reference. This convergence suggests that the 50th percentile is the correct level for mixed data not dominated by highly impacted systems. Thus, for the CCI project, the 50th percentile values were used to set the long-term targets for *High conservation value* coastal lakes. ANZECC provides no guidance on appropriate percentiles for *Slightly to moderately disturbed* systems, so DECC adopted the 60th percentile of all for these systems. The suggested targets are shown in Tables A10.3 and A10.4.

There was insufficient reference data available to do a similar process for riverine estuaries. Based on the experience from the coastal lakes, the 50th and 60th percentiles were also applied to the riverine estuaries to establish their long-term targets (Table A10.3).

Table A10.3. Long-term Ecological Condition Target values developed for the Great Lakes.

Long-term targets	High conservation value			Slightly to moderately disturbed		
	Chlorophyll-a (ug/L)	Turbidity (NTU)	Secchi (m) [a]	Chlorophyll-a (ug/L)	Turbidity (NTU)	Secchi (m) [a]
Lake	1.8	2.6	>3.5	2.6	3.6	
Estuarine rivers						
Upper	5.0	8.0		6.6	11.5	
Mid	4.2	7.5		5.0	10.7	
Lower	2.2	?[KA44]		2.3	?	

a: There was not enough Secchi depth data available with which to develop targets. DECC recommends that for seagrass protection, water clarity (Secchi) should also use 'acceptable' parts of the Great Lakes as reference.

Short-term 'event' targets for *High conservation calue* systems were derived by taking the 95th percentile of all data for NSW lakes and rivers, and the 99th percentile for slightly to moderately disturbed.

Table A10.4. Short-term 'event' Ecological Condition Target values developed for the Great Lakes.

Event targets	High conservation value		Slightly to moderately disturbed	
	Chlorophyll-a (ug/L)	Turbidity (NTU)	Chlorophyll-a (ug/L)	Turbidity (NTU)
Lake	7.0	13.0	15.0	21.0
Estuarine rivers				
Mid	9.1	31.0	14.0	54.0

Myall, Boolambayte and Bombah Broadwater lakes

Myall Lakes system is very different from the other coastal saline lakes. As there are no other systems like them, it is recommended that the reference approach be used on data from Myall and applied to all systems.

Data for chlorophyll in the three lakes was collated from the then DNR (1999–2002), NPWS / DNR (2003–2005; Dasey *et al*. 2004) and DECC (2006–2007). This data was then pooled and treated as 'reference system' data, as described in Table A10.1. Percentiles were calculated separately for the three lake systems. Targets for Broadwater were inferred from the Boolambayte system, as the Broadwater is considered moderately impacted. Turbidity data was only available for one time period and was considered of variable quality. There was too little Secchi data. Turbidity and Secchi targets were set to be the same as the coastal lakes.

Table A10.5. Long-term Ecological Condition Target values developed from the 80th percentile of available data for the Myall Lakes.

	High conservation value		
	Chlorophyll-a (ug/L)	**Turbidity (NTU)**	**Secchi (m)**
Myall	3.2	2.6	>3.5
Boolambayte	3.0	2.6	>3.5
Broadwater	3.0	2.6	>3.5

[DG45]

Application of these targets is complicated by the fact that algae are known to bloom naturally in the Myall Lakes as part of the complex gytja / water ecology (Dasey *et al*. 2004).

There was insufficient data to reliably set event targets for the Myall, but the coastal lake targets could be adopted for Broadwater if desired.

Appendix 11: Case studies from the Great Lakes Coastal Catchments Initiative project

This appendix is authored by Peter Scanes, Jocelyn dela Cruz, Geoff Coade, Jaimie Potts, Brendan Haine and Max Carpenter, of NSW Department of Environment and Climate Change.

1. Introduction

The objective of the CCI has been to predict and minimise the disturbance of the ecology of Wallis, Smiths and Myall lakes that may result from the increased inputs of pollutants via catchment runoff. The main pollutants are nutrients, which can result in excessive growth of nuisance algae; and sediments, which can smother or shade out seagrasses, macrophytes (aquatic plants) and other benthic (bottom-dwelling) organisms.

The primary sources of these pollutants are human activities in catchments. Activities on the land, such as urban and rural development, can result in situations that provide an increased source of pollutants that are able to be washed off into drains, creeks and rivers, and then delivered to coastal lakes during rainfall events. In general, urban activities generate large amounts of nutrients in the long term, with relatively little sediment, except during construction phases. Sediment delivered during construction phase can, however, have critical long-term impacts on ecological health. Rural activities can generate both nutrients and sediments, depending on the activities. Many rural activities expose soils, which are then eroded, resulting in large amounts of sediment and some nutrients. Other activities (intensive farming, cattle access to streams, inappropriate fertiliser use, etc.) can generate large amounts of nutrients.

Seagrasses and other bottom-dwelling plants and animals are extremely important components of estuarine ecosystems. They provide food and shelter to a wide range of fish and other organisms including – for seagrasses – the threatened seahorses and pipe fishes. There is a well-established relationship between water clarity and the depth that seagrass can grow to (and hence the area of seagrass that can grow in the estuary). This relationship exists because as more sediments are washed into the lake (as a consequence of catchment activities, which increase soil erosion), the water becomes more murky (turbid) and transmits less light to the seagrasses that grow on the floor of the lake. If the seagrasses do not receive enough light to grow, they die. This can also happen if light is reduced by other factors – such as excessive algal growth in the water, creating turbidity; or macroalgal (seaweed) growth on the seagrass leaves, directly blocking light.

Similarly, if seagrasses are physically covered by sediments that are washed into the water as a result of eroded soils, they are smothered and die.

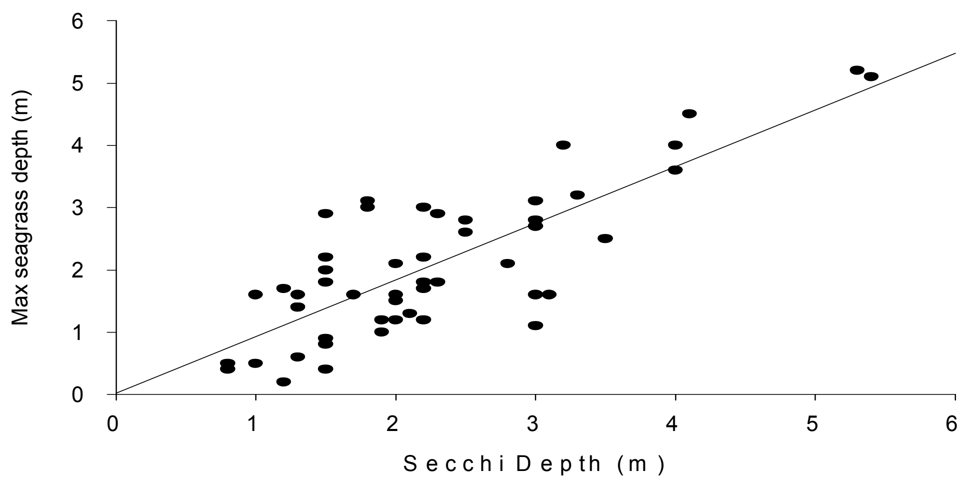

Figure A11.1. Diagram showing how the maximum depth that seagrass can survive at is directly related to the water clarity (measured by the depth to which a standard metal disk known as a Secchi disk can be seen by an observer on the surface) – the greater the depth where the disk is visible, the clearer the water is.

Excessive amounts of nutrients entering the lake from catchments can have a number of consequences for the ecology of the lake. Put simply, the amount of algae that can grow is a direct consequence of the amount of nutrient brought into the lake from its catchment and other sources. The growth of algae occurs in two phases: an initial very high level (bloom) when nutrients are washed in following rain; and a reduced ongoing bloom from recycled nutrients. The major bloom rapidly consumes all the available nutrients in the water, and then slowly dies and reduces in intensity. As it dies, the algal cells with their absorbed nutrients fall to the lake floor and are recycled by microbes in the lake sediments. Over time, this store of nutrients in the sediments increases, and the nutrients recycled to the water column from sediments sustain a relatively high level (but smaller amount than the bloom) of algae between rainfall events.

The algae that grow fall into two broad categories: free-floating (planktonic) microalgae (which can include toxic forms such as blue-green algae); and attached macroalgae (or seaweed). Which type of algae develops in any given case is hard to predict, and depends a lot on local conditions such as water depth and currents.

This paper presents three case studies that illustrate how the general ideas presented above are actually occurring in Wallis Lake. Two of the case studies show how actions in developed catchments are degrading the lake and the third demonstrates the condition of a largely unimpacted portion of the lake. The information was gathered by DECC scientists during the CCI studies in Wallis Lake.

Before getting to the case studies, however, some background is needed on how water moves around the lakes and therefore where pollution from a particular source is likely to end up.

Hydrodynamic (water movement) modelling by DECC showed clearly that the rivers / entrance channels and the main part of Wallis Lake operate as two largely non-interactive water bodies. Pollutants from the wider catchment that are transported by the rivers into the lake system during floods stay primarily in the main channel to the north of Wallis Island, with only a very small amount moving down the east or west channels towards Wallis Lake (Figures A11.2 and A11.3). Conversely, there is relatively little exchange of water between the main body of the lake and the entrance channels. This means that the main recreation areas in the channels are strongly influenced by the wider river catchments, but that Wallis Lake itself is mainly influenced by its small perimeter catchment. It also means that anything that enters the lake from its perimeter stays there. Within the lake there is only minimal mixing between the bays to the south of Earps and Booti islands, and the rest of the lake.

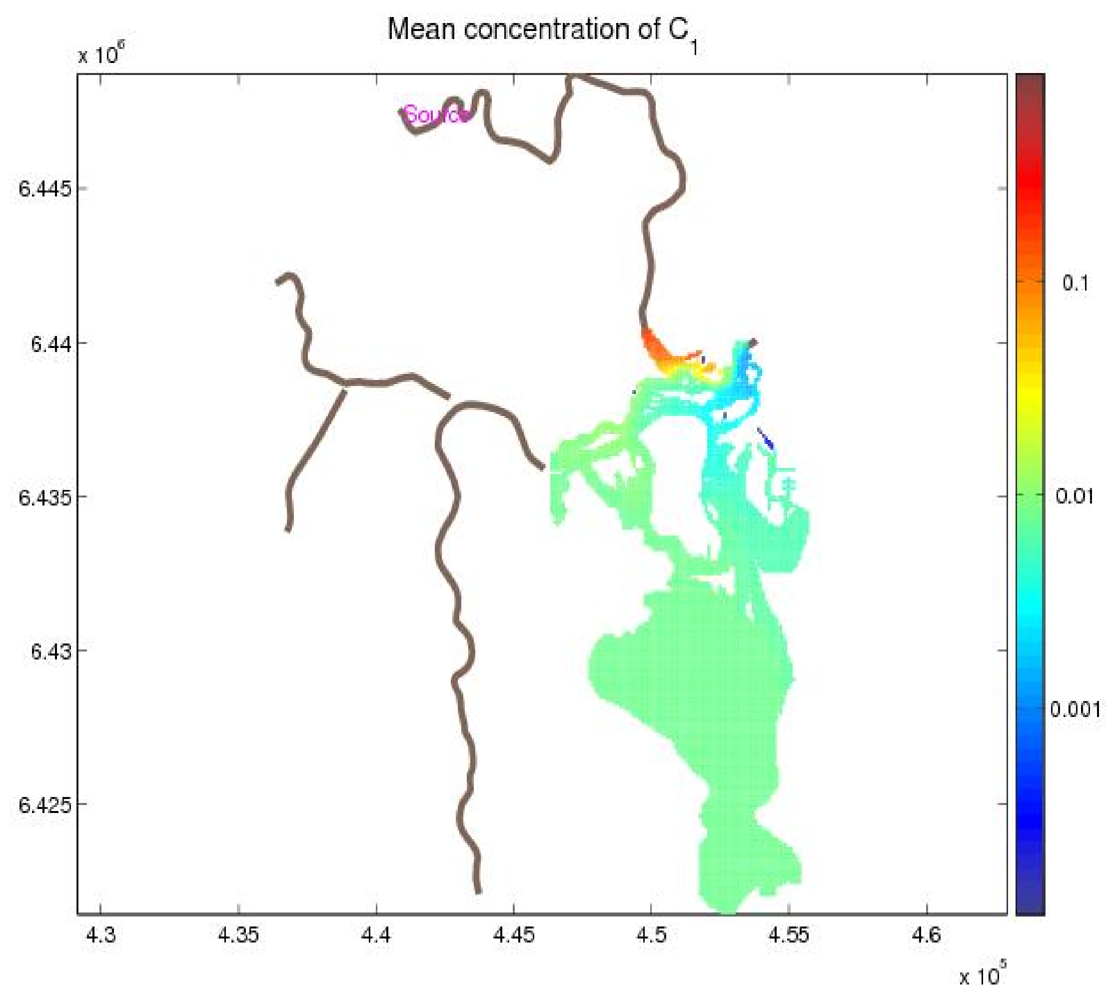

Figure A11.2. Fate of pollution from Wallamba River. Red areas are where pollution is concentrated. Note that none goes down into Wallis Lake.

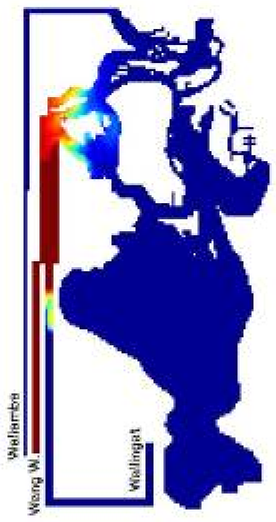

Figure A11.3. Fate of pollution from Wang Wauk River. Red areas are where pollution is concentrated. Note that none goes down into Wallis Lake.

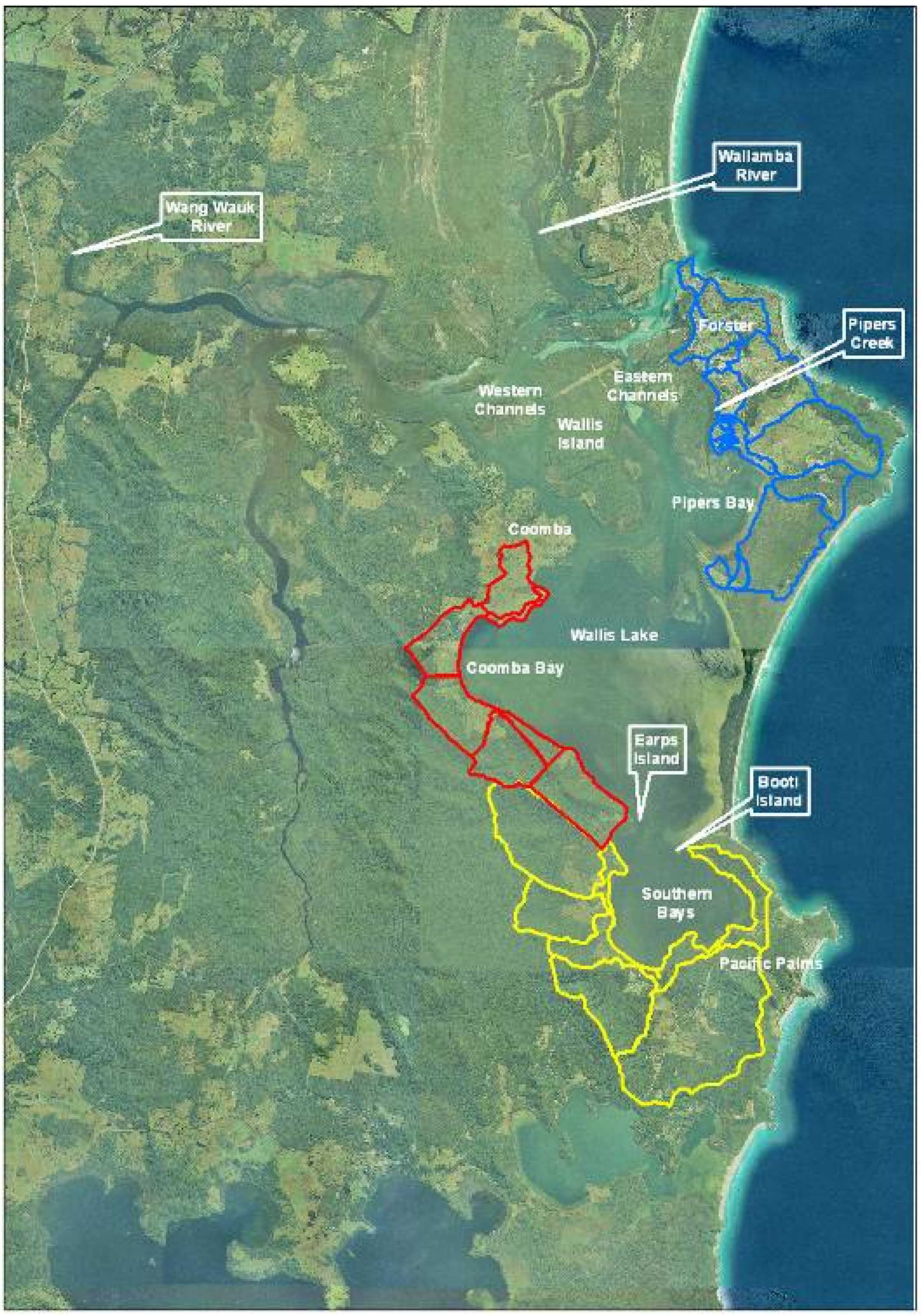

Figure A11.4. Map of Wallis Lake. Case study areas and their catchments are shown: yellow lines are catchments for southern bays; red lines are catchments for Coomba Bay; and blue lines are catchments for Pipers Creek.

2. Case study 1: Coomba Bay

Coomba Bay includes much of the western shore of Wallis Lake basin. Much of the catchment is forested, but there is about 1,600 ha of cleared agricultural land fringing the lake shore in the central and northern parts of the Bay. A small number of short creeks and drainage lines cross the agricultural land and enter the Bay. Estimates of nutrient and sediment input from the main part of the catchment were relatively small. The amount is expressed in terms of kg of nutrient per square kilometre of catchment per year. The actual figures (Table A11.1) are total nitrogen (113 kg/m^2/yr), total phosphorus (4.7 kg/m^2/yr) and total sediments (2.3 kg/m^2/yr). Note these figures do not include the gully erosion mentioned later.

Table A11.1. Loads of nutrients from the catchment of each case study area. Units are kg/km^2/yr.

	Total nitrogen	Total phosphorus	Total suspended solids
Pipers Bay	762.0	73.0	270.0
Coomba Bay	113.0	4.7	2.3
Southern bays	78.0	3.8	9.6

During DECC's CCI project, it was noticed that Coomba Bay, which had been selected as a relatively undisturbed area for comparisons of results, was at times showing unexpected characteristics of a degraded system. Initially, DECC observed very murky (turbid) waters along the central shore of the bay, which was associated with a localised absence of seagrass. Water quality data showed that there were also moderate concentrations of chlorophyll, indicating excessive algal growth. Aerial photography (see Figures A11.5(a) and A11.5(b)) also showed the absence of seagrass and an area of turbid water.

The section of Coomba Bay that has experienced the loss of seagrass is immediately adjacent to the site of a large erosion gully, which developed during the early 2000s. This gully was up to 300 m long and estimated to be 3–4 m wide and 2 m deep (GLC, pers. comm.). The gully was remediated in 2005 by GLC using funds from NHT1 (Figure A11.6). The main input point for this sediment was at the southern end of the observed mud deposits. If we assume the dimensions above and a density of 1.2 tonnes per cubic metre, this equates to a total of 2,100 tonnes of sediment while it was active. Calculations for the rest of Coomba Bay catchment (where no gully erosion was recorded) put the load of sediments at 0.004 tonnes / year.

Figure A11.5(a). Coomba Bay 7 June 2007, showing turbid (dirty) water, mud area and absence of seagrass (seagrass is seen as a dark colour in the water). Only a narrow band of seagrass has managed to survive between the smothered area and depths where the turbid water prevents sufficient light from reaching the lake bed.

Figure A11.5(b). Google Earth image of Coomba Bay showing turbid (dirty) water and absence of seagrass.

Detailed environmental investigations of seagrass distribution were done by DECC Waters and Catchment Science using diver surveys of shallow seagrass areas and underwater video surveys of deeper parts, supplemented by coring of sediments and analysis of water quality data. The results show clearly that an area of 2.5 ha was covered in a layer up to 200 mm thick (average 50 to100 mm) of fine, brown mud with little organic content (Figure A11.7). This mud was very similar to the surrounding soils and very different from normal black lake-bottom mud. This area was near the lake shore in water depths of 200 to 500 mm. Where the mud had deposited, there was no seagrass alive (Figure A11.5) and the waters were often very turbid (15 to 20 NTU; compared with an expected value of 0 to 2 NTU). Video transects out from the shore showed that beyond the immediate mud deposition zone seagrass beds had survived out to a depth of less than 2 m. This compares with a south Coomba and lake-wide average seagrass survival depth of 2.5 to 3.5 m. The turbidity was still high in this part of Coomba Bay and high turbidity has been shown to limit the depth to which seagrass will grow. It is estimated that more than 2.5 ha of seagrass has been directly smothered by this mud deposition and possibly as much as an additional 25 ha due to light reduction from turbidity. This mud has been there for over two years and does not look like going away quickly. While it is there, it continues to be resuspended by wave energy and cause turbidity, which is likely to continue to impact on the survival of the seagrass beds.

Chlorophyll concentrations in Coomba Bay were 3.1 µg/L, in comparison to less than 1.6 µg/L in other parts of Wallis Lake. This represents a mild level of excess algal growth. This indicates that nutrients released from the mud are stimulating a mild level of algal growth, which is probably inhibited partly by the murky water.

The dramatic consequences of a single erosion gully close to the lake emphasises the scale of possible localised impacts of catchment activities. Even seemingly minor failings in catchment management can have significant effects on the water quality and ecology of the lakes.

Figure A11.6(a). Coomba Bay erosion gully (photo courtesy of GLC).

Figure A11.6(b). Location of Coomba Bay erosion gully remediation works (photo courtesy of GLC).

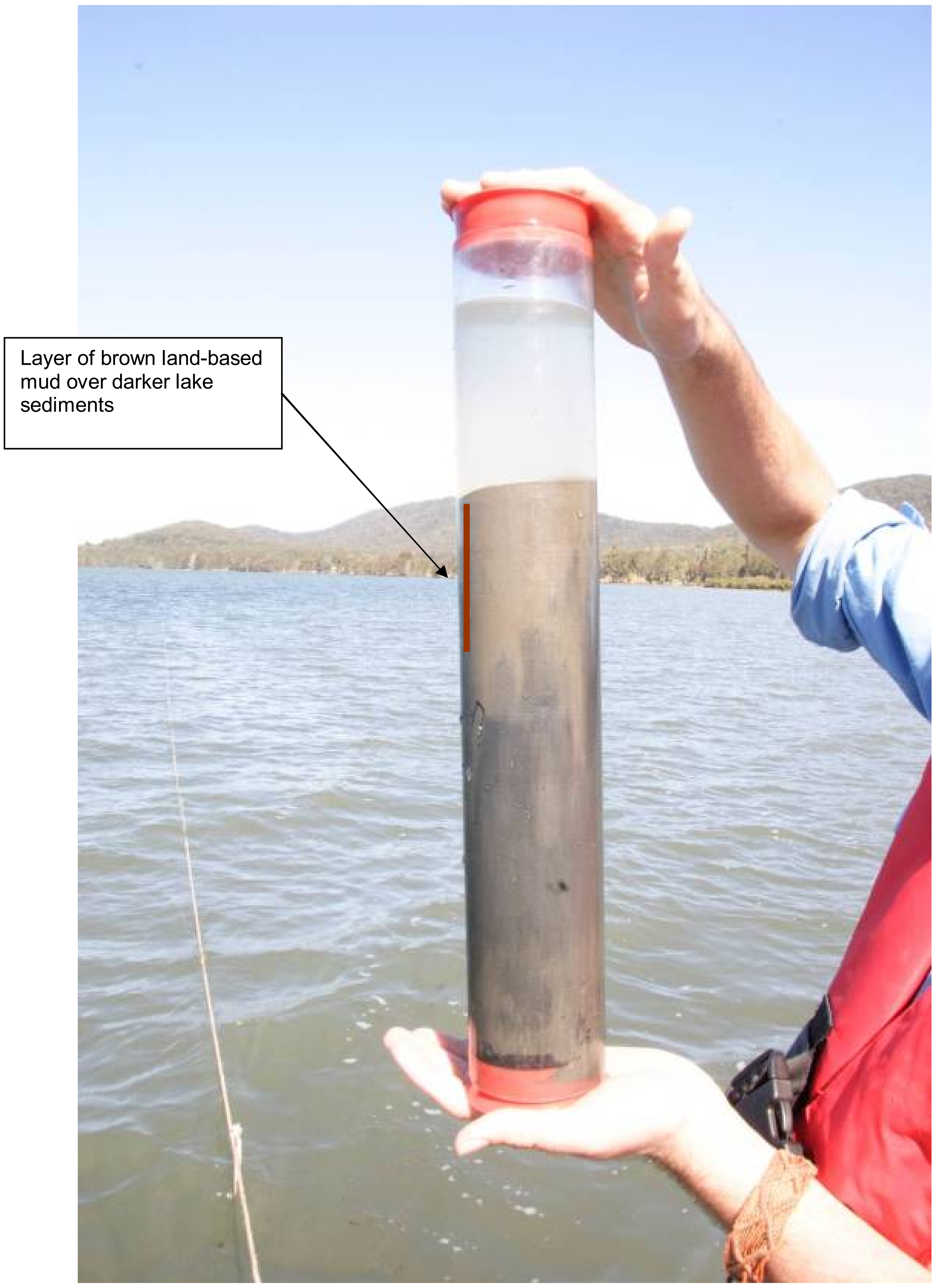

Figure A11.7. Land-based muds have smothered seagrass over an area of at least 2.5 ha along the shore of Coomba Bay.

3. Case study 2 – Pipers Creek and Pipers Bay

Pipers Creek estuary and Pipers Bay receive all the runoff water from medium density urban and light industrial development on the eastern side of the Wallis Lake (Figure A11.4).

The amounts of nutrients produced by the catchment are quite large (Table A11.1): total nitrogen (760 $kg/m^2/yr$), total phosphorus (73 $kg/m^2/yr$) and total sediments (270 $kg/m^2/yr$). Using these figures, we have estimated that about 14 tonnes of nitrogen and five tonnes of phosphorus reach Pipers Creek estuary each year.

As a consequence, large blooms of macroalgae are obvious on seagrass beds in the lower estuary (Figure A11.8). Chlorophyll concentrations in Pipers Creek were among the highest measured anywhere in the system, averaging 8.6 µg/L and peaking at 12 µg/L. The average value for Pipers Creek is five to six times greater than expected values and represents a significantly degraded ecosystem. The turbidity values were moderate, with values around 4 to 6 NTU. Seagrass only grows down to a depth of less than 2 m, so there has been a reduction of over 0.5 m from the depth expected for this type of environment.

Measurements of the release of nutrients from sediments in Pipers Bay indicate that the system is under significant long-term stress.

The ecological indicators for Pipers Creek show that it is one of the most degraded parts of the Wallis Lake system. The large amounts of algae, both as chlorophyll and attached macroalgae, suggest that nutrient enrichment is the greatest problem in Pipers Creek. Turbidity from catchment soil loss is a secondary issue.

Figure A11.8. Excessive growth of macroalgae over seagrass beds in Pipers Creek.

4. Case study 3 – Southern bays

The southern bays of Wallis Lake, in contrast to the previous case studies, are in near-pristine condition. They support a wide variety of seagrass, healthy algae and brackish waterplant (macrophyte) communities to a depth in excess of 3 m. All these benthic (bottom-dwelling) plant communities are dependent on clear, clean water with very low nutrient loads. Current water quality measurements for the southern bays have chlorophyll concentrations less than 1 mg/L, turbidity below 2 NTU and water clarity (Secchi depths) in excess of 3 m. These near-pristine conditions have allowed the continued survival of the ecologically important seagrass and macrophyte communities with their associated biodiversity, including the increasingly threatened estuarine sponges in the southern parts of Wallis. These clear-water brackish macrophyte and sponge communities are, to the knowledge of DECC, very rare in NSW coastal lakes. The hydrological separation of southern Wallis from the inputs of the major rivers (Wallamba, Coolongolook, Wang Wauk) – and the relatively small catchment with largely intact natural vegetation surrounding the southern bays – means that very little nutrients and sediments from the wider catchments ever reach these bays. They are mostly only impacted by their immediate surrounding catchment. Modelled estimates of loads from the surrounding catchment (Table A11.1) are total nitrogen (80 $kg/m^2/yr$), total phosphorus (4 $kg/m^2/yr$) and total sediments (10 $kg/m^2/yr$). The slightly higher loss of sediments is a result of the catchment being very steep and containing highly erodible soils. This makes the catchment very vulnerable to disturbance, and likely to produce extremely large amounts of nutrients and sediments if land use changes inappropriately or without appropriate controls in place.

If conditions are allowed to deteriorate, in particular if there are increased loads of sediments and nutrients entering these bays, all the symptoms of poor health that have been described for Coomba and Pipers Bay (high chlorophyll levels, turbid water, poor light penetration, loss of bottom-dwelling plants and seagrasses) will begin to occur and a locally unique ecosystem will be lost.

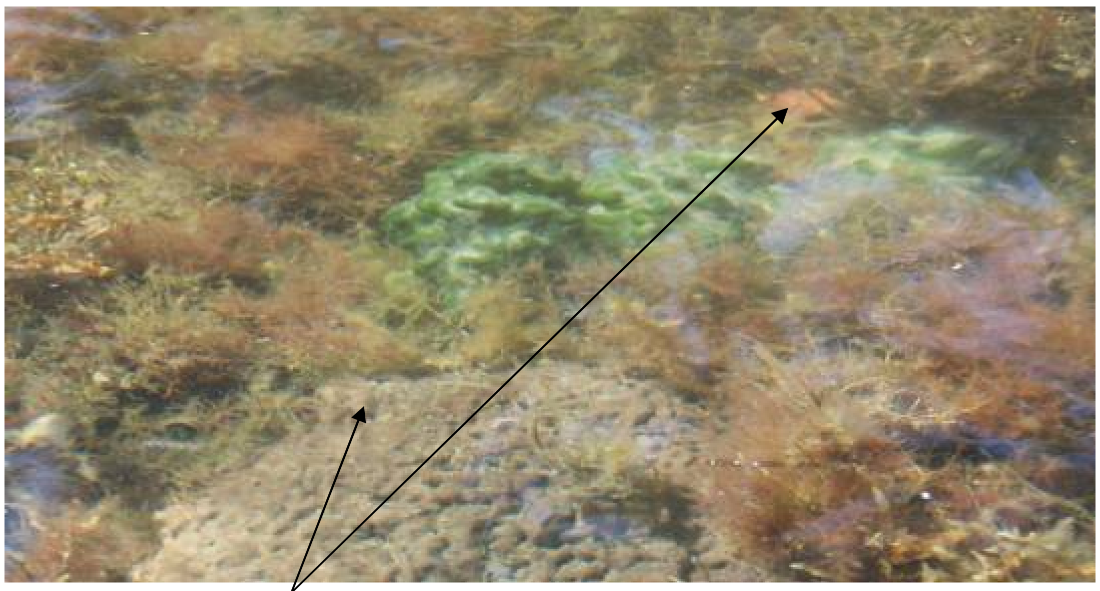

Figure A11.9. Healthy clear-water ecosystems around Earps Island, showing rare estuarine sponges and diverse benthic algae. These areas adjoin diverse and healthy seagrass and macrophyte beds.

5. What can we learn from this?

Years ago, the respected CSIRO scientist Dr Graham Harris was invited to advise GLC on how best to manage Wallis Lake. The (probably apocryphal) story goes that he was standing and looking at the lake when he said "If you are looking at the lake and wondering how to manage it, then you have your back to the real problem". He was, of course, saying that most of the environmental problems affecting coastal lakes have their root cause in the catchments and lands that surround the lake – you do not manage lakes, you manage their catchments.

This philosophy has been adopted by the National CCI program. The Great Lakes CCI project and the preceding Wallis Lake Catchment Management Plan have therefore been based on the concept that land use within the catchment has the potential to greatly alter the amounts of nutrients and sediments entering the lake via creeks and rivers. The increased amounts of these nutrients and sediments have the potential to substantially affect the ecological values of the lakes. The conceptual understanding that supports all the scientific and modelling studies has two main themes: that reduced light penetration through the water will lead to the death of plants attached to the lake floor, starting in deep waters and moving to shallower waters; and that excessive nutrients will result in the development of algal blooms.

The Wallis Lake case studies presented above show clearly that these ideas are not just theoretical, but are occurring right now. We examined the condition of one part of the lake with very small catchment-related inputs, where healthy and biologically diverse ecological communities flourish to the maximum depths possible in clear, low-nutrient water. We then contrasted this with two other sites: Pipers Bay, which is showing algal blooms resulting from large inputs of catchment nutrients; and Coomba Bay, where seagrass has been killed by a large input of sediments that is resulting in continual long-term turbidity in the waters of the Bay.

Unless catchments are protected from inappropriate changes to land use, the environmental and social values of Wallis Lake will continue to be degraded. The WQIP being developed by Great Lakes Council as part of the CCI will provide the basis for prediction of potential environmental harm from changes to land use in catchments and will support decision-making to help protect the environmental values of the Great Lakes.

These case studies illustrate the importance of awareness of three important themes commonly encountered in environmental management:

- *Theme 1* – guarding against 'death by a thousand cuts'. This is where a large number of relatively small and seemingly insignificant decisions are made in isolation of each other. While any one decision seems insignificant, when they are all added together to give a cumulative effect, the consequences can be large. This is a very common situation, and occurs in rural and urbanised settings. Consequences of this scenario have been illustrated by our data for Pipers Creek, where gradually increasing urban areas, with little knowledge and or regard of the consequences, has led to some of the worst eutrophication in Wallis Lake. If this is allowed to continue, we may see permanent damage to ecosystems and significant degradation of environmental values
- *Theme 2* – the potentially far-reaching impact of a 'single event'. When catchments are small and creeks are short, any catchment land use impacts are, by definition, very close to Wallis Lake. This means that there is very little chance for natural or human mitigation of damaging activities. As a consequence, poorly managed land use has a very high likelihood of resulting in environmental harm, and that harm may be significant and long-lasting. The Coomba Bay experience shows us very clearly the scale and longevity of the environmental impacts of a single event, particularly when it occurs close to the lake. This emphasises how we need to be really careful about what we do
- *Theme 3* – the protection of intact catchments to maintain ecosystem service value. There is no disputing that protection of intact catchments (catchments with lots of natural vegetation and wetlands) is the single most effective management action to preserve natural systems and the values that are held so strongly for these systems. DECC Waters and Catchment Science modelling shows that for some parts of Wallis Lake, any increase in pollutant loading will degrade the natural values. The southern bays of Wallis Lake (i.e. south of Earps and Booti islands) have largely intact catchments (with some exceptions around Pacific Palms) and still have some of the best examples of clear-water ecological communities in central NSW. The steep catchments and highly erodible soils in the catchment mean, however, that the utmost care must be taken if these ecological values and services are to be protected. The Wallis Creek catchment needs to be carefully managed, i.e. no increase in pollutants should occur, as CCI modelling shows that any increase will lead to diminishing environmental values.

This paper has focussed on case studies for Wallis Lake, but the ideas and themes are applicable for all the lakes. Myall Lake has many of the same values as south Wallis, and the Broadwater suffers some of the same issues as Pipers Creek and Wallamba River. Catchment management for all the lakes should focus on identifying and minimising existing pollution sources, and preventing any new examples of the sorts of problems typified in themes 1 and 2, and the associated case studies. The modelling done as part of the CCI will assist in targeting high-risk areas, setting priorities for protection and assessing consequences of changes in pollutant loads.

Appendix 12: Seasonal variation in pollutant loads for Wallis and Myall lakes

The catchment modelling done for the Great Lakes CCI project utilised daily records of temperature, sky cover, and wind speed and direction for the periods 1971 to 1978 ('wet'), 1991 to 1994 ('dry'), and 2000 and 2007 ('current'). This data was obtained from automatic weather stations (stations 060030, 060141 and 061078), owned and maintained by the Australian Bureau of Meteorology (BoM). These stations are not located within the Wallis Lake, Smiths Lake or Myall Lakes boundary, so interpolated daily records of total rainfall were obtained from the Australian BoM SILO Data Drill (http://www.nrw.qld.gov.au/silo/datadrill/). This data contains grids of rainfall amounts that have been interpolated from point observations.

The region is characterised by summer-dominated rainfall, particularly in the northern part of the Great Lakes (Figure A12.1). There is a slight north to south gradient in rainfall in the Great Lakes area, with marginally greater rainfall in southern regions.

Figure A12.1. Average monthly temperature and precipitation in the Great Lakes region.

1. Calibrated seasonal variations for Wallis Lake

The percentage of runoff, TN, TP and TSS by season is shown for the Wallis Lake calibrated sub-catchments in Figures A12.2 to Figures A12.4. Across all sub-catchments, runoff tends to be greatest in the summer and autumn months, although there is not a large variation between seasons. The seasonal differences are stronger for nutrients and sediments, with loads in winter and spring each comprising less than 20% of annual loads for all climate periods. The trends are consistent between sub-catchments, although runoff and loads in winter are further reduced in the southernmost sub-catchment (Coolongolook). This is matched by increased proportion of loads in winter relative to the other sub-catchments.

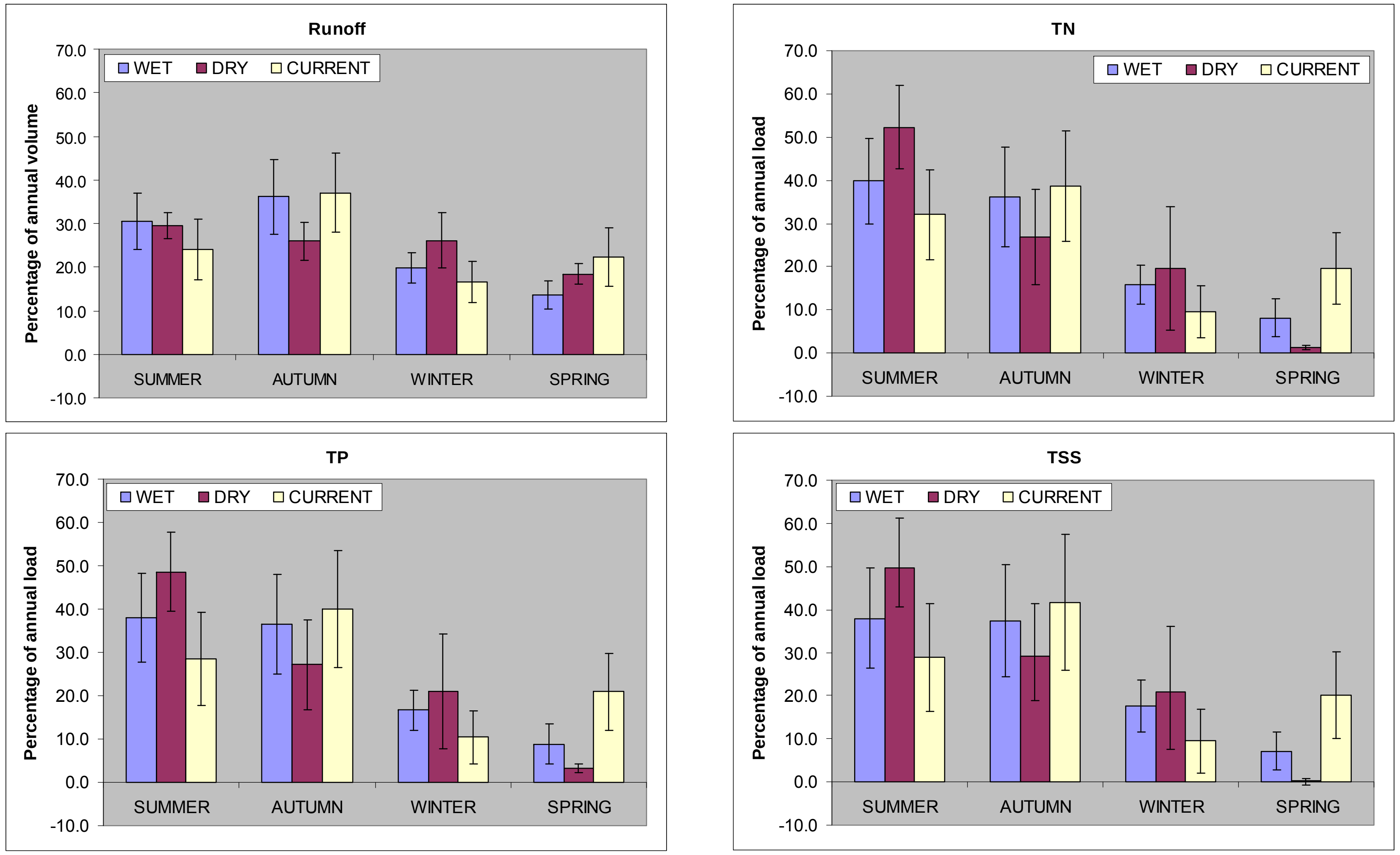

Figure A12.2. Mean runoff volume and TN, TP and TSS loads for the Wallamba River calibrated sub-catchment by season expressed as a percentage of the average annual total. Variation between years is shown with standard error bars.

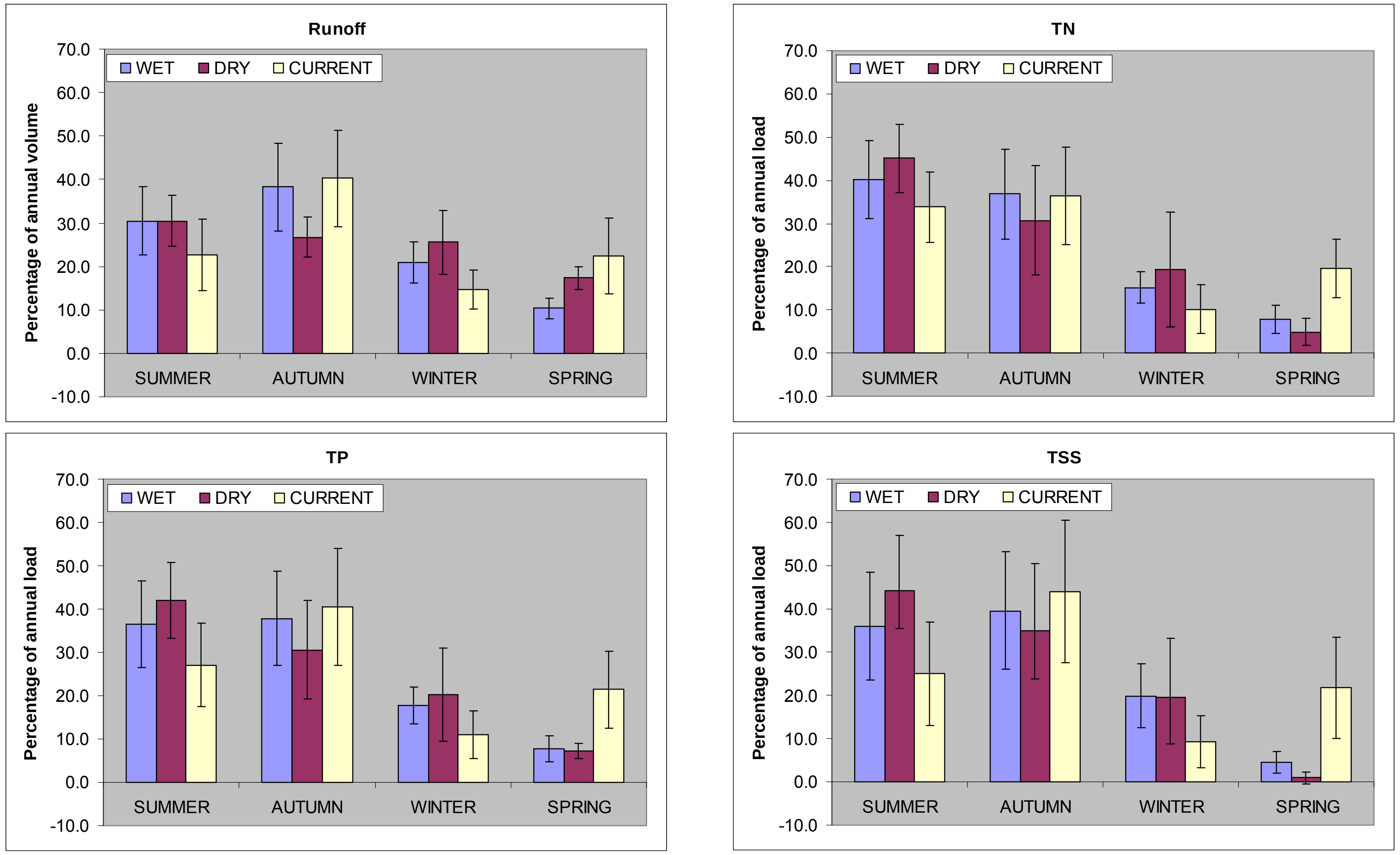

Figure A12.3. Mean runoff volume and TN, TP and TSS loads for the Wang Wauk River calibrated sub-catchment by season expressed as a percentage of the average annual total. Variation between years is shown with standard error bars.

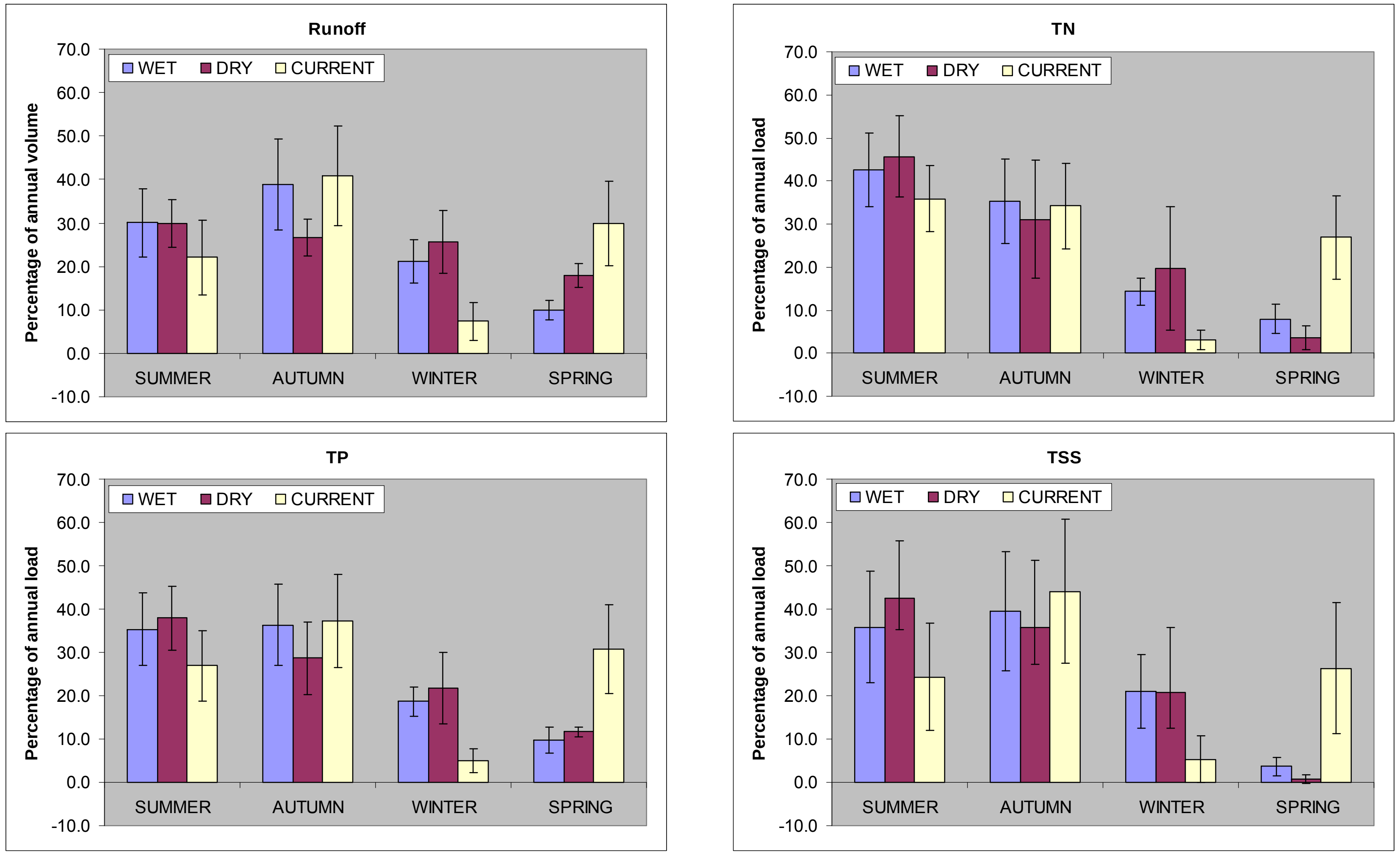

Figure A12.4. Mean runoff volume and TN, TP and TSS loads for the Coolongolook River calibrated sub-catchment by season expressed as a percentage of the average annual total. Variation between years is shown with standard error bars.

2. Calibrated seasonal variations for Smiths Lake

The percentage of runoff, TN, TP and TSS by season is shown for the Smiths Lake catchment in Figure A12.5. All plots show that the lowest volumes and loads occur during spring months, and the largest volumes occurring during summer or autumn. Similar patterns exist between the 'wet' and 'current' periods of the climate record. The 'dry' period shows a large amount of variability, although this period covers only four years of records.

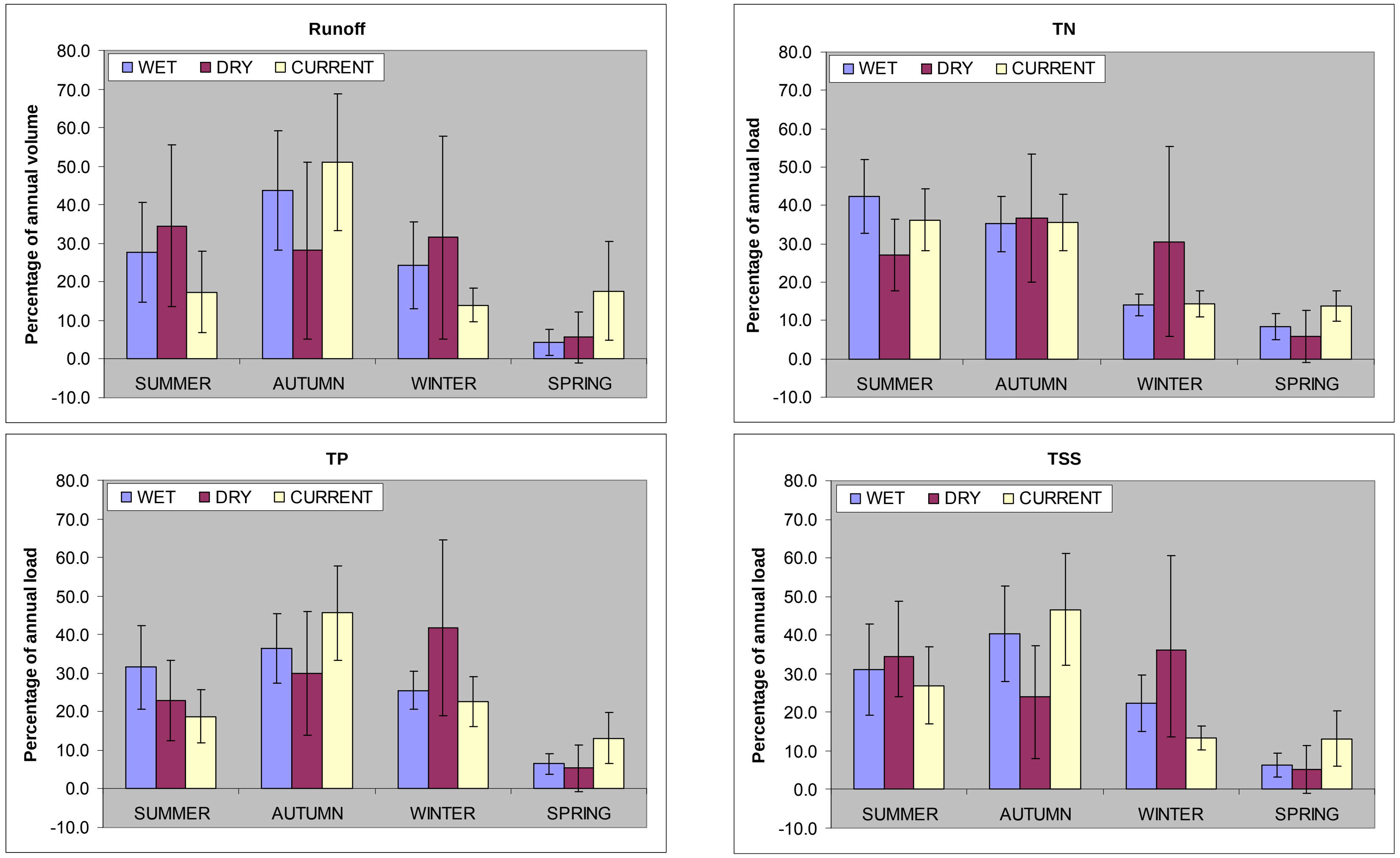

Figure A12.5. Mean runoff volume and TN, TP and TSS loads for the Smiths Lake calibrated sub-catchment by season expressed as a percentage of the average annual total. Variation between years is shown with standard error bars.

3. Calibrated seasonal variations for the Myall Lakes

The percentage of runoff, TN, TP and TSS by season is shown for the calibrated Bulahdelah sub-catchment in Figure A12.6. In the DSS, this area is split into two sub-catchments: the Upper Myall River and Crawford River. Similar patterns exist between the 'wet', 'dry' and 'current' periods of the climate record for all constituents. There is much more variation in seasonal distributions between years for TSS compared with runoff or TN and TP. The seasonal runoff volumes are relatively evenly split between seasons, although there is a slightly larger proportion in winter relative to other seasons. A similar distribution of loads between seasons exists for TP, although TN and TSS loads are greatest in autumn and spring.

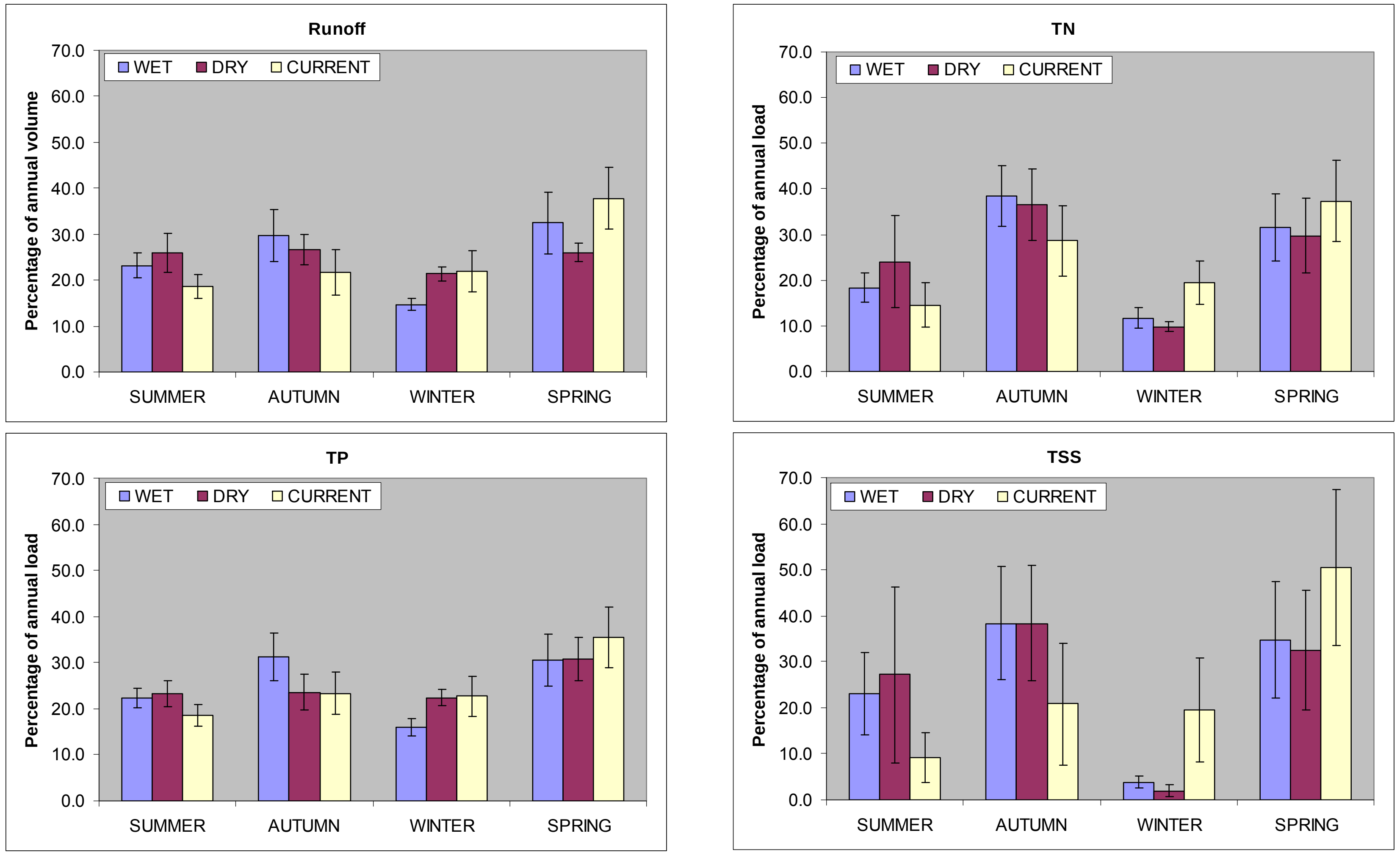

Figure A12.6. Mean runoff volume and TN, TP and TSS loads for the Bulahdelah calibrated sub-catchment by season expressed as a percentage of the average annual total. Variation between years is shown with standard error bars.

4. Implications for the Wallis, Smiths and Myall lakes Plan

Discussions in Sections 2.5 and 2.7 of the WQIP (Wallis Lake), 2.9 and 2.11 (Smiths Lake), and 2.13 and 2.15 (Myall Lakes) focus on estimates of annual load data from the DSS and average conditions in the estuary. When using these estimates to make management recommendations, consider that variability between years and seasons means that at any point in time, conditions in the catchment or estuary could differ from the predicted average. Estimates of impacts from the Plan actions (Sections 2.7, 2.11 and 2.15 of the WQIP) focus on the relative change (direction and magnitude) of impacts rather than absolute values. Estimates using extremes of uncertainty in weather and generation rates were also produced. These estimates provided impacts of the same direction and magnitude, and in most cases were numerically very similar to those presented in the Plan.

Appendix 13: Establishing the feasibility of the WQIP scenarios

The management actions outlined in the WQIP were developed based on a combination of new research findings, modelling outputs and expert knowledge. Different approaches were used for urban and rural areas, as the nature of the management actions varied considerably. The specific approaches are outlined below.

1. Urban management scenarios

As outlined in the engagement strategy report (Appendix 1), internal and external working groups were established to inform the Water Sensitive Urban Development and Design Strategy. This strategy informed the strategic direction for the actions outlined for the urban areas in the WQIP (e.g. the need for a development control plan for redevelopment, the need to have strict controls on development in Greenfield sites).

Urban stormwater modelling (MUSIC) was then undertaken to explore the specific details of what water quality improvements could be achieved for:

- Greenfield sites
- redevelopment
- rainwater tanks retrofitting
- urban retrofitting program.

The results of the modelling were then presented to the internal and external working groups and the CCI Advisory Committee at workshops to determine if the scenarios were feasible (both economically and politically) prior to inclusion in the WQIP.

Details on release area sizes, location, and predicted development rates and timing were determined based on expert knowledge and predictions provided by Great Lakes Council's Release Area Coordinator.

Predicted uptake of rainwater tanks in urban areas was determined by MidCoast Water staff involved in delivering the rainwater tank rebate program.

The nature and predicted rates of redevelopment were based on eight years of construction certificate data from Great Lakes Council's records.

2. Rural management scenarios

The Rural Management Practice Technical Group was responsible for determining the types of management actions to apply to rural land. For each of the management actions that could be modelled using the Great Lakes DSS (groundcover, dam refurbishment, fertiliser management), the committee established and described the existing situation in four levels of management practice (level 1 representing poor management, through to level 4 representing best management). These estimates were based on expert knowledge (field experience), and the results of the landholder survey and nutrient budgets undertaken as part of the CCI project.

To establish feasible management scenarios, the Rural Management Practices Technical Group[DG46] then made predictions on the amount of change that could occur (among the management levels) if the programs that they described were implemented. During workshops, consideration was given to the amount of uptake that could be expected from the rural community (based on extensive collective experience working with landholders and an understanding of how the rural community is currently changing). For the purposes of establishing WQIP scenarios, the available funding was not considered as a key limitation. Estimates of the amount of maintenance needed after seven years were also made based on the Advisory Committee's experience.

Note that rural actions were designed as seven-year programs. Costs for maintaining these levels of change past year 7 were estimated, but no option for ramping-up programs after year 7 was considered. Urban options were typically run out over 30 years because they depend on redevelopment rates, etc. This means that the estimate of feasibility after 30 years underestimates what could be achieved if rural programs are ramped-up after year 7. It is recommended that programs be revised and new estimates of cost and impact be developed as part of the seven-year review of the Plan to ensure that estimates of feasible change reflect new understanding and technology, and remove this limitation.

3. Other management actions

Wetland and riparian protection

Wetland protection actions were determined based on the experience of GLC staff involved in current wetland protection projects. Maps were used to determine the area of wetlands to be acquired and managed, and therefore the costs associated with those actions.

Feasibility of riparian protection was based on progress achieved on similar projects in previous years. The amount of resources required to achieve the actions identified were based on historical costs for similar works.

Unsealed road rehabilitation

The scenarios for unsealed road rehabilitation were determined based on average costs for sealing three different types of roads. An upper limit of a budget was then established based on approximate cost of other rehabilitation programs. This was then used to determine the amount of road rehabilitation that would be run through the DSS.

Appendix 14: WQIP scenario descriptions for Wallis Lake

This appendix describes scenarios for the WQIP that were modelled using the DSS developed as part of the Great Lakes CCI. Rural scenarios were developed by iCAM, GLC and the CCI Rural Management Practices Group. Urban scenarios were based on urban stormwater modelling undertaken as part of the CCI project by BMT WBM and discussions with key staff on engaging the urban community.

This Plan presents water quality improvement actions required to achieve the ‘feasible reduction in chlorophyll-a’ over a seven-year time frame. Some of the actions identified in the Plan cannot be completed during this time frame. For example, wetland protection and water-sensitive design of Greenfield sites will occur over a much longer period. For the purposes of benefit-cost analysis (Appendix 15), the costs and benefits of these programs were estimated over a 30-year period.

Most rural actions developed in this plan were designed as seven-year programs. Costs of maintaining these levels of change past Year 7 were estimated, but no option for ramping-up programs after Year 7 was considered. It is likely that additional benefits would have been achieved if the rural programs were increased between Year 8 and Year 30. However, in recognition of the inherent difficulties associated with making predictions about the implementation of actions in the first seven years, the Rural Management Practices Group was not confident estimating what program actions would be implemented beyond the seven-year time frame. Two of the rural actions – unpaved road remediation and riparian remediation – were developed as 30-year ongoing programs. Urban management options were typically run over 30 years because they depend on redevelopment rates that are likely to occur over the coming decades. Protection and management actions were costed over 30 years, as this time period is appropriate for the benefit-cost analysis presented in Appendix 15.

For summary purposes, the time frames that apply to the proposed remediation, protection and management support actions developed for this Plan are summarised in Table A14.1.

Table A14.1. Wallis Lake – Proposed remediation, protection and management support actions for this Plan, and the time frame for their implementation.

Actions	Time frame for implementation
Remediation actions – modelled using the DSS	
Groundcover management	Seven years to implement and 30 years of maintenance of the program
Nutrient management (Fertiliser)	Seven years to implement and 30 years of maintenance of the program
Infrastructure (Dam) management	Seven years to implement and 30 years of maintenance of the program
Riparian remediation	Implement over 30 years
Unpaved road remediation	Implement over 30 years
Urban Mitigation (Water Sensitive Urban Design)	Implement over seven years
Water Sensitive Redevelopment	Implement over 30 years
Protection actions – not modelled with the DSS	
Wetland protection	Implement over 10 years

Actions	Time frame for implementation
Riparian protection	Implement over 30 years
Water Sensitive Development of Greenfield sites	Implement over 30 years
Water Sensitive Urban Design protection	Implement over 30 years
Best management of unpaved roads	Implement over seven years
Improved pollution control systems / management systems	Implement over seven years
Improved management of lake use activities	Ongoing
Management support actions – not modelled with the DSS	
Adaptive Management Strategy / Ecological monitoring program	Undertake over 30 years
Future investigation relating to the Farm Scale Action Plan	Undertake over 30 years

General cost assumptions

Table A14.2 summarises the general assumptions made in the costing of the WQIP and its component actions. These assumptions cover the range of workshop types as well as all of the general expenses that might occur in implementing the WQIP. It should be noted that:

- the time lag between holding the education programs and changing practice will depend on the program being run, and could range from months to years
- there is crossover between programs, particularly in relation to the Catchment Officer role (the Catchment Officer would need to be assessing the whole farm and all of the farm features at the same time). The proportion of the person’s job that relate to the specific action is described in this appendix
- expanded dam, groundcover and nutrient management programs are assumed to be fully implemented by year 7. Annual plan costs to year 30 are assumed the same as years 0 to 7, to reflect increasing turnover rates in rural areas, subdivisions of farmland to smaller rural residential properties and increases in costs, and the consequent need for programs to be ongoing to maintain levels
- the healthy lakes program (current program) for urban education and capacity-building covers the cost of general community awareness-raising in relation to stormwater management, so the additional costs of showcasing the WSUD devices is the only additional cost outlined here in relation to engaging with the general community
- MidCoast Water already has a rebate program for the rainwater tanks, so it is only the cost of the tanks – not the program costs – that should be costed here
- Council staff member time should be costed at $108,465 / year (this includes on-costs) = $417.17 / day
- consultant costs are costed at $1,120 per day
- additional costs for workshops include a cost for catering at $250 per workshop
- advertising = $250
- bus for field trips = $600 / day

- WSUD remediation and protection should be costed per plan according to the proportion of urban area
- total costs for each program have been rounded to the nearest $5,000 to reflect the level of uncertainty in these estimates.

Table A14.2. Wallis Lake – Assumptions in costing the Water Quality Improvement Plan and its actions.

Description	Assumptions
Catchment Officer	• One full-time person would cost $80,000 per year to operate (including on-costs) • Each full-time person would have a mobile phone with a one-off cost of $450 plus $550 worth of line rental and calls per year • Each full-time person would need a car costing $18,200 per year (including petrol and hire) ($350 / week) **Total** to operate the person = $99,200 in the first year and $98,750 per year in the years that follow, given additional costs of mobile phone purchase in the first year
Technical Officer	As above **Total** to operate the person = $99,200 in the first year and $98,750 per year in the years that follow
Formal workshop	• 30 people attending at $15 / head catering = $450 • Hall or toilet hire of $100 • Materials $450 (photocopying $150, advertising $200, mail-out $100) • $3,000 per person per day (guest speaker) • Average of 1.5 persons per workshop = $4,500 for guest speaker **Total** to run a formal workshop = $5,500 / day
Basic field days	• Demonstration / Field day on a landholder's property similar to those run through the Sustainable Grazing program • **Total** to run basic field day = $500 / day • Morning tea $100 • Toilet or hall hire $100 • Materials / Consumables $300 This includes demonstration sites that could be returned to each year; the funding for the actions that are being demonstrated would come from the other actions (e.g. if it is a riparian management trial then the funding for that work would come from the riparian management section)

Dam refurbishment and removal

This scenario group is based on assumptions defined by the Rural Management Practices Technical Group, survey data collected as part of the Great Lakes CCI and literature. It examines:

- current dam management
- the expected impact of fully implemented *existing* programs for refurbishing or removing dams over a seven-year time frame
- the expected impact of fully implemented *expanded* programs for refurbishing or removing dams over a seven-year time frame.

The scenarios are applied to both improved and unimproved pasture lands.

Levels and effectiveness

Four levels of dam condition were defined by the Rural Management Practices Technical Group. The effectiveness of each level at trapping pollutants was estimated from data published by Erskine, Mahmoudzadeh & Myers (2002), Erskine, Mahmoudzadeh, Browning & Myers (2003) and Verstraeten, Prosser & Fogarty (2005). These three studies report on trapping efficiencies for dams near Sydney (Erskine, Mahmoudzadeh & Myers 2002; Erskine, Mahmoudzadeh, Browning & Myers 2003) and Canberra (Verstraeten, Prosser & Fogarty 2005). The condition of the 29 dams and their small catchments (<1000 ha) reported by the authors were used to assign a level based on the levels and descriptions defined by the Rural Management Practices Technical Group. The percentage effectiveness for each level was calculated from the average trapping efficiency of the dams studied by Erskine and Verstraeten assigned to each level.

Table A14.3. Wallis Lake – Effectiveness at trapping pollutants for each level of dam condition.

Level	Description	Effectiveness
1	• turbid water, algal blooms • little groundcover over and around dam • poorly functioning spillway • free stock access • headwall in danger of being breached • gullies entering dam eroded • high level of nutrients in catchment area • shallow sedimented dam • not effective in trapping sediments and nutrients	29%
2	• stock controlled by shifting stock around – can move anywhere • freeboard and spillway	55%
3	• stock access points • partially fenced	65%
4	• clear and clean water • stock excluded • spillway stable and appropriately managed • dam wall stable and appropriately managed • gravity-fed trough farm dam • catchment area well-grassed, minimal nutrient input contributed to dam • buffer zone intercepting flow • aquatic plants around fringes • no erosional headcut of dam • effective in trapping sediment	91%

Number of dams

Data collected by staff at the Department of Environment and Climate Change (DECC) was used to estimate the number of dams per hectare on pasture lands. The surveys did not specifically focus on dams, although there were questions related to the presence of dams on the property, the location of the dam spillway and extent of fencing around the dams. This information was mapped and provided to iCAM as geographical information system (GIS) ‘shape files’. Shape files of properties and dams were overlayed with land use maps to obtain estimates of dam numbers. A total of 126 dams were recorded across the 4,990 ha of management practice project areas that are classed as pasture, corresponding to a rate of one dam per 40 hectares.[11]

11 This value was initially estimated as being one dam per hectare, based on an assumption of one dam per holding and an average holding size of 13 hectares. At a meeting with the Rural Management Practices Technical Group in March 2008, it was suggested that a higher number of dams would have been expected in the catchments and that the DECC survey should be used to estimate the number of dams. Despite fewer dams than originally assumed, these scenarios use the rate estimated from the DECC survey data. An estimate of the number of farm dams for pasture land in the Myall Lakes using aerial photographs supported the fewer dams suggested by the survey.

There is a total pasture area of 48,615 ha in the Wallis Lake catchment. A rate of one dam per 40 hectares gives 1,228 dams in total.

Total effectiveness of dams

The proportion of dams corresponding to each level under each scenario was defined based on discussions with the Rural Management Practices Technical Group, and are shown in Table A14.4.

Table A14.4. Wallis Lake – Proportion of dams at each level of dam condition, by management scenario.

Level	Existing situation (%)	Existing programs (%)	Expanded programs (%)
1	40	34	20
2	49	48	35
3	10	15	35
4	1	3	10

These proportions were then multiplied by the effectiveness of each level to calculate a total effectiveness of dams for each scenario. GIS was used to estimate an average catchment area for dams on pasture land in the Myall Lakes. The catchment area of the dams was about 5% of the pasture land in the catchment. For this scenario, dams are assumed to affect 5% of the runoff from pasture lands. This estimated effectiveness of dams under each scenario is shown in Table A14.5.

Table A14.5. Wallis Lake – Estimated effectiveness of dams for management scenarios.

Scenario	Effectiveness of dams	Additional capture (from base case) (%)
Existing situation	0.023	-
Existing programs	0.024	0.14
Expanded programs	0.028	0.55

Action-specific costs

Assumptions made to estimate the costs specific to the dam remediation or removal actions are summarised in Table A14.6. They include direct costs or remediation and / or removal, as well as program costs.

Table A14.6. Wallis Lake – Estimation of costs for remediation of dams.

Description	Assumptions
Direct costs	Based on the description of the levels, it was decided that the cost of the dam repair should only cover work to the spillway, fencing off the dam and putting in a single trough to replace the dam. The dam repairs should be costed at $3,000–$5,000 per dam (assumed value = $4,000 per dam). A total of 85 dams per year (see below) across both the Wallis and Myall catchments; 22.3% (roughly 20 dams) in the Myall ($79,417)
Program costs	*Existing situation* • Currently 1/6 of a Catchment Officer achieves 10 dams per year • One full-time person per catchment *Expanded programs (across both the Myall and Wallis catchments)* • 140 dams need to move from level 1 to 4, which means that 45% of the dams need substantial work • 268 dams (20%) need to move out of level 1 to 2, and this would not require very much work (one day per dam) = 268 days • 350 dams (25%) need to move from level 2 to 3; this group is assisted to move from this group through the grazing program • it was noted that one would need to spend the same amount of time to move people through each of the levels, and it was therefore decided to allow 2.5 days per dam for the Catchment Officer negotiations 638 dams x 2.5 days = 1,595 days. At 210 effective working days per year = 7.5 yrs = shifting 85 dams per year One full-time Catchment Officer for Wallis and Myall (excl. Crawford). Based on proportion of dams, Wallis will have 0.767 x Catchment Officer per year ($76,029 [Year 1], $75,684 per year [subsequent years])
	• Technical person required to design dams and off-stream watering • This would cover the repair or removal of dams *Expanded programs* • 38% of a year for a technical person for Wallis catchment = $38,014 • One workshop for the Wallis catchment per year ($5,500 per workshop)
Total expanded program	Year 1: $380,127 Annual (excl. Year 1): $379,609 per year Total over 30 years: $11,390,000

Scenario implementation

A trajectory of impacts over 30 years is used to demonstrate the benefits of implementing the Plan compared with the current condition ('WQIP'), and the effects of development and redevelopment under current controls ('No Plan'). The scenario combinations for the 'No Plan' and 'WQIP' scenarios are shown in Table A14.7.

Table A14.7. Wallis Lake – Scenarios for Plan implementation for dam refurbishment.

Component scenario	No Plan		WQIP	
	Seven years	30 years	Seven years	30 years
Dams	Existing programs	Existing programs	Expanded programs	Expanded programs

Nutrient management

This scenario group is based on assumptions defined by the Rural Management Practices Technical Group. It has been applied to improved pastures only. Several levels of management have been identified and the proportion of the improved pasture lands operating at these levels under each of the scenarios has been identified. A 'score' has been given to each level of management to indicate the level of nutrient available. These have been used to calculate the equivalent percentage change in fertiliser.

Table A14.8. Wallis Lake – Description of the levels of nutrient management scenarios.

Level	Description	Score [12]
1	Does not implement any current recommended practice (CRP). Features may include: • low perennial grass cover • poor nutrient management (e.g. fertiliser application prior to rain, no soil testing) • no buffer • higher stocking rate and continual stocking (i.e. no response to season or drought strategy)	10
2	Land is not managed to CRP. Features may include: • some nutrient management practices in place (occasional soil testing on some paddocks) • low to moderate perennial grass cover • continual stocking (i.e. no response to season or drought strategy)	7
3	Land is not managed to CRP. Features may include: • moderate perennial grass cover • some nutrient management practices in place (some soil testing on paddocks, dung beetles) • continual stocking (i.e. no response to season or drought strategy)	4
4	Land is managed to CRP (e.g. BEEF). Features include: • high and persistent perennial grass cover • white clover in winter • best practice nutrient management (e.g. regular monitoring of nutrient levels through soil testing, fertiliser application in spring, dung beetles) • best practice riparian management (e.g. buffers ≥10m) • best practice stocking management (e.g. drought strategy implemented)	1

The nutrient management / fertiliser scenario then considers different proportions of total improved pasture area to be operating under each of these levels, as shown in Table A14.9.

Table A14.9. Wallis Lake – Proportion of total improved pasture area at each level of nutrient management, by management scenario.

Level	Existing situation (%)	Existing programs (%)	Expanded programs (%)
1	20	20	15
2	40	30	20
3	30	35	35
4	10	15	30

12 Used to estimate the percentage decrease in equivalent fertiliser use that is applied using the DSS.

Using these proportions and the scores for each level gave final weight scores, from which a percentage change in 'fertiliser' level was calculated to give the fertiliser multiplier. This multiplier was applied to improved pastures only.

Table A14.10. Wallis Lake – Scores and fertiliser multipliers, by nutrient management scenario.

Scenario	Score	Fertiliser multiplier
Existing situation	6.10	1.00
Existing programs	5.65	0.93
Expanded programs	4.60	0.75

Action-specific costs

Assumptions made to estimate the costs specific to the nutrient management actions are summarised in Table A14.11.

Table A14.11. Wallis Lake – Estimation of costs for fertiliser management.

Description	Assumptions
Program costs	This program would involve a person in a Catchment Officer role promoting and providing advice to people about fertiliser management. This would include the expansion of the dung beetle program, as it may replace the need to use fertiliser. The Catchment Officer would also need to have the technical skills to interpret soil tests so the person would cover all aspects of this program. One person to cover all three catchments with 1/3 effort in each of Myall Lakes, Wallis Lake and Crawford River. This reflects the fact that the biggest proportion of use of fertiliser is in the Myall Lakes and Crawford River, and the catchments are smaller so therefore they will get proportionally more effort per area ($33,067 [Year 1], $32,917 per year [subsequent years]).
	Need to run two LANDSCAN™ courses per year over all catchments. This would involve 40 people. Over the period of seven years this would involve 280 people (note that LANDSCAN™ is one of the key requirements to move landholders into level 4). Cost of a LANDSCAN™ course is $580 per farmer. Assuming 10 per group, $23,200 x two per year = $46,400 across all catchments (Wallis = $15,467)
Direct costs	Costs of providing basic soil tests in the first three years = $70 per sample (phosphate, nitrogen). Assuming that the number of dams is close to representing the number of places you will want to do a soil test (this is a big assumption and is probably not correct): to move 20% of people to level 2 (occasional soil test some paddocks) = 289 people x $70 = $20,230 to move 35% of the people to level 3 (occasional soil test number of paddocks) = 525 people x two soil tests x $70 = $73,000 to move 30% of people to level 4 (regular soil tests) = 450 x three soil tests x $70 = $94,500 *Costs split over seven years* Cost for Wallis = ($20,230 + $73,000 + $94,500) / 7 / 3 = $8,940 Note that dung beetles have not been costed as part of this program but are included in groundcover management, even though they are part of the recommendations for nutrient management.
Total expanded program	Year 1: $57,473 Annual (excl. Year 1): $57,323 per year Total over 30 years: $1,720,000

Scenario implementation

A trajectory of impacts over 30 years is used to demonstrate the benefits of implementing the Plan compared with the current condition ('WQIP'), and the effects of development and redevelopment under current controls ('No Plan'). The scenario combinations for the 'No Plan' and 'WQIP' scenarios are shown in Table A14.12.

Table A14.12. Wallis Lake – Scenarios for Plan implementation for nutrient management.

Component scenario	No Plan		WQIP	
	Seven years	30 years	seven years	30 years
Nutrient management	Existing programs	Existing programs	Expanded programs	Expanded programs

Groundcover

This scenario group is based on assumptions defined by the Rural Management Practices Technical Group. It was applied to all pasture (grazing) areas on both low slope and high slope areas. This scenario consists of an assumed proportion of the grazing lands with different levels of groundcover. Groundcover levels are given in Table A14.13.

Table A14.13. Wallis Lake – Description of the levels of groundcover condition scenarios.

Level	Description	Groundcover
1	• overstocked all of the time • preferential grazing • only grass cover • bare / scalded / erosion • noxious weeds, pests • no feral animal control • poorly designed access • regular burning • non-strategic water supply (isolated) • no dung beetles • cultivation • no drought management plan	<60%
2	• overstocked in adverse conditions • periodic burning (up to every five years)	60–80%
3	• stocking rate to maintain 80–90% cover • drought management plan	80–90%
4	• non-cultivated • maintain groundcover • maintain native vegetation (shrubs, grasses, trees) • land use matches capability – stock exclusion • build well-designed access tracks • rehabilitate erosion sites • prevent tracks and fences downslope • hazard reduction burning only • care with management of dispersible soils • match stock to feed • allow paddock resting • provide multiple stock watering points for even grazing • control weeds and pests • dung beetles, monitoring • drought management plan • stock exclusion during rainfall periods	>90%

The groundcover scenarios consider different proportions of the grazing lands to be under these different management levels as shown in Table A14.14.

Table A14.14. Wallis Lake – Proportion of groundcover area at each level of groundcover management, by management scenario.

Level	Existing situation (base case) (%)	Existing programs (%)	Expanded programs (%)
1	10	10	10
2	82	78	65
3	5	9	17
4	3	3	8

Note that existing programs and expanded programs both refer to the impact of programs over a seven-year time frame.

These values were then used to calculate an effective groundcover level for each of these scenarios. These proportions were used to weight values for each of the groundcover levels: level 1 is 50%, level 2 is 70%, level 3 is 85% and level 4 is 95%. The effective groundcover levels calculated across all steep pasture lands for each of the scenarios is:

- existing situation is 69.5%
- existing programs is 70.1%
- expanded programs is 72.55%.

The AnnAGNPS model has been used to estimate the effect of changes in groundcover on pollutant loads. The results from this model imply that a shift from current groundcover level (equivalent to 69.5% groundcover) to 100% groundcover on steep-sloping pasture lands would have the effect of decreasing pollutant loads generated from these lands by:

- 90% for TN
- 94% for TP
- 95% for TSS.

Note this is the median value by sub-catchment in the Wallis Lake catchment – there are some small differences by sub-catchment but the method is the same.

The effect of existing programs and expanded programs were then estimated proportionally using these decreases and the calculated effective groundcover. The multiplier on load implied by these changes was used as the basis of the interpolation (Figure A14.1).

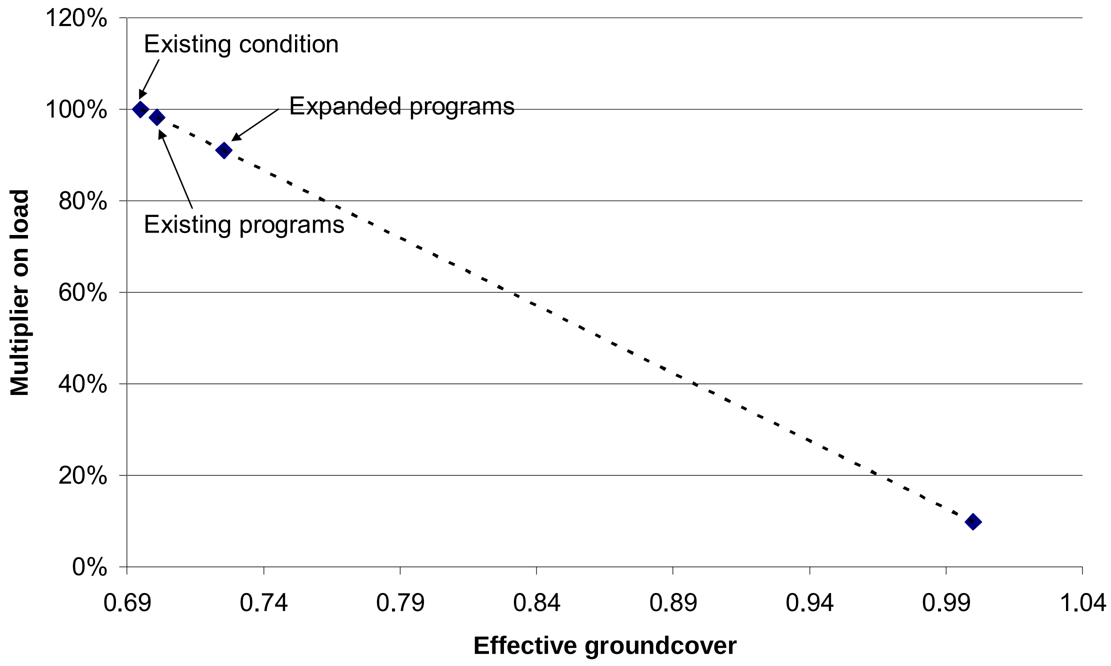

Figure A14.1. Interpolated effect of management programs for groundcover.

These were then applied in the model using the input settings allowed. Note the DSS allows for five groundcover levels to be applied to proportions of the catchment. Current groundcover corresponds to level 3. This meant that an equivalent proportion of area set to level 4 was calculated and run as the scenario to capture the effect of these changes in groundcover.

Action-specific costs

Assumptions made to estimate the costs specific to the groundcover actions are summarised in Table A14.15.

Table A14.15. Wallis Lake – Estimation of costs for groundcover management.

Description	Assumptions
Program costs	Note: There was a sustainable grazing officer that worked across the Wallis and Myall catchments. This position no longer exists as from June 2008. This means that the impact of existing programs will not be as great as predicted in the scenarios. It will also mean that it will be more work to get expanded programs up and running due to the loss of momentum. *Expanded programs* • with a break between sustainable grazing officer appointment (e.g. one year) • 1.5 x Catchment Officer ($148,800 [Year 1], $148,125 per year [subsequent years])
	Expanded programs • 60 workshops / field days a year costing around $500 per workshop ($30,000) • One formal workshop per year across the Wallis = $5,500 • One Prograze course across all catchments 15 properties attending per course @ $580 per farmer costs $26,000. Cost for Wallis catchment = $13,000

Description	Assumptions
Direct costs	Dung beetles – one colony per year covers 200 ha, and costs between $450 and $750 depending on the species. In the Myall this equates to 12 colonies. Assuming a cost per colony of $600 = $7,200 It was also noted that in level 4, we need to provide for multiple stock watering points to assist with even grazing. It was estimated that providing stock water would be approximately $2,500 per 40 ha. This would include solar pumps, gravity-fed systems and some internal fencing. In the Wallis, this equates to 231 stock watering points. Assuming a cost per watering point of $2,500 = $85,526
Total expanded program	Year 1: $287,027 Annual (excl. Year 1): $286,352 per year Total over 30 years: $8,590,000

Scenario implementation

A trajectory of impacts over 30 years is used to demonstrate the benefits of implementing the Plan compared with the current condition ('WQIP'), and the effects of development and redevelopment under current controls ('No Plan'). The scenario combinations for the 'No Plan' and 'WQIP' scenarios are shown in Table A14.16.

Table A14.16. Wallis Lake – Scenarios for Plan implementation for groundcover management.

Component scenario	No Plan		WQIP	
	Seven years	30 years	Seven years	30 years
Groundcover	Existing programs	Existing programs	Expanded programs	Expanded programs

Unsealed road remediation

Costs associated with upgrading an existing rural road (unsealed) to a consolidated and sealed surface with associated drainage / sediment controls were explored for three different unsealed road upgrades carried out by GLC. These projects provide broad examples of the locations and geology likely to be encountered within the Great Lakes local government area, and provide examples of the difficulties associated and the consequent range of costs involved (Table A14.17).

In all situations, preparatory works are required to bring an existing unsealed road and its substrate up to a standard capable of providing an appropriate carriageway surface for sealing.

Such works can include:

- realignment or widening of the existing road
- adding or augmenting drainage systems to the existing roadway
- excavation of the road footprint, followed by stabilisation and reconsolidation of the roadway structure to suit anticipated traffic loads
- extensive rock excavation and removal (including the use of explosives)
- elevation of the new road surface (via the importation and compaction of suitable gravels)
- implementation of sediment and erosion control structures
- clearing of near-roadside vegetation for rehabilitation, safe clear distances and establishment of table drains.

Given the extreme variability in the requirements of any given road project – and the additional complications of site location, availability of suitable plant and equipment, geological substrates and the availability of appropriate construction materials – each project is unique and, accordingly, is usually costed on an individual basis.

Once a road substrate and surface has been improved to a suitable standard, costing further improvements becomes simplified:

To provide sealing coat to a prepared rural road surface:
crushed gravel layer (emulsifier-coated) with bitumen spay sealer coat = **\$7.50 per m^2**

In order to account for the variability in the costs for road rehabilitation works, the cost of the unpaved road scenarios were based on the rounded average of the three examples provided below (\$600 / m^2).

The models assumed that the upgrade of the roads would result in an 80% reduction of loads off the improved areas.

For the Wallis Lake, the approximate cost of other rehabilitation programs were used to determine the amount of road rehabilitation that would be run through the DSS. This resulted in 4.2 km of roadwork over 30 years (980 m over seven years). While the models could not determine where exactly the rehabilitation would take place, it was assumed that high-risk areas – such as approaches to creek crossings and at creek crossings – would be sealed as a priority. Road remediation activities were focussed in the Wallamba River sub-catchment group.

Table A14.17. Wallis Lake – Costing of works for remediating unsealed roads.

Road section upgrade	Description of works	Length of works (m)	Cost of works ($)	Unit rate (per lineal metre)	Substrate geology
Wattley Hill Road	Rehabilitation and upgrade of 0.375 km of Wattley Hill Road, Bungwahl. The roadway has been extended from a 5 m width to 6 m width, with 2.6 m shoulders including table drains. The pavement surface is fully sealed. The existing road structure was widened, stabilised with lime, gravelled and compacted, then sealed. The works consist of the following: clearing of near-roadside vegetation for rehabilitation; safe, clear distances and establishment of table drains; excavation of the road footprint and stabilisation; gravelling (lifting the elevation of the road by about 100 mm); compaction and two-coat seal of 0.375 km of 6 m pavement and 2.6 m shoulders inclusive of table drains; and implementation of sediment and erosion control actions, as set out in a sediment and erosion control plan.	400	$120,000	$300	Soil landscape mapping of Great Lakes Council identifies the worksite soils as being comprised of alluvial deposits. The 1:100,000 Geological Series sheet for Bulahdelah identifies the worksite as being undifferentiated Quaternary alluvium. Immediately to the east of the worksite, near the Barbies Road / Wattley Hill Road junction, is Carboniferous geology of the Boolambayte Formation. This comprises brown lithic sandstones and boulder conglomerates at the base followed by interbedded siltstone, mudstone, lithic sandstone and minor pebble conglomerate, along with some minor limestone.

Road section upgrade	Description of works	Length of works (m)	Cost of works ($)	Unit rate (per lineal metre)	Substrate geology
Lakes Way (Sugar Creek Road to Bungwahl)	Reconstruction of 2.25 km of The Lakes Way (MR111) between Sugar Creek Road and Minnow Street, Bungwahl. The upgrade provides for two x 3.25 m travel lanes and 1.8 m shoulders with a full seal width. The upgrade will comply with 80 km/h and 60 km/h design speed requirements. The works involved the following activities: clearing of roadside trees and vegetation for construction; safe, clear distances and reduction of hazardous trees; excavation and filling of parts of the road footprint; establishment of a new road structure including 2.25 km of 3.25 m travel lanes (north and south-bound) and 1.8 m shoulders; establishment of bitumen seal, guard rails, and sediment and erosion control and management structures; removal of the seal on disused sections of the road in preparation of tree planting and revegetation; and ground surface stabilisation, tree planting and landscaping.	2,250	$2,250,000	$1,000	Soil landscapes mapping of Great Lakes Council identifies the worksite as passing through colluvial, erosional and transferral soil landscapes. Both colluvial and erosional landscapes exhibit relatively shallow soils with parent material (consolidated bedrock) close to the surface. Transferral landscapes usually exhibit deeper soils but also can exhibit outcrops of eroded parent material. To the east of the worksite, the transferral soil landscape grades into aeolian and alluvial landscape types along the shore of Smiths Lake. The worksite is located within an area of Carboniferous geology. Generally the worksite is underlain by undifferentiated sandstone, siltstone, claystone and shale beds. Occasional outcrops of limestone and volcanic origin material occur within the worksite.

Road section upgrade	Description of works	Length of works (m)	Cost of works ($)	Unit rate (per lineal metre)	Substrate geology
Seal Rocks Road	Reconstruction of 4.45 km of the Seal Rocks Road (between the villages of Bungwahl and Seal Rocks). The road at this location occurs within the Myall Lakes National Park. The road is to contain two x 3.25 m travel lanes and 0.75 m shoulders with a full seal width. It shall be a 60 km/h design speed. The existing structure is unsealed and on a suboptimal alignment. The works involve the following activities: clearing of required roadside trees and vegetation where the proposed road deviates from the existing alignment for construction; safe, clear distances and reduction of hazardous trees; excavation and filling of parts of the road footprint; establishment of a new road structure including 4.45 km of 3.25 m travel lanes (north and south-bound) and 0.75 m shoulders; establishment of bitumen seal, guard rails, water management structures, and sediment and erosion control and management structures; removal of the pavement on disused sections of the road in preparation of tree planting and revegetation; ground surface stabilisation, tree planting and landscaping; and monitoring and remediation as required.	4,450	$2,710,050	$609	In geological terms, the entire worksite is located within an area of Quaternary sands of Holocene age (6,500 years old) described as transgressive dunes, parabolic aeolian sand dunes or sand swamps. Similarly, soil landscape mapping of Great Lakes Council identifies the area as an aeolian soil landscape. The soils of the worksite are clearly sands and the Holocene dune / swale arrangement is clearly observable.

Unsealed road protection

Unsealed road protection assumes that the cost of best practice sediment and erosion control features, such as mitre drains, are included in the maintenance costs of road grading (and are therefore not costed in this Plan). The costs that are identified in the Plan cover identifying the priority areas for rehabilitation and building the capacity of staff undertaking the road grading to reduce sediment losses to the waterways. The costs of these actions are outlined in Section 3.3.3 of the WQIP and the costs have been attributed to each lake (Wallis, Smiths and Myall) according to the proportionate size of their catchments.

Riparian remediation

This scenario examines the impacts of remediating identified sites of high stream bank erosion. These sites are assumed to laterally erode 1 cm per year over a height of 1.5 m with 1.5 tonnes per m^3, giving an average load of 0.0225 tonnes per year per metre of stream bank. Sites were based on GIS data layers provided by the Great Lakes Council.

The costs of in-river repair works will vary with the length of the eroding site. Small sites are assumed to require 50 m of fencing and physical structures that cost $1,000. Large sites are assumed to require 300 m of fencing and physical structures that cost $10,000. The number of sites and costs for repairing active stream bank erosion sites in the Wallis catchment are in Table A14.18.

Table A14.18. Wallis Lake – Extent and costs of repairing stream bank erosion.

DSS sub-catchment code (see Figure A14.2)	Number of sites	Average length of site (m)	Cost of site ($)	Total cost ($)
HS1a	15	107	15,400	231,000
HS1b	20	139	15,400	308,000
HS1c	2	75	15,400	30,800
HS1d	27	10	1,900	51,300
HS2	341	2	1,900	647,900
HS3	26	2	1,900	49,400
HS7a	2	180	15,400	30,800
HS7b	5	142	15,400	77,000
HS7c	1	50	15,400	15,400
HS9a	2	2	1,900	3,800
HS9b	4	2	1,900	7,600
HS9c	2	2	1,900	3,800
Total				**1,456,800**

Note that only catchments with active stream bank erosion sites are given in this table.

Works entail the repair of 275 sites of active stream bank erosion, with 50 m on fencing for each smaller site (2 m in length) and 300m of fencing for longer sites (up to 180 m in length). Implement engineering and revegetation works as appropriate.

In the Wallis Lake catchment, remediation is to be completed over 30 years. A fixed annual budget for remediation costs was set at $30,000, so the total budget for riparian remediation site costs is **$900,000** over 30 years. This means that not all active stream bank erosion sites identified above will be remediated over 30 years.

Costs for staff time in remediating these sites were also accounted for. It was assumed that a large site would require four days each of the Catchment Officer's and Technical Officer's time, and that a smaller site would require four days of the Catchment Officer but only two days of the Technical Officer. This means that staff time would cost approximately $704,000 for the sites planned to be remediated in the Wallis Lake catchment.

The total cost of riparian remediation including site costs and staff costs is **$1,605,000** over 30 years.

Riparian protection

Riparian protection involves protection of 720 km of remnant riparian vegetation (and some revegetation as required) in agricultural areas. It is assumed that only 70% of these streams will be suitable for fencing (504 ha). Where fencing is used, the costs of providing fencing and off-stream water are $18,000 per km. Where fencing is not appropriate, riparian areas will be protected using Property Vegetation Plans. These are estimated to cost $700 per ha. Riparian areas are assumed to be 20 m wide on either side of the river (ie. 40m in total), so a total of 864 ha of Property Vegetation Plans were estimated as being required. It was assumed that 0.5 of a Catchment Officer per year would be required to implement the program.

The total cost of the riparian protection program is **$11,165,000** over 30 years.

Wetland protection

Wetland protection involves acquisition of 3,740 ha of healthy but threatened wetlands. These wetlands would be acquired over a period of 10 years at a total cost of $3,605 per ha (including 3% loading for possible remediation works). There is also assumed to be 34.4 ha of fencing required at a cost of $11,000 per km. A total of 209 ha of wetlands would also be managed using Property Vegetation Plans at a cost of $700 per ha. Program costs are for 0.2 of a Catchment Officer to manage the wetland acquisition program in the catchment. Total costs of wetland protection in the Wallis Lake are **$14,205,000**. When costed over a seven-year period, approximately 2,618 ha of wetland will be bought back, including 148 ha of Property Vegetation Plans and 24 km of fencing at a cost of **$9,943,000**.

Table A14.19. [DG47] **Wetland protection strategy – Wallis and Myall lakes.**

Program	Actions	Responsible authority	Cost
Future investigation	Identify the location and condition of wetlands, and priorities for conservation and rehabilitation ~	Contractor	30,000
	Prepare management plans for wetlands (including restoration, conservation and land use management) ~	Contractor, GLC	30,000
Future extension	Encourage community participation in the management and restoration of wetlands ~	GLC, CMA	
	Raise the profile of wetlands and their role in providing environmental services through tours, field days and educational material suitable to the general community ~	GLC, CMA	
Future on-ground	Reinstate natural wetland hydrology, particularly in acid sulfate landscapes ~	State, local and federal government	
	Zone coastal wetlands to an environmental protection zone based on future investigation findings (priority areas likely to be Wallingat River wetlands, Minimbah Creek and wetlands, Wallamba River wetlands, Shallow Bay wetlands) ~	State and local government	
	Develop partnerships with state and federal agencies to secure the buyback of conservation priority wetlands ~	State, local and federal government	

~ Input from Rural Management Practices Technical Group.

Management of urban land including protection and remediation (mitigation, water sensitive redevelopment, water sensitive development of Greenfield sites, water sensitive urban design protection[pt48])

These scenarios are based on modelling undertaken by Tony Weber (BMT WBM) using MUSIC – an urban stormwater model – for Wallis Lake. The modelling involved:

- nutrient and sediment export from existing land use area
- nutrient and sediment export from future land use area
- implementation of water-sensitive urban design (WSUD) devices
- redevelopment of 27% of existing urban land in selected sub-catchments
- 15% adoption of rainwater tanks in selected sub-catchments.

Existing and future urban areas

Existing urban areas and future release areas for the Wallis and Smiths lakes catchments are summarised in Table A14.20.

Table A14.20. Existing and future urban areas, Wallis and Smiths lakes catchments.

DSS sub-catchment code (see Figure A14.2)	Sub-catchment name	Area (ha)	
		Existing	Future
Wallis Lake			
HS1c	Khoribakh Creek	69.3	0.0
HS1d	Candoormakh and Pipeclay creeks	129.2	25.0
HS2	Bungwahl and Darawakh creeks	54.8	107.2
HS3	Minimbah and Tuncurry	410.8	30.0
HS4	Wallingat River	0.7	0.0
HS9a	Cureeki Creek	4.3	0.0
HS9b	Upper Coolongolook River	4.1	0.0
HS9c	Lower Coolongolook River	14.7	0.0
HS11	Coomba / Wallis Island	74.2	0.0
HS12	Coomba Bay	0.2	0.0
HS14	Pacific Palms	25.8	40.4
HS15	Booti Booti	2.6	0.0
HS16	Green Point	9.0	0.0
HS17	Pipers Bay (Cape Hawke)	137.9	134.9
HS18	Pipers Creek (South Forster)	294.0	65.3
HS19	Big Island	9.3	0.0
HS20	Forster	244.3	0.0
Smiths Lake			
	Smiths Lake	142.3	11.0

Generation rates for existing urban land were generated from model runs for each urban sub-catchment.

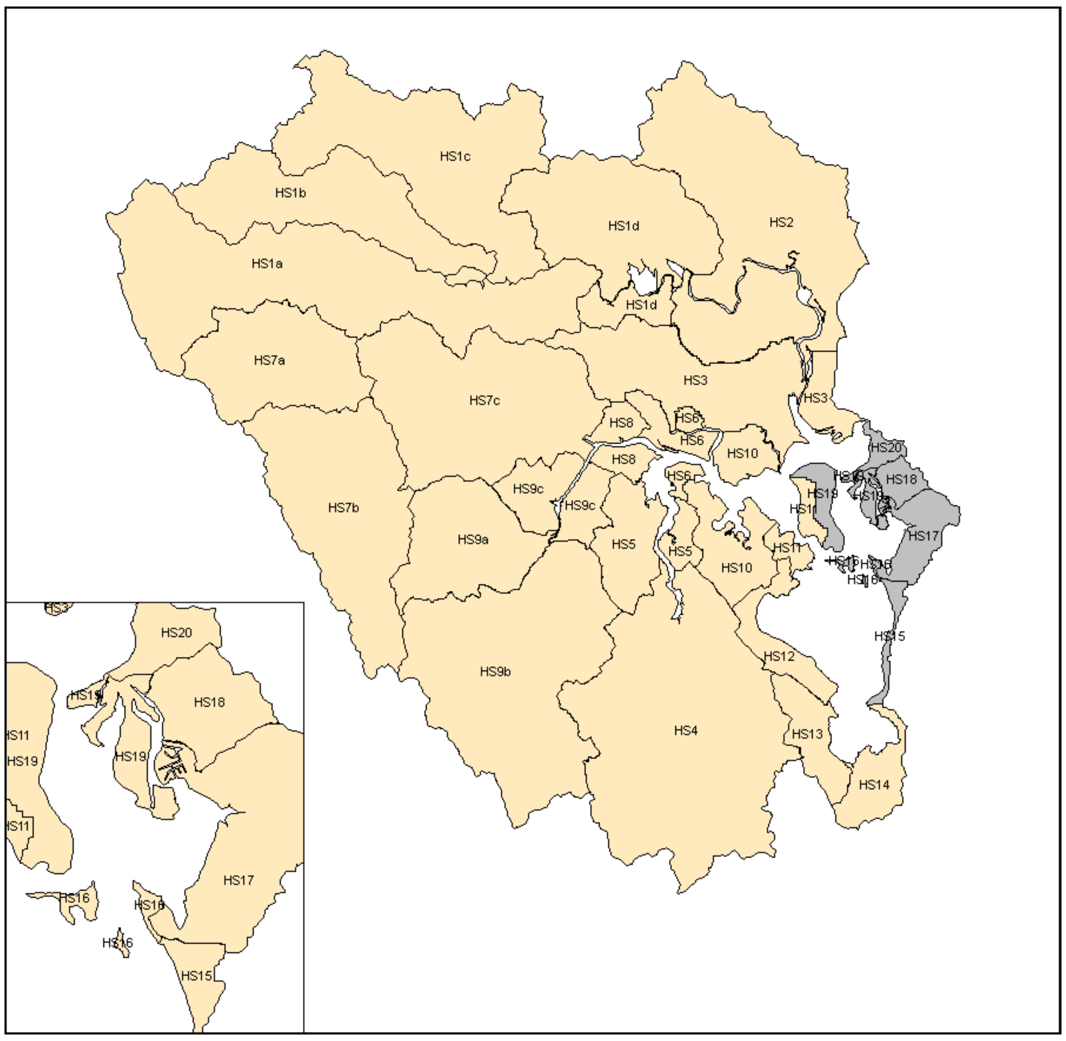

Figure A14.2. Sub-catchments of the Wallis and Smiths lakes, showing DSS sub-catchment codes.

The future release areas (Greenfield sites) are non-urban lands, such as agriculture or native vegetation cover, which have been identified as sites for future urban development. The Great Lakes Council policy of ‘no net increase’ of pollutants for Greenfield sites means that future development of the land must not exceed the current level of nutrient and sediment export. Generation rates for Greenfield sites were obtained from AnnAGNPS model results.

Costs for Greenfield sites were split into those for previously agricultural and forest lands. Approximately 20% of areas were assumed to be prior forest and 80% to be agricultural lands based on advice from Council. This gave a total acquisition cost of $26,460,000 and an annual maintenance cost of $1,024,000. These costs have been distributed over up to 10 years using an expected trajectory of Greenfield developments for the Wallis Lake catchment (Table A14.21).

Table A14.21. Urban development of Greenfield sites for the Wallis Lake catchment.

Site		Release year	Development %	Years for development	Property dwellings	No. of dwellings per year
1	Failford	5	80	5	64	12.8
2	Seven Mile Beach	5	40	5	120	24.0
5	'Fairview West' – South Forster	5	30	5	90	18.0
6	Green Point Drive – Green Point	5	20	5	60–70	2.8
7	Charlotte Bay – Smiths Lake / Pacific Palms	1	20	10	140	14.0
8	Balance Sth Forster (Lani / McBride / Burrawan Street / Quarry / Wilson, etc.)	5	10	5	60	12.0
9	Chapmans Road – Tuncurry	1	20	5	60	12.0
10	Follyfoot Farm – South Forster	5	10	2	20	10.0
11	'Berts Farm' – South Forster	1	10	10	17	1.7
12	Nabiac	5	10	10	14	1.4
13	Pacific Palms	5	10	5	4	0.8
14	South Forster – North catchment (L Leg)	5	40	5	68	13.6
15	North Tuncurry	1	5	10	125	12.5
17	Carmona Drive	5	20	5	3	0.6
18	Pipers Bay	1	10	5	7	1.4

In addition, program costs were also accounted for as one-sixth of the cost of the 'general awareness WSUD' noted in the section on WSUD protection below. Finally, costs for developing heads of consideration for voluntary planning agreements (Section 3.4.2 of the WQIP) were also accounted as: one week of staff time; $5,000 for a consultant (Year 1); proportional costs according to the areas of release areas within each catchment.

The total cost of the Greenfield option is $51,415,000 over 30 years.

Implementation of WSUD retrofitting

Approximate locations of WSUD features were marked out in several sub-catchments to identify likely areas available for WSUD measures and the relative area of the measures. The MUSIC sub-catchments were within the boundaries of the DSS sub-catchments HS1d, HS2, HS3, HS11, HS16, HS17, HS18, HS19 and HS20. From these analyses, Weber (2008) defined input parameters for MUSIC models and modelled the treatment train effectiveness for a number of test sub-catchments. Outputs from these runs were averaged to get a percentage load reduction rate to be used for all existing urban areas.

Weber (2008) defined three levels of implementation of WSUD devices:

- *Minimum Investment* – the typical application of WSUD measures in most local authority retrofitting situations
- *Maximum Practical Investment* – assessment of those WSUD features considered most practical to implement
- *Maximum Investment* – where the maximum possible retrofitting of WSUD features were assessed.

The effectiveness of each level is summarised in Table A14.22.

Table A14.22. Wallis Lake – Reduction in TN, TP and TSS loads with implementation of WSUD scenarios.

Scenario	% reduction in loads		
	TN	TP	TSS
Minimum Investment	16	28	37
Maximum Practical Investment	25	41	54
Maximum Investment	50	75	94

For the WQIP scenario set, only implementation of the Maximum Practical Investment of WSUD features is considered. Costs for mitigation actions using WSUD have been estimated from the MUSIC model for acquisition and annual maintenance. Acquisition costs for mitigation in Wallis Lake have been estimated at $1,740,422 and annual maintenance costs at $149,000. It was assumed that acquisition costs are incurred over the first seven years of Plan implementation, with annual maintenance costs for these years proportional to the amount of acquisition undertaken. Full annual maintenance costs are incurred for every year after Year 7. In addition, several areas of program costs need to be accounted for:

- Development Assessment and compliance assessment (target audience – Council staff)
  - Development Assessment implementation / capacity-building (Council staff)
  - two months in the first year – train on new Development Assessment approach and mentor Development Assessment planners (council staff) + one workshop with consultant (three days) + cost of workshop
  - two weeks per year every year thereafter for training and mentoring / advice
  - two weeks per year after the first year to audit the compliance practices (Council staff member) linked to staff reviews
  - starting in Year 2, a staff member would spend three weeks a year maintaining a database on the location and nature of the WSUD devices on properties (at the cost of a Catchment Officer salary)
- Complete development of WSUD DCP (Section 3.4.2 of the WQIP) – six weeks staff time, $20,000 on a consultant (Year 1), distribute costs proportional to the urban area
- Investigate Pipers Creek nutrient offset scheme (Section 3.4.2 of the WQIP) – six weeks staff time (mix of GLC and DECC) and $5,000 for additional consultant advice (Year 1) – allocate all to Wallis Lake
- Develop further sources of funds for urban water quality management (Section 3.4.2 of the WQIP) – six weeks staff time to provide input, $7,000 additional costs for consultant time / advice (Year 2), distribute costs according to urban area

- Maintenance of WSUD and construction (target audience – Council staff)
  - one workshop every two years
  - two weeks to prepare and coordinate
  - consultant – three days
  - advice / assistance with construction of WSUD – two weeks for a consultant per year every year
  - coordination of consultant, advice on construction, auditing – two weeks staff time per year every year
  - develop maintenance plans / inspection plans – four weeks staff time in the first year (to cover the backlog of structures that already exist), then one week per year every year after that (as new structures are developed)
  - maintain a data base of structures (staff member – three days a year, at the cost of a Catchment Officer)
  - *note* there may be some compliance assessment required. However, this is difficult to estimate at this stage.

The total cost of this action is $6,585,000.

WSUD protection – Engagement for urban water quality improvement

The program outlined in this section is to be applied across the Wallis, Smiths and Myall lakes. The costs of these programs have been included in the management action 'WSUD protection' and have been established for each lake proportional to the size of the urban area.

This program contains several components that have been costed separately:

- include water quality management clause in LEP (Section 3.4.2 of the WQIP) – three weeks staff time (Year 1), $5,000 for additional consultant costs, proportional to urban area
- review Rural Living Strategy (Section 3.4.2 of the WQIP) – six weeks staff time, $15,000 for consultant assistance (Year 2), distribute costs across per area of catchment
- build WSUD into road standards (Section 3.4.2 of the WQIP) – six weeks staff time, $20,000 for consultant assistance (Year 2), distribute costs according to size of urban areas per catchment
- resource erosion and sediment control (Section 3.4.2 of the WQIP) – eight weeks staff time to explore options for regional or sub-regional programs, $8,000 to develop programs (Year 2 to Year 5), spread costs evenly over the time and distribute costs proportional to urban area
- sediment erosion control internal audits (Council staff) (Section 3.4.2 of the WQIP)
  - two workshops every two years (start in Year 2)
  - workshop costs
  - consultant – $5,000 to design the audit program in Year 2
  - internal audits every year (staff costs for two months; this also covers the cost of preparing for the workshops)
  - audits every year – costs proportional to the size of the urban area
- urban stormwater management community education (Section 3.4.2 of the WQIP). Details are outlined below.

- sediment erosion control capacity-building (builders, contractors) (Section 3.4.2 of the WQIP)
  - o two workshops every two years
  - o two weeks to prepare and coordinate (staff member)
  - o consultant – five days
  - o workshop costs
- general awareness of WSUD (businesses, consultants, builders, real estate, Council staff) (Section 3.4.2 of the WQIP)
  - o two workshops every two years for the first five years, then one workshop every two years after that (starting in Year 2); one advertisement per year for the first five years
  - o two weeks to prepare and coordinate (staff member)
  - o consultant – five days
  - o workshop costs
  - o Year 2 to Year 7 – bus required for field trip ($600 per day per workshop)
- general awareness of WSUD – general community (Section 3.4.2 of the WQIP)
  - o demonstration WSUD sites field day with community
  - o one every two years from Year 2 to Year 7, then one every four years after that
  - o include workshop costs + bus costs + advertising
- water quality education program
- three 'stormwater scampers' with primary schools in the first year and then one every year after that. Each stormwater scamper would cost **$5,539** to run and include: 60 stormwater scamper booklets ($1,883), 10 stormwater scamper reports @ $28.47 each ($284), Stormwater Scamper calico bags x 60 ($212), coach hire ($400), staff contribution (four @ $45 per hour) = 60 hrs ($2,700), 40 laminated certificates ($60)
- one Seagrass Education Workshop per year, which would cost $1,620 based on two staff members working 36 hours in total (@ $45 per hour)
- integrating the WQIP findings into the school curriculum is a one-off project to be developed in Year 1. This would involve 14 weeks staff time to integrate locally relevant examples of water quality issues and solutions, as well as lake ecology, into subjects such as Geography, Marine and Aquaculture Technology, and Environmental Science in Year 1 ($34,149).

The cost of WSUD protection programs is $1,000,000 over 30 years. These costs are split by catchment according to area of urban land for Wallis Lake; this represents $840,000 over 30 years.

Redevelopment of existing urban land

Weber (2008) constructed several small-scale development scenarios that represent the likely impacts of change from:

- a single-dwelling residential lot subdivided into two lots
- 3 x 600 m^2 residential blocks, each (previously occupied by a single dwelling) to a small townhouse (six apartments) development

- three x 600 m^2 residential blocks, each (previously occupied by a single dwelling) to a small commercial development.

Generation rates for (unmitigated) redeveloped urban lands were calculated from these MUSIC model scenarios for the urban sub-catchments that cover Forster and Pipers Bay (Table A14.23).

Table A14.23. Wallis Lake – Sub-catchments used for urban area redevelopment scenarios.

Sub-catchment	Redevelopment type
Pipers Bay (HS17, HS18 and HS19)	Redevelopment of urban areas
Coomba Park (HS11)	Redevelopment / densification from rural residential to urban residential

In addition, several individual treatment measures were developed as 'deemed to comply' solutions. These mitigation solutions were developed to meet the DECC load-based reduction targets imposed on development from other areas of NSW. The differences between the unmitigated and mitigated scenarios were used to derive load reductions associated with mitigation.

Over a 30-year time frame, with 0.9% redevelopment, 27% of the existing area is assumed to be redeveloped. A total of 3,827 holdings that could be redeveloped was estimated from GIS data. Using the redevelopment rate of 0.9%, redevelopments were then split 40:40:20 between two-lot townhouse and commercial developments. A typical acquisition and maintenance cost per hectar was estimated for each of these development types from the MUSIC models. The area of a typical development was used to estimate the costs per development of each type. The total acquisition cost in each year was estimated at $757,057 and extra annual maintenance cost in each year at $201,120. Using these figures, the total redevelopment cost over 30 years was estimated at $111,265,000.

Adoption of rainwater tanks

MUSIC models for the urban areas of the Pipers Bay sub-catchments (HS17, HS18 and HS19) were constructed to model the impact of a 15% uptake of rainwater tanks. This equates to 82 rainwater tanks per year over seven years. An acquisition cost of $3,321 and annual maintenance cost of $96 per tank have been estimated from the MUSIC model. These assumptions give a total cost of the rainwater tank option of $3,395,000.

Scenario implementation

A trajectory of impacts over 30 years is used to demonstrate the benefits of implementing the Plan compared with the current condition ('WQIP'), and the effects of development and redevelopment under current controls ('No Plan'). The scenario combinations for the 'No Plan' and 'WQIP' scenarios are shown in Table A14.24.

Table A14.24. Wallis Lake – Scenarios for Plan implementation for urban water use management.

Component scenario	No Plan		WQIP	
	Seven years	30 years	Seven years	30 years
Greenfield	Seven years of development	Full development	Seven years of development	Full development
Water Sensitive Urban Design	None	None	Full implementation	Full implementation
Water Sensitive Redevelopment	6.3% of area redeveloped (No mitigation)	27% of area redeveloped (No mitigation)	6.3% of area redeveloped (With mitigation)	27% of area redeveloped (With mitigation)
Rainwater tank uptake	None	None	15% uptake	15% uptake

Foreshore and riparian management in urban areas

Costs associated with foreshore and riparian management in urban areas have been split proportional to the length of foreshore managed by Great Lakes Council around Wallis Lake (approximately 28 km) and Smiths Lake (approximately 9 km). Note that this action was added to the WQIP following the exhibition period and therefore has not been included in the economic analysis (Appendix 15), and the costs are shown over a seven-year period. Given the relatively low costs associated with this action, the overall results of the benefit-cost analysis will not be affected significantly.

Review of existing Foreshore Management Plans, Plans of Management and site-specific natural area work plans involves:

- one staff member half-time over two years ($98,750).

Enforcing legislation to protect foreshores involves:

- increased staff compliance effort in foreshore areas and follow-up on complaints. Identify impediments to compliance and inform the education program to reduce compliance issues. Costs are – four weeks in the first two years ($8,200) and two weeks every year after that ($1,900) = total of $22,100 over seven years.

Developing and implementing targeted education for residents of foreshore areas involves:

- three months to undertake needs assessment and establish education resources (signs, brochures, media materials). Develop an engagement strategy to be implemented over seven years ($24,600). Materials include signs, printing posters, pamphlets, etc. ($5,000). In Year 2 to Year 7, implement engagement strategy – four weeks every year ($7,600) plus materials ($2,000) = Total $39,200 over seven years.

Total cost of for the actions associated with foreshore and riparian management over seven years is $160,000.

Proportional cost for Wallis Lake over seven years is $121,600.

Proportional cost for Smiths Lake over seven years is $38,400.

Protect sea sponge beds

Staff time is costed at Catchment Officer costs for this project.

Steps identified for the protection of sea sponge beds

- Collect and collate current information (one week in the first year).
- Work with relevant agencies and stakeholders, including professional fishers, to develop a case for sea sponge bed protection. Include engaging with the community to establish support, and identifying and addressing issues in relation to such protection (develop a working party)
  - four weeks in the first year
  - one week per year for the first five years to discuss with agencies (on average, including conversations, etc.).
- Investigate options for protecting the sea sponge beds, including the legislation that could be used (one person for one week in the first year, then one week in Year 5).
- Action plan for protection (e.g. signage, community education) – (six weeks of staff time in the first year).
- Find funding for projects to implement the action plan (four weeks per year for Year 1 and Year 2).
- Identify and map the location of sea sponge beds in Wallis Lake (Year 1 – consultant at $50,000; then again in Year 5; then every five years after that).
- On-ground actions to implement Plan (signage, specific actions for erosion remediation, on-land vegetation protection / restoration); Year 3 to Year 8 – big projects at $100,000 [DG49]per year, then $20,000 per year every year after that for new projects and maintenance (for 30 years).
- Four community monitoring events per year (two weeks per year), including preparation and data analysis, cost of event including food for volunteers (one day per event) – every year for 30 yrs (starting in Year 2), and an additional four weeks in Year 1 for design of materials and program (staff time).
- Cost of workshop and advertising two times a year for the first two years to promote the project and recruit volunteers, and once every two years after that.
- Field days / education events / presentations – two weeks a year ever year for the first five years, then four days a year for the following years for 30 years; $150 per year for materials (posters and fact sheets).

The total cost of programs to protect sea sponge beds is $1,290,000 over 30 years.

Improved management of lake use activities

- Consider developing an integrated water quality monitoring program – Year 1 = three weeks staff time to coordinate investigation, $20,000 one-off cost for investigating the integration of monitoring programs.
- Consider review of oyster transport to make the results of flesh testing available before consignment – two weeks full time in Year 2.
- Remove old oyster lease materials – $10,000 spread evenly over 10 years from Year 1.

- Review Stormwater Management Plans to clarify outcomes required to protect the environment and priority oyster growing areas in relation to SEPP 62 – four weeks staff time to coordinate and $30,000 spread over Year 2 and Year 3 for revising the plans.
- MoU with tourism operators – two months full time staff to negotiate and formalise in Year 3.
- Support review of MoU to improve environmental and safety outcomes of wakeboarding – one month full-time staff member on initial negotiations in the first year, then one week each year for the following four years after that for ongoing input to delivering the MoU; $200,000 of upgrades of infrastructure and facilities for wakeboarders in Wallis Lake from Year 3 to Year 10 (spread evenly over each year).
- Investigate the impact and feasibility of closing boat ramps in the lower Wallamba River during high river levels to protect banks from erosion – two months staff time in Year 3 to implement this project.
- Investigate establishing marking poles to identify vulnerable seagrass areas – two months of staff time to set up the project (Year 3), then two weeks each year after that until Year 8 to coordinate the implementation of works; works cost $200,000, spread evenly over Year 4 to Year 8.

The total cost of programs to improve lake use management in Wallis Lake is $575,000 over 30 years.

Improved pollution control systems / management systems

Recommendations are summarised from Section 3.7 of the WQIP.

- Undertake an internal audit of compliance with conditions of consent – four weeks staff time undertaking audit, four weeks staff time developing the management systems to support compliance with conditions of consent (total of two months in Year 1).
- Review the need for a pool of pollution control experts – 1.5 weeks for Council staff, four weeks for a state government staff member (Year 2).
- Review fee structure of On-site Sewage Management Strategy – 1.5 weeks Council staff (Year 1).
- Report on On-site Sewage Management Strategy – one month staff time, $25,000 to develop GIS-based data base for reporting (Year 2).
- Revise On-site Sewage Management Strategy – 1.5 weeks staff time (Year 2).
- Explore the possibility of increasing cross-delegations for compliance with conditions of consent and pollution control regulations – six weeks staff time (Year 2).
- Investigate alternative models for formalising responses to complex pollution cases – 1.5 weeks Council staff time and four weeks state government staff time (Year 2).
- Initiate options for strengthening cross-agency networks – 1.5 weeks staff time (Year 1).

The total cost of programs to improve pollution control systems in Wallis Lake is $60,000.

Ecological monitoring program

The ecological monitoring program is to be undertaken every year unless otherwise stated.

Table A14.25. Wallis Lake – Costs of implementing ecological monitoring program.

Monitoring program	Estimated frequency	Itemised expense (per sampling time)	Estimated cost per occasion	Estimate cost per annum
Monitoring of runoff from high-risk areas	Event monitoring, and hence frequency, depends on rainfall	24 water samples, analysed for nutrients and TSS	24 x $150 Approximately seven events a year	$25,200
		Officer time: Four hours per high-risk area. Assume five high-risk areas	Four x hourly cost of a field officer x five sites = 20 hours = 2.8 days x seven events a year = 20 days a year @ $300 / day	$6,000
		Equipment hire (car, autosamplers, water level sensors)	$150 / day; $30,000 per annum each	
		Data analysis and reporting	One week @ $370 / day	$1,850
Total				$33,050
Best management practice assessments / monitoring at six sites	Three-yearly	Fish sampling?	$3,000 per site x six sites	$18,000 ÷ three years = $6,000
	Three-yearly	Officer time: Riparian and in-stream habitat assessments	Two x one day = $600	$600 ÷ three years = $200
	Three-yearly	Vehicle costs: Riparian and in-stream habitat assessments	Four days @ $150 / day	$600 ÷ three years = $200
		Data analysis and reporting	One week @ $370 / day	$1,850 ÷ three years = $616
Subtotal				***$7,016***
Estuary condition targets				
Chlorophyll and turbidity	Six-weekly = nine samples per year, plus three event samples	Two staff for two days (includes water quality meter calibration)	$1,200	$14,400
		Boat and vehicle use		
		Chlorophyll analyses (24 samples @ $30 each)	$720	$8,640
Seagrass / macrophytes	Quarterly	Community sampling	$1,125 four times a year	$4,500 ~

~ Costs for seagrass monitoring include officer time, car hire and catering for seagrass montiring volunteers. Note cost for seagrass monitoring have not been included in the total cost below.

The total cost of the ecological monitoring program for Wallis Lake is $730,000 over 30 years.

Future investigation relating to the Farm Scale Action Plan (Section 3.3.2 of the WQIP)

The majority of the costs identified in the Farm Scale Action Plan have been costed in the program costs (i.e. the cost of a catchment management practitioner's time to implement the actions identified – Sections 2.7, 2.11 and 2.15 of the WQIP). There are some cases where the Rural Management Practice Technical Group identified the need for additional specialised assistance such as researchers or other experts to assist with implementing the programs. These additional costs are summarised below. Details are outlined in Table 3.3.2 of the WQIP.

- Encouraging landholder uptake of improved management practices
  - future investigation – $60,000 (Year 1), $3,000 (Year 2),
  - future extension – $10,000 (Year 2 to Year 3)
- Riparian management
  - future investigation – $32,000 (Year 2 to Year 4), $60,000 (Year 6 to Year 8)
- Wetland management
  - future investigation – 40,000 (Year 3 to Year 5), $20,000 (Year 2 to Year 4), $2,000 (Year 3)
- Groundcover management
  - future investigation – $5,000 (Year 1), $20,000 (Year 3 to Year 4), $5,000 (Year 2), $10,000 (Year 2 to Year 3)
- Farm infrastructure management
  - future extension – $20,000 (Year 2 to Year 3), $15,000 (Year 2) then $10,000 every year after that
- Nutrient management
  - future investigation – $25,000 (Year 2), $15,000 (Year 2), $10,000 (Year 2), $65,000 (Year 5 to Year 7).

The total cost of future investigation and extension actions to support the farm action plan for Wallis Lake is $735,000 over 30 years.

Adaptive management strategy

The costs of this program are four weeks of staff time each year to do reporting and collating, spread across all lakes. The Wallis Lake contribution to this cost is $165,000 over 30 years.