Applying an Ecological Risk Assessment process to investigate nutrient enrichment in the Curdies River Catchment

A basis for future monitoring and management

June 2005

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CORANGAMITE CMA
HEALTHY CATCHMENTS - HEALTHY WATERWAYS

Applying an Ecological Risk Assessment (ERA) process to investigate nutrient enrichment in the Curdies River Catchment
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ISBN **1 74146 537 0**
Further information regarding this investigation, contact Nerissa Lovric
Telephone: +03 5233 5585
Facsimile: +03 5231 3823
Email: nerissa.lovric@dpi.vic.gov.au

For more information about this program contact the Customer Service Centre on 136 186
For more information about DPI visit the website http://www.dpi.vic.gov.au
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Foreword

"The investigation of nutrient enrichment in the Curdies River Catchment gives us all a better understanding of the characteristics of the catchment, the values and assets of the Curdies River and the threats to the lower reaches of the river and the estuary".

"It provides a basis for future monitoring and management. It is hoped that with a united approach we can improve the health of the Curdies River Catchment, upper and lower reaches of the river and the estuary".

"Improving the health of our rivers is a positive outcome for all".

Andrea Van De Wouw
Dairy Farmer, Curdievale Victoria
Board Member, Corangamite CMA

Preface

Estuaries are naturally highly productive environments. This productivity provides a nursery for juvenile fish, breeding grounds for migratory birds and habitat for numerous terrestrial species, not to mention the many human uses for estuaries. They provide so much and yet are fragile environments, vulnerable to disturbances in the surrounding catchment and the impacts of human activities.

Land-use has greatly increased the quantity of nutrients moving into our estuaries. The increase in nutrient supply, in many cases, has caused excessive productivity in the estuary. This allows opportunistic species such as toxic blue-green algae (cyanobacteria) to out compete other plant species, resulting in habitat loss, decreases in biodiversity, and long-term changes to the ecology of the estuary.

With the ever-increasing demand for the commodities supplied by the landscape more nutrients are being imported to catchments in an effort to gain more products from less land. This intensification combined with rapid coastal development and urbanisation further increases the productivity of our estuaries.

Many estuaries in Australia are now classified as nutrient enriched or eutrophic and have a high amount of phosphorus stored in the sediments. These phosphorus stores can be released during low-oxygen periods, and may now take decades (if ever) to deplete.

The Curdies Estuary in South West Victoria is an example of an estuary that has a history of high nutrient inputs from the catchment. The estuary has a wide, shallow embayment and limited flushing to the ocean. As such the estuary is prone to accumulation of sediment and nutrients.

This study aims to examine the risk to the ecological values of the estuary posed by high nutrient concentrations in the surface water and sediment, and to identify management and monitoring needs to protect the values of the estuary in the future.

The study provides a trial of the EPA's Ecological Risk assessment approach, outlined in the State Environmental Protection Policy (SEPP), (Waters of Victoria) (WoV), 2003.

The project has been funded by the Department of Sustainability and Environment - River Health Program, in conjunction with the Corangamite CMA River Health Program and undertaken by the Department of Primary Industries.

Summary of key recommendations

Key recommendation 1

Any condition targets or management goals that are set for the estuary, take into consideration the fact that there are high concentrations of nutrients in the sediments, that may continue to 'fuel' algal blooms for years to come. The targets should focus on reducing delivery of nutrients to the estuary, to reduce the net accumulation, over the long-term.

Key recommendation 2

Baseline monitoring be conducted to gather more information on the current condition of the estuary, particularly the aquatic and riparian vegetation communities, as they play a major role in providing food and habitat for fish and bird species in the estuarine system.

Key recommendation 3

A nutrient reduction program should be implemented for this catchment based on the results of this investigation into nutrient sources. Further monitoring will be required to fill information gaps, test assumptions and gather more information about the nutrient transport pathways (eg. how important is the role of sub-surface flow?).

Key recommendation 4

As a first step in launching the management program, the community and the various land and water management agencies in this catchment need to review these targets and clearly state whether they support them.

Key recommendation 5

The major focus of the management effort should be invested in addressing diffuse source nutrients from grazing land (particularly dairy farming).

Key recommendation 6

Monitoring of land-use changes in the Curdies catchment should be incorporated as part of an adaptive management program.

Key recommendation 7

Extension programs should be specifically designed and implemented to continue improving nutrient management practices within 'other land-uses', listed in tables 11 & 12.

Key recommendation 8

Monitoring to assess whether targets are being achieved, should be viewed as an essential element of the management program. This monitoring program relies on a long-term funding commitment at least 2006-2011. If funding can be secured, there is potential to use this catchment as a monitoring trial for the Corangamite CMA region.

Key recommendation 9

The use of Bayesian Networks should be further explored for application in a future- 'risk analysis phase' of this project. Implementation of the Curdies Nutrient management program, should seek to include research that will progressively test the current assumptions over the next 10 years. This is important to continue building up the information to better direct management effort in the future.

Water quality monitoring of minor tributaries is recommended as an essential element of the management program.

Contents

Introduction

Project Description

The Corangamite Catchment Management Authority's (CMA) Draft River Health strategy identifies the lower reaches and estuary of the Curdies River as having high social, economic and ecological values. The protection of these values or assets is a high priority for the region, also identified in the Corangamite CMA Regional Catchment Strategy 2003.

Analysis of Water Quality Data collected over the past 15 years from the two long-term monitoring stations in this catchment, has revealed that total phosphorus concentrations in the Curdies River has consistently exceeded the State Environment Protection Policy (SEPP) trigger levels.

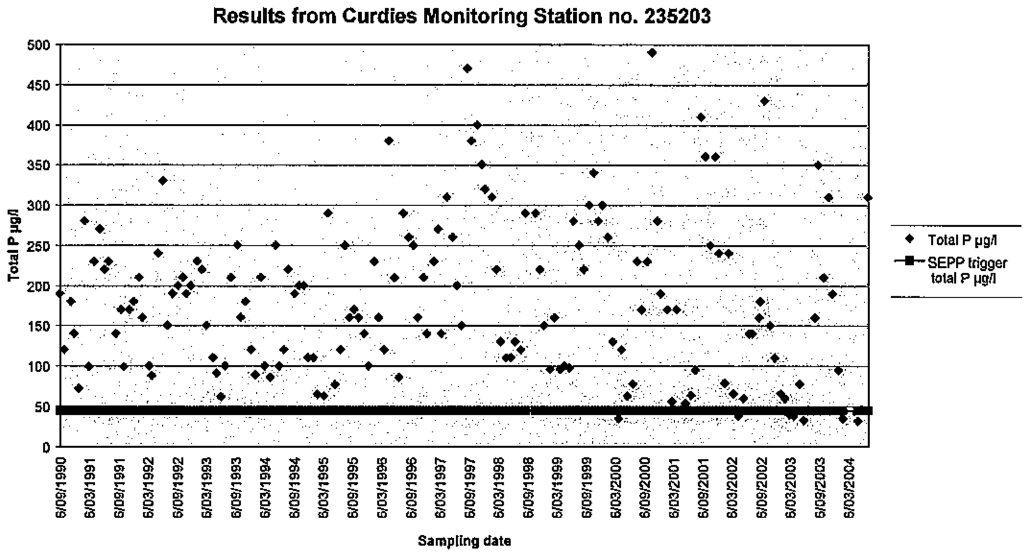
Figure 1 and table 1 show that the Total phosphorus concentration measured in the river is three to six times higher than the SEPP objective of 45 ug/l (for this segment of Victoria).

These results suggest that there is a problem (that is, a potential risk to the ecosystem) and is a 'trigger' for further action.

Given that there have not been any detailed investigations of this issue in the past, it was identified that a risk -based investigation in line with the EPA's Ecological Risk Assessment Framework (ERA) was required (see figure 2).

Analysis of 2004 data from the Victorian Water Quality Monitoring Network (VWQMN) reveals that the Curdies River has exceeded the SEPP objectives for total phosphorus, total nitrogen and dissolved oxygen.

Figure 1. Total phosphorus concentrations from Curdies River monitoring station 235203 have been consistently higher than the SEPP objective of 45 µg/l since 1990.



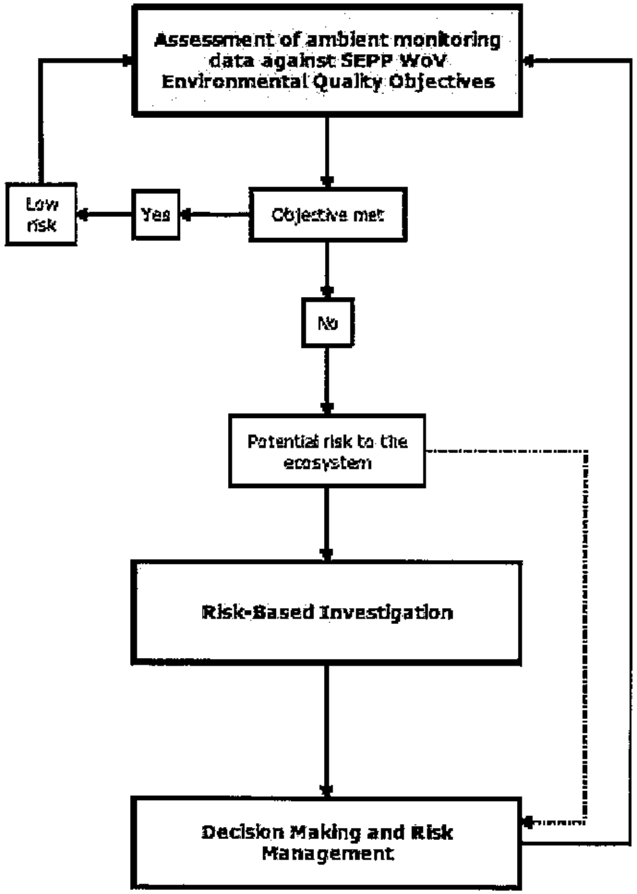


Figure 2. Risk-Based Decision Framework (EPA, 2004).

Figure 2 shows the steps involved in an ERA process. This approach involves organising and analysing data, information, assumptions and uncertainties to evaluate the possibility of adverse ecological effects (EPA, 2004).

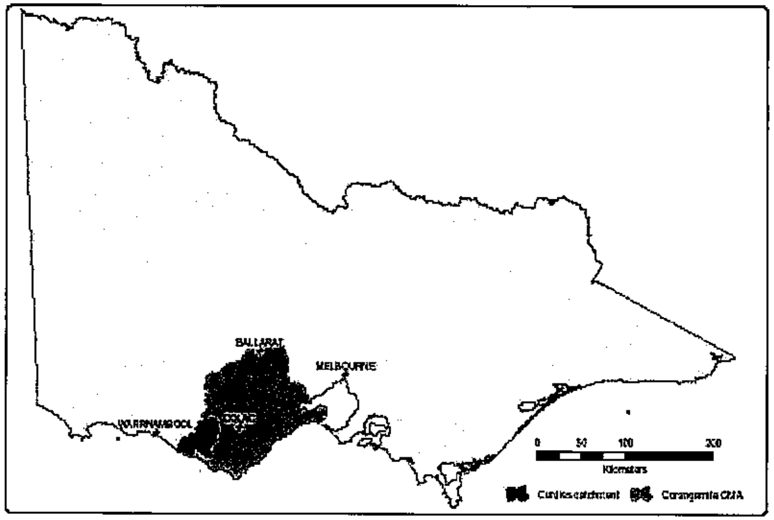
This project has not involved a detailed risk analysis phase as part of the investigation. Instead the ERA approach has been used as a systematic process to examine the issue of nutrient enrichment, develop a better understanding of the Curdies 'system', and provide a basis for the development of appropriate management actions and monitoring activities.

Catchment Characteristics

Catchment size

The Curdies River drains an area of approximately 1064 km^2 and is located in the far southwest of the Corangamite CMA region.

Figure 3. Location of Curdies River Catchment in the Corangamite CMA region.



Major towns

There are three small townships in the catchment- Cobden with a population of 1408, Timboon with a population 690 and Peterborough with a permanent population of 300, (Corangamite Shire Website 2005; Moyne Shire Website, 2005).

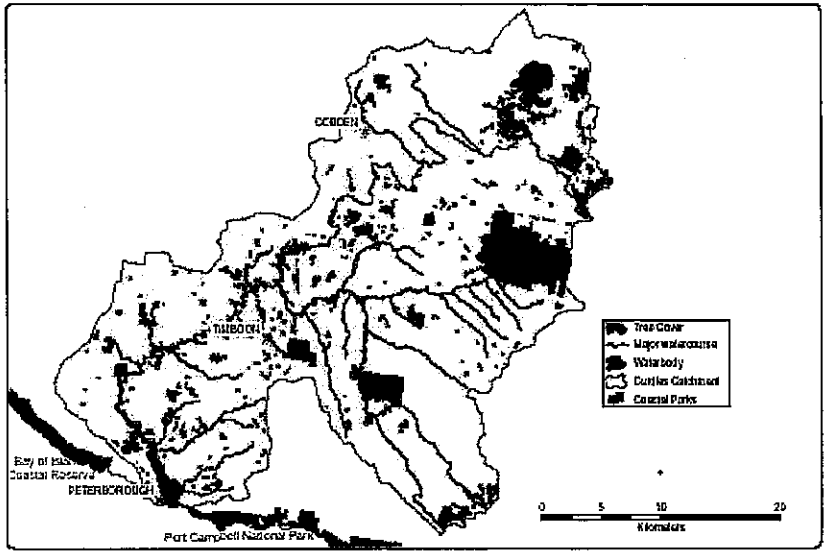


Figure 4. Towns and vegetation of the Curdies River Catchment.

Peterborough is expected to continue to grow over the next 10 years (pers. comms, Moyne Shire 2005). This is due to its coastal location on the Great Ocean Road tourist drive and proximity to National Parks including the world famous Port Campbell National Park and Bay of Islands Coastal Reserve.

Land Use

The Curdies catchment was once heavily forested with wide-scale clearing of the vegetation commencing in the 1940's. Between 1940 and 1970 over 165,000 ha of land was cleared for solider settlement properties, mainly in the Scotts Creek/Cooriemungle catchment (Fisher, 1997), (Figure 5. Data from a 2003 land-use survey of the catchment, revealed that less than 6 % of the original native vegetation cover remains (table 1) (Corangamite CMA Land-use study, 2003).

83.7% of the land in the Curdies River Catchment is currently grazed by dairy cows, beef cattle and sheep). It is estimated that in 2005 dairy farming occupies at least 71% percent of the total land under grazing (table 1).

Data from the Australian Bureau of Statistics identifies the region as one of Australia's most intense dairying catchments (ABS, 2004). A recent survey by Dairy Australia revealed that the average herd size for the South-West Victorian region is 250 cows (Dairy Australia, 2005). Over the past 10 years there has been an increase in the average farm size in the Curdies Catchment, as dairy farms have amalgamated and increased their production targets (ABS, 2001).

Another trend in land-use in the catchment over the past decade has been an increase in land used for plantation forestry, in particular Blue Gum plantations *(Eucalyptus globulus).* It is estimated that over 6,000 hectares have been converted from grazing to hardwood plantations, with a particular increase between 2003-2005 (pers. comms, Corangamite Shire 2005). The data shown in figure 5 was collected using remote sensing in 2003 and hence shows only hardwood plantations prior to this date. The data in table 1 has been updated using the 2005 estimate of area under plantation forestry and shows that this land-use equates to 5.6 % of the total catchment area.

Quarrying of limestone is another small scale use, occupying less than 0.2% of the total catchment area.

Figure 5. Landuse in the Curdies Catchment.

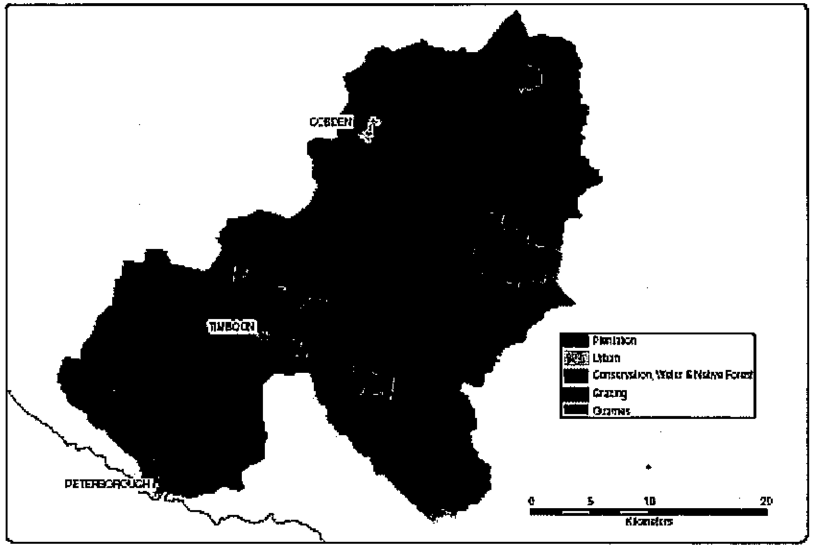


Table 2. Landuse in the Curdies Catchment.

LAND USE	AREA (Ha)	%
Grazing (dairy)	75480	71
Grazing (mixed beef, sheep)	13581	12.7
Nature reserves, remnant vegetation, minimal use	6628	6.2
Urban residential, roads	4352	4.3
Plantation forestry (hardwood)	6000	5.6
Quarries	187	0.2
Total	106228	100

Source: Corangamite Land-use mapping Data, 2003

Plantation Forestry updated for 2005.

Note - the percentage of dairy farming was estimated using an average farm size of 194ha for southwest Victorian dairy farms. *Source* - A Survey of Natural Resource Management on Australian Dairy Farms Technical Report. IRIS Research 2000, Published by IRIS Research Wollongong

1.This figure is an upper estimate of the land area recently converted to blue gum plantations in the Curdies catchment. No official figures were available were available at the time of publication. Rather than underestimate this figure, the figure has possibly been over estimated at the time of publication.

Sub-catchments

For the purposes of this study the catchment has been divided into three subcatchments, which include, in order of size, Scotts Creek/ Cooriemungle (34,723 Ha), The Upper Curdies River (40,744 Ha) and The Lower Curdies River and Estuary (30,547 Ha), (figure 6).

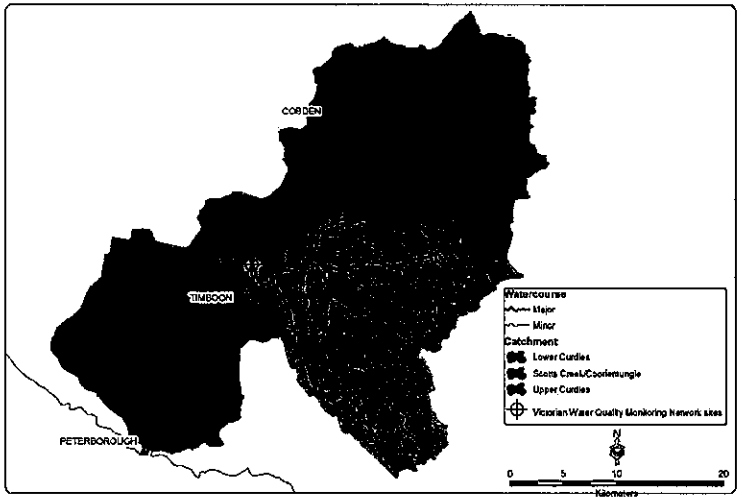


Figure 6. Subcatchments and water quality monitoring stations.

There are two active Victorian Water Quality Monitoring Network (VWQMN) sites in the catchment, which have been collecting nutrient data for fifteen years. Site 235203 is located on the Curdies River at Curdie and site 235237 is located on Scotts Creek at Digneys Bridge (figure 6).

The drainage pattern shown in figure 6, reveals the steeper topography of the Scotts Creek/Cooriemungle catchment and illustrates the density of the drainage network. This pattern is in contrast to the upper catchment, underlain by Quarternary Basalt, the stream starts as a wide shallow channel, cutting into the Tertiary marine sediments just below Cobden and resulting in a deeper incised valley that extends down to Peterborough (Sherwood, 2002).

Values / Assets

The Curdies River estuary has been identified in the Corangamite CMA's Draft River Health Strategy (CRHS) as being a priority waterway of high value to the community. Some of the values identified in the CRHS are as follows.

Environmental Assets

- Wetland rarity
- Significant Fauna - *Faunal species that are critically endangered, endangered or threatened in Victoria have been recorded within a 100 metre buffer of waterway.*
- Significant Flora - *Flora species that are critically endangered, endangered or threatened in Victoria have been recorded within a 100 metre buffer of waterway.*
- Sites of significance - *Waterways that are listed in technical or scientific reports as significant. (Refer to Corangamite Draft River Health Strategy 2004 for more information).*
- Statewide Endangered Ecological Vegetation Communities - *Vegetation communities that are restricted to less than 10% of pre-European extent.*

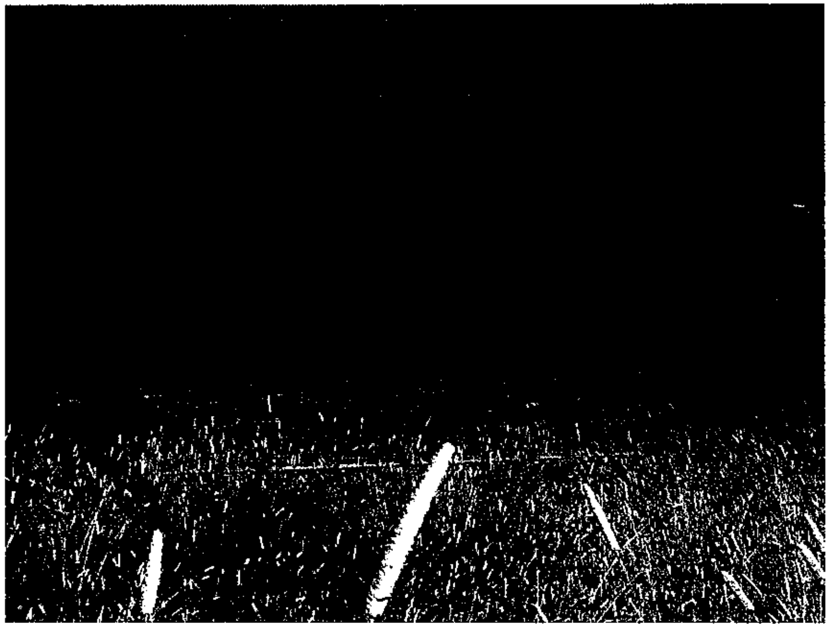
These include:
- Riparian Forest
- Reed Swamp
- Swamp Scrub
- Estuarine wetland
- Migratory Fish (Migratory species use estuary for passage)
- Fish-Proportion Introduced

Economic Assets

- Water Supply (Irrigation)
- Land Value
- Tourism
- Commercial Fishing (eels)
- Migratory Fish (Migratory species use estuary for passage)
- Fish-Proportion Introduced

Social Assets

- Passive Recreation
- Recreational Fishing
- Tourism



Swamp Scrub (Threatened vegetation community found in the Curdies Catchment). Only 2% of original extent remain. Photo courtesy of DSE 2004.

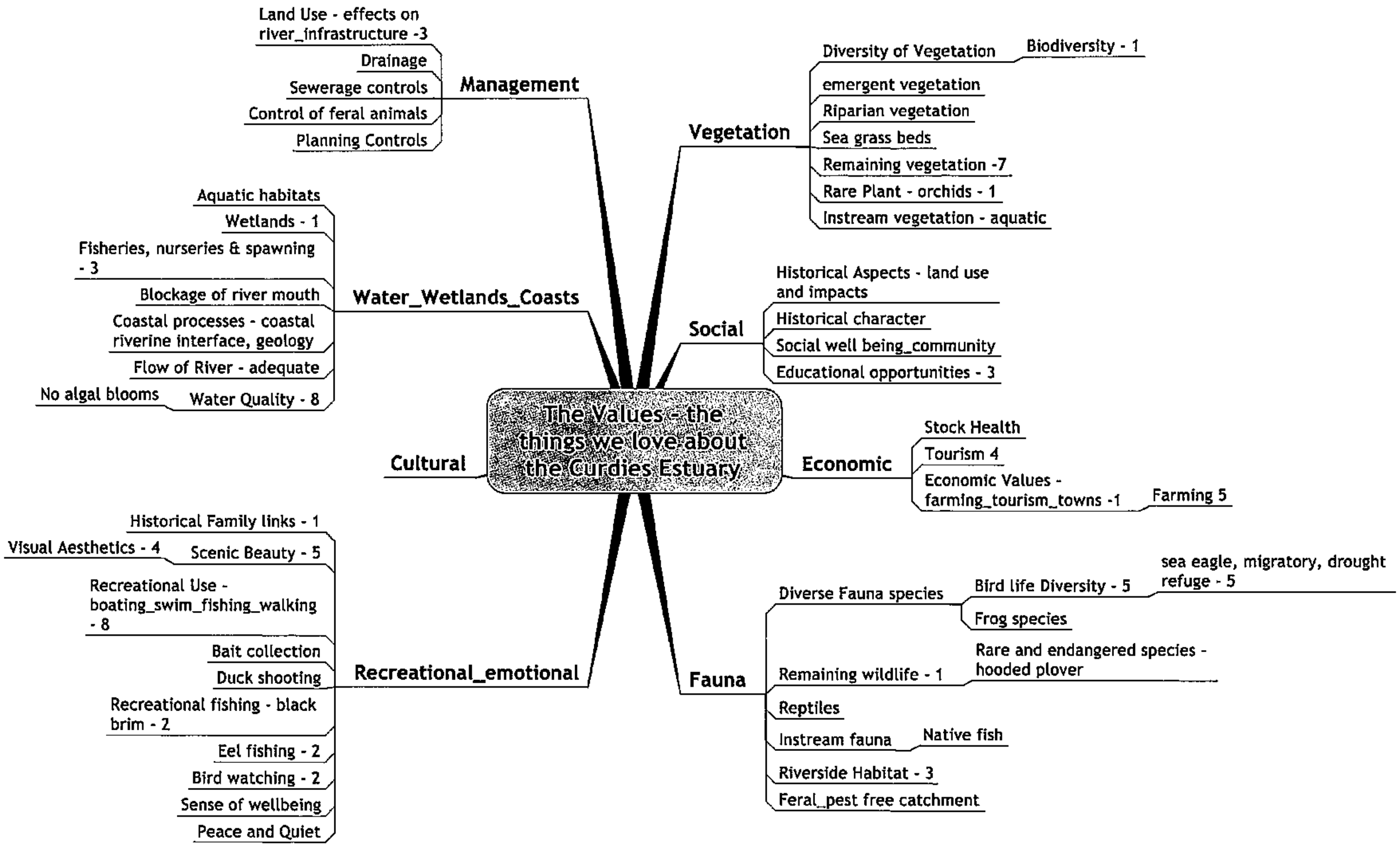
Values / Assets

The area is a popular with bird watchers for its extensive variety of bird species, including rare, endangered and migratory species. (Photograph courtesy of DSE).

Curdies Inlet and lower reaches are a popular recreational fishery renowned for Black Bream. (Photograph printed with permission of angler).

Agile Antechinus found in streamside vegetation of the lower reaches of the Curdies River.

Figure 7. Environmental features of the Curdies estuary of greatest value to the community as identified by the community.



Threats

The Draft Corangamite River Health Strategy, 2004, lists the following threats to River and Estuary health for the lower reaches of the Curdies River.

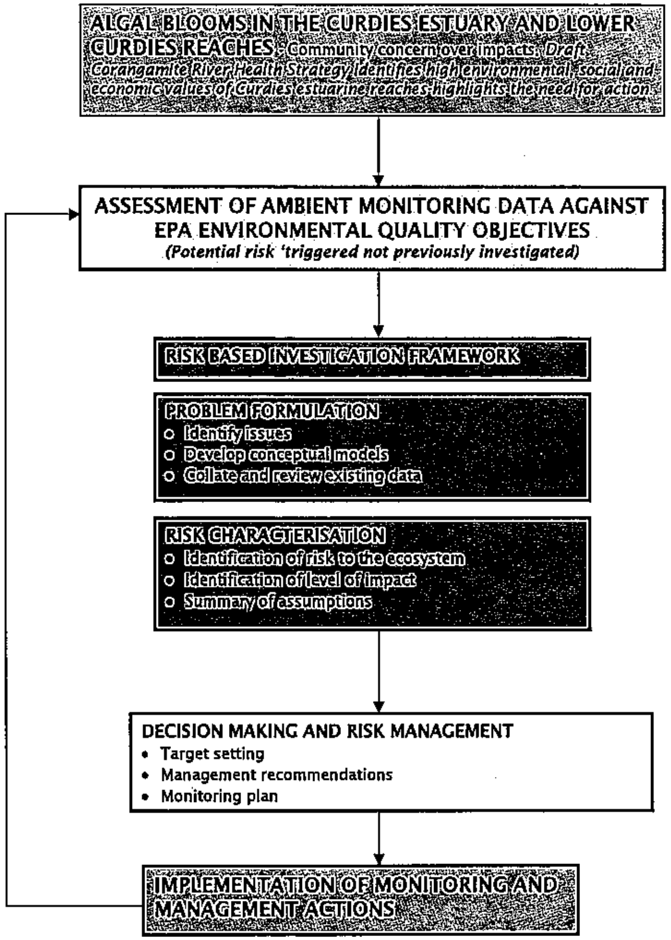
- Algal blooms
- Degraded Riparian Vegetation
- Loss of instream habitat
- Stock access
- Wetland connectivity
- Exotic Flora
- Introduced fauna
- Channel modification
- Water Quality Attainment
- Water Quality trends
- Water Quality Signal

Water Quality Attainment (failure of the VWQMN data to meet SEPP objectives) is highlighted throughout the report several times as a major threat to the Values of the Curdies River and Estuary. As shown in figure 1, the main parameter excessively exceeding the SEPP objectives is total phosphorus concentration.

Scope of the risk-based investigation

As mentioned earlier, the application of the EPA's Ecological Risk Assessment approach in this study has not involved a detailed risk analysis phase. As shown in the below diagram (figure 8) the focus of this study has been on the problem formulation phase, followed by risk characterisation, decision making and monitoring.

Figure 8: Steps followed in this investigation; adaption of the EPA's Framework for risk-based investigations (SEPP (WoV), 2004)



Major reasons for this approach include the fact that we already know there is a high risk of algal blooms occurring in the estuarine reaches of the Curdies as these reaches have bloomed three times in the past 13 years (table 2).

Table 2. Recorded Blue Green Algal Blooms in the Curdies Estuary and lower reaches (1990- 2005).

Date of bloom	Species
March 1991	Anabaena
April 1998	Blue Green Spp
July-August 2003	Nodularia Spumagina

A detailed risk analysis was also beyond the scope of this project, due to time and budget constraints.

Suggestions have been made in the monitoring section of this report as to how this phase could be applied in the future. The risk analysis phase could provide an effective method to incorporate monitoring results and verify the conceptual models which have been developed through the problem formulation phase of this project.

Results

Problem formulation

The first step in the problem formulation phase is to define the issue and the scope of the risk based investigation. The information used to guide these definitions included; the SEPP objectives that were triggered, community input, input from government agencies with management roles within the catchment (Appendix 1), and management goals from the Corangamite Draft River Health Strategy (CRHS).

Issue/Risk; Excessive Plant Growth/Algal bloom, in the Curdies Estuary and estuarine reaches upstream (17 km from the mouth to junction with freshwater upstream).

Timeframe; Risk under current conditions as well as next 10 years.

Management Goal; Healthy Ecosystem, Protection of priority reaches; ecological values- including diversity of vegetation, fish and bird communities

Hazard; High phosphorus concentrations monitored in estuary (via various studies, Appendix 2) and nutrient monitoring results from upstream Victorian Water Quality Monitoring Network (VWQMN) stations (1990-2005) (figure 6).
Sources; Investigate nutrient sources from the entire catchment area (1064 km^2). Point sources include; Cobden sewage treatment plant, Timboon and Peterborough sewage systems. Diffuse sources include; erosion; gully, bank, tunnel, landslips, stock access to waterways, dairy effluent, run-off from nutrient hot-spots on farms eg. tracks, feedpads, overland flow, sub-surface flow.

Measurement endpoints yet to be set (refer to monitoring plan)

The next stage of the problem formulation phase was to develop a Conceptual model, to explore the above issues.

The benefit of using a conceptual model is to provide a transparent and objective approach to examining complex ecological processes. They also allow the influence of multiple 'stressors' to be examined and provide an important basis for developing a risk analysis plan (EPA Victoria, 2004).
In this study the conceptual model was developed in three parts (*or components*);
1. Factors effecting whether an algal bloom will occur in the Curdies Estuary
2. Effects of algal growth/excessive plant growth on values
3. Sources of phosphorus to the estuarine reaches of the Curdies River

The process to develop the model involved gaining input from various stakeholders in the catchment including representatives from government agencies, community members and scientists. This was achieved via workshops, meetings and 1:1 interviews (Appendix 1).

The conceptual model that has been developed now represents a 'shared' understanding of the nutrient enrichment issue in the estuarine reaches of the Curdies River that will be used to provide a basis for the development of management and monitoring actions to address the issue.

It is important to be aware that the model may not be correct. They represent the best current shared understanding of the issue. It is important that future monitoring is conducted to verify and refine the assumptions behind the model. This is an important feature of the ERA approach- it needs to be 'cyclical', the conceptual model needs to be updated as new information is discovered (EPA Victoria, 2004).

Recommendations of the monitoring that will be required to verify the conceptual model in the future, has been identified in the Monitoring plan.

Conceptual models

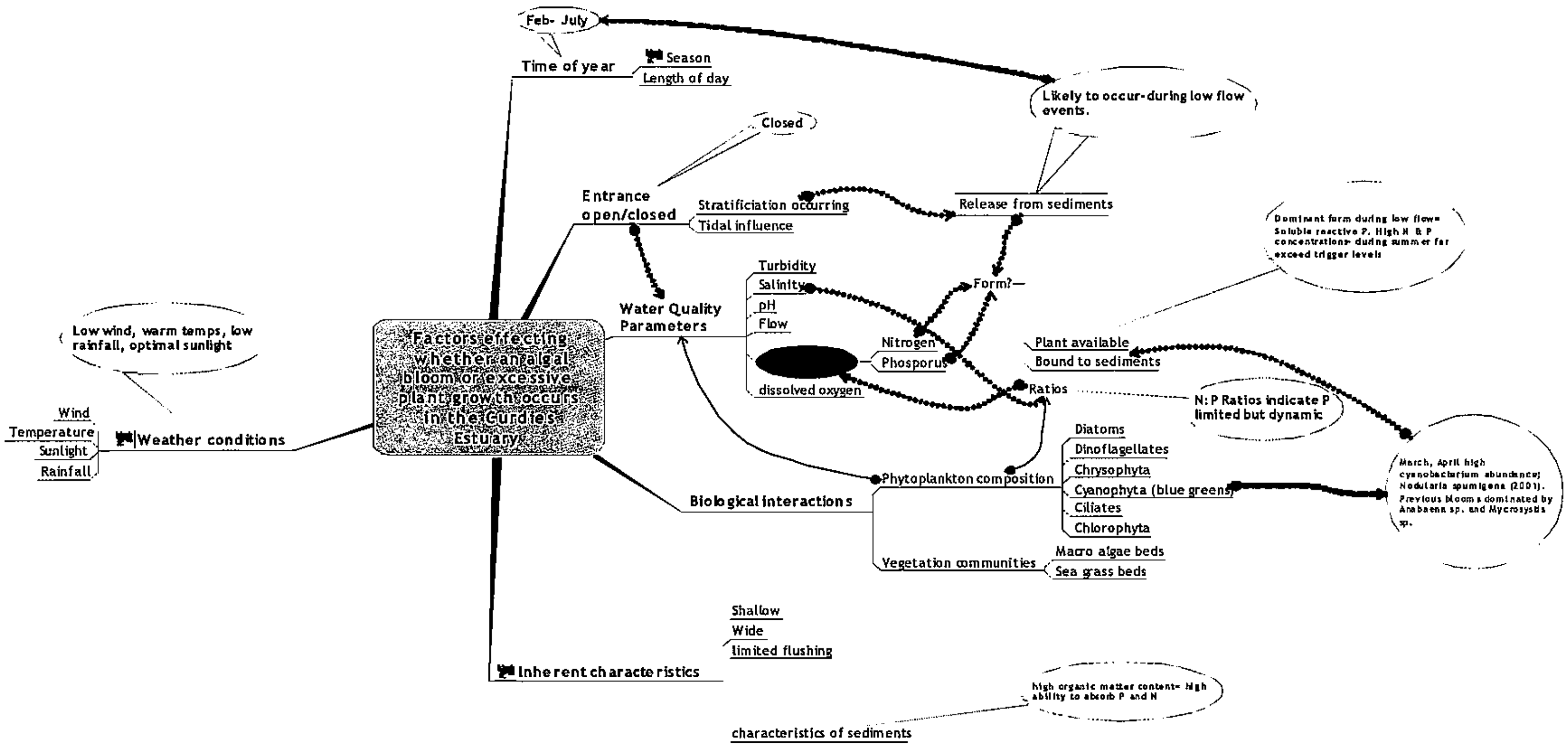
As described above, there are three components to the overall conceptual model developed through this study. Each component will be discussed separately, the overall model showing how the components fit together is shown in figure 7.

Component 1
Factors effecting whether a bloom occurs

The model below (figure 9), was developed to further investigate the factors effecting whether an algal bloom occurs in the estuarine reaches.

The annotated boxes or call outs in figure 9 highlight the high risk times or conditions that would favour an algal bloom. This model emphasised that all the factors are present and there is high potential, under the right conditions to produce a toxic blue-green algal bloom in this estuary. This information is based on past studies of the estuary, and information on previous blooms in this estuary.

Figure 9. Conceptual model of bloom factors.



Summary Component 1
Conclusions

- There is a high risk of algal blooms continuing to occur in the estuarine reaches of the Curdies River, now and over the next 10 years, if no action is taken.
- The risk could be increased under low flow conditions, as this would increase the period of time the estuary is stratified, and thus increase potential for release of nutrients from the sediments.
- The processes described in this model and the high nutrient concentrations in the sediments, need to be considered when setting realistic management goals for the estuary. Even If the phosphorus loads from upstream are successfully reduced, the fact that there is limited flushing of the estuary- means we can expect long-time periods (eg.~50 years) to reduce concentrations of phosphorus in the water column of the estuary.

Key recommendation 1

Any condition targets or management goals that are set for the estuary, take into consideration the fact that there are high concentrations of nutrients in the sediments, that may continue to 'fuel' algal blooms for years to come. The targets should focus on reducing delivery of nutrients to the estuary, to reduce the net accumulation, over the long-term.

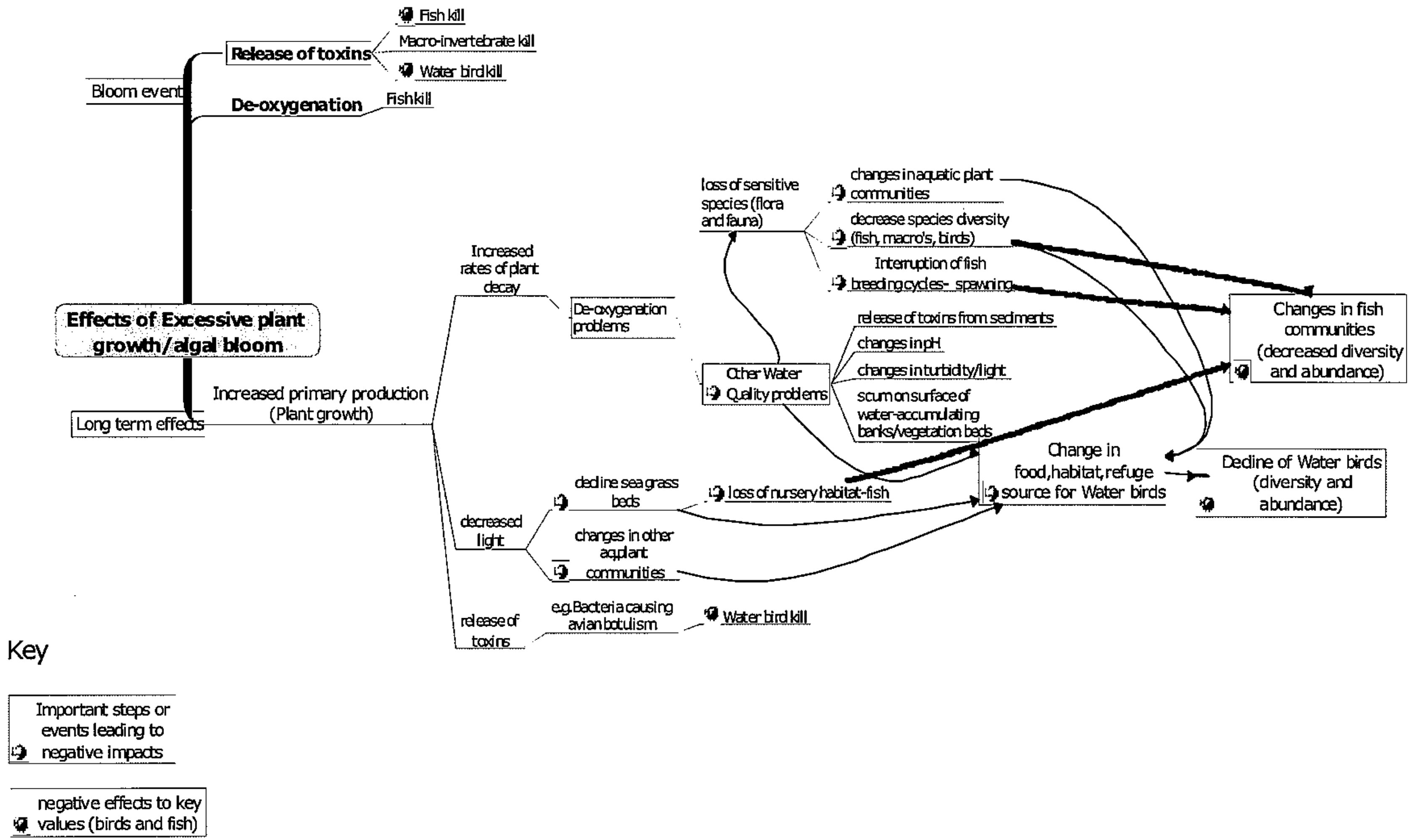
Component 2
Effects of algal growth / excessive plant growth on the values of the estuary

Following on from component 1, we examined the potential for negative effects on the ecological values of the estuary as a result of an algal bloom/or excessive plant growth occurring.

This model (figure 10) identifies that there is potential for two types of impacts; impacts immediately following a bloom event and long-term effects caused by increased rates of primary production.

Whilst developing this model it became clear that there was a lack of monitoring data on the baseline condition of the estuary and the ecological values of the area. This lack of data has made it particularly difficult to assess whether some of the long-term effects (which are often subtle) are in fact occurring.

Figure 10. Conceptual model-Effects of algal growth/excessive plant growth on the values of the estuary.



Key

Summary Component 2
Conclusions and major information gaps

- So far there have not been any reported fish kills, macro-invertebrate or water-bird kills following any of the algal blooms that have occurred in the estuary. This model combined with the component 1 model, highlight that there is potential for this to occur.
- We know very little about the aquatic plant communities (eg. sea-grass communities) in the estuary and their role in providing habitat for fish and bird communities.
- We don't know whether there have already been changes to these aquatic plant communities (NB. A baseline figure of 0.35km^2 was recorded in 1998 through the OzEstuaries- Estuary assessment framework for non-pristine estuaries (Appendix 3).
- Recreational fishers have not reported any noticeable changes in the recreational fish catch (over the past five years).
- Commercial eel fisherman- haven't reported any changes in eel catch (over the past five years).
- Local bird observers- have reported an increase in the appearance of floating algae in areas where migratory waders feed.
- Long-term residents have noticed changes in the riparian vegetation communities- at the upstream end of the estuary. Land that is frequently inundated is now reported to have a lower coverage of the tussock grass species that once grew there.
- General comments have been made by the public regarding an increase in the "murkiness" of the water and the sediment in the shallows of the estuary, possibly indicating increased rates of plant growth and decay.
- The potential link to 'avian botulism'- is currently based on speculation only. During this study (Feb, 2005) approximately 15 Black Swans were found dead in the Curdies estuary. A post-mortem on a swan that had been preserved by freezing- failed to find a cause of death. It has been postulated that the cause was 'avian botulism', which is caused by a type of toxic bacteria released from decaying plant material.

Due to the lack of information on the current condition of the estuary values (as described above) it is difficult to make sound conclusions regarding the extent to which these values have been affected by nutrient enrichment. Some of the anecdotal evidence suggests that we may be starting to see some evidence of long-term impacts.

Key recommendation 2

Baseline monitoring be conducted to gather more information on the current condition of the estuary, particularly the aquatic and riparian vegetation communities, as they play a major role in providing food and habitat for fish and bird species in the estuarine system (refer to Monitoring Plan).

Component 3
Sources of Phosphorus to the estuarine reaches of the Curdies River

The overall conclusion from components one and two is that there is enough information to indicate a high level of risk to the ecological values (particularly fish and bird communities of the estuary), and therefore instigate the decision making and risk management phase of the risk-based investigation (as shown in figure 8).

Further justification is provided by the fact that the SEPP objectives for Total Phosphorus have been triggered on a consistent basis over the past 15 years, indicating a potential risk to the aquatic ecosystem (figure 1).

Due to this and it's role in 'fueling' blue-green algal blooms, phosphorus has been chosen as the major nutrient to target through a management program, It is assumed that many of the nutrient management strategies to reduce phosphorus concentrations will also achieve nitrogen reductions. This is important given that the conditions in the estuary may shift between being limited by phosphorus or nitrogen, depending on the conditions in the area (particularly surface water salinity) see model for component 1.

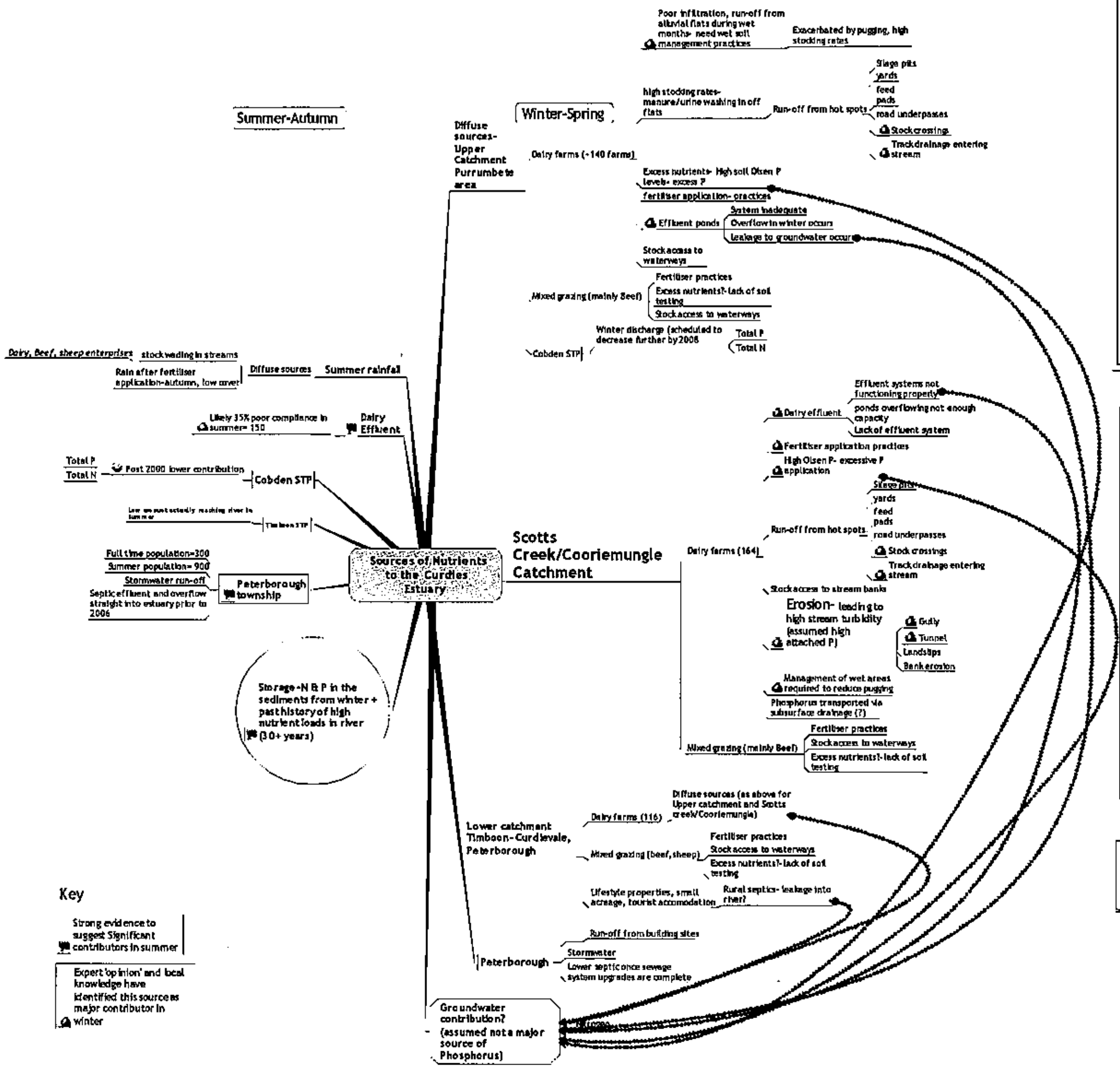
The Corangamite Nutrient Management Plan (CNMP), 2000, states that effective nutrient management strategies must be based on a sound understanding of not only the nutrient sources in a catchment but also a knowledge of the nutrient transport mechanisms. These sources and processes vary greatly between catchments due to the differing influence of land-use, geology, population density, rainfall intensity and erosion (Land & Water Australia, 2002).

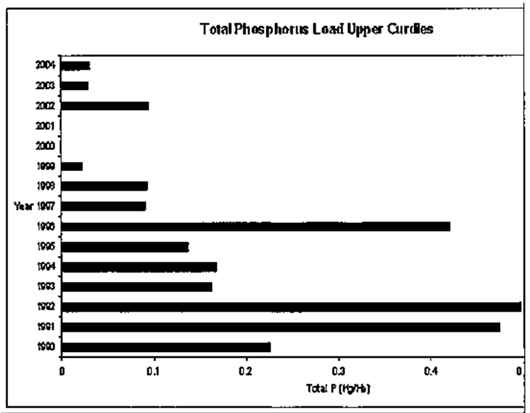
For this reason a detailed investigation was conducted into the relative sources of nutrients (particularly phosphorus) and how they are being transported in the Curdies Catchment, in order to provide a sound basis for management and monitoring recommendations.

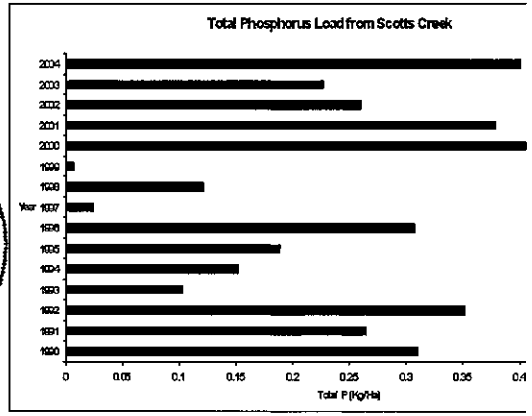
Important definitions to note; Point sources originate from a known activity or process such as a Sewage Treatment Plant (STP). Diffuse sources enter the waterway along its length rather than at defined points, examples include dissolved phosphorus transported in overland flow, phosphorus attached to soil particles mobilised by erosion and animal wastes deposited into streams by stock (CNMP,2000).

The results of the investigation into point and diffuse sources of nutrients in the Curdies catchment are summarised in Figure 11.

Figure 11. Component 3 Sources of Phosphorus to the estuarine reaches of the Curdies River







No data available from to calculate loads from Lower catchment

This conceptual model was developed based on the following information;

- Analysis of 15 years of water quality data from the two VWQMN stations in the catchment (figure 6)
- Quantification of point sources- using available data on concentration and flow *(monthly VWQMN data)*
- Input from scientists 'experts' in freshwater science, aquatic chemistry, nutrient management practicioners
- Input from the community and government agency representatives, based on past experience, observations, local knowledge

For more detailed explanation on the justification for these conclusions refer to Appendix 4.

Summary Component 3 Conclusions and Observations

- The sources and transport mechanisms vary between summer and winter. The highest contributions occur during winter, during high flows.
- Due to the lack of data from lower in the catchment- conclusions can only be made about the relative contributions from the Upper catchment and the Scotts Creek/Cooriemungle catchment (figure 6).
- Of these two catchments the Scotts Creek/Cooriemungle catchment was found to be a higher contributor during recent years (2000-2005) (particularly from diffuse sources). This catchment has a slightly lower catchment area than the upper catchment, however it has a higher discharge (possibly due to differing geology, soil types and topography).
- The nutrient sources in the Scotts Creek/Cooriemungle Creek catchment include a higher amount of erosion than the upper catchment. The stream turbidity data from this subcatchment showed consistently higher results than from the upper catchment.
- Prior to 2000 point sources were significant contributors, particularly from the Cobden STP in the Upper Catchment (refer to total phosphorus load graph above for Upper Curdies and explanations in Appendix 4). The history of high past nutrient loads may be responsible for the high concentrations now in the sediments of the estuary.
- The Timboon STP is a relatively small contributor of N & P (mainly due to recent upgrades and the small population of the town).
- Nutrients in run-off from the town of Peterborough were found to be a relatively small contributor, but were recognised as a significant. The main reason for the high significance is that the town is immediately adjacent to the estuary (low chance for nutrient reductions during transport), these nutrient inputs are highest in summer (peak population), which is the high risk time for algal blooms (component 1 model).
- No data was available to quantify the contribution from groundwater sources. As shown in the model above- this could be a potential pathway for nutrients (mainly nitrogen) to be transported to the estuary.

Other reasons for the higher loads from Scotts Creek/Cooriemungle Creek catchment

- There is a higher amount of sub-surface flow occurring in the Scotts Creek/Cooriemungle catchment. Not only from artificial drains that have been installed in recent years (mainly on dairy farms), other investigations into soil salinisation processes have shown that a lot of water movement occurs laterally through the soil profiles (due to geology, and the soil types (duplex- sandy surface over heavy clay sub-soils).

- According to local knowledge there is a perception that dairy farming in this sub-catchment is more intensive than the other sub-catchments of the Curdies catchment.
- There is a history of intensive fertiliser use in this catchment, since clearing 1970's. It is possible that some of the soils have reached saturation point- with the amount of phosphorus they can store. Excess phosphorus may now be leaching from these soils (particularly in wet conditions).

The high phosphorus and sediment loads from this catchment require urgent action. The nature of this catchment means that there is a high chance the nutrients will be transported via high flows in the main tributary to the estuary.

The shape of the estuary provides excellent conditions for settling out and storing these nutrients and sediments. As shown in the overall model figure 12 below (incorporating components 1, 2 & 3) there is high potential for a negative impact on the ecological values of this estuary. The subsequent economic and social values of the area that are largely based on this natural resource are therefore also at risk.

An aerial view of the shape of the Curdies Estuary.

Key recommendation 3

A nutrient reduction program is designed for this catchment based on the above information. Further monitoring will be required to fill information gaps, test assumptions and gather more information about the nutrient transport pathways (eg. how important is the role of sub-surface flow?).

Decision Making - management and monitoring recommendations

This section aims to;

1. Set targets for a nutrient management program for the Curdies Catchment
2. Make recommendations for a management program designed to achieve these targets
3. Identify priority monitoring activities to a) Evaluate progress towards achieving targets, b) Fill information gaps and test assumptions.

All this information is based on the conceptual models and further builds upon the key recommendations (refer to Summary of Key Recommendations).

Target setting

The draft Corangamite River Health Strategy (CRHS) has identified the following threats and targets for the two lower reaches of the Curdies River.

The following targets are presented in their current form. This section will discuss whether they adequately address water quality goals.

Tables 3 and 4 - Threats posing most risk - to the lower reaches from draft CRHS, 2004.

Table 3. Estuary (reach-1 Length of reach=10km).

Threats Posing Most Risk to Reach	
Threat	Risk Score
Algal Blooms	24
Degraded Riparian Vegetation	21
Loss of Instream habitat	15

Table 4. Curdies River -From Scotts Creek confluence to start of estuary (reach-2, length17.5km).

Threats Posing Most Risk to Reach	
Threat	Risk Score
Algal Blooms	20
Stock Access	14
Degraded Riparian Vegetation	11

Tables 5 and 6 - Ten year Resource condition targets from the draft CRHS, 2004.

Table 5. Estuary (reach-1 Length of reach=10km).

Attribute (from RiVERS Model)	ISC Key Indicator Scores	
	Current	Target
Degraded Riparian Vegetation	Streamside Zone ISC Score 3-4	Streamside Zone ISC Score 5-6
Loss of Instream Habitat	0 Very Poor	2 Marginal
Stock Access	0 Uncontrolled Stock Access	2 50% of Frontage Protected
Vegetation Width	1 5-9m	2 10-29m
Longitudinal Continuity	0 Very Poor	2 Moderate

Table 6. Curdies River -From Scotts Creek confluence to start of estuary (reach-2, length17.5km).

Attribute (from RiVERS Model)	ISC Key Indicator Scores	
	Current	Target
Stock Access	0 Uncontrolled Stock Access	2 50% of Frontage Protected
Water Quality Attainment	**1** **Fails to meet 1 SEPP objective**	**4** **Meets all SEPP objectives**

NB -the above Water quality attainment goal relates to monitoring at VWQMN station 235203 (Curdies) for the SEPP objectives for Total Phosphorus and Total Nitrogen.

Bold text- highlights goals that are relevant to addressing threats from algal blooms/excessive plant growth.

Tables 7 and 8 - Five year implementation targets from the draft CRHS, 2004.

Table 7. Estuary (reach-1 Length of reach=10km).

Activity Within Reach	Number	Unit
Riparian Weed Management	5	ha
Riparian Fencing	10	km
Riparian Revegetation	25,000	plants
Reinstatement of LWD		
River Mouth Management Plan	1	plan
		Sub-Total (1)

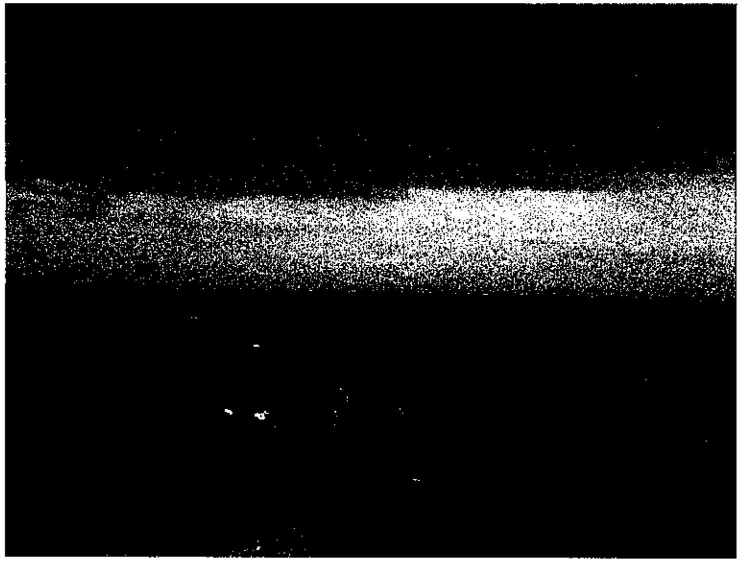


Table 8. Curdies River -From Scotts Creek confluence to start of estuary (reach-2, length17.5km).

Activity Within Reach	Number	Unit
Riparian Weed Management	9	ha
Willow Management	18	km
Riparian Fencing	18	km
Riparian Revegetation	45,000	plants
Upstream Reaches (Curdies River, Scotts Creek and Tributaries)		
Bed Stabilisation	10	km
Riparian Weed Management	76	ha
Willow Management	80	km
Riparian Fencing	135	km
Riparian Revegetation	212,500	plants
		Sub-Total (1)

(Left) Overlooking the Scotts Creek - Cooriemungle catchment - Management needs to take a whole of catchment approach to reducing nutrient loss.

Observations and recommendations from analysis of tables 3-8

- Algal blooms were rated the highest risks in both reaches (tables 3 & 4). The results of this study suggest that an additional threat be added to theses lists; *Nutrient enrichment-.resulting in long-term changes to estuarine ecology.* This threat was identified in component 2 of the conceptual model (figure 10).
- The current 10 year resource condition targets for reach-1 the Estuary (table 5) - do not include targets for addressing 'Nutrients in aquatic environments'. One nutrient target has been set for reach-2- (table 6). This study recommends additional Resource Condition targets are set for these two reaches.
- The rationale behind the five year implementation targets in tables 7 & 8 is: "that the algal bloom threat will be reduced through riparian fencing activities undertaken in reach and upstream reaches and tributaries" (CRHS, 2004). The findings from this study and the latest research in addressing diffuse nutrient sources from agricultural land does not support this rationale. Recent research in Western Australia found that "Fundamentally if we want to reduce nutrient losses to the environment, we need to implement management practices that deal directly with improving utilisation of nutrients on farm, rather than secondary measures that aim to trap or simply delay nutrient losses (Neville & Weaver, 2003).
- Additional five year management action targets have been suggested in table 9 based on management practices that aim to address the problem of positive nutrient balances (particularly on intensive dairy farms)- where nutrient inputs are higher than outputs.

Note: It is important to note that when the Corangamite Draft River Health Strategy was developed, it was recognised that further work would be required to better integrate water quality issues with the broader River Health issues. This need was also acknowledged in the Victorian River Health Strategy, 2002.

It is also important that the reverse applies; water quality targets are developed in the broader context of 'river health'. Tables 3-8 highlight that stock access and degraded riparian vegetation are also threatening the values in these reaches. The fencing and revegetation management action targets in tables 7 & 8 aim to address these threats.

The management action targets recommended from this study are designed to augment the current ones, it is recognised that buffer strips offer secondary control measures for nutrient management, and are extremely important in achieving the overall goals of improving River and Estuarine Health in this system.

Additional targets suggested from this study

By 2015 (Resource condition targets[1])

1. The total phosphorus concentration (75th percentile calculated annually) in the Curdies River at Curdie (VWQMN station 235203) will have shown a trend of sustained and significant decrease over the 10 year time-frame.
2. Water Quality monitoring results from Estuary (monthly monitoring nutrients and flow); Total P and Total N in the water column of the estuary will have shown a trend of sustained and significant decrease over the 10 year time-frame.

[1]*Refer to Appendix 5 for a definition of resource condition targets from the National Framework for Natural Resource Management (NRM), Standards and Targets).*

3. Sediment monitoring from the Estuary; Total N and P monitored in the sediments will show no increase from 2006 baseline measurements.

4. A decrease in the frequency of algal blooms from three in 13 years to less than one in 10 years.

5. No significant negative changes to the extent/ distribution or condition of key habitat types determined for the Curdies Estuary, over a 10 year period.

   (NB- key habitat types for the estuary to be defined; may include- algal beds, intertidal sand and mudflats, seagrasses and riparian salt-marsh communities).

6. No significant changes in species abundance or diversity of bird communities found in the estuary over the 10 years.

Note: Birds have been chosen as a biological indicator for this estuary for the following reasons;

- *They were identified as a key value of the estuary requiring protection- by the local community and management agencies (figure 7).*
- *The extent and condition of key habitat types is important to provide for feeding, shelter and breeding requirements (as with many other fauna species found in the estuary).*
- *They are relatively easy to observe, there are established procedures for bird surveys.*
- *There is a significant amount of local expertise and interest in birds ecology among the local community centred at Peterborough.*

It is important that the community and the various land and water management agencies with a role in this catchment (see Appendix 1) continue to be involved and informed on the findings of this study. A long-term commitment from these stakeholders, is an essential requirement to achieving the above targets.

Key recommendation 4

As a first step in launching the management program, the community and the various land and water management agencies in this catchment need to review these targets and clearly state whether they support them and intend working towards them.

Recommended program of management actions

This section recommends a program of management interventions designed to work towards achieving the 10 year targets listed above. Five year management action targets have been summarised in table 9.

The importance of on-going monitoring and adaptive management in achieving the 10 year targets cannot be over emphasised. It is essential that different approaches are trialed and the impacts are continually assessed. As mentioned earlier the conceptual models described in this study may not be correct, the assumptions need to be tested and results fed back into decision making (see Monitoring section for more discussion re-basing management on the current assumptions without further testing).

Dividing effort between different land-uses

As described in the introduction to this report, the predominate land-use in the Curdies Catchment (in 2005) is dairy farming (71%). Beef/sheep grazing occupies another 12.7% of the land area, equating to a total grazing category of 83.7%.

The findings from this study clearly identified diffuse sources of nutrients as major contributors to the high nutrient loads coming from the two upper catchments, that have been continuously monitored over the past 15 years (figure 11).

For these reasons management practices in grazing, particularly dairying (due to it's intensive nature) are recommended as the major focus of this management action program (tables 9 & 10).

Key recommendation 5

The major focus of the management effort should be invested in addressing diffuse source nutrients from grazing land (particularly dairy farming).

We need to keep in mind however that effective management of diffuse nutrient sources requires a whole of landscape approach (Land and Water, 2000), and it will still be important to maintain momentum in addressing point source nutrient sources in this Catchment. Additionally some of the management practices that are applied in the 'minor' land-uses eg. plantation forestry, limestone quarries, urban centres may need to be addressed in the future (table 12).

Changing trends in land-use in many areas, over recent years have highlighted that land-use is dynamic and may change considerably over the next 10 years. Monitoring land-use changes are therefore a major recommendation, as a critical component of the on-going program of adaptive management.

Key recommendation 6

Monitoring of land-use changes in the Curdies catchment should be incorporated as part of an adaptive management program.

Addressing diffuse source nutrients from grazing land (dairying)

As discussed in component 3 of the conceptual model, there has been very little research to draw on to quantify the contribution of the different sources of nutrients to diffuse run-off from agricultural land. In this study we have relied on the views of an 'expert'panel[1] to further rank the sources. The following categories have been developed as a result of this ranking.

Category 1: Major contributors (There is enough evidence[2] to suggests that these factors are playing a major role in contributing to diffuse movement of phosphorus from this landscape in dairying enterprises.)

- Dairy Effluent (poorly designed systems, lack of maintenance, difficulties in managing in a wet climate)
- Excess phosphorus levels in the soil (over use of fertilisers, build up of nutrients)
- Winter pugging of soils, stock access to wet areas (damage to soil infiltration rates, direct manure input to watercourses, bank erosion, (all exacerbated by high stocking rates)
- Gully erosion and bank erosion in the Scotts Creek/ Cooriemungle catchment.

Category 2: Suspected high contributors- not enough data to make sound conclusions

- Run-off from hot spots (feedpads, farm tracks, stock crossings)
- Fertiliser application practices (lack of calibration of equipment, application prior to rain)
- Sub-surface flow of nutrients through the soil profile (both natural, and via sub-surface drainage).

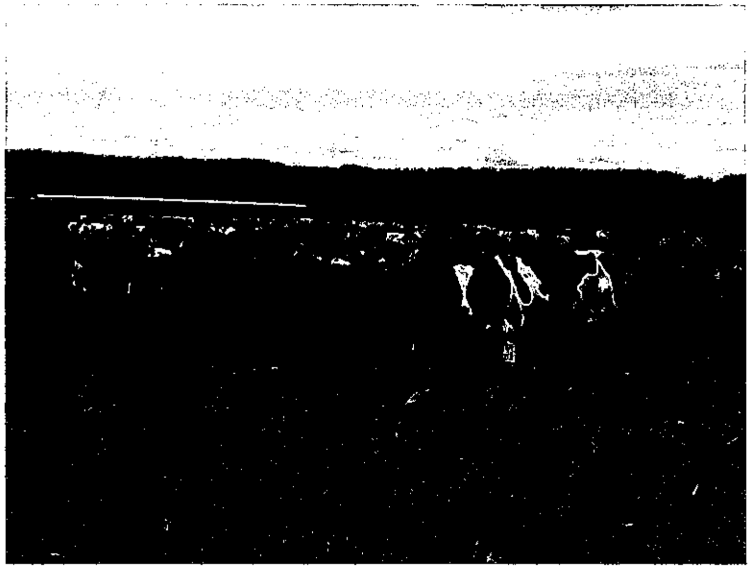
(NB- Although landslips are common in the Scotts Creek/ Cooriemungle catchment, this type of erosion was not identified as a major contributor to stream turbidity and therefore attached phosphorus concentrations (see Recommendations for further research).

Management practices to target these two categories of sources, have been identified in tables 9-10.

Abbreviation- Best Management Practices- (BMP's)

[2] A panel of 'experts' from a range of backgrounds related to nutrient management was formed to inform this project. Refer to appendix-1 for more information on membership.

[3]The 'evidence' referred to includes; knowledge of current management practices, turbidity data, erosion mapping, visual observations in winter.



Dairy farming occupies 71% of the land use in the Curdies Catchment and therefore needs to be a major focus for nutrient management.

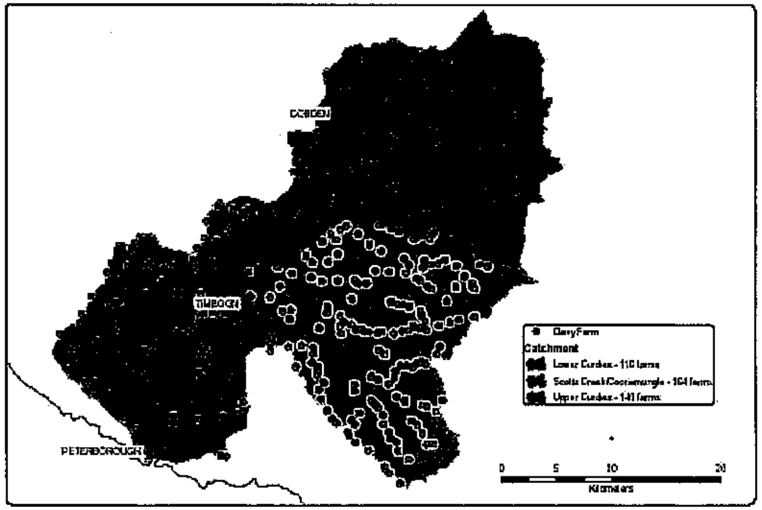


Figure 13. Location of dairy farms in the Curdies Catchment. Mapping in 2005 found that there are a total of 420 farms in the catchment.

Table 9. Management Activities to address category 1 & 2 sources
Dairy farming (2005 mapping- 420 farms in catchment, 71% of the land-use).

Category-1 Sources	**Management Practices to target**	**Relative amount of effort currently invested to promote BMP's (High, Medium, Low[1]) (2005)**
Dairy Effluent	• Assessing current performance of effluent system to identify problems • Upgrading the system to better manage the required volume of effluent (eg.re-sizing ponds) • Improving annual maintenance • Effective use of effluent as a fertiliser (to minimise movement of P off farm)	High*
Excess phosphorus levels in the soil	• Soil testing • Nutrient budgeting • Farm nutrient mapping • Effluent spreading practices	Medium*
Winter pugging of soils, stock access to wet areas	• On-off grazing • Monitoring soil water tables-to assess pugging risk • Land-class fencing-managing wet areas differently (revegetation) • Stand-off areas	Low*
Gully erosion and bank erosion in the Scotts Creek/Cooriemungle catchment	• Identification and prioritisation of gully and bank erosion (early detection and treatment) • Controlling stock access • Fencing and revegetation of erosion prone areas • Appropriate rehabilitation works eg. Drainage diversion.	Low

* High- Major extension and enforcement program currently operating in the catchment- over 80 farm visits per year, aiming to visit every farm in the catchment (co-operative effort-more than one government agency involved).
*Medium- BMP's currently promoted through dairy extension programs, approximately 20 farms involved per year, not targeting any particular geographic area.
*Low- No extension program currently promoting adoption of these practices (may have been past programs, but not a focus in past 5 years).

Table 10. Five year management targets (to address category 1 sources.

Category-1 Sources	Suggested 5 year management action targets
Dairy Effluent	• Dairy effluent audits (84 per year), total of 420 by 2011 • No. of new systems installed (30 per year) total of 150 by 2011 (based on estimate of 35% requiring upgrade). • No. of farm visits by technical specialists re- BMP's for use of effluent as a fertiliser (60 per year, 300 by 2011).
Excess phosphorus levels in the soil	• Completion of a soil condition survey to assess Olsen P levels in the Scotts Creek/Cooriemungle catchment • Baseline survey of the number of farmers soil testing, using a nutrient budgeting approach (aim for 90% responses ~ 380 farms) • Extension program to promote the adoption of nutrient budgeting approach (involve 300 farms by 2011).
Winter pugging of soils, stock access to wet areas	• Baseline survey to assess current adoption of wet soil management practices (aim for 90% responses ~ 380 farms) • Extension program to promote whole farm planning, sensitive management of wet areas (300 farms by 2011.
Gully erosion and bank erosion in the Scotts Creek/ Cooriemungle catchment	• Completion of erosion mapping and development of gully and bank erosion prioritised rehabilitation program by 2007. • No. of farms in the Cooriemungle catchment to identify gully erosion as a priority issue requiring action- on their whole farm plans (65 by 2011) based on estimate of 40% of the total 164 farms in the catchment effected. • Refer to bed stabilisation targets for this catchment (table-9). • Riparian fencing and Riparian revegetation targets (table-9) • *NB- the above estimates will need to be updated based on the results of gully rehabiliation program (2007).*

Table 10 - Five year management targets (to address category 2 sources).

- By 2008 initiate research, to further quantify the contribution of run-off from hot-spots, fertiliser application practices, sub-surface drainage.
- Continue to promote best management practices to address category-2 sources, where opportunities exist (via management action targets for category-1 sources eg. whole farm planning)
- Depending on findings of research- recommend more specific management targets to focus on these sources to incorporate in 2011-2016 management action targets.

Addressing diffuse source nutrients from grazing land (Beef/sheep)

The high risk management practices for nutrient movement from beef and sheep farms have been identified in the below table (table-11). Information has also been included to identify whether there are any current extension/ awareness programs already in place to address these.

Table 11. Beef/Sheep enterprises (unknown no. of farms, 12.7% of the land-use).

High Risk practices- movement of Phosphorus off farm.	Are there current extension/awareness programs to address these practices
Use of fertilisers- excess soil phosphorus	BeefCheque courses- although low involvement from this catchment
Fertiliser spreading practices	Unknown
Uncontrolled stock access to wet areas- drainage lines, stock crossings	Incentives have been provided through landcare (past 5 years)
Gully and bank erosion, particularly in the Scotts Creek/ Cooriemungle catchments	Not a major focus of the Landcare program- but some sites have been picked up- via revegetation projects.

Addressing point and diffuse sources from other land-uses

Table 12. Other land-uses (occupying less than 6% of the catchment area, refer to table 1. Land-use).

High Risk practices- movement of Phosphorus off site.	Are there current extension/awareness programs to address these practices
Urban (towns of Cobden, Timboon, Peterborough)	
Stormwater run-off- increasing risk with future developments (eg. Industrial estate at Cobden, Tourism at Peterborough) could result in increase volumes of Stormwater run-off due to increase in impervious surfaces. Stormwater management needs to be a high priority for these towns.	Corangamite and Moyne Shire Stormwater Management Plans- 2003- Will need on-going implementation and review. Support/encouragement from other government agencies with implementation.
Sewage Treatment Plants- On-going works will be required to continue upgrades to Cobden and Timboon treatment plants.	South-West Water, EPA implementation of current plans for upgrades to Cobden and Timboon treatment plants (as of 2005)
Rural septics-risk of lack of maintenance, leakage- in high rainfall areas (existing systems).	Corangamite and Moyne Shires- *Any person wishing to install or alter a septic tank system must obtain a permit. All systems must be installed in accordance with the Victorian Environment Protection Authority Code of Practice.* No current information on initatives to survey or maintain septic tanks to identify problems.
New dwellings- need to meet standards for sewage treatment, systems designed for high rainfall, local soil types.	Peterborough- scheduled for sewage system upgrade 2006. Moyne Shire and South West Water.
Plantation forestry (hardwood- blue gums)	
Fertiliser application at sowing	The Code of Forest practice is the main document that sets best management practices for plantation forestry.
Soil preparation practices; ripping and mounding- may have erosion risk if steep slopes	Local government has the ability to place specific conditions on permits in relation to distance from waterways, where deemed appropriate..
Harvest operations, soil compaction due to traffic, run-off from tracks, erosion risk after clearing (period of time soil is bare).	Currently there is no specific extension program underway to raise awareness of high risk nutrient management activities, how to minimise nutrient losses from these enterprises.

Key recommendation 7

Extension programs should be specifically designed and implemented to continue improving nutrient management practices within 'other land-uses', listed in tables 11 & 12.

Monitoring Program

As explained in earlier sections, ongoing monitoring is an important part of the Ecological Risk Assessment Approach. It is required to achieve the following objectives;

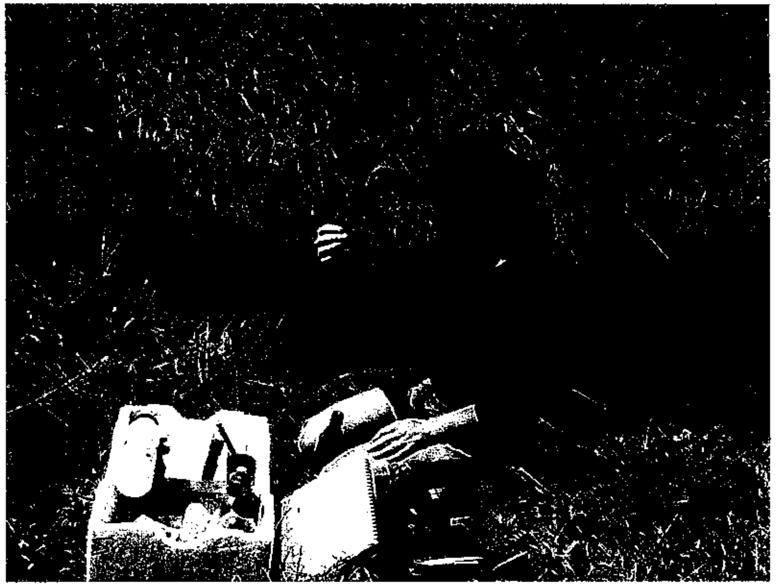
1. Evaluate the effect of management interventions, monitor whether targets are being achieved
2. Fill information gaps, test assumptions, revise the conceptual models
3. Inform the risk analysis phase- adding quantitative data to the conceptual model to allow predictive modelling.

In this section, the types of monitoring have been organised into two sections;
Part A-Minimum monitoring requirements to assess whether the targets are being achieved (objective 1 above)

Part B -Monitoring to better inform and test the assumptions of the conceptual models (objectives 2 & 3)

The monitoring activities have been listed in priority order. It has been recognised that water quality monitoring is not cheap and long-term investment is required (10+ years of data), to make sound conclusions on trends. Wherever possible the use of existing VWQMN stations has been recommended, and low cost methods to fulfil minimum data requirements have been identified.
More detail will be required in the design of these monitoring programs. These lists are intended as a starting point. Even though this section is at the end of this report, it is highlighted that monitoring should not be seen as an optional add on to the management section. It is an integral requirement to continue building an understanding of how the natural system of the Curdies estuary works, and identifying management changes that will protect the ecological values into the future.

Part A - Minimum monitoring requirements to assess whether the targets are being achieved



Brenda Skene, Corangamite Waterwatch Co-ordinator examines a water sample from the Curdies River.

Table 13. 2015 Resource condition targets and minimum monitoring requirements.

Target	Minimum monitoring requirements
1. The total phosphorus concentrations (75th percentile calculated annually) in the Curdies River at Curdie (VWQMN station 235203) will have shown a trend of sustained and significant decrease over the 10 year time frame.	Continue monthly water quality monitoring at VQWMN station 235203 (Curdie) (2005-2015 -ongoing) -VWQMN standard set of surfacewater monitoring parameters[1] NB- Loads can be calculated from this data using discharged (monthly) and Total Phosphorus (monthly).
2. Water Quality monitoring results from Estuary (monthly monitoring nutrients and flow); Total P and Total N in the water column of the estuary will have shown a trend of sustained and significant decrease over the 10 year time frame.	Establish a new continuous monitoring site at the top of the estuary inlet, before the main tributary widens out (refer figure 14). Ideally monitoring would include the VWQMN standard set of Surfacewater monitoring parameters (see below). Data required 2006-2015 - on going.
3. Sediment monitoring from the Estuary; Total N and P monitored in the sediments will show no increase from 2006 baseline measurements	Indicator; Total nutrients in the sediments and total dissolved nutrients in the sediments (see appendix-8 for more details on this indicator). 2006 baseline measurements required plus repeat measurement every 3-5 years.
4. A decrease in the frequency of algal blooms from three in 13 years to less than one in 10 years	Indicator; Frequency of algal bloom monitoring required (appendix-8). Monitoring of algal blooms is opportunistic, the estuary should monitored on frequent basis particularly in summer months or when blooms are more likely.
5. No significant negative changes to the extent/ distribution or condition of key habitat types determined for the Curdies Estuary, over a 10 year period. *NB key habitat types may include; algal beds, intertidal sand and mudflats, seagrasses and riparian salt marsh communities.*	Indicator; Extent/Distribution of key habitat types (appendix-8). Baseline mapping is required to identify critical habitat types, particularly to the bird and fish communities found in the estuary. Techniques include; Aerial photograph interpretation, GIS habitat mapping using underwater cameras fitted with a GPS unit. (Refer to appendix-8 for more details on this indicator). Frequency; re-assess every 2-3 years.
6. No significant changes in species abundance or diversity of bird communities found in the estuary over the 10 years.	Indicator; Number and abundance of bird communities- using the Atlas of Victorian Wildlife survey procedures and guidelines set by the Victorian Bird Observers Club. Frequency- at least twice a year to incorporate breeding season and arrival of migrants. Members of the local community with expertise in this area, are best positioned to carry out these surveys.

[1] VWQMN standard parameters; Surfacewater monitoring- Average annual flow, Average daily flow, Average monthly flow, Average season flow (Mar, Jun, Sep, Dec), Colour (Filt) (monthly), Discharge (monthly), Dissolved Oxygen (monthly), EC (field) (monthly), Instantaneous flow (continuous), Nitrates and Nitrites (monthly), pH (field) (monthly), React. Phosphorus (Filt) (monthly), suspended solids (monthly), Temperature (monthly), Total Kjeldahl Nitrogen (monthly), Total Phosphorus (monthly), Turbidity (field) (monthly).

Implementation of management action targets

1. Detailed records regarding the implementation of management activities will need to be kept, to allow reporting against management action targets (2006-2011). For example; details will need to be recorded on the number of dairy audits conducted per year and this information used to report against the target; Dairy effluent audits (84 per year), total of 420 by 2011.
2. In some cases baseline surveys will be required to assess current adoption rates of particular Best Management Practices (BMP's). Repeat surveys in the future can then be conducted to assess whether changes in adoption rates have occurred as a result of extension programs.
3. The baseline soil condition surveys that have been described in the management action targets will serve two functions. For example the soil condition survey to assess baseline Olsen P levels in the Scotts Creek/ Cooriemungle catchment will 1. Seek to confirm whether a build up of soil phosphorus levels is occurring in this catchment and 2. Provide a baseline assessment of the Olsen P concentrations on dairy farms in 2006, that can then be reassessed in 2011, allowing comparison. The baseline surveys of wet soil management practices and gully erosion mapping will also serve similar purposes eg 1. testing assumptions and 2. providing a baseline assessment for future comparison.
4. As previously mentioned, on-going monitoring of land-use is required in this catchment. Repeat surveys of the 2003 Corangamite CMA Land-use mapping- using remote sensing, are recommended every five years.

<u>**Key recommendation 8**</u>

Monitoring to assess whether targets are being achieved, should be viewed as an essential element of the management program. This monitoring program relies on a long-term funding commitment at least 2006-2011, if the funding can be secured, there is potential to use this catchment as a monitoring trial for the Corangamite CMA region.

Part B Monitoring to better inform and test the assumptions of the conceptual models

Component 1
Factors effecting whether an algal bloom/ excessive plant growth will occur (figure 10)

Key Monitoring requirements

1. Physio-chemical conditions present in the estuary when an algal bloom occurs- Eg. nutrient concentrations in the water column, chlorophyll 'a', light, temperature changes with depth. It would also be useful to know the length of time the estuary remains stratified, and therefore the length of the risk period for algal blooms.
2. Sediment fluxes- how much phosphorus and nitrogen is stored in the sediments?, under what conditions

does release of nutrients occur?, what role does storage of nutrients in the sediments play in 'fuelling' blue-green algae blooms. This information would be particularly useful in setting realistic targets/timelines for reducing the frequency of algal blooms. Monitoring to answer these questions would need to be specifically designed, it may be suited to a pHD or post-graduate project.

3. Detailed monitoring of the phytoplankton communities in the estuary, would provide more information as to what species of algae might be at risk of blooming, other than blue-greens, and which other species pose a high risk of a bloom, under certain conditions.

Component 2
Effects of the nutrient enrichment issue on the ecological values of the estuary

Key Monitoring requirements

1. As previously mentioned there are major information gaps on the baseline condition of the estuary- what are the key habitat types? Eg. aquatic vegetation communities, what condition are they currently in?, are they showing any impacts from nutrient enrichment?
2. Fish communities- baseline monitoring is required to answer the following questions; how diverse are they? Are sensitive species present?, is nutrient enrichment currently posing a threat to their breeding cycles?

3. Bird communities- similar to the above, what is the baseline diversity and abundance?, any evidence of changes- compared to historic records. Which key habitat types are essential to the rare/endangered species, what requirements are the migratory species relying on?

4. Macro-invertebrate communities of the estuary, monitoring to assess diversity and abundance, baseline survey- are sensitive species present, are the communities dominated by algal grazers?, what does the data indicate about the biological health of the estuary?.

5. Rates of plant decay, monitoring of dissolved oxygen levels, light, turbidity, at different times of the year, what is the trophic status of the estuary? What are the productivity levels of the estuary? Is it phytoplankton dominated?.

6. Presence of toxins eg. bacteria causing avian botulism- are there any plants producing these toxins in summer?

Component 3
Sources of Nutrients from the Curdies River Catchment

Key Monitoring requirements to fill information gaps

1. Improving the coverage of the current monitoring data- to better estimate contributions from sub-catchments. Installing a monitoring station at the top of the inlet at Peterborough (figure 14), would allow nutrient loads to be calculated from the lower catchment (see figure 13 contains 116 dairy farms). Installing additional monitoring stations- one higher in the upper catchment and one at the confluence of Cooriemungle creek and Scotts Creek, would improve the ability to make conclusions on whether management changes in these catchments were having an effect. figure 14 lists the priority of these stations and shows locations.

2. Additional Waterwatch monitoring could be used to supplement the information on which sub-catchments

are contributing high loads. Establishing monitoring sites on some of the minor tributaries lower in the catchment such as Spring creek (lower catchment), would help identify any additional hot-spots- that may have been missed.

3. Additional Storm-event sampling at Curdie station 235203 would be useful to gauge by how much the nutrient levels are under estimated- through the monthly sampling.

4. Transport processes- Monitoring various soil nutrient transport pathways (surface, interflow (sub-surface flow), leaching in major soil types under different conditions. This information will assist in designing effective best management practices.

5. Process studies to examine the effectiveness of best management practices designed to reduce nutrient movement to streams. This could involve farm scale monitoring of water quality- (at locations high in the catchment – headwater, or low order streams) either in paired catchments with and without management practices in place, or before and after experiments designed to detect water quality and nutrient load changes as a result of BMP implementation.

6. Groundwater- further monitoring is required to establish the role that groundwater may be playing in deliverying nutrients to the estuary.

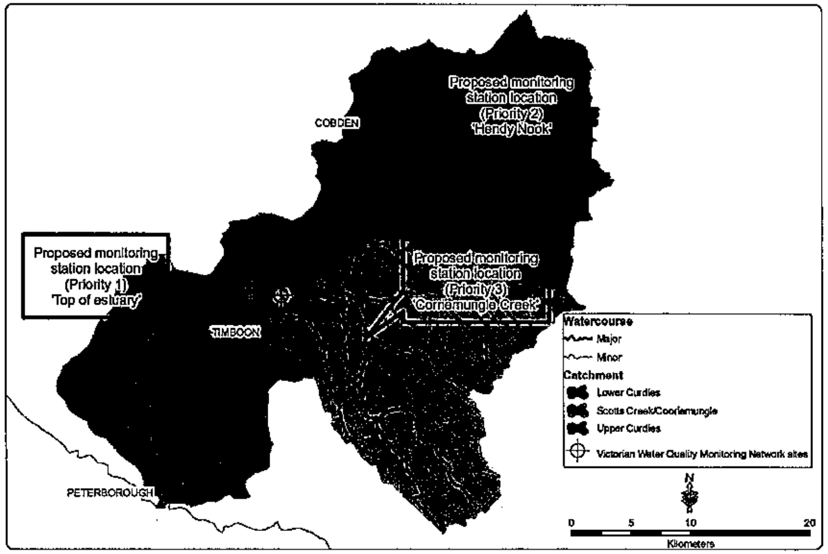


Figure 14. Suggested location of new monitoring stations.

Concluding comments on monitoring

There would be considerable cost involved with implementing all of the above monitoring recommendations. Decisions need to be made regarding the confidence we have in the current assumptions of the conceptual models, and how much funding should be allocated to testing the assumptions, versus how much funding to allocate to implementing management based on the current information.

In weighing up these decisions we need to consider the implications of acting on false assumptions. The problem with this is that we may have to wait at least 10 years (and spend large amounts of funding collecting intensive data over this time), until we can actually conclude whether water quality is improving. For this reason water management agencies are increasing their use of predictive models to forecast the effects of management actions on water quality.

One of the tools to perform predictive modelling involves the use of Bayesian Networks. Baysian Networks are diagrams that show the cause and effect relationships about particular systems and includes information on how much and in what way one part of the system affects another (EPA Victoria, 2005). They are essentially conceptual models with quantititative data incorporated, to help identify the role of each factor, and highlight which factors are most important.

Given that a conceptual model has now been established for the Curdies system, there is potential to go to the next step and turn this into a Bayesian Network. The Ecological Risk Assessment approach, recommends the use of these networks, particularly in the risk analysis phase of the framework.

In this case bayesian networks could provide a useful way of incorporating the results of future monitoring to improving our understanding of the Curdies System.
This would be possible as the networks are easy to adapt and change as new factors come into play, the "network" can learn from additional data and become better at predicting outcomes (EPA Victoria, 2005).

The ultimate benefit would be that in managing the Curdies system, managers could have more confidence in the chance that particular management actions will lead to the expected outcomes. This approach would also assist with the process of setting realistic management targets, and regularly revising them as new information becomes available.

Key recommendation 9

The use of Bayesian Networks should be further explored for application in a future 'risk analysis phase' of this project. Implementation of the Curdies Nutrient management program, should seek to include research that will progressively test the current assumptions over the next 10 years. This is important to continue building up the information to better direct management effort in the future.

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Appendix 1

List of stakeholders involved in the Curdies Nutrient Study (Jan, 2005- June 2005)

Community workshop participants/advisory group representatives

Name	Organisation/Representation
*Ron Irvine	Frontage owner- Curdies Estuary- Peterborough
*David Smurthwaite	Landcare Network Representative
*Dean Drayton	Dairy Farmer
*Shane Delaney	Dairy Farmer, Curdies Inlet and Recreation Reserve committee
*Mary & Merv Holloway	Dairy Farmers Upper Catchment
*Rosemary Bufton	Farmer/Naturalist
*Andrea Van De Wouw	Dairy Farmer
*Richard & Jenny Stevens	Local Bird Experts- frontage owners, Peterborough
*Margaret Gristede	Estuary frontage landholder
*Betty Davis	Lower Curdies Landholder
Steve Cummings	Estuary Frontage Landholder
*Bec McCann	Landcare Coordinator
Anne & Bill Fraser	Local Naturalists
Ian McConnell	Dairy Farmer
Jim Moulton	Friends of Bay of Islands Group
Fred Baxter	Long time resident of upper Curdies district
Rusty Taylor	Local Eel Fisherman
Neil Trotter	Schomberg Inn Publican- local resident Peterborough

*Denotes community advisory group representatives

Technical Advisory Group

Name	Organisation/Representation
John Turner	Corangamite CMA
Dr. David Tiller	EPA Victoria, Freshwater Sciences Unit
Clare Putt	EPA Victoria, Freshwater Sciences Unit
Dr. Helen Arundel	Western Coastal Board
Professor John Sherwood	Deakin University, Warrnambool
Dr. David Weaver	Nutrient Management Project, Agricultural Resource Management Program, Department of Agriculture (W.A.)
David Blythe	Environmental Officer, South West Water
Kath Gosden	Environmental Officer -Moyne Shire
Russell Guest	Planning officer- Moyne Shire
Lyall Bond	Planning & Environment Officer Corangamite Shire
Angus Ramsey	Licencing officer, Southern Rural Water
Graeme Ward	Dairy Research Officer, Primary Industries Research Victoria
Scott McDonald	Statewide Nutrients Coordinator - Dairy Program, DPI Kyabram
Steve McDougall	DSE-Biodiversity Officer
Brenda Skene	Corangamite CMA Waterwatch coordinator
Ann McDowell	EPA, Dairy Effluent Officer
Craig Murdoch	Fisheries Management, DPI Colac
Kate Maltby	Parks Victoria
Ailsa Morris	Parks Victoria
Ross Martin	DSE Crown Land Management
Neil Martin	Framlingham –Cultural Heritage Co-ordinator

Appendix 2

Curdies Estuary Studies 1990-2001

Lucus, T. 1990. *A study of the physical and chemical parameters of the Curdies River.* (Project report). School of Ecology and Environment, Deakin University, Warrnambool.

Key findings:

- During summer and low flows the phosphorus concentrations in the Curdies River downstream of Cobden were found to be 3.6 times greater than upstream of Cobden. Similar trend for Nitrogen and oxygen.

Pearce D. 1994. *Extent of Eutrophication of the Curdies River Estuary.* (Project report). School of Ecology and Environment, Deakin University, Warrnambool.

Key Findings:

- Estuary is nitrogen limited
- The estuary is eutrophic due to the high influx of nutrients

Maher, P. 2001. *Nutrients and Phytoplankton of the Curdies River, Southwest Victoria.* (Honors thesis). School of Ecology and Environment, Deakin University, Warrnambool.

Key Findings:

- 74% of Sites Sampled for phosphorus fell into the Office of the Commisioner for the environment (OCE) degraded category (a serious decline of natural ecosystems)
- 91% of sites sampled had phosphorus concentrations higher than ANZECC trigger levels.
- Total Phosphorus concentration decrease in the upper catchment over the past decade
- A point source with an unusually high concentration of phosphorus must have been entering the river during previous studies
- Curdies Estuary Sediments are typically phosphorus limited
- Curdies Estuary Sediments contain large quantities of organic matter
- Ground water contains high nitrogen concentration and low phosphorus concentration. Groundwater contribution considered not significant.
- Scotts Creek/Cooriemungle Creek is unlikely to be a major source of nutrients to the Curdies River.
- Cyanobacteria Nodularia spumigena present in concentrations high enough to constitute an algal bloom
- Previous Blooms were dominated by Anabaena and Microcystis sp

Appendix 3

ESTUARY ASSESSMENT FRAMEWORK FOR NON-PRISTINE ESTUARIES
Estuary 630 (CURDIES INLET)

Estuary ID 630

Name CURDIES INLET

Location

Latitude / Longitude -38.608 142.883 **Datum** GDA94

Condition Assessment This estuary is in modified condition

Initial Classification In the first stage of this condition assessment this estuary was classified as being modified.

Basis of Initial Classification This was based on the changes to the estuary ecology: nutrient loads.

Processed-Based Classification

The way Curdies Inlet functions is primarily a result of wave energy. It is a wave dominated estuary. This means that the estuary would have high sediment trapping efficiency; naturally low turbidity, salt wedge/partially mixed circulation and there is high risk of sedimentation.

Issues:

General Comments / Notes:

	Notes, Data and Supporting Qualitative Text	Rating (1-4)	Data Confidence	References
STATE COMPONENT (OVERALL)		3	C	
ECOSYSTEM INTEGRITY INDEX			D	
Eutrophication				
Chlorophyll a (µg/L) [median(80th)] HEAD				

Estuary 630 (CURDIES INLET)

Chlorophyll a (µg/L) [median(80th)] MIDDLE
Chlorophyll a (µg/L) [median(80th)] MOUTH
Chlorophyll a (µg/L) [median(80th)] AVERAGE
Harmful algal blooms
Turbidity [median(80th)]
Turbidity (NTU or secchi depth) HEAD
Turbidity (NTU or secchi depth) MIDDLE
Turbidity (NTU or secchi depth) MOUTH
Turbidity (NTU or secchi depth) AVERAGE
Shellfish closures
Fish/bird kills
Pathogens
Faecal coliforms (no/100mL) [median(80th)] HEAD
Faecal coliforms (no/100mL) [median(80th)] MIDDLE
Faecal coliforms (no/100mL) [median(80th)] MOUTH
Faecal coliforms (no/100mL) [median(80th)] AVERAGE
Critical habitat loss
Anoxic and hypoxic events
Invasive species

ESTUARY ASSESSMENT FRAMEWORK FOR NON-PRISTINE ESTUARIES

Estuary 630 (CURDIES INLET)

	Notes, Data and Supporting Qualitative Text	Rating (1-4)	Data Confidence	References
HABITAT CONDITION INDEX	No deviation calculated		D	2
Seagrass species present				
Seagrass coverage	35000 m2			1
Mangrove species present				
Mangrove coverage				2
Saltmarsh coverage				2
Wetland coverage				

	Notes, Data and Supporting Qualitative Text	Rating (1-4)	Data Confidence	References
FISH CONDITION INDEX			D	
Diversity	Fish species present: Yellow Eyed Mullet, Short-finned Eel, Long-finned Eel, Lesser River Goby, Common Galaxias, Black Bream, Australian Smelt, Sea Mullet			
Abundance				
Health				
Recruitment				

	Notes, Data and Supporting Qualitative Text	Rating (1-4)	Data Confidence	References
WATER QUALITY INDEX			D	
Nutrients [median(80th)]	Data exceeds ANZECC but is variable			3
Dissolved oxygen [median(20th)]				
Dissolved oxygen [surface] (%sat or mg/L) HEAD				

ESTUARY ASSESSMENT FRAMEWORK FOR NON-PRISTINE ESTUARIES

Estuary 630 (CURDIES INLET)

Dissolved oxygen [surface] (%sat or mg/L) MIDDLE				
Dissolved oxygen [surface] (%sat or mg/L) MOUTH				
Dissolved oxygen [surface] (%sat or mg/L) AVERAGE	8.95 (8.573) mg/L	1	A	1
Dissolved oxygen [bottom] (%sat or mg/L) HEAD				
Dissolved oxygen [bottom] (%sat or mg/L) MIDDLE				
Dissolved oxygen [bottom] (%sat or mg/L) MOUTH				
Dissolved oxygen [bottom] (%sat or mg/L) AVERAGE				
pH				
Heavy metals				
Are heavy metals a problem in this estuary (Y/N)?				
Other toxicants (including pesticides)				
Salinity	4.512; 3.25 (5.75)		A	1
Temperature				
Depth				
Ammonia (μg/L) AVERAGE	0.400 (0.532) [mg/L]		A	1
Oxidised nitrogen (μg/L) AVERAGE	0.166 (0.476) [mg/L]		A	1
Phosphate (μg/L) AVERAGE	0.338 (0.679) [mg/L]		A	1

	Notes, Data and Supporting Qualitative Text	Rating (1-4)	Data Confidence	References
SEDIMENT QUALITY INDEX			D	
Sediment toxicants				
Sediment load TN				
Sediment load TP				
Invertebrate diversity				

Invertebrate abundance

	Notes, Data and Supporting Qualitative Text	Rating (1-4)	Data Confidence	References
PRESSURE COMPONENT (OVERALL)			D	
UTILISATION INDEX	1995 BRS data: Crop/pasture & Plantations comprise 0 % of the catchment. Native woody vegetation comprises 12.6071 % of the catchment.		D	4
Recreation Pressure				
Aesthetic & Amenity	Present			1
Yachting & Boating	Absent			1
Shellfish	Present			1
Swimming	Present			1
Recreational Fishing	Present			1
Infrastructure Pressure				
Sewage Treatment Plants	None			1
Urbanisation and urban runoff	Present Peterborough township			1
Dredging	Present - mouth opening			1
Commercial Pressure				
Industry	Absent			1
Aquaculture	Absent			1
Reclamation / Declamation	Absent			1
Commercial fishing	Present - eel fisheries			1
Tourism	Present			1
Agriculture	Present			1

ESTUARY ASSESSMENT FRAMEWORK FOR NON-PRISTINE ESTUARIES

Estuary 630 (CURDIES INLET)

	Notes, Data and Supporting Qualitative Text	Rating (1-4)	Data Confidence	References
Habitat clearing				
Ports & Port Works	Absent			1
Shipping Activity	Absent			1
SUSCEPTIBILITY INDEX			D	
Flow-modifying structures				
Catchment loads				
Flows and flushing				
Acid sulphate soils				
RESPONSE COMPONENT (OVERALL)				
Institutional Arrangements				
Management Actions				
Community Initiatives				
Details of References	1. VIC state data, 2. AGSO, 3. Expert opinion through state workshop, 4. Derived from BRS landcover data			
Key Contacts				

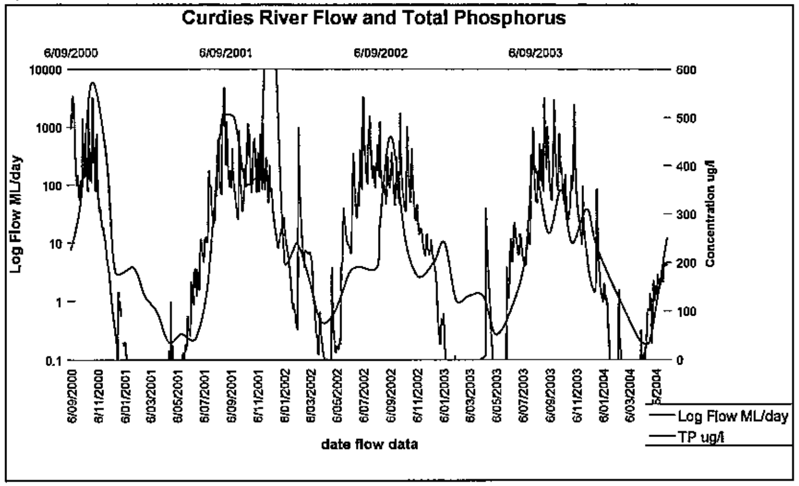
Appendix 4

Results of Nutrient Source Investigation

Diffuse Versus Point Sources:

The sources and transport mechanisms vary between summer and winter. The highest contributions occur during winter, during high flows. Similar trends occur for nitrogen and turbidity over the fifteen-year period. This trend is typical of diffuse source dominated systems. Total phosphorus was chosen as an indicator due to its role in 'fuelling' algal blooms.

Graph 1. Total Phosphorus v's Flow at Curdie station (235203).

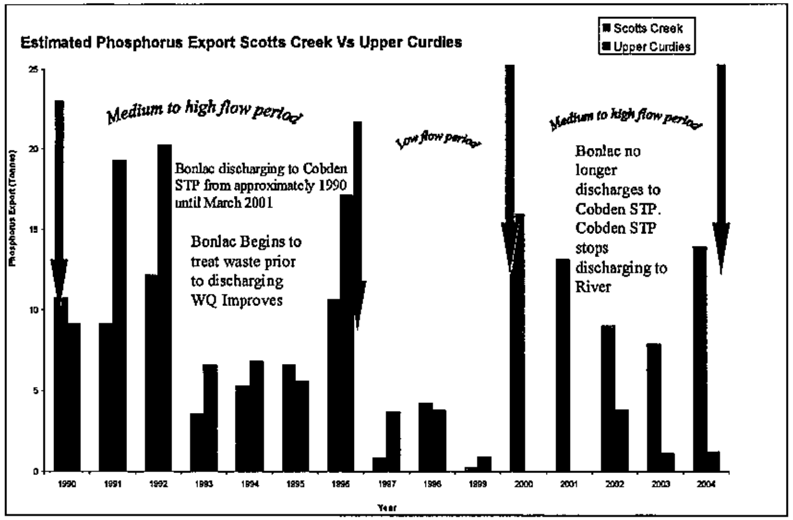


Graph 1. A clear trend can be observed - when flow increases - total P increases. This indicates that diffuse sources of phosphorus are dominating rather than point sources.

Scotts Creek/Cooriemungle Creek versus Upper Curdies Subcatchment:

The graph-2 shows the total phosphorus load for each of the subcatchments over the past fifteen years. From 1990 to 2000 the upper Curdies (blue) is a significant source of total phosphorus, however after 2000, the total phosphorus from the upper Curdies decreases dramatically. This trend seems to correspond quite closely with the history of the Cobden sewage treatment plant. The dramatic decrease in phosphorus load from the upper Curdies in 2000 corresponds with major improvements in sewage management practises (land application) and Bonlac no longer discharging to the treatment plant. There does not appear to be any significant changes in the total phosphorus loads from Scotts Creek/Cooriemungle Catchment (Green), fluctuations are most likely due to rainfall variability. Loads calculated using VWQMN data.

Graph 2. YearlyTotal Phosphorus Load. Scotts Creek/ Cooriemungle v's Upper Curdies.

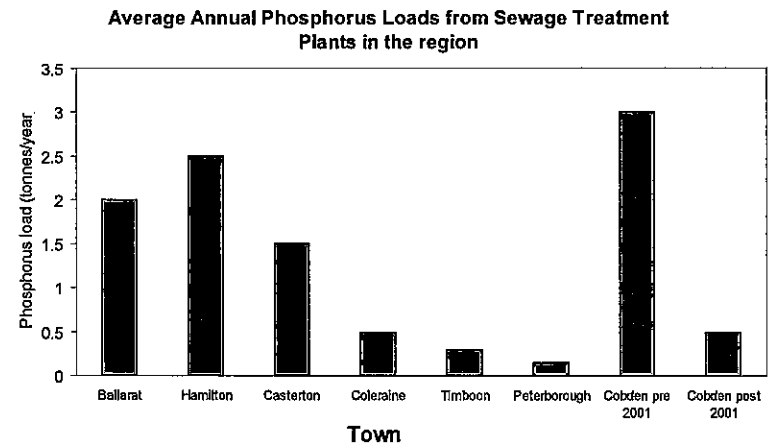


Graph 2. A significant reduction in annual phosphorus load from the Upper Curdies can be seen after 2000. There does not appear to be any significant increase or decrease in phosphorus load from Scotts Creek/Cooriemungle subcatchment.

Cobden Sewage Treatment Plant:

Graph- 3 illustrates the significance of the Cobden sewage treatment plant pre 2001. These figures have been calculated using data supplied by South West Water. Where no data was available- in the case of Timboon and Peterborough, estimates were calculated using the average waste generated per person multiplied by the town population. Figures for other treatment plants in the region have been taken from Ierodiaconau et al 2004. It is interesting to note that although these figures are entirely independent from the VWQMN data used in the previous graph the significant reduction in phosphorus load from the Cobden sewage treatment plant can still be seen.

Graph 3. Average annual phosphorus loads from sewage treatment plants in the region.



Graph 3. Comparison of average annual phosphorus loads from sewage treatment plants in the Curdies Catcment with other sewage treatment plants in the region.

Sediment Loads:

Calculation of yearly sediment loads from the VWQMN data from each subcatchment reveals that:

The Upper Curdies has contributed an average of 235 tonnes of sediment per year into the estuary. The total sediment contribution from this part of the catchment over the past fifteen years is approximately 3500 tonnes.

Scotts Creek/Cooriemungle Creek has contributed an average of 850 tonnes of sediment per year into the estuary. The total sediment contribution from this part of the catchment over the past fifteen years is approximately 12500 tonnes, almost four times higher than the upper Curdies.

This is a total of approximately 16000 tonnes of sediment into the estuary from these two subcatchments alone. This data does not consider the sediment load from the lower part of the catchment, and is likely to be an underestimate (due to the lack of storm event sampling).

Phosphorus Loads:

Phosphorus loads have been calculated using measurements taken from the two existing gauging stations in the Curdies Catchment.

The Upper Curdies has contributed an average of 6.5 tonnes of phosphorus per year into the estuary. The total phosphorus contribution from this part of the catchment over the past fifteen years is approximately 97 tonnes.

Scotts Creek/Cooriemungle Creek has contributed an average of 8 tonnes of phosphorus per year into the estuary. The total phosphorus contribution from this part of the catchment over the past fifteen years is approximately 123 tonnes.

This is a total of approximately 220 tonnes of phosphorus into the estuary from these two subcatchments alone. When the area of the subcatchments is considered the Scotts Creek/Cooriemungle Creek subcatchment is caurrently contributing approximately eight times more phosphorus per hectare than the upper Curdies. This data does not consider the phosphorus load from the lower part of the catchment.

Groundwater- Maher 2001, measured nutrients in the upper Curdies River during a minimum flow period. It is assumed that a significant proportion of the base flow from this part of the river originates from groundwater input. The results from these measurements indicate that groundwater does not contribute a significant quantity of phosphorus to the Curdies River.

Appendix 5

Definitions from the National Framework for Natural Resource Management (NRM) Standards and Targets; Natural Resource management Ministerial Council, October, 2002

Additional information has been included from the State Envornment Protection Policy (SEPP), (WoV)- 2003 *(represented in italics).*

Achievable resource condition targets (10 years)

Specific, timebound and measurable targets, relating largely to resource condition, eg. Nutrients in aquatic environments. These targets must be pragmatic and achievable (NRM Ministerial Council, 2002).

SEPP (WoV), 2003; regional resource condition targets that provide measurable and time-bound progress towards the attainment of regional aspirational targets by taking into account regional environmental, social and economic values.

Management action targets (1-5 years)

Short term targets (1-5 years), relating mainly to management actions or capacity-building. These targets must contribute to progress towards the longer-term resource condition targets.

SEPP (WoV), 2003; regional management action targets that are set to assess the implementation of rehabilitation actions that will lead to the achievement of regional resource condition targets.

Appendix 6

Resource Condition Indicators

Selected indicators from the National Framework for Natural Resource Management Standards and Targets (Natural Resource Management Ministerial Counci, 2002)

The indicators are currently divided into two categories:

- AGREED INDICATORS
  These indicators have been fully agreed by the Monitoring and Evaluation Working Group that contains representatives from all jurisdictions. They are awaiting final endorsement by the Natural Resource Management Ministerial Council.
- INDICATORS FOR ADVICE
  These indicators are in the process of being finalised by the Monitoring and Evaluation Working Group so they can be presented to Natural Resource Management Ministerial Council.

1. Frequency of algal blooms in estuarine, coastal and marine waters

Indicator status: for advice

How can we monitor algal blooms in estuarine, coastal and marine waters?

Detailed monitoring methods for algal blooms can be found in numerous publications including:

- the Monitoring Guidelines (ANZECC/ARMCANZ 2000b);
- guidelines for State of the Environment reporting (Ward at al. 1998);
- scientific publications;
- Waterwatch monitoring manuals; and
- state/territory government department (eg. Environment Protection Agency or equivalent) monitoring manuals.

The most appropriate monitoring methods will depend on the region and particular aspects of the study. Whenever possible, methods should be consistent with national (ANZECC/ARMCANZ 2000b) protocols to maintain consistency between regions and allow for comparison. Expert local advice should also be obtained to ensure that monitoring is conducted at an appropriate spatial and temporal scale to allow the data to be statistically assessed so that demonstrated changes are verifiable. Differing levels of complexity will be required for data collection and analysis and interpretation.

2. Total nutrients in the sediments WITH dissolved nutrients in the sediments

How can we monitor the concentrations of total nutrients and dissolved nutrients in estuarine, coastal and marine sediments?

Monitoring methods for nutrients in sediments can be found in several
publications including;

- The Monitoring Guidelines (ANZECC/ARMCANZ 2000b); scientific publications; and state/territory government department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

Monitoring methods will depend on the region and particular aspects of the study. Whenever possible, methods should be consistent with national (ANZECC/ ARMCANZ 2000b) protocols to maintain consistency between regions and allow for comparison. Expert local advice should be obtained to ensure that monitoring is conducted at an appropriate spatial and temporal scale to allow data to be statistically assessed so that demonstrated changes are verifiable. Differing levels of complexity will be required for data collection and analysis and Interpretation.

3. Extent/distribution of key habitat types

How can we monitor the extent/distribution of key habitats in estuarine, coastal and marine ecosystems?

In general, mapping changes in the extent/distribution of habitat is relatively straightforward and can often be undertaken by community groups such as Seagrass-Watch. Aerial photography and satellite imagery can be used, although ground-truthing by local groups is advised (see information provided in OzEstuaries). Certain aspects of some methods used to monitor habitat extent/distribution will require expert knowledge (e.g. plant identification, satellite (imagery and sonar interpretation).

Monitoring methods depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (Ward et al. 1998) protocols to maintain consistency between regions and allow for comparison. Expert local advice should be obtained to ensure that monitoring is conducted at an appropriate spatial and temporal scale to allow data to be statistically assessed so that demonstrated changes are verifiable.

Not all habitat types will be present in a natural resource management region - reporting only needs to be undertaken for those habitats present and where the stressor 'habitat removal/disturbance' is present. Although other stressors may result in loss of key habitat, other indicators are more suitable for monitoring against those stressors because extent (area – hectares or km2) is a gross level indicator (e.g. although increased aquatic sediments, toxicants or nutrients may result in a change in seagrass extent, other indicators are more directly linked to each stressor than is a change in seagrass extent).

Extent/distribution of key habitat types (indicator status: for advice).

Information on protocols for determining a change in habitat extent can be found in the guidelines for State of the Environment reporting (Ward et al. 1998), scientific publications and OzEstuaries<www.ozestuaries.org/ indicators/indicators.html>.