North Central
Catchment
Management Authority

Lake Eppalock Catchment

Land Capability Assessment and Planning Project

Volume 2

Water Quality Risks & Land Unit Descriptions Report

AUGUST 2000

A VICTORIAN NUTRIENT MANAGEMENT INITIATIVE

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The Lake Eppalock Catchment - Land Capability Assessment and Planning Project, is presented in three volumes.

- Volume 1 – Strategic Planning Options and Recommendations
- Volume 2 – Water Quality Risk and Land Unit Descriptions
- Volume 3 – Water Quality Status and Threats

In addition, this project provides background information to a GIS (Geographic Information System) product provided to local government and referral authorities.

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User Note
The map information provided in this publication is suitable for broadscale planning purposes, rather than specific site investigation. The precision of mapped boundaries is affected by the scale of the map. Any enlargement of the map will result in distortion of the information and is unlikely to improve its accuracy.

The authors strongly advise that further detailed investigation be carried out prior to new development proceedings.

Front Cover: Lake Eppalock

Photo courtesy of Frank McKinley

EXECUTIVE SUMMARY

The North Central Catchment Management Authority has commissioned a study to assess the capability of the land within the Lake Eppalock Catchment with respect to water quality impacts. The project is a strategic outcome of the 'Framework for the Sustainable Use and Management of Lake Eppalock and its Catchment' document. The Framework is a partnership between key management stakeholders to provide good quality urban water, and irrigation, stock and domestic supply by improved catchment management.

The project objectives are outlined below.

1. To provide improved information (including quantitative data) to enable land managers, prospective applicants for development, and responsible authorities to make better informed decisions about land uses and developments in the Lake Eppalock Catchment. This information needs to be prepared in accordance with the principles of the 'Framework for Sustainable Use and Management of Lake Eppalock and its Catchment'.

2. To ensure that:

   - The provisions of the City of Greater Bendigo, Macedon Ranges Shire, Mount Alexander Shire, Mitchell Shire and Hepburn Shire planning schemes and the procedures used by councils incorporate a coordinated approach to the implementation of water quality maintenance objectives.

   - Councils have policies in place for assessing and determining approvals for land use changes and new developments that fully address future sustainable use and management of the catchment.

The outcome of the project will be twofold:

i) improved, consistent and accessible information on the impacts of land uses on water quality to support planning decisions; and

ii) consistent planning schemes and procedures for the whole of the Lake Eppalock catchment.

The project was divided into three components, each of which has been reported separately. The three components are:

1. Volume 1 Strategic Planning Options.
   Developing common planning schemes and procedures for the five local government areas that cover the catchment.

2. Volume 2 Water Quality Risks and Land Unit Descriptions.
   Mapping of the land across the catchment at 1:40 000 scale and identifying water quality risks for selected land uses.

3. Volume 3 Water Quality Status and Threats.
   Assembling and analysing past and current water quality information for Lake Eppalock and feeder rivers and streams.

These three reports provide background information to a Geographic Information System (GIS) product provided to local government and statutory referral authorities.

Strategic Planning Options

Draft common planning schemes and operating procedures for local government authorities and referral authorities have been proposed that are compatible with the

Victorian Planning Provisions (VPP). The following VPP components have been proposed:

- Addition to the Municipal Strategic Statement
- Local Planning Policy
- Planning Provisions
- Operating procedures

The proposed operating procedures form a Planning Decision Making Partnership between local government and referral authorities.

Water Quality Risks and Land Unit Descriptions

The impact of the land uses on water quality within the Lake Eppalock Catchment was the subject of this component of the project. Nine land uses were investigated:

- Broadacre grazing
- Intensive cropping (potatoes)
- Intensive horticulture (viticulture)
- Native vegetation or Forestry establishment
- Native vegetation or Forestry removal
- Septic tank effluent disposal
- Secondary gravel or earthen roading
- Rural subdivision
- Land-based extractive industries including mining

The land of the Lake Eppalock Catchment was mapped at the 1:40 000 scale to identify land units with common geology, topography and key soil attributes. This information provided the data and the spatial mapping framework for the analysis of water quality risks.

The impact of land uses on water quality was determined using a probability analysis decision tree. The assessment was based on the cause and effect linkage between the land use, the impact of land use on water quality threatening processes, and water quality. To undertake the assessment, the major threatening processes to water quality induced by a land use (and the land management practices used within a land use) were identified. Water quality assessments in other catchments indicate that four threatening processes are critical:

1. Water erosion
2. Nutrient leaching
3. Overland movement of surface solutes
4. Recharge to groundwater

Water quality risks were assessed for each threatening process and land use through the identification of the key land management practice within a land use that is the major contributor to the instigation of the threatening process. Given that land management practices vary (heavy grazing vs light grazing for example), a land management scenario mimicking what is occurring in the various sub-regions of the catchment was developed to assess the impact of the land management practice on the threatening process.

The four threatening processes identified are all driven by water processes, with extreme rainfall events causing an acceleration in the deterioration of water quality. The probability of extreme rainfall events at critical times of the year was included in the analysis.

An overall water quality risk assessment for a land use was developed by combining the water quality risks for the various threatening processes. This assessment included the likely contribution of a threatening process to water quality issues based on geological type and the location in the landscape.

Over 150 land units have been described across the Lake Eppalock Catchment. Water quality risk analysis for the nine land uses have been undertaken for each of the land units.

Maps showing the overall water quality risk are presented in the report in addition to tabulated data on the threatening processes.

Land uses that are the major contributors to poor water quality in the Lake Eppalock catchment are urban development, septic tanks, land clearing and poor agricultural practices.

Water Quality Status and Threats

This report aims to develop an understanding of the priority land uses and actions which require planning options to ameliorate the threats posed to water quality. This was undertaken by assembling information from a number of sources:

- Water quality information within the Lake Eppalock and its catchment.
- Results from a stakeholder workshop to identify threats using local knowledge.
- Literature and current related projects.

This report provides support to the other aspects of the project by identifying the drivers (causes) of each water quality risk used in the Land Capability Assessment mapping. Further, this investigation also helps to identify the priority areas and threats used in the Strategic Planning Options report. From the stakeholder workshop the perceived land uses that have greatest impact on water quality in the Lake Eppalock catchment are urban development, septic tanks, grazing stream margins, land clearing, poor agricultural practices and intensive animals industries.

ACKNOWLEDGMENT

This project has been developed under the guidance of a Technical Reference Group. This group constitutes the following members:

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David Schier	Goulburn-Murray Water.
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LAKE EPPALOCK CATCHMENT LAND CAPABILITY ASSESSMENT AND PLANNING PROJECT

MAY 2000

Volume 2 - Water Quality Risks and Land Unit Descriptions

Prepared by Centre for Land Protection Research

1 INTRODUCTION

1.1 Lake Eppalock Catchment Land Capability Assessment and Planning Project

The North Central Catchment Management Authority has commissioned a study to assess the capability of the land within the Lake Eppalock Catchment with respect to water quality impacts. The project is in keeping with the '*Framework for the Sustainable Use and Management of Lake Eppalock and its Catchment*' document. The Framework is a partnership between key management stakeholders to provide good quality urban water, irrigation, stock and domestic supply by improved catchment management.

1.2 Project Objectives

The project objectives are to:

1. Provide improved information (including quantitative data) to enable land managers, prospective applicants for development, and responsible authorities to make better informed decisions about land uses and developments in the Lake Eppalock Catchment. This information needs to be prepared in accordance with the principles of the '*Framework for Sustainable Use and Management of Lake Eppalock and its Catchment.*'

2. To ensure that:

- The provisions of the City of Greater Bendigo, Macedon Ranges Shire, Mount Alexander Shire, Mitchell Shire and Hepburn Shire planning schemes and the procedures used by councils incorporate a coordinated approach to the implementation of water quality maintenance objectives.

- Councils have policies in place for assessing and determining approvals for land use changes and new developments, that fully address future sustainable use and management of the catchment.

1.3 Land Use Description

The land uses under investigation in this study are;

- ***Broadacre grazing*** – pasture production for the extensive grazing of domestic livestock e.g. sheep and cattle.

- ***Intensive cropping (potatoes)*** – the cropping of potatoes often in rotation with broadacre grazing.

- ***Intensive horticulture (viticulture)*** – perennial production of grapes.

- ***Native vegetation or forestry establishment*** – the establishment of native vegetation or plantation forestry on existing cleared farmland or as part of a production forest system.

- ***Native vegetation or forestry removal*** – the removal (harvesting or clearing) of greater than 75% cover of existing native vegetation, plantation or farm forest.

- ***Septic tank effluent disposal*** – the disposal of septic tank effluent (on-site domestic sewage and sullage treatment) through absorption or transpiration beds.

- ***Secondary gravel or earthen roading*** – roads or tracks that are unsealed and have no concrete curbing and run-off water disposal systems.

- ***Subdivision*** – the subdivision of land to 'rural living' or 'hobby farm' size allotments (>1 ha).

- ***Land-based extractive industries*** – land-based mining or the extraction of quarry products.

1.4 Purpose of the Report

This report provides interim information on the mapped land units, water quality risks and strategic planning options. The report is in three volumes;

- Volume 1 – Strategic Planning Options.

- Volume 2 – Water Quality Risks and Land Unit Descriptions.

- Volume 3 – Water Qualtity Status and Threats

Detailed planning options for particular land uses and water quality risks have not been addressed at this stage of the project and will be developed through consultation with the key stakeholders.

1.5 Lake Eppalock Catchment, Water Quality and Planning

Lake Eppalock is a primary water impoundment for North Central Victoria supplying domestic water to Bendigo as well as irrigation water to the Campaspe Irrigation Districts. In addition to being a water impoundment, Lake Eppalock has significant recreation value for a range of water sports and other pursuits that may impact on the lake itself (as well as the lake environs). The maintenance and improvement of water quality within the whole Lake Eppalock Catchment is a key aspect to maintaining the economic, social and environmental well being of Central Victoria.

Water quality within the Lake Eppalock Catchment, but particularly the lake itself, has been an issue for at least the last twenty years, instigating a number of reports on water quality (ICLE 1981; RWC 1989; Davis 1998). Turbidity and phosphorous, although generally within acceptable ranges, have been considered the greatest threats to water quality. A number of low level blue-green algae blooms have been reported over the last ten years. The estimated cost of a blue-green algae bloom on Lake Eppalock over the summer period is $12.6 million (CWQC 1997). Causal factors for the water quality threats are flow regimes on inflow rivers, land management practices within the catchment, and past bank erosion of Lake Eppalock.

The catchment for Lake Eppalock extends to the top of the Great Dividing Range around Mount Macedon, Woodend and Trentham. Land uses within the catchment are generally grazing, however some more intensive land uses such as cropping and horticulture, are becoming more common. Increasingly areas are being consumed for residential and other urban uses as well as rural residential and hobby farming uses. Land use competition is increasing in the catchment particularly for peri-urban type activities and small farms. This situation is likely to increase with expanding opportunities for commuting as current road improvements come on stream. In addition, there is potential for increased development along the shore of Lake Eppalock itself.

The whole of the Lake Eppalock Catchment is proclaimed although Land Use Determinations only cover a small percentage of the catchment. The whole of the catchment is 'open'. The water quality of the Campaspe and Coliban rivers and Lake Eppalock is strongly impacted by land use and land management activities in the catchment. Sediments and nutrients (from minor water discolouration through to blue green algae blooms) are two key water quality issues that can impact on water users.

Currently, there is very limited coordination (in respect to land management issues) between the five local government authorities that have land use planning jurisdiction over the catchment. This leads to an inconsistent approach to planning with respect to the protection of water quality within the lake. In order to improve the planning process, information on the natural resource base and its capability under different land uses and land management practices is required. The land capability and biophysical information is then required to be developed into products that are meaningful and useable by planners at the local level, statutory referral authorities and the North Central Catchment Management Authority.

2 METHODS

2.1 Project Logic and Overview of Water Quality Risk Assessment

Water quality in the Lake Eppalock Catchment is impacted by many factors including;

- natural land and climate factors i.e. soil, geology, hydrogeology and climate
- water course management factors i.e. impoundments, stream flow amendments and water diversions
- land management factors i.e. land use and land management factors within a land use.

Under pre-European conditions, water quality was generally a reflection of the natural land and climate factors. Since European settlement, water quality has been impacted by not only the natural factors, but also water course management factors and land management factors. Complex interactions exist between these factors making the identification of the main factors contributing to poor water quality difficult to elucidate.

In open water supply catchments such as Lake Eppalock, efforts to improve water quality need to focus on issues that will make a significant difference and are potentially achievable. In light of this, it can be argued that the natural land and climate factors cannot be changed (the soil, geology, hydrogeology and climate are given), and water course management factors can be changed only in part (changes to diversions or impoundments). Water course management factors are, however, difficult to change often requiring significant movement in state or federal policy. However, land use and land management factors can be changed to improve water quality albeit requiring significant effort and time to realise improvements. Therefore, it is generally held that the greatest gains to water quality in open water supply catchments can be achieved through alterations to land use and land management practices.

The retrospective controlling of land uses and land management practices is not readily achievable through any current process. However, control of new land uses or land management practices can be achieved in part through the Victorian Planning Provisions (VPP) at the local government level. This process allows for linkage to other land management or natural resource management authorities (referral authorities) to allow a wide spectrum of views. Knowledge of the impacts of land use and management on water quality by those implementing the VPP will provide a process for minimising high risk land uses and land management practices on water quality within a catchment management and holistic planning framework.

A number of approaches exist to assess land use and management practices on water quality:

- Quantitative – application of scientific studies that have quantified the impact of land use and land management practices on water quality;
- Qualitative – application of best understanding of the impacts of land use and management on water quality in relative terms; and
- Semi-quantitative – a combination of the two approaches to provide the available linkages between land use and management and water quality.

The Lake Eppalock Catchment is relatively data poor with respect to water quality information and land use and land management impact information. Quantitative information does not exist on the impacts of land use and land management on water quality. It is for this reason that a quantitative approach cannot be attempted for this study. The catchment is however well served for land type and condition information. This information can be used, in conjunction with a knowledge of the processes that lead to water quality deterioration, to undertake a semi-quantitative analysis of the impacts of land use and land management practices on water quality.

A semi-quantitative analysis requires an understanding of the main threatening processes to water quality occurring in a catchment. To identify the threats, the major management stakeholders in the Lake Eppalock Catchment identified the major values and threats. One value identified was water quality. The major threats to the water quality value were seen as:

- poor land management practices;
- land clearing;
- increasing urbanisation;
- domestic and industrial discharges;
- septic tanks;
- poor agricultural management, overgrazing and fertilizer usage;
- animal intensive agriculture;
- unclear and inadequate responsibility and accountability; and
- lack of strategic land use planning.

The assessment of values and threats identified two key issues:

- lack of strategic planning and linkage between the agencies responsible for planning; and
- a number of key land uses and land management practices with perceived deleterious impacts on water quality.

Both of these issues have been tackled in this project.

As land uses and land management practices are considered a major threat, the semi-quantitative process has been used to make linkages between land use, land management practices and water quality. To do this, the major threatening processes to water quality induced by a land use or land management practice were identified. Water quality assessments in other catchments indicate that four threatening processes are critical:

1. water erosion;
2. nutrient leaching;
3. overland movement of surface solutes; and
4. recharge to saline groundwater.

The four threatening processes listed above will occur naturally irrespective of land use and management practices due to climate, topography and soil type factors. The susceptibility of the land to the threatening processes varies dependent upon the interaction between climate, topography and soil type. Post European land uses and land management practices have accelerated the threatening processes and thus degraded the water quality in the Lake Eppalock Catchment. The analysis of water quality risks will rate the susceptibility of the land to the four threatening processes (using mapped information on the land) and assess the impact of land use and land management practices on the processes. Linkages will then be drawn between the threatening processes and water quality.

In order to assess the impact of land use and land management practices on the threatening processes, the key land management factor within a particular land use that impacts most strongly on the threatening process needs to be identified. As an example, water erosion in a grazing land use situation is most strongly impacted by the amount of vegetative (pasture) cover during vulnerable times of the year. The amount of vegetation cover is therefore the key land management factor that impacts on water erosion in a grazing land use, and water erosion is one of the main threatening processes to water quality.

The key to the semi-quantitative analysis is the cause and effect linkage between land use and water quality. The linkage is the potential impact of land management practices on the water quality threatening processes mentioned above. Figure 2.1 provides a diagrammatic representation of the cause and effect linkages. The linkages for each land use is presented in Table 2.1.

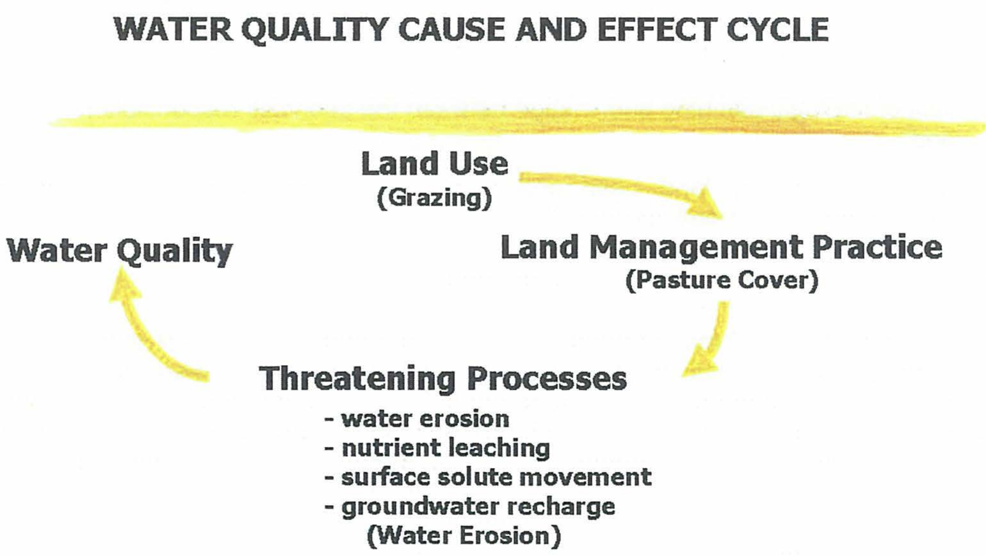


Figure 2.1 Linkages between land use and management practices, threatening processes and water quality.

Table 2.1. Cause and effect linkage between land use, key land management practice, water quality threatening processes and water quality.

Land use	**Key land management factor**	**Threatening process to water quality**
Broadacre grazing	Vegetation cover (pasture cover)	Water erosion Surface solute movement
	Nutrient input (fertiliser application)	Nutrient leaching
	Pasture type and grazing intensity	Groundwater recharge
Intensive cropping (potatoes)	Vegetation cover (crop cover)	Water erosion Surface solute movement
	Nutrient input (fertiliser application)	Nutrient leaching
Intensive horticulture (viticulture)	Vegetation cover (inter-row and vine cover)	Water erosion
	Nutrient input (fertiliser application)	Nutrient leaching
	Inter-row vegetation cover	Surface solute movement
	Irrigation type	Groundwater recharge
Native vegetation or forestry establishment	Vegetation cover	Water erosion
Native vegetation or forestry removal	Vegetation cover	Water erosion
	Type of replacement vegetation	Groundwater recharge
Septic tank effluent disposal	Density of septic tanks	Nutrient leaching Surface solute movement Groundwater recharge
Secondary gravel or earthen roading	Standard of road construction and maintenance	Water erosion
Subdivision	Density of septic tanks	Nutrient leaching Surface solute movement Groundwater recharge
	Standard of road construction and maintenance	Water erosion
Land-based extractive industries	Standard of erosion control measures	Water erosion
	Standard of salinity control measures	Groundwater recharge

The rationale for selection of the threatening processes for each land use is based on the impact of the land use on, and the availability of management practices to counteract, the threatening process. Explanation of the rationale for each is as follows;

Broadacre grazing. Broadacre grazing is able to accelerate all of the four threatening processes. Best management practices are available to reduce the impact of the threatening processes on water quality. Maintenance of vegetation cover, nutrient applications in balance with nutrient removal, and pasture species type are all able to ameliorate the threat to water quality.

Intensive cropping (potatoes). Intensive cropping is able to accelerate all of the threatening processes although there are no best management practices to reduce groundwater recharge apart from improved irrigation scheduling. Potatoes require moist soil conditions during the growing season and the current irrigation technology makes improvements to irrigation scheduling difficult. Therefore, groundwater recharge was not considered a threatening process that had appropriate management practices to minimise the threat.

Intensive horticulture (viticulture). Intensive horticulture (viticulture) is able to accelerate all of the four threatening processes. Best management practices available to reduce the impact of the threatening processes on water quality include; maintenance of vegetation cover, nutrient applications in balance with nutrient removal, and irrigation type.

Native vegetation or forestry establishment. The major threatening process during native vegetation establishment is water erosion as a result of bare soil surfaces due to machinery operations and poor vegetation cover. The threat of nutrient leaching, surface solute movement and groundwater recharge is unlikely to be altered by vegetation establishment until the vegetation shows significant growth at which time the threat will reduced.

Native vegetation or forestry removal. The removal of native vegetation or forestry will have the biggest impact on groundwater recharge and water erosion in the short term. In the medium to long term the threat of water erosion will be dependent upon the amount of vegetation cover, and the threat of groundwater recharge by the type of replacement vegetation. Given the inherent poor to moderate fertility of many of the soils in the catchment, nutrient leaching and surface solute movement are not likely to be key threats.

Septic tank effluent disposal. The key threats to water quality from septic tank effluent disposal are nutrient leaching, surface solute movement and groundwater recharge. Septic tank density is a key land management practice which can reduce the threat, assuming septic systems comply with the *Code of Practice. Septic Tanks,* (EPA 1996).

Secondary gravel or earthen roading. Water erosion of soil on the road and road verges is the primary water quality threat. Road construction and maintenance standards impact on the water quality threat. Standards of construction and maintenance as proposed in the *Code of Forest Practices for Timber Production* (DNRE 1996) provide management guidelines to reduce the threat.

Subdivision. Subdivision for rural allotments generally coincide with a low level of services. Effluent disposal through septic tanks and unsealed roads are characteristics of these developments. The threat to water quality is therefore the same threatening processes identified for septic tank effluent disposal and secondary gravel and earthen roading.

Land-based extractive industries. Extractive industries generally require the removal of vegetation, and the removal and stockpiling of soil. Water erosion and groundwater recharge are therefore the primary threats to water quality. No code of practice exists for extractive industries to reduce the environmental impacts although guidelines do exist.

2.2 Land and Soil Mapping

Significant land information exists for the Lake Eppalock Catchment. Land capability studies have been completed for much of the southern part of the catchment at a scale of 1:25 000 (Baxter and Boyle 1996, Singleton and Lorimer 1992). Land capability and land systems studies (Bluml, Boyle and Jones 1995; Lorimer and Schoknecht 1987) exist for the northern part of the catchment at a scale between 1:25 000 and 1:100 000. Although these studies covered much of the catchment, unmapped areas existed between the studies and the information was not consistent at the 1:40 000 scale.

To complete a traditional survey of the Eppalock Catchment would have been inefficient given the existing information and the tools that are now available. These tools, such as digital elevation models (DEM) and gamma-ray spectrometry (GRS) data are more readily available to the surveyor and can assist in giving more accurate interpretation of the land types and attributes. These tools along with computer based modelled methods and field validation, were used to derive a land map which was the basis for the water quality risk assessment.

2.2.1 Modelling from Land Systems Information

There was no previous soil mapping at an appropriate scale for this project across most of the northern half of the Lake Eppalock Catchment. Due to this absence of data, there was the necessity to model these geological lithologies from the existing 1:100 000 land systems coverage.

Using Lorimer & Schoknecht (1987), the land systems were spatially divided into the described components. A digital elevation model (DEM) was a primary data layer for the landform attributes: slope, relative elevation, curvature and elevation. These were used in conjunction with remotely sensed data. The GRS data, commonly called radiometric data, is the natural radioactivity emitted from the earth and collected by aircraft. Energy and Minerals (NRE) and Australian Geographic Survey Organisation supplied the GRS data. A stream buffer layer also assisted in the derivation of some of the drainage components. This information was then field checked for accuracy then modified for a more accurate result.

2.2.2 Modelling by Extrapolating from Existing Information

In the southern section of the catchment the soil information was quite extensive at a 1:25 000 scale. In these areas the existing information was used in the formation of the soil map. This information was also used to create rules for predicting the soil of the area immediately surrounding the existing surveys.

The method used to extrapolate the existing information utilises a regression model to create a set of rules from existing soil information and data (DEM derived layers, GRS, geology and land systems). The rules are then applied over a larger area than the existing mapping within similar geological/climatic areas. This methodology has proven to be quite accurate if kept within the similar land types. This information was then field checked for accuracy.

2.3 Water Quality Risk Assessment

2.3.1 General Process

A semi-quantitative process was used to identify the risk to water quality in Lake Eppalock and the upper catchment impoundments from identified land uses and land management scenarios. As mentioned earlier, the linkage between land use and land management practices and water quality within water courses or impoundments is complex. The lack of detailed scientific trials in this catchment removes one avenue for developing the linkage. The alternate route is to utilise an understanding of land behaviour, particularly knowledge with respect to land use and management and the impact that this may have on land degradation and therefore the risk of water quality degradation. This semi-quantitative approach was used for the Lake Eppalock Project.

The process involved the following;

1. Mapping of the land and soil across the catchment at the 1:40 000 scale (spatial identification of land units) (see Section 2.2).

2. Assuming that there were four key threatening processes to water quality that are impacted by land use and land management practices;

- Water erosion
- Soil nutrient leaching by water
- Surface movement of solutes by water
- Recharge to the groundwater

For each of the identified land units across the catchment

3. Assessment of the threatening process susceptibility (Section 2.3.4, Tables 2.3 – 2.7). The susceptibility of land to a threatening process is governed by climate, topography and soil type factors irrespective of land use and land management activities.

4. Assignment of a probability rating to the susceptibility assessment based on assumed variation within a land unit (see Section 2.3.2).

5. Assessment of the probability of a threatening process hazard based on normal seasonal or extreme seasonal rainfall events (see Section 2.3.2 and 2.3.5). The hazard of the land to a threatening process is governed by the same factors as for susceptibility but also includes the impact of rainfall extremes.

For the desired land uses

6. Identification of the key land management factors that impact on (accelerate or reduce) the threatening process (Table 2.1)

7. Identification of benchmark levels for the key land management factors (Table 2.2). The benchmark levels are those at which the land management factor is accelerated or reduced.

8. Development of land management scenarios for the key land management factors using the benchmark levels. Assign probabilities for the scenarios occurring in each land unit (Appendix 1).

9. Assessment of the water quality risk for the threatening processes from the land management scenarios, through the use of water quality threatening process – land management risk matrix (Section 2.3.6, Tables 2.8 – 2.17). The water quality risk probability was analysed using a decision tree program (Precision Tree, Palisade Corporation).

10. Assess the overall water quality risk through the combination of the water quality risk probabilities for the relevant threatening process for each land use (Section 2.3.7, Tables 2.18 – 2.20).

2.3.2 Data Uncertainty

The water quality risk analysis assesses the probability of a land unit falling into a low, moderate or high water quality risk rating. The data was analysed using decision trees which allowed the analysis of variable uncertainty. Variable uncertainty arises from the complex interactions between land, land use, climate and water quality, and the lack of homogeneity within a land unit. In particular, the following values were uncertain and probabilities of a value occurring was utilised in the analysis;

- **Variation within a land unit and its impact on assessing the probability of a threatening process susceptibility.** The susceptibility of a threatening process was considered to be uncertain due to soil type variations. Land units lower in the landscape were considered to have higher variation. The threatening process susceptibility was calculated from the soil and land attributes and the result of the calculation was considered the dominant susceptibility class. The proportion of the unit falling into this class was assigned based on the position in the landscape. The minor susceptibility class was assigned one susceptibility class higher than the dominant. The proportioning between the dominant and minor susceptibility classes was 70% in the dominant susceptibility class and 30% in the minor susceptibility class for very gentle slopes, drainage depressions and flats, while all other land elements were considered to have 90% in the dominant susceptibility class and 10% in the minor susceptibility class.

- **Extremes in rainfall and its impact on assessing the probability of a threatening process hazard.** Rainfall extremes (high rainfall events) were considered to strongly impact on all of the threatening processes and therefore have a greater effect on water quality than normal rainfall events. Extreme rainfall events during the January to June period were considered to pose the greatest threat to the acceleration of water erosion, extreme rainfall events during the July to December period the greatest threat to accelerating nutrient leaching and surface solute movement, and extreme annual rainfall events the greatest threat in accelerating groundwater recharge and septic tank effluent disposal failure. The probability of extreme rainfall events was considered to be the proportion of years when rainfall exceeds the long term median plus 50% of the long term median. This value approximates the mean plus two standard deviations. The threatening process hazard was calculated from the threatening process susceptibility and the proportioning of rainfall probabilities between normal and extreme rainfall events. The probability of a threatening process hazard occurring was assumed to be the same as the susceptibility probability (as determined using variation within a soil unit uncertainty) except for the extreme rainfall years in which the hazard is one class higher than the susceptibility class. As an example, a mapped land unit had a calculated erosion susceptibility of moderate. The probability of rainfall extremes (January to June) for this land unit was 25% (25% of years have rainfall higher than the median + 50%). Therefore, the water erosion hazard probability is 75% moderate and 25% high.

2.3.3 Water Quality Risk Analysis Framework

The details of the linkages between land use, key land management factors, land management factor benchmark level and the water quality threatening process – land management risk matrix is presented in Table 2.2.

Table 2.2 Framework for the analysis of the water quality risks.

Land use	**Threatening process**	**Susceptibility assessment**	**Variation within land unit**	**Rainfall factor for hazard assessment**	**Key land management factor**	**Land management factor benchmark levels**	**Water quality threatening process – land management risk matrices**
Broadacre grazing	Water erosion	Water erosion susceptibility table (Table 2.3)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with summer/autumn rainfall extremes	Vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Erosion risk matrix (Table 2.8)
	Nutrient leaching	Nutrient leaching susceptibility table (Table 2.4)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with winter/spring rainfall extremes	Nutrient input	• Normal - no, irregular or maintenance fertiliser applications • High - regular greater than maintenance fertiliser applications	Leaching risk matrix (Table 2.9)
	Surface solute movement	Surface solute movement susceptibility table (Table 2.5)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with rainfall extremes	Vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Surface solute risk matrix (Table 2.10)
	Ground water recharge	Groundwater recharge susceptibility table (Table 2.6)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with rainfall extremes	Pasture type and grazing intensity	• Annual • Perennial light grazing • Perennial heavy grazing	Recharge/pasture type risk matrix (Table 2.11)

Table 2.2 continues on the next page

Table 2.2 cont. Framework for the analysis of the water quality risks.

Land use	Threatening process	Susceptibility assessment	Variation within land unit	Rainfall factor for hazard assessment	Key land management factor	Land management factor benchmark levels	Water quality threatening process – land management risk matrices
Intensive cropping (potatoes)	Water erosion	Water erosion susceptibility table (Table 2.3)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with summer/autumn rainfall extremes	Vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Erosion risk matrix (Table 2.8)
	Nutrient leaching	Nutrient leaching susceptibility table (Table 2.4)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with winter/spring rainfall extremes	Nutrient input	• Normal - no, irregular or maintenance fertiliser applications • High - regular greater than maintenance fertiliser applications	Leaching risk matrix (Table 2.9)
	Surface solute movement	Surface solute movement susceptibility rating (Table 2.5)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with rainfall extremes	Vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Erosion risk matrix (Table 2.8)

Table 2.2 continues on the next page

Table 2.2 cont. Framework for the analysis of the water quality risks.

Land use	Threatening process	Susceptibility assessment	Variation within land unit	Rainfall factor for hazard assessment	Key land management factor	Land management factor benchmark levels	Water quality threatening process – land management risk matrices
Intensive horticulture (viticulture)	Water erosion	Water erosion susceptibility table (Table 2.3)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with summer/autumn rainfall extremes	Vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Erosion risk matrix (Table 2.8)
	Nutrient leaching	Nutrient leaching susceptibility table (Table 2.4)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with winter/spring rainfall extremes	Nutrient input	• Normal - no, irregular or maintenance fertiliser applications • High - regular greater than maintenance fertiliser applications	Leaching risk matrix (Table 2.9)
	Surface solute movement	Surface solute movement susceptibility rating (Table 2.5)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with rainfall extremes	Inter-row vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Erosion risk matrix (Table 2.8)
	Ground water recharge	Groundwater recharge susceptibility table (Table 2.6)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with rainfall extremes	Irrigation type	• Drip • Sprinkler	Recharge/irrigation type risk matrix (Table 2.12)

Table 2.2 continues on the next page

Table 2.2 cont. Framework for the analysis of the water quality risks.

Land use	Threatening process	Susceptibility assessment	Variation within land unit	Rainfall factor for hazard assessment	Key land management factor	Land management factor benchmark levels	Water quality threatening process – land management risk matrices
Native vegetation or forestry – establishment	Water erosion	Water erosion susceptibility table (Table 2.3)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with summer/autumn rainfall extremes	Vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Erosion risk matrix (Table 2.8)
Native vegetation or forestry – removal	Water erosion	Water erosion susceptibility table (Table 2.3)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with summer/autumn rainfall extremes	Vegetation cover	• Low - <30% surface cover • Moderate - 30%-70% surface cover • High - >70% surface cover	Erosion risk matrix (Table 2.8)
	Ground water recharge	Groundwater recharge susceptibility table (Table 2.6)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with rainfall extremes	Replacement vegetation	• Perennial native vegetation/trees • Annual vegetation	Recharge/vegetation type risk matrix (Table 2.13)
Septic tank effluent disposal	Nutrient leaching Surface solute movement Ground water recharge	Septic tank site rating table (Table 2.7)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years where rainfall exceeds 900 mm/annum	Density of septic tanks	• <2.5 dwellings ha • 2.5 – 10 dwellings ha • >10 dwellings ha	Septic tank density risk matrix (Table 2.14)

Table 2.2 continues on the next page

Table 2.2 cont. Framework for the analysis of the water quality risks.

Land use	Threatening process	Susceptibility assessment	Variation within land unit	Rainfall factor for hazard assessment	Key land management factor	Land management factor benchmark levels	Water quality threatening process – land management risk matrices
Secondary gravel or earthen roading	Water erosion	Water erosion susceptibility table (Table 2.3)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with summer/autumn rainfall extremes	Standard of road construction and maintenance	• According to the *Code of Forest Practices for Timber production*[1] • Not according to the *Code of Forest Practices for Timber production*[1]	Road construction according to the Code risk matrix (Table 2.15)
Subdivision	Subdivision will combine septic tank and secondary gravel or earthen roading						
Land-based extractive industries	Water erosion	Water erosion susceptibility table (Table 2.3)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with summer/autumn rainfall extremes	Standard of erosion control measures	• According to the *Environmental Guidelines for Sand and Gravel Extraction*[2] • Not according to the *Environmental Guidelines for Sand and Gravel Extraction*[2]	Extractive industry according to the Guidelines risk matrix (Table 2.16)
	Ground water recharge	Groundwater recharge susceptibility table (Table 2.6)	Probability (%) that the threatening process susceptibility is as assessed from the polygon soil and land attribute information	% of years with rainfall extremes	Standard of salinity control measures	• According to the *Environmental Guidelines for Sand and Gravel Extraction*[2] • Not according to the *Environmental Guidelines for Sand and Gravel Extraction*[2]	Extractive industry according to the Guidelines risk matrix (Table 2.17)

1 DNRE (1996)

2 Cummings, (1996)

2.3.4 Threatening Process Susceptibility Assessment

The calculation of the threatening process susceptibilities for each land unit was calculated using generalised land and soil attribute information and the rules provided in Tables 2.3 – 2.7. The susceptibility class equates to the most limiting factor. The probability of the dominant and minor susceptibility classes was determined using the method described in Section 2.3.2.

Water erosion

Table 2.3a Capacity of the soil to move.

Soil parameters			**Soil dispersibility**		
Texture group (A1)	**Structure grade (A1)**	**Horizon depth (m) (A1 + A2)**	**Very Low – Low E3(1), E3(2), E4,E5,E6,E7,E8**	**Medium - High E3(3), E3(4), E2**	**Very High E1**
Sand	apedal	<0.2	M		
		0.2 - 0.4	L		
		>0.4	L		
Sandy loam	apedal	<0.2	M	H	
		0.2 - 0.4	L	M	
		>0.4	L		
	weakly pedal	<0.2	H	E	
		0.2 - 0.4	M	V	
		>0.4	M		
Loam	apedal	<0.2	M	H	
		0.2 - 0.4	L	M	
		>0.4	L		
	weakly pedal	<0.2	H	E	
		0.2 - 0.4	M	V	
		>0.4	M		
	peds evident	<0.2	H	E	
		0.2 - 0.4	H		
		>0.4	H		
Clay loam	apedal	<0.2	M	H	
		0.2 - 0.4	L	M	
		>0.4	L		
	weakly pedal	<0.2	H	E	
		0.2 - 0.4	M	V	
		>0.4	M		
	peds evident	<0.2	H	E	
		0.2 - 0.4	H	E	
		>0.4	M		

Table 2.3a continued next page

Table 2.3a cont. Capacity of the soil to move.

Soil parameters			Soil dispersibility		
Texture group (A1)	**Structure grade (A1)**	**Horizon depth (m) (A1 + A2)**	**Very Low – Low E3(1), E3(2), E4,E5,E6,E7,E8**	**Medium - High E3(3), E3(4), E2**	**Very High E1**
Light clay	weakly pedal	<0.2	H	E	E
		0.2 - 0.4	M	V	E
		>0.4	M	V	E
	peds evident	<0.2	M	V	E
		0.2 - 0.4	M	H	E
		>0.4	M	H	E
	highly pedal	<0.2	H	E	
		0.2 - 0.4	M	V	
		>0.4	M	V	
Medium to heavy clay	weakly pedal	<0.2	M	H	E
		0.2 - 0.4	M	H	V
		>0.4	M	H	V
	peds evident	<0.2	H	E	E
		0.2 - 0.4	M	V	E
		>0.4	M	V	E
	highly pedal	<0.2	H	E	E
		0.2 - 0.4	M	V	E
		>0.4	M	V	E

L - Low   M - Moderate   H - High   V - Very high   E - Extreme

Table 2.3b Water erosion susceptibility based on slope and capacity of the soil to move.

Slope %	**Topsoil erodibility (from Table 2.3a)**				
	Low	**Moderate**	**High**	**Very high**	**Extreme**
<1%	Very low	Very low	Low	Low	Moderate
1 - 3%	Very low	Low	Moderate	Moderate	High
4 - 10%	Low	Moderate	Moderate	High	Very high
11 - 32%	Moderate	Moderate	High	Very high	Very high
>32%	Moderate	High	Very high	Very high	Very high

Nutrient Leaching

Table 2.4 Soil nutrient leaching susceptibility.

	Susceptibility		
	Low	**Moderate**	**High**
Drainage	Very poorly drained (1) Poorly drained (2) Imperfectly drained (3)	Moderately well drained (4)	Well drained (5) Rapidly drained (6)
Depth of solum (m)	> 1	0.4 - 1.0	<0.4
Texture group of B horizon	Clay loams Light clays Medium heavy clays	Loams	Sands, Sandy loams

Surface Solute Movement

Table 2.5a Surface solute capacity for movement.

	Solute holding capacity		
	Low	**Moderate**	**High**
Surface soil texture group	Sands Sandy loams	Loam Clay loam	Light clay Medium to heavy clay
Infiltration	Fast	Moderate	Slow

Table 2.5b Solute movement susceptibility.

	Solute movement susceptibility		
	Solute holding capacity (from Table 2.5a)		
Slope	**Low**	**Moderate**	**High**
<3%	Low	Low	Low
4-10%	Moderate	Moderate	Low
11-32%	High	Moderate	Low
>32%	High	High	Moderate

Groundwater Recharge

Table 2.6 Groundwater recharge susceptibility.

	Recharge susceptibility		
	Low	**Moderate**	**High**
Soil depth (cm)	> 100	25 – 100	< 25
Bedrock outcrop	Nil	1-10%	> 10%
Permeability (mm/day)	< 50	50 – 200	200 - 1000
Clay content of the clayiest layer (%)	> 35	25 – 35	<25
Soil type	Uniform clays, uniform cracking clays, duplex soils with conspicuously bleached A2, mottled B horizons and/or gleying characteristics	Gradational, duplex acid, whole coloured, duplex A2 may be present but sporadically bleached	Uniform soils, red and whole coloured duplex, A2 present but not bleached, high iron content
Side slopes (%)	-	-	> 25

Septic Tank Capability Rating

Table 2.7 Septic tank capability rating[1].

	Septic tank capability rating		
	Low	**Moderate**	**High**
Slope (%)	>20	15 – 20	<15
Site drainage	Very poor Poor Rapid	Imperfect Moderate	Well
Coarse fragments (%)	>40	20 – 40	<20
Aggregate stability (Emerson Test class)	1,2,3 or 7	-	4,5,6 or 8
Soil permeability	High Very slow	Slow	Moderate
Depth to groundwater (m)	<1.2	1.2 - 1.5	>1.5

1 EPA (1996)

2.3.5 Threatening Process Hazard Assessment

The threatening process hazard looks at the impact of rainfall extremes of the threatening process susceptibility. The threatening process hazard was calculated using the rules in Section 2.3.2 Data Uncertainty.

2.3.6 Water Quality, Land Management Practices and Threatening Process Linkages

The linkage between the threatening process hazard, the land management practice benchmark levels and the water quality risk is made through a matrix. The threatening process hazard is determined from the threatening process susceptibility based on the probability of normal or extreme rainfall events using the criteria described in Section 2.3.2. The matrix for each threatening process – land management practice combination is presented in Tables 2.8 – 2.17).

Water erosion – vegetation cover

Table 2.8 Water erosion hazard – vegetation cover water quality risk matrix.

		Vegetation cover scenario		
		Low (<30% surface cover)	**Moderate (30%-70% surface cover)**	**High (>70% surface cover)**
Erosion hazard	**Very Low**	1	1	1
	Low	2	1	1
	Moderate	3	2	1
	High	3	3	2
	Very High	3	3	3

Water Erosion Water Quality Risk Rating 1 Low
2 Moderate
3 High

Leaching hazard – nutrient input

Table 2.9 Leaching hazard – nutrient input water quality risk matrix.

		Nutrient input scenario	
		Low (no, irregular or maintenance fertiliser applications)	**High** (regular greater than maintenance fertiliser applications)
Leaching hazard	**Low**	1	1
	Moderate	1	2
	High	2	3

Soil Nutrient Leaching Water Quality Risk Rating
1 Low
2 Moderate
3 High

Surface solute movement – vegetation cover

Table 2.10 Surface solute movement – vegetation cover water quality risk matrix.

		Vegetation cover scenario		
		Low (<30% surface cover)	**Moderate** (30%-70% surface cover)	**High** (>70% surface cover)
Surface solute movement hazard	**Low**	2	1	1
	Moderate	3	1	1
	High	3	2	1

Surface Solute Movement Water Quality Risk Rating
1 Low
2 Moderate
3 High

Groundwater recharge – pasture type

Table 2.11 Groundwater recharge – pasture type water quality risk matrix.

		Pasture type and grazing intensity scenario		
		Annual pasture – all grazing intensities	**Perennial pasture heavy grazing**	**Perennial pasture light grazing**
Groundwater recharge hazard	**Low**	2	1	1
	Moderate	2	2	1
	High	3	3	2

Groundwater Recharge Water Quality Risk Rating
1 Low
2 Moderate
3 High

Groundwater recharge - irrigation type

Table 2.12 Groundwater recharge – irrigation type water quality risk matrix.

		Irrigation type scenario	
		Drip	**Sprinkler**
Groundwater recharge hazard	**Low**	1	1
	Moderate	1	2
	High	2	3

Groundwater Recharge Water Quality Risk Rating 1 Low

2 Moderate

3 High

Groundwater recharge – vegetation type

Table 2.13 Groundwater recharge – vegetation type water quality risk matrix.

		Vegetation type scenario	
		Annual	**Perennial vegetation/trees**
Groundwater recharge hazard	**Low**	2	1
	Moderate	2	1
	High	3	1

Groundwater Recharge Water Quality Risk Rating 1 Low

2 Moderate

3 High

Septic tank – density (all threatening processes)

Table 2.14 Septic tank density water quality risk matrix.

		Septic tank density (No./ha)		
		<2.5	**2.5 - 10**	**>10**
Septic tank capability	**Low**	3	3	3
	Moderate	2	2	3
	High	1	2	3

Septic Tank Density Water Quality Risk Rating for all threatening processes 1 Low

2 Moderate

3 High

Water erosion – road construction standard

Table 2.15 Water erosion – road construction and maintenance standard water quality risk matrix.

		Code of Forest Practices for Timber Production[1]	
		Complies	**Does not comply**
Water erosion hazard	**Very Low - Low**	1	1
	Moderate	1	2
	High - Very High	2	3

[1] DNRE (1996)

Water Erosion Water Quality Risk Rating 1 Low
2 Moderate
3 High

Water erosion – land-based extractive industry

Table 2.16 Water erosion – extractive industry standard water quality risk matrix.

		Environmental Guidelines for Sand and Gravel Extraction[1]	
		Complies	**Does not comply**
Water erosion hazard	**Very Low- Low**	1	1
	Moderate	1	2
	High – Very High	2	3

[1] Cummings (1996)

Water Erosion Water Quality Risk Rating 1 Low
2 Moderate
3 High

Groundwater recharge – land-based extractive industry

Table 2.17 Groundwater recharge – extractive industry standard water quality risk matrix.

		Environmental Guidelines for Sand and Gravel Extraction (land-based)	
		Complies	**Does not comply**
Groundwater recharge hazard	**Low**	1	1
	Moderate	1	2
	High	3	3

[1] Cummings (1996)

Groundwater Recharge Water Quality Risk Rating 1 Low
2 Moderate
3 High

2.3.7 Overall Water Quality Risk Assessment

Section 2.3.6 describes the assignment of water quality risks for each of the defined threatening processes based on land use and land management scenarios. Many of the land uses have multiple threatening processes with respect to water quality, and these need to be combined to produce an overall water quality risk.

Decision trees were used to assign the overall water quality risk. The input to the decision trees was the water quality risk probabilities for the threatening processes (the probabilities determined using the method described in Section 2.3.6), and a relative proportioning of the importance of the threatening process relative to the other threatening process/es for each land use. As an example, the broadacre grazing land use has four threatening processes that are unlikely to have equal importance on water quality, and the importance is likely to vary across the catchment due to changing geological and landscape settings. The relative proportioning of the threatening processes was assessed on a land use and geology type basis using the following;

- the relative importance of a threatening processes within a landscape element, and
- the relative importance of a threatening process between landscape elements.

The proportions were constructed through a discussion process involving experts in the areas of land evaluation and hydrogeology. The process for assessing the relative importance of a threatening processes within a landscape element involved an assessment of each of the landscape elements and the assignment of a 'percentage contribution to poor water quality' for each of the threatening processes. Therefore, for each landscape element in each geology class, the sum of the threatening processes is 100%. The process for assessing the relative importance of a threatening processes between landscape elements involved the assignment of a low, moderate or high 'impact on water quality' relative to the other landscape elements.

The final relative proportions for each of the contributing threatening processes used to assign the overall water quality risk was calculated using the percentage value (converted to a decimal) of the relative importance of a threatening processes within a landscape element, multiplied by 1.0, 1.25 or 1.5 for low, moderate or high (respectively) 'impact on water quality' rating assessed for the relative importance of a threatening processes between landscape elements. Tables 2.18 - 2.21 describe the proportioning of the threatening process for each of the land uses used to assign the overall water quality risk.

Broadacre Grazing and Intensive Horticulture

Table 2.18a Proportions for the threatening processes for the determination of the overall water quality risk for broadacre grazing and intensive horticulture on sedimentary and metamorphic geologies.

LANDFORM	Water erosion	Nutrient leaching	Solute movement	Ground water recharge
Sharp crest (a)	0.37	0.10	0.10	0.75
Gentle broad crest (b)	0.50	0.10	0.10	0.60
Very steep slope (c)	N/A	N/A	N/A	N/A
Steep slope (d)	0.75	0.10	0.20	0.25
Moderately steep slope (e)	0.90	0.05	0.20	0.18
Moderate slope (f)	0.90	0.05	0.20	0.18
Gentle slope (g)	0.67	0.10	0.37	0.18
Very gentle slope (h)	0.31	0.25	0.31	0.31
Drainage depression (i)	0.60	0.10	0.37	0.25
Flat (j)	0.20	0.25	0.31	0.37

Table 2.18b Proportions for the threatening processes for the determination of the overall water quality risk for broadacre grazing and intensive horticulture on permian geology.

LANDFORM	Water erosion	Nutrient leaching	Solute movement	Ground water recharge
Sharp crest (a)	0.50	0.10	0.20	0.45
Gentle broad crest (b)	N/A	N/A	N/A	N/A
Very steep slope (c)	N/A	N/A	N/A	N/A
Steep slope (d)	N/A	N/A	N/A	N/A
Moderately steep slope (e)	N/A	N/A	N/A	N/A
Moderate slope (f)	0.90	0.05	0.20	0.19
Gentle slope (g)	0.68	0.10	0.30	0.19
Very gentle slope (h)	0.31	0.25	0.25	0.38
Drainage depression (i)	0.50	0.10	0.38	0.30
Flat (j)	0.25	0.25	0.25	0.45

Table 2.18c Proportions for the threatening processes for the determination of the overall water quality risk for broadacre grazing and intensive horticulture on basalt and alluvial geologies.

LANDFORM	Water erosion	Nutrient leaching	Solute movement	Ground water recharge
Sharp crest (a)	0.10	0.20	0.10	0.90
Gentle broad crest (b)	0.20	0.20	0.20	0.60
Very steep slope (c)	N/A	N/A	N/A	N/A
Steep slope (d)	0.20	0.20	0.20	0.60
Moderately steep slope (e)	0.38	0.20	0.25	0.38
Moderate slope (f)	0.44	0.15	0.31	0.31
Gentle slope (g)	0.38	0.20	0.20	0.38
Very gentle slope (h)	0.20	0.20	0.20	0.50
Drainage depression (i)	0.20	0.10	0.38	0.50
Flat (j)	0.20	0.20	0.20	0.50

Table 2.18d Proportions for the threatening processes for the determination of the overall water quality risk for broadacre grazing and intensive horticulture on granite geology.

LANDFORM	Water erosion	Nutrient leaching	Solute movement	Ground water recharge
Sharp crest (a)	0.30	0.15	0.15	0.50
Gentle broad crest (b)	0.20	0.60	0.20	0.25
Very steep slope (c)	N/A	N/A	N/A	N/A
Steep slope (d)	0.75	0.30	0.10	0.10
Moderately steep slope (e)	0.75	0.45	0.10	0.10
Moderate slope (f)	0.60	0.38	0.31	0.10
Gentle slope (g)	0.38	0.20	0.38	0.25
Very gentle slope (h)	0.38	0.20	0.38	0.25
Drainage depression (i)	0.25	0.25	0.44	0.25
Flat (j)	0.20	0.25	0.44	0.25

Intensive Cropping (Potatoes)

Table 2.19 Proportions for the threatening processes for the determination of the overall water quality risk for intensive cropping (potatoes) on basalt geology.

LANDFORM	Water erosion	Nutrient leaching	Solute movement
Sharp crest (a)	0.30	0.40	0.30
Gentle broad crest (b)	0.34	0.33	0.3
Very steep slope (c)	N/A	N/A	N/A
Steep slope (d)	0.34	0.33	0.33
Moderately steep slope (e)	0.50	0.30	0.38
Moderate slope (f)	0.56	0.20	0.44
Gentle slope (g)	0.50	0.30	0.30
Very gentle slope (h)	0.34	0.33	0.33
Drainage depression (i)	0.35	0.20	0.56
Flat (j)	0.34	0.33	0.33

Native Vegetation or Forestry Establishment

Overall water quality risk is the same as the water quality risk for water erosion threatening process for native vegetation or forestry removal.

Native Vegetation or Forestry Removal, and Extractive Industries

Table 2.20a Proportions for the threatening processes for the determination of the overall water quality risk for native vegetation or forestry removal, and extractive industries on sedimentary and metamorphic geologies.

LANDFORM	Water erosion	Ground water recharge
Sharp crest (a)	0.44	0.98
Gentle broad crest (b)	0.63	0.75
Very steep slope (c)	N/A	N/A
Steep slope (d)	1.05	0.38
Moderately steep slope (e)	1.13	0.31
Moderate slope (f)	1.13	0.31
Gentle slope (g)	0.98	0.44
Very gentle slope (h)	0.63	0.63
Drainage depression (i)	0.90	0.50
Flat (j)	0.40	0.75

Table 2.20b Proportions for the threatening processes for the determination of the overall water quality risk for native vegetation or forestry removal, and extractive industries on permian geology.

LANDFORM	Water erosion	Ground water recharge
Sharp crest (a)	0.75	0.60
Gentle broad crest (b)	N/A	N/A
Very steep slope (c)	N/A	N/A
Steep slope (d)	N/A	N/A
Moderately steep slope (e)	N/A	N/A
Moderate slope (f)	1.13	0.31
Gentle slope (g)	0.98	0.44
Very gentle slope (h)	0.63	0.75
Drainage depression (i)	0.75	0.60
Flat (j)	0.50	0.90

Table 2.20c Proportions for the threatening processes for the determination of the overall water quality risk for native vegetation or forestry removal, and extractive industries on basalt and alluvial geologies.

LANDFORM	Water erosion	Ground water recharge
Sharp crest (a)	0.20	1.20
Gentle broad crest (b)	0.40	0.90
Very steep slope (c)	N/A	N/A
Steep slope (d)	0.40	0.90
Moderately steep slope (e)	0.63	0.63
Moderate slope (f)	0.75	0.50
Gentle slope (g)	0.63	0.63
Very gentle slope (h)	0.40	0.75
Drainage depression (i)	0.40	0.75
Flat (j)	0.40	0.75

Table 2.20d Proportions for the threatening processes for the determination of the overall water quality risk for native vegetation or forestry removal, and extractive industries on granite geology.

LANDFORM	Water erosion	Ground water recharge
Sharp crest (a)	0.40	0.75
Gentle broad crest (b)	0.50	0.63
Very steep slope (c)	N/A	N/A
Steep slope (d)	1.20	0.20
Moderately steep slope (e)	1.20	0.20
Moderate slope (f)	1.05	0.25
Gentle slope (g)	0.75	0.50
Very gentle slope (h)	0.75	0.50
Drainage depression (i)	0.63	0.63
Flat (j)	0.50	0.63

Septic Tank Effluent Disposal

Overall water quality risk is the same as the water quality risk for septic tank effluent disposal. (refer to Table 2.14)

Secondary Gravel or Earthen Roading

Overall water quality risk is the same as the water quality risk for water erosion threatening process for secondary gravel or earthen roading. (refer to Table 2.15)

Subdivision

The overall water quality risk for subdivisions is based on septic tank effluent disposal and secondary gravel or earthen roading overall water quality risk assessments.

Table 2.21a Proportions for the threatening processes for the determination of the overall water quality risk for subdivisions on sedimentary and metamorphic geologies.

LANDFORM	Septic tank effluent disposal	Secondary gravel or earthen roading
Sharp crest (a)	0.75	0.63
Gentle broad crest (b)	0.75	0.63
Very steep slope (c)	N/A	N/A
Steep slope (d)	0.63	0.75
Moderately steep slope (e)	0.63	0.75
Moderate slope (f)	0.63	0.75
Gentle slope (g)	0.63	0.75
Very gentle slope (h)	0.63	0.63
Drainage depression (i)	0.63	0.75
Flat (j)	0.63	0.50

Table 2.21b Proportions for the threatening processes for the determination of the overall water quality risk for subdivisions on permian geology.

LANDFORM	Septic tank effluent disposal	Secondary gravel or earthen roading
Sharp crest (a)	0.75	0.63
Gentle broad crest (b)	N/A	N/A
Very steep slope (c)	N/A	N/A
Steep slope (d)	N/A	N/A
Moderately steep slope (e)	N/A	N/A
Moderate slope (f)	0.63	0.75
Gentle slope (g)	0.63	0.75
Very gentle slope (h)	0.75	0.63
Drainage depression (i)	0.75	0.63
Flat (j)	0.75	0.63

Table 2.21c Proportions for the threatening processes for the determination of the overall water quality risk for subdivisions on basalt and alluvial geologies.

LANDFORM	Septic tank effluent disposal	Secondary gravel or earthen roading
Sharp crest (a)	0.75	0.50
Gentle broad crest (b)	0.75	0.50
Very steep slope (c)	N/A	N/A
Steep slope (d)	0.75	0.50
Moderately steep slope (e)	0.63	0.63
Moderate slope (f)	0.63	0.63
Gentle slope (g)	0.63	0.63
Very gentle slope (h)	0.63	0.50
Drainage depression (i)	0.63	0.50
Flat (j)	0.63	0.50

Table 2.21d Proportions for the threatening processes for the determination of the overall water quality risk for subdivisions on granite geology.

LANDFORM	Septic Tank Effluent Disposal	Secondary Gravel or Earthen Roading
Sharp crest (a)	0.63	0.50
Gentle broad crest (b)	0.75	0.50
Very steep slope (c)	N/A	N/A
Steep slope (d)	0.75	0.75
Moderately steep slope (e)	0.75	0.75
Moderate slope (f)	0.75	0.75
Gentle slope (g)	0.63	0.63
Very gentle slope (h)	0.63	0.63
Drainage depression (i)	0.63	0.63
Flat (j)	0.63	0.50

2.4 Planning

New Victoria Planning Provisions (VPP) were introduced into Victoria in 1996. The new provisions provide a focus on strategic planning and required councils to review and amend their existing schemes into the new format schemes. The VPP structure included a State Planning Policy Framework that covered a range of State policy statements addressing matters such as Settlement, Environment, Housing, Economic Development and Infrastructure.

Each of the groupings above addresses a range of specific land use issues. Catchment planning and management is included in the grouping of Environment and has as one of its key objectives,

'to assist the protection and, where possible, restoration of catchments, waterways, waterbodies, groundwater, and the marine environment'.

The document then specifies a range of implementation processes, including the use of mapping information to identify the beneficial use of groundwater resources and potential impacts on the quality of those resources through land use and development.

The VPP structure also includes a Municipal Strategic Statement (MSS) which allows the council to specify its vision for strategic directions at the local level. The MSS may include specific strategic statements and directions for catchment management and other actions identified and assessed as locally important through strategic work undertaken by the council. Local policies can also be added to this local planning framework to support zoning and overlay controls that specifically identify areas of importance to the council such as catchment areas. Where a place is covered by a specific overlay, the provisions specify that a planning permit is required from the responsible authority for buildings and works nominated in the overlay. The provisions may specify a range of exempted matters and decision guidelines that must be considered by the council before it can issue a planning permit.

It is within this planning structure that this project has progressed. Proposed changes to planning schemes within the Lake Eppalock Water Supply Catchment must therefore be able to be strategically justified through the land capability assessment process and then effectively translated into the new format planning schemes. This is the planning method and approach that has underpinned this project.

3 WATER QUALITY RISKS

3.1 Water Quality Risk Definition

Water quality risks were assessed according to five classes. The definitions of the classes are presented in Table 3.1.

Table 3.1 Definition of the water quality risk classes.

Water quality risk class	Definition
Low	Low probability of impacting on water quality given the land use and land management scenario. Changes to land use and land management are not required.
Low-Moderate	Low to moderate probability of impacting on water quality given the land use and land management scenario. Changes to land management practices may be required if the land use is to be pursued.
Moderate	Moderate probability of impacting on water quality given the land use and land management scenario. Changes to land management practices are required if the land use is to be pursued.
Moderate-High	Moderate to high probability of impacting on water quality given the land use and land management scenario. Moderate probability that the land use may not be appropriate.
High	High probability of impacting on water quality given the land use and land management scenario. High probability that the land use may not be appropriate.

Water quality risks were assessed for each land use based on a land management scenario for the key land management practice that impacts on the water quality threatening process/es. Land management scenarios were developed for each of the mapped land units (Appendix 1). The land management scenario was considered to be typical of current or most likely land management practices for the land unit.

Land management practices are the key variable in this analysis of water quality risk and therefore changes to the land management scenario will alter the water quality risk. Sensitivity analysis can be undertaken to identify the land management scenario with the least impact on water quality.

3.2 Overview of Water Quality Risks

3.2.1 Broadacre Grazing

The overall water quality risk from broadacre grazing is generally low or low-moderate for all parts of the catchment (Table 3.2). The water quality threatening processes included water erosion, nutrient leaching, surface solute movement and groundwater recharge. The results reflect the impact of the land management scenarios on the water quality threatening processes viz;

Water erosion and surface solute movement. High rates of vegetation cover year round in the mid and southern areas of the catchment (reducing the water quality risk) and moderate rates of vegetation cover on shallow soil areas in the north of the catchment.

Nutrient leaching. Common practice for maintenance fertiliser applications or no fertiliser application (reducing the water quality risk).

Groundwater recharge. High rates of annual pastures throughout the catchment (increasing the water quality risk).

Table 3.2 Area (ha) of overall water quality risk classes for broadacre grazing for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	5952.95	26059.47	350.67	9338.63	235.92
Hepburn	1495.04	10373.18	-	6423.28	1230.03
Macedon Ranges	3400.29	51342.28	713.32	15171.80	1065.88
Mitchell	4207.87	14930.23	151.19	10989.84	2.31
Mount Alexander	6582.95	29719.18	549.24	2958.54	5342.98
Total Lake Eppalock Catchment	21639.1	132424.3	1764.42	44882.09	7877.12

3.2.2 Intensive Cropping (Potatoes)

The overall water quality risk from intensive cropping (potatoes) is moderate-high in the applicable areas of the catchment (Table 3.3). The water quality threatening processes included water erosion, nutrient leaching and surface solute movement. The results reflect the impact of the land management scenarios on the water quality threatening processes viz;

Water erosion and surface solute movement. Significant periods of the year when the soil surface has no vegetation cover as a result of tillage or harvesting operations (increasing the water quality risk).

Nutrient leaching. Potatoes are a high value crop and it is likely to be common practice for higher than maintenance fertiliser applications (increasing the water quality risk).

Table 3.3 Area (ha) of overall water quality risk classes for intensive cropping (potatoes)* for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS					
Local government area	**Not applicable**	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	41847.49	-	-	-	-	90.15
Hepburn	17317.75	-	-	-	2171.26	32.52
Macedon Ranges	68483.83	-	-	-	2099.85	1109.89
Mitchell	30280.44	-	-	-	1.00	-
Mount Alexander	45152.64	-	-	-	0.25	-
Total Lake Eppalock Catchment	203082.15	-	-	-	4272.36	1232.56

* Potato cropping is only suited to some areas of the Lake Eppalock Catchment.

3.2.3 Intensive Horticulture (Viticulture)

The overall water quality risk from intensive horticulture (viticulture) is low and low-moderate for all areas of the catchment (Table 3.4). The water quality threatening processes included water erosion, nutrient leaching, surface solute movement and groundwater recharge. The results reflect the impact of the land management scenarios on the water quality threatening processes viz;

Water erosion and surface solute movement. Moderate rates of inter-row vegetation cover were assumed for all areas of the catchment. The assumptions is base on the use of tillage or heavy grazing as a weed control option (increasing the water quality risk).

Nutrient leaching. The use of maintenance fertiliser applications was considered to be a more common practice than greater than maintenance fertiliser applications (reducing the water quality risk).

Groundwater recharge. Drip irrigation systems were considered to be the norm (as compared to sprinkler systems) for any current or new vineyards (reducing the water quality risk).

Table 3.4 Area (ha) of overall water quality risk classes for intensive horticulture (viticulture) for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	18597.08	13599.01	88.40	9509.15	144.00
Hepburn	3071.79	6230.79	6098.01	1532.20	2588.74
Macedon Ranges	27371.46	21032.24	6993.69	13327.94	2968.24
Mitchell	8770.40	10518.89	151.83	10839.27	1.05
Mount Alexander	12281.45	24047.42	263.25	3202.56	5358.21
Total Lake Eppalock Catchment	70092.18	75428.35	13595.18	38411.12	11060.24

3.2.4 Native Vegetation or Forestry Establishment

The overall water quality risk from native vegetation or forestry establishment is generally low and low-moderate for all areas of the catchment, with some areas classed as high in all of the local government areas (Table 3.5). The water quality threatening process was water erosion. The results reflect the impact of the land management scenarios on the water quality threatening processes viz;

Water erosion. Moderate rates of vegetation cover were assumed for vegetation establishment as a result of machinery trafficking and herbicide application (increasing the water quality risk).

Table 3.5 Area (ha) of overall water quality risk classes for native vegetation or forestry establishment for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	334.99	16939.22	-	14354.97	10308.46
Hepburn	0.86	1766.41	-	15708.37	2045.89
Macedon Ranges	4423.04	8715.73	-	42642.47	15912.33
Mitchell	-	7606.36	-	8708.49	13966.59
Mount Alexander	4.18	11721.71	-	22176.64	11250.36
Total Lake Eppalock Catchment	4763.07	46749.43	-	103590.94	53483.63

3.2.5 Native Vegetation or Forestry Removal

The overall water quality risk from native vegetation or forestry removal varies across the catchment and reflects the impact on groundwater recharge (Table 3.6). The water quality threatening processes included water erosion and groundwater recharge. The results reflect the impact of the land management scenarios on the water quality threatening processes viz;

Water erosion. Moderate rates of vegetation cover were assumed for vegetation removal as a result of machinery trafficking (increasing the water quality risk).

Groundwater recharge. The type of vegetation to replace the removed native vegetation or forest was generally assumed to be of a perennial type (i.e. replaced with trees) (moderating the short -medium term water quality risk).

Table 3.6 Area (ha) of overall water quality risk classes for native vegetation or forestry removal for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	17940.28	2731.15	-	11659.41	9606.80
Hepburn	3285.77	5200.38	-	2346.35	8689.03
Macedon Ranges	23064.39	14812.46	-	12286.24	21530.48
Mitchell	7365.70	1819.94	-	9021.04	12074.76
Mount Alexander	11555.35	14158.06	-	9219.48	10220.00
Total Lake Eppalock Catchment	63211.49	38721.99	-	44532.52	62121.07

3.2.6 Septic Tank Effluent Disposal

The overall water quality risk from septic tank effluent disposal is generally moderate-high and high for all areas of the catchment (Table 3.7). The water quality threatening processes included nutrient leaching, surface solute movement and groundwater recharge. The threatening processes were assessed together using the criteria from the *Code of Practice* (EPA 1996). The results reflect the low capability of soils (particularly dispersive clays), and the impact of high rainfall in the southern areas of the catchment (significantly increasing the risk).

Table 3.7 Area (ha) of overall water quality risk classes for septic tank effluent disposal for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	24.00	76.75	-	-	41836.89
Hepburn	33.96	4977.56	611.73	-	13898.28
Macedon Ranges	159.72	8980.67	2412.03	-	60141.15
Mitchell	-	-	-	-	30281.44
Mount Alexander	5.18	65.70	50.92	-	45031.09
Total Lake Eppalock Catchment	222.86	14100.68	3074.68	-	191188.85

3.2.7 Secondary Gravel or Earthen Roading

The overall water quality risk from secondary gravel or earthen roading is generally low-moderate for all areas of the catchment, with some areas classed as high in all local government areas (Table 3.8). The water quality threatening process was water erosion. The results reflect the impact of the land management scenarios on the water quality threatening processes viz;

Water erosion. Moderate rates of compliance with the *Code of Forest Practices* (DNRE 1996) were assumed for the construction and maintenance of secondary roads (moderating –increasing the water quality risk).

Table 3.8 Area (ha) of overall water quality risk classes for secondary gravel or earthen roading for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	17274.21	-	13815.87	10847.56	-
Hepburn	1767.27	-	12354.73	5399.53	-
Macedon Ranges	13138.77	-	33464.12	25090.68	-
Mitchell	7606.36	-	8707.99	13967.09	-
Mount Alexander	11725.89	-	21995.74	11431.26	-
Total Lake Eppalock Catchment	51512.50	-	90338.45	66736.12	-

3.2.8 Subdivisions

The overall water quality risk from subdivisions is generally moderate-high and high for all areas of the catchment (Table 3.9). The risk from subdivisions was a composite of risks from septic tank effluent disposal and secondary gravel or earthen roading. The water quality threatening processes included water erosion, nutrient leaching, surface solute movement and groundwater recharge. The results are a reflection of those for septic tank effluent disposal and secondary gravel or earthen roading, and are moderated by the latter land use.

Table 3.9 Area (ha) of overall water quality risk classes for subdivisions for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	66.75	-	1.75	15143.43	26725.71
Hepburn	33.96	6.67	5336.71	337.69	13806.50
Macedon Ranges	44.97	354.14	7034.57	13873.51	50386.38
Mitchell	-	-	-	6951.08	23330.36
Mount Alexander	5.18	1.43	114.69	10981.97	34049.62
Total Lake Eppalock Catchment	150.86	362.24	12487.72	47287.68	148298.57

3.2.9 Land-based Extractive Industries

The overall water quality risk from land-based extractive industries is low for all areas of the catchment (Table 3.10). The water quality threatening processes included water erosion and groundwater recharge. The results reflect the impact of the land management scenarios on the water quality threatening processes viz;

Water erosion and groundwater recharge. High rates of compliance with the environmental guidelines (Cummings, 1996) were assumed for extractive industries (decreasing the water quality risk).

Table 3.10 Area (ha) of overall water quality risk classes for extractive industries for each local government area and the total catchment.

	OVERALL WATER QUALITY RISK CLASS				
Local government area	**Low**	**Low-moderate**	**Moderate**	**Moderate-high**	**High**
Greater Bendigo	18451.54	13323.12	4783.22	5285.86	93.90
Hepburn	3808.11	7198.61	1080.15	1371.43	6063.23
Macedon Ranges	27348.89	25687.32	6586.92	2602.77	9467.67
Mitchell	7973.51	8651.10	10837.51	1693.81	1125.51
Mount Alexander	12031.50	21470.38	5419.11	5935.92	295.98
Total Lake Eppalock Catchment	69613.55	76330.53	28706.91	16889.79	17046.29

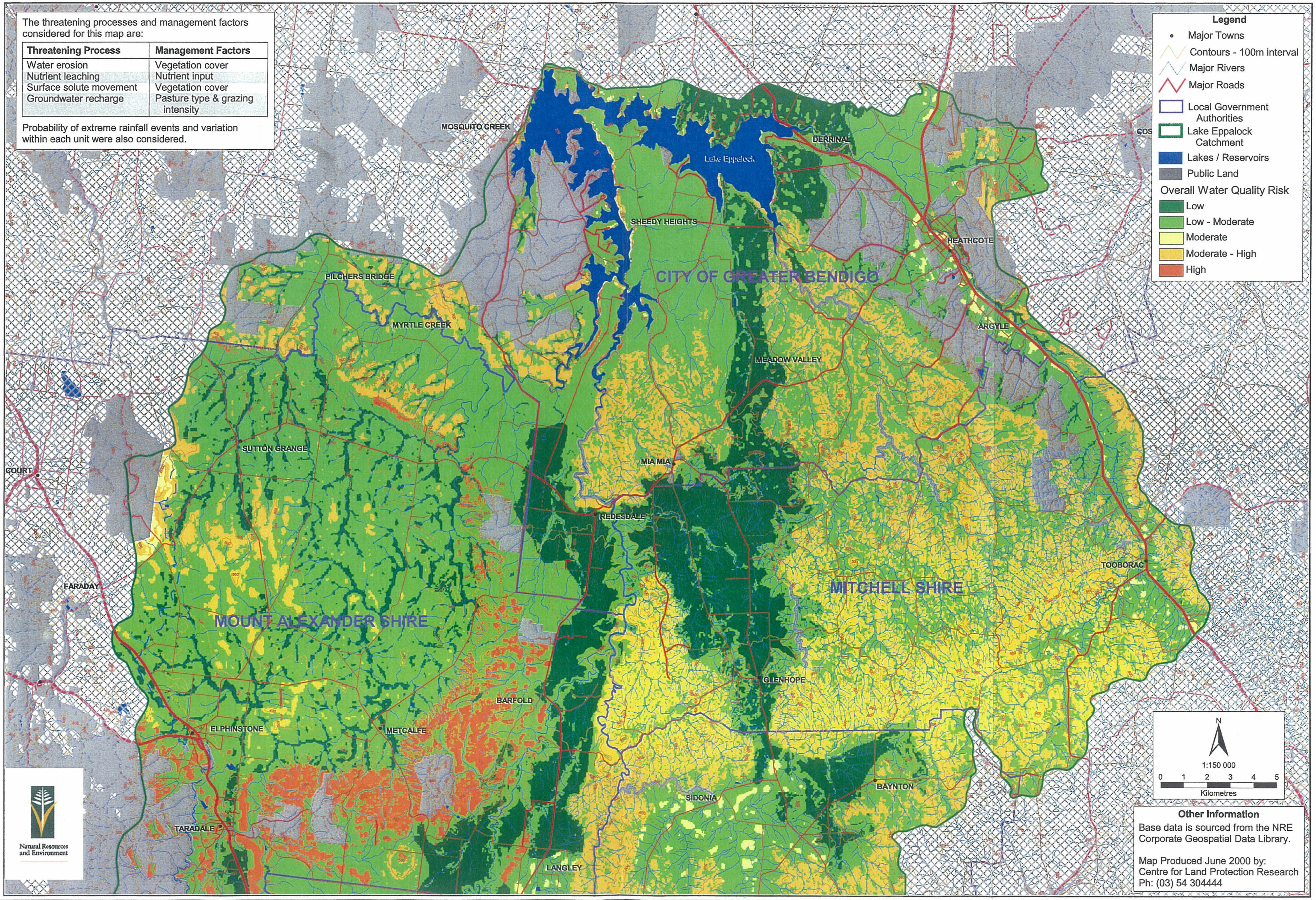
3.3 Overall Water Quality Risk Maps

Maps showing the spatial distribution of the overall water quality risks are as follows;

- Map 3.1a Overall Water Quality Risk for Broadacre Grazing, Northern Lake Eppalock Catchment
- Map 3.1b Overall Water Quality Risk for Broadacre Grazing, Southern Lake Eppalock Catchment
- Map 3.2a Overall Water Quality Risk for Intensive Cropping (Potatoes), Northern Lake Eppalock Catchment
- Map 3.2b Overall Water Quality Risk for Intensive Cropping (Potatoes), Southern Lake Eppalock Catchment
- Map 3.3a Overall Water Quality Risk for Intensive Horticulture, Northern Lake Eppalock Catchment
- Map 3.3b Overall Water Quality Risk for Intensive Horticulture, Southern Lake Eppalock Catchment
- Map 3.4a Overall Water Quality Risk for Native Vegetation or Forestry - Establishment, Northern Lake Eppalock Catchment
- Map 3.4b Overall Water Quality Risk for Native Vegetation or Forestry - Establishment, Southern Lake Eppalock Catchment
- Map 3.5a Overall Water Quality Risk for Native Vegetation or Forestry - Removal, Northern Lake Eppalock Catchment
- Map 3.5b Overall Water Quality Risk for Native Vegetation or Forestry - Removal, Southern Lake Eppalock Catchment
- Map 3.6a Overall Water Quality Risk for Septic Tank Effluent Disposal, Northern Lake Eppalock Catchment Catchment
- Map 3.6b Overall Water Quality Risk for Septic Tank Effluent Disposal, Southern Lake Eppalock Catchment
- Map 3.7a Overall Water Quality Risk for Secondary Gravel or Earthen Roading, Northern Lake Eppalock
- Map 3.7b Overall Water Quality Risk for Secondary Gravel or Earthen Roading, Southern Lake Eppalock Catchment
- Map 3.8a Overall Water Quality Risk for Subdivision, Northern Lake Eppalock Catchment
- Map 3.8b Overall Water Quality Risk for Subdivision, Southern Lake Eppalock Catchment
- Map 3.9a Overall Water Quality Risk for Land-based Extractive Industries, Northern Lake Eppalock Catchment
- Map 3.9b Overall Water Quality Risk for Land-based Extractive Industries, Southern Lake Eppalock Catchment

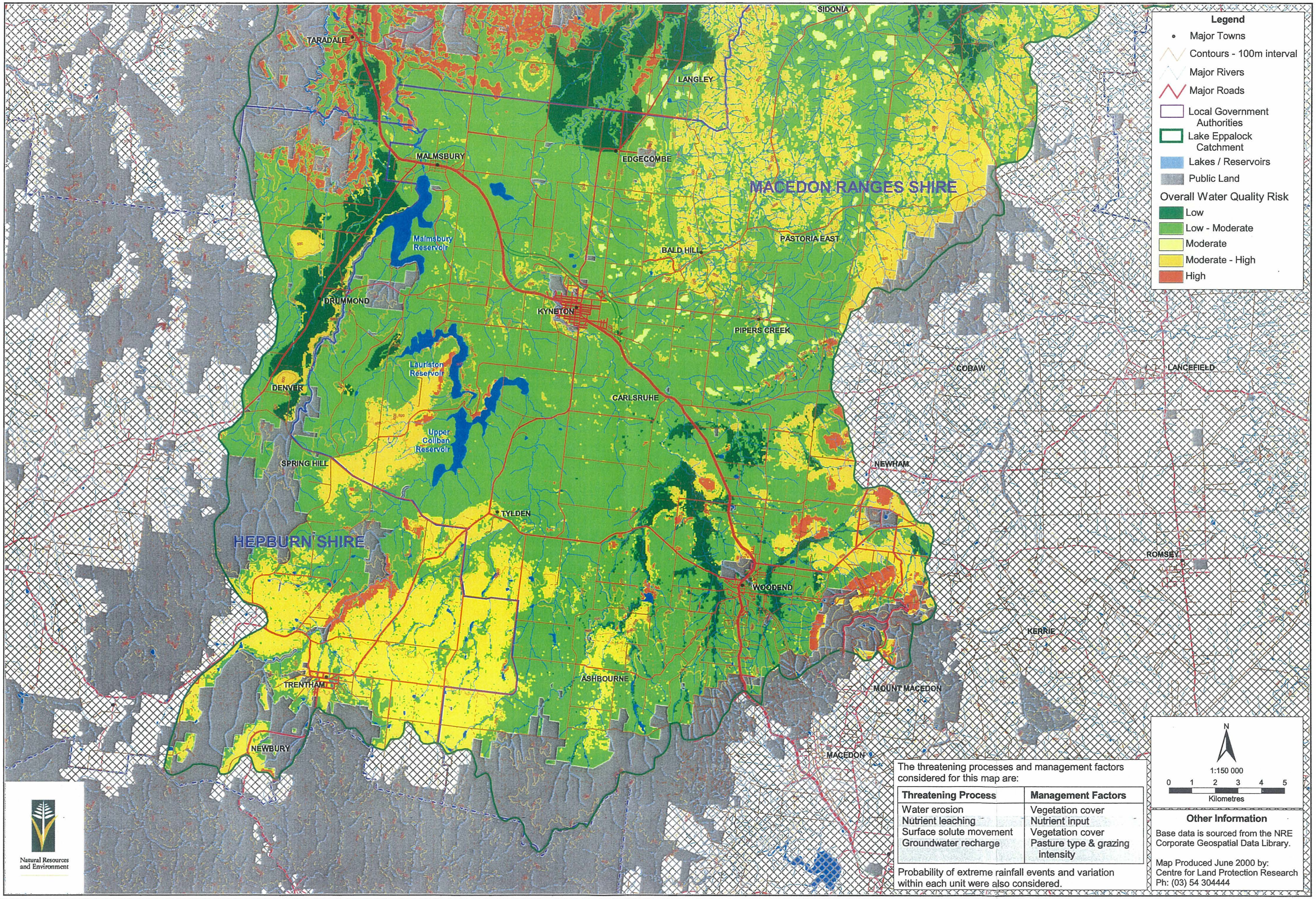
Map 3.1a Risk of Broadacre Grazing on Water Quality, Northern Lake Eppalock Catchment

Map 3.1a Broadacre Grazing



Map 3.1b Risk of Broadacre Grazing on Water Quality, Southern Lake Eppalock Catchment

3.1b Broadacre Grazing



The threatening processes and management factors considered for this map are:

Threatening Process	Management Factors
Water erosion	Vegetation cover
Nutrient leaching	Nutrient input
Surface solute movement	Vegetation cover
Groundwater recharge	Pasture type & grazing intensity

Probability of extreme rainfall events and variation within each unit were also considered.

Other Information

Base data is sourced from the NRE Corporate Geospatial Data Library.

Map Produced June 2000 by:
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Natural Resources and Environment

Map 3.2a Risk of Intensive Cropping (Potatoes) on Water Quality, Northern Lake Eppalock Catchment

Map 3.2a Intensive Cropping