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A Risk Rating Scheme for Adjacent Land Uses of Victoria

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This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed here are those of the authors and do not necessarily reflect the opinions of the Environment Protection Authority or Worcester Polytechnic Institute.

This report is the product of an educational program, and is intended to serve as partial documentation for the evaluation of academic achievement. The reader should not infer the report as a working document.

Abstract

The Environment Protection Authority (EPA) of Victoria, Australia, needed to identify areas at a high risk of phosphorus overloading. Using NEXSYS, a computer program, phosphorus export values can be predicted. With these values, an analysis of Victoria was done, and a risk map was developed. A user's guide was made to explain the indicated risk areas. The map and guide will aid experts in improving high risk areas and serve as an educational tool for the public.

Authorship Page

All sections of this proposal were contributed to equally by Randal Brown, Kara Gibbs, Timothy Hogan, and William Rowell.

Randal Brown was responsible for a large portion of the writing of this project. He also assisted in the divisions of the map of Victoria, and took a part in the NEXSYS analysis for the risk maps.

Kara Gibbs was also responsible for a large portion of the writing of this project. She also worked on the division of Victoria into several regions and played a part in the NEXSYS analysis for the risk maps.

Timothy Hogan was responsible for writing parts of this project report. He also completed both analyses of the NEXSYS program and assisted in the NEXSYS analysis for the risk maps.

William Rowell was also responsible for writing some parts of this report. His major role was in the creation of the risk maps of the state, created with ArcView.

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Cheers y'all!!!!

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Executive Summary

The Environment Protection Authority (EPA) in Victoria, Australia sponsored this project. The EPA works to improve and maintain environmental conditions throughout Victoria. The water quality has been decreasing in some areas of the state. This has been blamed in part on high levels of phosphorus being exported, or lost, from the land to the surrounding waters. As a result, the water in Victoria is becoming polluted and the aquatic wildlife are suffering.

A computer program called NEXSYS was created in 1995 by CSIRO to predict nutrient export rates from various land uses. The EPA wished to use this program during its study and research to gain a better understanding of the causes of high levels of nutrient loadings. Unfortunately, this program had yet to be extensively examined to determine its accuracy and usability.

There were four main goals for the project. The first was to analyze NEXSYS. The second goal was to create a risk rating process. Third, a risk map of Victoria was made that shows regions with a high risk of phosphorus overloading. The final goal was to create a user's guide for the risk map to act as a supplement to the map.

NEXSYS is a program designed to predict nutrient export rates. By selecting the type of land use and other characteristics of the land that the user wishes to examine, the program will help the user determine a phosphorus export range that could be expected. An examination was done for all possible NEXSYS outputs to determine its usability. Once the program was found usable, Victoria was broken up into thirty sections. The sections were divided up by grouping areas with similar land and environmental

characteristics together. Each section was run through NEXSYS and a phosphorus export range was found for each section.

Creating the risk map was done with ArcView, a Geographic Information System (GIS) application. Using the NEXSYS outputs for various sections in Victoria, a phosphorus export map was first created. This map showed each section's phosphorus range, according to NEXSYS. The risk map ranked the sections from one to five, based on the phosphorus export rates. The sections with rating of five that had the highest export rates were considered the areas at the highest risk of excessive phosphorus loading. The sections with a one rating were considered to have very low risk of phosphorus export from the land.

To see if NEXSYS would also work on a smaller scale, a small region in Victoria was analyzed. This region is located in southeastern Victoria, known as the Latrobe-Thompson River Basin. The analysis was performed using the same procedure followed in the Victoria study. The basin was broken into 64 sections, and its land characteristics were run through NEXSYS to obtain a nutrient export range. Each section was then given a risk rating number, which was shown on a risk map. The results showed that our procedure was able to work on a smaller scale, and the results made intuitive sense to EPA staff members.

The user's guide was created to act as an explanation of the risk map. It shows the risk map, explains what the risk ratings mean, and shows what variables were entered into NEXSYS for each section. Explanations of the problems associated with high levels of phosphorus in the environment were also included.

The outcomes of this project proved to be very useful, but in the future could be more accurate. First, NEXSYS was found to be useable for this project. It produced phosphorus ranges that were accurate enough so a risk rating map could be created. The EPA does not currently have a map of this type, so its uses have not been thoroughly explored. The risk rating map that was created indicated regions in Victoria in danger of phosphorus overloading. This map identified eight sections that were at the highest risk of phosphorus runoff and seven that were at the lowest risk. The user's guide was created to give environmental experts at the EPA a quick reference to see where the high risk areas are. Also, the user's guide may be used to inform catchment managers, politicians, and the general public of the areas in Victoria that are susceptible to nutrient runoff, common causes of these problems, and possible solutions to alleviate the hazardous conditions. Through this, the EPA hopes to better distribute its funding to areas that are at high risk. The guide is intended to serve as a supplement to the map and as an educational tool.

An extension of this project could include more detailed maps that can be created in a similar manner as that used for the Latrobe-Thompson River Basin. These maps have the capability of helping the EPA pinpoint areas that are the source of nutrients being transported to the water. From this, the EPA could monitor the area, inform the locals of the situation, and hopefully find ways to improve the water conditions.

Chapter One – Introduction

The Environment Protection Authority (EPA) in Victoria, Australia was the sponsor for this project. Established in 1970 under the Environment Protection Act, the EPA strives to improve and maintain high environmental conditions of Australia. The EPA maintains these standards through work approvals, licenses, and inspections.

Over the years, the quality of the waterways in Victoria has been diminishing. This is a result of nutrient runoff from the land. Excessive amounts of nutrients, primarily phosphorous, are entering the waterways and causing environmental problems by lowering the quality of the water. The EPA wished to create a map of Victoria that identifies the regions at high risk from nutrient runoff, and give each region a risk rating number that will identify the severity of the problem.

Before the map could be created, a method for estimating nutrient run-off needed to be determined. NEXSYS is a program developed in Australia by CSIRO for predicting the amount of nutrients that are released from the land each year. Based on land use and on certain soil and climate characteristics, such as slope of the land, erosivity, and rainfall. The user of the program enters the data NEXSYS asks for, such as if the slope of the land is greater or less than eighteen degrees. After a series of similar queries, NEXSYS produces a range of nutrient levels being released from the land. The program is new and had not yet been thoroughly tested to determine its accuracy. This project attempted to test NEXSYS by carefully examining the values and ranges NEXSYS creates, and finally conclude whether or not the program is a viable tool in nutrient risk assessment.

Once the NEXSYS evaluation was complete, a Geographic Information System (GIS) map was created utilizing the values NEXSYS produced. A GIS is a map-making program that allows the user to overlay numerous bits of information onto one map. Each region in Victoria was given a risk rating number by comparing the values NEXSYS produces to acceptable nutrient levels, which are specified by the EPA.

Finally, a user's guide was produced to explain the risk rating system and the parameters and justifications used in creating the risk values on the GIS map. The user's guide will be an educational tool for the user, indicating the causes of high nutrient levels, the effects, and possible solutions to reduce the problem.

The EPA wishes to use the map for two reasons. First, it will be a quick reference to identify the high risk areas of nutrient runoff throughout Victoria. Second, the EPA wishes to show the map and the user's guide to the public to help them gain a better understanding of the problems associated with nutrient runoff and to show which areas are most affected.

An Interactive Qualifying Project (IQP) is a degree requirement at Worcester Polytechnic Institute. The purpose of an IQP is to combine science and technology with current social issues. This project involved using science and technology, which include NEXSYS and GIS mapping programs, as well as knowledge of the environment, to assist in analyzing environmental contamination. Contamination is a social issue that affects thousands of people throughout Victoria. The results of this project will assist the EPA in determining which areas are susceptible to nutrient pollution.

Chapter Two - The Literature Review

This literature review is intended to organize and present the highlights of the research that contributed to this project. All information contained here is from reputable sources in the field of water quality management. Research areas that were focused on included water quality standards, nutrient pollution in waterways, land uses, and the risks of erosion. The results of this research were used to gain an understanding of the problems resulting from high nutrient content in rivers as well as learning how to map pollution statistics by using Geographic Information System (GIS).

It is important to understand which nutrients are entering the waterways and the sources from which they come. Hundreds of nutrients naturally occur in soil, rocks, plants, trees, and water. Three of the most important nutrients to sustain plant life are carbon, nitrogen, and phosphorus. The amounts of these nutrients found naturally in the environment are adequate to support the ecosystem. However, with the introduction of nutrients from fertilization and human and industrial waste, this pre-existing balance is interrupted.

2.1 Pollution

Pollutants come from a wide variety of sources, and can come in a number of forms. In any case, pollutants are disrupting the environment and must be removed to ensure the protection of the ecosystem. In order to do this, it is important to understand where the contamination are coming from, how they were transported to the environment, and the problems they are causing.

2.1.1 Point Sources

Pollutants discharged into waterways can be classified into two categories, point sources or non-point sources. Point sources are easy to determine, because the pollutants are being released from a particular point. An example of a point source is a wastewater treatment plant facility. Once the wastewater has been treated, it is released into a river or stream at a particular spot (Davis, 1998).

2.1.2 Non-Point Sources

Non-point sources are more difficult to determine because the pollution is not coming from a specific area or region. Some examples of non-point sources are found in agricultural or urban areas. In most cases, the pollutants are carried by rainwater from these areas and deposited in the nearest waterway (Davis, 1998). For this study, only agricultural areas will be examined.

2.1.3 Agricultural Runoff

The primary source of nutrient pollution comes from agricultural runoff. When the rainwater falls to the ground, it does one of two things. It either seeps into the ground until it reaches the ground water or it runs along the surface of the ground until it reaches a water body. In either case, as the water flows, it picks up tiny particles or sediment in the ground and carries it to its final destination (Davis, 1998).

In Australia, the soil is very low in the nutrients needed to support plant growth (Bambrick, 1994). In order to sustain their crops, farmers must use fertilizer. Fertilizers contain the nutrients required for plant growth, most notably phosphorous and nitrogen.

When it rains, some of the fertilizer is swept away and deposited into the nearest waterway (Davis, 1998).

2.1.4 Wastewater Discharge

Wastewater treatment facilities treat wastes produced from municipalities and industries. They do this by converting the raw wastewater into water through a series of treatment processes, then releasing the treated water into the nearest river. However, the treated water is not as pure as the water found naturally in the environment. Raw wastewater is composed of a number of nutrients, including phosphorous and nitrogen, as well as other substances. It is impossible for the wastewater treatment plant to remove all of the phosphorous and nitrogen; therefore some of it is released into the waterway (Merritt, 1996).

2.1.5 Phosphorous

Phosphorous is found in nature, but only in small quantities. It is also a very important nutrient for plant growth. In a truly pristine environment, the phosphorous needed for algae growth would reach the waters by natural weathering of rock. Since the amount of phosphorous is limited in nature, phosphorous is termed the limiting nutrient for algae growth because the amount of algae that grows in a particular lake or stream is directly related to the amount of phosphorous available (Davis, 1998). When phosphorous reaches the waterway through other means than the weathering of rocks, such as agricultural runoff or wastewater discharge, algae growth increases and creates an imbalance in the waterways.

2.1.6 Nitrogen

Nitrogen is naturally found everywhere. It is also a necessary nutrient for plant growth. For this reason, nitrogen is an important ingredient in fertilizers. During agricultural runoff, fertilizer is swept away by the washing rainwater into the nearest waterway. Nitrogen will affect the water quality depending on its amount in the water. In high concentrations, nitrogen is toxic to fish. In lower concentrations, nitrogen will contribute to algae growth (Davis, 1998).

2.1.7 Algal Blooms

When sufficient amounts of phosphorous is available, algae will grow. In places where there is an excessive amount of phosphorous available that is continually entering the waterway, such as from agricultural runoff or wastewater treatment discharge, algal blooms are common. Algae blooms are excessive algae growth occurring in a small area of the waterway (Herath, 1997). Algal blooms appear as surface scum or colored water. Although algae are necessary to support the food chain, extreme amounts can decrease the dissolved oxygen levels in the water and produce toxins (Cottingham, 1995).

The frequency and severity of algal blooms have increased significantly in Victoria over the past twenty years. The main factors that influence the formation and growth are nutrients, light, temperature, turbidity, and pH. Algal blooms can reach 1,000 km in length and cost millions of dollars to remove (Cottingham, 1995).

When algae die, it settles to the bottom of the lake or river, where it is broken up by bacteria. During this process, bacteria consume large amounts of dissolved oxygen from the water. This oxygen is required by plants and wildlife to breathe. If the amount of dissolved oxygen drop to critical levels, certain fish and other aquatic life will not be able to breathe and will suffocate (Davis, 1998).

Certain types of algae are capable of producing biotoxins. If there is an overabundance of this type of algae in the water, the toxins they produce can be deadly to fish and other marine animals. There have been a number of documented cases of this phenomenon in Australia over the past twenty years. One such occurrence happened in 1984 in Port Phillip Bay. Fish were dying and their bodies were covered with lesions, and in some cases the fins were completely eroded and the eyes dissolved. Usually, these types of symptoms are the result of high concentrations of heavy metals or organic toxins in the water. However, in this case, scientists ruled out that possibility and concluded that biotoxins produced from a large algal bloom were the source of the problem (Davis, 1998).

Reservoirs and lakes support the highest number of algal blooms, because the water is not flowing at a high velocity, so the algae roots can take hold of the ground. The points of discharge from wastewater treatment plants are also favorable conditions for algal blooms because of the high phosphorous concentrations in the water (Cottingham, 1995).

2.1.8 Eutrophication

Eutrophication is another result of nutrient runoff into lakes. This is a natural process in which lakes become shallower as sediment and nutrients are introduced to the waterway. As the soil and nutrients build up in and around the waterway, algae and plants grow. Over a period of time, the lake will fill in with sediment and plants until it reaches a point where it will no longer resemble a lake. This natural process can be expedited through human processes, such as nutrient runoff from agriculture areas or wastewater treatment plants (Davis, 1998).

2.2 Erosion and Runoff

One of the most severe agricultural problems in the world is water erosion. This is caused by the energy of rain or other forms of precipitation hitting the earth. Raindrops can fall at speeds up to 20 miles per hour, which are able to break up the top layer of soil. As rain water flows to surrounding bodies of water along the ground, it carries with it the loosened soil, which may contain nutrients and pollutants (Purdue University: Water Erosion, 1999).

Water runoff occurs under two conditions. If the ground is saturated, no additional water can be absorbed into the earth, and any additional water has to flow off of the landmass to a lower elevation, usually ending up in a stream or river. The second situation in which runoff occurs is when there is heavy rainfall and the ground cannot absorb the water as quickly as it is falling, and the excess water must flow somewhere else (Widdows, et al. 1997).

2.2.1 Erosion Rates

The erodability of natural sediments depends on several physical, chemical, and biological factors, which include soil content, soil density, organic content, and exposure to different environmental factors. Based on grain size of the particles and the threshold of erosion velocity, the erosion rate of a particular sample can be roughly predicted (Widdows, et al. 1997).

Erosion rates are usually dependent on the vegetation in the area. The more vegetation there is, less soil is exposed directly to rainfall and the ground is not as erosive. Some types of vegetation offer more ground cover than others do, because the plants are more spread out. As the rain falls to the ground, it hits the vegetation, causing the speed of the raindrops to decrease. This causes the rain to hit the soil with much less of an impact. (Cerdá, 1995).

The amount of cover needed to prevent significant erosion and runoff has been analyzed. The general consensus is that at least 50% groundcover is needed to significantly reduce runoff. Grass best reduces soil erosion, because of the extensive network of roots that protect the soil. During the winter, a grass cover above 70% is needed to control erosion because the grass roots are inactive, as well as other vegetation being dead (Gutierrez and Hernandez, 1996).

2.2.2 Problems Associated with Runoff

There are many problems that are associated with runoff. One area that is affected is the land. Water runoff removes the topsoil and its nutrients, exposing the less rich sub soil to the surface. This makes it harder for plant life to grow. Water runoff can hit especially hard to agricultural areas because crops may be lost due to the poor soil. (Juracek, 1998).

The bodies of water are also affected. Soil is carried into the water from runoff and becomes suspended or settles to the bottom. If a significant amount enters a waterway and remains suspended, the water becomes cloudy and sunlight cannot penetrate to the same depths as before. Plants in the water depend on sunlight to process food. Without acceptable light, the plants will not be able to survive (Juracek, 1998). Suspended solids harm the animal life as well as the photosynthesizing organisms. The sediment clogs fish gills and can smother spawning and nursery areas (EPA, Office of Water, 1995).

Nature's delicate balance can be altered if changes, either large or small, occur in the environment. If a species either increases or decreases significantly in population, it can pose a threat to all the other species of the ecosystem. If the population drops, it may cause their predators to starve, and if it rises, it can take up resources needed by other species. Any change in the environment could cause this effect, from unusually high nutrient levels to man-made pollutants to decreased water clarity (Gutierrez, 1996).

A high percentage of Australian species are unique to the continent because of its geographical isolation from other continents. Specifically, 92% of the mammals and 85% of the flowering plants in Australia are indigenous to the country (World Directory of Country Environmental Studies, 1996). Because of the unique species, Australia needs to protect all aspects of its environment. If the ecosystem is altered, causing these plants and animals to die, there is no other place in the world that can replenish the population.

2.2.3 Agricultural Erosion Types

There are five types of erosion: sheet, interrill, rill, channel, and gully erosion. All five are found in Victoria. Each erosion type causes soil to move from an area of higher elevation to a lower elevation by means of water flow. Some types of erosion have more severe results than others, but each is a problem that must be dealt with (Purdue University: Water Erosion, 1999).

Sheet erosion is the removal of soil in a uniform sheet. The force of rain causes a consistent amount of topsoil to be removed. It can be recognized by either soil deposits at the base of a slope, or by light-colored deposits of soil on the surface. Sheet erosion is the least detrimental form of erosion, but the most common (Purdue University: Sheet Erosion, 1999).

Interrill erosion is a modification of sheet erosion. Exposed soil is never perfectly flat. As rainfall begins to cause sheet erosion, rain that lands on the higher areas on the soil surface tend to flow to the lower areas such as minor cracks and scratches. These imperfections soon have a thin layer of water covering them. When a raindrop falls directly into one of these tiny streams its downward motion increases the turbulence of the water. This extra turbulence causes the water that was simply washing away what was on the surface of the soil to dig a little deeper into it, deepening the scratch. This process is known as interrill erosion. Rill, channel, and gully erosion are all later effects of unchecked interrill erosion (Purdue: Interrill Erosion, 1999).

Rill erosion is the erosion of land once water enters small cracks in the soil, or rills. It picks up loose soil along the walls of the cracks and carries it with the rest of the water to a lower elevation. As this occurs, cracks become wider and deeper, forming larger rills. Rills will often form between rows of crops. It can be prevented by tilling the soil. Tilling is when the soil is disrupted and replaced. This removes any small rills that may have formed, but it also loosens the soil. Unfortunately, if rills do reform, the soil is more susceptible to being carried away. Since rill erosion is not easily visible, it is often overlooked. This can be detrimental since it is the type of erosion that is responsible for the most soil loss in Victoria (Purdue University: Rill Erosion, 1999).

Channel erosion is the erosion of soil through a canal deeper and wider than a rill. These are intentional canals that are dug to remove excess water during floods or during irrigation. It carries more soil and nutrients at a time. They can be tilled if needed to remove them, but usually this is not done because of their size. As in rill erosion, soil is removed from the walls of the channel, but in greater quantity. This is also a problem throughout the state (Purdue University: Channel Erosion, 1999).

Gully erosion is similar to channel and rill erosion. Gullies are channels that have been eroded so much that they cannot be removed through tilling, are very wide and deep. These carry large amounts of water after rainfall and deposit soil and material at the base of the slope, or into waterways (Purdue University: Gully Erosion, 1999).

2.2.4 Urban Runoff

Water runoff does not only occur on agricultural fields. It can also occur in urban and industrial areas. In these cases, it may not necessarily be soil erosion that causes the polluted runoff to occur. When rainfall hits the earth in the city, it doesn't wash away the soil, but rather picks up contaminants from the streets and sidewalks as it flows into stormdrains. This can include garbage, motor oil, and grease (EPA, Office of Water, 1995). In most cases, the stormdrains flow directly to the nearest body of water. Although it is a different process, the result is the same. Pollutants and contaminants are carried into the waterways and cause changes in the environment.

In rural areas, soil erosion usually remains at a fairly stable rate unless land use or rainfall changes. This is not true in urban areas. Construction contributes significantly to waterway sediment loads. The amount of suspended material in water runoff from a construction site can increase up to 1000 times the normal amount (World Directory of Country Environmental Studies, 1996).

2.2.5 Erosion Control

Australia, New Zealand, and the United States all have modern erosion control programs. In fact, in nearly all agricultural-based cultures, erosion has been recognized as a problem. In many European countries, erosion is at a fairly low level through enlightened land-use programs. According to modern soil conservationists, using the land sparingly and in ways that will allow the least amount of soil to erode is the solution to erosion problems. Using better planting practices and planting crops that protect the soil are two ways of helping to control erosion (Considine, Douglas 1996).

There are several temporary solutions that have been applied to construction sites. One solution used is temporary embankments built to catch any runoff soil. Later, this soil can be replaced where it is needed. Embankments can be a fibrous matting or even a plastic tarp. However, these techniques are not commonly used because of time and money that has to be spent incorporating them. There has been recent new research done to try and find new techniques for conserving the soil (Cheremisinoff and Young 1981).

consequence assessment is then statistically evaluated to decide how reliable they are and how probable it is that any of the scenarios created in the consequence assessment step will occur. This combination of all three steps and statistics is what is called risk estimation (Covello, 1993).

2.3.1 Low Input Risk Assessment

One major problem with risk assessment is that it is very hard to obtain accurate measurements with low amounts of data. The predictive nature of risk assessment makes it very dependent on large amounts of reliable data. Low input risk assessment is one method to deal with this problem. The assessor chooses an aspect of an exposure problem that has a large amount of available data, analyzes this aspect, and relates it to other exposure problems. This method is less reliable than other risk assessment techniques, but useful conclusions can still be drawn (Covello, 1993).

2.3.2 Limitations

Risk assessment is a system by which an investigator makes a best guess about what is happening or can happen in an area. By its very nature, risk assessment possesses a high degree of uncertainty in its results even when a large, accurate database is used. This uncertainty does not necessarily render the results useless. Only when the assessment is viewed as fact instead of as a guiding tool does it become misleading. Unfortunately, the majority of people have a strong distrust of anything uncertain (Cothern, 1996). This aspect of human nature, along with the highly technical and statistical nature of assessment results, makes effective communication of results extremely difficult (Covello, 1993). As a result, many management teams misinterpret assessment results and are confused about how to implement them.

In many instances of environmental clean up projects there is some form of public interest in the project. Effective communication with the public sector must take into account issues of public opinion as well as the aforementioned communication problems. One reason for this is the tendency of assessors to ignore the fact that risk assessment cannot be done without being influenced by the assessors biases and values. Assessment requires the assessor to decide what variables are most pertinent to the problem being discussed and to make value judgments on how serious an effect the problem will have on the stability of the ecosystem of interest (Cothern, 1996).

An ecosystem's stability is based on two of its general aspects, its resistance and resilience to contamination. The resistance of an ecosystem to contamination is essentially its ability to absorb a given contaminant concentration without there being a significant change in the ecosystem. The resilience of an ecosystem is the speed at which aspects affected by the contaminant, such as dissolved oxygen, return to their original states after the contaminant is removed (Suter II, 1993).

Depending on the value an assessor places on what are acceptable changes in stability, and what aspects of stability the assessor is looking at, the results can be very different. Public presentations of conflicting "scientific" results from assessments done by interest groups, government agencies, and corporations on the same topic have created a strong public distrust of risk assessment in America (Covello, 1993). This has created an atmosphere where even legitimate assessments are seen as only representing the interests of their sponsor and not the actual environmental risk the area is in.

2.4 United States EPA

The United States Environmental Protection Agency (US EPA) aims to help the environment in similar ways the Victorian Environment Protection Authority (EPA) does. Both organization's mission is to protect human health and to safeguard the natural environment, air, water, and land. Like the EPA in Victoria, the US EPA was established in 1970. Over the past 29 years, the US EPA has strove to control pollution through research, monitoring, standard-setting, and enforcement. In order to protect the waters in the United States, the EPA has established a set of guidelines for water quality.

2.4.1 U.S. Water Quality

The U.S. EPA has devised a rating system to rate the quality of water in the United States. In order for the quality of water to meet acceptable levels, it must be able to support a healthy community of aquatic organisms as well as human activities such as swimming (United States EPA, 1999). The following terms are used by the EPA and states in the U.S. to rate water quality:

- *Good/Fully Supporting:* Good water quality supports a diverse community of fish, plants, and aquatic insects, as well as the array of human activities assigned to a river, lake, or pond.
- *Good/Threatened:* Good water quality currently supports aquatic life and human activities in and on the river, but changes when factors such as land use threaten water quality or data indicate a trend of increasing pollution in the river.
- *Fair/Partially Supporting:* Fair water quality supports aquatic communities with fewer species of fish, plants, and aquatic, and/or occasional pollution interferes

with human activities. For example, suspended solids may reduce the population of some aquatic species in a river, while other species are not affected.

- *Poor/Not Supporting:* Poor water quality does not support a healthy aquatic community and/or prevents some human activities on the river or lake.
- *Not Attainable:* The State has performed a use-attainability analysis and demonstrated that use support of one or more designated uses is not attainable due to one of six specific biological, chemical, physical, or economic/social conditions. (United States EPA, 1999).

2.4.2 Water Quality Indicators

Water quality indicators present information on the status waterways. These indicators are useful because they can measure pressures or stresses that degrade water quality. These indicators are applied to rivers, streams, lakes, reservoirs, estuaries, wetlands, and groundwater.

There are four indicators used by the United States EPA that relate to this study. The first one is designated as Indicator 12, entitled Surface Water Pollutants. This indicator shows changes in concentration levels for selected surface water parameters (United States Environmental Protection Agency, 1996). The Surface Water Pollutants indicator measures water quality. This includes suspended sediment, fecal coliform, total phosphorus, nitrate, dissolved solids, and dissolved oxygen.

The second indicator is designated as Indicator 15, entitled Contaminated Sediments. This indicator shows chemicals that, when found in high concentrations, can pose a threat to ecological or human health. Sediment contamination is a problem because chemicals often persist longer in sediment than in water. This happens because of the resistance they have to degradation. Water also acts as a good dispersal agent for chemicals that cause high levels of concentration.

Selected Point Source Loadings to Surface Water is the third relevant indicator, Indicator 16a, used by the United States EPA. This indicator is used to show source loadings. Currently this indicator only covers two key pollutants, biochemical oxygen and lead. The EPA is aiming to include other pollutants such as nitrogen, phosphorus, and suspended solids in the future. This indicator measures increases and decreases of contamination stability levels (United States Environmental Protection Agency, 1996).

The fourth indicator is called Non-point Source Sediment Loadings from Cropland, Indicator 17. This indicator measures the rates of erosion from agricultural cropland. Measuring erosion is important because it provides experts with a good indicator of how much sediment is being delivered to surface waters. The US EPA does this task by taking field measurements and creating statistical models (United States Environmental Protection Agency, 1996).

2.5 Victorian EPA

Over the years, the EPA has taken steps to improve the water quality throughout the state of Victoria. They have done this through extensive research on what causes water quality to decline and devised ways to improve and maintain water quality. To guarantee the quality of water, EPA has set standards in each of the ten catchment regions in Victoria to improve and maintain the quality of the water.

2.5.1 Catchment Evaluation and Health

Environmental indicators have been defined as "measurable attributes of the environment that can be monitored via field observation, field sampling, remote sensing, or compilation of existing data" (Walker, 1996). Different indicators have been created to determine the overall health of a catchment. The first, condition indicators, are those indicators that define the state of the catchment system relative to a desired one. In this case, you take a 'template' catchment with an ideal setting and compare it to other catchments. A second type of indicator is a trend indicator. These indicators measure how a catchment system is changing over time (Walker, 1996).

Catchment health implies a viable condition, a self-sustaining state or states, which are compatible with human use and habitation. This means that a catchment is healthy if it can remain self-sustaining while meeting human needs, without posing a threat to itself or surrounding catchments. The health of a catchment is not just limited to the quality of the water within a certain region. It includes the health of all things living and present in a catchment from the quality of the soil to the health of the plants and animals (Walker, 1996).

2.5.2 Victorian Water Quality

Water quality is very important to the overall health of a catchment. The Victorian Government has come up with seven initiatives to help to maintain the quality of Victorian waterways. These initiatives have been devised to protect both the health of the water as well as the plants, animals, and humans living around it. The EPA and local government agencies are responsible for maintaining these initiatives. The initiatives are meant to focus attention on options that control nutrients at their source in order to prevent them from entering waterways (Nutrient Management Strategy, 1995).

The first initiative is The Treatment of Wastewater. In order for organizations to discharge treated water to any body of water, two criteria have to be met. First, they must comply with pre-existing discharge conditions. Secondly, a report must be submitted which outlines an acceptable program that meets their license conditions (Nutrient Management Strategy, 1995).

Guidelines for Nutrients are the second initiative. This initiative is the responsibility of the EPA. They are in charge of preparing guidelines to assist in the development of specific nutrient objectives for individual catchments. Included in these guidelines are acceptable levels for nutrient concentrations in different types of waterways, which are helpful for catchment management authorities (Nutrient Management Strategy, 1995).

The third initiative is Stormwater Runoff. Runoff from heavy storms can cause problems in waterways. Oils, dirt, nutrients, and garbage can be carried away during heavy rainfall, especially from urban centers. To alleviate these problems, stormwater management guidelines are currently being developed. Ideally, these guidelines would be created during urban development projects. Key issues to be addressed when dealing with stormwater runoff are the identification of major inputs to stormwater runoff and a review of existing strategies and guidelines for the control of stormwater runoff. The design and construction of urban stormwater treatment facilities should also be considered (Nutrient Management Strategy, 1995)

The fourth initiative is Irrigation Drainage. As of 1995, the Goulburn Broken Water Quality Working Group was devising a strategy for managing nutrients in irrigation drainage. This strategy is designed to identify ways to efficiently manage concentrations of nutrients in irrigation. Since salinity is a major problem with irrigation, another goal of the strategy is to minimize the amount of salt deposited from irrigation (Nutrient Management Strategy, 1995).

The fifth initiative is Best Management Practices, or BMP's. This initiative is designed to determine ways of managing both point and non-point sources. BMP's will allow farmers to maximize the use of their land without the export of excess nutrients in to surrounding waterways. Four BMP's guidelines have been developed for use in agriculture. They are:

- *Agriculture (Diffuse Sources):* General BMP guidelines for agricultural land and specific BMPs for major agricultural industries and regions of Victoria. They focus principally on minimizing soil loss from agricultural land.
- *Dairy Shed Effluent:* Statewide guidelines for the management of dairy shed effluent developed for Victoria.
- *Cattle Feedlots:* A code of practice for the management of cattle feedlots. A major component of the code deals with the containment, treatment, and disposal of wastes.
- *Irrigation Management:* Guidelines to control nutrients by better irrigation management (Nutrient Management Strategy, 1995).

Initiative six is The Education and Participation of the Community. The more the community knows about nutrient pollution, the easier it will be to prevent unnecessary pollution. They should know about the causes and effects of nutrient concentrations in waterways, actions that can be taken to reduce levels of nutrients, and the costs and benefits of managing nutrient levels (Nutrient Management Strategy, 1995).

The seventh initiative is research and investigation on the quality of Victorian waterways. Algal blooms affect numerous waterways in Victoria every year. Through investigation of the causes of these algal blooms specific to the different catchments, experts to find ways of preventing them. Research into new technologies and management practices will give these experts the tools necessary to keep the waterways safe (Nutrient Management Strategy, 1995).

2.5.3 Water Quality Indicators

The Victorian EPA uses several water quality indicators to determine water quality. An indicator is any biological, physical, or chemical property that is used to measure water quality. Based on pre-determined acceptable values for each test, the overall water quality of a sample can be determined. The indicators include the amount of dissolved oxygen, bacterial population, temperature, toxicant levels, nutrients and biostimulants, total dissolved and suspended solid content, and aesthetic characteristics. Each of these indicators measures a different important characteristic of the water. Dissolved oxygen must be at a high enough concentration to maintain all life present in the waterway. Bacteria and toxicant concentrations must be kept to a minimum to prevent disrupting the life present. A low or high pH indicates certain toxicants, and must be kept near neutral to maintain life. Temperature does not have a preset value, but can't vary from the original value excessively. A sharp drop or rise in temperature indicates high levels of contaminants, and can be detrimental to aquatic life. Aesthetic characteristics include color, odor, and taste. Any strange color or odor is a sign of polluted waters (State Environment Protection Policy 1988).

The last two indicators, nutrients and biostimulants, and dissolved and suspended solids directly apply to the specific problem of erosion. Acceptable nutrient levels are unique to an area, and have been pre-determined by the EPA. Phosphorus and nitrogen are the two nutrients that are of high concern. High levels of either one of these can be dangerous to aquatic life, and can promote algae growth. It is important to keep these at fairly low levels. Dissolved and suspended solids result when sediment enters a waterway. This is one of the conditions that erosion causes. Dissolved and suspended particles decrease water clarity, causing water quality to decrease. This decreases photosynthesis rates and can actually clog fish gills. Both of these problems are necessary to keep under control to maintain a healthy, aquatic environment (State Environment Protection Policy 1988).

2.6 NEXSYS

NEXSYS is a Windows compatible computer program designed at CSIRO by experts in nutrient assessment. It is a program made to predict the amount of nutrients that are released from the land per year, based on certain soil and climate characteristics, such as slope of the land, erosivity, and rainfall. The user of the program enters the data NEXSYS asks for, such as if the slope of the land is greater or less than eighteen degrees. After a series of similar queries, NEXSYS produces a range of nutrient levels being released from the land. This range is called the conditional range. The second range

NEXSYS provides is called the total range, which is the absolute range of nutrient runoff based solely on the land use, and not on any land or climate characteristics (NEXSYS documentation).

NEXSYS uses a rule-based system to determine what the ranges are. A rule-based system asks if/then/else questions. It attempts to determine if event (a) occurs, will event (b) occur as well. If event (b) doesn't happen, it then asks what other events might possibly take place. These rules are stored within NEXSYS and cannot be altered by the user (NEXSYS documentation).

Depending on the land use specified, NEXSYS will ask the user different questions about the land and activities that take place on it. These questions, or steps, help NEXSYS to determine the acceptable range for the particular nutrient in question. There are a total of eighteen different steps NEXSYS can take to determine a nutrient export range (NEXSYS documentation).

One of these steps is age, which is used for urban land uses. The age of an urban area is determined by when the development of that area ceased. When areas are being developed, soil disturbance can cause high sediment and nutrient loading. It can take several years for nutrient and sediment levels to decrease. NEXSYS considers five years to be an adequate cut-off between "old" and "new" urban areas (NEXSYS documentation).

Industry is the second step to determine what the type of suburb the area is. Areas that have concentrations of industry usually have high levels of nutrient, or pollution, exports to rivers and streams. NEXSYS asks the user if the area is predominantly industrial or not predominantly industrial (NEXSYS documentation).

A third step used only for urban areas is where NEXSYS asks if the soil in the area is sandy or not. Packed soils do not drain as well as soil types that have concentrations of sand. NEXSYS will ask if the soil is predominantly sandy or not (NEXSYS documentation).

Another important step for urban areas is if the area is sewered or not. NEXSYS only accounts for nutrient export rates for surface and near-surface runoff, not sewage loads (NEXSYS documentation). Since sewage that has been treated is a point source, it is assessed separately. Septic tanks, which are diffuse sources, can be significant sources for nutrient loading. NEXSYS will ask the user if the area is sewered or non-sewered.

Runoff management is another step used by urban lands. This practice is designed to minimize sediment and particularly, phosphorus loads. Typical methods for managing runoff are swale drains, gross pollutant traps, artificial wetlands, and detention basins (NEXSYS documentation). NEXSYS will ask if runoff management is used to reduce sediment and phosphorus loads.

NEXSYS accounts for erosivity, which is how rainfall affects soil when it hits the ground. It is a measure of the power of a rain event and is dependent on the rain drop size and the rate or intensity of the rainfall (NEXSYS documentation). NEXSYS asks if the erosivity of a land use is high or low. High erosivity is defined as having $R > 3000$ and low erosivity is $R < 3000$ (NEXSYS documentation).

Rainfall levels are sometimes needed in determining export ranges for grazing, cropping, and horticulture. NEXSYS uses mean annual rainfall as a measurement of how much those land uses typically get. NEXSYS asks if rainfall for the area is either high or low. High rainfall is more than 700 millimeters per year and low rainfall is less than 700 millimeters per year (NEXSYS documentation).

A concern for grazing land uses is gully erosion, or gullying. Gully erosion can produce extremely high sediment loads and associated loads (NEXSYS documentation). NEXSYS will ask if there are actively eroding gullies or not.

Fertilizer is applied to areas of land that are used for grazing, cropping, or horticulture. The application of fertilizer usually increases the concentration of phosphorus and nitrogen. NEXSYS is concerned with fertilizer application where runoff is likely to occur. Specific amounts of fertilizer aren't used by NEXSYS. Instead, it asks if the application is high or low. High indicates that fertilizer is applied at least once a year. Low indicates that it is used less than once a year (NEXSYS documentation).

Irrigation is a concern for grazing, cropping, and horticulture land uses. It increases the possibility of runoff occurring. NEXSYS asks if an area is irrigated or if an area is not irrigated (NEXSYS documentation).

NEXSYS asks how close an area is to a creek, or drainage line. This is of particular importance because excess nutrients can be delivered to a major waterway quickly via a drainage line. A region's proximity to a drainage line is defined as being within 100 meters. If the land is located beyond 100 meters, it is not considered to be close to a drainage line (NEXSYS documentation).

Ground cover is an important concern for grazing and horticulture. It prevents certain types of erosion, including sheet and rill erosion. Good ground cover means that over 75% of the land is covered with some type of vegetation. Poor ground cover means that less than 75% of the ground is covered (NEXSYS documentation).

The slope of the land is important in determining how likely runoff will occur. Land uses that use slope in determining nutrient exports in NEXSYS are grazing, forests, cropping, and horticulture. For grazing and forests, the New South Wales (NSW) "steep lands" definition of high slope is used. A high slope is one which is greater than 18 degrees, whereas a low slope is less than 18 degrees. Cropping uses slopes lower than those for grazing and forests. High slopes on cropping land are greater than ten degrees and low slopes are those less than ten degrees (NEXSYS documentation).

Forest management is usually used in forests designated for timber production. Forests are managed to minimize the disturbance to the land and surrounding environment. Land disturbance can cause an increase in sediment and nutrient loads. NEXSYS will ask if a forest is managed or not when determining nutrient export ranges (NEXSYS documentation).

A forest's type is a concern for NEXSYS when looking at forested lands. Forests are either old growth or plantation forests. Old growth forests are typically harvested selectively to preserve the forest. Plantation forests are usually grown specifically for timber production. These forests, once harvested, are replenished with new trees (NEXSYS documentation).

NEXSYS also uses geology when determining nutrient export rates. These geology types are basaltic, granitic, and sedimentary. High export rates are associated with basaltic geology. Granitic and sedimentary geology have low export rates (NEXSYS documentation).

2.7 Geographic Information Systems (GIS)

In order to take effective measures to improve water quality, information on the quality need to be obtained and analyzed. Different factors can affect water quality ranging from industrial pollutants to natural pollutants when found in large quantities. A beneficial way to accomplish this goal is using Geographic Information Systems (GIS). GIS is used to electronically enter, store, manipulate, and analyze geographical or spatial data (Currie, Donahue, Marceau, 1997).

Geographic Information Systems is a combination of hardware and software that display data on top of a digitized map. This data is stored in a database, such as Microsoft Access, and is fed into the GIS software to produce a map. These maps are obtained from satellites or are scanned into a computer. (See Appendix B for examples of these digital maps). GIS software allows data to be captured, stored, checked, integrated, manipulated, analyzed, and displayed at any given time (Currie, Donahue, Marceau, 1997). One of the features of GIS software is the ability to overlay data on the map allowing all of the data to be viewed at once or just parts of it.

In order to operate properly, GIS needs the location of the variables that are entered into the database. These locations can be in the form of x, y, and z coordinates, which denote latitude, longitude, and elevation (USGS, 1997). Usually this data is typed into a database, which can be very tedious and time consuming.

2.7.1 Data Analysis

Analysis of data using GIS takes place in five steps: data capture, data integration, projection and registration, data structures, and data modeling. Step one, data capture, reads the information on the digitized map. The map must be in digital form or GIS will be unable to utilize it. Map imperfections of any kind can alter the results during the analysis stage. This stage can be very time consuming in situations where maps need to be searched for and digitized.

The second stage of GIS is data integration. This is the phase where the information from the database is integrated with the digital map. Combinations of the mapped information can be used to build and analyze new variables.

Data in Access is stored in the form of a table. When a table is specified for use within GIS, it is able to integrate the data with the map in the form of symbols or color shadings. Each symbol represents a different data type, or variable. The sizes of these symbols can be larger or smaller depending on the amount of data applied to that particular region. In the case of color shading, darker colors may represent high concentrations of a particular variable, whereas lighter colors represent lower concentrations of data.

Projection and registration is the third step. This is the most fundamental component of making GIS maps. Since much of the information in a GIS comes from existing maps, a GIS uses the processing power of the computer to transform digital information, gathered from sources with different projections to a common projection (Geographic Information Systems, 1997).

Step four is the structuring of data. This is the step during which the user decides the format of the data. There are two choices the user can choose from, raster or vector representations. Raster representations consist of rows of uniform cells coded according to data values. Vector representations have been captured as points, lines, or areas.

The fifth step is data modeling. This is the stage when the final map is represented. GIS can generate a map to show differences in data concentrations on different parts of the map.

Chapter Three - Methodology

The methodology for this project consisted of four parts. The first task was to analyze the usability of NEXSYS[1] as a dependable tool in nutrient risk assessment[2]. The second objective was to create a risk rating scheme based on phosphorus export throughout Victoria. The third objective was to use NEXSYS and the GIS[3] program, Arcview, to create a set of nutrient risk maps of Victoria. NEXSYS was used to predict phosphorous exports from various land uses across Victoria. This information was then used in conjunction with interviews from experts at the freshwater science department at the EPA to create a risk rating system and risk maps of Victoria. The final objective was to create a user's manual for the maps to explain the risk rating system. This combination of risk map and user's manual will be used to educate catchment managers and the public about the problem of nutrient export and help to acquire funding where it is most needed.

3.1 Collection of Information

In order to create risk maps of Victoria, specific information about the land and climate of the different areas of Victoria was needed. This data was found through various resources, including EPA and other environmental committee publications, websites, and books. Environmental publications proved to be the most useful sources for information needed as input to NEXSYS. The Catchment Management Authorities and Landcare Victoria have each published booklets on the catchments of Victoria that contain specific data on various parameters needed by NEXSYS. The majority of these resources were found in the Freshwater Science Department of the EPA or the EPA's library. Websites, books, and

[1] See section 2.6
[2] See section 2.3
[3] See section 2.5

feedback from members of the EPA Freshwater Science Department had more general information that was vital to ascertaining which regions are at highest risk. An accurate and complete analysis of the conditions of the various regions was completed with such a wide range of sources.

Written text was not the only form of data that was used during the research. Numerous maps and charts contained essential information, and provided extensive data for input to NEXSYS. A compilation of data found in all sources was tabulated and used with NEXSYS. Previously collected data was displayed in a chart or graph form, which was much easier to interpret than reading long sections of text.

Another source of information came through interviewing individuals with experience-based knowledge within the EPA. These individuals have backgrounds in either the use of GIS as a mapping tool, NEXSYS, or with environmental assessment. Specific questions can be answered in an interview, and the response can be clarified if needed. This is a much more efficient way to obtain information than searching through books and articles, since useless information does not have to be weeded out before the useful data is found. The experts interviewed for this project came from different fields. In order to account for this, questions were customized for each interview.

Three individual interviews were done, as well as two group interviews. Two interviews were with professors from Worcester Polytechnic Institute. The meeting concentrated on visualization and GIS mapping. The interviews helped to provide a better understanding of GIS mapping, how it works, and how to manipulate the data. The third individual interview was with one of the developers of NEXSYS. Specific questions were asked on how to distinguish between different factors that the program requires and how the information that was used came about. The main goal of this interview was to clarify some vague areas about NEXSYS.

The last two interviews were conducted with environmental experts at the EPA. Each expert had a different area of knowledge, which provided a broad range of information. During these interviews, questions were asked and answered as well as explanations and advice on how to perform the risk analysis step were given. The area of greatest importance covered in this group interview was categorizing the regions of Victoria in terms of risk. A second major topic of the interview was classifying the regions of Victoria for the NEXSYS requirements. Some of the data needed could not be found, but the EPA experts had first-hand knowledge about the areas, and offered input about the conditions in these regions. The information acquired during these interviews was not attainable through reading, but through personal experience and application.

3.2 NEXSYS

At the beginning of this project, it was not known if NEXSYS was a useful tool for nutrient management of large areas. The end products would be useless if NEXSYS was found to be impractical or inaccurate. To determine the practicality of NEXSYS, criteria were created to determine which conditional ranges produced by NEXSYS were useful.

3.2.1 Usability Analysis

The first step in the analysis of NEXSYS came through data collection. All of the possible combinations of land use and environmental conditions were plugged into NEXSYS and the ranges they produced were recorded. Each land use was found to have between five and nine sets of ranges[4]. The ranges for each land use were then sorted by size from smallest to greatest and a cutoff for usable ranges was established through consultation with the EPA.

[4] See Appendix F

The cutoff for usable ranges was determined to be ranges of size less than or equal to half of the total range for each land use. An example can be taken from the urban land use, which has a total range for phosphorous export from 0.4 kg/ha/yr to 4.0 kg/ha/yr. The usable range size for this example would be:

$$\frac{4.0\ \text{kg/ha/yr} - 0.4\ \text{kg/ha/yr}}{2} = 1.8\ \text{kg/ha/yr}$$

This means that for an acceptable range, the two values NEXSYS determines as the maximum and minimum export values must be within 1.8 kg/ha/yr of each other.

3.3 Risk Rating Scheme

Once the phosphorus export data was found through NEXSYS, a way to evaluate this information had to be devised. There were several export ranges that were given, and these had to be classified into a risk scheme. Peter Newall and Leon Metzeling from the EPA assisted in this task. Their knowledge was an irreplaceable resource. A phosphorus export map was made, with several colors indicating different export values. This map was looked at, and analyzed. A rating scheme of one through five was used to indicate the different areas' levels of phosphorus overloading. The scheme was finally based solely on export values, and no other factors were taken into consideration. A description of the scheme that was created is detailed in Chapter 4 of this document.

3.4 Geographic Information Systems (GIS)

The usefulness and steps of creating GIS maps were discussed earlier in Chapter 2 of this report. This section focuses on the creation of GIS maps of Victoria for this project. The steps taken to create the final product as well as the learning process leading up to the creation of the final map will be discussed here.

To create a useful map for both experts and laymen, it was necessary to spend time learning how to use the ArcView GIS. This was done by talking to three professionals who have knowledge of the program and by doing research in books and the Internet. Two professors from Worcester Polytechnic Institute (WPI) were interviewed on the uses of GIS. Matthew Ward, a Computer Science professor, was consulted on the usefulness of the system as a graphical tool. He gave useful information about how to represent data, either vector or raster, and how GIS manipulates the data to form a map. An interview conducted with Fabio Carrera, an expert on GIS, explained how the program works and why it is used. Mr. Carrera also held an informative session on how to use GIS software. The third person consulted on GIS was Helen Schilling, a member of the Freshwater Science department at EPA. Her extensive use of ArcView and her guidance proved to be a valuable resource during the creation of maps for this project.

After gaining sufficient knowledge about GIS, it was possible to begin the process leading up to the creation of the maps within ArcView. The data that was most important for use in NEXSYS was land use, rainfall, slope, irrigation, ground cover, and type of cropping. All of these were already in GIS format at EPA. These are considered to be the most important criteria for two reasons. The first reason is that several of them occur in more than one land use. The second reason has to do with the land use in Victoria. Since cropping and grazing are the predominant land uses in Victoria, it is essential to include the criteria that pertain to them in the maps.

The land uses specified in GIS and NEXSYS were very different. NEXSYS uses the following five categories for land use:

- Urban
- Cropping
- Grazing
- Horticulture
- Forests

The GIS database breaks Victoria up into the following nine land uses:

- Pasture - Dryland
- Pasture - Irrigated
- Forestry - Public Softwood
- Forestry - Private Softwood
- Broad Acre Cropping and Crop Pasture
- Remnant Native Vegetation
- Non-farmland (excluding remnant vegetation)
- Other Private Land (non-farmland)

It was necessary to combine these land uses into a form that could be used with both NEXSYS and ArcView GIS. Since some of the criteria for NEXSYS are specified in GIS, it was decided that land use layers that contained information on NEXSYS criteria would be created. The following nine land use layers were created:

- Horticulture
- Market Gardening
- Row Cropping
- Non-row Cropping
- Urban
- Irrigated Grazing
- Non-irrigated Grazing
- Managed Forests
- Unmanaged Forests

One important step in preparing these layers involved the original horticulture layer found in GIS. During a meeting with experts in the Freshwater Science department at EPA, it was decided that GIS' horticulture layer actually contained data on row cropping, market gardening, along with horticulture. This required the alteration of the land use database, which will be discussed in Chapter 4.3 along with the steps taken to create the maps.

3.5 Map User's Guide

A supplementary user's guide was developed to help interpret the GIS maps. The manual consisted of descriptions of the five levels of risk represented on the map, a description of what information was used to find the phosphorus export values, and explains the problems associated with high levels of phosphorous in the environment. The user's guide was created after the maps had been made.

After completing the map creation and research on phosphorus, the user's guide was taken straight from the information acquired thus far. The five levels of risk that are described in the manual were derived directly from the risk rating scheme. This is the format that was followed to determine which areas were at what risk level of phosphorus overloading. The process of this scheme is described in section 3.3. Another key part of the manual was devised using the information that was plugged into NEXSYS to find the phosphorus export estimations. Finally, the causes, effects, and remedies of phosphorus overloading are briefly described. These were found throughout the research process.

Chapter Four – Data Presentation and Analysis

The research done at the beginning of this project resulted in the collection of a large amount of information concerning NEXSYS, land use, risk-rating techniques, GIS map creation, and the ten major catchments in Victoria. The data collected was not always useful. Some proved to be incomplete and some was found to need further analysis before it could be used. What was found to be useful has been analyzed and is presented in the following sections.

4.1 NEXSYS Analysis

NEXSYS is designed to give a range of phosphorus or nitrogen export coefficients as an output. These are based on the land use and environmental conditions of a region. The developers found the maximum and minimum export values each land use category was capable of producing. This is referred to as the total range. For each combination that was entered into NEXSYS, a smaller range was produced. These smaller ranges were the ranges of interest, since they were the ones used to determine usability.

The purpose of the risk map is to identify the areas at highest risk of nutrient overloading. If the majority of the results obtained from NEXSYS were in the form of large ranges, it would make comparing areas hard and very unreliable. To determine if the majority of ranges were usable, all combinations of conditions in each land use category and their resulting export ranges were found. A statistical analysis of this data was then performed to decide how the usefulness of NEXSYS's ranges. The analysis was used only for this purpose and was not considered during the development of the risk map's rating scale.

After all the ranges produced by the various combinations were found, they were sorted and classified as usable or unusable. This was done by using the procedure in the methodology, which defined a usable range as one with a relatively narrow range of export values for its land use category. An example of this breakdown process can be seen in the initial urban land use breakdown:[1]

Urban:

Total Range: 0.4 to 4.0 kg/ha/yr

Total Combinations: 25

Ranges with sizes between 0.0 and 1.8 will be considered useable ranges for Urban.

# of combinations	Range	% of total combinations for land use	
2	0.4 to 0.9 kg/ha/yr:	8.0	
1	0.9 to 1.5 kg/ha/yr:	4.0	Useable Ranges
4	1.5 to 2.0 kg/ha/yr:	16.0	
5	2.0 to 4.0 kg/ha/yr:	20.0	
3	1.5 to 4.0 kg/ha/yr:	12.0	Unusable Ranges
10	No range for selected conditions:	40.0	

Total Percentage of Useable Ranges: 28.0%

Total Percentage of Unusable Ranges: 72.0%

[1] See Appendix D for a complete analysis of each land use

The percentages were found using the following general equation:

$$\frac{\text{Number of combinations that produced range X}}{\text{Total number of possible combinations in land use Y}} * 100\% = \text{Percentage of combinations in land use Y that produce range X}$$

The total percentage of usable and unusable ranges was then found by adding the percentages in each category together. The results of this initial analysis found NEXSYS to be insufficient. Only one of the five land uses was found to have more than 35% of its combination's results fall in a usable range. In order for NEXSYS to be considered usable, the percentage of useable ranges should be greater than 50% for all land uses, which they were not in this analysis.

In the initial analysis, it was observed that although there was a high number of combinations of land uses and conditions, many of these combinations included one or more choices with "unknown" used as the input. It seemed likely that the prominence of large export ranges might be the result of the program compensating for a lack of data inputs. A second analysis was done using the same procedure as the initial analysis except that all combinations in which "unknown" was used as an input for a choice were ignored[2].

The percentage of combinations that fell in the usable range category for each land use this time was much higher[3]. Although one land use category scored below 50%, three scored higher than 65%. The category that had less that 50% useable ranges was disappointing, but since the other categories scored so high, it was decided that NEXSYS was a practical tool for nutrient export analysis.

[2] See Appendix C
[3] See Appendix E

4.2 Victoria's Environmental Conditions

For NEXSYS to work to its full potential, all of the environmental parameters the program requires must be found. For this project, the information came from three sources: environmental publications, web resources, and experts at the Environment Protection Authority (EPA). First, the environmental publications and web resources were examined and any information that was relevant was extracted. However, only a limited amount of material came from these sources. In order to fill in the holes, experts at the EPA were interviewed to inquire about their first-hand knowledge on Victoria and the missing information.

Several characteristics of each region needed to be found. NEXSYS requires the following inputs for phosphorus export predictions:

- Land use
- Rainfall
- Slope
- Age of urban areas
- Industrial presence
- Sewer presence
- Sandy soil
- Erosivity
- Groundcover
- Fertilizer
- Irrigation
- Gully erosion presence
- Geology
- Proximity to a drainage line
- Forest management
- Timber type
- Type of cropping
- Runoff trapping presence
- Erosion management presence

Land use was the first, and most important, condition that needed to be found. It is very important to know because NEXSYS bases all of its calculations on this information. Every parameter that is required for NEXSYS has an unknown choice, except for land use. Without this knowledge, no phosphorus export coefficients can be predicted.

There are five major land uses throughout Victoria[4]: urban, grazing, cropping, forests, and horticulture. Although there are several urban areas throughout the state, due to limited capabilities and time, only Melbourne was singled out as being an urban area. Grazing areas make up a large portion of southern Victoria and scattered regions of the central and northeast as well. The northwestern part of the state is largely used for cropping, as well as scattered regions throughout central Victoria. Cropping land uses include non-row and row cropping, and also market gardening. Forested areas are located in the east, northwest, and along the coast. NEXSYS considers anything that is forested, or a National Park or Reserve to be included in the forests land use category. National Parks consists of forests, scrubland, and even deserts. There are scattered small areas of horticulture throughout Victoria.

Rainfall and slope are perhaps the next most important conditions that are required for a precise NEXSYS output. The purpose of knowing rainfall rates is that erosion rates will increase with higher rainfalls, as rain is the main factor in nutrient runoff. It was necessary to designate rainfall as being either high or low. High rainfall was considered by NEXSYS to be annual levels greater than 700 mm, and low rainfall was considered to be less than 700 mm annually. The northwest and western parts of the state were found to have low rainfall, while the eastern and southern borders of the state were found to have high rainfall. This information was located in a GIS database at the EPA[5].

The slope of the state varies greatly. A high slope is considered by NEXSYS to be above 18 degrees for forested and grazing areas, or above 10 degrees for cropping and

[4] See Land Use Map in Appendix B
[5] See rainfall Map in Appendix B

horticultural areas. The variation in the definition of what is a high slope is a result of different nutrient export coefficients. Cropping and horticultural areas are more susceptible to erosion than forests and grazing areas, so a lower degree of incline can still cause a significant degree of nutrient pollution of a nearby waterway. High inclines greatly increase the severity of water erosion. Much higher amounts of nutrients will be lost from lands with high slopes than lands with lower slopes. This information was not easily attainable, so with help from experts at the EPA, judgments were made on what areas would be judged as having high slopes, and which ones would be considered to have low slopes. There are large mountain ranges in the eastern half of the state and smaller ones in central Victoria and on Wilson's Promontory, located in the south. These areas and their surrounding foothills were considered to have a high slope, while the coastal areas and areas further from the ranges were determined to have a low slope.

Several factors that were needed for the analysis of urban areas were acquired through interviewing experts in the EPA. One of these factors is the age of Melbourne. NEXSYS requires that the age of an urban area must be specified. This age is determined by how long ago major development of the area stopped. It must be specified as being either less than or more than five years ago. Age is important because during construction and development, there can be a large increase in the amount of pollution. This excess pollution is carried into the stormwater drains, and can cause the phosphorus loading of the area to rise significantly. There are small areas on the fringes of the city that are currently being developed, but compared to the overall size of Melbourne, it is a small fraction. For the purposes of this project, and since the city will not be divided in terms of phosphorus export, Melbourne will be considered to be greater than five years old.

There were several other factors that the EPA assisted in determining. Urban areas also needed to be distinguished between being either predominantly industrial or not predominantly industrial. There are three general categories for classifying areas of a city: residential, commercial, and industrial areas. Industrial areas are of the most concern because they produce the most phosphorus output. Western Melbourne has small areas of industry in the west, but again, as a whole, Melbourne is considered to be predominantly non-industrial. Melbourne is sewered, and for this study, it is not considered to have an effective stormwater runoff management system in place.

Phosphorus export levels increase with sandier, more porous, soils. Melbourne is considered to have predominantly sandy soil, according to a map generated by the Victorian Government. Sandy soil is important because it does not retain as much water as other types of soil, so any rainwater that enters the ground is easily passed on to the water table under the surface, and carried into waterways.

Erosivity greatly influences the output of NEXSYS. It is a numerical value that is found in the Universal Soil Loss Equation. Unfortunately, this can only be found through evaluating a series of conditions. NEXSYS does compensate for leaving erosivity unknown by accounting for rainfall and slope. Since this was so difficult to find, it was left as unknown in all instances.

Groundcover varies for different types of land uses. NEXSYS requires a differentiation between areas of either having a groundcover of greater or less than 75%. Generally, for grazing areas, the groundcover is greater than 75% and for horticultural areas, it is less than 75%. Increased groundcover decreases the amount of exposed soil, allowing less soil runoff to occur. If there is a low amount of soil being carried to the streams, the phosphorus loading will also decrease. Experts were consulted for this information as well.

Fertilizer usage varied with type of land use. Whether application occurs less than annually or more frequently than annually needed to be determined. For cropping areas, it was more than annually, while fertilizer was applied less than once a year for grazing areas. This was also determined by experts, using common sense to make these judgements. Fertilizers often contain high amounts of phosphorus and other pollutants, which can be carried by rain to the waterways.

The presence or absence of irrigation also needed to be determined. The majority of cropping areas and a small fraction of the grazing areas are irrigated. The irrigated grazing areas are in the north and southeast Victoria. This was determined by a GIS database that was present at the EPA. Irrigation was only required by NEXSYS for cropping and grazing areas. Nearly all of the cropping areas with little rain are irrigated in the state, and this was the assumption made.

Whether or not gully erosion existed in a grazing area needed to be specified. The areas where gully erosion is found are in parts of southwestern and eastern Victoria. Gullying is not a major concern in Victoria, but where it is found, it affects a fairly large region. A map indicating the areas where gully erosion exists was found on a government website[6].

[6] See Gully Map in Appendix B

Geology was another factor that NEXSYS asks for, which is the rock or soil type that composes the land. The rock types were found on a map generated by the Department of Mines in Melbourne. Unfortunately, this map was too large to be reproduced for this report. There were five choices for this category: basaltic, granitic, sedimentary, other, and unknown. Basaltic areas are located in the southwest, with granite scattered randomly in the central and northeastern regions, and sedimentary rock generally found in the north central, northwest, east, and southern areas of the state. Different types of rock contain different levels of phosphorus, and they can be either porous or fairly impermeable. The amount of water that seeps through these rocks and delivers polluted water to surrounding creeks greatly depends on the geology. Basaltic rock releases the highest phosphorus levels, and sedimentary and granitic bedrocks are about equal, and lower than basaltic. The 'other' option was not needed in any of the conditions entered into NEXSYS since there is very little land in Victoria that does not fit into the three bedrock types, and is considered negligible for this analysis.

Proximity to a drainage line is another parameter of NEXSYS that should have been answered. With the specific divisions of Victoria that were done, NEXSYS did not require this input once. This was a coincidence, but a fortunate one. Since a large region has to be considered as a whole for the statewide analysis, it would have been very difficult to distinguish between an area being either within or beyond 100 meters of a creek or river. For the detailed map, the categorization would have been easier, but again, it was never asked for.

NEXSYS classifies forests as either managed or unmanaged for timber production. NEXSYS defines timber production as occurring on an area where trees are harvested. This means that, for this project, National Parks consisting of forests, bush, and even desert have been classified as unmanaged forest. Unmanaged forests are located in the east, some areas along the coast, and deserts in the northeast. Managed forests are small areas in scattered regions throughout the state.

The type of timber present also needed to be specified for managed forests. They can be composed of either old growth or new plantation. In general, private land is new plantation, since the trees are generally harvested for sale and replenished for future use. Public lands contain a majority of old growth, since more selective lumbering practices are used. The result is a lower phosphorus export than for plantation growth. This did not need to be judged for the areas that were identified for use with NEXSYS. The managed forests were in such small areas that they were not considered in the evaluation, due to time constraints.

The cropping land use category had numerous specific parameters that needed to be found. The type of cropping varies throughout Victoria. Cropping type is relevant because the amount of erosion that occurs under each situation can vary greatly. Row cropping is present in small patches of central Victoria, while non-row cropping is found in the north. Market gardening is the smallest cropping type, which is located in scattered patches throughout central and northern regions of the state. With row cropping, large amounts of earth are exposed between the rows, and are more susceptible to erosion than non-row or market gardening. The different crop types were found in a book published by the EPA. The presence or absence of runoff trapping and erosion management also needed to be specified for these areas. Although some areas may have effective systems in place, all cropping areas were considered to have neither. This information was found through consulting experts at the EPA since none of it could be found via written documentation.

4.3 Risk Analysis

Once the different phosphorus export ranges were found with NEXSYS, a risk rating technique had to be devised. This was done through the help of experts at the EPA, and it was decided to base the ratings solely on the phosphorus export values. No other factors, such as life present in the region, were considered. A scale of one to five was used to describe the risk value of an area. One was designated as being the lowest risk; with five being the highest. The ratings were devised to rank areas of Victoria in relation to each other. The ratings are all relative, not absolute. This means that a certain rating, such as a rating of four, may not be at a high risk, but it is compared to the rest of the state.

The five different risk ratings and the ranges that correspond to them are listed below.

Risk Ratings		Phosphorus ranges included in each risk level (in kg/ha/yr)
1 =	Lowest Risk	0.01 to 0.07
2 =	Low Risk	0.01 to 0.13 0.07 to 0.13
3 =	Moderate Risk	0.05 to 0.2 0.05 to 0.5
4 =	High Risk	0.4 to 0.9
5 =	Highest Risk	0.5 to 3.0 0.5 to 5.0

A risk rating of one was assigned to areas that had the lowest level of phosphorus export relative to other ranges produced across Victoria. A risk rating of five was assigned to areas with the highest level of phosphorus export. Since five is assigned to areas with the highest level of export they are considered to be at the highest risk of nutrient pollution compared to Victoria as a whole. However, this does not mean that these areas will definitely suffer from nutrient pollution, only that it is more likely to do so relative to the other sections of Victoria. Depending on factors such as wildlife and waterway conditions, an area can assimilate different amounts of phosphorus. An area with a risk rating of five may be capable of assimilating the amount of phosphorus that is associated with this rating without any problems arising. Due to the complex nature of this aspect of risk assessment, this project did not factor it into out risk scale and leaves it as an avenue for further study.

4.4 Geographic Information Systems Results

The creation of a risk map for Victoria was a lengthy process. Information for this process was gained from databases within the GIS system at EPA as well as from interviews and discussions with EPA experts. At the end of this process, presented our sponsors with a risk rating map based on information from NEXSYS.

4.4.1 GIS Data Collection

Data needed for GIS was found in the databases at EPA and from discussions with EPA experts, Peter Newall and David Tiller. Information about land use and rainfall were found in database format ready for use in ArcView. Maps of Victoria broken into its catchments and river basins were also available within EPA. Data that could not be obtained in GIS format was gained through discussions with Peter Newall and David Tiller. They provided us with information on the slope of different land types within Victoria. It was essential to get as much information about land use, rainfall, and slope as possible since these categories were the main basis behind our risk map.

4.4.2 Map Creation

After deciding on the land use layers, it was possible to create the layers for the map. These data layers were used to created a phosphorus level map to be used in the creation of the final risk map. These layers contained data on land use, rainfall, and the slope of land. The following paragraphs discuss the creation of these layers.

The first layers created were the land use layers. EPA had a land use database in their GIS library. This database contained approximately 14,500 records on Victoria's land use. Since the database had to be altered to create the horticulture, row cropping, and market gardening layers, it was necessary to separate the database for each land use. Nine copies of the original land use database were made, naming them all after their respective land use. With each database, there needed to be a corresponding shape file with the same name. A shape file is the database saved in visual format. The databases were changed within ArcView itself. All records not related to the current land use were deleted.

To create the horticulture, market gardening, and row cropping layers, it was necessary to select the areas on the horticulture map that corresponded to each of them so that they were highlighted on the map. Once highlighted on the map, the database table for that land use was opened. Highlighted areas on the map also appear highlighted in the respective table. This allowed for the deletion of records not needed in the particular layer. This was done for all three categories. Once all databases were trimmed, they were added as layers on the GIS map.

Two rainfall layers were added next. The GIS database that contained data on rainfall also contained data that was not needed for this project. Again, the database was trimmed to only have fields containing data needed for this map. Once this was done, it was added to the map as two layers. One layer contained data on rainfall levels that were greater than 700mm of per year. The second layer contained data on rainfall levels that were less than 700mm per year.

Originally, it had been hoped that maps representing slope could be made using data within ArcView. This was not possible because the data could not be represented in the desired fashion. Time constraints made it difficult to spend more time with these maps. In place of this method, it was decided that two experts within the Freshwater Science group would be interviewed. Peter Newall and David Tiller provided information on the slope of the land within Victoria. They were able to identify areas that had slopes greater than or less than eighteen degrees as well as areas with slopes greater than or less than ten degrees. Their identifications were approximations, not exact representations of the slope of different regions. Once these areas were identified, regions of Victoria were outlined by hand for the creation of a phosphorus export map.

To continue the layers of the GIS project, it was necessary to convert the hand drawn divisions into digital form. This was done by hand as well, just with a mouse on the computer within ArcView. A new line layer was created and the boundaries for the divisions were drawn. Once all of the divisions had been drawn, they were converted to polygons using the polygon tool. This would allow areas to be colored for different risk levels.

After the phosphorus ranges were determined by the NEXSYS evaluation and ratings were assigned to them, the risk map was started. Each risk level received its own unique color. Each area on the phosphorus map was colored with the risk color that had been assigned to it. Once all areas were colored in, the risk map was complete.

In order to test the method on a smaller scale, the Latrobe/Thompson basin was analyzed. Creating this risk map followed the same steps as the previous map. The smaller scale of the Latrobe/Thompson basin risk map allowed for more regionalization than the map of Victoria. This in turn cut down on the degree of generalization of land uses and conditions present on the map. The result of this was somewhat unexpected. It was assumed that, due to the smaller scale, this map would be more accurate than the statewide map. Since this map showed the land uses and conditions with a finer amount of detail, it required more detailed data then the statewide map did. Finding data on specific sections of a single basin in Victoria was very difficult and, as a result, the resolution of this map was less than expected.

4.5 Map Analysis

Once Victoria was divided into 30 sections, the risk rating was done for each section, and the results were put on a map of Victoria. The map was color-coded so each color represents one of the five risk ratings. The five risk ratings were developed to show the relative levels of phosphorus export across Victoria. The ratings were based on the nutrient export ranges produced by NEXSYS.

There are eight sections in Victoria with a risk rating value of 5[7]. This means these areas are at the highest risk of nutrient runoff. Five of the eight highest risk regions are found in western Victoria, where cropping and grazing are the primary land uses. Two other regions are found in the center and north central section of Victoria. The final region with a risk rating of 5 is located in eastern Victoria. Five of these sections have grazing as the primary land use and three are mainly cropping. The ranges of nutrient export rates for these areas are 0.5 kg/ha/yr to 5.0 kg/ha/yr, 0.6 kg/ha/yr to 5.0 kg/ha/yr, and 0.5 kg/ha/yr to 3.0 kg/ha/yr.

Only one section in Victoria was given a risk rating of 4. This region was Melbourne and its suburbs, which was considered an urban land use. The range produced by NEXSYS that validated the risk rating value was 0.4 kg/ha/yr to 0.9 kg/ha/yr.

Seven sections in Victoria were given a risk rating value of 3. These regions are located mainly in the central and southwestern section of the state. All seven regions with a risk value of 3 were considered to be primarily grazing areas. These grazing areas did not rate as high as some of the other grazing land primarily because the areas rated 5 were all in regions where gully erosion is present. The grazing areas with a risk rating of 3 were not in active gully regions. This exemplifies how dependent phosphorus exports are on gully erosion. The nutrient export ranges produced by NEXSYS for these ranges were 0.05 kg/ha/yr to 0.5 kg/ha/yr and 0.05 kg/ha/yr to 0.2 kg/ha/yr.

There are seven sections that were given a risk rating of 2. These are the forested areas in east and southeast Victoria. The ranges that NEXSYS determined as the nutrient

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[7] See Victorian Risk Map in Appendix B

export rates for these regions are from 0.01 kg/ha/yr to 0.13 kg/ha/yr and 0.07 kg/ha/yr to 0.13 kg/ha/yr.

The final seven sections in Victoria were given a risk rating value of 1, which means these areas are at the lowest risk of high levels of nutrient runoff. These regions are found in the western part of the state. Their primary land use is forested areas, however most of the land is national parks, which, according to NEXSYS, was classified as forested land. Because the land here is not harvested, there are fewer sources for phosphorus contamination than there is for harvested forest, which scored a risk ranking of 2. The nutrient export range produced for these regions is from 0.01 kg/ha/yr to 0.07 kg/ha/yr.

Chapter Five – Conclusions and Recommendations

The main goal of this project was to develop a methodology for indicating high risk regions in Victoria in terms of phosphorus loading. The methodology involved using NEXSYS to determine phosphorous loads. A risk rating system was created and validated by comparing the values NEXSYS produced to acceptable nutrient levels across Victoria. After this was done, a map of Victoria was created using ArcView GIS to show the locations of the high risk regions. Finally, a user's guide to the map was created to explain the risk rating system, and describe the generalizations made while creating the map. This section discusses the positives and negatives of using NEXSYS, other programs that may be used in place of it, recommendations for a more accurate map, and how the process of statewide risk assessment can be improved.

5.1 NEXSYS Evaluation

This project used NEXSYS for the nutrient modeling aspect of the project. Even though NEXSYS was found to be a useful tool to evaluate nutrient runoff, the project team did not feel that the positives outweighed the negatives that were found. Therefore, it is recommended that it only be used for the preliminary stages of a true statewide risk assessment.

There are some advantages to the program that make it very user-friendly. For one, NEXSYS is very easy to use and understand. The user simply clicks on the answer for the question NEXSYS shows, and goes to the next question until the program has run out of queries. Immediately, the user is given two export values, the total nutrient export range for the land use category and the range for the conditions selected. The total range is a fixed number that the developers determined to be the minimum and maximum nutrient export values that could possibly be released from a selected land use category. The values of the selected conditions are the range NEXSYS determines as the actual nutrient export. The two ranges allow the user to quickly determine how the range for the selected conditions compares to the total range for the land use. With this the user can see if the range for the selected conditions is high or low compared to the overall range.

NEXSYS requires data that is generally easy to find. Examples of data requirements by NEXSYS include land uses, rainfall rates, slope of the land, and type of crop. Much of this information can be found in books, atlases, or through web resources. The user simply needs to know where the resources are, look at the information they provide, and make the proper selection in NEXSYS.

Sometimes information can be very difficult to uncover if the user doesn't know where to find it. If the user does not know the answer to one of the queries, "unknown" is the option that can be selected and the next query is displayed. This is a better alternative than having to select an answer that the user does not know, which may produce false results.

Another positive aspect of NEXSYS is that it takes into account a number of factors when determining its export ranges. For example, when evaluating grazing areas, it takes into account fertilizer use, irrigation, proximity to creeks, gullying, ground cover, erosivity, rainfall, and slope of the land. By asking for all these factors, NEXSYS is able to produce a more precise export range.

Even though NEXSYS is very user-friendly, there are some problems with the program. For one, the export ranges for phosphorous produced by NEXSYS can be very large. This is especially true in the cropping land use category, where the export coefficients range from 0.05 kg/ha/yr to 15.0 kg/ha/yr. Large ranges are of little use to environmental experts who are trying to determine precise nutrient loading values.

Even though NEXSYS considers many variables, it only does so in general terms. For a variable such as annual rainfall, it sets a cutoff point to divide high rainfall from low rainfall at 700 mm per year, instead of asking for an exact value or range of rainfall per year. Even though using general queries may make it easier for the user to obtain the information needed for NEXSYS, the results won't be as accurate.

NEXSYS requires the user to simplify all land uses into five categories: cropping, grazing, forest, horticulture, and urban. It is very difficult to integrate a map into five land uses from other maps because most land use maps have more than five categories. For example, the EPA database has a land use map with nine categories, which includes broad acre cropping and crop pasture, forestry (private softwood), forestry (public softwood), horticulture, non-farmland (excluding remnant vegetation), other private land (non-farmland), pasture (dryland), pasture (irrigated), and remnant native vegetation. The process of merging the map in EPA's database into one that will accommodate NEXSYS can be very tedious and time consuming.

5.2 Suggested Improvements for NEXSYS

Several improvements could be made if a more detailed program was used. This would aid in creating a more precise nutrient export map for the state. Using a program with more variables could decrease the range size that is given as an output. An increase in the number of variables would also mean more data was needed to run an assessment. As more data is required, the chance of not being able to find all the data needed for an assessment also increases. It is recommended that, although a more accurate program than NEXSYS could be used in future risk assessments, this new program should ask for data in range form in order to try to keep a balance between precision and availability of data.

Other methods of improving the NEXSYS outputs exist. One solution is to have queries that ask for specific values rather than generalizations. For example, when NEXSYS asks for slope, it can be entered as high or low. High slope is considered above eighteen degrees and low slope below. If a degree of incline or a range of degrees could be entered, NEXSYS could narrow down the range, and give a more precise phosphorus export range.

A last method to obtain narrower range sizes is to add a time component into the program. If the program could consider data from both recent samples and from older ones, a trend could be observed. This trend could indicate the rate of increase or decrease in phosphorus loading, which could change the severity of risk for an area. These improvements could be made to a later version of NEXSYS if a revision is planned, or they could be incorporated into a different program.

5.3 Risk Assessment

When looking at the statewide risk map, an important trend can be seen. The highest risk sections have predominantly cropping and grazing land uses. These regions are scattered throughout the state. There are no forest or urban areas in this highest risk category. The urban area, Melbourne, was at a high risk though. Grazing areas without high rainfall were in the moderate range. Forests were the land use category at the low and lowest risk. This shows that forests, in general, have conditions that do not promote excess phosphorus leaching and cropping, grazing, and urban land uses do.

Based on these trends, and those described in the chapter four, areas of concern can be identified. There is a small area of grazing land located in the east of the state that is in a high slope, high rainfall area, that should be closely examined. Other regions of concern are the grazing areas in the southwest and center of the state. They are also in areas where the conditions encourage high phosphorus export. All of the cropping areas are in the highest risk category. The fertilizer usage here, along with environmental conditions, encourages high phosphorus export.

5.4 Risk Assessment Evaluation

The risk assessment that was conducted for this project is adequate, but also very general. When Victoria was broken up into 30 smaller regions, the boundaries were based predominantly on land use. Only the dominant land use for the region was entered into NEXSYS and a nutrient export range was found, and finally a risk rating value given to the region. In some instances, smaller areas of different land uses were grouped together into regions with larger land uses and were unaccounted for when the data was being entered into NEXSYS. Therefore, the risk rating value for the region may not accurately depict smaller areas within the region. It is recommended that any future risk assessments that are done break Victoria up into even smaller sections such as individual catchments. This would increase the accuracy of the risk rating system since fewer generalizations about the regions would be made. The rating would be more representative of areas within the region as well as the region as a whole.

A major factor to consider when performing a risk assessment is not only the actual values of the phosphorus export, but also what the effects will be. An area with extremely high phosphorus levels that is near a source of water is of much more concern than an area far away from a water source. This project focused on the export from the land only, not how much is carried to streams. However, when considering which areas need further investigation, it is a factor to account for.

An example can be shown in the case study done on the Latrobe-Thompson basin[1]. The basin is known to be a high risk area concerning nutrient pollution, yet most of the basin was found to be at the lowest risk of nutrient pollution based on the NEXSYS evaluation. There is only one area of high risk on the map of any significant size, which is a strip of orange (high risk) along the southern part of the basin. Lake Wellington, the largest body of water in the basin, and most of the major rivers in the basin are located in this high risk area of the map. If the basin is evaluated solely on the percentage of land in the basin that is considered a high risk, it comes out as being in fair condition instead of as an area of high risk. If the evaluation of the basin includes the extent the phosphorus export of an area can effect the local waterways as well as the amount of phosphorus an area is exporting, Latrobe-Thompson would show up as a high risk area. It is recommended that a reliable method of assessing the degree to which a land use can affect the waterways in the area be developed for further risk assessments.

[1] See Appendix B Map 5

Another important factor in nutrient pollution that concerns an areas waterways this project could only partially address is determining the point at which the waterways can no longer absorb phosphorous without problems occurring. The EPA has a map within its database that shows the maximum phosphorus concentrations that the land can handle throughout Victoria. If it were possible, the risk assessment would take this map into account when giving each section a rating number. However, there is no known method of integrating the maximum concentrations to the ranges produced by NEXSYS. It is recommended that future risk assessments of Victoria be designed to better account for this factor, if it is possible.

5.5 Additional Data

One area in the risk assessment that could be improved upon is that for this project, was that too many generalizations had to be made. Several weeks were spent searching for detailed data on the variables that NEXSYS requires. There was quite a bit available, but there was also a significant amount that was not. The missing data was found through interviewing environmental experts at the EPA. Although the generalizations made were necessary due to time restrictions, they were a source of imprecision in the final maps. In the future, an improvement could be made if more of this data could be found. If a more detailed analysis is done in the future, it is recommended that more data be readily available. This would increase the precision and usefulness of the maps.

One avenue by which the Victorian EPA might be able to acquire this local data in the future is to use their good relations with local community environmental groups in

Victoria to collect general data on the land in each basin. The information on the general land characteristics for each basin in Victoria could be combined with the precise data collected through annual sampling by EPA and catchment management scientists in a database that could be used to create a better nutrient assessment program in the future. The collection of general data using local community environmental groups would have the advantages of low cost since no training would have to be offered by the EPA and it would require very little time on the part of the community groups. Data such as the presence of gullying and rainfall during a storm event require very basic measuring instruments, no scientific training, and very little time to assess. A simple booklet containing forms in a table format could be developed so that community environmental groups could quickly and easily record data in a standard format that would be useful to catchment managers and the EPA.

5.6 GIS Maps

The maps made using ArcView are only as accurate as the data that was available when creating them. Assumptions were made based on discussions with experts within EPA. These assumptions, while useful, are not as accurate as actual data. With more time, additional data might be found and used with ArcView to produce maps with a finer level of resolution than the one created during this project.

One recommendation is to create risk maps for each of the major thirty-nine river basins in Victoria. Since some land uses were not considered to have as profound an impact on waterways as others, it would be useful to regionalize Victoria as much as possible to gain a detailed understanding of how certain land uses affect the environment.

A regionalization of Victoria could start with the division of the state into its thirty-nine major catchments. A finer regionalization of these individual catchments on separate maps could provide more detailed information on future maps.

A detailed map of the Latrobe-Thompson River Basin was done to exemplify the potential of breaking up Victoria into smaller sections. It showed a small area of Victoria with much more detail than the statewide map. With all of Victoria broken up into small maps, a much more accurate analysis could be made. This map could also be improved through more accurate detail, but it was created more for the purpose of showing the possibilities of future analysis.

A second recommendation is to find more data to support a risk rating map. One problem was that this information was found in different forms. Some was on maps of different scales. These maps could have been scanned in and scaled to the correct size if there was more time, which would be a good idea for future analysis. Estimations had to be made by figuring out what areas of Victoria occupy which areas of different maps. This was fairly accurate, except, again, specific borders of different areas had to be estimated, and caused some inaccuracy. For example, finding GIS data that will show the slope for areas of Victoria instead of approximations would improve the accuracy of the map. Additional data on criteria such as ground cover, land use, and detailed information on proximity to waterways would also enhance the accuracy of the map. The more accurate the map is, the more useful it will be to the EPA in making judgements of which areas in the state are in danger of phosphorus overloading.

5.7 Risk Map Validation

Due to the time constraints of this evaluation, the risk map was not validated. To determine whether or not the map is accurate and precise enough for application, a validation would have to be done. This could be done through one of two methods. One is by asking environmental experts if the high risk areas indicated really are at high risk, according to their knowledge and experience with sampling of the state. A second method is by obtaining actual phosphorus levels and comparing them to the risk map, which was based on the ranges produced by NEXSYS.

5.8 Future Possibilities

The desired outcomes of this project were accomplished. NEXSYS proved to be a useful tool in phosphorus loading estimation, a risk rating scheme was devised, maps were made indicating high risk areas, and a user's guide was created to supplement the map. Overall, the process proved to be a successful, effective method to identify risk areas and to hopefully serve as a template for future risk analyses.

Appendix A – Environment Protection Authority

The Environment Protection Authority (EPA) is an authority of the Victorian government that maintains standards of environmental quality. It does this through licenses, inspections, pollution abatement notices and land use planning referrals. The areas of primary concern for the EPA are air, water, land, noise control, waste control, and commercial activities.

This body of the Australian government was established under the Environment Protection Act of 1970. It was organized in response to community concern about pollution. For the first time in Victoria, all areas of pollution control were brought together under one organization, which is now known as the Environment Protection Authority.

The EPA's role has changed since it originated. It has evolved from "command and control" methods to being more flexible and willing to adapt in order to find the best solution to a situation. The EPA doesn't control any of the government sectors; it must achieve its goals through influencing government officials who control the laws and regulations. The EPA also works with several countries to influence international policy development.

Four fundamental principles around which the EPA is structured are: the precautionary principle, the protection of intergeneration equity, the polluter pays principle, and the protection of bio-diversity. The precautionary principle is based on the idea that action is more productive than reaction. It involves a combination of research, legislation, and economical solutions to solve possible environmental problems before they have a chance to cause any harm. Protecting the environment for future generations is the goal behind the second principle. It attempts to ensure that the environment will remain healthy for generations to come. By punishing polluters and enforcing strict fines upon those who contaminate the environment, the EPA attempts to ensure that Victoria stays clean at the responsible parties' expense. The last principle is an extension of the second. It recognizes that not only must the environment be protected for the enjoyment of our children, but also to ensure that their basic quality of life is not lowered by polluted water and air.

The EPA has formed a network to help protect the environment. In recent years, it has been attempting to work with industry in a cooperative effort to protect the environment instead of attacking industry. A joint venture has formed between the EPA and Overseas Projects Corporation of Victoria Limited, which trades to market and executive environmental projects locally and overseas. They also provide environmental consulting services within Australia and in other countries. Their consultation services include the development of legislation, policy and strategy, air quality management, pollution prevention, institutional strengthening, training courses, corporate systems development, and technical and scientific assessment.

The EPA's vision of the future is a very structured one. First, it wants to "meet the aspirations of Victorians, now and in the future, for a safe and ecologically sustainable environment through the protection and restoration of air, land and water quality and the control of unwanted noise" (Environment Protection Authority, 1998). To help them to attain this vision they are currently pursuing projects in all areas of environment protection. Programs started by the EPA aim to meet the community's aspirations of a clean, healthy environment through control and reduction of pollution and noise. The programs also aim to sustain business investment, which is essential to keep the organization running. The government funds a large portion of the cost to run the EPA, but private businesses also contribute additional money needed for the organization.

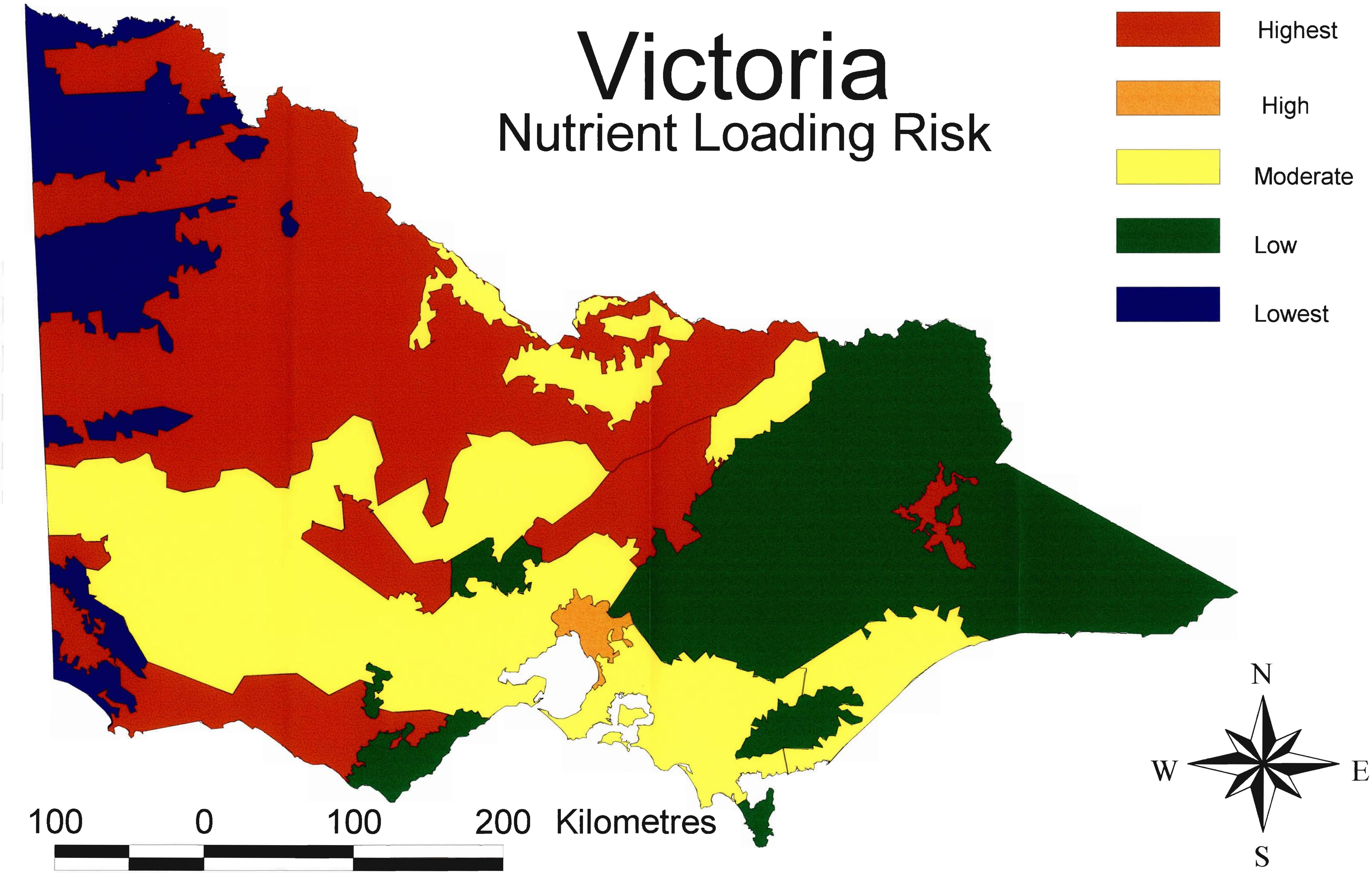
All forms of water environments are essential to the balance of a clean environment. Marine, freshwater, and estuarine ecosystems support important recreational and commercial activities. State environment protection policies are developed and revised to protect these environments. They outline beneficial and detrimental uses of these ecosystems. The EPA's key issue is the level of pollutants that enter these water bodies. There are regulations on sewage treatment and general waste release into the waters. In 1997, a water reform package of $1.3 billion was spent to improve sewage treatment.

Through the efforts of the Environment Protection Authority, improvements are being made throughout Australia and the world. Numerous measures are being taken to prevent future contamination of our environment. The EPA strives to improve the environment today and preserve it for the future.

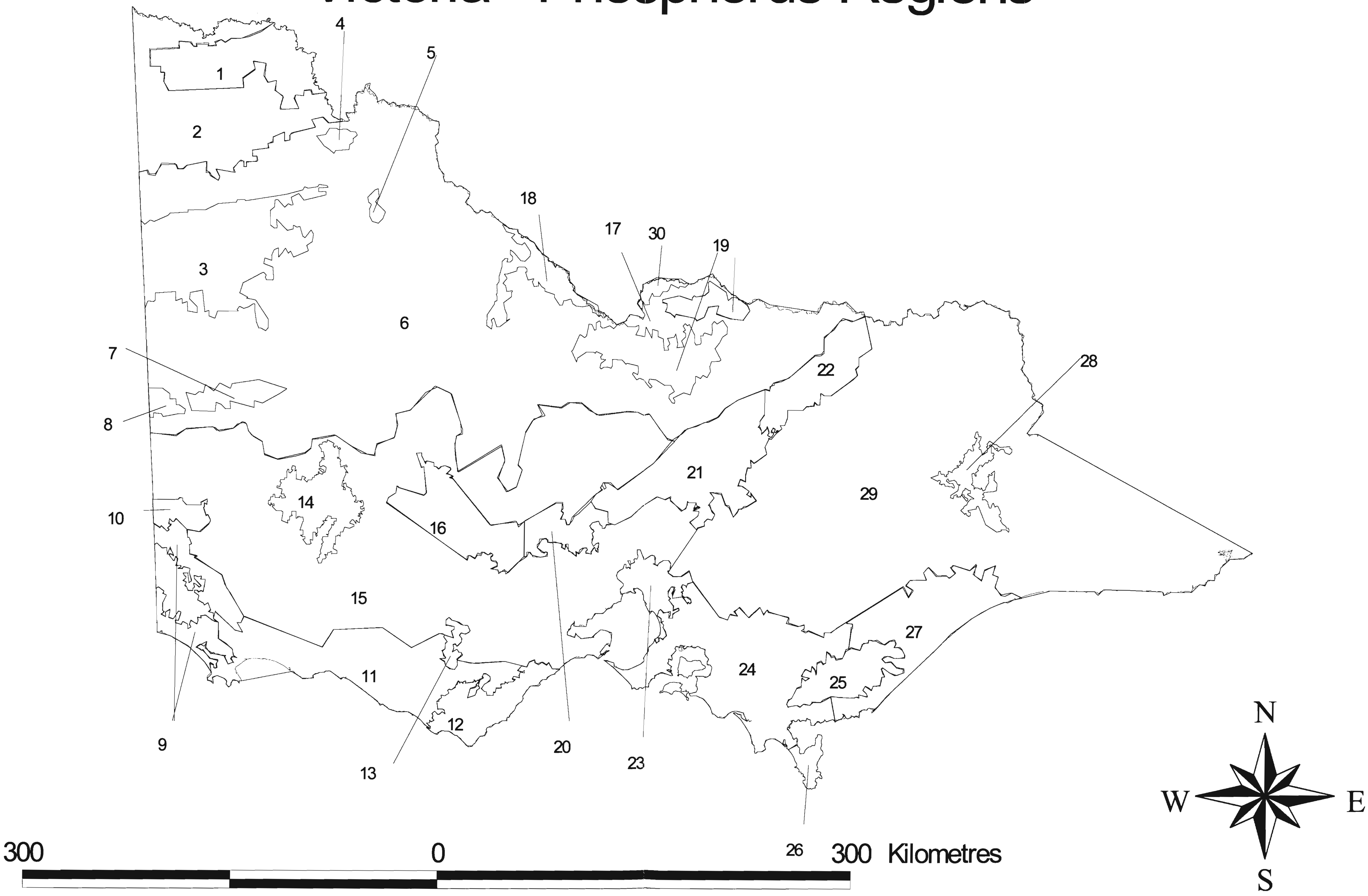
Appendix B – GIS Maps

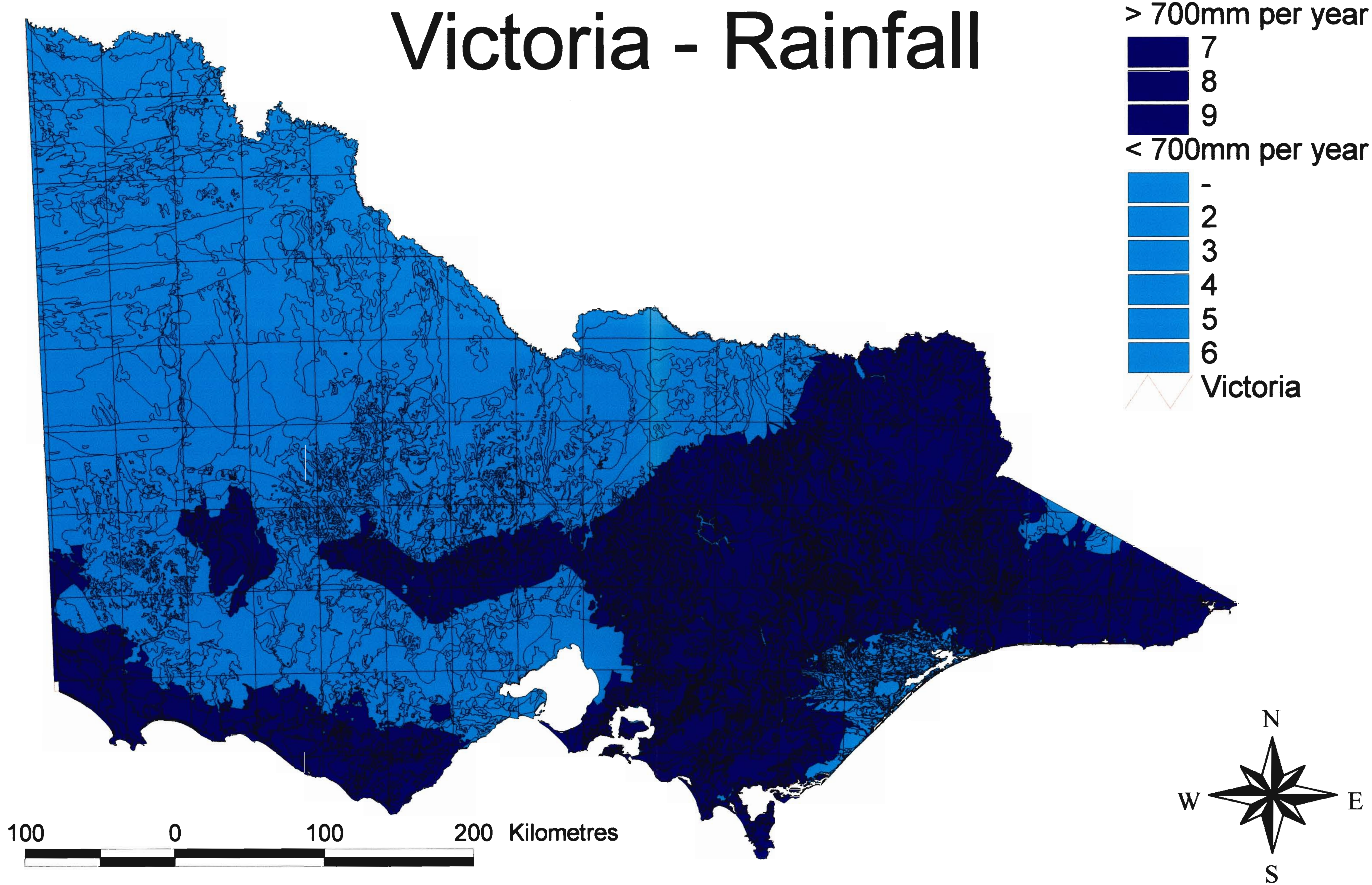
The following maps were created with ArcView GIS. Each region has a map for risk, rainfall, and land use.

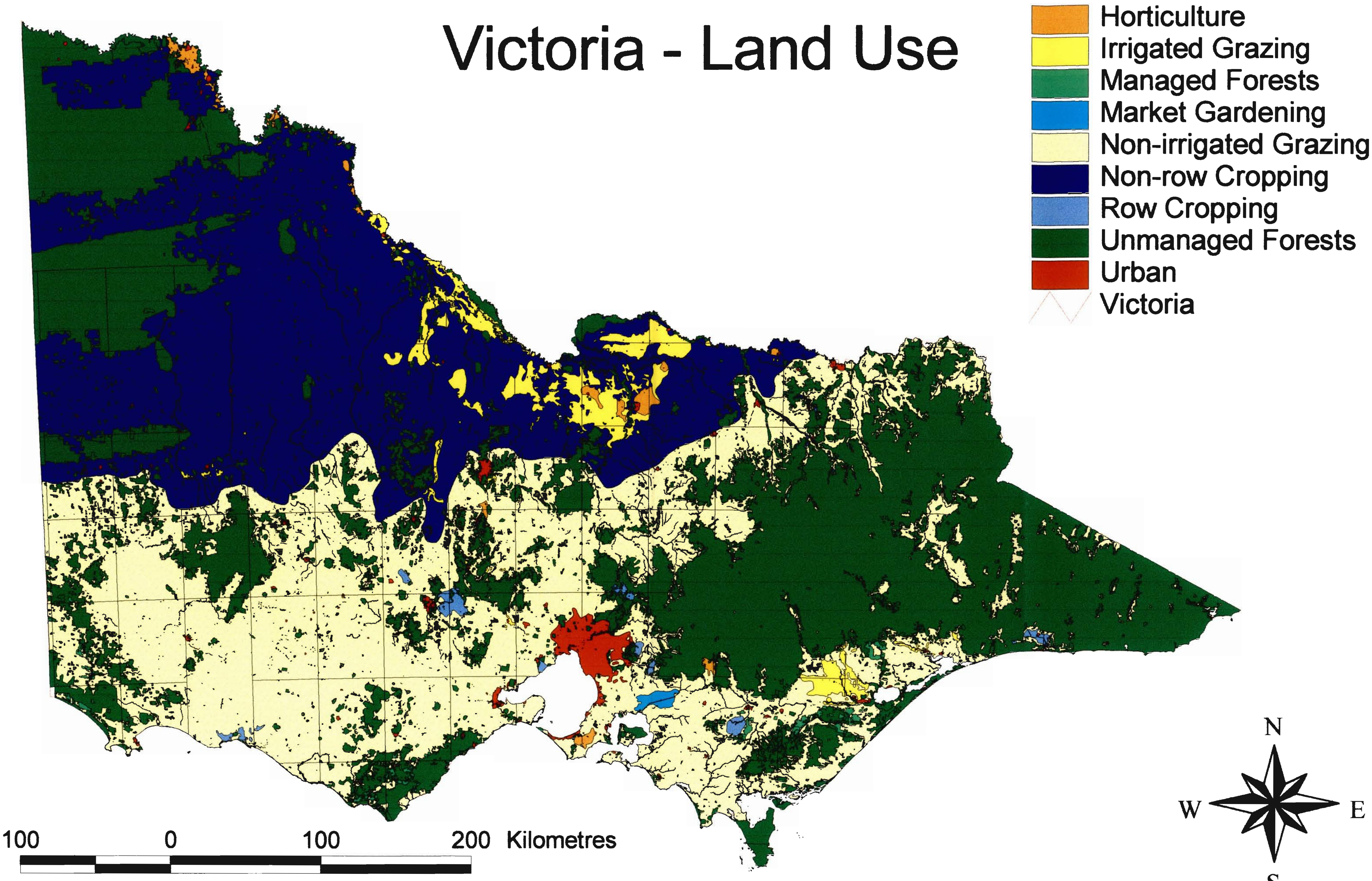
Table of Maps


Victoria
Nutrient Loading Risk
Highest
High
Moderate
Low
Lowest
N
W
E
S
100
0
100
200
Kilometres

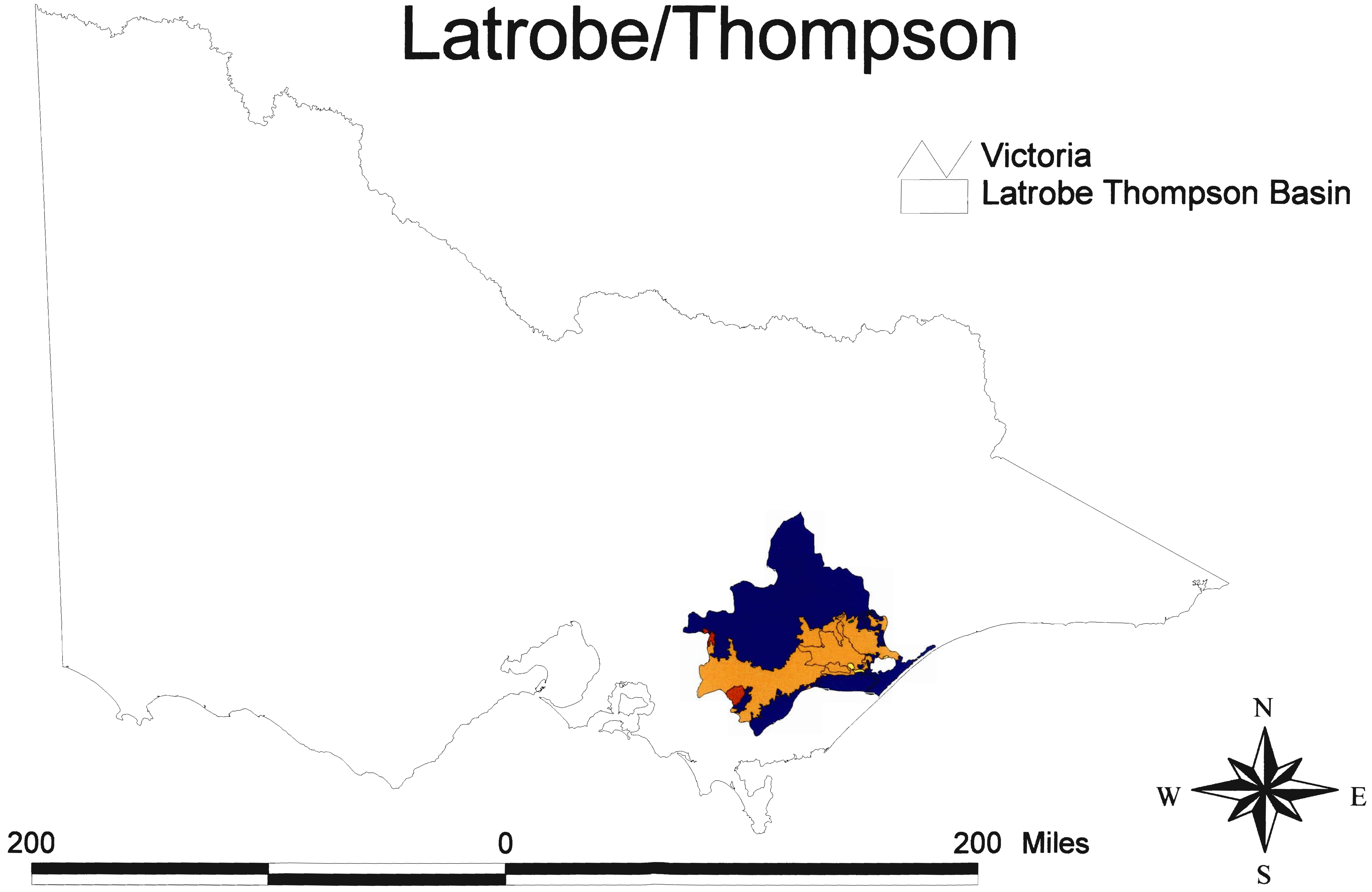
Victoria - Phosphorus Regions



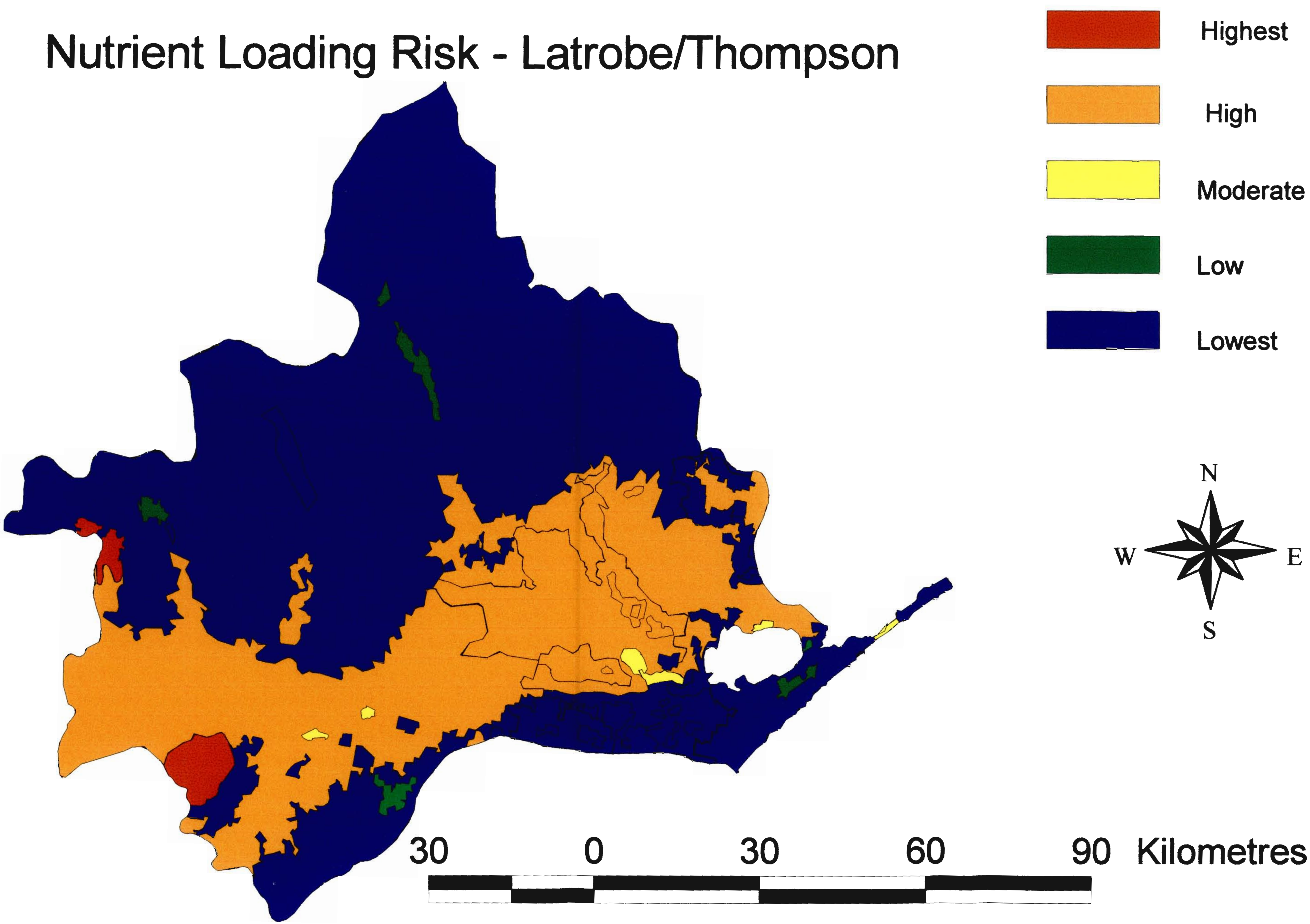

Victoria - Rainfall
> 700mm per year
7
8
9
< 700mm per year
-
2
3
4
5
6
Victoria
100
0
100
200
Kilometres
N
W
E
S


Victoria - Land Use
Horticulture
Irrigated Grazing
Managed Forests
Market Gardening
Non-irrigated Grazing
Non-row Cropping
Row Cropping
Unmanaged Forests
Urban
Victoria
N
W
E
S
100
0
100
200 Kilometres

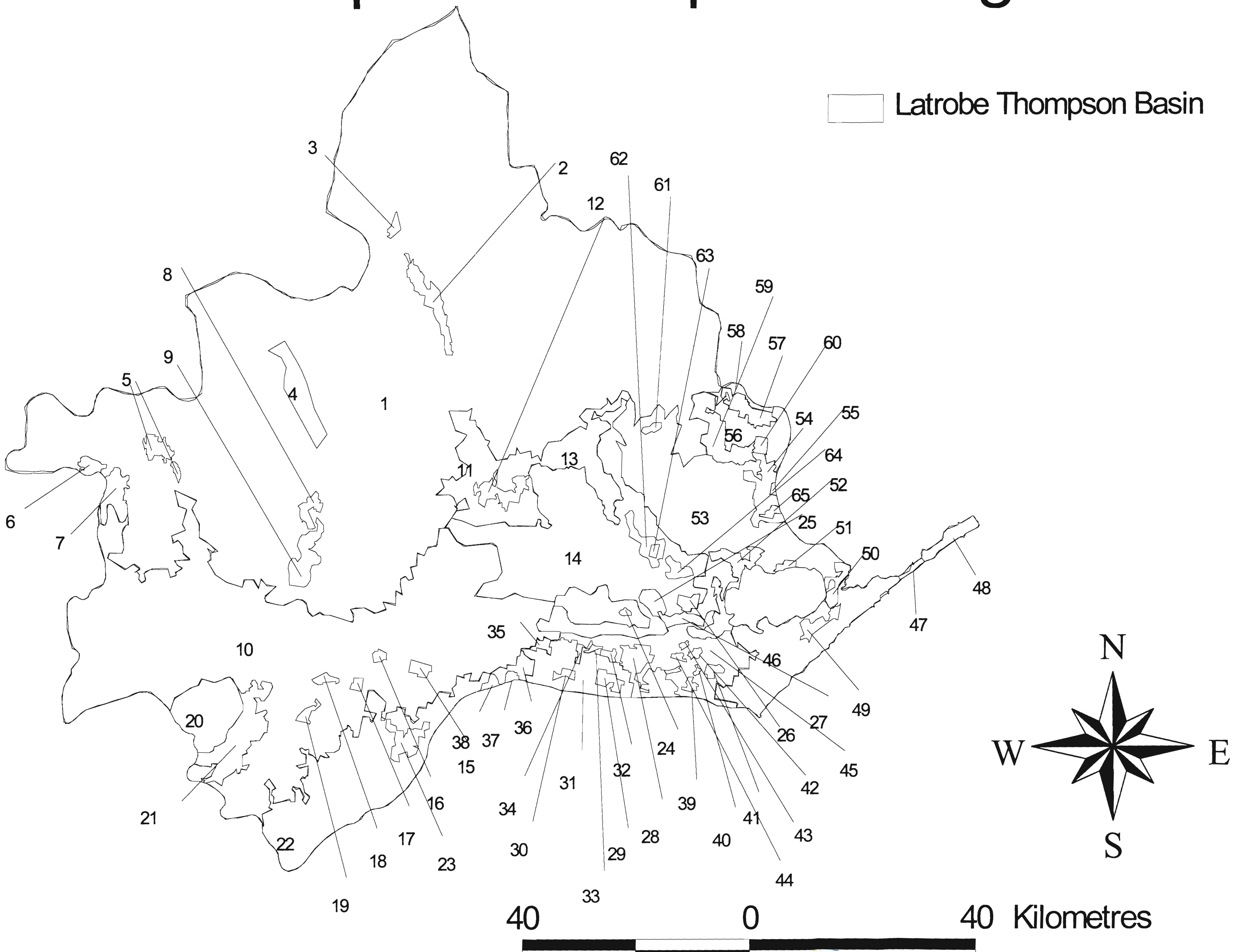
Latrobe/Thompson



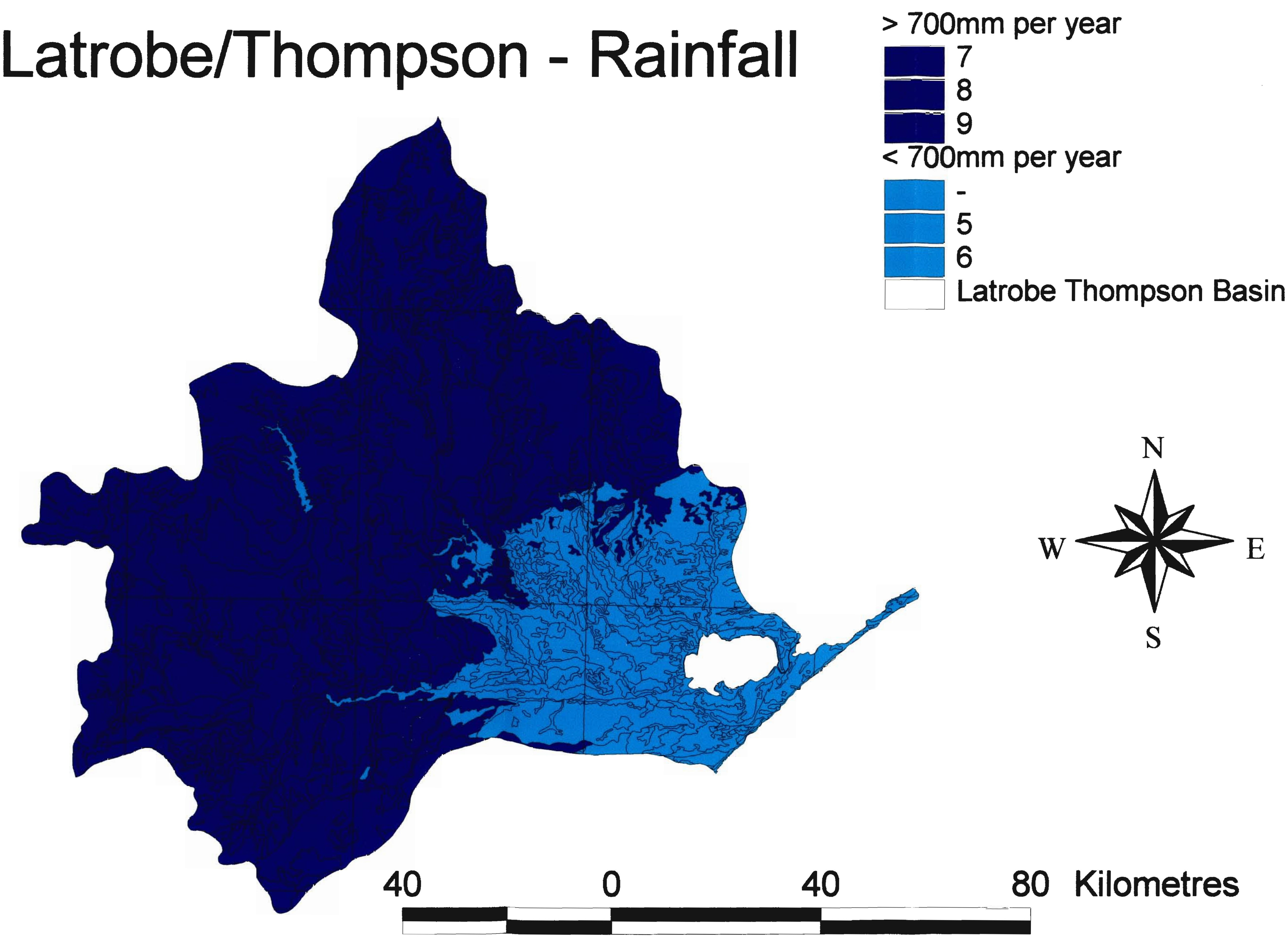
Nutrient Loading Risk - Latrobe/Thompson



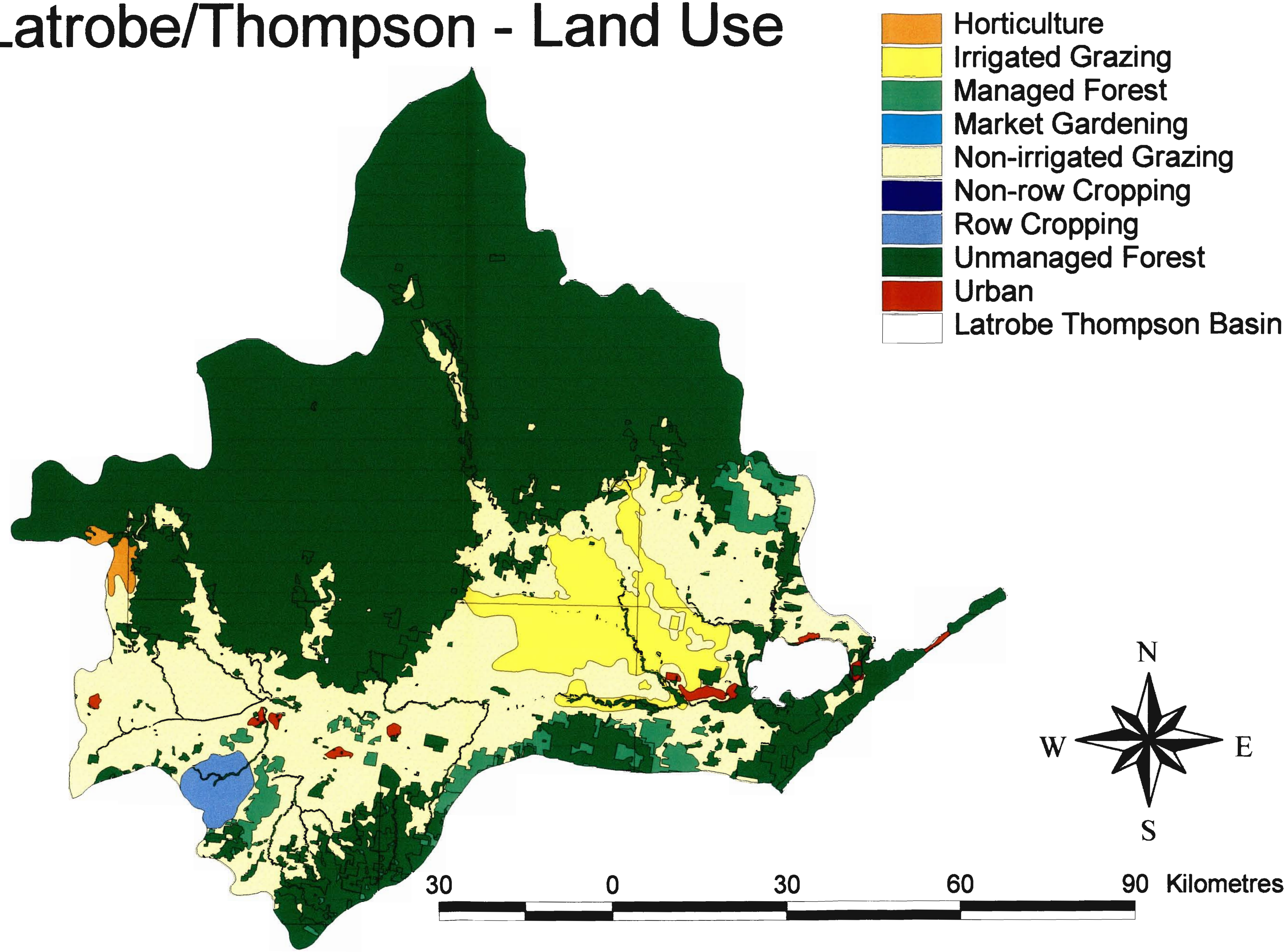
Latrobe/Thompson - Phosphorus Regions



Latrobe/Thompson - Rainfall

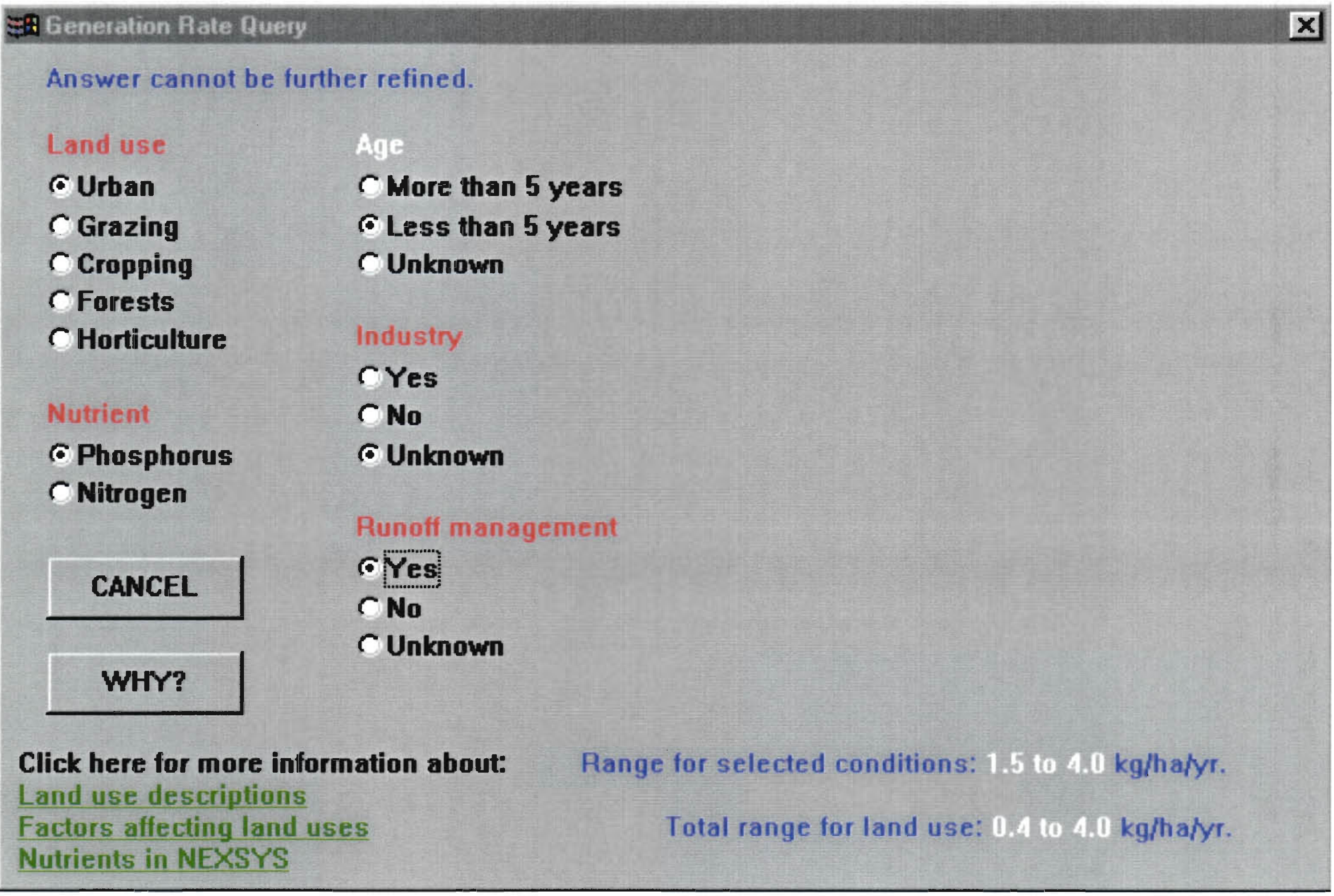


Latrobe/Thompson - Land Use



Appendix C – NEXSYS

A screen dump of NEXSYS



Appendix D – Usable Range Percentages I

Useable ranges were determined to be any range that's size was equal to or smaller than half the size of the total range of the land use in question. The following equation was used to convert the number of times a range appeared in each land use category into the percentage of total combinations for the land use category that it represented:

$$\frac{\text{\# of combinations that produced range}}{\text{Total \# of combinations}} * 100 = \text{\% of all combinations in land use category that produced range}$$

Urban:

Total Range: 0.4 to 4.0 kg/ha/yr

Total Combinations: 25

Ranges with sizes between 0.00 and 1.8 will be considered useable ranges for Urban.

# of combinations	Range	%	
2	0.4 to 0.9 kg/ha/yr:	8.0	
4	1.5 to 2.0 kg/ha/yr:	16.0	Useable Ranges
1	0.9 to 1.5 kg/ha/yr:	4.0	
5	2.0 to 4.0 kg/ha/yr:	20.0	
3	1.5 to 4.0 kg/ha/yr:	12.0	Unusable Ranges
10	No range for selected conditions:	40.0	

Total percentage of useable ranges: 28.0%

Total Percentage of unusable ranges: 72.0%

Grazing:

Total Range: 0.05 to 3.0 kg/ha/yr

Total Combinations: 246

Ranges with sizes between 0.00 and 1.475. will be considered useable ranges for Grazing.

# of combinations	**Range**	**%**	
2	0.05 to 0.2 kg/ha/yr:	0.813	
5	0.05 to 0.5 kg/ha/yr:	2.033	
1	0.5 to 1.0 kg/ha/yr:	0.407	Useable Ranges
41	0.05 to 1.0 kg/ha/yr:	16.667	
1	1.0 to 3.0 kg/ha/yr:	0.407	
38	0.5 to 3.0 kg/ha/yr:	15.447	Unusable Ranges
86	0.2 to 3.0 kg/ha/yr:	34.959	
72	No range for selected conditions:	29.268	

Total percentage of useable ranges: 19.92%

Total percentage of unusable ranges: 80.081%

Cropping:

Total Range: 0.2 to 15.0 kg/ha/yr

Total Combinations: 218

Ranges with sizes between 0.00 and 7.4 will be considered useable ranges for Cropping.

# of combinations	Range	%	
5	0.2 to 0.6 kg/ha/yr:	2.294	
15	0.2 to 2.0 kg/ha/yr:	6.881	
5	2.0 to 5.0 kg/ha/yr:	2.294	Useable Ranges
32	0.6 to 5.0 kg/ha/yr:	14.679	
41	0.2 to 5.0 kg/ha/yr:	18.807	
8	5.0 to 15.0 kg/ha/yr:	3.670	
37	2.0 to 15.0 kg/ha/yr:	16.973	
39	0.6 to 15.0 kg/ha/yr:	17.890	Unusable Ranges
36	No range for selected conditions:	16.514	

Total percentage of useable ranges: 44.955%

Total percentage of unusable ranges: 55.047%

Forests:

Total Range: 0.01 to 0.2 kg/ha/yr

Total Combinations: 27

Ranges with sizes between 0.00 and 0.095 will be considered useable ranges for Forests.

# of combinations	Range	%	
2	0.01 to 0.07 kg/ha/yr:	7.407	
3	0.07 to 0.13 kg/ha/yr:	11.111	Useable Ranges
3	0.13 to 0.2 kg/ha/yr:	11.111	
12	0.01 to 0.13 kg/ha/yr:	44.444	
4	0.07 to 0.2 kg/ha/yr:	14.815	Unusable Ranges
3	No range for selected conditions:	11.111	

Total useable ranges: 29.629%

Total unusable ranges: 70.37%

Horticulture:

Total Range: 0.1 to 5.0 kg/ha/yr

Total Combinations: 35

Ranges with sizes between 0.00 and 2.45 will be considered useable ranges for Horticulture.

# of combinations	Range	%	
1	0.1 to 1.0 kg/ha/yr:	2.857	
3	3.0 to 5.0 kg/ha/yr:	8.571	Useable Ranges
8	0.1 to 3.0 kg/ha/yr:	22.857	
10	1.0 to 5.0 kg/ha/yr:	28.571	
13	No range for selected conditions:	37.143	Unusable Ranges

Total useable ranges: 34.285%

Total unusable ranges: 65.714%

Appendix E – Usable Range Percentages II

Useable ranges were determined to be any range that's size was equal to or smaller than half the size of the total range of the land use in question. This set of data was created without taking into account the "unknown" option in NEXSYS to see if the results are any better. The following equation was used to convert the number of times a range appeared in each land use category into the percentage of total combinations for the land use category that it represented:

$$\frac{\text{\# of combinations that produced range}}{\text{Total \# of combinations}} * 100 = \text{\% of all combinations in land use category that produced Range}$$

Urban:

Total Range: 0.4 to 4.0 kg/ha/yr

Total Combinations: 9

Ranges with sizes between 0.00 and 1.8 will be considered useable ranges for Urban.

# of combinations	Range	%	
2	0.4 to 0.9 kg/ha/yr:	22.222	
3	1.5 to 2.0 kg/ha/yr:	33.333	Useable Ranges
1	0.9 to 1.5 kg/ha/yr:	11.111	
3	2.0 to 4.0 kg/ha/yr:	33.333	
0	1.5 to 4.0 kg/ha/yr:	0.000	Unusable Ranges
0	No range for selected conditions:	0.000	

Total percentage of useable ranges: 66.666%

Total Percentage of unusable ranges: 33.333%

Grazing:

Total Range: 0.05 to 3.0 kg/ha/yr

Total Combinations: 18

Ranges with sizes between 0.00 and 1.475 will be considered useable ranges for Grazing.

# of combinations	Range	%	
1	0.05 to 0.2 kg/ha/yr:	5.556	
2	0.05 to 0.5 kg/ha/yr:	11.111	
0	0.5 to 1.0 kg/ha/yr:	0.000	Useable Ranges
5	0.05 to 1.0 kg/ha/yr:	27.778	
1	1.0 to 3.0 kg/ha/yr:	5.556	
9	0.5 to 3.0 kg/ha/yr:	50.000	Unusable Ranges
0	0.2 to 3.0 kg/ha/yr:	0.000	
0	No range for selected conditions:	0.000	

Total percentage of useable ranges: 44.445%

Total percentage of unusable ranges: 55.556%

Cropping:

Total Range: 0.2 to 15.0 kg/ha/yr

Total Combinations: 30

Ranges with sizes between 0.00 and 7.4 will be considered useable ranges for Cropping.

# of combinations	Range	%	
3	0.2 to 0.6 kg/ha/yr:	10.000	
6	0.2 to 2.0 kg/ha/yr:	20.000	
1	2.0 to 5.0 kg/ha/yr:	3.333	Useable Ranges
6	0.6 to 5.0 kg/ha/yr:	20.000	
4	0.2 to 5.0 kg/ha/yr:	13.333	
1	5.0 to 15.0 kg/ha/yr:	3.333	
3	2.0 to 15.0 kg/ha/yr:	10.000	
5	0.6 to 15.0 kg/ha/yr:	16.667	Unusable Ranges
1	0.2 to 15.0 kg/ha/yr:	3.333	
0	No range for selected conditions:	0.000	

Total percentage of useable ranges: 66.666%

Total percentage of unusable ranges: 33.333%

Forests:

Total Range: 0.01 to 0.2 kg/ha/yr

Total Combinations: 13

Ranges with sizes between 0.00 and 0.095 will be considered useable ranges for Forests.

# of combinations	Range	%	
2	0.01 to 0.07 kg/ha/yr:	15.385	
3	0.07 to 0.13 kg/ha/yr:	23.077	Useable Ranges
2	0.13 to 0.2 kg/ha/yr:	15.385	
5	0.01 to 0.13 kg/ha/yr:	38.462	
1	0.07 to 0.2 kg/ha/yr:	7.692	Unusable Ranges
0	No range for selected conditions:	0.000	

Total useable ranges: 53.847%

Total unusable ranges: 46.154%

Horticulture:

Total Range: 0.1 to 5.0 kg/ha/yr

Total Combinations: 10

Ranges with sizes between 0.00 and 2.45 will be considered useable ranges for Horticulture.

# of combinations	Range	%	
1	0.1 to 1.0 kg/ha/yr:	10.000	
2	3.0 to 5.0 kg/ha/yr:	20.000	Useable Ranges
4	0.1 to 3.0 kg/ha/yr:	40.000	
3	1.0 to 5.0 kg/ha/yr:	30.000	
0	No range for selected conditions:	0.000	Unusable Ranges

Total useable ranges: 70.000%

Total unusable ranges: 30.000%

Appendix F – Victorian Catchments

In 1994, the Victorian Parliament passed the *Catchment and Land Protection Act.* This bill broke up Victoria into ten catchment areas, which are known as Catchment Management Authorities (CMA). The ten CMA's are Mallee, Wimmera, Glenelg, Corangamite, North Central, Goulburn, Port Phillip and Westernport, West Gippsland, North East, and East Gippsland. These areas were broken up and legislative bodies were established so bills could be passed for each catchment instead of for all of Victoria, where the laws might not apply.

Mallee

Mallee is one of the ten major catchments in Victoria. It is located in the northwest corner of the state and its 4,323,630 hectares accounts for twenty percent of Victoria. Mallee has highly permeable soil and receives an annual rainfall of between 250mm and 350 mm and has negligible problems with surface runoff as a source of non-point pollution (Mallee Regional Catchment Strategy, 97).

The Mallee catchment area only has a population of 62,500 with 37% of it living in the city of Mildura. Despite this, 62% of the land in Mallee is privately owned and primarily devoted (61%) to freehold dryland agriculture. The 1% of the privately owned land left over is used for freehold horticulture. Most of the public land is in the form of national parks (22%) and state forests (8%). The remainder is made up of linear corridors (5%) and miscellaneous uses (3%) (Mallee Regional Catchment Strategy, 97). Erosion is a problem caused by the large amount of land that is used for agriculture. Up to 7% percent of agricultural land is eroded every March. This is due primarily to wind erosion since water erosion and surface runoff are negligible in most of the catchment.

The few areas that do have a problem with surface runoff and water erosion are the two Raak Regional Resource Management Units (here after referred to as RRMUs), the perimeter of the Murray Trench, and the alluvial terraces of the Floodplain RRMUs. Areas of highest concern within the areas are the Happy Valley near Robinvale, Merbein, and the Red Cliffs. Turbidity is a primary concern because Mallee's water is used for drinking water and irrigation. Turbid water shortens the life of irrigation equipment that is exposed to it, increases drinking water treatment costs, and reduces the biodiversity of waterways (Mallee Regional Catchment Strategy, 97). The low number of high priority areas has allowed managers to effectively deal with most of them through fencing and revegetation. There goal is the "Revegetation/stabilization of eroding sites along all waterways by 2001." (Mallee Regional Catchment Strategy, 97) Community groups such as the Murray River Landscape Study, Catchment Management Authority, Department of Natural Resources and Environment, and local government are all expected to help in achieving this goal. Mallee depends on four major areas as sources of non-saline water. One of the largest of these sources is the Murray River, which is not part of the Mallee catchment but is a major source of irrigation and drinking water. The other three sources are Wimmera River/Grampian Reservoir, Yarriambiak Creek System, and Avoca River (Mallee Regional Catchment Strategy, 97).

One of the major pushes in Mallee is to reduce soil salinity. When Mallee was first settled there were 88,000 hectares of salt plains in the catchment. There are presently 97,000 hectares of salt plains in Mallee. If current practices are continued in the region over the next fifty years then 10% of what is presently farmland and 5% of what is public land is expected to become salt plains for a total of 330,000 hectares of salt plain in 2049 (Mallee Regional Catchment Strategy, 97).

Salinity monitoring programs have been set up across Mallee which have been very useful in targeting areas in serious danger or of high land value. Salinity management programs have been set up as well which have made significant inroads into salt contamination of the soil. The Mildura-Merbein groundwater interception scheme alone has been stopping 38,000 tons of salt annually since its creation in 1978 (Mallee Regional Catchment Strategy, 97). Mallee authorities hope that decisive action such as this will keep Mallee's soils in good shape for the twenty eight nationally threatened species of fauna that reside in it, and for agricultural use, well into the future.

Wimmera

The following information was derived from the Wimmera Regional Catchment Strategy, 1997. The Wimmera catchment is a 30,000 square kilometer region located on the western border of Victoria. Over 80% of the land use is for agriculture, while the rest is broken up into urban, mining, industry, recreation, and forestry areas. During normal conditions, the weather is very arid and the rate of evaporation usually exceeds the rainfall rate. As a result, many of the lakes in Wimmera are dry, usually for many years at a time.

Even though there is a high agricultural use in Wimmera, the soil is in poor condition. It is apt to become erosive, waterlogged, and develop a crusty surface. About 85% of cropped soil and 66% of the dryland pastures in Wimmera has poor soil qualities. Overall, the water quality in Wimmera is poor. The problems result from high nutrient, pH, salinity, and dissolved oxygen levels. This has led to an increase in the number of algal blooms in the region.

Wimmera is broken into nine areas, or Resource Management Units (RMU), based on similar landform, soil type, vegetation, rainfall, and slope of the land. The RMU's are the Wimmera Plains, West Wimmera Plains, Flat Grey Plains, South West Wimmera Plains, Mallee Calcareous Plains, Desert Sands, Undulating Alluvial Plains, Grampians, and the Northern Footslopes.

The West Wimmera Plains are found in northwest Wimmera. The landform is an undulating plain with occasional ridges and dunes. The major land uses are for cropping or grazing farmland.

Situated south of the Wimmera Plains are the Flat Grey Plains. This is a floodplain created by overflowing of the Wimmera River and Yarriambiack Creek. The RMU is used for irrigated cropping and grazing land.

The South West Wimmera Plains are composed of flat plains with area of wetlands. Cropping and grazing are the major land uses, with some areas of vegetative public land.

In northeast Wimmera, the Mallee Calcareous Plains are situated. The undulating plains with sand dunes are used for grazing and cropping purposes (Wimmera Regional Catchment Strategy, 1997).

The Desert Sands is found in western and northwestern Wimmera. Across the regions are sand dunes created by the wind. In this area, grazing and cropping farmland is found, as well as a few national parks (Wimmera Regional Catchment Strategy, 1997).

The Undulating Alluvial Plains are located in southern Wimmera. Alluvial deposits from the surrounding lakes and rivers formed the area. The region is primarily used for cropping and grazing pastures (Wimmera Regional Catchment Strategy, 1997).

The Grampians are found in southeast Wimmera. The region is composed of a number of national parks, including Grampians National Park, Black Range State Park, and a portion of Mt. Arapiles-Tooan State Park. The landscape includes wildlife and recreation areas (Wimmera Regional Catchment Strategy, 1997).

The Northern Footslopes are situated in southeastern Wimmera. Due to the regions' varying landscape, the RMU is been broken down into six sub-divisions. These are the

Tertiary Rises, Granites, Volcanic Plain, Sedimentary Rises, Uplands and Grampians Alluvial Plains, and Steep Hills. The Northern Footslopes land use includes grazing, cropping, and forestry areas (Wimmera Regional Catchment Strategy, 1997).

Glenelg

The Glenelg Regional Catchment is located in the southwest corner of Victoria along the coast. It is just south of the Wimmera region and just west of the Corangamite region. It covers 25,000 square kilometers of land, and contains two mountain ranges, one in the northern region, and the other in the southwest (Glenelg Regional Catchment Strategy, 1997). In 1991, the population was 100,000. The basins that are found in this area are the Glenelg, Portland, and Hopkins (Glenelg Regional Landcare Plan, 1993).

The conditions here have significant variation. The region's climate is similar to that of the Corangamite region with warm, dry summers and cool wet winters. Regional temperatures range from about 4-27°C. The land consists of flat, volcanic plains with soil consisting of heavy volcanic clay. Average rainfalls are between 500 mm to 910 mm per year, with the heaviest rainfall occurring between April and November (Glenelg Regional Catchment Strategy, 1997).

The land use for the Glenelg region is broken up into four major areas. Over 80% of the land is used for non-irrigated grazing. Native forest (16%), productive forest (2%), and various urban and industrial areas (1%) cover the remaining 19%. 44% of Victoria's wetlands are located in Glenelg (Glenelg Regional Catchment Strategy, 1997). The major cities in the catchment are Warrnambool, Portland, Hamilton, Ararat, and Ballarat (Glenelg Regional Catchment Strategy, 1997).

There are several types of problems that affect the Glenelg Regional Catchment. Soil erosion, algal blooms, salinity, acidic soil, sedimentation of streams, high nutrient levels, stream erosion, heavy grazing and pest animals are the problems in various areas of the catchment (Glenelg Regional Catchment Strategy, 1997). Soil erosion in this area includes sheet, rill, gully, and tunnel erosion. In Glenelg, erosion of tributary streams is the major concern. Sediment is eroded from the smaller streams, and then is deposited into the major rivers. Sedimentation lowers the habitat value and causes various problems (Mitchell, 1990).

The contamination of the region's waterways and land is a result of pesticides, animal waste, inorganic fertilizers, and soil additives. These contribute a high concentration of phosphorus and nitrogen to certain streams, which increases the occurrence of algal blooms. These contaminants not only pollute the waterways, but they also contribute to the problem of acidic soil (Glenelg Regional Catchment Strategy, 1997).

The conditions of the various basins range from moderate to very poor. The Glenelg and Portland basins' streams, in general, are in moderate or poor condition, while the Hopkins basin is mostly in very poor condition. The water quality in the Hopkins basin is very low, and as a result, there are few animals and little plant growth (Mitchell, 1990). In general, water quality is highest in the forested areas of Glenelg, but is still considerably lower than the rest of Victoria. The entire region, however, is in need of improvement (River Health Bulletin: Glenelg Basin, 1994).

Corangamite

The Corangamite region is located along the southern coast, just to the east of the Glenelg region and south of the North Central region. It occupies 13,340 square kilometers, with 280 kilometers of coastline. 17,500 hectares of the land are on the coastal fringe (Corangamite Regional Catchment Strategy, 1997). The total population of the region is about 500,000. The boundaries of the Corangamite region include the Corangamite, Otway, Barwon, and Moorabool basins (Draft Landcare Plan for the Corangamite Region, 1993).

This area is one of variety and inconsistency. The climate consists of warm, dry summers and cool, wet winters with average temperatures of 4-27°C. The soil varies from sand to heavy volcanic clay. Rainfall varies greatly here, with annual rainfall rates between 500 and 2000 millimeters. The highest rainfall in the state is 2000 mm per year, which is present in the Otway Ranges. The lowest rainfall is seen in Lara and its surrounding areas (Draft Landcare Plan for the Corangamite Region, 1993).

Drainage patterns have been interrupted in the past by lava flows. There used to be large creeks and streams in the area, but today, several small creeks that empty into various lakes have replaced these. None of these streams flow to the ocean. Most of the lakes in the area are saline, with some having a higher salinity than seawater (River Health Bulletin: Corangamite Basin, 1994).

Around 75% of the land in the region is made up of privately owned farms. These farms consist mostly of non-irrigated pastures. Non-farmland and remnant native vegetation is present in patches of the north and southeast. Privately owned softwood forests are located in the south and horticulture areas are also present in the extreme north. Ballarat and Geelong are the two major urban areas of Corangamite (Corangamite Regional Catchment Strategy, 1997).

There are several major waterways present in the Corangamite catchment. The major rivers are the Moorabool, Barwon, Woady Yaloak, Curdies, Aire, Leigh, and Gellibrand. The area has been noted for its value in recreational and environmental use. The unique and prosperous wetlands and aquatic habitats that are also present are renowned nationally (Corangamite Regional Catchment Strategy, 1997).

The high value associated with Corangamite's waterways implies that the waterways are generally healthy, but this is not the case. Several tests have been done to determine overall water quality, and the results were not good. In the Barwon basin, the healthiest basin of the region, the majority of the streams and creeks are in good or moderate condition. However, in the Otway, Moorabool, and Corangamite basins, the majority of streams are in moderate to poor condition. (Mitchell, 1990). Over 40% of the streams in the area have stream bank vegetation in very poor condition. Poor stream bank vegetation decreases an area's resistance to erosion (Corangamite Regional Catchment Strategy, 1997).

The plant and animal life in Corangamite is threatened. Humans, animals in the area, and natural processes such as erosion and salinity, have caused severe destruction. There are 1830 types of vascular plants, with 87 of these being either rare or threatened species. Vegetation covers only about 20% of the region, so any destruction to these areas could be detrimental to the endangered and threatened species (Corangamite Regional Catchment Strategy, 1997). Since development began in the area, 20 species of native animals have become extinct, and 50 more species are endangered. Trees have been cut down to sell for profit or to clear for development, and 75% of the total trees that were originally present are gone. Due to salinity problems in the area, 10,000 hectares of vegetation have been lost. Rabbits are a common problem in the area and account for destroying another 15,000 hectares. Their burrowing accelerates the water erosion process and damages the overall water quality (Draft Landcare Plan for the Corangamite Region, 1993).

Soil loss due to water erosion occurs in 27% of the land in the Corangamite Region. Severe water erosion has created 120,000 hectares of barren land that is incapable of regrowth, especially in the Otway Ranges. Overgrazing, vegetation removal, and urbanization have also contributed to increased erosion rates (Draft Landcare Plan for the Corangamite Region, 1993).

North Central

The North Central Catchment Region is located in the northwestern section of Victoria. The region is comprised of four smaller catchments, the Avon Richardson, Avoca, Loddon, and Campaspe. Within these four catchments flow the five major rivers of the region. They are the Murray, Campaspe, Loddon, Avoca, and Avon Richardson Rivers (North Central Regional Catchment Strategy, 1997).

Like the other catchment regions in Australia, North Central has a diverse selection of plants and animals. There are over 1900 vascular plants, 45 mammal, 60 reptile, 19 amphibian, 19 fish, and 320 bird species. However, diversity has diminished over the years due to alterations in land use (North Central Regional Catchment Strategy, June 1997).

Agriculture makes up 67% of the total land usage in the North Central Region. The rest of the land is used for rural residential and sub-commercial holdings (18.41%), urban land (.5%), and other non-agricultural lands (14.13%) (North Central Regional Catchment Strategy, June 1997).

Agricultural land can be broken into five subcategories. Dryland pastures take up 1,050,000 hectares of land, 443,000 hectares for dryland crops, 5,500 hectares for horticulture, 226,500 hectares for irrigated crops and pastures, and 340,000 hectares for other miscellaneous uses (North Central Regional Catchment Strategy, June 1997). By examining these numbers, it can be determined that North Central is mostly used for grazing purposes.

With agriculture being the main use of the land, excess nutrients are added to the soil from fertilizers and animal waste. Phosphorus and nitrogen loads are expected to increase over the next 25 years particularly in the southern end of the catchment (North Central Regional Catchment Strategy, June 1997).

Evidence of excessive nutrients can be seen in the extensive algal blooms at Lake Boga and Kow Swamp, which cost $2.3 million and $4.0 million respectively to clean up. It has been determined that the North Central Catchment Region has the highest occurrence of algal blooms in the state of Victoria (North Central Regional Catchment Strategy, June 1997).

Waterways in the North Central Catchment have mostly been designated in poor condition, with 61% poor condition, 31% in moderate condition, and 7% in excellent condition. In order to combat the increase in nutrient loading and to improve the quality of the water, $2,950,000 in 1997 was allocated both from the state and federal government (North Central Regional Catchment Strategy, June 1997).

Organizations within Victoria have taken responsibility for improving the state of waterways and surrounding land uses in North Central. Extensive programs have been set up to deal with soil erosion, nutrient loading, salinity, and soil quality. These programs are aimed at improving the overall quality of the North Central catchment region.

The objective for the salinity program is to continue the implementation of existing management plans as well as allocating the appropriate resources to extend these plans. These management plans are directed at both irrigation and dryland salinity problems (North Central Regional Catchment Strategy, June 1997).

Water quality programs are aimed at improving the quality of all water bodies in North Central. This includes overall water quality, waterway quality, floodplain water quality, and groundwater. All four programs are attempting to minimize the export of nutrients from surrounding land uses (North Central Regional Catchment Strategy, June 1997).

A program for soil quality has been divided in to three sub-programs, soil structure, soil acidification, and soil erosion. Several actions are being taken to improve all three problems. Surveys of soil structure decline are being taken to identify the most important areas based on Regional Management Units (RMUs). Reference sites have been set up to monitor the levels of soil degradation as well. These two strategies are being applied to soil acidification as well as the development of a soil acidification-monitoring program. There are four actions being taken to improve soil erosion. The first is to review land and water management plans to determine which areas need the most attention. The second is to support soil conservation activities with funding. Thirdly, the development of a soil conservation program is underway to complement conservation activities. The fourth action is to monitor the impact of soil erosion in relation to nutrient management programs (North Central Regional Catchment Strategy, June 1997).

Goulburn

The Goulburn Broken catchment is located in central Victoria between the North Central and North East catchments. It borders the Port Phillip and West Gippsland catchments on the south and New South Wales at its northern border. It covers about 17% of Victoria and its 2,400,000 hectares is home to a population of 200,000 people (The Goulburn Broken Catchment Strategy, 1997).

Goulburn's primary form of industry is agriculture, food processing, and to a lesser extent tourism. It is home to the Shepparton Irrigation Region, or SIR, which produces 4.5 billion dollars a year in Victorian exports. This is roughly 25% of Victoria's total export earning every year and the SIR is often called the "food bowl" of Australia. Goulburn also contains the Eildon, which is one of Victoria's most important water supply catchments. These two areas make Goulburn a valuable resource for all Victoria, but only if the health of the catchment is maintained (Goulburn Broken Catchment Strategy, 1997).

The problem of greatest concern in Goulburn at present is the extremely high water table in most areas of the catchment. High water tables can lead to severe salinisation of the soil. There are currently 4,500 hectares of salt deposits in Goulburn. If nothing is done, this will increase by 5% a year and will be around 38,000 hectares in fifty years. Salty soil is very hard to farm since most agriculturally valuable plants are not salt tolerant and will not grow under these conditions (Goulburn Broken Catchment Strategy, 1997).

Goulburn's water table has already risen past the level that was predicted for 2000. Currently, 43% of the SIR has a water table within two meters of the surface. If this trend is not curbed, 65% of the SIR will have a high water table by 2020, and severe land salinisation will have occurred. Much of the major wetlands and 1,500 kilometers of river will also have suffered severe damage (Goulburn Broken Catchment Strategy, 1997).

Monitoring, education, and salt management programs have been implemented along with subsurface drainage plans and better land use practices to fix this problem.

Another serious problem that Goulburn is faced with is nutrient pollution and the resulting algal blooms. In 1997, Goulburn contributed 300 tons of phosphorous and 3,000 tons of nitrogen to the Murray River alone (Investigation of Nutrients from Urban Stormwater and Local Water Quality Issues in the Goulburn Broken Catchment, 1995).

Irrigation drainage has been found to be one of the major contributors to phosphorous loading in the catchment. Irrigation drainage is very high in nutrients and low in salinity. This makes it an ideal water supply for farming. Plans for the retention and reuse of tail-water and storm water on farms are being developed and implemented to help with the nutrient loading problem. Education programs on the problem, its effects, and what everyone can do about it has also begun to be implemented throughout the catchment (Goulburn Broken Catchment Strategy, 1997).

Port Phillip and Westernport

Melbourne is located at the heart of the Port Phillip and Westernport catchment area. The region comprises over 1,421,000 hectares of land and has a variety of land uses, which mainly include agricultural, urban, and forestry areas. This region is one of the most diverse in Victoria, with 1600 native flora and 600 native animals. However, due to limited urban space, natural vegetation covers only 28% of the total land area in Port Phillip and Westernport (Port Phillip and Westernport Regional Catchment Strategy, 1997).

Overall, the water quality in Port Phillip and Westernport is poor, compared to the rest of Victoria. The two bodies of water all the water in the catchment area flow into are Port Phillip Bay and Western Port. According to Melbourne Water Corporation, 57% of the catchments' stream length is in moderate, poor, or very poor condition. As a result, algal blooms and high bacterial levels are common problems (Port Phillip and Westernport Regional Catchment Strategy, 1997).

Port Phillip and Westernport can be broken down into five smaller catchments, Westernport, Dendenong, Yarra, Maribyrnong, and Werribee. The Westernport catchment is located southeast of Melbourne. Agriculture is the major industry in this area, with mostly livestock and horticultural farming. Half of the total stream length in this region is rated in poor or very poor condition. In the southern part of this catchment area, gully erosion and land slips are common (Port Phillip and Westernport Regional Catchment Strategy, 1997).

The Dandenong catchment is the smallest and most urbanized region in Port Phillip and Westernport. Residential or industrial areas occupy over 70% of the land use in the region. Overall, the water quality in Dandenong is in moderate to poor condition, with the lakes and streams around the Dandenong Creek in the center of the region being in the worst condition. Many of the problems that face the water quality in the region are attributed to urban and stormwater runoff. As a result, bacteria, sediment, nutrient, litter, and metal levels are extremely high in the rivers as well as Port Phillip Bay (Port Phillip and Westernport Regional Catchment Strategy, 1997).

The Yarra catchment is the largest catchment in Port Phillip and Westernport, with 400,000 hectares of land. Over half of the region's population resides in this catchment. The largest land use is for agricultural purposes. Overall, the water quality in the Yarra catchment is the best in Port Phillip and Westernport, but is poor compared to the rest of Victoria. The major contributors that are polluting the water come from stormwater runoff, wastewater treatment plant discharge, and agricultural runoff. As a result, bacteria, suspended solids, nutrient, and turbidity levels are high and the salinity levels are amongst the worst in Victoria (Port Phillip and Westernport Regional Catchment Strategy, 1997).

The Maribyrnong catchment is located northwest of Melbourne, with 143,000 hectares of land. Agriculture is the largest land use, with mostly grazing and broad area crop farming. As a whole, the water quality in Maribyrnong is very poor. This is a result of high metal, pH, suspended solids, and nutrient levels. Erosion is a severe problem, usually found in the form of gully, tunnel, or sheet erosion. In the Maribyrnong and Moonee valleys, flooding is common despite the relatively low amounts of rain the catchment receives (Port Phillip and Westernport Regional Catchment Strategy, 1997).

The Werribee catchment includes 270,000 hectares of land to the west in Port Phillip and Westernport. Its flat landscape provides good land for broad area cropping and livestock agriculture. Over half of the total length of the lakes and streams have poor or very poor water quality, according to Melbourne Water Corporation. This has led to blue-green algae blooms and high levels of salinity in the region. Gully, tunnel, and sheet erosion are also causing problems in the catchment (Port Phillip and Westernport Regional Catchment Strategy, 1997).

West Gippsland

West Gippsland Catchment is located in the southeast corner of Victoria. The region is broken up into three river basins, LaTrobe, Thomson, and South Gippsland. Seventeen rivers run through this catchment including LaTrobe, Thomson, Macalister, and the Tarra Rivers. The abundance of waterways makes the West Gippsland Catchment an ideal area for agriculture. The catchments' 1,885,200 total hectares support a population of 192,000 people (West Gippsland Regional Catchment & Land Protection Board, 1997).

The land types in the catchment vary around the region. Northern regions have steep hills, especially in the Eastern Highlands. Across the middle of the region are the Central and Red Gum Plains with the Macalister Irrigation District situated in the middle. Plains are located in the south with the Strzelecki Ranges heading to the west, concluding with the South Gippsland Plains in the most western part of the catchment (West Gippsland Regional Catchment & Land Protection Board, 1997).

Rainfall across West Gippsland varies depending on the location within the catchment. Southwesterly air streams, summer thunderstorms, and easterly depressions account for most of West Gippsland's rainfall. Measurements of rain can be as much as 1600mm per year on Baw Baw Plateau or as little as 600mm per year on the eastern part of the Central Plains. Intense rainstorms have been known to occur, some dropping rainfall totals up to 300mm in twenty-four hours. Rainfall events often lead to localized flooding and erosion.

Land use in West Gippsland includes tourism and recreation, agriculture, forestry, and residential uses. Agriculture is made up of dairy farming, horticulture and vegetable growing. Forestry is becoming a more popular land use application. Plantations are expanding at a rate of about 1,300 hectares per year (West Gippsland Regional Catchment & Land Protection Board, 1997).

Soil quality is fairly good throughout West Gippsland. The northern and southern parts of the catchment have red and brown soils, which provide excellent drainage. These areas are more suitable for agriculture. However, due to the low nutrient content in the soil, fertilizers need to be added for better plant growth. The middle belt of the catchment has hard, acidic soils. Because of the different soil types in this catchment, different management strategies for nutrient application need to be applied (West Gippsland Regional Catchment & Land Protection Board, 1997).

Agriculture is an important aspect of the West Gippsland economy. Approximately 580,000 hectares are used for agriculture and 96,000 hectares are used for plantation forestry (West Gippsland Regional Catchment & Land Protection Board, 1997). Agriculture in the catchment includes rain-fed dairy and beef production, irrigated dairy farming in the Macalister Irrigation district, potato growing in red soils areas, beef and sheep raising in Central, Giffard, and Red Gum Plains, and the growing of vegetables, fruit, and flowers.

North East

The North East Catchment Region is located in the northeastern corner of Victoria, just north of East Gippsland. The catchment covers an area of 1,975,000 hectares, approximately 10% of the land in Victoria (North East Regional Landcare Plan, 1993). Sixty-one percent is designated as public land and the remaining 39% is designated as private. The Murray River bounds the catchment on the north and east, the Victorian Alps to the south, and the Ovens River to the west. The region provides a home to approximately 176,400 people, according to the 1994 Census. The catchment is broken down in to three basins, the Upper Murray, Kiewa, and Ovens basins. Alpine high plains, steep mountain ranges, slopping hills, and flat plains make up the topography in the North East Catchment. This landscape reflects the impact of agriculture and water storage over the years.

Agriculture is the main land use in this region. Major valleys in the north have been cleared for agriculture use. Ovens Basin is the location for 75% of Victoria's tobacco production. Livestock, sheep, beef cattle, dairy cattle, and grape production takes place in Ovens and King valleys. The central and southeastern part of the Ovens Basin is the location for hardwood logging and forestry grazing (North East Regional Catchment Strategy, 1997).

Forestry is the second main land use in this region. Located on public land with rainfall greater than 800mm per year, commercial forestry is one of the most important economical land uses. State owned pine plantations use 35,000 hectares of land. The Ovens Valley and the Upper Murray use 21,100 hectares and 12,900 hectares respectively (North East Regional Landcare Plan, 1993).

In 1993, the three basins were measured for nutrient pollution. Nutrient levels were found to be slightly higher than desired, but still within acceptable ranges. The Upper Murray had significant phosphorus levels in the lower Mitta Mitta River. The Kiewa Basin had elevated levels of phosphorus and nitrogen, but was classified to have a status rated low to moderate. Nutrient levels were increasing in the Ovens River, part of the Ovens Basin as well as at Reedy Creek (North East Regional Catchment Strategy, 1997).

The region receives a diverse amount of rainfall each year. As much as 2000mm can fall in a year in the alpine region. Rainfall is as low as 500mm a year on the plains. During the months between May and October (winter and spring) approximately 60% of the catchment's rainfall hits the ground (North East Regional Landcare Plan, 1993).

Erosion is a major problem in all sections of the North East Catchment. Water erosion is the main concern, opposed to wind erosion. The table below shows erosion percentages for the three catchment areas in the North East Region.

Basin Sheet & Rill	Area agri. Land ('000 ha)	Insignificant / Low	Moderate	Severe
Upper Murray	293	61%	28%	9%
Kiewa	91	99%	0%	0%
Ovens	387	78%	21%	0%
Basin **Gully & Tunnel**				
Upper Murray	293	57%	33%	9%
Kiewa	91	75%	1%	23%
Ovens	387	57%	31%	11%

(North East Regional Catchment Strategy, 1997)

East Gippsland

East Gippsland is one of the ten regions established by the *Catchment and Land Protection Act of 1994.* It is located in the eastern part of Victoria and covers approximately 2.13 million hectares, which is about 10% of Victoria's total land area (East Gippsland Regional Catchment Strategy, 1997).

Overall, the total quality of the water in East Gippsland is very good. About 73% of the total length of the rivers and streams are rated in excellent condition and only 3.5% is in poor or very poor condition, as distinguished by the Department of Water Resources. During normal conditions, the water has good turbidity and salinity levels. However, during very rainy seasons, the suspended solids and colloidal matter in the water reach unsafe levels (East Gippsland Regional Catchment Strategy, 1997).

The Department of Natural Resources and Environment (NRE) has divided the catchment up into nine regions, which are called Resource Management Units (RMU). The RMU's are identified by their similar characteristics, such as soil types, landform, and climate. In East Gippsland, these areas are the Red Gum Plains, Coastal Complex, Alluvial Soils, Lowland Forests, Foothills, Mountains, Mountain Basins, Mountain Plateau, and Alpine (East Gippsland Regional Catchment Strategy, 1997).

The Red Gum Plains are located in southwestern East Gippsland. The region is identified by its relatively flat land, which is composed of clay soil. The conditions of the land allow for many grazing pastures. The soil fertility is relatively poor due to nutrient deficiency, water clogging, and poor soil structure. Forest areas exist in the region, but are not widespread as they are mostly found on private land or on the Moormurng Flora and Fauna Reserve (East Gippsland Regional Catchment Strategy, 1997).

The Coastal Complex stretches across the coastline of the Tasman Sea in East Gippsland. Tourism is the major industry, with the sandy beaches and coastal lakes the main attraction. Most of the land in the Coastal Complex is privately owned, but there are also a number of national parks within the RMU (East Gippsland Regional Catchment Strategy, 1997).

The Alluvial Soils regions are spread out in the southern part of East Gippsland. The land is mostly used for horticulture, dairy, and cattle production due to the high fertility of the soil. The fertile soil is the result of flooding and alluvial deposits, which occurs during rainy seasons. Even though the soil is very rich, fertilizer is still used on many of the farms. The rivers, lakes, and shallow aquifers provide a sufficient supply of water for irrigation (East Gippsland Regional Catchment Strategy, 1997).

The Lowland Forests are located north of the Coastal Complex and stretch across East Gippsland. The region comprises a series of undulating hills made of sandy soil. The

Lowland Forests are very dry and therefore susceptible to fire. Some of the land in this region is set aside for national parks, which include Coajingolong National Park, Lake Tyers Forest Park, and Ewing March Wildlife Reserve (East Gippsland Regional Catchment Strategy, 1997).

The Foothills and Mountain regions are located near the center of East Gippsland. These two regions combined comprise over half of the total land in East Gippsland. Soil type and rainfall vary over the Foothills and Mountain regions, which reach as high as 1,200 meters. Timber harvesting is a major industry in the regions' forests (East Gippsland Regional Catchment Strategy, 1997).

The Mountain Basins are situated west of the Mountain RMU, in the middle of the major river valleys. These regions have a lower amount of rainfall and warmer temperatures than the surrounding mountains. The basins are prime broad acre grazing area areas due to the fertile soil and close proximity to rivers and stream for irrigation (East Gippsland Regional Catchment Strategy, 1997).

The Mountain Plateau is located in the northeast section of East Gippsland. The fertile land's chief use is grazing pastures. Due to the regions' topography, the climate is more temperate and the supply of water is more reliable than the lower parts of the region (East Gippsland Regional Catchment Strategy, 1997).

The Alpine regions are situated in the north and northwest East Gippsland. The region attracts a lot of tourists because of the mountains and scenery. In the lower altitudes, timber is harvested. A portion of the region is part of Alpine National Park (East Gippsland Regional Catchment Strategy, 1997).

Appendix G – Risk Map Characteristics

1 - Statewide Risk Map Section Characteristics

Before a risk rating could be done, Victoria had to be broken up into small sections with the same characteristics. This allowed the different conditions of that section to be plugged into NEXSYS so a nutrient export range could be produced. Victoria was broken up into 30 sections, each with similar land characteristics. Not every area within each section has exactly the same characteristics, so the evaluation was based on the most common conditions for that section. The following is a list of every section and the data that was used as input for NEXSYS to get the export values associated with that section.

All ranges given are in kilograms/hectare/year.

Section 1
Land use - cropping
Crop - non-row
Slope - low
Erosion management - no
Irrigation - yes
Erosivity - unknown
Rainfall - low
Range - 0.6 to 5.0

Section 2
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 3
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 4
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 5
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 6
Land use - cropping
Crop - non-row
Slope - low
Erosion management - no
Irrigation - yes
Erosivity - unknown
Range - 0.6 to 5.0

Section 7
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 8
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 9
Land use - grazing
Feritilizer use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

Section 10
Land use - forests
Forest management - no
Geology - basaltic
Range - 0.07 to 0.13

Section 11
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 12
Land Use - grazing
Feritilizer use - low
Gullying - yes
Range - 0.5 to 3.0

Section 13
Land use - grazing
Feritilizer use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.5 to 5.0

Section 14
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 15
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 16
Land use - grazing
Feritilizer use - low
Gullying - no
Ground cover - good
Irrigation - yes
Range - 0.05 to 0.5

Section 17
Land use - grazing
Feritilizer use - low
Gullying - no
Ground cover - good
Irrigation - yes
Range - 0.05 to 0.5

Section 18
Land use - cropping
Crop - non-row
Slope - low
Erosion Management - no
Irrigation - yes
Erosivity - unknown
Rainfall - low
Range - 0.6 to 5.0

Section 19
Land use - grazing
Feritilizer use- low
Gullying - no
Ground cover - good
Irrigation - yes
Range - 0.05 to 0.5

Section 20
Land use - grazing
Feritilizer use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.5 to 5.0

Section 21
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 22
Land use - grazing
Feritilizer use - low
Gullying - yes
Range - 0.5 to 3.0

Section 23
Land use - grazing
Feritilizer use - low
Gullying - no
Ground Cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

Section 24
Land use - urban
Age - more than 5 years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 25
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 26
Land use - grazing
Feritilizer use – low
Gullying - yes
Range - 0.5 to 3.0

Section 27
Land use - grazing
Feritilizer use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.05 to 0.5

Section 28
Land use - forests
Forest management - no
Geology - granite
Slope - high
Range - 0.01 to 0.13

Section 29
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 30
Land use - grazing
Feritilizer use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

2 – Latrobe/Thompson Risk Map Section Characteristics

Before a risk rating could be done, the Latrobe Thompson basin had to be broken up into small sections with the same characteristics. This allowed the different conditions of that section to be plugged into NEXSYS so a nutrient export range could be produced. The Latrobe/Thompson basin was broken up into 65 sections, each with similar land characteristics. Not every area within each section has exactly the same characteristics, so the evaluation was based on the most common conditions for that section. The following is a list of every section and the data that was used as input for NEXSYS to get the export values associated with that section.

All ranges given are in kilograms/hectare/year.

Section 1
Land use - forest
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 2
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

Section 3
Land use - grazing
Fertiliser use - low
Gullying - no
Ground Cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

Section 4
Land use - forest
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 5
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

Section 6
Land Use - Horticulture
Ground Cover - Poor
Slope - High
Rainfall - Low
Irrigation - Yes
Range - 3.0 to 5.0 kg/ha/yr

Section 7
Land use - horticulture
Ground cover - poor
Slope - high
Rainfall - low
Irrigation - yes
Range - 3.0 to 5.0

Section 8
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 9
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 10
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 11
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 12
Land use - forest
Forest management - yes
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 13
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 14
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 15
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 16
Land use - urban
Age - more than five years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 17
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 18
Land use - urban
Age - more than five years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 19
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 20
Land use - cropping
Crop - row crops
Runoff trapping - no
Slope - low
Erosion management - no
Irrigation - yes
Erosivity - unknown
Rainfall - low
Range - 2.0 to 15.0

Section 21
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 22
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 23
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 24
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 25
Land Use - urban
Age - more than five years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 26
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 27
Land Use - urban
Age - more than five years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 28
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 29
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 30
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 31
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 32
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 33
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 34
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 35
Land use - forest
Forest management - managed
Geology - sedimentary
Type of Timber - unknown
Range - 0.01 to 0.13

Section 36
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 37
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 38
Land use - grazing
Fertiliser - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.05 to 0.5

Section 39
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 40
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 41
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 42
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 43
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 44
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 45
Land use - grazing
Fertiliser use - low
Gullying -no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.05 to 3.0

Section 46
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 47
Land use - urban
Age - more than five years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 48
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 49
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.05 to 0.5

Section 50
Land use - forest
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 51
Land use - urban
Age - more than five years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 52
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 53
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 54
Land use - forest
Forest management - unmanaged
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 55
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.05 to 0.5

Section 56
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 57
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 58
Land use - forest
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 59
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 60
Land use - forest
Forest management - managed
Geology - sedimentary
Type of timber - unknown
Range - 0.01 to 0.13

Section 61
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 62
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 63
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 64
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 65
Land use - forest
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Appendix H – User's Guide to Phosphorus Risk Maps

Risk Map Legend

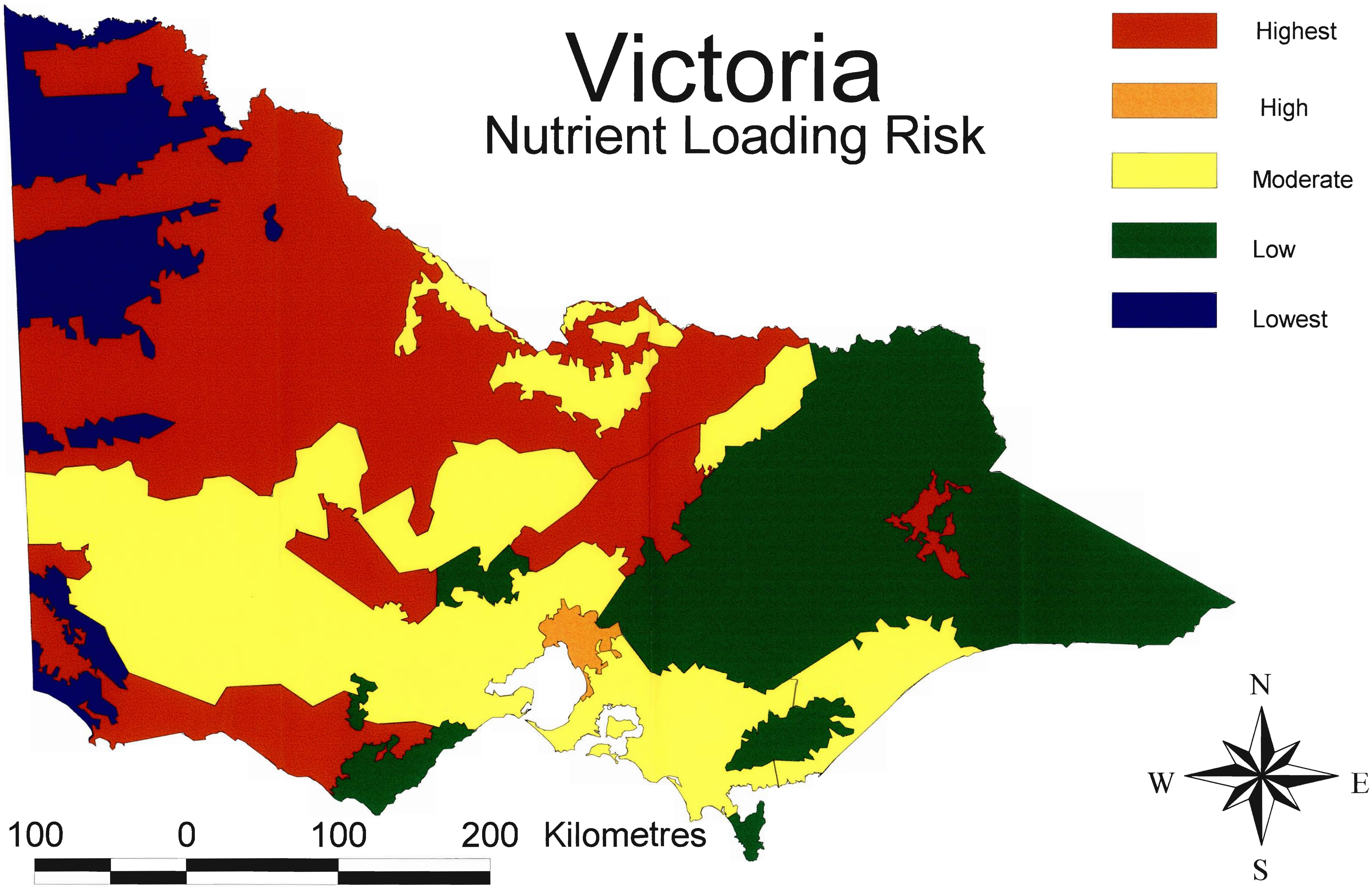
Highest Risk – These areas are at the highest risk of phosphorus overloading. The conditions here are very favourable for phosphorus export

High Risk – These areas are at high risk of phosphorus overloading. The conditions here are favourable for phosphorus export.

Moderate Risk – These areas are at moderate risk of phosphorus overloading. The conditions here are acceptable for phosphorus export.

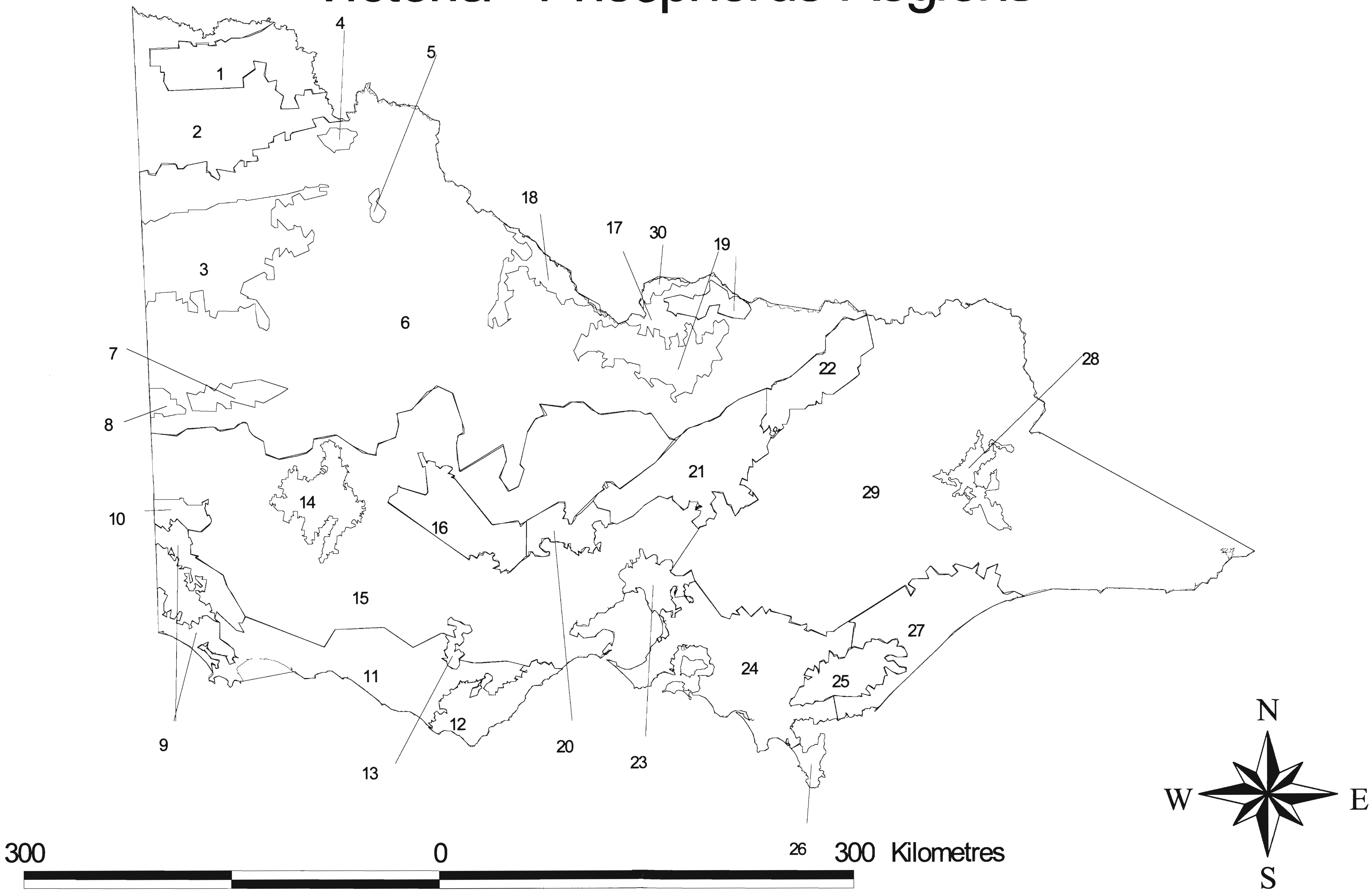
Low Risk – These areas are at a low risk of phosphorus overloading. The conditions here are unfavourable for phosphorus export

Lowest Risk – These areas are at a very low risk of phosphorus overloading. The conditions here are very unfavourable for phosphorus export.



Victoria
Nutrient Loading Risk
Highest
High
Moderate
Low
Lowest
N
W
E
S
100
0
100
200
Kilometres

Victoria - Phosphorus Regions



What is a Risk Map?

This map was created to show the level of danger that various areas of Victoria are in regarding nutrient pollution. The level of danger in an area is based on nutrient export values estimated by a program known as NEXSYS. Nutrient export values are the amount of a nutrient that is lost from an area of land to surrounding waterways. The purpose of this map is to help catchment managers, politicians, environmental experts, and the general public see which areas of Victoria are in serious danger of nutrient pollution and which are not. This allows one to quickly see what areas need further attention so problems associated with nutrient pollution can be reduced or eliminated.

NEXSYS is a computer program developed by CSIRO to predict nutrient export levels of different land types. If the environmental conditions of an area are known, they can be used with this program to predict the phosphorus levels that can be expected to leach into the waterways. The phosphorus export levels predicted for each area were studied, and areas that have abnormally high levels were indicated as high risk on the map. Risk ratings of one through five were assigned to each section of Victoria, indicating their risk level compared to the rest of the state.

Due to the predictive nature of this map, and the statewide scale it was done on, the information it contains is general and should only be used as a tool for spotting possible future sights of serious nutrient pollution. These phosphorus and risk values are accurate only for the sections of Victoria when considered as a whole. Anyone interested in a specific area's output within a section should first consult the "Section Characteristics" chapter of this manual to ensure that the characteristics assigned to that section are representative of the area of interest.

Section Characteristics

Before a risk rating could be done, Victoria had to be broken up into small sections, each with relatively homogeneous characteristics. This allowed the different conditions of that section to be entered into NEXSYS so a nutrient export range could be produced. Victoria was broken up into 30 sections. Not every area within each section has exactly the same characteristics, so the evaluation was based on the most common conditions for that section. The following is a list of every section and the data that was used as input for NEXSYS to get the export values associated with that section.

The units for each of the given ranges are in kilograms/hectare/year.

<u>Section 1</u>
Land use - cropping
Crop - non-row
Slope - low
Erosion management - no
Irrigation - yes
Erosivity - unknown
Rainfall - low
Range - 0.6 to 5.0

<u>Section 2</u>
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

<u>Section 3</u>
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

<u>Section 4</u>
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

<u>Section 5</u>
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

<u>Section 6</u>
Land use - cropping
Crop - non-row
Slope - low
Erosion management - no
Irrigation - yes
Erosivity - unknown
Range - 0.6 to 5.0

<u>Section 7</u>
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

<u>Section 8</u>
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

<u>Section 9</u>
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

<u>Section 10</u>
Land use - forests
Forest management - no
Geology - basaltic
Range - 0.07 to 0.13

Section 11
Land use - forests
Forest management - no
Geology - sedimentary
Slope - low
Range - 0.01 to 0.07

Section 12
Land Use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 13
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.5 to 5.0

Section 14
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 15
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 16
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - yes
Range- 0.05 to 0.5

Section 17
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - yes
Range- 0.05 to 0.5

Section 18
Land use - cropping
Crop - non-row
Slope - low
Erosion Management - no
Irrigation - yes
Erosivity - unknown
Rainfall - low
Range - 0.6 to 5.0

Section 19
Land use - grazing
Fertiliser use- low
Gullying - no
Ground cover - good
Irrigation - yes
Range - 0.05 to 0.5

Section 20
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.5 to 5.0

Section 21
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 22
Land use - grazing
Fertiliser use - low
Gullying - yes
Range - 0.5 to 3.0

Section 23
Land use - grazing
Fertiliser use - low
Gullying - no
Ground Cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

Section 24
Land use - urban
Age - more than 5 years
Industry - no
Sandy soil - yes
Range - 0.4 to 0.9

Section 25
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 26
Land use - grazing
Fertiliser use – low
Gullying - yes
Range - 0.5 to 3.0

Section 27
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - high
Range - 0.05 to 0.5

Section 28
Land use - forests
Forest management - no
Geology - granite
Slope - high
Range - 0.01 to 0.13

Section 29
Land use - forests
Forest management - no
Geology - sedimentary
Slope - high
Range - 0.01 to 0.13

Section 30
Land use - grazing
Fertiliser use - low
Gullying - no
Ground cover - good
Irrigation - no
Erosivity - unknown
Rainfall - low
Range - 0.05 to 0.2

Nutrient Pollution – The problem, causes, and remedies

Nutrient pollution in waterways is becoming a problem all over the world. In Victoria, the main source of nutrient pollution is storm runoff from farmland, pastures, and cities. Phosphorus and nitrogen are washed off the land during rainstorms and swept into local waterways. Nutrient pollution occurs when nutrients, especially phosphorus, are found in concentrations that exceed that needed by the life in the waterway.

Once in the waterways, the excess of nutrients begins to cause a chain reaction of problems. An overabundance of phosphorus will cause certain aquatic plants and animals to die, while encouraging algal growth. This imbalance creates a very unhealthy waterway and should be avoided if possible.

There are many factors that contribute to the problem. Some of them are preventable, while others are natural and can't be avoided. High amounts of rainfall and steeply sloped land cause increased erosion. Eroded soil is then carried, with any nutrients present in the land, to the nearest waterway. These nutrients are present in small amounts naturally, but are present in much larger concentrations where fertiliser is used.

There are ways to prevent nutrient pollution. Good farming practices involving erosion management and responsible applications of fertilisers can play a large role in preventing nutrient pollution. Catching and treating stormwater runoff from urban areas before it enters waterways also decreases the phosphorus content. Fixing and preventing nutrient pollution is possible, but only through the cooperation of all people involved. It will take environmental experts, politicians, and landowners all working together to stop nutrient pollution from continuing.

Glossary

Cropping - Refers to any form of farming involving crops that are grown on an annual basis. *Also see Row Crops, Non-Row Crops, and Market Gardening.*

Erosion Management - Refers to whether effective measures have been taken in an area to minimise erosion. These measures can be structural or non-structural in nature but runoff trapping is not considered because it is asked for separately. *Also see Runoff Trapping*

Erosivity - A measure of the power of a rain event. It is dependent on the rain drop size and on the rate or intensity of the rainfall. This factor was not used in this evaluation because there was a lack of data on it and annual rainfall rate, though less accurate, can be used as a substitute in NEXSYS.

Fertiliser Use - The main aspect of fertiliser use this map accounts for is the frequency with which it is used on the land. Application of fertiliser once or more per year is considered to be high and application of fertiliser less than once per year is considered to be low.

Forests - Forests generally describe all timbered lands including National Parks, Nature Conservation Reserves, State and private forests, and vacant crown lands.

Geology – This refers to the type of soil/rock that exists in an area. It can be basaltic, sedimentary, or granitic.

Grazing - An area used for livestock production. This does not include lucerne grown for hay or silage purposes.

Ground Cover - The percentage of land that is covered by vegetation. Vegetation is used here to mean any plant-life, such as grasses, that is known to stabilise soil. If 75% or more of the land in an area is covered by vegetation it is considered to have good ground cover. Areas where less than 75% of the land is covered by vegetation is considered to have poor ground cover.

Gullying - The presence of eroding gullies, or large ditches, in an area.

Horticulture - Refers to farming practices involving orchards and vineyards. Market gardens do not fall in this category.

Land Use - The type of land in an area. NEXSYS recognises five different categories of land use: forest, cropping, grazing, horticulture, and urban.

Managed Forests - Managed forests are forested areas that are being used for timber production.

Market Gardening - Any crop grown in rows on a smaller scale than is typical for row crops. Market gardening is considered to require a high amount of fertiliser and water application. Farming areas such as nurseries are considered to be market gardens.

Non-Row Crops - Any crop grown on an annual basis that does not involve the formation of rows between the plants. For this project, examples of these types of crops are as follows: broad acre cereal crops, hay/silage crops, and hops.

Old Growth - Native forests that are being selectively harvested for timber.

Plantation Forest - Forested area maintained for timber production. Different techniques are used for this type of forest harvesting than for old growth harvesting. Fertilisers are applied in plantation forests.

Rainfall - The mean annual rainfall an area receives. Mean annual rainfall below 700mm is considered to be low and mean annual rainfall above 700mm is considered to be high.

Row Crops - Any crop grown on an annual basis where rows are formed in-between the plants. For this project, examples of these types of crops are as follows: corn, potatoes, and tobacco.

Runoff Trapping - Refers to the practice of preventing runoff from storms entering local waterways. The most common form of this a farm dam.

Slope - The degree of incline the land in an area possesses.

Unmanaged Forests - Forested areas that are not currently being used for timber production. This includes areas such as National Parks and Nature Conservation Reserves.

Urban - An area of dense human population and activity such as cities. For this project only Melbourne was considered an urban area. Other cities of significant size that were overlooked were Ballarat, Bendigo, Geelong, and Mildura.

Appendix I – Glossary

Alluvium – Fine soil particles (such as sand, clay, or silt) deposited as soil on adjacent land to a stream, usually during flooding.

Aquifers – A geological formation through water can percolate, sometimes very slowly, for long distances. Springs and wells are charged from aquifers and the contamination of an aquifer may lead to the contamination of wells and springs over a wide area. Aquifers are described as 'confined' when they are overlain by aquicludes and as 'unconfined' when their upper surface is at ground level.

Biodiversity - Biological diversity in an environment as indicated by numbers of different species of plants and animals.

Catchment Area - An area which water drains to a particular location such as a main river system or a lake.

Detention Basins – A relatively small storage lagoon for slowing stormwater runoff, it is filled water for only a short time after a heavy rainfall.

Land slide – A slip of a large portion of soil or rocks from the side of a mountain, cliff, cutting or other type of slope.

Salinity – The degree of concentration of salt solution found in a substance.

Turbidity – The cloudiness in a liquid caused by the presence of finely divided suspended material.

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