ENVIRONMENT PROTECTION AUTHORITY

# River Murray and Lower Lakes catchment risk assessment for water quality

## Introduction and methods

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SA Water
Government of South Australia
South Australian Murray-Darling Basin Natural Resources Management Board
EPA South Australia

# River Murray and Lower Lakes

## catchment risk assessment for water quality

### Introductions and methods

**The River Murray and Lower Lakes catchment risk assessment project for water quality**
**Introduction and methods**

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## Definitions

| | |
|---|---|
| *aesthetic value* | the visual appearance of water |
| *blackwater* | wastewater from toilets on vessels |
| *consequence* | an outcome of a hazardous event expressed qualitatively or quantitatively, in relation to an environmental value, including a measure of the magnitude of the effect |
| *environmental value* | intrinsic attributes or uses of the river that require maintenance of a sufficient level of water quality such that those values are not impaired (eg aquatic ecosystem health, suitability for recreational activities and raw water supplies) |
| *event* | an incident or situation that occurs in a particular place at a particular time (eg pump discharge, rainfall event) |
| *greywater* | water that has been used for washing, laundering, bathing or showering on vessels |
| *hazard* | the source of potential harm; an activity, structure or land use that poses a risk to water quality |
| *hazardous event* | an incident or situation that releases the intrinsic potential (for adverse impact) of a hazard |
| *likelihood* | an estimate of the frequency which a stressor (eg pathogen, salt, nutrient discharge) from a hazard is released and impacts an environmental value |
| *potable use* | water intended for human consumption (drinking and domestic use) |
| *raw water* | water in its natural state prior to any treatment; in the context of the current study, water entering into a treatment plant |
| *recreation and aesthetics* | the environmental value of recreational water quality and aesthetics, including primary and secondary contact and visual use |
| *risk* | the chance of something happening that will have an impact on the environment; specified in terms of the likelihood of an event or circumstances occurring, and the consequences that may flow from it |
| *risk assessment* | the overall process of risk identification, analysis and evaluation |
| *risk level* | the magnitude of risk (eg low, moderate, high, very high) |
| *scenario* | a combination of events and conditions |
| *stressor* | any physical, chemical, or biological entity that induces an adverse response |
| *source of risk* | a term encompassing both hazard and event |
| *zone* | the segment of river assigned to a particular environmental value |

# Abbreviations

| | |
|---|---|
| DEH | Department for Environment and Heritage |
| DWLBC | Department of Water, Land and Biodiversity Conservation |
| EPA | Environment Protection Authority |
| GIS | geographic information system |
| LAP | local action planning |
| HM | heavy metals |
| HY | hydrocarbons |
| MDA | Murray Darling Association |
| MMLGA | Murray Mallee Local Government Association |
| MW LAP | Mannum to Wellington Local Action Planning |
| NU | nutrients |
| OR | natural and other biodegradable organic matter |
| PA | pathogens |
| PE | pesticides |
| SAMDB NRMB | South Australian Murray-Darling Basin Natural Resources Management Board |
| SA | salinity |
| SAMDB | South Australian Murray-Darling Basin |
| SA Water | South Australia Water Corporation |
| TU | turbidity |
| Water Quality EPP | Environment Protection (Water Quality) Policy 2003 |

# Executive Summary

The *River Murray and Lower Lakes catchment risk assessment for water quality* project was established to help key stakeholders—the Environment Protection Authority (EPA), SA Water and the South Australian Murray–Darling Basin Natural Resource Management Board (SAMDB NRMB) with an interest in catchment management to prioritise actions to best mitigate water quality risks.

This report provides an introduction and in-depth description of the methods used to derive the results of the study. Accompanying this report is the companion *River Murray and Lower Lakes catchment risk assessment: Results and management options*. The risk assessment methods were refined following a successful trial of the method and risk assessment concepts in the Mannum–Mypolonga area. The risk management process included seven main steps (adapted from the *Australian Handbook for Environmental Risk Management* HB203:2004):

1) communicate and consult
2) establish the context
3) risk identification
4) risk analysis
5) risk evaluation
6) risk mitigation
7) monitor and review.

Risks to water quality were assessed for the entire 640 km length of the river, and the Lower Lakes and Coorong in South Australia within the River Murray Water Protection Area. Local action planning (LAP) areas were used as individual consultation regions, and workshops were conducted to obtain community based information on the nature and location of water quality risks. This information was combined with agency and other stakeholder knowledge to form a database of information on water quality risks.

Several significant facets of the river need protection from pollution and management of overall water quality; these *environmental values* are the endpoint to which risks are assessed. The environmental values considered in this risk assessment project were:

- aquatic ecosystem health
- raw water supply
- recreational (including aesthetics).

The study identified and categorised *hazards* (source of potential harm) that pose a risk to water quality/environmental values. Some examples of hazards include stormwater outlets, flood-irrigated areas, horticulture areas, septic tanks and marinas. Each hazard requires an *event* or process to create a risk to water quality (eg rainfall event, pump discharge, accidental spillage). The event releases the *stressor*, defined as a potential water quality contaminant (pathogens, turbidity, nutrients, heavy metals, organic matter, pesticides, salinity) that could affect environmental values (eg pathogens can have direct health implications for raw water supplies and recreational users; nutrients may cause algal growth in aquatic ecosystems).

A qualitative screening risk assessment approach was used to prioritise risks at a broad catchment scale. Water quality risks were identified and categorised as very high, high, moderate or low, based on the likelihood of the event occurring and consequences (on environmental values) that might flow from it. Some of those assessments were based on detailed knowledge and others on limited knowledge, so the certainty associated with each assessed risk was documented to indicate reliability of the results and where additional information was required. The risk assessment process was designed to be iterative, and as more data and information is obtained for priority risks, the assessments can be refined.

The catchment risk assessment method is based on a high-resolution geographic information system (GIS), which allowed integration of information from an extensive data search of potential hazards including aerial photography, land use, EPA licences and stormwater infrastructure. Knowledge such as spatial location, number and proximity of hazards was determined, an assessment of pollutant movement to the river/lakes was considered and some discharge volumes were estimated. The GIS was used in the risk assessment workshops to display information to all participants (thus providing a common understanding) and to enter the location of hazards, to display the risk rating, and produce detailed and informative maps in reports.

Using the outcomes of the risk assessment (numbers, classification and event conditions) management options have been proposed. These potential actions were categorised as capital or on-ground works, capacity building, monitoring, policy, research requirements or compliance, both building on current programs by identifying high priorities for consideration and developing new mechanisms to reduce risks. The relevant stakeholders for the implementation of each mitigation option were identified as a basis for consultation and negotiation on future management of risks.

A detailed database of water quality risks has been constructed as part of this project and will be made available to stakeholders. This information will be maintained and updated as required. The risk management phase of the project is ongoing.

# 1 Introduction

The River Murray and Lower Lakes areas are intrinsically important as ecosystems, state drinking water supply sources, and recreational and tourism resources. Thus water quality management in the Murray–Darling Basin is important for the whole of South Australia. Numerous pressures affect the water quality and sustainability of the River Murray and Lower Lakes but a lack of integrated information makes strategic development to protect and improve water quality difficult.

## 1.1 Study purpose

The *River Murray and Lower Lakes catchment risk assessment for water quality* project was designed to engage and provide information to a wide range of interested people and organisations on the sources of water quality risks within the River Murray and Lower Lakes catchment in South Australia.

The major objectives of the project were to:

- identify the nature and location of hazards that present a potential risk to water quality by consulting and engaging with community and other stakeholders
- develop a qualitative high-level understanding of those hazards and their risk to water quality using a risk assessment approach and GIS
- identify potential solutions to mitigate these risks, including on-ground action and capital works, investigations and enforcement, monitoring, education and awareness raising
- identify gaps in the knowledge and resources required to support the full implementation of mitigation strategies.

The risk assessment project partners, the South Australian Murray–Darling Basin Natural Resources Management Board (SAMDB NRMB), Environment Protection Authority (EPA) and SA Water, have a direct interest in River Murray water quality, and will use the information gathered to develop management strategies. The SAMDB NRMB also has the important role of managing the region's investment strategy. More specifically, the outcomes from the project will:

- provide partners and other agencies with a solid foundation of baseline information to aid future decision-making and investment strategies
- identify opportunities to work with managers of high-risk activities to proactively address these risks
- provide information for and guidance to the SAMDB NRMB on investment priorities for the water quality program to achieve the greatest benefits to the River Murray resource
- assist the EPA to identify compliance and licensing requirements, and educational needs, and prepare business plans
- provide input to SA Water's risk management framework and water quality improvement strategies
- inform the local action planning (LAP) network along the river to help community-level risk mitigation strategies and funding submissions.

## 1.2 Why a risk management approach?

Environmental risk arises from the relationship between humans and human activity, and the environment. It can be grouped into two categories: risk to the environment, and/or risk to an organisation from environment-related issues (HB203:2004). Risk management is the culture, processes and structures that are directed towards managing adverse threats to river water quality. The strength of the risk management approach is that it combines technical assessment and consultation into a process that supports informed, consistent and defensible decision making. This is particularly important as resources (both human and financial) are limited and management must prioritise investment allocation.

## 1.3 Stages of the risk assessment project

This risk assessment project has three major stages:

- Stage I: Method development—completed in 2004 with release of reports, *Concept and methods* (Billington 2005) and *Mypolonga-Wellington trial*[1] (Billington and Bradley 2005)
- Stage II: Risk assessment and reporting—conducted in 2004–06 and produced a report for each LAP area along the river as well as this report outlining the approach and methods (refined following the trial for the assessments and reports)
- Stage III: Risk management implementation—began in 2006 and is ongoing.

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1 The project method was slightly modified following the trial in the following areas:

- Consequence matrices were changed to better align aquatic ecosystem environmental value consequences to consequences for the other environmental values.
- Definitions of some risk parameters were modified to improve clarity. Differences in definitions between Australian Standards (eg HB203:2004) and guidelines, which have focused on specific water quality outcomes (eg drinking water quality), are largely related to terminology and not the overall risk method.
- GIS database and mapping methods were refined.

# 2 Methods

## 2.1 Risk management process

The risk management process used in this study took seven main steps [Figure 2.1; adapted from *Australian/New Zealand Handbook for Environmental Risk Management* (HB203:2004)]:

- **communicate and consult**—communicating and consulting with internal and external stakeholders as appropriate at each step of the risk management process
- **establish the context**—defining environmental values and 'management zones' along the River Murray
- **risk identification**—identifying the nature and location of risks to water quality
- **risk analysis**—assessing identified risks, and predicting the likelihood that risks will eventuate, and the nature and magnitude of possible consequences
- **risk evaluation**—making decisions, based on the outcomes of the risk analysis, about which risks need mitigation
- **risk mitigation**—identifying the range of options for mitigating risks, assessing these options and implementing a risk management strategy
- **monitor and review**—ongoing monitoring and review of risks and performance of the risk management strategy.

Risk assessment is the combined process of identifying, analysing and evaluating risks (Figure 2.1).

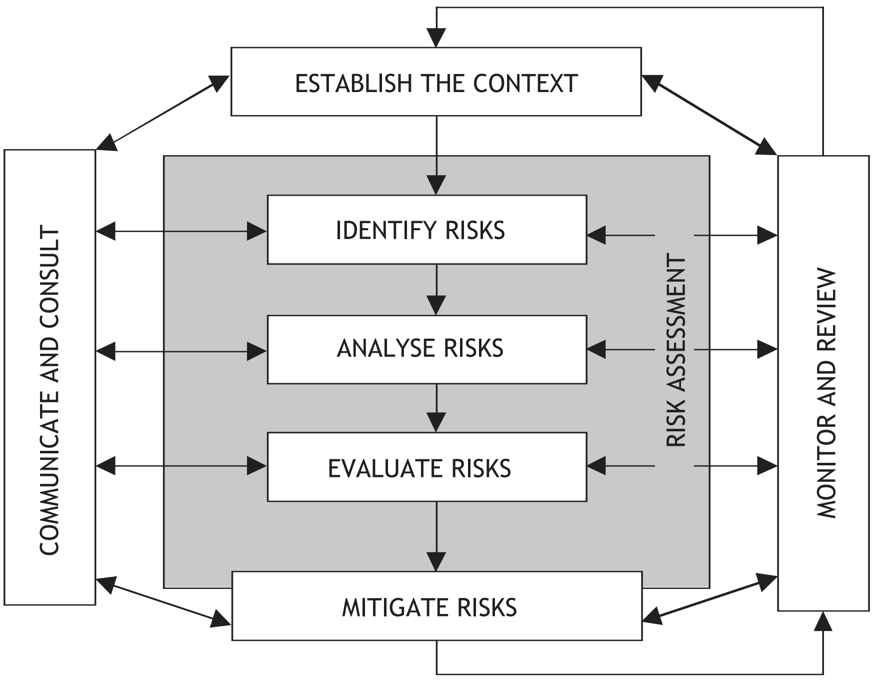


**Figure 2.1 Overview of risk management process** (adapted from AS/NZS 4360:2004)

The entire process is iterative and may be repeated many times with additional risk information or modified risk evaluation criteria, leading to a process of continual improvement.

The seven steps of the risk management processes undertaken for the current project are described in more detail in subsequent sections.

## 2.2 Communication and consultation

### Background

Communication and consultation with internal and external stakeholders is a crucial component at all stages of the risk management process (Figure 2.1).

A strength of the current project was its engagement and consultation with many agencies, groups and people involved in the management or protection of the river and its catchment, including local community members. Different people brought different knowledge and expertise, all valuable in the context of a project assessing risks across a wide spatial area. For example, local community members are knowledgeable about local risks which state government agency staff may be unaware of. However, agency staff could have more technical knowledge and access to monitoring results and internal agency reports.

A project team capable of identifying, assessing and researching the risk to water quality along the River Murray and Lower Lakes was formed. This team was responsible for implementing the project, maintaining communication links, and consulting internal and external stakeholders. It also engaged scientists and other experts knowledgeable about the river, and researched the literature on areas such as water quality, wetland ecology, algal biology, stormwater, land use activities and human health.

A communication strategy was developed for the current study with the core objectives to:
- raise general community awareness of hazards to water quality within the River Murray corridor and options to mitigate risks
- collate information from the community and agencies on the location and nature of risks, and provide feedback following assessment of this information
- within target groups create an understanding of:
    - potential risks to water quality from their activities
    - options to mitigate risks
    - their responsibilities and obligations for risk management
    - the general objectives and benefits of risk assessment
- report on the project's progress and outcomes.

The strategy identified target audiences and key messages to be used to establish a good understanding of the nature and management of risks to water quality.

### Target audiences

The target audiences identified for these messages were grouped into the categories of primary, secondary, and tertiary.

***Primary target audience***
The primary target audience was those who could assist in identifying or assessing risk information and/or could influence the secondary audience. The following people/agencies/groups were considered part of the primary audience:

- LAP network: community consultation workshops held in each LAP area included knowledgeable participants from their local area suggested by the various LAP area coordinators
- Community: community members with knowledge of risks, community group representatives
- state and local government agencies: EPA, SA Water, SAMDB NRMB, INRM, Department of Water, Land and Biodiversity Conservation (DWLBC), Department for Environment and Heritage (DEH), Department of Health, local councils and the Local Government Association (LGA)
- project steering committee: included representatives from agencies (EPA, SA Water, SAMDB NRMB, DWLBC, Department of Health), the LAP network, and the Murray Mallee Local Government Association (MMLGA)
- industry representative groups: irrigation bodies, farming associations, boating industry associations, marina owners
- media: regional media, local media (newspapers, bulletins).

***Secondary target audience***

The secondary target audiences were the general audience whose awareness of the project and water quality issues could be increased, for example:

- community: general public, vessel owners, riverside property owners, farmers, schools
- industry members: irrigators, animal licensed activities, horticulture, marina owners
- government: local council staff, government agency staff

***Tertiary target audience***

The tertiary target audience was internal and external stakeholders who needed to be kept closely informed about the implementation and progress of the project but who were not immediately involved:

- partner agency boards and executives: chief executives, board and directors within EPA, SA Water and SAMDB NRMB
- funding agencies: SAMDB NRMB
- ministers: Minister for the River Murray, and Minister for Environment and Conservation.

### Key communication messages

- 'Government is working together with community to identify risks to the River Murray.'
- 'We all have a responsibility to protect the water quality of the River Murray.'
- 'Agriculture, industry, recreation and households all can affect water quality.'
- 'Many everyday activities and structures are hazards to water quality—they need identification.'
- 'We must prioritise our investment in improving water quality to ensure funds are spent effectively.'

Each target group received all or some of the key messages. It was important to determine which message suited the needs of each target group.

### Key communication tools

The communication tools used depended on the target audience and included:

- formal media releases
- webpage on SAMDB NRMB site with links from the EPA and SA Water websites
- local LAP newsletter stories and updates
- project presentations to local government (councils), state agencies and key stakeholder groups (EPA, SAMDB NRMB)

- factsheets/flyers summarising the project aims, outcomes and benefits
- community workshops for hazard identification
- local and regional media coverage—radio and television
- hardcopy and CD productions of final reports and maps.

## 2.3 Establishing the context

### Scope and boundary for assessment

The study area was defined for the purposes of this project as the River Murray, Lower Lakes and Coorong, and adjacent surrounding areas encompassed by the Water Protection Area (*Environment Protection Act 1993)* within South Australia. Risks to water quality were assessed for the entire 640 km length of the river, and the Lower Lakes and Coorong in South Australia

For the purposes of the community consultations and reporting of results, the study area was broken into eight existing 'LAP areas' (Figure 2.2):

- Renmark to border
- Berri to Barmera
- Loxton to Bookpurnong
- Riverland West
- Mid Murray
- Mannum to Wellington
- Goolwa to Wellington
- Coorong District.

Consultation and reporting for the Berri-Barmera and Loxton-Bookpurnong LAP areas, and for the Goolwa to Wellington and Coorong District LAP areas, were combined for efficiency of consultation: the two Riverland LAP areas span either side of the river in a similar area, and the Lower Lakes and Coorong areas spanned either side of the lakes.

### Scale of risk assessment

Stage II of the risk assessment was essentially a broad screening of risks at a regional spatial scale. More in-depth examination of individual water quality risks (eg USEPA 1998) is very complex and resource intensive. Environmental risk assessments are frequently conducted in tiers that proceed from comparative assessments at large spatial scales to more in-depth analyses of priority risks or areas at smaller spatial scales (USEPA 1998, WHO 2003). The successive tiers require higher data and resource intensity, with the outcome of a given tier to make a management decision, or continue to the next level (tier) of effort. Stage III of the current project examines the priority risks identified in Stage II in more detail and collects information where necessary to refine the risk assessment.

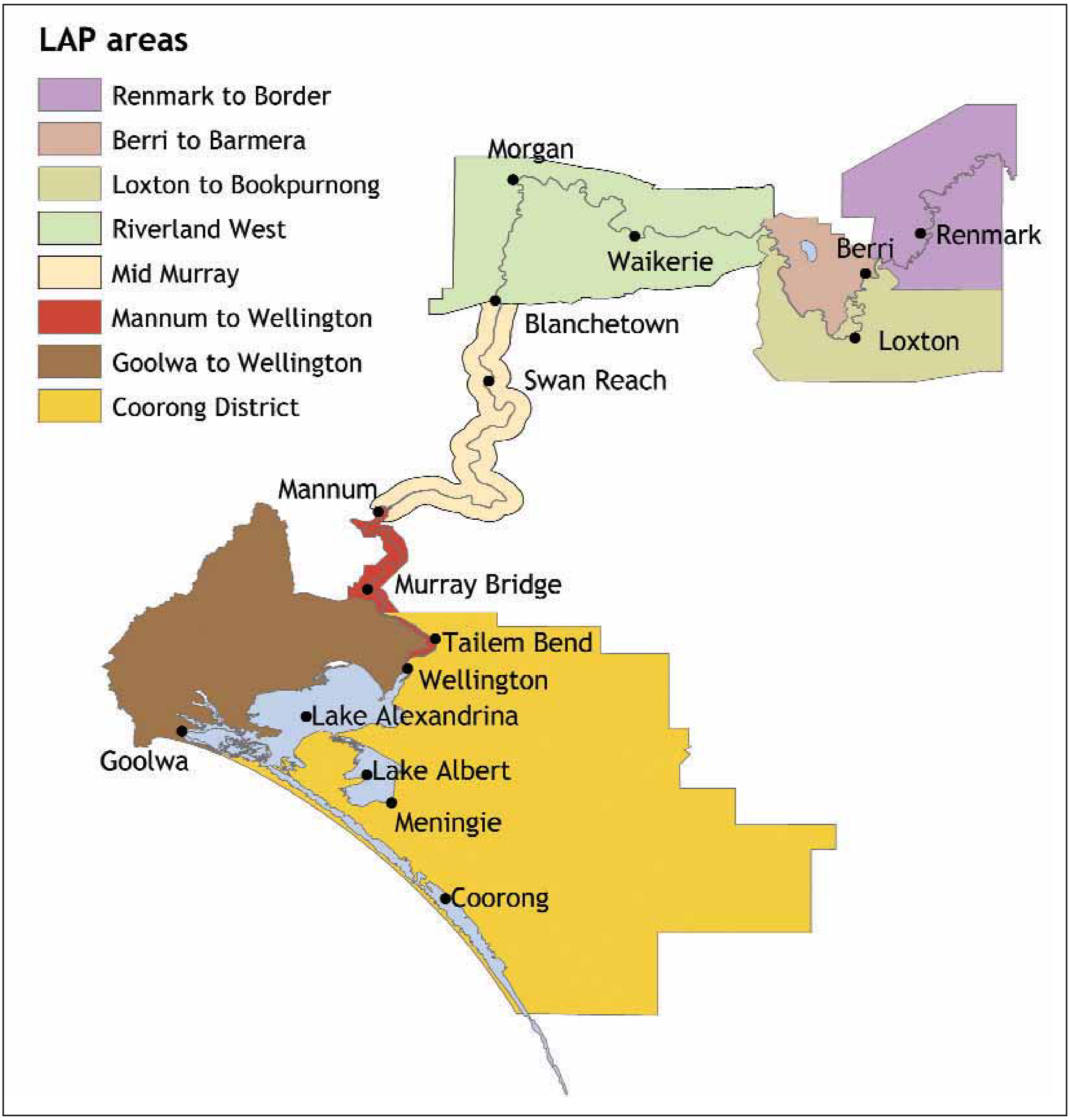


**Figure 2.2 Map of LAP areas along the River Murray, Lower Lakes and Coorong**

## Identification of environmental values and zones

Several significant facets of the river need protection from pollution and management of overall water quality. They are defined as environmental values and are the endpoint to which risks are assessed. The environmental values considered in this risk assessment project were:

- aquatic ecosystem health
- raw water supply
- recreational (including aesthetics).

Different environmental values (eg potable water supply, aquatic ecosystems) require different types and levels of water quality protection (ANZECC 2000).

For the purposes of the project, the river was divided into spatial zones relating to these environmental values (eg 'recreation zone') and risks to water quality were assessed separately for each value.

***Aquatic ecosystem health environmental value***

The aquatic ecosystem environmental value relates to the intrinsic value of the aquatic ecosystem, including flora, fauna and habitat. This value is preserved by protecting the water from risks that harm the ability to support and maintain a balanced community of aquatic organisms. Aquatic ecosystem health has previously been noted to be significantly impaired in many locations along the River Murray and eastern Mount Lofty Ranges[2].

Aquatic ecosystem zones were assessed for the entire length of the river, in three-kilometre increments. This method of segmentation was chosen purely to divide the river into workable zones for the risk assessment process. The aquatic zones do not relate to any particular ecological asset or feature but provide information on potential risks to aquatic ecosystem health along the entire length of the river.

***Raw water supply environmental value***

The raw water environmental value relates to the suitability of water for supply to a drinking water treatment plant. This value is preserved by protecting the water from risks that impact on the treatment plant ability to supply drinking water of a high standard. The River Murray is extremely important as a water supply with approximately 90% of the population of South Australia now wholly or partly dependent on reticulated water from the River Murray. Of the urban and rural water supplies controlled by SA Water, the share of the total intake derived from the Murray has varied from 85% in drought years to less than 30% in years of above-average rainfall. For the purpose of the assessments in this project the primary focus of the environmental value of raw water supplies is human health. Other taste and odour attributes associated with the presence of manganese and iron have not been assessed.

For the purposes of the current project, raw water supply zones were established as the areas three kilometres upstream and 500 m downstream of each water off-take on the river. The arbitrary size of this zone is based on previous measurement and tracking of 'salt slugs' in 'run of the river' salinity studies by DWLBC along the length of the river. These large volume slugs were generally well mixed within three kilometres of entering the river and it was considered that this provided a precautionary basis for assessment of other risks. Raw water supply zones were extended 500 m downstream from each off-take point to account for wind-driven upstream water movement in low-flow conditions.

***Recreational environmental value (including aesthetics)***

The recreational environmental value relates to the suitability of water for recreation. The River Murray is widely used for recreational activities, such as swimming, water-skiing, wake-boarding, boating and fishing. In this study, the focus was on identifying risks to primary contact recreation (eg full body contact with the water such as swimming and water-skiing) as this requires the most stringent protection of water quality[3]. However the risk to recreation values from impairment of river aesthetics was also considered (eg if an oil slick resulted from a fuel tank rupture, people would be deterred from swimming in that location).

[2] Secondary contact recreation is partial body contact (eg wading, paddling, boating and fishing), where the probability of swallowing water is unlikely.

[3] See website <www.epa.sa.gov.au/pdfs/river_health_murray.pdf>

The location of major recreation zones on the river (ie areas with high levels of recreational activities, mostly surrounding highly populated shack areas and campground locations) was identified during the community workshops. The length assigned to each recreation zone was variable, depending on the spatial extent of recreation activities at a particular location.

***Other environmental values not considered directly in the current project***

Risks to irrigation water quality were not directly assessed within the scope of this risk assessment. Pumped irrigation constitutes greater than half the annual River Murray water usage in South Australia (*Basin Salinity Management Strategy 2001–2015*, DWLBC), and the need for maintaining irrigation water quality (particular suitable salinity levels) is acknowledged.

Protection of water quality in the River Murray, Lower Lakes and Coorong is also very important to local Indigenous people such as the Ngarrindjeri for whom the land and waters are considered a living body. Indigenous groups were consulted during this project but risks to cultural water quality values were not directly assessed.

## Legislative and NRM planning framework

A strength of the River Murray Catchment Risk Assessment for Water Quality is its emphasis on creating links between community and other stakeholder involvement, a key principle of integrated natural resource management.

The SAMDB NRMB is responsible for the annual review of the regional NRM investment strategy. Demand for project funds intended to achieve water quality improvements will continue to be high and it is currently difficult to accurately determine investment priorities. This project will increase the board’s knowledge to aid future assessments and decision making on strategies and investment to mitigate significant risks to water quality within the River Murray corridor.

The current legislative framework provides a context for considering and approving development proposals and guiding decision makers and regulators on managing water quality risks. Legislation of particular relevance is outlined below.

***Environment Protection (Water Quality) Policy 2003***

The *Environment Protection (Water Quality) Policy 2003* (Water Quality EPP) was developed to manage water quality in the state of South Australia. It applies to all inland surface water, groundwater and marine water and addresses issues such as:

- general environmental duties to protect water quality
- management and control of point and diffuse sources of pollution
- what people who conduct a particular activity are obliged to do
- water quality criteria, discharge limits and listed pollutants
- establishment of codes of practice to minimise water quality risks.

***Environment Protection Act 1993***

Schedule 1 of the *Environment Protection Act 1993* sets out activities of environmental significance that require an EPA licence, such as sewage treatment works or septic tank effluent disposal schemes, waste or recycling depots, cattle feedlots, piggeries, wineries or distilleries, marinas and boating facilities such as slipways.

***Development Act 1993 and Regulations***

The *Development Act 1993* and *Regulations* set out activities of environmental significance (Schedule 21) and activities of major environmental significance (Schedule 22) which must be referred to the EPA. Advice and/or direction from the EPA on such activities must be taken into account by the planning authority. Schedule 8 also has mandatory referrals to the EPA and DWLBC to provide advice and/or direction to proposed developments in the River Murray Water Protection Area.

***River Murray Act 2003***

The *River Murray Act 2003* was developed to improve protection of the River Murray and its values. Its objectives are to:

- protect, restore and enhance the River Murray
- ensure that activities and/or changes of land use that may adversely affect the River Murray are discouraged or prevented.

***Natural Resources Management Act 2004***

The *Natural Resource Management Act 2004* (NRM Act) combines legislation currently dealing with water resources management, pest animal and plant control, and soil conservation and landcare. The principal object of the NRM Act is to achieve ecologically sustainable development by establishing a framework for the integrated use and management of natural resources.

## 2.4 Risk identification

Risks identification determines the risks to be managed.

### Hazard identification and location

A *hazard* is a source of potential harm (HB 203:2004) and is defined in the current study as an activity or structure that poses a risk to water quality/environmental values. On the River Murray, typical hazards that were identified included:

| Hazard type | Description of hazard type |
|---|---|
| ANIMAL HUSBANDRY | Piggeries, cattle feedlots |
| CHEMICAL STORE | Stores of chemicals near the river |
| CREEK/RIVER | Tributary creeks and rivers |
| DAIRY FARM | Dairy farms (not flood irrigated) |
| DRAINAGE DISPOSAL SITE | Land areas where irrigation drainage water is disposed of |
| DREDGING SITE | Sites of regular dredging activity |
| FERRY | Ferry operations that cross the river/lakes |
| FLOOD-IRRIGATED AREA DISCHARGE | Pumped discharges from flood irrigated farms |
| FUEL STORE | Fuel stores (for irrigation pumps) |
| GRAZING | Areas of unrestricted riparian grazing |
| HORTICULTURE | Irrigated horticultural areas |
| INDUSTRY | Industries (eg wineries, abattoirs) |
| INFORMAL CAMPING | Camping sites with no sanitation facilities |
| LANDFILL | Current or disused landfills |
| MARINA | Formalised mooring location (>5 vessels) with additional facilities (eg shop) |
| PETROL STATION | Petrol stations near river/lakes |
| QUARRY | Quarries adjoining the river/lakes |
| REFUELLING FACILITY | Vessel refuelling facilities |
| SLIPWAY | Slipways where vessels are maintained |
| STORMWATER INFRASTRUCTURE | Stormwater discharge pipes or retention ponds |
| TOILETS/SEPTIC TANKS | Septic tanks at dwellings (eg shack areas) and public facilities |
| TRANSPORT INFRASTRUCTURE | Bridges, causeways, roads |
| VESSEL LAUNCHING/BOAT RAMP | Boat ramps and/or high-use recreation sites |
| VESSEL MOORING(S) | Formalised mooring location(s) without additional facilities |
| VESSEL WASTE DISPOSAL STATION | Vessel wastewater pump out stations |
| WASTEWATER DISPOSAL AREA | Land areas where waste water is disposed of |
| WASTEWATER INFRASTRUCTURE | Wastewater pipes/pumps, Septic tank effluent disposal scheme (STEDS) |
| WETLAND/LAGOON | Wetland/lagoons (permanent/ephemeral) |

The location of the water quality hazards along the river was identified by collating existing information (eg government agency and local body reports), information from community consultation workshops held in each LAP area, and high-resolution aerial photography information. At the LAP workshops, community and agency participants marked the location of hazards on large (A1) aerial photographs that were printed from the GIS database. Some information, such as road, town and wetland names, were included on the photographs to make identification of hazards easier. All identified hazards within the study boundary area that were considered to have the potential to adversely impact the water quality of the river were assessed for risk. Where a group of similar hazards existed in a defined area (eg group of shacks with septic tanks, multiple houseboat mooring site), only one hazard location was entered and the risk assessment was combined.

## Hazardous events

Each hazard requires an *event* or process to create a risk to the water quality of the river. This is termed a *hazardous event* and it causes the intrinsic potential of the hazard to be released. Figure 2.3 illustrates an example where a fuel tank generally requires a spillage to pose a risk as a source of pollution. The term 'source of risk' encompasses both the hazard and event.

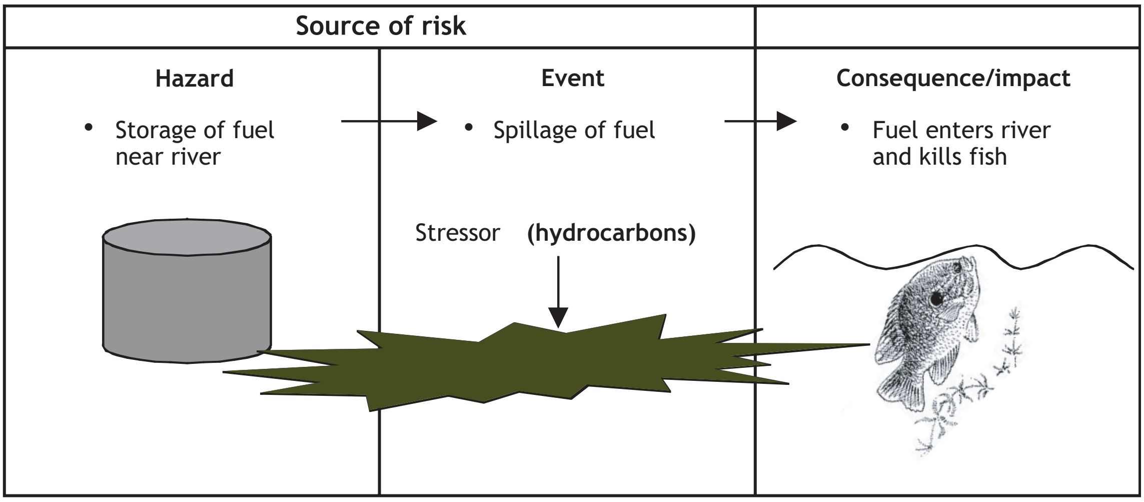


**Figure 2.3 Schematic diagram of terminology** (adapted from HB203:2004)

In this study hazards were classified according to event type and given an arbitrary event code (Table 2.1). Eleven different event types were identified.

Some hazards (eg flood-irrigated dairy farming area discharges) were capable of posing a risk to water quality through more than one event (eg *discharges*—normal pumping discharges, and *event discharges*—pumping discharges following rainfall events). The risks were assessed separately for each event type. Ongoing events such as leakage from a horticultural area or a septic tank were also included (leakage event type).

Some hazards (marina and other vessel activities, boat launching/ski beach areas) had common and multiple sources of risk present at the one location. For example, marinas generally contain risks from greywater and blackwater discharges from houseboats, spillages from refuelling facilities and wash-down of pollutants from slipways. For simplicity and ease of final interpretation and GIS mapping, these more complex hazards were given a single event code that represents the combined risk from the various hazards present at that site.

**Figure 2.4 Examples of hazards: houseboats and wastewater lagoons**

**Table 2.1 Hazardous events**

| Event type | Event code | Example of hazard |
|---|---|---|
| Discharge (general discharges) | A | flooded-irrigated area drainage pump discharges, permanently flowing creeks and wetlands |
| Event discharge (during rainfall events) | B | urban stormwater, agricultural and industrial area runoff, piggeries, wastewater ponds that overflow during storms; creeks/rivers and wetlands during rainfall events |
| Accidental spillage | C | Spillage at refuelling facilities, petrol stations, bridges, boat ramps, effluent pump stations |
| Infrastructure failure | D | Failure of wastewater storage (stormwater/ effluent ponds, holding tanks) or transport (pipelines, pump fittings) facilities |
| Human/animal excretion (on water and banks of river) | G | Informal camping areas (no facilities), riparian grazing areas |
| Wash down | H | Slipways, some ferry decks |
| Leakage (subsurface into watertable/river) | L | Septic tank effluent leaching, underground fuel store leakages, landfill leachate, irrigation-induced and regional groundwater discharges |
| Sediment disturbance | T | Dredging |
| Marina discharges (including vessels in marinas) | Q | Greywater and blackwater discharges from boats in marina |
| | | Refuelling facility spills, recreational craft emissions |
| | | Slipway wash down |
| Vessel discharges (vessels not in marinas) | R | Greywater and blackwater discharges from houseboats and other vessels |
| | | Accidental fuel spillage from vessels |
| Vessel launching | S | Accidental spillage and runoff from boat ramps |
| | | Erosion at skiing/wakeboarding areas (vessel wake-induced) |

## Stressors

The occurrence of a hazardous event releases the *stressor*, which in the broader context is any physical, chemical or biological entity that induces an adverse response (HB 203:2004; USEPA 1998). In the current project, the stressor was defined as a potential water quality contaminant that could affect environmental values. In the example shown in Figure 2.3, the stressor is the hydrocarbons/fuel.

The stressors considered in the current study are shown in Table 2.2 along with their potential effects on aquatic ecosystem, raw water supply and recreational environmental values. The stressors considered were salinity, pathogens, nutrients, turbidity/suspended sediment, heavy metals, natural (or other biodegradable) organic matter, hydrocarbons and pesticides. The selection of these key stressors was based on current knowledge of catchment activities in the river corridor, current river water quality issues (EPA 2001), and reference to relevant guidelines documents such as the Water Quality EPP (EPA 2003), the Australian Drinking Water Guidelines (NHMRC and NRMMC 2004), and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000). Several important points should be noted:

- a hazardous event may release multiple stressors from a particular hazard. For example, a rainfall event may cause a stormwater outlet to discharge sediment, heavy metals, hydrocarbons, nutrients and organic matter.
- a particular stressor may not affect all environmental values the same way. Some stressors do not affect a particular environmental value at all. For example, salinity changes may greatly affect the aquatic ecosystem and raw water supplies greatly but are largely irrelevant in the context of recreational activities. Table 2.2 shows which stressors were considered for a particular environmental value.
- the stressors listed in are primary stressors. A primary stressor may be the cause for multiple secondary stressors to arise, which then cause the environmental impact. For example, elevated nutrient levels may cause an algal bloom (2∞ stressor), which impacts the river ecosystem and water treatment operations. After algal die-off, dissolved oxygen may be depleted (an additional 2∞ stressor) resulting in fish kills (the impact).
- stressors listed in Table 2.2 can be further sub-categorised for more in-depth analyses. For example, heavy metals can be broken down into individual metals, pesticides into individual pesticides.
- additional stressors and factors other than those shown in Table 2.2 may need to present for an effect to occur. For example, even if elevated nutrient levels are present, other factors such as light, temperature and flow conditions may need to be suitable for an algal bloom to develop.
- for a stressor to cause an effect it must firstly come in contact with the environmental value (eg river ecosystem) and then result in a particular consequence. This issue is discussed in more detail in the consequence measures section below.

Improved flow and water management regimes are viewed as essential for improving water quality and ecosystem health in the River Murray, Lower Lakes and Coorong. While acknowledging its importance, this current report does not specifically look at flow issues as these are addressed in other programs.

**Table 2.2 Stressors (water quality contaminants) and their potential effect on environmental values***

| Stressor | Environmental value | | |
|---|---|---|---|
| | **Aquatic ecosystem** | **Raw water supply** | **Recreational use** |
| **Salinity (SA)** | Can decrease species diversity and health | Predominantly water taste implication | Not applicable |
| **Pathogens (PA)** eg *E coli, Giardia, Cryptosporidium* | Not applicable | Potential health implications | Potential health implications |
| **Nutrients (NU)** eg phosphorus and nitrogen compounds | Contributes to algal growth/blooms that can lead to reduced DO levels and fish kills; ammonia can be toxic to biota | Contributes to algal growth/blooms which can cause taste and odour issues; nitrate may be toxic at high levels (>10 mg/L) | Contributes to algal growth/blooms, which can be toxic and a skin irritant, and can affect visual clarity of the water |
| **Turbidity (TU)**† suspended solids | Changes optical properties, affects photosynthesis, smothers habitats | Increases cost of water treatment (filtration, coagulation) | Changes optical properties, limits visual clarity |
| **Heavy metals (HM)** eg arsenic, lead, zinc, copper | Potential toxicant; may bioaccumulate in some species | Potential health implications for certain metals (eg arsenic) | Health implications from skin contact at high concentrations |
| **Natural and other biodegradable organic matter (OR)** eg oils, leaves, hair, dissolved organic carbon | Breakdown leads to reduction in DO which can result in fish kills; breakdown may also release nutrients and subsequently increase algal growth | Increases cost of treatment, increases chlorine demand, responsible for by-product formation during disinfection | Aesthetics at high concentrations |
| **Hydrocarbons (HY)** eg fuels, diesel | Toxic; affects surface-dwelling organisms | Health and treatment system implications | Health implications, aesthetics |
| **Pesticides (PE)** eg insecticides, fungicides | Toxic; may bioaccumulate | Health implications | Health implications from skin contact at high concentrations |

* Shaded cells are stressors considered as part of the risk assessment for a particular environmental value; other stressors not applicable (would not affect a particular environmental value) or not considered to occur or be applicable in current project

† Assessment of turbidity includes suspended solids (SS) within the water column; loss of clarity within the column caused by larger-sized SS particles is temporary as they settle out

DO—dissolved oxygen

## 2.5 Risk analysis

### Risk analysis method background

*Risk* is defined as the chance of something happening that will have an impact on the environment (HB 203:2004). Risk is specified in this study in terms of the likelihood of an event or circumstances occurring, and the consequences that may flow from it.

Methods of determining levels of risk may use qualitative, semi-quantitative and quantitative analysis. Environmental risk studies are often qualitative or semi-qualitative due the complex nature of the environment that might be impacted and multiple impacts that may occur (HB 203:2004). The current risk assessment approach used largely qualitative measures and this was considered appropriate given the:

- broad scope of the project (spanning 640 km of river and assessing a wide range of environmental values) which made the qualitative approach the most cost effective
- lack of quantitative data on many stressors (pollutant concentrations and volumes, contaminant transport dynamics)
- lack of cause and effect studies on the effect of pollutant discharges into the river
- lack of high-resolution data on aquatic ecosystem health.

The qualitative method uses subjective risk ranking models to assess risk. These models are used to rank scenarios, events or options in terms of risk or impact rather than to provide a numerical estimate of effect. The disadvantage of qualitative assessments is that they can be influenced by the perceptions of those doing the assessment. To minimise subjective influences, objective data were used where possible to inform the risk assessment process including the mechanisms set out in Table 2.3.

**Table 2.3 Analysis and interpretation mechanisms**

| Mechanisms | Acquired knowledge |
|---|---|
| Appraisal of spatial information | Spatial location and number of activities with hazard in management zone, proximity of activity to river or discharge as compared to risk end-point, ability of hazard to reach river (hydrology, hydrogeology, stormwater networks), location of water quality sampling sites and hence level of representation |
| Visual inspections and communication with management, including EPA-licensed activities | Spatial location, hazards present, proximity of activity to river or discharge as compared to risk end-point, ability of hazard to reach river (hydrology, hydrogeology, stormwater networks), failure rates of pollutant storages, management of licensed premises, risk mitigation strategies in place |
| Related research and management plans | Ability of hazard to reach river (hydrology, hydrogeology, stormwater networks), design specification of pollution ponds, stormwater networks, location of assets (recreation, aquatic ecosystem), capacity of hazardous events to lead to impacts of concern |
| Water quality monitoring data | Volume and concentration of pollutant discharge, quality of receiving waters |

## Risk assessment framework

Risk was measured in terms of a *likelihood* and *consequence*, in the context of existing measures to control the risk (HB 203:2004). The likelihood and consequence measures used in the current study were developed following consultation with relevant agencies (EPA, DWLBC, SAMDB NRMB, SA Water, Department of Health) and external experts, and review of relevant reference documents and frameworks (USEPA 1998; EPA 2003; WHO 2003; CRC Water Quality and Treatment 2004; NHMRC and NRMMC 2004; NHMRC 2005). The measures developed provided the risk assessors with a structured framework for decision making.

Appendix A describes the risk assessment process in practice for two hazards (stormwater and flood-irrigation discharges).

***Likelihood measures***

Likelihood is an estimate of the frequency that a hazardous event occurs and releases a stressor (eg pathogen, salt, nutrient discharge), which subsequently impacts on an environmental value. The likelihood measures used in the current study (Table 2.4) are scaled from 1 (rare) to 5 (almost certain) based on descriptive criteria. The time scale description is only a general indication as other factors affect likelihood as described below.

**Table 2.4 Likelihood measures** (adapted from AS/NZS 4360:2004)

| **Level** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **Likelihood** | **Rare** | **Unlikely** | **Possible** | **Likely** | **Almost certain** |
| Description (qualitative) | Occurs only in exceptional circumstances | Could occur but not expected | Could occur | Will probably occur in most circumstances | Is expected to occur in most circumstances |
| Description (indicative time scale) | Less often than 10 yearly | 1–10 yearly | monthly-yearly | weekly -monthly | daily -weekly |

The *Australian and New Zealand Handbook for Environmental Risk Management* states that likelihood should apply to the resulting environmental impact (HB 203:2004). Often a chain of events, each with an associated likelihood leads to a final environmental impact. Each event in the chain is dependent on the probability of the previous event occurring and by factoring together these conditional likelihoods, the final likelihood can be estimated. In the current project, likelihood was assessed by factoring in conditional likelihoods up to the point of the stressor contacting the environmental value, not to the level of the stressor resulting in defined impact. The current level of knowledge regarding the full nature of processes from pollutant source to impact was insufficient to support this more detailed level of assessment and it was not considered practical to obtain this information within the context of the project's broad catchment-scale scope. In practical terms the following was considered:

- Likelihood of a hazardous event occurring to release the stressor: eg likelihood of a diesel tank of given volume rupturing and releasing oil. Table 2.5 gives a general indication of typical likelihood values that were assigned for several common types of risks on the river, and a description of how these likelihood values were arrived at. Another factor that went into assessing conditional likelihoods of a hazardous event occurring was historical information gained from the community workshops (eg an effluent pond may have overflowed several times in the past due to infrastructure failure, thereby increasing the likelihood ranking for that particular hazard). As noted above, likelihoods were assessed in the context of existing measures in place to control risk (eg a bunded fuel tank would be given a much lower likelihood than an unbunded fuel tank).

- Likelihood of the stressor reaching the environmental value: For this likelihood value, the location of each hazard relative to the river was assessed (by field inspections and use of aerial photography and GIS to measure distances). Likely transport pathways and geochemical processes (eg adsorption or filtration of contaminants by soil/vegetation) were also factored into the assessment where possible. For aquatic ecosystem and recreational environmental values the conditional likelihood was assessed up to the point of the stressor entering the river (eg probability of the fuel in Figure 2.3 being able to reach the river once it spills). For raw water supply values, an additional conditional likelihood considered was the probability of the stressor reaching the potable water supply off-take point once it had entered the river (eg using example above, how far away from the off-take point would the diesel enter the river and what possible dilution would take place before it reached the off-take point).

**Table 2.5 Examples of typical likelihood values for different hazards***

| Hazard<br>• event | Typical likelihood value | Qualitative likelihood description and time frame indicator |
|---|---|---|
| Urban stormwater<br>• event discharge | 3–4 | Rainfall events resulting in significant urban runoff occur on a weekly (Lower Murray area) to monthly (Riverland area) basis |
| Flood irrigation areas<br>• discharge<br>• event discharge | <br>4<br>2 | Regular pumped discharges of drainage water during the irrigation season but area much less frequent discharge during winter<br>Rainfall events must be reasonably large to generate runoff from these areas and these are infrequent (yearly or greater) |
| Horticultural areas<br>• leakage | 4 | Leakage to groundwater is ongoing but related to irrigation (does not occur year-round) |
| Rivers/creeks<br>• discharge<br>• event discharge | <br>5<br>2 | Permanently flowing rivers/creeks<br>Rainfall events must be reasonably large to generate runoff from dryland catchment areas in the river region and these are infrequent (yearly or greater) |
| Vessel mooring areas<br>• vessel discharge | 3 | Greywater discharges occur regularly (whenever houseboats are used). Blackwater discharges have a lower likelihood. Likelihood value is for combined risk from greywater and blackwater discharges. |
| Ferries<br>• wash down<br>• accidental spillage | <br>4<br>1 | Wash down and resultant runoff is common from some ferry decks<br>Large spillages (eg petrol tanker) could occur but are unlikely |
| Fuel stores<br>• accidental spillage | 1 | Fuel tanks are very unlikely to rupture |
| Toilets/septic tanks<br>• leakage | 3 | Leakage from septic tank soakage trenches is common to soil/groundwater but would be greatest during high-use periods (eg holiday weekends). Passage through soil reduces the likelihood that this leakage will affect environmental values. |
| Vessel launching/boat ramps<br>• vessel launching<br>• accidental spillage | <br>4<br>2 | Common, particularly on weekends in summer<br>Fuel spillage into water could occur but not likely |
| Wetland/lagoons<br>• discharge<br>• event discharge | <br>4<br>2 | For permanently connected wetlands, although there may be low outflow to river or reverse flow into wetland when evaporation rates high<br>Related to likelihood of rainfall events generating large volumes of runoff that would flush through a wetland or flooding due to artificial flushing strategies or increased river flows |

* Specific likelihood classes are adjusted, depending on local knowledge and proximity to the environmental value

However, as a result of this approach, the likelihood classes defined within this assessment may be an overestimate, as not all hazardous events would ultimately result in an environmental impact (eg cause fish kills or algal blooms). Although assessing likelihood in this manner is a limitation of the current method, once the initial broad screening of risk is performed, particular priority risks can be examined in more detail.

***Consequence measures***

In the current study, consequence is defined as the outcome of a hazardous event expressed qualitatively in relation to a specific environmental value, including a measure of the magnitude of the effect (HB 203:2004). Five levels of consequence were developed for each environmental value, from (1) minor to (5) catastrophic depending on pre-determined criteria (see Tables 2.6–2.8). For example, Table 2.6 describes a minor (value of 2) level of risk as only having a localised impact, while a high risk (value of 4) has a widespread impact on the ambient water quality of the river. Development of the consequence measures ensured that they were scaled to the range of risks along the river and aligned (in a relative sense) between different environmental values. This enables differentiation between risks and facilitates the prioritisation process. Due to the lack of high pollutant load point discharges (except for Lower Murray dairy flood-irrigated dairy pasture discharges) and large volume of water for dilution, localised and low-level risks were very important in the context of this study. The consequence measures were developed with the aim of being able to distinguish between the relative severity of low-level risks while still separating clearly the higher-level risks.

These are qualitative consequence measures so the consequences values contained in this study are only inferring causality. To assign causality, much greater amounts of evidence and research would be required which were outside the scope of the current study. In the case of aquatic ecosystem effects such evidence would have to include (USEPA 2000):

- direct site-specific measurements of the causes and effects of ecosystem impairment (in fact natural ecosystem variations can make it very difficult to observe (detect) stressor related perturbations (USEPA 1998)
- measurement of the effects of exposure to stressors at the site against effects in controlled laboratory studies
- measurements of steps in the chain of causal processes resulting in the observed aquatic ecosystem effects
- associations of cause and effect in deliberate manipulations of field situations.

In the case of raw water supply environmental value such evidence would have to include:

- direct site-specific measurements of causes and effects of the impairment of treatment plant operations
- measurements of steps in the chain of causal processes resulting in the observed effects at the treatment plant
- direct correlations between water treatment operational costs and processes with stressor levels.

In the case of the recreational environmental value such evidence would have to include:

- direct site-specific measurements of causes and health effects on bathers. It is somewhat difficult to assign this cause and effect relationship as illnesses such as gastro-intestinal infections may not be attributable solely to water exposure and different susceptibilities to illness exist within populations (eg WHO 2003; Wiedenmann *et al* 2006)
- measurement of avoidance behaviour of recreational bathers due to aesthetic impacts.

**Table 2.6 Aquatic ecosystem consequence measures**

| **Level** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **Consequence** | **Insignificant** | **Minor** | **Moderate** | **Major** | **Catastrophic** |
| **Description** | No discernable impact on aquatic ecosystem health | Minor localised impacts on aquatic ecosystem health | Significant localised impact on aquatic ecosystem health | Major and widespread impacts on aquatic ecosystem health | Extreme and widespread impacts on aquatic ecosystem health |
| **Qualitative consequence measures**<br>**(potential impact on aquatic ecosystem health)** | No discernable effects on aquatic ecosystem or impact is so small to be considered trivial<br>It would be unlikely that there would be any exceedence of aquatic ecosystem water quality criteria at the discharge point, and if there was an exceedence it would be minor and temporary | Aquatic ecosystem health temporarily compromised over a localised* area<br>Possible minor changes in species abundance and community structure but these could be mistaken for being due to seasonal changes or natural variation<br>Recovery would likely occur within a short time frame<br>Impact likely to result from a localised and minor exceedence† of aquatic ecosystem water quality criteria that does not persist over time *eg urban stormwater discharge* | Aquatic ecosystem health compromised in a localised area for a long time period OR temporarily over a wider area<br>May result in significant changes in native species abundance and community structure AND/OR localised habitat loss AND/OR triggering of algal/nuisance species growth. Recovery likely to occur within a few years<br>Impact likely to result from an exceedence<br>of aquatic ecosystem water quality criteria that persists in a localised area *eg small-moderate sewage spill in an ecologically sensitive area* | Aquatic ecosystem health compromised over a wide area for a moderate term<br>May result in major changes in native species abundance and community structure AND/OR major habitat loss AND/OR triggering of algal/nuisance species growth. Recovery may take several years<br>Impact likely to result from a sustained moderate exceedence<br>of aquatic ecosystem water quality criteria over a wide area OR short-term major exceedence over a small area *eg large point source discharge* | Aquatic ecosystem health severely compromised over a wide area and for long-term<br>May result in extensive losses of aquatic organisms and habitat with the potential for whole ecosystem destruction. Recovery may not occur within a generation<br>Impact likely to result from an extreme and wide-scale exceedence of aquatic ecosystem water quality criteria due to the release of a large volume of contaminants into the receiving water body *eg very large oil or chemical tank spill in an ecologically sensitive area* |

* Considered to be less than approximately 20 m radius from the discharge point

† Or further exceedence where the current ambient water quality of the River Murray exceeds ANZECC guideline levels (eg for turbidity)

**Table 2.7 Raw water supply consequence measure***

| Level | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Description** | Insignificant impact on water treatment operations | Minor impact on water treatment operations | Moderate impact on water treatment operations | Major impact on water treatment operations | Extreme impact resulting in complete failure or shut-down of water treatment operations |
| **Qualitative consequence measures**<br>**(potential impact on water treatment operations)** | Minimal modification to normal treatment operations<br>No additional operating costs | Minor impact to normal operations<br>Some increase in operating costs | Significant modification to normal operations (eg increase in chlorine or coagulant dosing amount), increased monitoring<br>Significant increase in operating costs | Systems compromised and additional operations required (eg filtration pre-treatment, ultra-violet disinfection, major increase in chemical dosing), high level of monitoring<br>Major increase in ongoing operating costs and large capital costs for new treatment systems | Likely to result in a complete failure of treatment operations and/or shut-down of water supply<br>Major increase in costs (eg potential need for treatment system remediation and provision of alternative water supply) |

* Risk was assessed to raw water supply off-takes before any treatment to make the raw water potable

**Table 2.8 Recreational consequence measure***

| Level | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Consequence** | **Insignificant** | **Minor** | **Moderate** | **Major** | **Catastrophic** |
| **Description** | No discernable impact on recreational values | Minor localised impact on recreational values | Significant localised impact on recreational values | High and wide-scale impact on recreational values | Extreme and wide-scale impact on recreational values |
| **Qualitative consequence measures**<br><br>**(potential impact on recreational values)** | No predicted risk to human health<br><br>It would be unlikely that there would be any exceedence of recreational water quality criteria at the discharge point, and if there was it would be minor and temporary | Minor localised[†] risk to human health[§] with potential for low prevalence of self-limiting illnesses[‖] (eg minor ear/nasal cavity infections, gastro-enteritis or skin irritations)<br><br>OR<br><br>temporary localised aesthetic impact<br><br>Impact likely to result from a localised and minor exceedence of recreational water quality criteria that does not persist over time | Significant localised risk to human health** with potential for moderate prevalence of self-limiting illnesses[†] with some illnesses requiring medical intervention (eg gastro-intestinal infections such as Giardiasis, respiratory illnesses)<br><br>OR<br><br>localised aesthetic impact<br><br>Impact likely to result from an exceedence of recreational water quality criteria that persists in a localised area | Major widespread risk to human health** with potential for high prevalence of both self-limiting illnesses and those requiring medical intervention (eg *E coli* O157, Giardiasis, acute febrile respiratory illness, AFRI)<br><br>OR<br><br>widespread aesthetic impact<br><br>Impact likely to result from a sustained moderate exceedence of recreational water quality criteria over a wide area OR short-term major exceedence over a small area | Extreme risk to human health** with potential for high prevalence of illnesses requiring medical intervention and possible deaths (eg from AFRI)<br><br>OR<br><br>severe aesthetic impact resulting in long-term unsuitability for swimming (eg very large oil tank spill)<br><br>Likely to result in closure of major areas of the river/lakes for primary contact<br><br>Impact likely to result from an extreme and wide-scale exceedence of recreational water quality criteria due to the release of a large volume of contaminants into the receiving waterbody |

* See ANZECC 2000 and NHMRC 2005 for more detail on recreational water quality criteria and assessment

† Considered to be less than approximately 20 m radius from the discharge point

§ Risk resulting from primary (whole body) contact (eg swimming, skiing). Secondary contact recreation is partial body contact (eg wading, paddling, boating and fishing) where the probability of swallowing water is unlikely

‖ Self-limiting illnesses are those not requiring medical intervention

**Risk matrix**

A combination of the qualitative likelihood and consequence values was used to derive risk using the matrix shown in Table 2.9. For example, a hazardous event with a likelihood of 3 (possible) and consequences of 2 (minor) would have a risk level of moderate. Each hazard was assessed for risk to the aquatic ecosystem environmental value, with additional risk assessments performed where a hazard was in a raw water supply and/or recreational zone.

The terms 'low', 'moderate', 'high', and 'very high' are necessarily relative (and arbitrary) and are intended purely to support further investigation and management decisions, rather than to attach a specific level of risk to any hazard. As mentioned above, much more detailed information would be required to assign definite risk levels.

**Table 2.9 Risk matrix***

| Likelihood | Consequences | | | | |
|---|---|---|---|---|---|
| | **Insignificant** | **Minor** | **Moderate** | **Major** | **Catastrophic** |
| | **1** | **2** | **3** | **4** | **5** |
| 5 (almost certain) | low | mod | high | v high | v high |
| 4 (likely) | low | mod | high | v high | v high |
| 3 (possible) | low | mod | high | v high | v high |
| 2 (unlikely) | low | low | mod | high | v high |
| 1 (rare) | low | low | mod | high | high |

*Adapted from HB203:2004
v high = very high risk; high = high risk; mod = moderate risk; low = low risk

**Certainty of risk analysis**

The risk analysis above provides a qualitative determination of the level of risk. In order to account for limitations in available data and information gathered, a 'certainty' level was also assigned to each risk analysis, ranging from low (1) to very high (5), as shown in Table 2.10. This measure was designed to help highlight gaps in the information presently available, and to guide and prioritise future data gathering studies.

However, where there are threats of serious or irreversible environmental damage a lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation (precautionary principle; HB203:2004).

**Table 2.10 Certainty level matrix**

| Level | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Certainty** | **Uncertain** | **Low** | **Moderate** | **High** | **Certain** |
| **Description** | Perception only; no information or knowledge forms the basis of the opinion | Perception based; some information known on process but not directly relevant to region, or information at a regional level has significant limitations | Limited information is known; expert knowledge would lead to this outcome, some differences in opinion | Information is known; process has been described and documented at a regional level and experts can verify this position | Information is known and well represents the specific nature of the process; described and documented at a regional level and experts would agree on this position |

## Cataloguing of risks using GIS

GIS was used extensively in the current study and was a vital tool for cataloguing and displaying risks. GIS output maps were used as simple visual displays of the location, hazard type, event type and magnitude of risks from the various hazards. Figure 2.5 is an example of a final map; Figure 2.6 is a guide to interpreting maps. Further more specific details on the GIS methods are given in Appendix B.

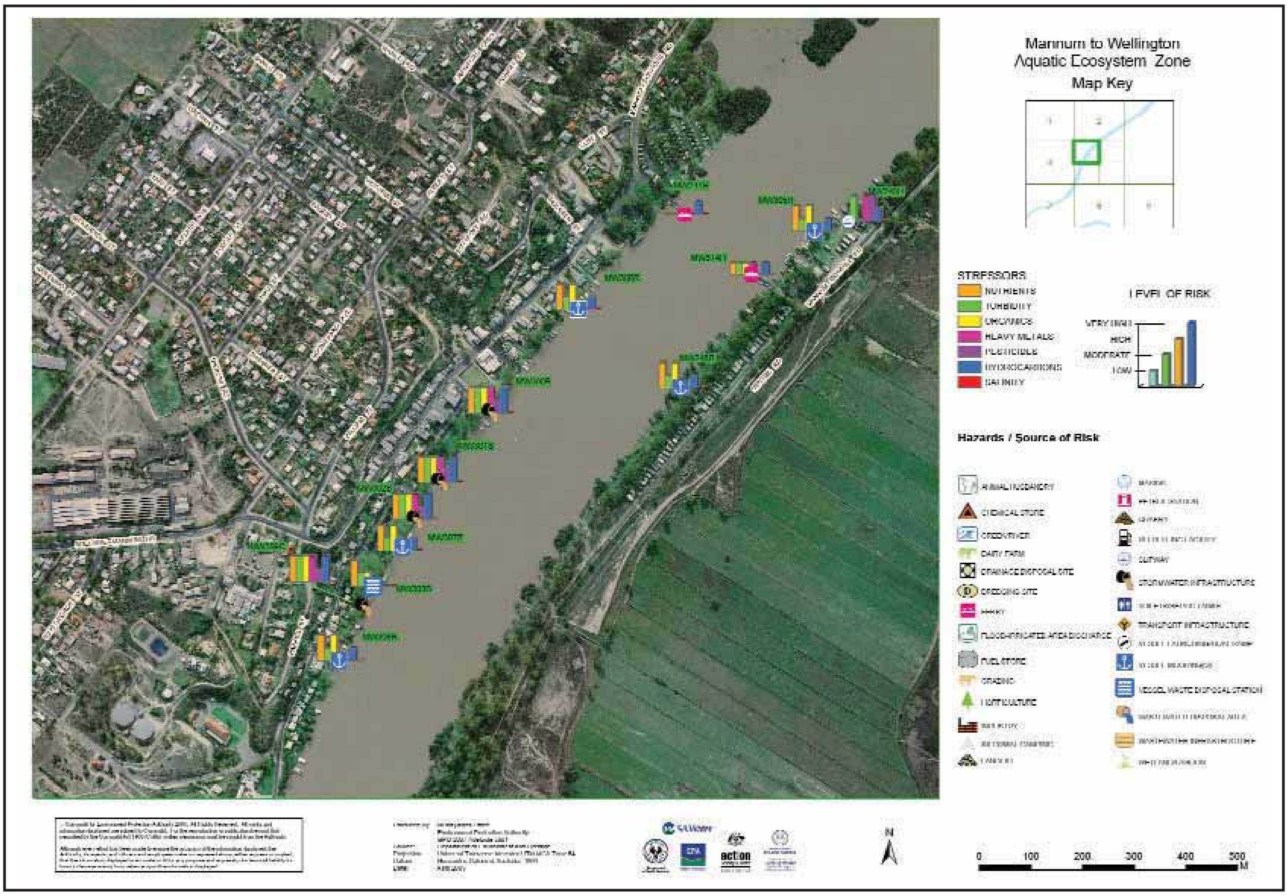


**Figure 2.5 Example of final map output**

Hazards are displayed on a separate series of maps for each environmental value (aquatic ecosystem, raw water, and recreation and aesthetics).

Each hazard has a unique 'GEOCODE' (a descriptive reference code) denoting the relevant LAP region, unique hazard number and event type code. For example, MW00171B describes an *event discharge* (Event Type B) from hazard number 171 in the Mannum to Wellington (MW) LAP area.

Map representation of hazards and their corresponding water quality risks is shown in the example below:

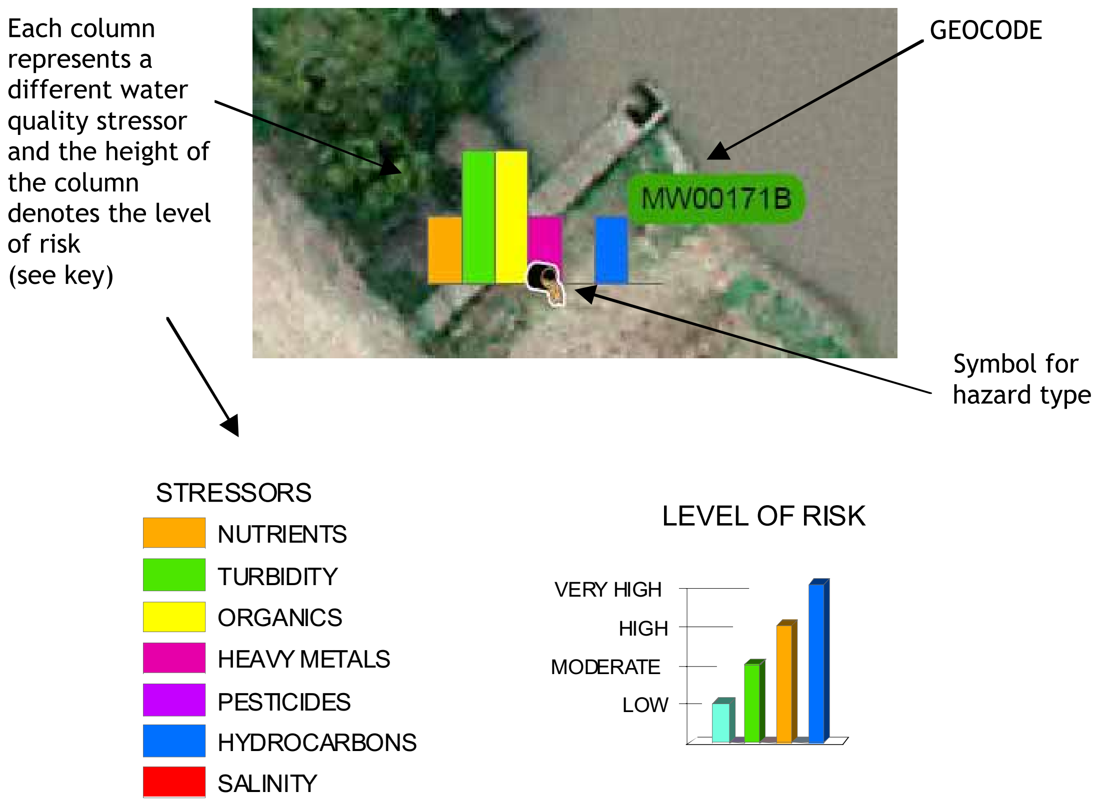


**Figure 2.6 Guide for interpreting maps**

## Risk evaluation

The purpose of risk evaluation is to make decisions, based on the outcomes of the risk analysis, about which risks are priorities for mitigation and which risks may be tolerable or acceptable (HB203:2004). An outcome of the risk assessment project will be the development of strategies to mitigate the identified risks to water quality. The frequency and level of risk different types of hazards was evaluated to gain an understanding of the priorities for management, in terms of both individual hazards and regions of the river.

The risk distribution graph (Figure 2.7) also indicates the most appropriate style of management to mitigate potential risks. For example, a high risk resulting from a regular high-volume point discharge of pollutants might require immediate action and large capital investment to remedy (eg alternative disposal or treatment systems). A high risk that derived from a low likelihood and a high consequence value (eg large fuel storage) may need contingency measures to reduce the consequence (eg bunding of tank). In contrast, a single low-risk hazard would not normally trigger a priority recommendation for action.

The issue of cumulative risks is also important to consider, particularly in the current context of increasing development along the River Murray and Lower Lakes. An example of this might be septic tank soakage trenches in the Water Protection Area; one septic tank would have a low overall impact while the impact of 100 septic tanks in a defined area (eg new multiple-allotment development) could be very detrimental. Allowing risks to accumulate to adverse levels could be described as 'death by a thousand cuts'. In the current study, the GIS-based maps allow an assessment of the density of risks and hazards and the issue of cumulative risks.

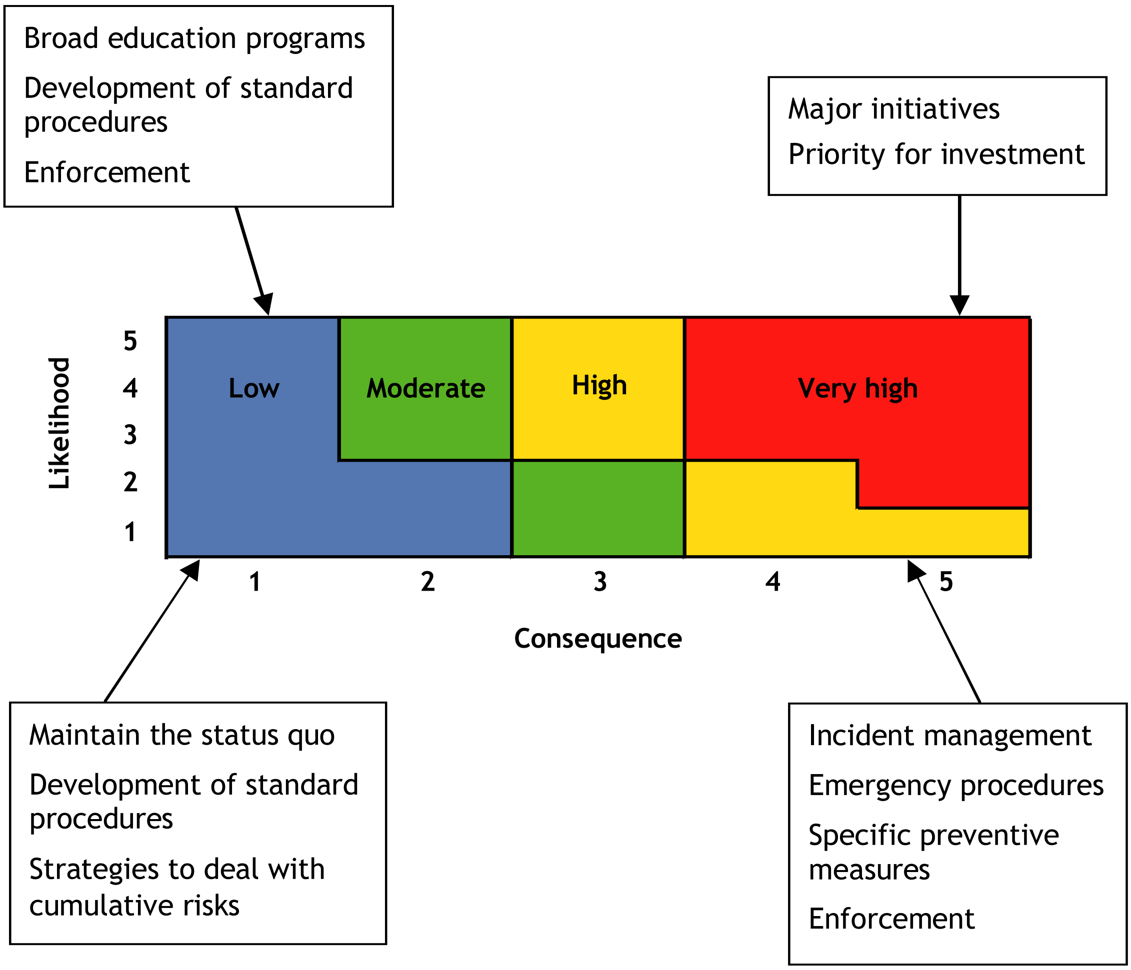


**Figure 2.7 Risk distribution and styles of management that may be appropriate** (adapted from AS/NZS 4360:1999) Note: Indicative only and risk management strategies will be developed on the specifics of individual and/or grouped risks.

### Risk mitigation/management

Risk mitigation or management identifies and assesses the options, and prepares strategies (HB203:2004). The individual LAP reports provide preliminary suggestions on potential risk management options. A comprehensive risk management strategy has been developed for Stage III of the project following further consultation with stakeholders. This strategy will examine in more detail the recommended options for mitigating priority risks.

An integrated, multi-agency approach, in collaboration with the community, is required to effectively implement risk management actions. Risk assessments are designed to be iterative and many levels of iteration may be needed to answer management questions and ensure scientific validity. The National Water Quality Management Strategy Implementation Guidelines (ARMCANZ and ANZECC 1998) provide advice on the risk management process, such as:

- examining in more detail the options for mitigating priority risks, and the potential costs and benefits (eg environmental, economic) of these options
- identifying priority areas for focusing of management efforts
- consulting with the community to set environmental values and water quality targets
- formulating and implementing management strategies and plans to mitigate risks.

### Monitoring and review

It is essential to monitor the effects of implementation of risk management strategies and to ensure that the strategy remains effective (HB 203:2004). Factors may change which affect the likelihood and consequences of an outcome, as may factors that affect the suitability or cost of the mitigation options. Monitoring and research activities may uncover new information that can be used to improve risk assessment.

The ongoing revision of this project's database, will ensure its maintenance and relevance to water quality risk mitigation along the River Murray and Lower Lakes.

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# Appendix A Risk assessment examples

## Example 1: Stormwater discharge hazard

**Description**
A stormwater pipe discharges runoff from a small residential housing catchment into the River Murray (Figure A1). The river area in the vicinity of the discharge is popular for recreational activities (water-skiing and swimming). Monitoring data from another adjacent stormwater outfall indicated moderate and temporary (during 'first flush' of event) exceedence of the ANZECC water quality criteria for turbidity, heavy metals, nutrients, hydrocarbons, and indicator (for pathogens) bacteria. However, the sediment plume does not visibly appear to discharge further than about 5–10 m into the river as shown in the photo below. Rainfall events that generate significant urban runoff occur about 12–15 times a year in this region of the river.

**Figure A1 Stormwater pipe discharges runoff into the River Murray**

**Risk assessment**
The environmental values to be separately assessed against are aquatic ecosystem (assessed for all areas along the river) and recreational.

***Aquatic ecosystem environmental value***
The following table (Table A1) shows the values that were used to assess the risk to the aquatic ecosystem environmental value.

**Table A1 Values to assess risk to aquatic ecosystem environmental value**

| Stressor | Likelihood | Consequence | Risk | Uncertainty |
|---|---|---|---|---|
| Turbidity (TU) | 3 | 2 | moderate | 3 |
| Nutrients (NU) | 3 | 2 | moderate | 3 |
| Heavy metals (HM) | 3 | 2 | moderate | 3 |
| Hydrocarbons (HY) | 3 | 2 | moderate | 3 |

A likelihood value of 3 was given because in this relatively dry region, significant urban runoff only happens on about a monthly basis. The discharge entered directly into the river (not flowing across any vegetation or through a wetland area), thereby potentially directly impacting the environmental value.

The contaminants in the discharge moderately exceeded water quality criteria (see data above) but were given a consequence value of 2 because the exceedences were noted as temporary, the catchment is relatively small and the sediment plume does not visibly appear to discharge out of a localised area (Table 2.6). It was also noted that the plume is diffusing out in all directions, indicating the very slow flow conditions typical in the river. The combination of a likelihood of 3 and consequence of 2 resulted in a moderate risk ranking (value of 2) using the risk assessment matrix (Table 2.9). As some limited information was available on the hazard a moderate certainty value (value of 3) was given to the risk rankings.

***Recreational environmental value***
The following table (Table A2) shows the values that were used to assess the risk to the recreational environmental value.

**Table A2 Values to assess risk to recreational ecosystem environmental value**

| Stressor | Likelihood | Consequence | Risk | Certainty |
|---|---|---|---|---|
| Turbidity (TU) | 3 | 1 | low | 3 |
| Nutrients (NU) | 3 | 1 | low | 3 |
| Hydrocarbons (HY) | 3 | 1 | low | 3 |
| Pathogens (PA) | 3 | 2 | moderate | 3 |

The same likelihood value applied as above. As the River Murray is very turbid, the turbidity risk ranking was rated as low consequence to the recreational values. Similarly, low recreational consequences were assessed for the nutrients and hydrocarbon levels in the runoff. The pathogen stressor was given a minor consequence ranking due to possible minor localised health consequences if bathers contact this water during or immediately following rainfall events. This resulted in a moderate risk ranking.

**Management options**
Overall, this individual risk would be a relatively low priority for action.

Options for mitigation include fitting a gross pollutant trap or directing runoff through a grassed swale or wetland before entering the river. This would reduce levels of particulate contaminants. Catchment education could be conducted reminding people not to tip substances (eg oil, paint, fertiliser) down stormwater drains.

In relation to the recreational impacts, a sign could be placed requesting people not to swim in the vicinity during or immediately following rainfall events.

Cumulative risk levels may be important to consider if there are other stormwater discharges in the vicinity.

## Example 2 Flood irrigation drainage discharge hazard (eg Lower Murray)

**Description**

A drainage pump discharges from one of the larger flood-irrigation areas into the river (Figure A2). Intensive dairy farming is conducted on the irrigation area with three milking sheds present. The pipe contains varying amounts of surface irrigation runoff (in irrigation season), saline groundwater (year-round) and stormwater (following rainfall events). Discharge volumes in summer are high due to excess surface irrigation runoff and drainage (average several megalitres per day) with drainage pumps activated every 2–4 days.

Following large rainfall events continual pumping is required for several days to drain the area. High concentrations of pathogens, nutrients, and organic matter, have been measured in a previous monitoring study of the discharge and the salinity is also elevated 2–3 times above typical river levels. The discharge has been noted in river monitoring reports to impact the ambient water quality downstream.

The drinking water supply off-take for a small township is 100 m downstream and monitoring at this site has detected pathogens (*Cryptosporidium*) and organic matter that impact on the treatment operations and may be attributable to the irrigation area discharge. In particular, large spikes in pathogen concentrations appear during large rainfall events.

**Figure A2 Drainage pump discharges from a flood-irrigation area into the river**

**Risk assessment**

The environmental values to be separately assessed against are aquatic ecosystem (assessed for all areas along the river) and raw water supply. The discharge must be assessed for both 'normal' (dry) conditions and rainfall events.

***Aquatic ecosystem environmental value***
The following table (Table A3) shows the values that were used to assess the risk to the aquatic ecosystem environmental value:

**Table A3 Values to assess risk to aquatic ecosystem environmental value**

| Stressor | Likelihood | Consequence | Risk | Certainty |
|---|---|---|---|---|
| Pathogens (PA) | | | | |
| • discharge | 4 | 4 | very high | 3 |
| • event discharge | 2 | 4 | high | 3 |
| Nutrients (NU)—discharge | 4 | 4 | very high | 3 |
| • event discharge | 2 | 4 | high | 3 |
| Organic matter (OR)—discharge | 4 | 4 | very high | 3 |
| • event discharge | 2 | 4 | high | 3 |
| Salinity (SA)—discharge | 4 | 1 | low | 3 |
| • event discharge | 2 | 1 | low | 3 |

A likelihood value of 4 for normal dry conditions was assigned (using Table 2.4) because frequent (daily-weekly) pumped discharges or irrigation runoff and drainage occur and the discharge enters directly into the river. A likelihood value of 2 was assigned for event discharges, as rainfall events that generate significant runoff from these areas are not frequent. The levels of nutrients, pathogens and organic matter in the discharge far exceeded water quality criteria and the volume of discharge was large and noted to be affecting ambient water quality outside of the mixing zone. Using Table 2.6, a consequence value of major (value of 4) was given for pathogens, nutrients and organic matter. This resulted in a very high risk ranking for normal discharge and a high ranking for event discharges. The risk was low for salinity due to a lower consequence value given that the river is historically quite a variable salinity environment. As some limited information was available on the content of the discharge plume and its impact, a moderate certainty value was given to the risk rankings.

***Raw water supply environmental value***
The following table (Table A4) shows the values that were used to assess the risk to the raw water supply environmental value:

**Table A4 Values to assess risk to raw water supply environmental value**

| Stressor | Likelihood | Consequence | Risk | Certainty |
|---|---|---|---|---|
| Pathogens (PA)—discharge | 3 | 3 | high | 3 |
| • event discharge | 3 | 4 | very high | 3 |
| Nutrients (NU)—discharge | 3 | 3 | high | 3 |
| • event discharge | 3 | 3 | high | 3 |
| Organic matter (OR)—discharge | 3 | 3 | high | 3 |
| • event discharge | 3 | 3 | high | 3 |

A likelihood value of 3 was applied as there is 100 m of potential dilution distance to the off-take, compared to the immediate impacts of the discharge on the ecosystem described above. The likelihood for a rainfall event was assigned a 3 as the large volume of water discharged under these conditions was expected to increase the probability of the discharge reaching the off-take point (taking into consideration that the conditional likelihood of occurrence of an event discharge was less than for a discharge). The pathogen stressor was given a very high risk ranking during rainfall events due to causal evidence of pathogen spikes at the treatment plant. Other stressor risks come out as high. Certainty is at a moderate level and could be improved by more in-depth monitoring and tracing the flow-path of the plume from the discharge to the treatment plant.

**Management options**

Overall this individual risk would be a high priority for mitigation action. Upgrading of major amount of infrastructure could be required (improved water delivery and recycling systems) for the flood-irrigated area to reduce its pollutant loads.

In relation to the raw water supply, to protect the township's health, an option would be to upgrade the treatment plant to include a filtration system to remove pathogens. Alternatively, the off-take point could be moved or reorientated to reduce the risk of the discharge reaching it.

# Appendix B Risk assessment GIS database procedure guideline[4]

## General

GIS was used extensively at all phases of the project, including for:

- display of high resolution aerial photography at community workshops
- cataloguing risk assessment information and notes
- examination of existing spatial data layers (eg land uses, EPA licence, wetlands, irrigation and drainage networks)
- assessment of the proximity of hazards to the river or the proximity of the discharge point to risk end-point (eg inlet for raw water supply)
- displaying details of stormwater networks or the areal extent of agricultural land uses, and therefore allowing a relative measure of risk within the management zone
- examination of the number of hazards in a particular zone (eg shacks or houseboats)
- output of high quality maps for reports and accompanying CDs.

GIS provides a framework where the risk assessment can be easily revised in the future as additional information is collected, thus providing a 'living database' for resource managers, planners and policy makes.

There were six main steps in developing the risk assessment GIS tool:

- delineating management zones and the scope of the study
- capturing hazard locations into a spatial GIS database and geocoding
- performing the risk assessment in a Microsoft Excel database
- joining the GIS spatial and risk assessment databases
- map creation and formatting
- outputting maps.

## Delineating management zones and the scope of the study

The study area was within the river corridor defined as the River Murray Water Protection Area (Environment Protection Act 1993). This river corridor was used within the GIS to define the spatial scope of the study and hazards within this area were identified and their risk assessed.

The relative importance of each environmental value differs along the length of the River Murray. As such, arbitrary zones were established in the GIS represented by a line drawn down the river defining the start and end of the zone for a particular environmental value. The length of each zone has been described in the main body of the text and provided the scope for each specific risk assessment.

4 The following guideline is written to assist a proficient Microsoft Excel and GIS user who would have the ability to create Excel spreadsheet formula digitise and edit shape files, query and edit the GIS attribute table, create grids and map layouts. ARC Map™ was the GIS program utilised in the current study although other GIS systems may be just as appropriate.

## Capturing hazard locations into a spatial GIS database and geocoding

Capture of hazard locations into the GIS database was done primarily by manually entering/digitising point information from the large (size A1 printed) high-resolution aerial photographs used in the community workshops. Additional location information was entered from existing GIS layers (see Billington 2005 for more information on the GIS data sources), documents or plans, or the knowledge of the catchment risk advisors or community representatives. Some of the hazard sites were visited and a GPS used to accurately record location. Figure B1 shows the point information entered into the GIS database with a background of high-resolution aerial photographs.

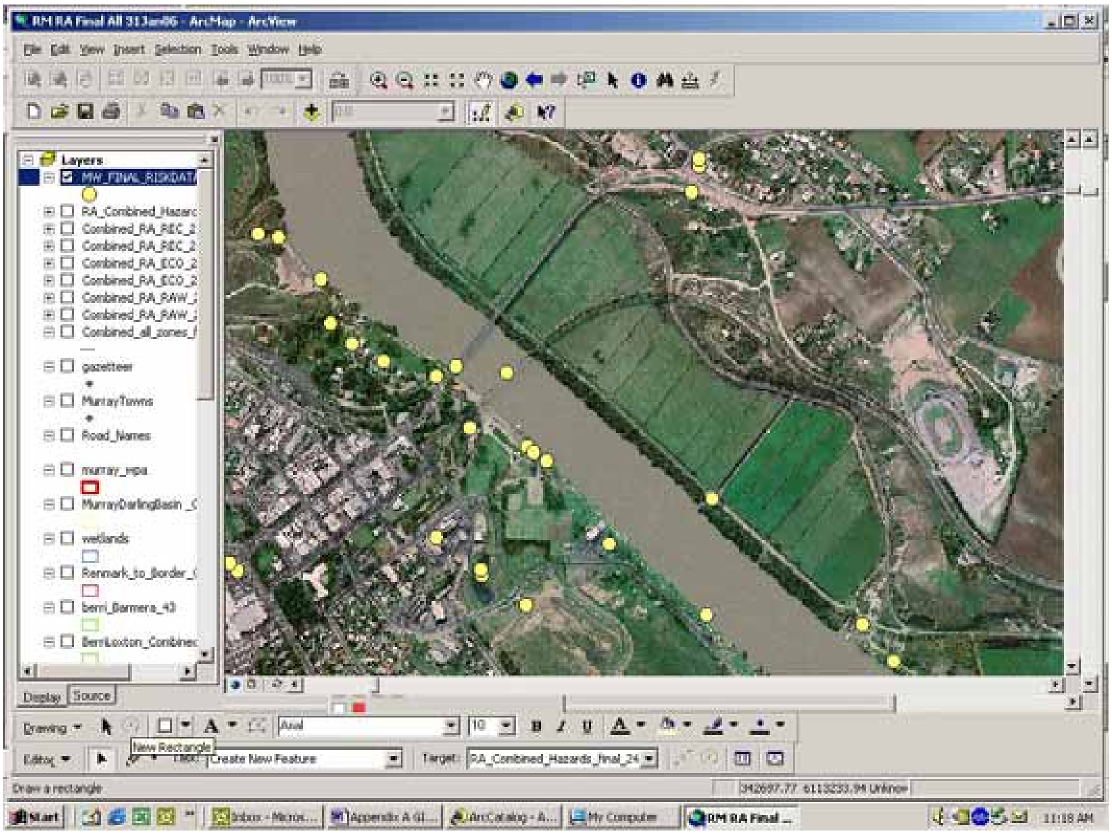


**Figure B1 High-resolution aerial photograph with hazard (point) locations (yellow circles)**

It was considered too cumbersome to enter detailed risk attribute information during the workshops. Alternatively each hazard was given a unique 'GEOCODE' (a descriptive reference code) that was also entered into the GIS database. The GEOCODE is a useful reference code as it contains information denoting the relevant LAP region, unique hazard number and event type code (Figure B2).

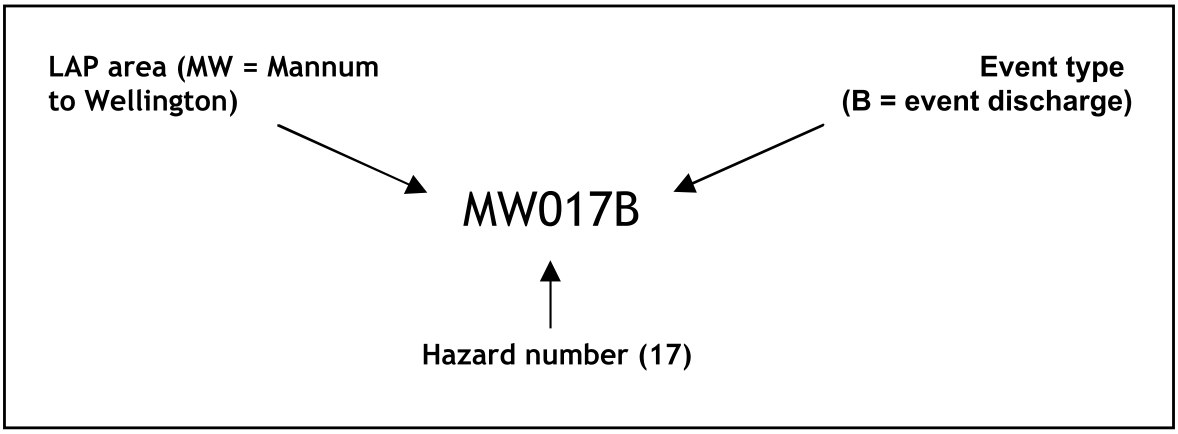



**Figure B2 GEOCODE description**

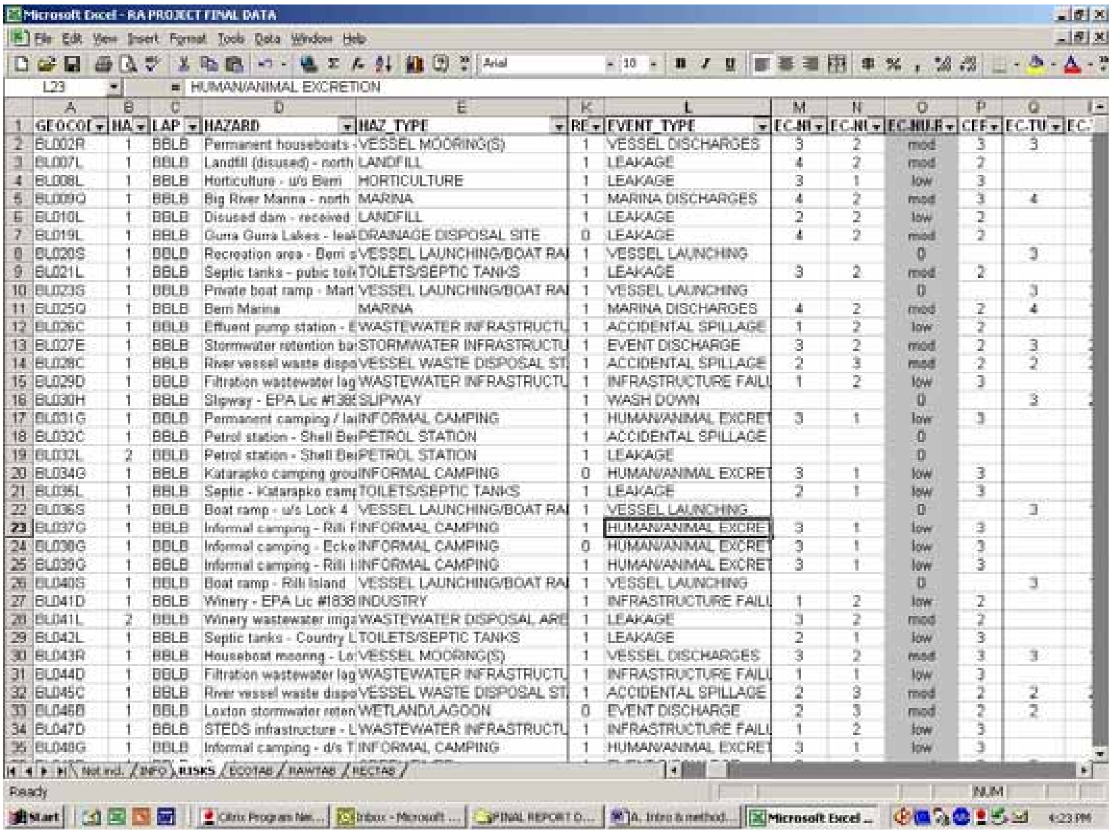
## Performing the risk assessment in a Microsoft Excel database

The unique GEOCODE ID was also entered into a Microsoft Excel spreadsheet where the risk assessment information was recorded and calculated. The other items entered into the Microsoft Excel spreadsheet included hazard code, event type, likelihood rating, consequence rating, risk ranking and certainty level of risk level as shown in Appendix Figure B3. A notes column was also created in the spreadsheet so additional information on a particular risk could be inputted (eg information gained at the community workshops that might have lead to a particular risk value being assigned). This data can be searched and grouped using the 'autofilter' and 'sort' functions in Microsoft Excel.

Embedded in the excel spreadsheet was an Excel 'lookup' formula which was written to automatically calculate risk level (low, moderate, high, very high) from likelihood and consequence values using a risk matrix placed on a separate excel worksheet (see Figure B3). The risk matrix is the same as the one shown in Table 2.9 but a 'proxy' number of 9 was added to the likelihood with the result that each combination of likelihood and consequence had a unique value which enabled the calculation of risk. The formula on the risk assessment worksheet had the general format:

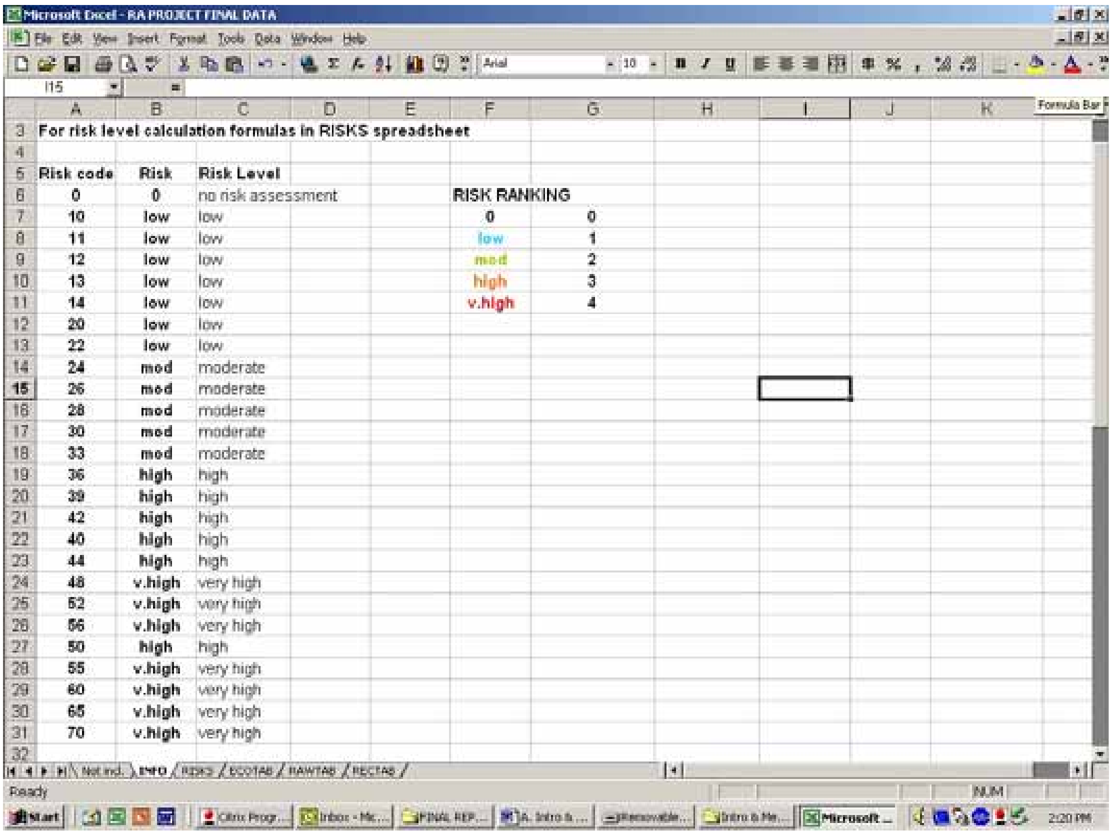
= VLOOKUP((*likelhood*+9)**consequence*,Codes!$A$6:$B$31,2,FALSE)

Where *likelihood* and *consequence* in this formula would be replaced with the cell reference where these values were found for a particular risk and the 'Codes' reference range refers to that shown in Figure B4.



| | GEOCOD | HA | LAP | HAZARD | HAZ_TYPE | RE | EVENT_TYPE | EC-NI | EC-NI | EC-NI-R | CEF | EC-TU |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | BL002R | 1 | BBLB | Permanent houseboats - | VESSEL MOORING(S) | 1 | VESSEL DISCHARGES | 3 | 2 | mod | 3 | 3 |
| 3 | BL007L | 1 | BBLB | Landfill (disused) - north | LANDFILL | 1 | LEAKAGE | 4 | 2 | mod | 2 | |
| 4 | BL008L | 1 | BBLB | Horticulture - u/s Berri | HORTICULTURE | 1 | LEAKAGE | 3 | 1 | low | 3 | |
| 5 | BL009Q | 1 | BBLB | Big River Marina - north | MARINA | 1 | MARINA DISCHARGES | 4 | 2 | mod | 3 | 4 |
| 6 | BL010L | 1 | BBLB | Disused dam - received | LANDFILL | 1 | LEAKAGE | 2 | 2 | low | 2 | |
| 7 | BL019L | 1 | BBLB | Gurra Gurra Lakes - lea | DRAINAGE DISPOSAL SITE | 0 | LEAKAGE | 4 | 2 | mod | 2 | |
| 8 | BL020S | 1 | BBLB | Recreation area - Berri s | VESSEL LAUNCHING/BOAT RA | 1 | VESSEL LAUNCHING | | | 0 | | 3 |
| 9 | BL021L | 1 | BBLB | Septic tanks - pubic toil | TOILETS/SEPTIC TANKS | 1 | LEAKAGE | 3 | 2 | mod | 2 | |
| 10 | BL023S | 1 | BBLB | Private boat ramp - Mart | VESSEL LAUNCHING/BOAT RA | 1 | VESSEL LAUNCHING | | | 0 | | 3 |
| 11 | BL025Q | 1 | BBLB | Berri Marina | MARINA | 1 | MARINA DISCHARGES | 4 | 2 | mod | 2 | 4 |
| 12 | BL026C | 1 | BBLB | Effluent pump station - E | WASTEWATER INFRASTRUCTU | 1 | ACCIDENTAL SPILLAGE | 1 | 2 | low | 2 | |
| 13 | BL027E | 1 | BBLB | Stormwater retention ba | STORMWATER INFRASTRUCTU | 1 | EVENT DISCHARGE | 3 | 2 | mod | 2 | 3 |
| 14 | BL028C | 1 | BBLB | River vessel waste dispo | VESSEL WASTE DISPOSAL ST | 1 | ACCIDENTAL SPILLAGE | 2 | 3 | mod | 2 | 2 |
| 15 | BL029D | 1 | BBLB | Filtration wastewater lag | WASTEWATER INFRASTRUCTU | 1 | INFRASTRUCTURE FAILU | 1 | 2 | low | 3 | |
| 16 | BL030H | 1 | BBLB | Slipway - EPA Lic #138 | SLIPWAY | 1 | WASH DOWN | | | 0 | | 3 |
| 17 | BL031G | 1 | BBLB | Permanent camping / la | INFORMAL CAMPING | 1 | HUMAN/ANIMAL EXCRET | 3 | 1 | low | 3 | |
| 18 | BL032C | 1 | BBLB | Petrol station - Shell Be | PETROL STATION | 1 | ACCIDENTAL SPILLAGE | | | 0 | | |
| 19 | BL032L | 2 | BBLB | Petrol station - Shell Be | PETROL STATION | 1 | LEAKAGE | | | 0 | | |
| 20 | BL034G | 1 | BBLB | Katarapko camping grou | INFORMAL CAMPING | 0 | HUMAN/ANIMAL EXCRET | 3 | 1 | low | 3 | |
| 21 | BL035L | 1 | BBLB | Septic - Katarapko camp | TOILETS/SEPTIC TANKS | 1 | LEAKAGE | 2 | 1 | low | 3 | |
| 22 | BL036S | 1 | BBLB | Boat ramp - u/s Lock 4 | VESSEL LAUNCHING/BOAT RA | 1 | VESSEL LAUNCHING | | | 0 | | 3 |
| 23 | BL037G | 1 | BBLB | Informal camping - Rili F | INFORMAL CAMPING | 1 | HUMAN/ANIMAL EXCRET | 3 | 1 | low | 3 | |
| 24 | BL038G | 1 | BBLB | Informal camping - Ecke | INFORMAL CAMPING | 0 | HUMAN/ANIMAL EXCRET | 3 | 1 | low | 3 | |
| 25 | BL039G | 1 | BBLB | Informal camping - Rili I | INFORMAL CAMPING | 1 | HUMAN/ANIMAL EXCRET | 3 | 1 | low | 3 | |
| 26 | BL040S | 1 | BBLB | Boat ramp - Rili Island | VESSEL LAUNCHING/BOAT RA | 1 | VESSEL LAUNCHING | | | 0 | | 3 |
| 27 | BL041D | 1 | BBLB | Winery - EPA Lic #1838 | INDUSTRY | 1 | INFRASTRUCTURE FAILU | 1 | 2 | low | 2 | |
| 28 | BL041L | 2 | BBLB | Winery wastewater irriga | WASTEWATER DISPOSAL ARE | 1 | LEAKAGE | 3 | 2 | mod | 2 | |
| 29 | BL042L | 1 | BBLB | Septic tanks - Country L | TOILETS/SEPTIC TANKS | 1 | LEAKAGE | 2 | 1 | low | 3 | |
| 30 | BL043R | 1 | BBLB | Houseboat mooring - Lo | VESSEL MOORING(S) | 1 | VESSEL DISCHARGES | 3 | 2 | mod | 3 | 3 |
| 31 | BL044D | 1 | BBLB | Filtration wastewater lag | WASTEWATER INFRASTRUCTU | 1 | INFRASTRUCTURE FAILU | 1 | 1 | low | 3 | |
| 32 | BL045C | 1 | BBLB | River vessel waste dispo | VESSEL WASTE DISPOSAL ST | 1 | ACCIDENTAL SPILLAGE | 2 | 3 | mod | 2 | 2 |
| 33 | BL046B | 1 | BBLB | Loxton stormwater reten | WETLAND/LAGOON | 0 | EVENT DISCHARGE | 2 | 3 | mod | 2 | 2 |
| 34 | BL047D | 1 | BBLB | STEDS infrastructure - L | WASTEWATER INFRASTRUCTU | 1 | INFRASTRUCTURE FAILU | 1 | 2 | low | 3 | |
| 35 | BL048G | 1 | BBLB | Informal camping - d/s T | INFORMAL CAMPING | 1 | HUMAN/ANIMAL EXCRET | 3 | 1 | low | 3 | |

**Figure B3 Risk assessment Excel spreadsheet example**



For risk level calculation formulas in RISKS spreadsheet

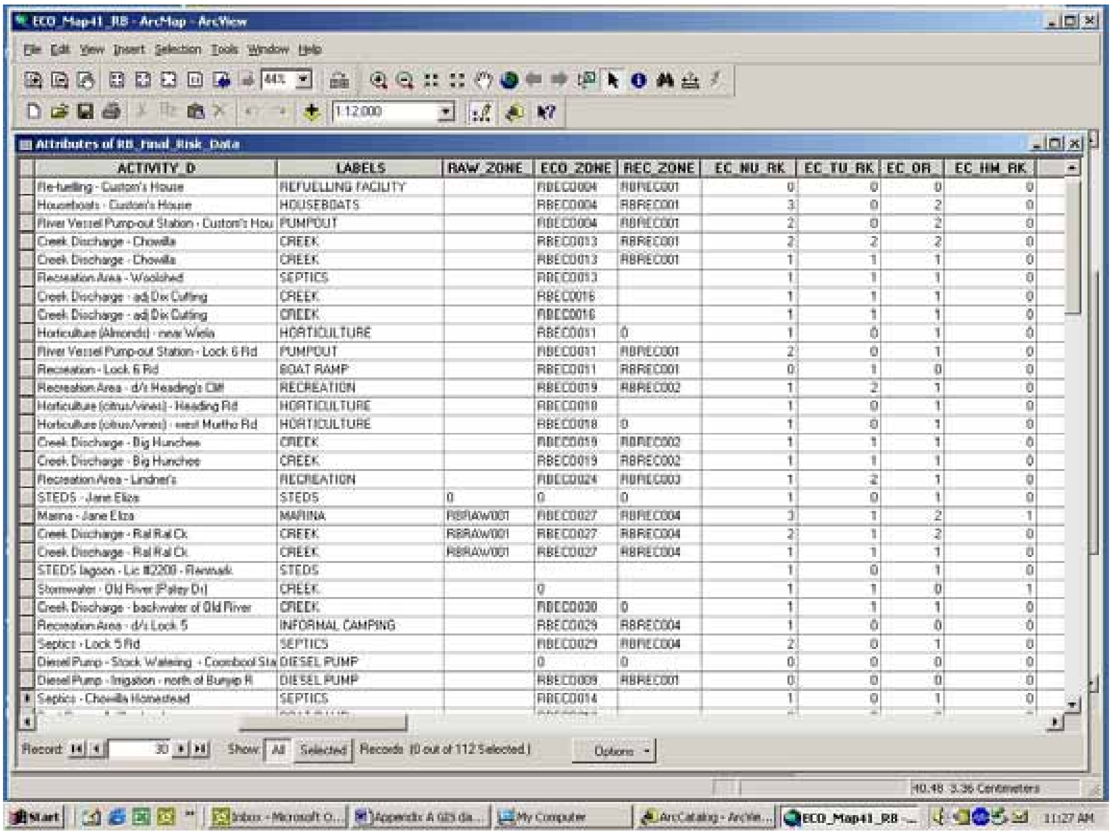
| Risk code | Risk | Risk Level | | RISK RANKING | |
|---|---|---|---|---|---|
| 0 | 0 | no risk assessment | | | |
| 10 | low | low | | 0 | 0 |
| 11 | low | low | | low | 1 |
| 12 | low | low | | mod | 2 |
| 13 | low | low | | high | 3 |
| 14 | low | low | | v.high | 4 |
| 20 | low | low | | | |
| 22 | low | low | | | |
| 24 | mod | moderate | | | |
| 26 | mod | moderate | | | |
| 28 | mod | moderate | | | |
| 30 | mod | moderate | | | |
| 33 | mod | moderate | | | |
| 36 | high | high | | | |
| 39 | high | high | | | |
| 42 | high | high | | | |
| 40 | high | high | | | |
| 44 | high | high | | | |
| 48 | v.high | very high | | | |
| 52 | v.high | very high | | | |
| 56 | v.high | very high | | | |
| 50 | high | high | | | |
| 55 | v.high | very high | | | |
| 60 | v.high | very high | | | |
| 65 | v.high | very high | | | |
| 70 | v.high | very high | | | |

**Figure B4 Risk calculation values**

## Joining the GIS spatial and risk assessment databases

The risk assessment information was imported into the GIS database with the GEOCODE providing a common attribute so that the spatial layer and the spreadsheet could be easily joined. Prior to this join, the Excel spreadsheet was converted to an excel database (IV) file (*.dbf) using the 'save as' function. An example of a joined attribute table is shown in Figure B5.

Subsequently, the attribute table can also be used to query the risk attributes (likelihood, consequence and level of certainty for a particular site, or statistics can be derived for the entire database, or part thereof. The GIS database can be readily updated as and when necessary by modifying the attribute table. It was essential that this regime of using a unique GEOCODE be maintained to help classify and query the GIS data.



| ACTIVITY_D | LABELS | RAW_ZONE | ECO_ZONE | REC_ZONE | EC_NU_RK | EC_TU_RK | EC_OR | EC_HM_RK |
|---|---|---|---|---|---|---|---|---|
| Re-fuelling - Custom's House | REFUELLING FACILITY | | RBECO004 | RBREC001 | 0 | 0 | 0 | 0 |
| Houseboats - Custom's House | HOUSEBOATS | | RBECO004 | RBREC001 | 3 | 0 | 2 | 0 |
| River Vessel Pump-out Station - Custom's Hou | PUMPOUT | | RBECO004 | RBREC001 | 2 | 0 | 2 | 0 |
| Creek Discharge - Chowilla | CREEK | | RBECO013 | RBREC001 | 2 | 2 | 2 | 0 |
| Creek Discharge - Chowilla | CREEK | | RBECO013 | RBREC001 | 1 | 1 | 1 | 0 |
| Recreation Area - Woolshed | SEPTICS | | RBECO013 | | 1 | 1 | 1 | 0 |
| Creek Discharge - adj Dix Cutting | CREEK | | RBECO016 | | 1 | 1 | 1 | 0 |
| Creek Discharge - adj Dix Cutting | CREEK | | RBECO016 | | 1 | 1 | 1 | 0 |
| Horticulture (Almonds) - near Wiela | HORTICULTURE | | RBECO011 | 0 | 1 | 0 | 1 | 0 |
| River Vessel Pump-out Station - Lock 6 Rd | PUMPOUT | | RBECO011 | RBREC001 | 2 | 0 | 1 | 0 |
| Recreation - Lock 6 Rd | BOAT RAMP | | RBECO011 | RBREC001 | 0 | 1 | 0 | 0 |
| Recreation Area - d/s Heading's Cliff | RECREATION | | RBECO019 | RBREC002 | 1 | 2 | 1 | 0 |
| Horticulture (citrus/vines) - Heading Rd | HORTICULTURE | | RBECO018 | | 1 | 0 | 1 | 0 |
| Horticulture (citrus/vines) - west Murtho Rd | HORTICULTURE | | RBECO018 | 0 | 1 | 0 | 1 | 0 |
| Creek Discharge - Big Hunchee | CREEK | | RBECO019 | RBREC002 | 1 | 1 | 1 | 0 |
| Creek Discharge - Big Hunchee | CREEK | | RBECO019 | RBREC002 | 1 | 1 | 1 | 0 |
| Recreation Area - Lindner's | RECREATION | | RBECO024 | RBREC003 | 1 | 2 | 1 | 0 |
| STEDS - Jane Eliza | STEDS | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Marina - Jane Eliza | MARINA | RBRAW001 | RBECO027 | RBREC004 | 3 | 1 | 2 | 1 |
| Creek Discharge - Ral Ral Ck | CREEK | RBRAW001 | RBECO027 | RBREC004 | 2 | 1 | 2 | 0 |
| Creek Discharge - Ral Ral Ck | CREEK | RBRAW001 | RBECO027 | RBREC004 | 1 | 1 | 1 | 0 |
| STEDS lagoon - Lic #2200 - Renmark | STEDS | | | | 1 | 0 | 1 | 0 |
| Stormwater - Old River (Paley Dr) | CREEK | | 0 | | 1 | 1 | 0 | 1 |
| Creek Discharge - backwater of Old River | CREEK | | RBECO030 | 0 | 1 | 1 | 1 | 0 |
| Recreation Area - d/s Lock 5 | INFORMAL CAMPING | | RBECO029 | RBREC004 | 1 | 0 | 0 | 0 |
| Septics - Lock 5 Rd | SEPTICS | | RBECO029 | RBREC004 | 2 | 0 | 1 | 0 |
| Diesel Pump - Stock Watering - Coombool Sta | DIESEL PUMP | | 0 | 0 | 0 | 0 | 0 | 0 |
| Diesel Pump - Irrigation - north of Bunyip R | DIESEL PUMP | | RBECO009 | RBREC001 | 0 | 0 | 0 | 0 |
| Septics - Chowilla Homestead | SEPTICS | | RBECO014 | | 1 | 0 | 1 | 0 |

**Figure B5 Attribute table containing join of risk assessment and spatial information**

## Map creation and formatting

Once all the risk attributes were in the GIS attribute table, standard cartographic templates in the GIS program (symbols, bar/column graphs, colours, size) were used to display the level of risk for each hazard in each zone (Figure B6).

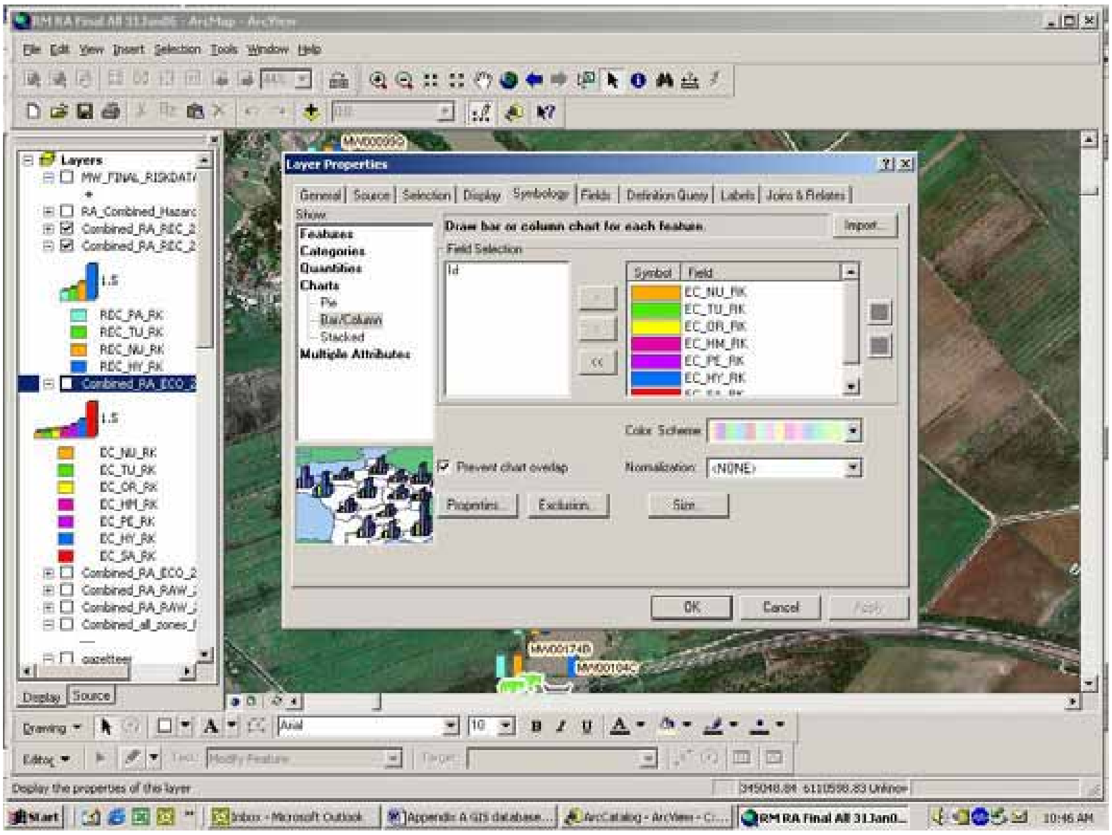



**Figure B6 Standard cartographic template for risk maps**

An example outcome of applying these templates is shown below (Figure B7). Where some of the hazards were very close together, some of the information and graphs initially overlapped. In these cases some of the graph elements were converted to graphics and moved so they no longer overlapped.

## Map output

A standard mapping template was established for each environmental value and used to format final maps. Each GIS map file was outputted to a PDF file for publishing on CD. An example of a map output is shown in Figure 2.5 in the main body of this report. A key map was created to easily guide users to relevant maps for a particular region of river.

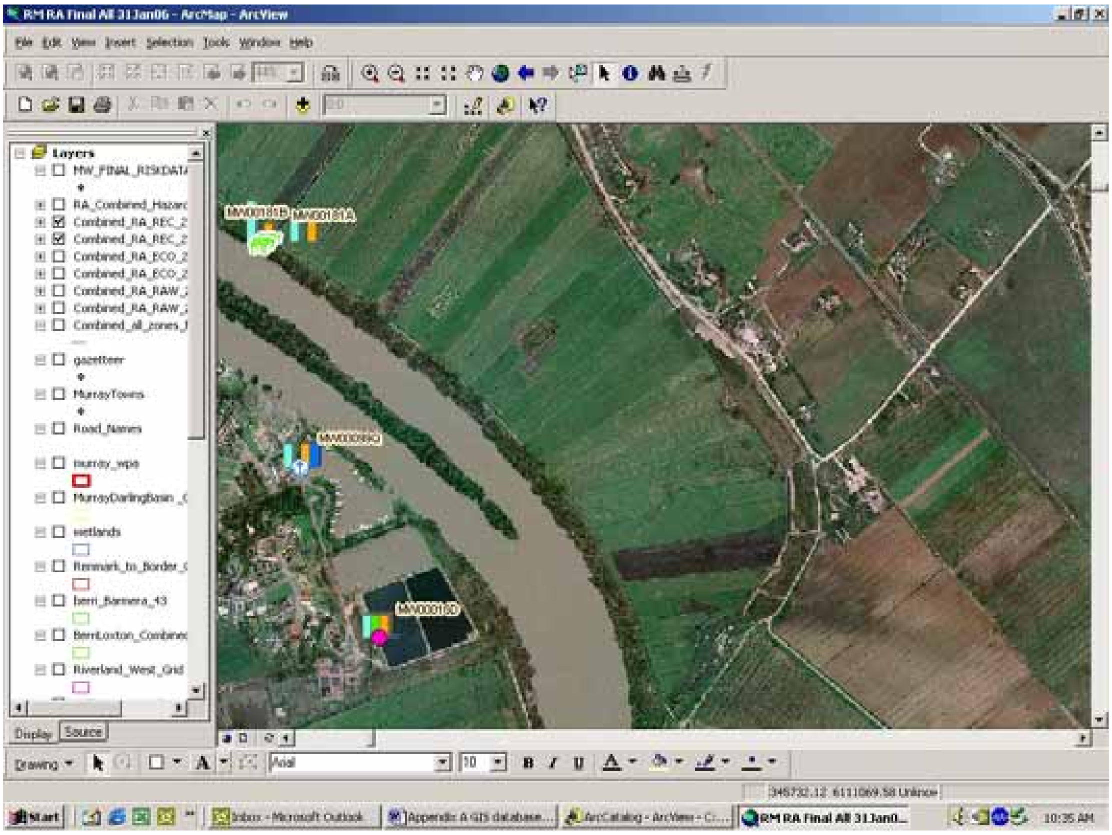


**Figure B7 Standard cartographic template for risk maps**