



Rous Water

Catchment Management Plan for Emigrant Creek Catchment



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Rous Water's Catchment Management Plan for the Emigrant Creek Catchment

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1. Executive Summary

In keeping with the “catchment to tap” management approach recommended in the Australian Drinking Water Guidelines (ADWG), Rous Water is developing and implementing a Catchment Management Plans (CMPs) for its major drinking water supply catchments. The CMPs cover the “catchment to treatment plant” component of the water supply system and feed into the more engineering-focused “treatment plant to tap” management plans being implemented by Rous Water and its customer councils. Altogether, this body of management plans forms the Drinking Water Management Systems (DWMS) that is required under the *Public Health Act 2010*.

The CMP described in this document covers the Emigrant Creek catchment. Rous Water's Vision for the catchment is:

“a healthy, productive catchment with fully functioning ecosystems that produces clean water”

In order to systematically work towards achieving that vision in the most resource-effective manner, this CMP has been developed by completing the following actions:

- Preparing a written description of the catchment and source water.
- Setting water quality objectives for raw drinking water and ecosystem health.
- Assessing source water quality against those water quality objectives.
- Assessing risks to water quality with the catchment in its current state.
- Identifying future actions for Rous Water and stakeholders to reduce risks.

The water quality data analysis found the principal water quality parameters of concern to be microbial faecal indicators (and, by inference, pathogens), nutrients, (particularly phosphorus), and sediment (turbidity).

The risk assessment identified and assessed approximately 100 risks. Of these, currently high and significant risks were associated with: HAZMAT spills on roads; road construction runoff; unrestricted stock grazing; failing on-site sewage management systems; fertiliser runoff; agricultural soil erosion runoff and natural manganese.

A series of management actions was identified that was anticipated to be capable of reducing residual risks to low or medium levels in the medium- to long-term. The CMP Action Plan consists of actions allocated to both Rous Water and other stakeholders. This Action Plan represents the major output from the drafting of the CMP. To achieve enhanced outcomes towards the Rous Water's Vision would require implementation of those actions. The actions are not summarized in the Executive Summary because they are too numerous to present succinctly. However, the final section of this CMP presents those actions as a series of tables in a reasonably concise format.

This CMP provides a useful model for the completion of future CMPs for other Rous Water catchments. Furthermore, many of the actions in the CMP are potentially applicable at a much broader scale than just the Emigrant Creek catchment.

2. Drinking Water Management System

Rous Water is building a Drinking Water Management System (DWMS) in accordance with the twelve elements of the *Framework for Management of Drinking Water Quality* set out in the *Australian Drinking Water Guidelines 2011* (ADWG) and with reference to the *NSW Guidelines for Drinking Water Management Systems 2013*. The DWMS contains or references all policies, procedures and registers, as supporting documents and appendices that are required to meet the *Public Health Act 2010* requirement for drinking water suppliers to develop and implement a quality assurance program to maintain drinking water quality.

Rous Water has previously drafted drinking water quality risk assessments and management plans for the DWMS, including for the Emigrant Creek water supply system (Rous Water, 2012). Those plans include treatment plants to point of delivery to customers. Whilst catchment issues were flagged in those assessments, it was intended to cover catchments separately, under a Catchment Management Plan (CMP).

Prior to the risk assessment work carried out under the principles of the 2011 ADWG and in recognition of the strategic importance of this water supply source, Rous Water has previously conducted a drinking water quality risk assessment study (during 2001) which included the water catchment area (Egis, 2001). This risk assessment identified a range of water quality risks and hazards present in the water catchment area. At that time Rous Water adopted a series of strategies and actions to address these issues which were subsequently addressed through the development of the Emigrant Creek Water Treatment Plant (completed in 2006) and the Rous Water catchment management program. This current project reflects a need to update this risk assessment and catchment management program to reflect changed conditions, improved catchment understanding, and the updated requirements of the ADWG.

The CMPs will consider in detail the risks to drinking water quality that arise in each catchment. The CMPs include a qualitative catchment risk assessment and an action plan that includes catchment management measures to reduce risks to water quality and improve the general aquatic health within the catchment.

Element two of the ADWG requires the assessment of the drinking water supply system. This includes understanding the characteristics of the drinking water supply system, what hazards may arise, how these hazards create risks, and the processes and practices that affect drinking water quality. The drinking water supply system (refer Figure 2-1) is defined as everything from the point of collection of water to the consumer and can include catchments, source waters, storage reservoirs and intakes, treatment systems, service reservoirs and distribution systems and consumers.

Water quality can be influenced, positively or negatively, at each of these points, and because they are all interrelated, integrated management is essential.

In summary, in accordance with the ADWG “catchment to tap” philosophy, CMPs (including their risk assessments) are being undertaken by Rous Water in order to fully implement the requirements of the ADWG as part of the overall Rous Water DWMS.

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Water quality management process

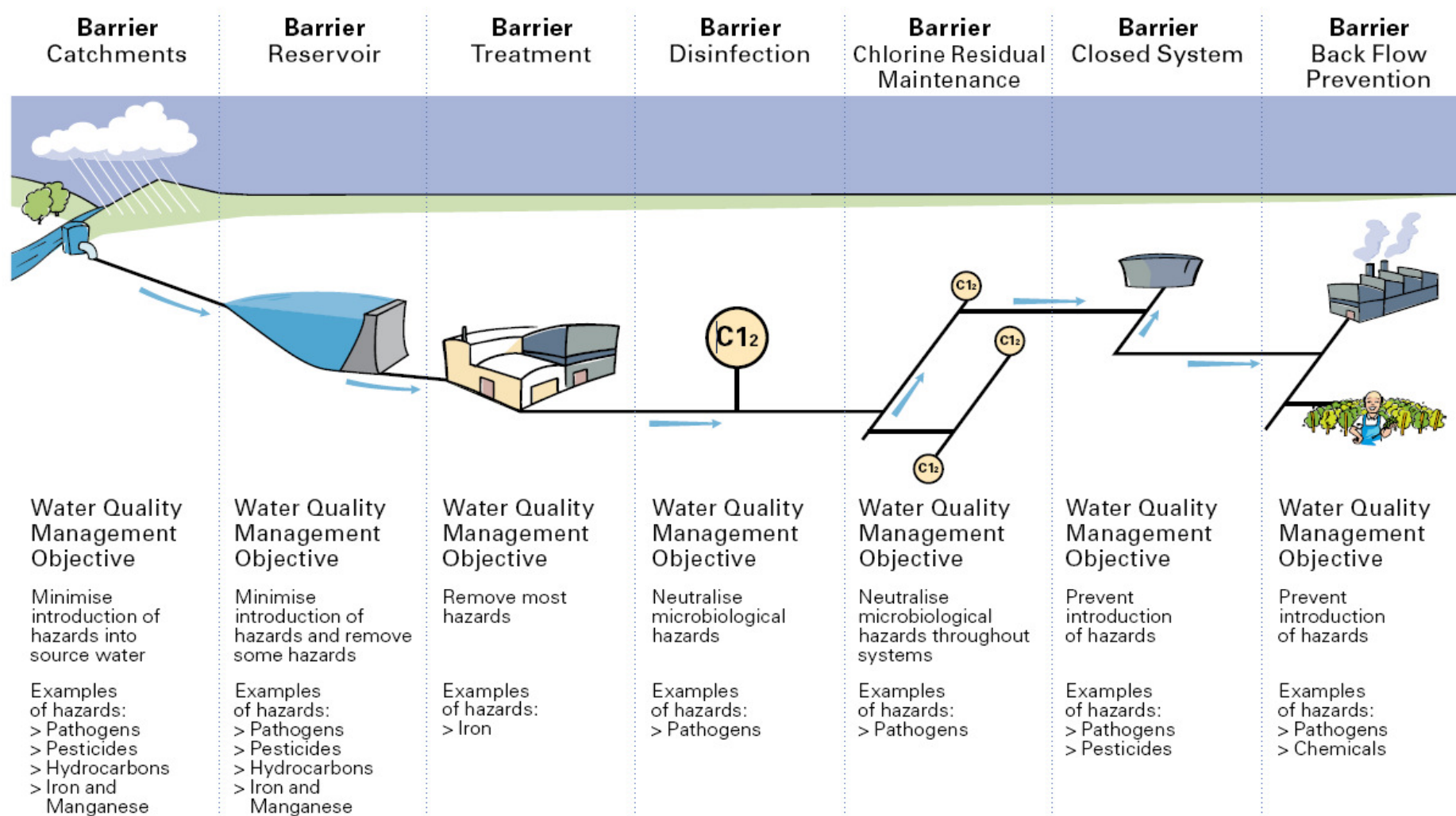


Figure 2-1 Illustrative, generalised water supply system – water quality management process (SA Water)

3. Catchment management approach




3.1 Overview

Rous Water's Vision for Emigrant Creek Catchment is:





"a healthy, productive catchment with fully functioning ecosystems that produces clean water"

In order to achieve this goal, ten elements were considered necessary for effective catchment management, as summarised in Table 3-1.




Table 3-1 Elements for effective catchment management.

Symbol	Element	Task	Current actions
	1. Prioritise catchment risks	Catchment risk assessment.	Completed during 2013 and summarised within this plan.
	2. Have effective legislation	Influence development, review and implementation of legislation, aiming at awareness and protection of water quality.	<i>Environmental Planning and Assessment Act 1991, Local Government Act 1993, Native Vegetation Act 2003, Noxious Weeds Act 1993, Pesticides Act 1999, Soil Conservation Act 1938, Water Management Act 2000, Protection of the Environment Operations Act 1997.</i> Supporting implementation guidelines: <i>Development Control in the Rous Water Supply Catchment Areas. Includes Development Control Plan for Development within the Rous Water Catchments. Rous Water On-site Wastewater Management Guidelines.</i>
	3. Have effective buffer zones	Protect and improve buffer zones around dams and weirs, and encourage riparian zone management.	Bush Regeneration Program that is focused on the establishment of vegetated buffer zones around all of the existing and proposed surface water sources. Note: in the case of Emigrant Creek Dam, the buffer is a relatively narrow 20m.

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Symbol	Element	Task	Current actions
	4. Work with stakeholders	Collaborative projects, working to common goals with other statutory bodies, clear communications with stakeholders.	<p>Healthy Catchments Program - aims to provide a small funding source to support strategic, on-ground activities. Commenced in 2004 and has involved projects on over 20 different properties. Currently suspended.</p> <p>Memorandum of Understanding with constituent Councils regarding the implementation of <i>Rous Water On-Site Wastewater Management Guidelines</i>, Service Level Agreement with Constituent Councils.</p>
	5. Monitor high risks areas	Monitoring source water quality, and catchment activities which pose risks.	Rous Water conducts environmental water quality monitoring in order to assess the overall health of our water catchment areas, and water quality trends.
	6. Foster research and disseminate findings	Build expertise in catchment management and risk assessment across all stakeholders.	<p>Southern Cross University is an active research partner.</p> <p>Publications: <i>Farm chemical risk assessment and associated monitoring program</i>.</p> <p>Research on biomanipulation, iron, manganese, nuisance phytoplankton, nutrients, and sediments at Emigrant Creek Dam.</p> <p>Research on terrestrial and aquatic biota of Emigrant Creek Dam.</p>
	7. Perform proactive surveillance	Observations to changes in catchment management or the occurrence of particular risks.	<p>Rous Water officers' conduct regular and random inspections of the catchment areas in order to identify any activity or conditions that present a risk to catchment integrity and water quality.</p> <p>A draft <i>Catchment Surveillance Inspections Program</i> has been prepared.</p>

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Symbol	Element	Task	Current actions
	8. Engage the community	Awareness of catchment management issues, leading to adaptation.	Rous Water has a full-time Community Education Officer, conducting a number of community awareness projects aimed at enhancing community understanding of the values of water, a key catchment management objective. For example, interpretive signage at the Emigrant Creek public access area, information sheets and media releases.
	9. Plan for extreme events or emergencies	Contingences for flooding, drought, bush fire or pollution spill.	Rous Water has developed a series of Emergency Management plans for various emergency scenarios. Of key relevance for water catchment areas is the <i>Contamination of Water Source Incident Management Plan</i> .
	10. Catchment risk mitigation actions	Actions taken to reduce risks to water quality within the catchment.	Rous Water Healthy Catchments Program Collaboration with other on-ground catchment programs.

3.2 Framework for catchment risk assessment

A framework was developed to assess catchment risks within the source water of the Rous water supply system. The framework was aligned to the *Framework for Management of Drinking Water Quality* as given in the ADWG which was in turn based on the Australian Risk Management Standard. The framework was developed to assist natural resource managers understand the risks to various water quality parameters within the catchment and reservoir and to provide an understanding of how these water quality parameters impact aquatic ecosystem health.

The framework incorporates the entire risk process, from establishing a team, to assessment and implementation. The process was designed to be reviewed every five years or if a specific need arises (e.g. a new hazard is identified). There are limitations in knowledge within this Plan, but with targeted research and investigations and additional monitoring in the future, reviews of this Plan will provide continual improvement.

The framework has been divided into seven main steps with the first six discussed in this Plan (refer Figure 3-1). The final step 'Implementation' requires significant future resources, investment and collaborative actions from catchment stakeholders.

One of the key components of the framework was to determine the level of risk of a given scenario or 'event' and where necessary determine actions designed to mitigate or

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minimise risks which could affect the management goal. In this case, that goal was the protection and improvement of source water quality and aquatic ecosystem health.

The risk level was determined by examining the likelihood and consequences of an event. The key to developing any risk analysis is establishing where the effect will be measured. Conventionally, risks are assessed at the endpoint (the end of the process where the impact occurs). Likelihood applies to the occurrence of the impact at the end-point.

For the protection of source water, assessing the likelihood of an event is complex, as the final impact (for example algal toxins in a reservoir) is the result of a sequence of events and conditions (e.g. runoff with high nutrient loads, minimal pollutant detention, reservoir dynamics and an algal bloom). Each of these events or conditions has its own probability of occurrence and severity of consequence. Each event in the chain depends on the previous event occurring in the first place. These conditional probabilities need to be factored into the determination of the final likelihood of the impact.

For this assessment, the endpoint was considered to be the point of source water extraction prior to drinking water treatment. As a result, the risk assessment was inclusive of the hazard occurring in the catchment, being transported to a watercourse and then traveling to the Emigrant Creek Dam.

The risk to the final user that consumes the drinking water product was not explicitly assessed in this document because a previous risk assessment considered those matters (Rous Water, 2012).

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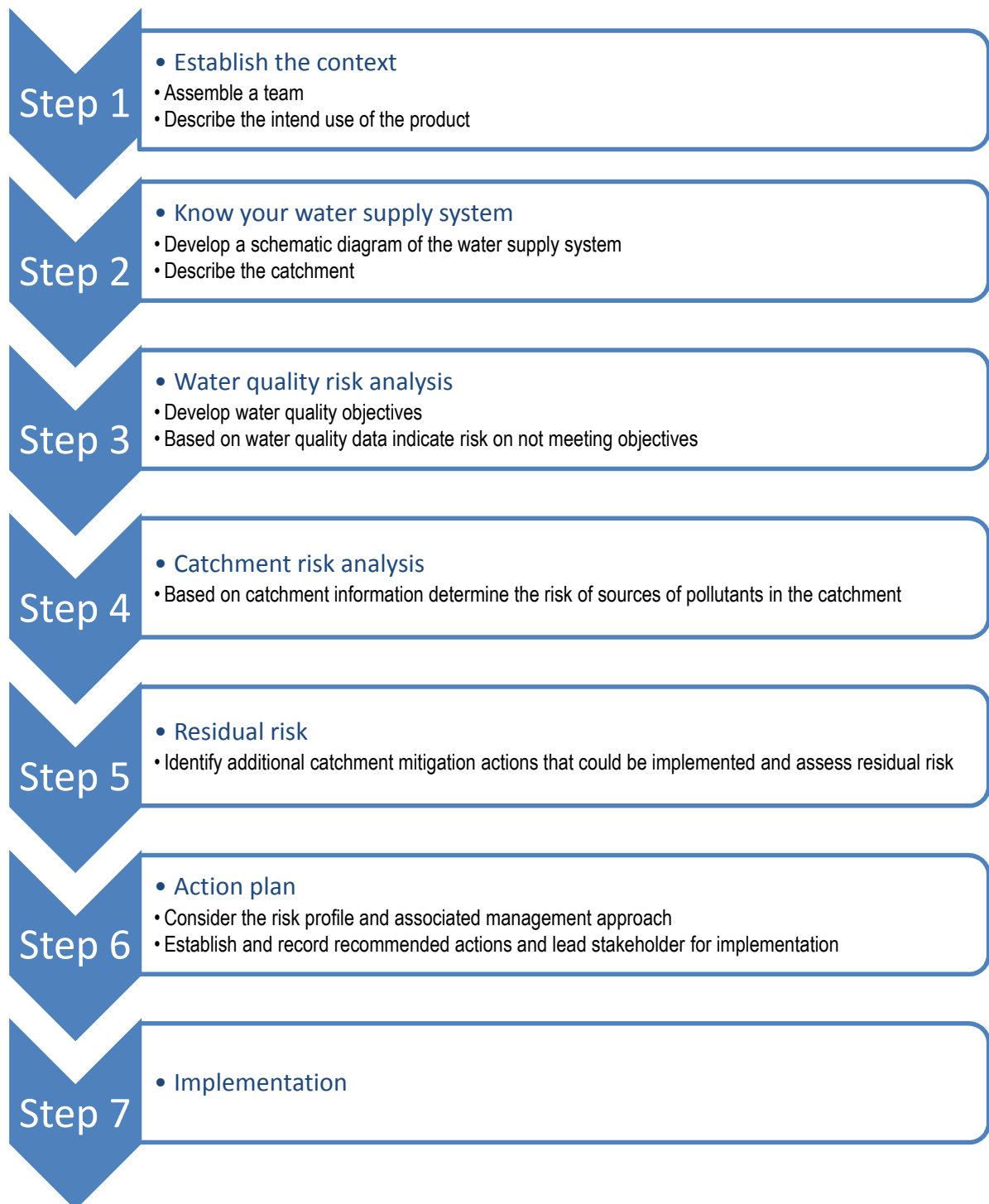


Figure 3-1 Framework for Catchment Risk Assessment as developed and adopted for this project

3.3 Establish the context

3.3.1 Assemble a team

A group of people with appropriate skills, knowledge and experience were brought together from Rous Water and catchment stakeholders (Table 3-2). This group was able to provide input into all the aspects of the risk framework, from developing source water quality objectives to potential mitigation actions. The knowledge and credibility of those people was of key importance, as the risk framework covered many disciplines and incorporated subjective information on risk levels, uncertainty and key pollutant processes. The team was assembled at a workshop which was held on the 13th and 14th of May, 2013. Further input was sought prior to and post the workshop to assemble background information and fill gaps in knowledge.

Table 3-2 Workshop attendees

Name	Job title	Affiliation
Mr John Bruce	OSSM Officer	Ballina Shire Council
Mr Simon Scott	Strategic Planner	Ballina Shire Council
Mr Andrew Swan	Strategic Engineer, Water and Sewer	Ballina Shire Council
Mr Christopher Bond	Inspector	NSW Fire and Rescue
Mr Geoff Sullivan	Senior Environmental Health Officer	North Coast Public Health Unit
Mr Bob Jarman	Community Support Officer	Northern Landcare Support Services
Mr Peter Lynch	Environment Protection Officer	Environment Protection Authority
Mr Jolyon Burnett	Chief Executive Officer	Australian Macadamia Society
Anthony Acret	Catchment Assets Manager	Rous Water
Wayne Franklin	Technical Services Director	Rous Water
Karla Billington	Consultant	Natural Logic
Dan Deere	Consultant	Water Futures

The Emigrant Creek Catchment is located within the Northern Rivers Catchment Management Authority (CMA) Region, and whilst the CMA is not active in the Emigrant

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Creek catchment, they do have educational material, such as Best Practice Management Guidelines which may be suitable for landholders.

3.3.2 Construct schematic diagram of water supply system and current operational procedures

Emigrant Creek Dam (nominal capacity 820 ML) was constructed in 1967 and 1968 to provide a water supply to Lennox Head and Ballina. It was the major supply for those areas before connection to the Rous Water supply system in 1996. The Dam now forms an integral part of the Regional Water Supply system and is operated when supply levels at Rocky Creek Dam drop to low levels. As a result the Dam is only operational periodically and can be turned off if the source water quality does not meet desirable treatment objectives.

The Emigrant Creek Water Treatment Plant (WTP) is capable of supplying up to 6 ML/day of treated water and was constructed in 2005. The following series of processes are used to remove pollutants from source water (refer Figure 3-2):

1. 'Raw' water is **pumped** from Emigrant Creek Dam to the water treatment plant.
2. **Chemical dosing.** At the pump station, potassium permanganate is added to the water to oxidise any dissolved manganese. Solid particles are formed through this process that can then be filtered out later in the process. Lime is then added to the water to raise the alkalinity. This prevents corrosion of copper pipes in the distribution system.
3. This 'dosed' raw water passes through the **balance tank** to allow for reaction time and for the water to stabilise before further treatment.
4. At the Membrane Filtration Plant, the water passes through microscopic **membrane filters** that remove solids and microscopic organisms including bacteria, Cryptosporidium and Giardia; improve colour and eliminate odour.
5. **Ozonation** takes place after membrane filtration in the ozone contact tank. The filtered water flows into a large concrete tank where ozone (O₃) is pumped into the water and has contact with the water for at least 10 minutes. This provides further disinfection of the water.
6. **Biologically activated carbon (BAC) filters** are located after the ozone contact tank to remove algal toxins, taste and odour causing compounds and herbicides/pesticides from the water.
7. Caustic Soda, Ammonia and Chlorine are added to the water to further correct the water properties and kill any bacteria or micro-organisms that may be in the water. Water is then placed in the **Clearwater balance tank** in order for disinfection to take place.
8. The water is then **pumped** to Knockrow Reservoir for storage and distribution to the community.
9. All the 'dirt' and chemicals removed during the filtration processes forms a **sludge** that is pumped into a wastewater collection tank, where it undergoes thickening and drying to make it suitable for disposal in Ballina Council's landfill. The excess water from the system is recycled back into the treatment process.

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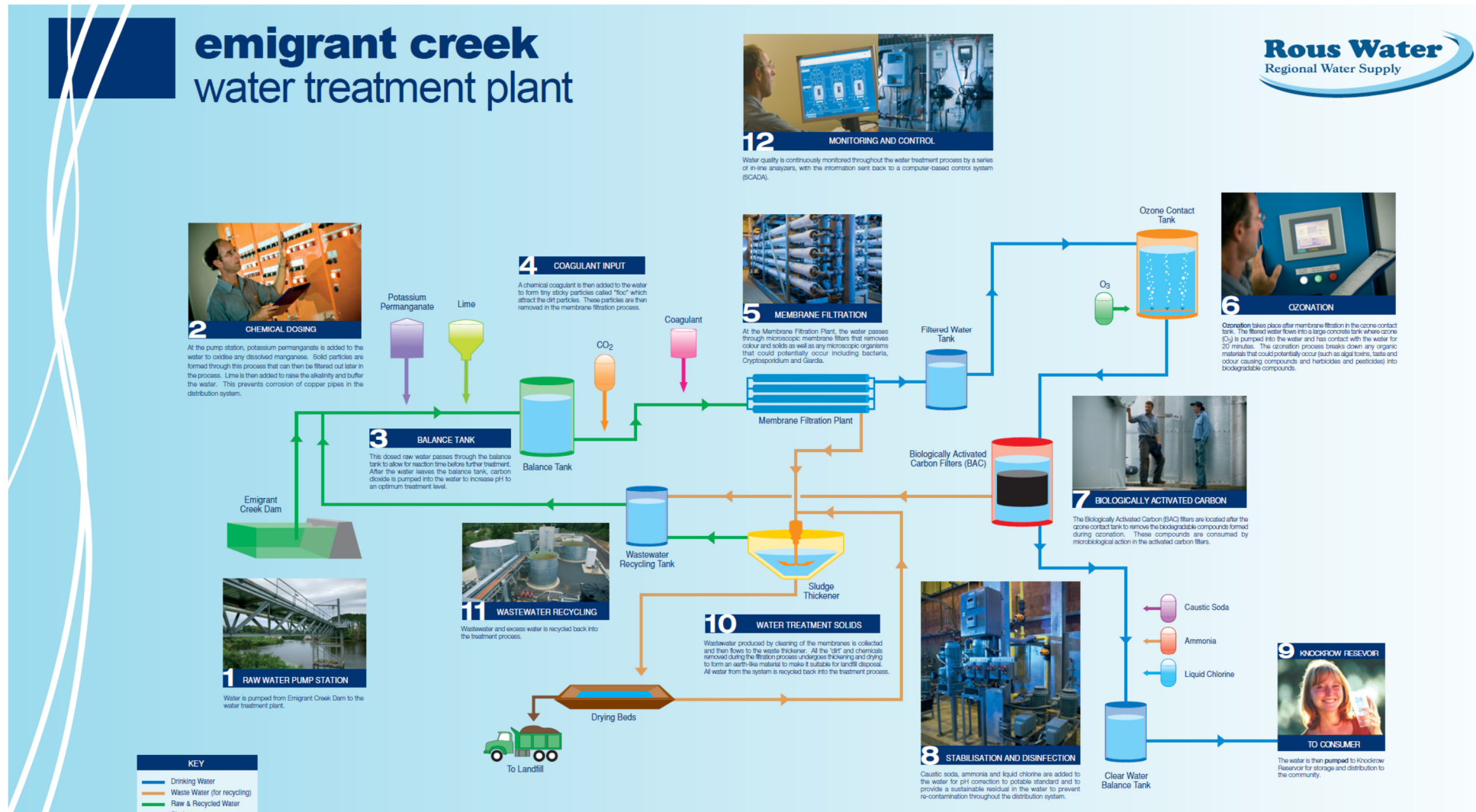


Figure 3-2 Schematic Emigrant Creek Water Treatment Plant

3.4 Know your catchment

3.4.1 Describe the catchment

The Emigrant Catchment has been described, looking at geomorphology, climate, land uses and significant point sources of pollution. This provides context for the risk analysis and communication with catchment managers. A generalised conceptual model of the catchment was sketched out by SKM during 2004 and provides a suitable overview (included here as Figure 3-3).

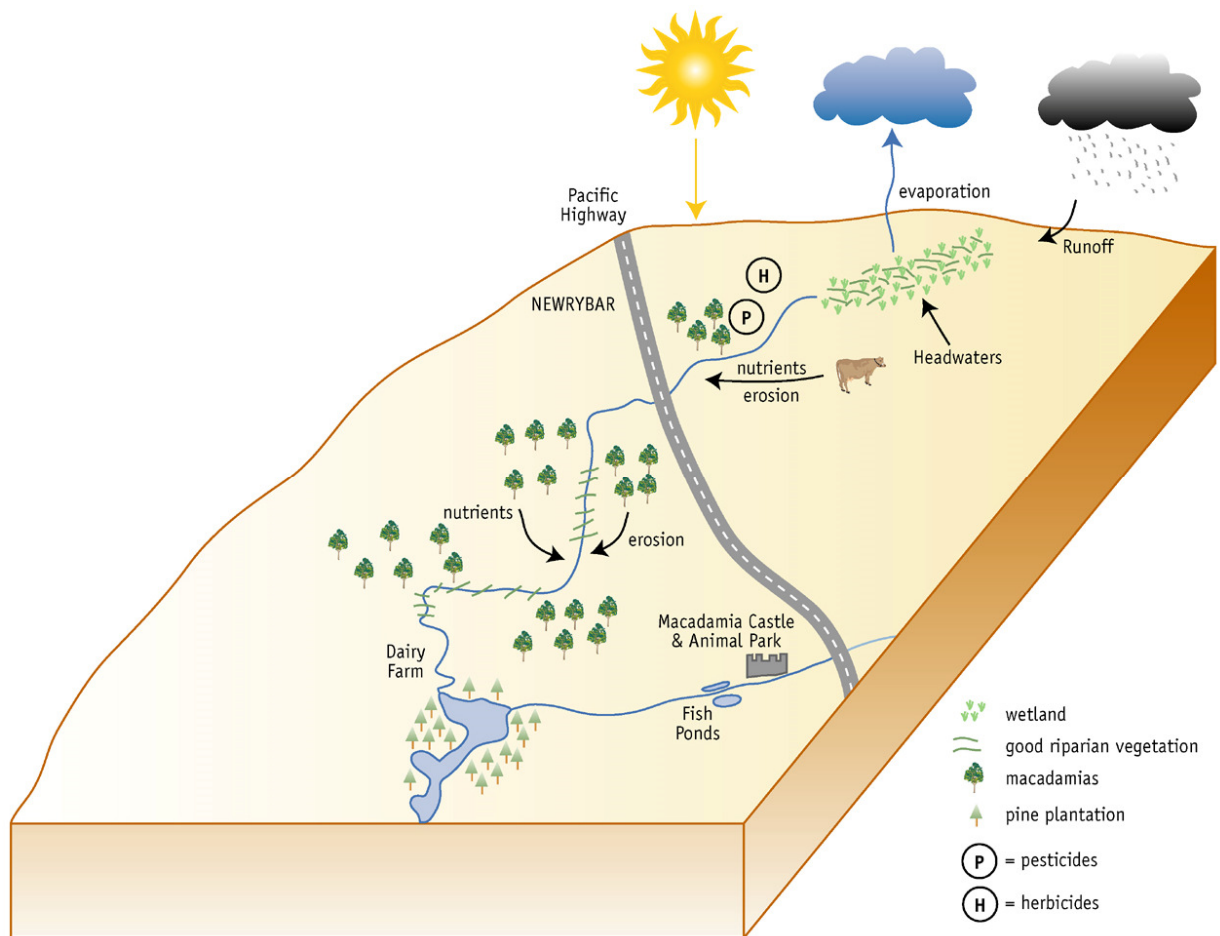


Figure 3-3 Conceptual model of Emigrant Creek Catchment (from SKM, 2004)

Location and size

The water catchment for Emigrant Creek Dam is 1,910 hectares (approximately 3 kilometres by 6.5 kilometres). It stretches from the Dam itself, which is located between Tintenbar and Knockrow, east of the Pacific Highway, and north past the village of Newrybar (refer Figure 3-5).

Emigrant Creek is a tributary of the lower reaches of the Richmond River Catchment, which has its estuary at Ballina, 13 km south east of the Dam. The creek travels 40 km between its headwaters and the estuary. The creek is tidal as far upstream as Tintenbar, which is about 4.5 km downstream of the dam wall.

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Geology

The catchment contains volcanic 'krasnozems' soils and 'basalt' rocks, mixed with older layers of sedimentary rocks (especially slate). The basalt was laid down by sequences of lava flows 20 million years ago from a huge ancient volcano, of which Mt Warning is its remaining core. The krasnozems soils are well-drained and poor-sealing clays. Infiltration of rainfall through these soils and open fractured basalt layers is significant and is connected to regional groundwater. Water which infiltrates these layers picks up minerals from the volcanic geology, producing water with high levels of iron and manganese.

Climate

The catchment area has a humid subtropical climate with mild winters and hot summers and a high rainfall. Rainfall data from Clunes has been examined (BOM site 058127). For the period of record (1962 to current) total annual rainfall varied between 1,136 mm (10th percentile) and 2,343 mm (90th percentile), with a median value of 1,451 mm.

Although rain falls throughout the year, there is a marked wet season in summer through to early autumn (January to April being the wettest). Late winter to spring is usually the driest period and is accompanied by rising evaporation rates. Dry periods with minimal rain are not uncommon and can last for several months.

Thunderstorms (or significant rainfall events) are common in the summer months. On average, the Richmond River catchment along with other north coast catchments are affected by cyclonic rain depressions once every couple of years. These events bring intense rainfall periods. For example:

- During 2010, 125 mm of rainfall was recorded on the 3rd of May at Clunes. These significant rainfall events can lead to erosion, overflow of on-site sewage management systems and catchment runoff which transports pollutants into watercourses. On a yearly basis, the Richmond River catchment produced <2% suspended sediment load during dry seasons, whereas about 75–91% of the yearly suspended sediments were exported during floods which occurred <5% of the year (Hossain and McConchie, 2002).
- A study conducted by Clark (1999) from November 1998 to February 1999 examined soil and nutrient loss from six Macadamia farms in the Richmond River catchment, including one farm in the Emigrant Creek Catchment. The farm within Emigrant Creek lost a total of 6.27 tonnes/Ha of soil following storm events during the study period, which contained 30.5 kg/Ha of total nitrogen and 18.0 kg/Ha of total phosphorus (SKM, 2004). It was concluded that fertiliser application probably contributed the majority of the exported nutrient load.

Inter-annual variation in pollutant load is also significant. Hossain and McConchie, 2002, state that "annual suspended sediment exports from the Richmond River Catchment varied more than 7-fold from dry year to wet year".

Flooding due to significant rainfall events have also occurred, such as the event in February 2001, when 200 to 400 mm of rainfall fell in the Upper Richmond Catchment. This flood led to a major fish kill in the lower catchment and the flooding of Lismore. Water quality analysis showed dissolved oxygen levels to be extremely low (0.03 mg/L) (Dawson, 2002).

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December and January are generally the hottest months with mean summer temperatures ranging between 27°C in the inland valleys and 20°C at higher altitudes. Winter temperatures rarely fall below 7°C.

Some extended periods of drought have been recorded within the catchment. In terms of impact on water resources and its extraction, the drought in 2002/2003 is thought to have been the worst on record (Office of Water, 2010).

Water resources and watercourses

The average annual discharge from the Richmond River is 1,920 GL. This annual discharge fluctuates significantly from as little as 15% to as much as 233% of the annual average discharge. This range illustrates the significant variability in flows between wet and dry years. Variability in streamflows also occurs between seasons and across the Richmond River Catchment. In the wetter months (summer to early autumn) flow can be six times greater than the dryer months (late winter to spring). Those streams located in the north and north-eastern part of the Richmond River Catchment (location of Emigrant Creek Catchment) where rainfalls are higher, exhibit markedly higher flows than those in the western and south-western part of the catchment which experiences lower rainfall. The ratio of runoff to rainfall is approximately 18 per cent which is slightly above average for coastal rivers (Office of Water, 2010).

The headwaters of Emigrant Creek are a wetland zone at the north end of the catchment. Groundwater discharge contributes base flows to the headwaters of tributaries of Emigrant Creek as well as along the creek and tributaries themselves. Groundwater carries essential dissolved nutrients and organic matter and can support algal and plant growth in overlying wetlands (DLWC, 2002 in SKM 2004). SKM, 2004, suggest that "The significance of the quantity and quality of water contributed from the headwaters to the waterbody of Emigrant Creek warrants protection of the headwater zone".

Watercourses that are cleared of riparian vegetation erode, depositing more sediment within the river system. The floodplain vegetation within the catchment has changed from wetland, native grasses and riparian vegetation, to pasture grasses, such as kikuyu, paspalum and couch, and sugar cane fields (Dawson, 2002).

Stock often have access to riparian areas for grazing. Previously, Barberie (1991) (in SKM, 2004) observed watercourses erosion along a small section of Emigrant Creek where dairy cattle used to access and cross the watercourse (refer Figure 3-4). It was also reported that while some of the watercourses along Emigrant Creek are well vegetated down to the water level, the upper reaches of the catchment and to the east of the Pacific Highway are not well vegetated.



Figure 3-4 Stock Crossing Emigrant Creek

The 2003 Healthy Rivers Commission Inquiry into the North Coast Rivers indicated that the Richmond, Tweed and Brunswick Rivers are in worse than 'average' condition. The Inquiry highlighted issues such as water extraction, a lack of riparian vegetation, bank erosion and poor water quality as the main reasons for this. Their findings build on the 1999 report by the then Department of Land and Water Conservation "The Richmond River Catchment – Stream Health Assessment Report", which identified that the Alstonville Area Subcatchment (where Emigrant Creek is located), has 19.7% of streams were in good health and 32.7% were in poor health.

Water allocations are regulated under the Water Sharing Plan - Richmond River Area Unregulated, Regulated and Alluvial Water Sources, 2010. The Water Plan provides for the environment by trying to mimic natural flow variability and provides allocations to catchment users (including Rous Water). Emigrant Creek Dam has a surface water licence entitlement of 2,620 ML, which is 33% of the total entitlement from the Alstonville Water Source. The secure yield¹ for Emigrant Creek Dam is 1,600ML/yr., which will be difficult to supply as demand grows and yields are reduced in dry years.

Rous Water owns and maintains a small buffer of land surrounding Emigrant Creek Dam – this buffer zone has an average width of approximately 20 m. This area (approximately 25 ha) is fenced with no public access and over the past 10 years has been progressively revegetated by Rous Water with the objective of establishing a self-sustaining sub-tropical rainforest buffer zone around the dam, so as to realise a range of ecological and water quality benefits. There are no recreational facilities surrounding the dam or public access to the dam itself, other than a viewing platform and short walk downstream of the

¹ Secure yield can be defined as the amount of water required so that the system can supply 80% of the normal demand (that is, a 20% reduction in average consumption) through a repeat of the worst drought on record. This secure yield allows for an allocation for environmental flow from the Emigrant Creek Dam (Ballina Shire Council, State of the Environment Report, 2012).

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dam (i.e. not in the catchment). The rainforest buffer zone surrounding the dam is maintained by the Rous Water bush regeneration team, whilst the dam itself and the public access area is managed by the Rous Water Dam Maintenance Officer.

Natural Ecosystems

The combination of volcanic geology and subtropical climate mean that the natural ecosystem that existed within the catchment at the time of European settlement was a dense cover of lowland subtropical riparian rainforest – known as the “Big Scrub”. As with much of the North Coast, most of the catchment was probably logged for timber between the mid-19th century and the early 20th century, before being almost completely cleared for grazing. No substantial remnants of rainforest are left within the actual catchment. Just 400 metres downstream from the dam, however, there is an area of remnant rainforest at Killen Falls Reserve. It provides an example of what the whole catchment area was probably like and a seed source for regeneration of native species. These small remnants constitute one of the most diverse ecosystems in NSW supporting more than 300 plant species and an equally diverse fauna population.

Some regrowth has occurred in the catchment since the 1970's. Secondary native rainforest species and the exotic Camphor Laurel are well represented, providing a useful nucleus for further succession and expansion of rainforest corridors throughout the catchment.

Hossain and McConchie, 2002 compare suspended sediment exports from subcatchments in the Richmond Catchment finding that “among the 3 major subcatchments, Richmond and Wilsons River subcatchments generated >93% of the suspended sediment load, while sediment exports from the Bungawalbin Creek subcatchment always remained low due to its flat topography and extensive forest coverage”, concluding that “land use changes in the Richmond River subcatchments indicate a possible increase of suspended sediment load of about 6-fold from their pristine condition”.

Land use and land management

The most dominant landuse within the catchment is pasture for stock grazing and plantation macadamias. In total there are 150 separate land titles in the catchment with the following landuses presented (refer Figure 3-5):

- Horticulture - including macadamias, coffee bananas and stone fruit.
- Broadscale grazing - approximately 500 head of cattle.
- Rural residential development, including some unofficial dwellings, and Newrybar village with a population of 461 in 2011.
- Tourism, including the Macadamia Castle and Animal Park, which is estimated to have 500 visitors per day under peak holiday conditions.
- Roads, including Friday Hut Road, the current Pacific Highway and the new alignment of the Pacific Highway (refer Figure 3-6).
- Plant nursery.
- Fuel bowser within Newrybar village.

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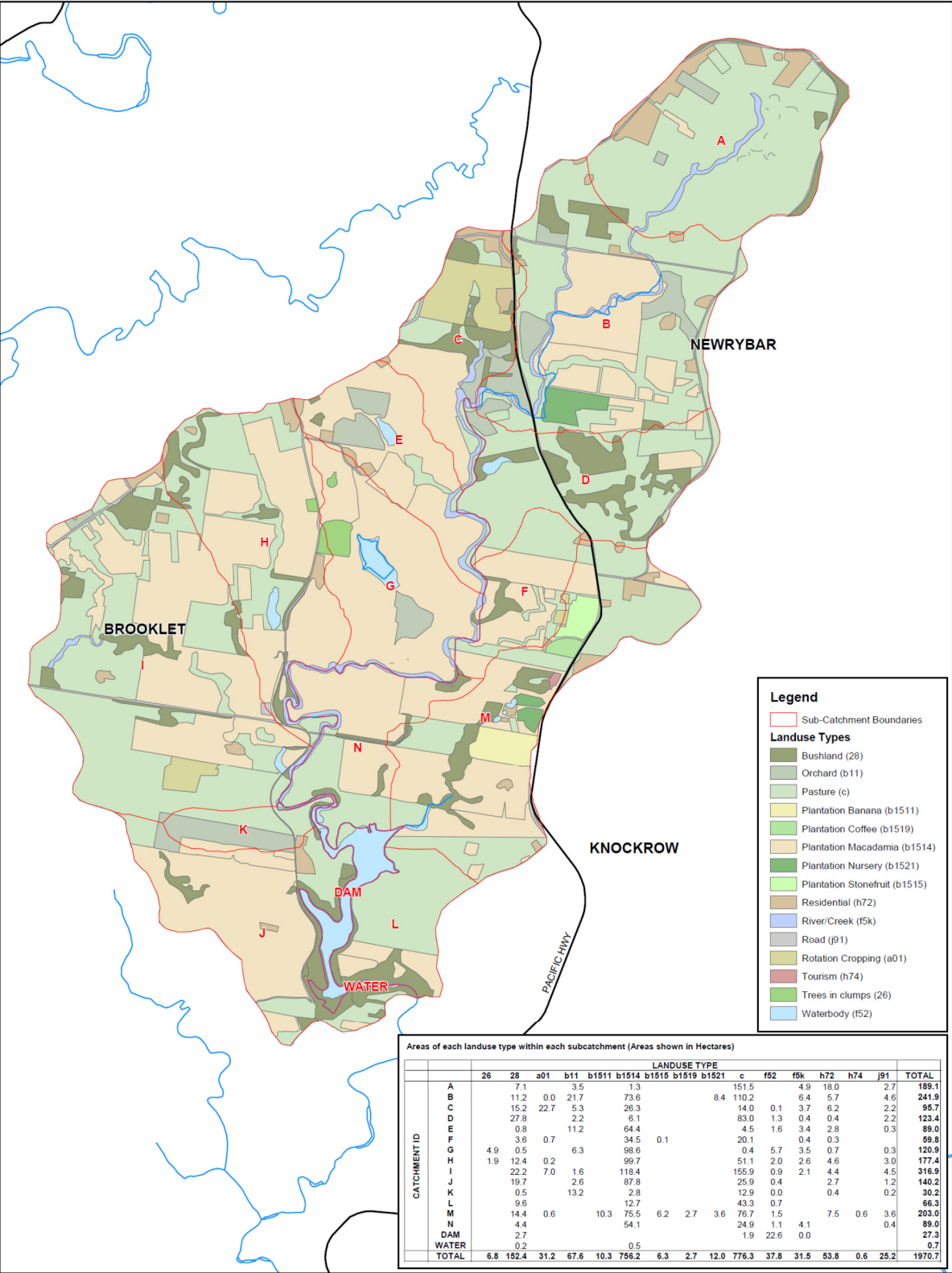


Figure 3-5 Landuse in the Emigrant Creek Catchment (Sourced SKM, 2004). Original image developed for larger viewing scale, obtainable from A. Acet.



Figure 3-6 New Pacific Highway construction works, showing potential sediment sources.

Grazing

Grazing is an extensive landuse within the catchment, encompassing approximately 40% of the catchment area. The majority of grazing properties are lifestyle properties (i.e. non-commercial) and are likely to be owned by people with limited farming experience. This lack of knowledge can lead to issues with regard to land management, such as over stocking, over grazing, degradation of watercourses and riparian zones. Alternatively, some lifestyle owners are highly committed to environmental outcomes and have the resources (time and funds) to invest in property improvements, including environmental outcomes.

Pathogen risks associated with stock access to watercourses have been cited in various studies (most recently in the Australian water catchment context by Billington et al., 2011). In relation to drinking water aspects of public health, the most important hazards arising from stock accessing waterways upstream of drinking water supply off-takes were *Cryptosporidium parvum*, *Salmonella* spp., *Campylobacter* spp. and pathogenic *Escherichia coli*.

It is well understood from such studies that excluding stock access to watercourses, partially in close proximity to water supply weirs and offtakes, will significantly reduce this risk. Catchment interventions that do not include physical exclusion of stock from watercourses are of little value. For instance, off stream watering and shade structures do little to reduce the risks posed by *C. parvum* in a typical grazing water supply catchment unless stock are also physically excluded from the watercourse. Furthermore, watercourse fencing needs to be continuous to be effective – gaps in the fencing will significantly reduce the effectiveness of this action.

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The overwhelming source of risk posed by *C. parvum* in typical grazing water supply catchments arises from pre-weaned calves and lambs. Removing calves and lambs from catchments, or housing them in fenced areas that are as hydrologically isolated as practicable from waterways that are associated with the supply of drinking water, can reduce risks due to this pathogen by approximately 3 log₁₀ – similar to the reductions achieved by water filtration or UV disinfection systems. This reveals that any intervention in a catchment that grazes both adult and juvenile stock but that only targets adult stock is all but futile with respect to *C. parvum* risk reduction. On the other hand, targeting only juvenile stock is the most cost-effective first intervention that should be applied.

Typical buffer distances used in riparian restoration programs of 5 to 10 m are quite adequate to entrap most pathogens and reduce their flow into watercourse by orders of magnitude. However, riparian buffers lose their effectiveness when overwhelmed by major floods or high intensity storms. Under such circumstances water harvesting from drinking water off-takes could potentially be avoided if at other times catchment management were the principal means of control of pathogens from stock

On-site sewage management systems

Rural residential buildings, houses within Newrybar village and the Macadamia Castle have on-site sewage management systems. There were an estimated 205 on-site sewage management systems (OSSMS) within the catchment in 2011², with concern of their failure and transport of pathogens and nutrients into waterways highlighted in several catchment studies (SKM, 2004, EGIS, 2002).

An audit of on-site sewage management systems conducted by Ballina Shire Council in 2011 surveyed 62% of land parcels in the Catchment, and found that 37% were not operating satisfactorily (25%) or not being established in accordance with Council requirements (12%). While Ballina Shire Council was able to conduct this audit (with Rous Water funding), there are limited resources to follow up failures to ensure compliance and no resources to conduct further risk-based audits within the Catchment, with inspections only occurring at the point of property sale or if a complaint has been made to Council (John Bruce, OSSM Officer, Ballina Shire Council, pers. comm.).

Council does not require landowners to regularly pump out their septic tanks, and has identified that there is a heightened risk with large-scale (> 10 EP) systems. Rous Water has developed *On-Site Wastewater Management Guidelines*, and has also established a Memorandum of Understanding (MoU) with its constituent Councils (excluding Byron Shire Council) as to how these guidelines shall be implemented.

Transport

Roads which intersect the catchment include Friday Hut Road, the current and new alignment of the Pacific Highway and Watsons Lane.

Car and truck accidents occur periodically along the Pacific Highway and several at where Emigrant Creek crosses along Friday Hut Road. It is understood that not all accidents are reported to RMS. Currently there is no written understanding between

² Estimate extrapolated from Ballina Council on-site sewage management system audit in 2011.

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Rous Water and the NSW Fire and Rescue, Police or EPA regarding notification of spills or complaints that may have water quality implications.

Redevelopment of the Pacific Highway has led to considerable erosion issues within the catchment, although it is considered that construction is complying with regulatory requirements and best management.

The EPA licenses the construction works and Rous Water and EPA sit on a management committee overseeing the environmental impacts of the project. Furthermore, although the upgrade of the Pacific Highway is a potential temporary source of pollutants, such as sediment, into the catchment (see e.g. Figure 3-6), the new road is potentially better able to capture spills than at present. For instance, historically the Highway did not have swales to capture and settle road run-off or spills and run-off entered into the catchment directly.

The new Pacific Highway includes considerable improvements with regard to the protection of water quality, with swales, sediment traps and other pollution control measures

Macadamia farming

In addition to land use, land management practices that are applied within individual enterprises are very important in influencing water quality risks. For example, previous macadamia farming practices have traditionally maintained a bare soil strip along the tree row, with herbicides use to maintain this condition. Bare soil along the tree row is conducive to soil degradation and erosion, where degradation is the predisposing condition to erosion (Firth *et al.*, 1988, in SKM, 2004).

Current best management practice (BMP), such as CMA *Best Practice Management Guidelines for Macadamia*, now advocates establishing, maintaining and managing ground cover in the orchard and managing surface run-off to reduce erosive forces.

It is considered that there has been a considerable level of adoption of BMP Guidelines within the macadamia industry in the Catchment, although there are issues with mature plantations, as groundcovers are unable to grow once the tree canopies shade out the ground (refer Figure 3-7). In this case orchard floor contouring and other soil conservation measures are recommended to minimise surface water runoff.

Prevention and minimisation of soil erosion will continue to be a key challenge and priority within the Emigrant Creek catchment. Higher turbidity levels places additional loading on water treatment processes, and can also be associated with other contaminants.

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Figure 3-7 Macadamia plantations. Top: developing plantation with suitable cover crop. Bottom: mature plantation with poor, shaded cover crop.

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Other pollutant sources

Other known sources of hazards within the catchment include:

- Three disused cattle tick dip sites one of which is located within the dam floor.
- Farms (approximately 20 to 30) likely to have 1000 to 5000 L diesel storage tanks.
- Previous practice of allowing water weed (e.g. hyacinth, *Cabomba*, *Salvinia*) to spread over most of the Emigrant Creek Dam area and then harvest and left to rot along the shoreline. This practice may have contributed to subsequent algal blooms due to leaching of phosphorus and organics back to the dam and increased light to the storage surface. Harvesting of a given weed has provided opportunities for other waterweeds to inundate the dam.

Future developments and planning

Future development within the Catchment presents a risk to water quality. Development within the catchment is regulated under the *Environmental Planning and Assessment Act 1991*, through the Local Environmental Plan (LEP). Following an extended review and renewal process, Ballina Shire Council prepared a new LEP as part of the NSW Government's planning reform process, which involved the adoption of a standardised planning instrument. However whilst the *Ballina LEP 2012* has recently been gazetted, the revised environmental land use zoning for the water catchment area of Emigrant Creek Dam was not included in the gazettal as the Department of Planning is conducting a review of environmental zones across the NSW North Coast. The catchment overlay and the associated clause (that aims to protect drinking water catchments by avoiding any adverse impacts of development on the quality and quantity of water entering drinking water storages) has not been included for the Emigrant Creek catchment due to this review process. Accordingly, the planning provisions from the *Ballina LEP 1987* continue to apply. Whilst the catchment overlay will be advantageous when gazetted, the land use table for the 7(c) zone from the *Ballina LEP 1987* does however provide for an appropriate range of catchment landuses and is considered acceptable during the intervening period.

Rous Water is not a mandatory referral body for development within the catchment, however applicable clauses in both the *Ballina LEP 1987* and the *Ballina LEP 2012* do provide for referral to Rous Water at Council's discretion. Under existing arrangements, Ballina Shire Council regularly consults Rous Water on matters of significance for the catchment, and therefore this will continue in the future.

Water Quality

Waterweed (e.g. hyacinth, cabomba, salvinia) infestation and the occurrence of cyanobacterial blooms in Emigrant Creek Dam are testimony to the fact that activities and processes within the catchment are contributing to eutrophication of surface waters. Rous Water has previously completed a 'Drinking Water Quality Risk Assessment Review' for the Emigrant Creek water catchment area in 2001 which identified specific water quality risks/hazards (Egis, 2001). Table 3-3 provides a summary of water quality risks for the Emigrant Creek water catchment area based on this original risk assessment (see Table 3-3). These risks will be further considered within the catchment risk analysis (refer to section 5).

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Table 3-3 Water quality risks for the Emigrant Creek water catchment area (EGIS, 2001).

Source of Risk	Most significant water quality parameter (hazard)
Septic tanks leakage and infiltration and dumping septic wastes in catchment.	<ul style="list-style-type: none"> • Microbial pathogens (e.g. viruses, protozoans)
Spraying and use of farm chemicals (spills).	<ul style="list-style-type: none"> • Pesticides, herbicides
Dairy in catchment (especially storm events)	<ul style="list-style-type: none"> • Microbial pathogens, algae nutrients
Existing and future development, agricultural activities (macadamia wash off/orchards/cattle/sheep/dead animals) and urban, industrial and tourism.	<ul style="list-style-type: none"> • Microbial pathogens (e.g. protozoans) • Algae nutrients
Algae, water weeds in Emigrant Creek dam.	<ul style="list-style-type: none"> • Taste and odour • Toxins
Access to Emigrant Creek dam; cattle crossing, road run off, recreation.	<ul style="list-style-type: none"> • Microbial pathogens, viruses
Human access; vandalism, defecation, erosion, fuel leaks, rubbish, etc.	<ul style="list-style-type: none"> • Public outrage • Microbial pathogens

4. Water quality risk assessment

4.1 Overview

In order to assess water quality risks, the professional judgement, knowledge and experience of the risk assessment team was used to assess the risk qualitatively. However, fortunately, Rous Water had a reasonable body of data available from which to undertake some quantitative analysis to provide an objective input to the risk assessment. This section of the CMP describes that water quality analysis and how it was used to input to the risk assessment.

In outline, the approach involves setting water quality objectives and then comparing measured water quality to those objectives.

4.2 Water quality objectives

Threats to the water supply system have been considered in several studies conducted by or for Rous Water (e.g. EGIS, 2002; SKM, 2004, Rous Water, 2012). These studies list water quality parameters (or hazards) that may cause or contribute to degraded water quality (Table 4-1).

By considering both the cause and effect of source water quality problems, communication and mitigation actions can be developed with water utilities and catchment managers. For example, while water utilities are focused on algal blooms and toxins, catchment managers act to minimise nutrient loads.

Where monitoring data was available, water quality objectives have been set for two goals: the protection of source water and aquatic ecosystems. Both goals are considered by Rous Water to be of fundamental importance.

By assessing the water quality data, the risk from various sources of hazards within the catchment have been taken into account. The water quality risk analysis has taken into consideration the available monitoring data collected within the catchment since 2004. This information was compared to water quality objectives to determine how often (likelihood) and by how much (relevant to the consideration of consequence) these objectives were exceeded.

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Table 4-1 Water quality parameters representing potential hazards

Water Quality Parameter	Reason for inclusion	Comment
<i>Cryptosporidium</i>	Risk to human health	No catchment data
<i>Giardia</i>	Risk to human health	No catchment data
<i>E. coli</i>	Indicator of human health risk	
Dissolved organic carbon (DOC)	Major cost in water treatment, increases chlorine demand, responsible for bi-product formation during disinfection	No catchment data
Fe (soluble)	Taste concerns	No catchment data
Mn (soluble)	Taste concerns	No catchment data
Nitrate	Effect on human health	Only considered as it directly relates to human health
Total nitrogen	Potential cause of algal blooms and biofilms	
Total Kjeldahl nitrogen (TKN)	Potential cause of algal blooms and biofilms	Limited catchment data n = 37
Oxidised Nitrogen	Potential cause of algal blooms and biofilms	
Total P	Potential cause of algal blooms and biofilms	
Ortho phosphorous	Potential cause of algal blooms and biofilms	
Salinity	Taste	
Turbidity	Indicator of cost of treatment and catchment health	
<i>Anabaena</i> spp.	Potential toxin production that affects human health only considered species that produce toxins which can impact human health	No catchment data
<i>Microcystis</i> spp.	Potential toxin production that affects human health only considered species, that produce toxins which can impact human health	No catchment data

4.3 Setting water quality objectives

Source water quality objectives were set under two conditions (refer Table 4-2):

1. A level that minimises the risk to the water supply system. This condition assumed that preventive management strategies (i.e. treatment processes) are in place and the barriers are performing as required. This level of risk requires the definition of **risk minimisation objectives**. Risk minimisation objectives were set by determining the most stringent water quality requirements within the system (usually related to direct health impacts on the consumer) and then working backwards through the system to see how much each barrier (WTP, reservoir, etc.,) could reduce the risk.
2. The second condition is a water quality objective that removes risks to the water supply. These water quality objectives were set at the lowest required/most conservative value within the entire water supply – usually the drinking water guideline, or at a value which would ensure that events such as algal blooms do not occur. In this case all current preventive management strategies and barriers were considered to have failed, and so the water quality objectives are the same throughout the system. This level of risk requires the definition of **risk removal objectives**. This water quality objectives allow assessment of maximum risk, as if there were a complete treatment plant failure, as recommended within the ADWG.

Aquatic ecosystem objectives have not been set locally and hence default ANZECC (2000) objectives for a lowland river have been used as a default. There was discussion within the stakeholder workshop, that these values may be too conservative for nutrient parameters, given that these catchments are naturally high in nutrients (due to geology) as demonstrated by the water quality data within pristine catchments such as Rocky Creek Catchment. While such suggestions were recognised, it was not within the scope of this CMP to develop alternative aquatic ecosystem objectives for Emigrant Creek Catchment. In summary, the water quality risk analysis compares monitoring data (where it exists) to water quality objectives to consider the water quality risk within the Emigrant Creek Catchment.

4.4 Monitoring data

Water quality data was collated from January 2004 at various locations within Emigrant Creek Catchment (refer Figure 4-1). Water quality parameters which were sampled regularly (although not at the same interval) are listed in Table 4-3.

4.5 Analysis

Statistics for the overall dataset have been provided. Then, from the data that exceeded the water quality objectives (the data subset), to statistics were determined, as follows:

- The percentage of samples that exceeded water quality objectives was calculated to provide an indication of likelihood.
- The median value of the data subset was calculated to help support an assessment of the consequence of that exceedance.

This analysis provided an indication of water quality risk (Table 4-3). However, it was appreciated that monitoring programs have limitations and confidence in monitoring results are subject to qualification.

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Table 4-2 Risk removal and risk minimisation water quality objectives

Water quality parameter	Risk removal objectives	Risk minimisation objectives	Aquatic ecosystem objective (ANZECC – lowland rivers)
pH	5.7 – 6.5	6.5 – 8.5	6.5 – 8.0
Conductivity	< 500 µS/cm	< 800 µS/cm	125 – 2,200 µS/cm
Turbidity	< 10 NTU	< 20 NTU	6–50 NTU
Temperature	NA	Na	20 th – 80 th percentile 16°C – 23 °C
Dissolved oxygen	NA	NA	> 6 mg/L
Nitrogen - total		< 0.35 mg/L	< 0.35 mg/L
Nitrogen - oxidised			0.03 mg/L
Nitrogen – total Kjeldahl			0.32 mg/L
Phosphorus – total	0.02 mg/L	< 0.025 mg/L	< 0.025 mg/L
Phosphorus – ortho	< 0.01 mg/L	< 0.02 mg/L	< 0.02 mg/L
<i>E. coli</i>	0	< 500	NA
Blue-green algae	< 500 algal cells/mL	> 2000 algal cells/mL: immediate action indicated; seek expert advice. NB: >6500 algal cells/mL: seek advice from health authority. >15 000 algal cells/mL: may not be used for potable supply except with full water treatment, which incorporates filtration and activated carbon.	
Chlorophyll-a			0.005 mg/L
Soluble iron	0.1 mg/L	0.3 mg/L	
Soluble manganese	0.03 mg/L	0.05 mg/L	

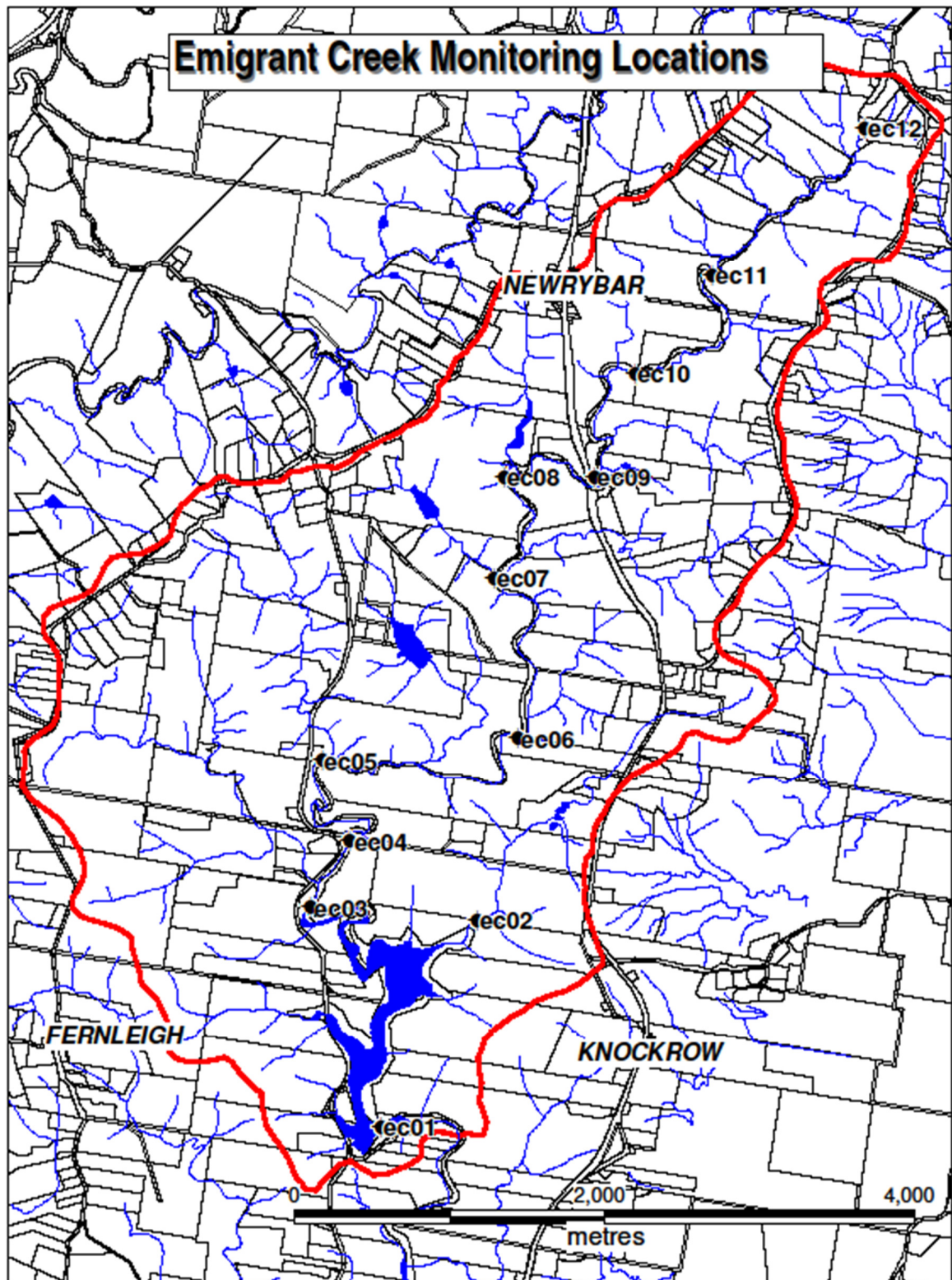


Figure 4-1 Monitoring locations - Emigrant Creek (sourced Rous Water)

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Table 4-3 Water quality data summary. Orange and red shading represent moderate and large exceedances, respectively.

Parameter tested	Results				Risk removal			Risk minimisation			ANZECC		
	Number of samples	20th percentile	50th percentile	80th percentile	Risk removal objective	Percentage exceedance	median exceedance	Risk minimisation objective	Percentage exceedance	median exceedance	ANZECC objective	Percentage exceedance	median exceedance value
pH	395	6.7	6.8	6.9	5.7 - 6.5	95%	6.8	6.5 - 8.5	5%	6.4	6.5-8.0	5%	6.4
Electrical conductivity (µS/cm)	388	94	99	105	500	0%	-	800	0%	-	125-2000	0%	-
Turbidity (NTU)	978	7.6	9.6	13.9	< 10 NTU	46%	13.2	< 15 NTU	10%	28.25	6 and 50	7%	63.3
Temperature (°C)	997	15.9	20	23.1	-	-	-	-	-	-	16 and 23	20%	24.1
Dissolved oxygen (mg/L)	983	6.0	7.1	8.2	-	-	-	-	-	-	> 6	19%	5.13
Nitrogen (oxidised) (mg/L)	37	0.35	0.46	0.59	-	-	-	-	-	-	<0.04	100%	0.46
Nitrogen (total Kjeldahl) (mg/L)	36	0.2	0.2	0.3	-	-	-	-	-	-	<0.322	6%	0.5
Nitrogen (total) (mg/L)	187	0.43	0.59	0.86	-	-	-	<0.35	91%	0.62	<0.35	91%	0.62
Phosphorus (total) (mg/L)	168	0.05	0.08	0.16	<0.02	93%	0.087	<0.025	93%	0.087	<0.025	93%	0.087
Phosphorus (ortho) (mg/L)	166	0.01	0.02	0.05	<0.01	71%	0.028	<0.02	55%	0.035	<0.02	55%	0.035
Chlorophyll 'a' (mg/L)	58	0	3	6.6	-	-	-	-	-	-	<0.005	74%	4
<i>E. coli</i> (MPN or CFU per 100 ml)	63	217	560	2,329	0	100%	560	<500	56%	1310	-	-	-

4.6 Discussion of water quality risk

4.6.1 Turbidity

The risk minimisation objective for turbidity has been set at 15 NTU for the source water, with the WTP having a shut off limit of 30 NTU.

For the period January 2004 to February 2013 the water quality objective for turbidity was exceeded on 15% of sampling occasions (n=978 samples). The median turbidity value for the complete dataset was 8.9 NTU, while the median value for the data subset which exceeded the objective was 32.1 NTU (or approximately twice the objective value for risk minimisation).

Turbidity has an ANZECC objective of less than 6 NTU under the ANZECC lowland rivers – with highly turbid water reducing light penetration and elevated sediment loads smoothing aquatic organisms. This more stringent objective value was exceeded on 84% of sampling occasions, with a median value for the data subset of 9.5 NTU. Thus while turbidity values nearly always exceeded the ANZECC water quality objective, the exceedance is generally not considerably higher than the objective value, although peak values have occurred with major run-off events (e.g. 60 to 70 NTU).

4.6.2 *E. coli*

The risk minimisation objective for *E. coli* was set at 500 MPN or CFU per 100 ml. For the period January 2004 to February 2013 the water quality objective for *E. coli* was exceeded on 56% of sampling occasions (n=63 samples). The median *E. coli* value for the complete dataset was 560 counts per 100 ml, whilst the median value for the data subset which exceeded the objective was 1,310 counts per 100 ml (or approximately three times the objective value for risk minimisation). While this exceedance may seem considerable, pathogen risk is usually measured on a log scale with mean values exceeding 5,000 being common for partially impacted catchments, or exceeding 15,000 for extensive agriculture during wet weather events (CRC, 2004). It is noteworthy that incidents of high *E. coli* (> 5,000) have been detected on seven sampling occasions, although on all but two occasions the WTP was most likely off as the source water turbidity at the time exceeded 30 NTU.

4.6.3 Nutrients

Algal toxins, infestation of water weeds and biofilms within the distribution system are of concern to Rous Water. Water quality objective from the ANZECC Water Quality Guidelines are used to assess nutrient content of the source water which contributes to these risks. In comparison to the ANZECC lowland rivers water quality objectives, nutrients within the Emigrant Creek are consistently higher than the objective values, contributing to eutrophication of surface waters within the catchment and the Emigrant Creek Dam (as observed through algal blooms and infestation of water weed).

Nitrogen

Nitrogen is an essential nutrient for biota and when in excess can stimulate the growth of aquatic plants including higher plants or macrophytes such as water hyacinth and microscopic plants or algae such as cyanobacteria. Total Nitrogen (TN) encompasses all

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forms of nitrogen including inorganic forms such as nitrate, nitrite and ammonia plus organic forms such as urea.

For the period January 2004 to February 2013 the water quality objective for TN was exceeded on 91% of sampling occasions (n=187 samples). The median TN concentration for the complete dataset was 0.59 mg/L, while the average concentration for the data subset which exceeded the objective of less than 0.35 mg/L was 0.62 mg/L (or twice the objective value).

Oxidised nitrogen (NO_x)

NO_x includes the species nitrate plus nitrite. Nitrate can be an indicator of fertiliser contamination from agricultural runoff and can contribute to eutrophication. Nitrate is normally in low concentrations in surface waters but can be in elevated concentrations in groundwater. Elevated nitrate can also be found in sewage effluent as a result of the oxidation of ammonia. Nitrogen in the form of NO_x is readily available for plant uptake and can contribute to excessive plant growth including algal blooms. For the purposes of this assessment, NO_x concentrations have been calculated as the sum of total Kjeldahl nitrogen plus nitrate.

For the period January 2004 to February 2013 the water quality objective for NO_x was exceeded on 100% of sampling occasions (n=37 samples). The median NO_x concentration for the complete dataset was 0.46 mg/L, which exceeds the water quality objective of less than 0.04 mg/L by approximately 10 times.

Total phosphorus

Phosphorus is also an essential nutrient for biota and when in excess can stimulate the growth of higher plants and microscopic plants or algae. Both phosphorus and nitrogen can limit primary productivity in natural waters. Phosphorus occurs in water in both dissolved and particulate forms. Particulate forms include phosphorus bound in organic compounds or adsorbed to suspended particulate matter including sediment particles. Dissolved phosphorus includes inorganic orthophosphate which is readily available for plant uptake. Total phosphorus (TP) is a measure of both the dissolved and particulate forms and can occur in elevated concentrations due to a variety anthropogenic and catchment disturbances ranging from the discharge of sewage effluent to poor watercourse bank management.

For the period January 2004 to February 2013 the water quality objective for TP was exceeded on 93% of sampling occasions (n=168 samples). The median TP concentration for the complete dataset was 0.08 mg/L, while the median concentration for the data subset which exceeded the objective of less than 0.025 mg/L was 0.087 mg/L (or approximately 2.5 times the objective value).

Soluble phosphorus

Rous Water Laboratory measures orthophosphate as soluble phosphorus whilst ANZECC/ARMCANZ (2000) provide a default trigger value for Filterable Reactive Phosphorus (FRP). Soluble phosphorus is a bioavailable form of phosphorus and for the purposes of the current assessment, data from Emigrant Creek for soluble phosphorus is compared to the ANZECC/ARMCANZ (2000) default trigger value for FRP.

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For the period January 2004 to February 2013 the water quality objective for soluble phosphorus concentrations was exceeded on 55% of sampling occasions (n=166 samples). The median concentration for the complete dataset was 0.025 mg/L, while the median concentration for the data subset which exceeded the objective of less than 0.002 mg/L was 0.035 mg/L (or approximately 50% greater than the objective value).

A similar water quality assessment was completed by SKM in 2004 for the data period 1997 to 2000. Exceedance percentages have been compared with the above findings (based on the same water quality objectives as provided in SKM, 2004) and it was found that the percentage of samples which exceeded the water quality objective has generally increased. For example, the water quality objective for TN was exceeded 3% to 16% of the time within the SKM report (depending of sample location) whilst in this assessment 67% of samples exceeded the TN objective value. Similarly, the water quality objective for TP was exceeded 11% to 33% of the time within the SKM report (depending of sample location) whilst in this assessment 75% of samples exceeded the TP objective value. While the data period from 1997 to 2000 is limited and hence this change in nutrient concentration could reflect variations in rainfall/runoff, it may also represent changes in pollution sources and an increase in the eutrophication status of the resource.

4.6.4 Dissolved oxygen

The concentration of dissolved oxygen (DO) is an important indicator of the health of the aquatic ecosystem. Persistently low dissolved oxygen will harm most aquatic life and will have acute effects. The dissolved oxygen (DO) concentration measured in a waterbody reflects the equilibrium between oxygen-consuming processes (e.g. respiration) and oxygen-releasing processes (e.g. photosynthesis and the physical transfer of oxygen from the atmosphere to the waterbody) (ANZECC/ARMCANZ, 2006).

The DO concentration in a waterbody is highly dependent on temperature, salinity, biological activity (microbial and primary production), degradation of organic matter and rate of transfer from the atmosphere (ANZECC/ARMCANZ, 2006). Many toxic compounds such as some metals become increasingly toxic at reduced DO concentrations.

For the period January 2004 to February 2013 the water quality objective for DO concentrations was exceeded on 19% of sampling occasions (n=983 samples). The median concentration for the complete dataset was 7.1 mg/L, whilst the median concentration for the data subset which was less than the objective of greater than 6 mg/L was 5.1 mg/L.

4.7 Limitations of the water quality data

4.7.1 Parameters not sampled

Within the water quality dataset there is no substantial monitoring data for some parameters which may be considered water quality hazards (iron, manganese, dissolved organic carbon). Therefore, the risk assessment for the CMP is based as much on the professional judgement, knowledge and experience of the risk assessment team which was used to assess the risk qualitatively, as described in the next major section of this report.

4.7.2 Uncertainty

Level of certainty in monitoring outcomes may be broadly grouped into: 'variability' and 'knowledge uncertainty' (Commission on Geosciences, Environment and Resources, 2000). The ADWG Framework, explores these concepts stating:

"Variability represents the true differences that can exist in the specific values of parameters that contribute to a risk such as contaminant concentrations over time and space, flow, number of people exposed etc. These characteristics contribute to uncertainty because they vary and we usually cannot describe them completely because we have incomplete monitoring data and there is no single correct answer that will cover all circumstances.

Knowledge uncertainty, however, represents our inadequate state of knowledge that exists in the values of parameters measured. Knowledge uncertainty may be reflected in a lack of assurance that methods are accurately measuring what we intend them to or in a lack of understanding of how a process works."

The ADWG Framework concludes that:

"There is value in being able to distinguish the relative impacts of variability and knowledge uncertainty. Variability cannot be reduced by measuring it more accurately. However, by better characterising variability, the nature of a hazard and thereby, the dimensions of the risk, can be better understood. Understanding the role of variability in contributing to uncertainty may lead to actions to change a system to reduce its variability, e.g. increase reservoir storage times to minimise fluctuations in water quality.

In contrast, knowledge uncertainty can be reduced by additional measurement and research. The increased understanding from reducing knowledge uncertainty can provide greater assurance that the preventive measures being considered will achieve their intended purpose. This requirement supports the need for a research capability within the water industry."

To reflect this, a certainty level was assigned to each analysis. The level assigned ranged from a 'low' level of certainty where monitoring data was very limited and was not considered to represent the natural variation, to 'very high', where documented, directly relatable data was available. The results are presented in the next section of the report and summarised in Table 5-5.

5. Catchment risk assessment

5.1 Methodology overview

Activities within the catchment are often the first in a chain of events that can present a risk to the water supply system. As a result, the catchment and its management are a critical barrier for the protection of source water quality and aquatic ecosystem health. In the Emigrant Creek Catchment there are several diffuse and point sources that could pollute watercourses.

The catchment risk analysis methodology was undertaken as a stakeholder workshop. The process first involved determining the risk of the pollution sources that affect water quality given the current state of the mitigation actions that are in place, and then considering the residual risk of providing improved mitigation actions. The results of the risk assessment were captured using an Excel™ workbook.

5.2 Hazard identification

Each catchment hazard requires a process or event to occur to create an adverse outcome for the water supply system. Knowledge of these hazardous events, and the land use activities (source) with which each is associated, was used to determine likelihood and consequence of such risks. For example, pathogens (**hazard**) are found in septic tanks (**source**), and pollute the water due to the surfacing or subsurface movement of poorly treated effluent to a watercourse and transport to the Emigrant Creek Dam (**hazardous event**). Examples of important hazardous events include:

- Routine discharge.
- Event discharge (e.g. storm event).
- Overflow.
- Erosion.
- Spill.

These three parameters: *hazard*, *source* and *hazardous event* were used to provide the context for each risk analysis and were combined together in a draft risk assessment worksheet as part of the initial hazard identification (see illustration in Table 5-1). For efficiency during the workshop, the hazard identification was drafted by the consultants prior to the workshop, and entered into the risk assessment template. Note that it was possible to identify additional hazards during the workshop.

Table 5-1 Example of Hazard Identification

Hazard	Source	Hazardous Event
Pathogens	Dairy	Runoff transports manure from pasture to the watercourse.
	Dairy	Overflow from effluent ponds is transported to the watercourse.
	Septic tanks	Discharge from septic tanks is transported to the watercourse.

5.3 Current risk

The so-termed **current risk** was first determined by examining the likelihood and consequence of a particular hazardous event occurring. For the purpose of the catchment risk analysis the **endpoint** of the risk assessment was defined as the interface between the catchment (inclusive of the Emigrant Creek Dam) and the point of offtake for water treatment. At this point the relative risk of each source of pollution was assessed, taking into account the current versus the desirable performance of catchment mitigation measures within the context of the entire water supply system.

5.4 Residual risk

Significant current risks were reviewed further to consider possible additional catchment management actions that would further mitigate the risk to the water supply system. The risks were reassessed to consider the potential change if these additional catchment management activities were implemented. The resulting risk estimates were termed the **residual risk**.

5.5 Risk rating criteria

The classification criteria used to rate likelihood, consequence, risk and uncertainty are given as follows.

5.5.1 Likelihood

Five classes of likelihood were used, largely as described in the ADWG, ranging from (E) rare to (A) almost certain (Table 5-2).

Qualitative measures used to assess the attribute of likelihood were: proximity of source to watercourse; transport capability (runoff); and expected occurrence of hazardous event.

5.5.2 Consequence

Five classes of consequence were used, loosely based on that described in the ADWG, ranging from (1) insignificant to (5) catastrophic (refer Table 5-3).

Qualitative measures used to assess the attribute of consequence were: number of source type; discharge rate from activity; and level of impact (e.g. toxicity).

5.5.3 Risk

The two classes of likelihood and consequence were combined to determine risk based on the ADWG semi-quantitative risk matrix (Table 5-4).

5.5.4 Uncertainty

The analysis provided a qualitative assessment of risk. It is appreciated that knowledge can be limited and hence the certainty of the risk result can vary (refer section 4.7.2). To account for this, a level of uncertainty was assigned within the stakeholder workshop for each hazardous event (Table 5-5).

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Table 5-2. Likelihood rating system (largely based on ADWG)

Level	Likelihood	Description	Frequency
A	Almost certain	Is expected to occur in most circumstances	> 90%
B	Likely	Will probably occur in most circumstances	70-90%
C	Moderate	Might occur or should occur at some time	30 – 70%
D	Unlikely	Could occur at some time	10 –30%
E	Rare	May occur only in exceptional circumstances	<10%

Table 5-3. Consequence rating system (loosely adapted from ADWG)

Level	Consequence	Description source water	Description aquatic ecosystem
1	Insignificant	Risk in catchment leads to circumstance of isolated exceedence of aesthetic parameter with little or no disruption to normal operation.	Insignificant impact on aquatic ecosystem, including flora, fauna and habitat.
2	Minor	Risk in catchment leads to circumstance of potential local aesthetic, isolated exceedence of chronic health parameter.	Minor localized impacts but without longer-term impact on aquatic ecosystems.
3	Moderate	Risk in catchment leads to circumstance of potential widespread aesthetic impact or repeated breach of chronic health parameter.	Significant localized impacts but without longer-term impact on aquatic ecosystems, and/or short term and localized impacts on water quality.
4	Major	Risk in catchment leads to circumstance of potential acute health impact, no declared outbreak expected.	Damage to a moderate portion of the aquatic ecosystem resulting in moderate impacts on aquatic populations and habitats and /or long-term impact on water quality.
5	Catastrophic	Risk in catchment leads to circumstance of potential acute health impact, declared outbreak expected.	Damage to an extensive portion of aquatic ecosystem resulting in severe impacts on aquatic populations and habitats and /or long-term impact on water quality.

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Table 5-4 Risk matrix (as per ADWG)

Likelihood	Consequences				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A Almost certain	Moderate	High	Very high	Very high	Very high
B Likely	Moderate	High	High	Very high	Very high
C Possible	Low	Moderate	High	Very high	Very high
D Unlikely	Low	Low	Moderate	High	Very high
E Rare	Low	Low	Moderate	High	High

Table 5-5 Uncertainty matrix

Level	Uncertainty	Description
1	Uncertain	Perception only, no information or knowledge the forms the basis of the opinion.
2	Estimate	Perception based, some information known on process, but not directly relevant to local region, or information at a regional level has significant limitations.
3	Reliable	Limited information is known, information could relate to cause or effect. Expert knowledge would lead to this outcome - some differences in opinion may occur.
4	Confident	Information is known, information could relate to cause or effect. Process has been described and documented at a regional level. Experts can verify this position.
5	Certain	Information is known and well represents the specific nature of the process, information relates to cause and effect. Process has been described and documented at a regional level. Experts would readily agree on this position.

5.6 Risk assessment results

Fifty hazard/hazardous event combinations were assessed across the themes of roads, stock grazing, residential, horticulture, on-site sewage and other. Eight high risks, 16 medium risks and 25 low risks were identified (taking into account the current mitigation actions). Results of the risk assessment were captured using an Excel™ workbook (refer Appendix A) with an extract example presented in Table 5-6.

5.7 Discussion of catchment risks

The whole risk assessment output is given in the separate catchment risk assessment workbook. For brevity, the current risks that were considered to be high during the workshop are summarised in Figure 5-1 along with the potential additional mitigation actions and the calculated estimated risk (assuming that the recommended actions are fully implemented).

A high level risk is likely to continue to be in place with regard to the construction of the new Pacific Highway, until such time as construction finishes, and possibly, albeit indirectly, for some time afterwards, as material washed in during construction continues to move through the catchment and dam. Whilst sediment traps are in place, it is likely that these will be overwhelmed (i.e. each time the design capacity of 90%ile five-day event capture capacity (approx. 80 mm event) is breached. During these large run-off events, large quantities of suspended sediment and nutrients will be transported through the catchment and will settle within watercourses. Future run-off events will remobilise this material and it will over time progressively move toward Emigrant Creek Dam. It is noted that this is a construction risk and once the highway is complete (and associated sediment has been transported through the catchment), this risk will be alleviated and associated pollution risks with regard to the current Pacific Highway will be reduced, as the new highway has significantly better pollution control mechanisms than at present.

All other risks were estimated to be capable of being reduced to medium or low with the implementation of additional mitigation actions by either Rous Water or by the identified catchment stakeholder (as described in the in the Action Plan, given in the following section of the CMP). Note, however, that risks will not usually be reducible based on Rous Water acting alone. The majority of on-ground works and changes to land management practices will need to be completed by landholders. This is not to say that Rous Water does not have a considerable role to play, e.g. as advocate, facilitator, funding partner, educator or coordinator.

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Table 5-6 Illustrative extract from catchment risk assessment Excel™ workbook

Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
Roads	Chemical	Light vehicles, cars	Chemical HAZMAT spills (including toxicants and hydrocarbons) enters watercourse after vehicle road accident	State emergency services	<ul style="list-style-type: none"> Once operational, the new Highway will have good, modern pollution/spill control systems, e.g. containment ponds, better than those present with the current Highway. Call centre receives calls and task either the local RFS and/or the Fire Brigade - capture, bund, remove, HAZMAT spill response, but with potentially competing priorities e.g. to reopen the highway quickly. Alternative routes exist that allow most vehicles to get around spills in the area - reduce the risk of being pressured to open too soon, e.g. the F3 case. 	Catastrophic	Unlikely	High (10)	Confident	<ul style="list-style-type: none"> Education and awareness - drinking water catchment. In high risk areas develop capture drains to pollution spills. Formalise the response protocol with the Fire Brigade to ensure Rous Water can "make safe". Formalise who calls Rous Water and under what circumstance otherwise the first responder and aware organisations might not tell Rous Water. Rous Water to define entry and exit points from the catchment to see if water catchments could be shown on the CAD system. This risk will probably drop from the main highway in the future, but will remain significant from the local roads. Formal agreement with HAZMAT and Rous Water - Rous Water is on the first notification list. In the event of a spill that represents a significant public health/environmental risk to consumers and/or other stakeholders (e.g. downstream users), Rous Water is to consult and work with NSW Health and the EPA regarding the establishment of clear communications regarding the issue to any potentially affected stakeholders. 	Minor	Rare	Low (2)

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Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
Stock grazing	Pathogens - chlorine resistant	Grazing animals	Runoff from broad scale grazing land enters watercourse carrying excessive chlorine-resistant pathogens	Catchment landholder	Inherently limited by the small total number of grazing animals in the catchment, mostly hobby farm, not intensive, but there are some pockets of more dense grazing. Largely unfenced watercourses Grass cover is generally good during wet periods but can be poor during dry periods.	Moderate	Possible	Medium (9)	Estimate	<ul style="list-style-type: none"> • Breeding paddocks to restrict pre-weaned stock access as remote as practicable from watercourses. • Discourage the youngest stock from being in areas hydrologically connected to the water. • Encourage grazing methods, such as cell grazing, to manage stock and vegetation cover. • Encourage stock congregation areas to be located away from watercourses (e.g. watering points, shade, raceways, yards, stables) and minimise surface water run-off from these areas to watercourses. • Encourage manure management, e.g. use of dung beetles or manure harrowing or slashing in some cases). • Check with DPI regarding the quantity of stock, the proportion of pre-weaned stock, the husbandry methods for these animals and the demographics of the farmers. This may require a follow-up landholder survey if DPI doesn't have this information. 	Minor	Unlikely	Low (4)

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High current risks	Potential additional mitigation activities	Residual risk
HAZMAT spills on roads and highway	<ul style="list-style-type: none"> Formalise the response protocol with the Fire Brigade to ensure Rous Water can "make safe". Education and awareness - drinking water catchment. Risk reduced with new Pacific Highway. 	Low
Pathogens - unrestricted grazing stock. Manure directly deposited in watercourse	<ul style="list-style-type: none"> Riparian fencing to restrict stock access from watercourses. Encourage stock congregation areas away from watercourses (e.g. watering points, shade, raceways, yards, stables). 	Medium
Pathogens - on-site sewage systems fail, effluent enters watercourse	<ul style="list-style-type: none"> Update the Service Level Agreement with constituent councils. Establish a long-term systematic risk-based auditing and compliance enforcement program. Investigation of large scale systems. 	Medium
Nutrient run-off from fertiliser use in horticulture enters watercourse	<ul style="list-style-type: none"> Attempt to better characterise the relative contributions of pollution sources. Promote increased adoption of best practice management guidelines. 	Medium
Nutrient and turbid run-off from agricultural soil erosion enters watercourse	<ul style="list-style-type: none"> Attempt to better characterise the relative contributions of pollution sources. Promote increased adoption of best practice management guidelines, including cover crops, orchard floor contouring, riparian buffer strips, improved soils health, watercourse stabilisation. 	Medium
Nutrient and turbid run-off from road construction enters watercourse	<ul style="list-style-type: none"> New Pacific Highway noted a high risk for period of construction. Post construction risks associated with the highway will be minimised. Maintain current management activities 	High
Risks associated with future landuse development	<ul style="list-style-type: none"> New Pacific Highway noted a high risk for period of construction. Maintain current management activities 	High
Manganese in source water enters watercourse	<ul style="list-style-type: none"> Be proactive and seek to influence planning to ensure adequate control of undesirable development. 	Medium

Figure 5-1 High catchment risks under the current management scenario

6. Action Plan

6.1 Overview

The distribution of risk – represented by likelihood and consequence – can be used to target options for mitigation as illustrated conceptually in Figure 6-1. For example, if the risk distribution predominately has a low likelihood but a very high consequence, the most appropriate way to manage this risk is to develop and adhere to emergency plans and procedures, or implement preventive measures. Alternatively, if the likelihood of the hazardous event is very high and the consequence low, education programs and codes of practice might be the most effective management options.

In this section, the risks have been analysed to determine the highest priority catchment management actions. The stakeholders anticipated to take the lead responsibility for action have been suggested and will be contacted during the early stages of implementation to seek collaboration. Specific actions for Rous Water have also been provided, as have key performance indicators.

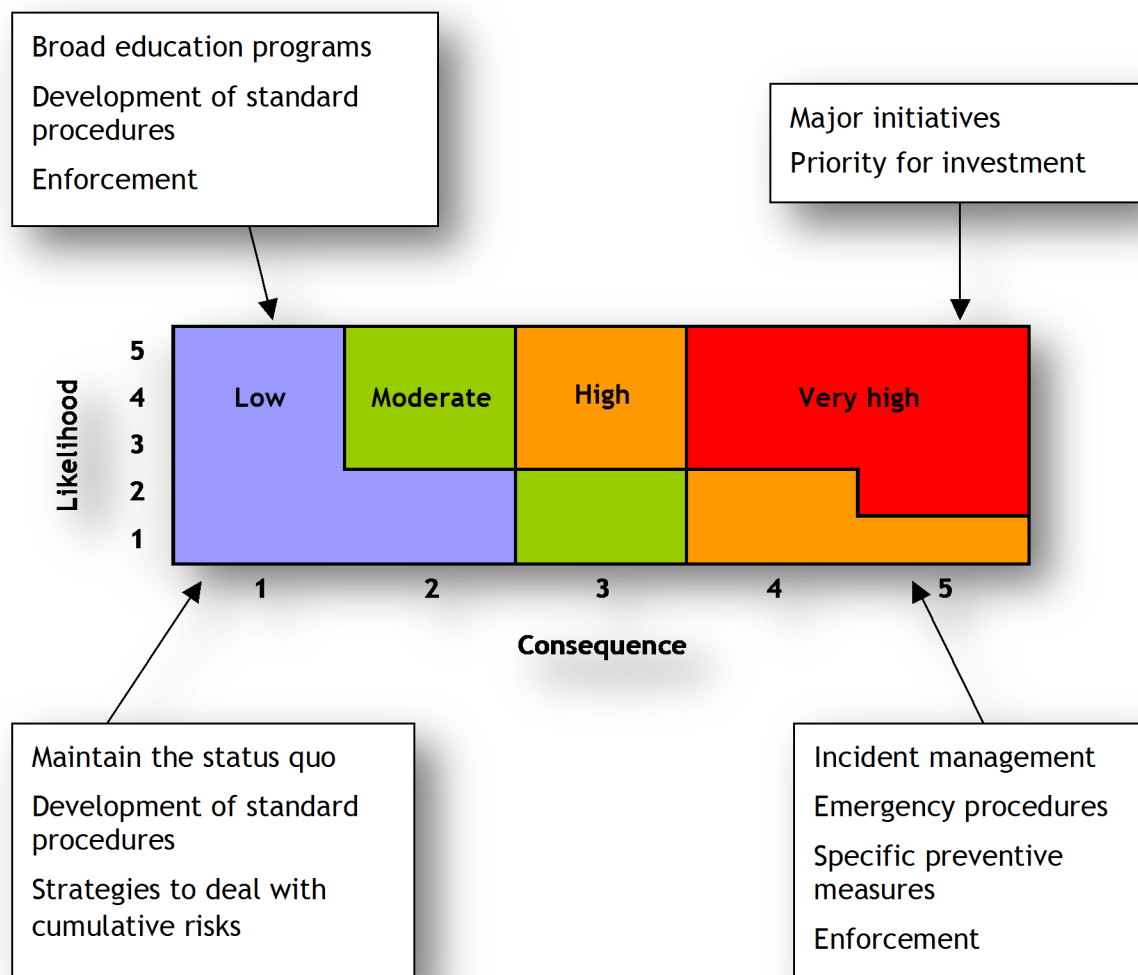


Figure 6-1 Risk distribution and associated styles of management

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6.2 Specific actions

The following tables summarise the actions recommended following the risk assessment process that were aimed at reducing high or medium raw (maximum) risks to low risk levels. The actions have been summarised in a structure that approximately matches that used by Rous Water for its overall asset risk assessments. For brevity, in this section of the report, only the final risk ratings have been shown, not the specific breakdown into likelihoods, consequences and uncertainty ratings. Furthermore, once again for brevity, hazards and hazardous events have been grouped into logical groupings, and only the limiting (highest-rated) risk is shown for each of those groupings. The full risk assessment is attached to the end of this report and gives the more detailed breakdown.

6.2.1 Broadscale grazing

Hazards and hazardous events	Raw risk	Existing Mitigation Measures (Controls)	Adequate (Yes/No)	Further Action or Treatment Plan and Responsibility	Future residual risk
Pathogens, nutrients and suspended sediment due to runoff from grazing land carrying faeces, nutrients and sediments as well as direct deposition of faeces in water.	High	<ul style="list-style-type: none"> • Inherently limited by the small total number of grazing animals in the catchment, mostly hobby farm, not intensive, but there are some pockets of more dense grazing. Largely unfenced watercourses. • Grass cover is generally good during wet periods but can be poor during dry periods. • Very limited fencing in some locations. • Education and promotion of good riparian management. • Some good examples, such as Fernleigh, but at a cost. • Active landcare programs noting some incentive funding. • Non-intensive farming, fertilizer application is not considered extreme. 	No	<ul style="list-style-type: none"> • Rous Water <ul style="list-style-type: none"> ○ Facilitate funding proposal and project co-ordination. • Stakeholders (Landholders and CMA) <ul style="list-style-type: none"> ○ Watercourse fencing. ○ Off-stream watering points. ○ Stock crossings. ○ Management of stock congregation points such as yards, raceways, watering points and shade and minimise surface runoff from these locations to watercourses. ○ Encourage manure management, e.g. use of dung beetles or manure harrowing or slashing in some cases. ○ Promote cell grazing and minimising of young stock access to watercourses 	Medium

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6.2.2 On-site sewage management

Hazards and hazardous events	Raw risk	Existing Mitigation Measures (Controls)	Adequate (Yes/No)	Further Action or Treatment Plan and Responsibility	Future residual risk
Pathogens (particularly viruses) as well as nutrients due to septic system failure in which effluent enters watercourse leaching pathogens and nutrients into the water course.	High	<ul style="list-style-type: none"> Ballina Shire Council has since 2001 had a Strategy and since 2003 a Shire wide inspection program to review existing on-site sewage management systems. All systems within water catchments were regarded as medium or high risk. This program is funded by a small levy on the rates of properties that do not have access to town sewer supplemented by application and inspection fees. Its capacity to devote specific resources to the Emigrant Creek catchment is however constrained as only one officer is currently employed on the program that seeks to supervise an estimated 3,000 or more systems Shire-wide. There is a backlog of enforcement work continuing including from properties surveyed within the Emigrant Creek catchment. The accelerated program checked 146 septs, approximately 2/3 of the catchment, around "30% failed". Based on this and other inspections, typically approximately 1/5 to 1/3 fail (e.g. effluent runoff) and approximately 1/3 have other non-compliances. Effluent disposal sizing is based on nutrients, as per a sizing table. Council education of designers and installers. Council review and feedback of submitted designs. Provision of educational factsheets about managing systems, including notes on inspection, pump-out frequency, etc. Rous Water has guidelines relevant to catchment areas - pathogen focus. 	No	<ul style="list-style-type: none"> Rous Water <ul style="list-style-type: none"> Review Service Level Agreement with constituent Council (i.e. Ballina Council). Participate in collaborative efforts with Council regarding sewage management solution for Newrybar that may include a small, centralised system with reuse as an option. Participate in collaborative efforts with Council regarding the ongoing requirements for auditing and compliance requirements. Promote awareness of water quality risks associated with OSSMS to drinking water quality. Further promote the use of the Rous Water OWMS Guidelines and review as required. Stakeholders (Council) <ul style="list-style-type: none"> Complete audit of OSSMS in the catchment and work towards achieving compliance of OSSMS within the catchment (noting that the resourcing of enforcement action is a key factor) Consider requirement to have periodic pump-outs of septic tanks within drinking water catchments. 	Medium

6.2.3 Macadamia Plantations

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Hazards and hazardous events	Raw risk	Existing Mitigation Measures (Controls)	Adequate (Yes/No)	Further Action or Treatment Plan and Responsibility	Future residual risk
Nutrients and suspended sediment due to runoff from horticultural land.	High	<ul style="list-style-type: none"> • Best practice guidelines for macadamia use with good compliance believed to be in place, e.g. dropping application rates to reasonably low levels • Inherent limit to over-application due to cost of fertilisers. • These sites generally only irrigated by natural rainfall. • Promotion of smother grass (until the canopy closes). • Some use of bunding/buffer strip, but effect variable, e.g. depending on extent of cover and direction of row vs. slope. • Canopy management to reduce canopy extent for productivity (which in turn fosters cover crop). 	No	<ul style="list-style-type: none"> • Rous Water <ul style="list-style-type: none"> ○ Collaborate with the Australian Macadamia Society to attract funding and participate in project co-ordination. ○ Review BMP Guidelines providing feedback on source water protection, providing improvements as required. ○ Facilitate the promotion of BMP within the industry • Stakeholders (Australian Macadamia Society) <ul style="list-style-type: none"> ○ Further promote the adoption of BMP within the industry, including adequate cover crops between rows, multiple applications of fertiliser per year (rather than one single application) and orchard floor infrastructure to manage surface water runoff (particularly for mature plantings). ○ Training and field days for farmers to improve skills/awareness regarding nutrient management, including the awareness of weather conditions prior to and at the time of fertiliser or pesticide application. 	Medium

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6.2.4 HAZMAT management

Hazards and hazardous events	Raw risk	Existing Mitigation Measures (Controls)	Adequate (Yes/No)	Further Action or Treatment Plan and Responsibility	Future residual risk
HAZMAT chemicals (e.g. hydrocarbons and tinkered materials) spilled into the catchment from roads.	High	<ul style="list-style-type: none"> Once operational, the new Highway will have good, modern pollution/spill control systems, e.g. containment ponds, better than those present with the current Highway. Call centre receives calls and task either the local RFS and/or the Fire Brigade - capture, bund, remove, HAZMAT spill response, but with potentially competing priorities e.g. to reopen the highway quickly. Alternative routes exist that allow most vehicles to get around spills in the area - reduce the risk of being pressured to open too soon, e.g. the F3 case. Dilution and natural sedimentation and volatilisation. Stormwater capture, GPT and biofiltration basins on the new road may help to settle and volatilise some hazards (refer modelling and environmental assessment undertaken for the new highway). For pesticides: controls relating to APVMA, Pesticides Act, contractor controls, s120 POEO. Most roads are sealed other than short no-through road lanes. However, the lanes tend to intersect with the creeks. Council maintenance staff have training on how to avoid causing pollution from roads and actively maintain council roads, (but not on-farm roads, refer to ag source discussion). Workshop given by Rous Water and NSW Fisheries to promote roads management. Staff from Council actively maintain and grade roads. Standard control practices include pollution control licence and compliance with the "Blue Book" best practices, e.g. 90%ile five-day event capture capacity (approx. 80 mm event), to 50 mg/L TSS limit, with an EPL (Environment Protection Licence), subject to inspection by EPA. Strictly regulated with no history of breaching the EPL. The only concern is the limit of that EPL in relation to larger storm events. Short-term problem, albeit with some residual sediment slugs. 	No	<ul style="list-style-type: none"> Rous Water <ul style="list-style-type: none"> Establish communications protocols with NSW Fire and Rescue and RFS communications centre. Review communications protocols with NSW Fire and Rescue and RFS periodically and report all incidents where communication was not effective. Work together with NSW Health and the EPA to ensure that clear communications are issued regarding any spill event that represents a significant public health/environmental risk to consumers and/or other stakeholders. Stakeholders (NSW Fire and Rescue and RFS) <ul style="list-style-type: none"> Implement communications protocols to include Rous Water. 	Medium

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6.2.5 Actions relevant to all hazards and risks

Hazards and hazardous events	Raw risk	Existing Mitigation Measures (Controls)	Adequate (Yes/No)	Further Action or Treatment Plan and Responsibility	Future residual risk
All	High	<ul style="list-style-type: none"> • See above action tables. • Watercourse stabilisation programs. • Water quality monitoring and reporting. • Landuse development planning 	No	<ul style="list-style-type: none"> • Rous Water <ul style="list-style-type: none"> ○ Co-ordinate an assessment of watercourse condition, focusing on bed and bank stability and channel sediment profiles. ○ Prepare and implement reach-based rehabilitation plans addressing key river health threats (lack of riparian vegetation, emerging weeds, stock access, and bank erosion). ○ Co-ordinate the development of a nutrient budget for the catchment, to identify major sources of nutrients, including current landuses and the impact of previous landuses (greater number of dairies previously) and historical land management (considerable use of fertilisers acknowledged). ○ Review Rous Water Catchment Monitoring Plan in light of the risk assessment and consider the inclusion of addition parameters either within the regular parameters (iron, manganese, dissolved organic carbon) or as short term assessment (hydrocarbons, volatiles) to further quantify the risk. ○ Continue to advocate for specific provisions that will protect and improve water quality within drinking water catchments. ○ Continue to build community awareness regarding the protection of water quality within drinking water catchments, with specific attention to the risk associated with new developments. • Stakeholders (Landholders, CMA and council) <ul style="list-style-type: none"> ○ Remediate significant watercourse erosion if source is identified as significant contributor. ○ Contribute to the development of a nutrient budget for the catchment. ○ Specific provisions which will protect and improve water quality within drinking water catchments including a cap on dwelling density and the enforcement of a drinking water catchment overlay, with limitations on complying landuses. 	Medium

6.3 Implementation

6.3.1 Institutional Framework and Role of the Catchment Management Plan

The Emigrant Creek CMP has been prepared to guide catchment management, investment and monitoring activities aimed at protecting and enhancing water quality and catchment health associated with the Emigrant Creek catchment.

Effective catchment management requires a whole-of-government and a whole-of-community approach and Rous Water recognises that it is unable to achieve significant change on a whole-of-catchment basis by working in isolation. It is for this reason that Rous Water works with many organisations and individuals, so that partnerships can be established between groups having shared natural resource management interests and objectives. The Emigrant Creek CMP identifies the critical water quality and catchment health issues to be addressed in the Emigrant Creek catchment, allowing Rous Water to partner with all stakeholders where the interests of the respective organisations are aligned.

A key purpose of the Emigrant Creek CMP is, therefore, to identify opportunities for working together where shared interests can result in positive outcomes for the catchment, positive outcomes for the Emigrant Creek water supply and positive outcomes for all participants in the projects and initiatives.

6.3.2 Implementation Timeframe and Process

The Emigrant Creek CMP outlines the range of programs and actions that Rous Water will pursue in the Emigrant Creek catchment over the 10-year period commencing in 2013/14 and finishing in 2022/23.

In accordance with the *Local Government Act 1993*, the CMP actions to be completed by Rous Water within the Emigrant Creek catchment shall be included in the Rous Water Integrated Planning and Reporting Process. In addition, the activities of both Rous Water and Ballina Shire Council under the Emigrant Creek CMP shall be included in the Water Supply Agreement established for the Rous Water regional water supply system.

This implementation process will allow effective monitoring and evaluation so that the completion of actions and the effectiveness of the Emigrant Creek CMP can be regularly reviewed.

7. References

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8. Appendix A Catchment Risk Assessment Worksheet

Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
Roads	Chemical	Light vehicles, cars	Chemical HAZMAT spills (including toxicants and hydrocarbons) enters watercourse after vehicle road accident	State emergency services	<ul style="list-style-type: none"> Once operational, the new Highway will have good, modern pollution/spill control systems, e.g. containment ponds, better than those present with the current Highway. Call centre receives calls and task either the local RFS and/or the Fire Brigade - capture, bund, remove, HAZMAT spill response, but with potentially competing priorities e.g. to reopen the highway quickly. Alternative routes exist that allow most vehicles to get around spills in the area - reduce the risk of being pressured to open too soon, e.g. the F3 case. 	Catastrophic	Unlikely	High (10)	Confident	<ul style="list-style-type: none"> Education and awareness - drinking water catchment. In high risk areas develop capture drains to pollution spills. Formalise the response protocol with the Fire Brigade to ensure Rous Water can "make safe". Formalise who calls Rous Water and under what circumstance otherwise the first responder and aware organisations might not tell Rous Water. Rous Water to define entry and exit points from the catchment to see if water catchments could be shown on the CAD system. This risk will probably drop from the main highway in the future, but will remain significant from the local roads. Formal agreement with HAZMAT and Rous Water - Rous Water is on the first notification list. <p>In the event of a spill that represents a significant public health/environmental risk to consumers and/or other stakeholders (e.g. downstream users), Rous Water is to consult and work with NSW Health and the EPA regarding the establishment of clear communications regarding the issue to any potentially affected stakeholders.</p>	Minor	Rare	Low (2)

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Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
Roads	Chemical	Tankers	General road runoff, e.g. fuels, oils, tyres, brake fluids, road surface erosion, paints, pesticides, paints, coatings, metals... existing highway and minor roads	State emergency services	• Dilution and natural sedimentation and volatilisation.	Minor	Likely	Medium (8)	Confident	• Watching brief: Long-term, targeted monitoring to verify that indicator hazards remain within safe levels, e.g. for hydrocarbons, VOCs and metals.	Moderate	Rare	Low (3)
Roads	Chemical	Vehicles	General road runoff , e.g. fuels, oils, tyres, brake fluids, road surface erosion, paints, pesticides, paints, coatings, metals... new Pacific Highway		• Dilution and natural sedimentation and volatilisation. • Stormwater capture, GPT and biofiltration basins on the new road may help to settle and volatilise some hazards (refer modelling and environmental assessment undertaken for the new highway).	Minor	Unlikely	Low (4)	Confident	• Watching brief: Long-term, targeted monitoring to verify that indicator hazards remain within safe levels, e.g. for hydrocarbons, VOCs and metals.			#N/A

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Stock grazing	Chemical	Cattle Dip (3 decommissioned in catchment) one in bottom of Dam (see specific risk analysis below)	Leakage from cattle tick dip sites in catchment enters source water	Catchment landholder	<ul style="list-style-type: none"> Fenced out and/or capped and sealed by highway. NSW Ag database of location NSW Ag have assessed significance Inherently controlled through chemicals tending to be bound rather than mobile 	Minor	Rare	Low (2)	Reliable				#N/A
Stock grazing	Chemical	Cattle tick dip site within dam floor	Leakage from submerged cattle tick dip site contaminates source water		<ul style="list-style-type: none"> Inherently controlled through chemicals tending to be bound rather than mobile (report on the submerged dip site verifies that the contaminants aren't mobile) 	Minor	Rare	Low (2)	Certain				#N/A
Other	Chemical	Prohibited activities	Pollutants of potential concern from dumped chemicals/containers (by the public) enters source water		<ul style="list-style-type: none"> Dilution and natural sedimentation and volatilisation. Drum muster. Waste management facilities/tips. Note controls mentioned for on-farm chemicals, e.g. bunding. Education program on illegal waste dumping. Catchment signage and phone number. 	Moderate	Rare	Low (3)	Confident				#N/A
Other	Chemical	Contamination	Dangerous chemicals are deliberately placed in source water	State emergency services / EPA	<ul style="list-style-type: none"> Fenced site. Permanent groundsman. Catchment signage and phone number to call. 	Catastrophic	Rare	Medium (6)		<ul style="list-style-type: none"> Complete Security Vulnerability Assessment for Rous Water assets using the national guidelines. 			#N/A

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Residential	Hydrocarbons	Refuelling station for public vehicles (there is one petrol bowser within the catchment at Newrybar)	Fuel leakage or spill from petrol station - noting strong connectivity between ground water and surface water.	State agencies and Council	<ul style="list-style-type: none"> Dilution and natural sedimentation and volatilisation. 			#N/A					#N/A
Horticulture and grazing	Hydrocarbons	Refuelling tanks on farms approx. 20 to 30 (1000-5000 and diesel storage tank on most properties)	Fuel spill from on-farm diesel reserve tank, diesel leaches into dam	Catchment landholder	<ul style="list-style-type: none"> Some are bunded to 110% of volume (Australian Standard) (but most aren't bunded) Some may be signed. Typically storage tanks are located remotely from the watercourse. Diesel would tend to be retained in the soil, and if it did reach the water, would tend to float, most wouldn't influence the water at the abstraction depth. Farm food safety programs tend to include management of these hazards. 	Minor	Unlikely	Low (4)	Reliable	Include education on this as part of other messaging.			#N/A
Horticulture	Hydrocarbons Back-siphonage	Small portable diesel-powered water pump operation along Emigrant Creek in summer	Fuel Spill or chemical back-siphonage draws or spills hazard into water	Catchment landholder	<ul style="list-style-type: none"> Volume of diesel is small. Some pumps would have a non-return valve, e.g. a foot valve, to keep the pump primed. 	Moderate	Rare	Low (3)					#N/A

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Stock grazing	Pathogens - chlorine resistant	Grazing animals	Runoff from broad scale grazing land enters watercourse carrying excessive chlorine-resistant pathogens	Catchment landholder	Inherently limited by the small total number of grazing animals in the catchment, mostly hobby farm, not intensive, but there are some pockets of more dense grazing. Largely unfenced watercourses Grass cover is generally good during wet periods but can be poor during dry periods.	Moderate	Possible	Medium (9)	Estimate	<ul style="list-style-type: none"> • Breeding paddocks to restrict pre-weaned stock access as remote as practicable from watercourses. • Discourage the youngest stock from being in areas hydrologically connected to the water. • Encourage grazing methods, such as cell grazing, to manage stock and vegetation cover. • Encourage stock congregation areas to be located away from watercourses (e.g. watering points, shade, raceways, yards, stables) and minimise surface water run-off from these areas to watercourses. • Encourage manure management, e.g. use of dung beetles or manure harrowing or slashing in some cases). • Check with DPI regarding the quantity of stock, the proportion of pre-weaned stock, the husbandry methods for these animals and the demographics of the farmers. This may require a follow-up landholder survey if DPI doesn't have this information. 	Minor	Unlikely	Low (4)

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Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
Stock grazing	Pathogens - chlorine resistant	Grazing animals	Unrestricted livestock to watercourse - manure directly deposited in watercourse including stock crossings, carrying excessive chlorine-resistant pathogens	Catchment landholder	<ul style="list-style-type: none"> • Very limited fencing in some locations. • Education and promotion of good riparian management. • Some good examples, such as Fernleigh, but at a cost. • Active landcare programs noting some incentive funding. 	Major	Likely	High (16)	Estimate	<ul style="list-style-type: none"> • Riparian fencing to restrict stock access from watercourses (noting need to maintain fencing and weed management). • Promote good practices such as behavioural modifiers, off-stream watering and shade areas (noting the very diverse nature of the landholders). • See above row 	Major	Unlikely	Medium (8)

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Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
On-site sewage	Pathogens	On-site sewage management systems (≈ 205 septic tanks in catchment, 10 toilet system at Macadamia Castle)	Septic system failure - effluent enters watercourse leaching pathogens in the water course	Council	<ul style="list-style-type: none"> • Council has since 2001 had a Strategy and since 2003 a Shire-wide inspection program to review existing on-site sewage management systems. All systems within water catchments were regarded as medium or high risk. This program is funded by a small levy on the rates of properties that do not have access to town sewer supplemented by application and inspection fees. Its capacity to devote specific resources to the Emigrant Creek catchment is however constrained as only one officer is currently employed on the program that seeks to supervise an estimated 3,000 or more systems Shire wide. There is a backlog of enforcement work continuing including from properties surveyed within the Emigrant Creek catchment. • Accelerated program checked 146 septic systems, approx. 2/3 of the catchment, around "30% failed". Based on this and other inspections, typically approx 1/5 to 1/3 fail (e.g. effluent runoff) and approx 1/3 have other non-compliances. • Effluent disposal sizing is based on nutrients, as a table. • Council education of designers and installers. • Council review and feedback on submitted designs. • Provision of educational factsheets about managing systems, including notes on inspection, pump-out frequency, etc. • Rous Water has guidelines relevant to catchment areas - pathogen focus. 	Moderate	Likely	High (12)	Estimate	<ul style="list-style-type: none"> • Gaia Resort, Macadamia Castle, Newrybar School, Newrybar Café - where is the sewerage system, septic system and effluent application area? Is the loading too high? • Some setbacks don't comply with current requirements. • Opportunity for more education for real estate agents, conveyancing solicitors, property vendors and purchasers. • Opportunity to seek further funding to establish a long-term systematic risk-based auditing and compliance enforcement program. • Update the Service Level Agreement (Rous Water vs. constituent councils) to include updated thinking on septic systems. • There is a need for better standards for large-scale systems to respond to expansion of existing uses. 	Minor	Possible	Medium (6)

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Other	Pathogens	Wildlife (Native and Feral)	Excreta discharging into/adjacent to watercourse or storage from wildlife carrying pathogens, e.g. waterbirds, including perching on the offtake tower.		<ul style="list-style-type: none"> No significant large feral mammal problem. Most concerns relate to birds, rabbits, smaller native animals. 	Minor	Likely	Medium (8)	Certain	<ul style="list-style-type: none"> Not applicable 			#N/A
Other	Pathogens	Prohibited recreational activities	Human waste enters watercourse from recreational activities carrying pathogens	Utility	<ul style="list-style-type: none"> No known significant areas of recreational activity away from toilets within the catchment. 	Insignificant	Unlikely	Low (2)					#N/A

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Stock grazing	Pathogens - chlorine sensitive	Grazing animals	Runoff from broad scale grazing land enters watercourse carrying excessive chlorine-sensitive pathogens	Catchment landholder	Inherently limited by the small total number of grazing animals in the catchment, mostly hobby farm, not intensive, but there are some pockets of more dense grazing. Largely unfenced watercourses Grass cover is generally good during wet periods but can be poor during dry periods.	Minor	Unlikely	Low (4)	Estimate	<ul style="list-style-type: none"> Breeding paddocks to restrict pre-weaned stock access as remote as practicable from watercourses. Discourage the youngest stock from being in areas hydrologically connected to the water. Encourage grazing methods, such as cell grazing, to manage stock and vegetation cover. Encourage stock congregation areas to be located away from watercourses (e.g. watering points, shade, raceways, yards, stables) and minimise surface water run-off from these areas to watercourses. Encourage manure management, e.g. use of dung beetles or manure or harrowing or slashing in some cases). Check with DPI regarding the quantity of stock, the proportion of pre-weaned stock, the husbandry methods for these animals and the demographics of the farmers. This may require a follow-up landholder survey if DPI doesn't have this information. 	Insignificant	Rare	Low (1)
Stock grazing	Pathogens - chlorine sensitive	Grazing animals	Unrestricted livestock - direct access to watercourse including stock crossings, carrying excessive chlorine-sensitive pathogens	Catchment landholder	<ul style="list-style-type: none"> Very limited fencing in some locations. Education and promotion of good riparian management. Some good examples, such as Fernleigh, but at a cost. Active landcare programs noting some incentive funding. 	Moderate	Possible	Medium (9)	Estimate	<ul style="list-style-type: none"> Riparian fencing to restrict stock access from watercourses (noting need to maintain fencing and weed management). Promote good practices such as behavioural modifiers, off-stream watering and shade areas (noting the very diverse nature of the landholders). See above row 	Moderate	Unlikely	Medium (6)

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Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
Other	Pathogens - chlorine sensitive	Wildlife (Native and Feral)	Excreta discharging into/adjacent to watercourse or storage from wildlife carrying pathogens, e.g. waterbirds, including perching on the offtake tower.		<ul style="list-style-type: none"> No significant large feral mammal problem. Most concerns relate to birds, rabbits, smaller native animals. 	Minor	Unlikely	Low (4)					#N/A
Other	Pathogens - chlorine sensitive	Prohibited recreational activities	Human waste from prohibited recreational activities	Utility	<ul style="list-style-type: none"> No known significant use of the dam for prohibited recreational activity. 	Insignificant	Unlikely	Low (2)					#N/A
Horticulture	Pathogens - chlorine sensitive	Compost	Application of inadequately composted manure fertilisers - pathogens		<ul style="list-style-type: none"> <i>E. coli</i> and <i>Salmonella</i> are monitored on the harvested crops. Proper composting of some manures. Awareness of food safety and personal safety implications of non-composted manure which would help with any communication of water quality risks. Cost of manure helps to avoid excessive application. 	Minor	Unlikely	Low (4)	Reliable	<ul style="list-style-type: none"> If/when best practice guidelines are upgraded, add in communication messages relating to water quality implications of non-composted manures. 			#N/A

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Horticulture	Pesticides	Agricultural land (e.g. macadamia) leading to pesticide runoff from general pesticides and rodenticides	Pesticides present in runoff to surface water or percolates to groundwater	External landholder - normal operation	<ul style="list-style-type: none"> • Pesticides Act • APVMA and DPI controls on what can be used in Australia, its amount, by whom and how; label sets out how to use pesticide. • Strategic industry-wide risk assessment of pesticide use on macadamia farms. • Best practice guidelines for macadamia used with good compliance believed to be in place. • Bananas and stone fruit are thought to have good compliance with good practice. • Templates for on-site farm-by-farm pesticide management plans. • Accreditation program for nursery. • Training course mandatory for users of large quantities of key pesticides. • Spray frequency reduction, e.g. 3 to 4 x pa vs. monthly in the past. 	Minor	Unlikely	Low (4)	Confident	<ul style="list-style-type: none"> • Further adoption of current practices. • Further research to enhance biological controls. • Better communication of the need to call the pollution line rather than Rous Water in following up spills. • If/when best practice guidance is updated, comment on the rodenticide risks. • Check extent of pesticide use for non-macadamia horticulture - noting some, such as blueberries, are potential less careful than macadamias. 			#N/A
Other	Pesticides	Land management in reservoir reserve	Pesticides present in reservoir reserve run-off from land management in reservoir reserve	Utility	<ul style="list-style-type: none"> • Pesticides Act. • Very limited range of low risk pesticides used. • Spraying by Rous Water staff rather than contractors. • SWMS include environmental controls. 	Insignificant	Rare	Low (1)	Certain				#N/A
Roads	Pesticides	Roadsides	Pesticides from roadside maintenance enters watercourses	Council and State agencies	<ul style="list-style-type: none"> • For pesticides: controls relating to APVMA, Pesticides Act, contractor controls, s120 POEO. 	Minor	Unlikely	Low (4)		<ul style="list-style-type: none"> • Maintain good compliance checks and oversight on contractors. • Watching brief: Long-term, targeted monitoring to verify pesticide - liaise with NSW Health/Rous Water/EPA. 			#N/A

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Residential	Pesticides	Urban	Pesticides from households enters watercourse	Householder and Council	<ul style="list-style-type: none"> Pesticides Act APVMA and DPI controls on what can be used in Australia, its amount, by whom and how; label sets out how to use pesticide. Limited range of lower risk substances, supplied in lower volume containers, available to the unlicensed general community. 	Minor	Unlikely	Low (4)	Estimate	<ul style="list-style-type: none"> Educating the community (e.g. at point-of-sale) and pesticide application contractors to encourage use of lowest-risk pesticide, and appropriate use. 			#N/A
Stock grazing	Nitrogen Phosphorus Turbidity	Grazing animals	Runoff from broad scale grazing land enters watercourse carrying excessive nutrients and sediment	Catchment landholder	Non-intensive farming, fertilizer application is not considered extreme.	Minor	Likely	Medium (8)		Encourage cell grazing, organic/biological farming methods and control of fertilizers.	Minor	Unlikely	Low (4)
Stock grazing	Nitrogen Phosphorus Turbidity	Grazing animals	Unrestricted livestock - direct access to watercourse including stock crossings carrying excessive nutrients and sediment	Catchment landholder	Non-intensive farming, fertilizer application is not considered extreme.	Minor	Likely	Medium (8)		As above	Minor	Unlikely	Low (4)

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On-site sewage	Nitrogen Phosphorus	On-site sewage management systems (≈ 205 septic tanks in catchment, 10 toilet system at Macadamia Castle)	Nutrients from effluent enters watercourse	Council	<ul style="list-style-type: none"> • See above • Effluent disposal sizing is based on nutrients, as a table. 	Minor	Likely	Medium (8)	Estimate	• As above	Minor	Unlikely	Low (4)
Horticulture	Nitrogen Phosphorus Turbidity	Agriculture - fertilisers - nutrient runoff	Nutrients from fertiliser enters watercourses	Catchment landholder	<ul style="list-style-type: none"> • Best practice guidelines for macadamia use with good compliance believed to be in place, e.g. dropping application rates to reasonably low levels. • Inherent limit to over-application due to cost of fertilisers. • These sites generally only irrigated by natural rainfall. • Promotion of smother grass (until the canopy closes). • Some use of bunding/buffer strip, but effect variable, e.g. depending on extent of cover and direction of row vs. slope. • Canopy management to reduce canopy extent for productivity (which in turn fosters cover crop). 	Moderate	Likely	High (12)	Reliable	<ul style="list-style-type: none"> • Promote increased adoption of the appropriate tools (harvest the low-hanging fruit whilst further characterisation takes place relating to relativity of sources). • Attempt to better characterise the relative contributions of nominated potential pollution sources, e.g. horticulture vs. grazing vs. internal loading vs. natural runoff vs. rural residential vs. roads in order to help set priorities. 	Minor	Possible	Medium (6)

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Horticulture	Nitrogen Phosphorus Turbidity	Soils - nutrient runoff	Agricultural erosion enters watercourses carrying nutrients and sediments	Catchment landholder	<ul style="list-style-type: none"> • Best practice guidelines for macadamia use with good compliance believed to be in place. • Promotion of smother grass (until the canopy closes). • Some use of bunding/buffer strip, but effect variable, e.g. depending on extent of cover and direction of row vs. slope. • Canopy management to reduce canopy extent for productivity (which in turn fosters cover crop) 	Major	Possible	High (12)	Reliable	<ul style="list-style-type: none"> • Continue to build on the good work and progress to date by promoting improved cover crop and improved buffer strips to maintain soil on farm. • Find means of improving riparian buffer zones for sediment/nutrient capture but without promoting rat habitat. • Improved canopy management. • Improved soil health. • Orchard floor contouring. • Sediment traps and the maintenance thereof. • Prioritise actions that maintain soil on farm to combine improved productivity outcomes with improved water quality outcomes. • Education of soil conservation areas of government and industry. 	Moderate	Unlikely	Medium (6)
Other	Nitrogen Phosphorus Turbidity	Soils	Watercourse erosion from bed and bank erosion within the main creek channels and ephemeral streams, involving natural process, possibly exacerbated by anthropogenic processes.	Catchment landholder	<ul style="list-style-type: none"> • Much of the main creek is on crown title and can be stabilised, although the level of stabilisation activity is minimal, and many drainage lines are not readily accessible as are on private land. 	Minor	Possible	Medium (6)	Estimate	<ul style="list-style-type: none"> • Enhanced mitigation options, seek third party funding through landcare etc. 	Minor	Unlikely	Low (4)

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Roads	Nitrogen Phosphorus Turbidity	Soils	Unsealed road runoff enters watercourses increasing nutrients and sediments in the waterway	Council	<ul style="list-style-type: none"> • Most roads are sealed other than short no-through road lanes. However, the lanes tend to intersect with the creeks. • Council maintenance staff have training on how to avoid causing pollution from roads and actively maintain council roads, (but not on-farm roads, refer to ag source discussion). • Workshop given by Rous Water and NSW Fisheries to promote roads management. • Staff from Council actively maintain and grade roads. 	Insignificant	Unlikely	Low (2)	Estimate	• Review hot spots, e.g. road crossings of creeks, for possible targeted catchments.			#N/A
Roads	Nitrogen Phosphorus Turbidity	Soils	Runoff from road construction enters watercourses increasing nutrients and sediments in the waterway		<ul style="list-style-type: none"> • Standard control practices include pollution control licence and compliance with the "Blue Book" best practices, e.g. 90%ile five-day event capture capacity (approx. 80 mm event), to 50 mg/L TSS limit, with an EPL (Environment Protection Licence), subject to inspection by EPA. Strictly regulated with no history of breaching the EPL. The only concern is the limit of that EPL in relation to larger storm events. • Short-term problem, albeit with some residual sediment slugs. 	Major	Possible	High (12)	Reliable	<ul style="list-style-type: none"> • Follow up with RMS to promote further riparian works. • Question - what happens to the excess soil that is harvested from the site and dumped within the catchment? • New Pacific Highway noted a high risk for period of construction 	Major	Possible	High (12)
Other	Nitrogen Phosphorus Turbidity	Soils	Erosion post bush fire enters watercourses	RFS	<ul style="list-style-type: none"> • Landholders do occasional burn-offs. Minor levels. • The area is rainforest so not prone to burn. 	Moderate	Rare	Low (3)					#N/A

Rous Water's Catchment Management Plan for the Emigrant Creek Catchment

Theme	Hazard	Source	Hazardous Event - describe how hazard moves from source into water	Primary Responsibility	Current mitigation actions and or significant gaps	Current Consequence	Current Likelihood	Current Risk	Uncertainty	Possible additional mitigation actions	Resid. Consequence	Resid. Likelihood	Residual Risk
Other	Phosphorus	Water weed in dam	Decomposition of the aquatic noxious water weeds, e.g. hyacinth and cabomba after harvesting and excessive hyacinth creating dam management and operational problems.	Utility	<ul style="list-style-type: none"> Mechanical removal of weed. Proactive manual maintenance of hyacinth levels by removal. 	Minor	Unlikely	Low (4)	Confident	<ul style="list-style-type: none"> Remove weed for composting out of the catchment to help remove nutrients from the system (as distinct from mulching it down on the banks of the dam). 			#N/A
Other	Turbidity	Surface Water	Rapid variations in raw water quality	NA	<ul style="list-style-type: none"> On line turbidity on the pump line from the dam which allows avoidance of turbidity spikes (trigger 30 NTU) - anecdotally storms. 	Moderate	Possible	Medium (9)	Estimate				#N/A
Other	DOC - THM/DBP Precursor	Soils	High organic matter (DOC/TOC) in catchment from natural sources enters watercourse	NA	<ul style="list-style-type: none"> Refer controls on turbidity hazards. 	Moderate	Possible	Medium (9)	Uncertain				#N/A

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Other	Algal toxins	Watercourse, weir pool	Cyanobacterial, algal blooms and water weed infestations in source water.	Utility	<ul style="list-style-type: none"> WTP has capability to treat blue green algae (e.g. ozone/BAC). Aerator/destratifier in the dam to help keep phosphorus in the sediment. Refer nutrient controls mentioned elsewhere - noting that nutrient levels are currently above at-risk trigger levels. Dam has two depths of abstraction but dam isn't particularly deep, just over 10 m deep. 	Major	Unlikely	Medium (8)	Confident	<ul style="list-style-type: none"> Refer catchment actions, e.g. stabilising sediment and managing nutrients Hyacinth growth appears to have increased over the years, which may increase the algae risk when plants are removed. Consider how to manipulate the biota of the dam. Consider a nutrient budget for the dam to help understand relative internal/external loadings and relative contributions of various external sources. Consider reviewing historical data to look for possible triggers for problem blooms. 	Minor	Unlikely	Low (4)
Stock grazing	Endocrine disruptors, antibiotics	Animal wastes	Excretion of veterinary products enters source water	Catchment landholder	<ul style="list-style-type: none"> Absence of intensive or dairy sites within the catchment APVMA and DPI regulation of the relevant compounds and their use. State/district response teams are formed to respond to reports of adverse events related to ag, vet, med compounds. 	Minor	Unlikely	Low (4)					#N/A
On-site sewage	Endocrine disruptors, antibiotics	On-site sewage management systems (≈ 205 septic tanks in catchment, 10 toilet system at Macadamia Castle)	Endocrine disruptors from septic system failure - effluent enters watercourse	Catchment landholder	See above	Minor	Unlikely	Low (4)					#N/A

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Other	Hardness (calcium carbonate/limestone)	Geology	Naturally occurring	NA	• Not applicable - water requires hardening	Insignificant	Rare	Low (1)					#N/A
Other	Heavy Metals	Existing or historical waste disposal or mining sites / contaminated sites and hazardous wastes	Erosion or discharge of soil/percolated metals into source water	Catchment landholder	• Ongoing testing, ICP-MS.	Insignificant	Rare	Low (1)					#N/A
Other	High temperature (potential to increase taste & odour complaints)	Bio physical	Increase from background levels	NA		Minor	Rare	Low (2)					#N/A
Other	TDS	Geology	Natural levels leads to high TDS in watercourses and storages	NA		Insignificant	Rare	Low (1)					#N/A

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Other	Low dissolved oxygen	Source water	Rous Water has dissolved oxygen (DO) problems in the raw water storage. Low DO in Emigrant Creek Dam is also linked with leaching of phosphorus (algae nutrient) and dissolved manganese and iron increases.	NA	<ul style="list-style-type: none"> An aerator/destratifier operates in the dam, but no controls in the catchment streams (ecosystem risk). Controls aimed at reducing sediment and nutrient loads will assist. 	Minor	Likely	Medium (8)					#N/A
Other	Iron	Source water	Iron is found at high levels in the raw water. These will increase to DO depletion rate in bottom waters of the reservoir over summer.	NA	<ul style="list-style-type: none"> An aerator/destratifier operates in the dam. Downstream controls - the WTP removes iron to <0.1 mg/L provided the coagulation and filtration processes operate correctly. 	Minor	Likely	Medium (8)					#N/A

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Other	Manganese	Source water	Manganese is released from reservoir sediments when overlaying water DO levels fall below about 4 to 5 mg/L. Very high (up to 1.8 mg/L) levels can occur in the reservoir near the bottom. Manganese at levels >0.03 mg/L in treated water can accumulate as a slime in the pipe network, and if dislodged under high flow conditions will give rise to black water and staining of laundry. The impact of such an event can be major.	NA	<ul style="list-style-type: none"> An aerator/destratifier operates in the dam. Downstream controls - permanganate dosing required, not helpful to the MF unit. 	Major	Likely	High (16)			Moderate	Possible	Medium (9)

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Other	Various - foams - runoff	Residential property	Structural fire leading to foams and chemical runoff		<ul style="list-style-type: none"> Typically foams wouldn't be required for fires in the catchment. 	Moderate	Rare	Low (3)	Confident				#N/A
Other	Manganese Iron DO	Source water	Exotic carp and gambusia causing benthic sediment release along with nutrients and sediment.		<ul style="list-style-type: none"> No current specific action, but the fish farm has been shut down due to the Pacific Highway. 	Moderate	Possible	Medium (9)	Estimate		Minor	Unlikely	Low (4)
Other	Alum Fire-related	Fire or spill at the plant	Contamination arising due to pollution incident from the plant, e.g. HCl, Cl ₂ , ACH, perhaps linked to spill or fire-related event.		<ul style="list-style-type: none"> Bunding/containment from chemical deliveries, drive-through bunding and containment bunding. Generic emergency response procedures for contamination of source waters could be used to help manage and escalate such an event. Option usually exists to shut off the plant whilst HAZMAT experts assist with clean-up. 	Major	Rare	Medium (5)	Certain	<ul style="list-style-type: none"> Carp and gambusia reduction options 			#N/A

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Residential	Various	Urban	Future excessive development, e.g. expansion of existing developments, or new developments.	<ul style="list-style-type: none"> Pesticides Act APVMA and DPI controls on what can be used in Australia, its amount, by whom and how; label sets out how to use pesticide. Limited range of lower risk substances, supplied in lower volume containers, available to the unlicensed general community. 	<ul style="list-style-type: none"> LEP - controlling undesirable landuses and intensification of landuse. Likely to be replaced by a new standard instrument that would become a standard LEP. 	Major	Possible	High (12)	Confident	<ul style="list-style-type: none"> Be proactive and seek to influence planning to ensure adequate control of undesirable development. 	Moderate	Possible	Medium (9)