Tarwin Water Supply Catchment Water Quality Management Plan

Report Prepared for South Gippsland Water and South Gippsland Shire Council

By Ecos Environmental Consulting and Water Technology

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Executive Summary

South Gippsland Water (SGW) and South Gippsland Shire Council (SGSC) and other relevant stakeholders are preparing a Water Catchment Policy for the Tarwin River Water Supply Catchment. The Policy, which is consistent with the DEPI Guidelines for Planning Permit Applications in Open, Potable Water Supply Catchment Areas (DEPI 2012), will address land use planning issues and the cumulative impact of on-site wastewater/septic tank systems in the Tarwin River Water Supply Catchment area. The Catchment Policy will allow strategic land use planning to occur based on identification of areas of risk and the appropriate implementation of risk based management responses.

As part of the Policy development, a Catchment Land Use and Development Management Strategy has been prepared by South Gippsland Water and South Gippsland Shire Council. The strategy outlines the process to be adopted in the development of the Catchment Policy and includes amongst other items the development of a Tarwin Water Supply Catchment Management Plan (TWSCMP).

The Plan consists of:

- A quantitative catchment process model; and
- Risk management planning (informed by the quantitative modelling).

Ecos Environmental Consulting and Water Technology were commissioned to develop the TWSCMP including the Quantitative Catchment Process Model and associated water quality risk management planning. The Plan is described in this document.

Background

Variations to the requirements of the DEPI catchment guidelines are permitted through various mechanisms including when water corporations, in consultation with other stakeholders, prepare a water Catchment Policy to address land use planning issues and the cumulative impact of onsite waste water/septic tank systems in a catchment area.

The development of a Tarwin Water Catchment Policy is consistent with the approach advocated by the DEPI guidelines. It is a primary objective of the TWSCMP to support the Water Catchment Policy by taking into account community interests and providing science-based guidance on catchment water quality processes.

For the management plan development process, an emphasis was placed on the involvement of stakeholders to assist in guiding the development of the plan and to ensure that the plan was consistent with the stakeholder's understanding of the main issues affecting water quality in the Tarwin catchment.

Consequently, development of the plan involved two stakeholder workshops to provide opportunities for stakeholder input and feedback, the development of linked pathogen source and hydrological models, and a final stakeholder workshop to provide comment on the draft plan.

The TWSCMP has been prepared to guide catchment management, investment and monitoring activities aimed at protecting and enhancing water quality and catchment health associated with the water supply sub-catchments in the Tarwin River Catchment.

The TWSCMP will act as a reference document for SGW that will inform the direction of its Water Catchment Policy, its Catchment Monitoring, Assessment and Improvement Program, and assessment of planning permit applications.

For the three councils whose jurisdiction overlaps with the Tarwin water supply catchment - SGSC, Baw Baw Shire, and Latrobe Shire - the TWSCMP will provide planning staff with a clearer understanding of catchment water quality issues and enable a greater degree of co-operation and understanding between SGW and the councils in relation to planning issues.

For the regional agencies and industry groups the TWSCMP provides a point of reference for understanding water supply catchment management issues where they intersect with the interests of these organisations.

A key aim of the TWSCMP is to identify opportunities for working together where shared interests can result in positive outcomes for the catchment, positive outcomes for the regional water supply, and positive outcomes for all participants in the projects and initiatives.

Tarwin Water Supply Catchment

The Tarwin Water Supply Catchment above the Meeniyan Water Supply Offtake is an open water supply catchment and consists largely of cleared grazing land, with some plantation forestry, and small regional towns. There are two water supply offtake locations supplied by large catchment areas:

(i) Dumbalk which is supplied from the Tarwin River East Branch; and
(ii) Meeniyan which is supplied from the Tarwin River downstream of the confluence of the east and west branches (Figure 1).

Overall grazing land uses constitute 86% of the catchment area signifying the major importance of this land use on water quality in the Tarwin River and its tributaries.

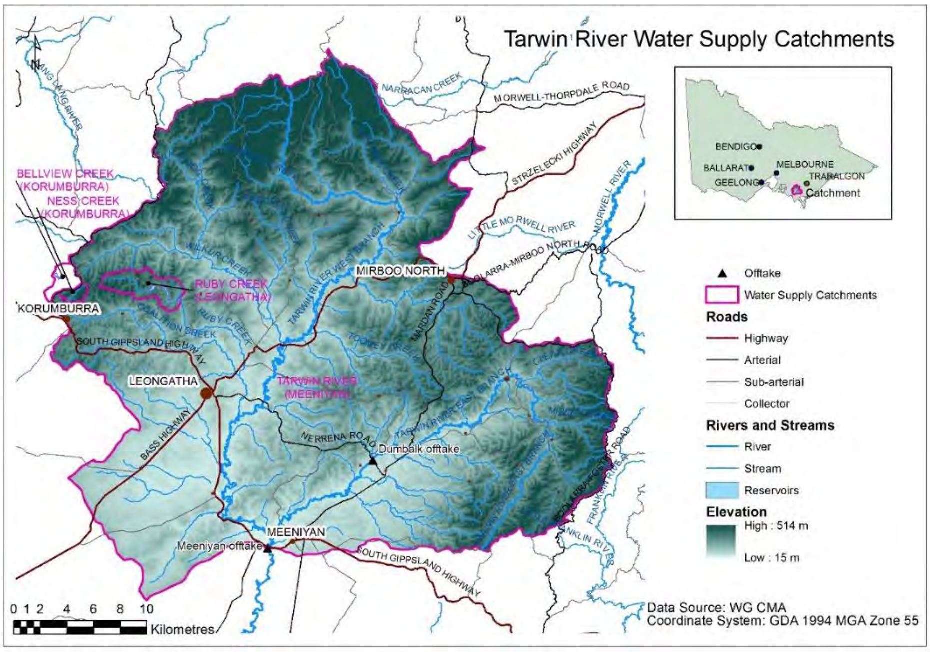


Figure 1. Tarwin River Water Supply Catchment Elevation.

Water quality issues in the Tarwin River Water Supply Catchment

Historical analysis of storm water samples in Meeniyan and other towns with partial or no sewerage service has indicated very high concentrations of microbial indicator organisms like *E. coli* and nutrients (nitrogen and phosphorus).

Around 14% of on-site wastewater systems in use in the catchment are toilet-only systems, which treat only the toilet wastewater (i.e. blackwater). The remaining portion of wastewater from showers, baths, basins, etc., is discharged to local creeks, rivers and ground waters via the storm water system. Discharge of greywater to the environment means that local stormwater can be expected to have a high nutrient and pathogen loadings.

Densities of unsewered dwellings

A legacy of past subdivision practice has resulted in the creation of numerous lots in the Farming Zone (FZ) less than 1000 m^2. Many of these lots were created before planning permits were required, with many being created as a result of historic road realignment practices. Changes to the Planning Scheme mean that such small lot subdivisions are unlikely to be permitted. However the legacy of smaller undeveloped lots remains.

With respect to minimum lot sizes for development SGSC's adopted Rural Land Use Strategy supports the development of new dwellings on lots under 4.1ha, and therefore is in conflict with the DEPI Catchment guidelines which support a much lower dwelling density (1 dwelling per 40 ha). However the guidelines permit smaller lots and higher densities if it is consistent with the local Catchment Policy and a range of other conditions required by the guidelines are met. As the Tarwin Water Catchment Policy is completed, the potential conflicts in planning policy are expected to be resolved.

Future development potential

Under the current planning regime, the number of possible future unsewered dwellings that may be permitted in the Tarwin Water Supply Catchment is estimated to increase from the current 1875 by 2366 (i.e. 126%) to around 4241 dwellings in the future.

Grazing pasture landuse and stock access to waterways

As noted above, grazing land uses constitute around 86% of the catchment area. Most of this is grazing of cattle for milk and beef production. Cattle are a potential source of human infectious pathogenic protozoa and bacteria; in particular *Cryptosporidium parvum, Giardia duodenalis, Salmonella* spp. *Campylobacter* spp. and some pathogenic strains of *E. coli*. The pathogen of most concern is *Cryptosporidium* due to its resistance to oxidizing disinfectants and greater environmental persistence compared to other microbial pathogens.

On-site wastewater treatment systems

On-site wastewater treatment systems such as septic tanks are a source of bacterial and protozoan pathogens but unlike cattle, on-site systems are also a source of human infectious viruses including Adenovirus, Rotavirus, Norovirus and Hepatitis A Virus. Consequently modelling involved assessing the fate of a key reference species from each of the major pathogenic groups; protozoa, bacteria and viruses. Reference pathogens were *Cryptosporidium* (protozoa), *Campylobacter* (bacteria) and Adenovirus (viruses).

Development of the Tarwin eWater "Source" Model

Modelling for the TWSCMP was conducted using the eWater "Source" water catchment software package. Using the model, a range of management scenarios were modelled and compared to the base case of current management. Modelling scenarios are described in more detail later in this summary.

Pathogen generation rates

Source combines a rainfall runoff model with landscape generation rates of constituents; *i.e.* pollutants such as sediments, nutrients or microbial pathogens. Determination of generation rates for pathogens is an active area of research and published rates are still relatively rare. To aid the Source pathogen modelling effort, two quantitative pathogen generation rate models (one for cattle and one for on-site treatment systems) were developed as part of this study to provide estimates of pathogen loads generated in each subcatchment for each modelling scenario.

Source runoff model verification

The Source model was validated for the Tarwin River catchment at sites with available gauged flow data. It was concluded that from the perspective of discharge, the model was suitable for predicting contaminant loads at the monthly time-step, although peak daily loads are slightly underestimated. The model performed best at the most downstream point of the catchment which was the Meeniyan water supply offtake.

Key Management Areas and related programs

To direct the modelling effort and management plan development, a stakeholder Working Group identified the Key Management Areas (KMAs) of interest and also provided guidance in the form of a vision, guiding principles, specific goals, and the makeup of management programs to assist in meeting the goals.

Vision, Key Guiding Principles and KMAs

In order to address the hazards to water quality in the Tarwin River catchment, the Working Group developed the following vision for the catchment:

> *"Our vision is for the Tarwin Water Supply Catchment to have productive and sustainable communities and healthy ecosystems that provide clean water."*

The Working Group also developed guiding principles to ensure the vision's fulfilment:

> *"The vision will be fulfilled by supporting and promoting a culture of sustainable development and cooperation and focussing on mutually beneficial outcomes through the implementation of the best and/or most appropriate management practices. We will identify and progressively work through the challenges to achieve our long-term goals."*

To meet these guiding principles two Key Management Areas (KMA's) were identified for the Plan, reflecting the main focus and actions required, in order to work towards and achieve the Vision for the catchment (Table 1).

Table 1. The KMAs, aims, and six supporting goals

Item	Description
KMA 1	**Riparian and Land Management**
Aim	*Protect water quality in the Tarwin River Water Supply Catchment through the protection and restoration of riparian vegetation and control of stock access.*
Goals	Goal 1: Protect water quality in the Tarwin River and its tributaries by restoring and conserving riparian buffer zones.
	Goal 2: Control loads of sediments, nutrients and pathogens to waterways by excluding stock from waterways except under licenced conditions for controlled grazing.
	Goal 3: Provide landholders and management agencies with a clear definition of the waterways that are to be managed for water supply protection.
KMA 2	Wastewater Management
Aim	*Ecologically sustainable development that minimises transport of contaminants to waterways, and supports good water quality and stream health in the Tarwin River Water Supply Catchment.*
Goals	Goal 4: Protect water quality in the Tarwin River and its tributaries by improving the quality of wastewater discharge and reducing the quantity of surface water discharge.
	Goal 5: Manage and reduce loads of pathogens and nutrients from on-site wastewater management systems.
	Goal 6: Minimise adverse impacts on waterways through continuous improvement in stormwater management and recycling.

Best Management Practice Programs

A series of Best Management Practice (BMP) actions that support the goals of the KMAs were developed with the support of the Working Group. These BMPs are aspirational and are described only briefly in this management plan. For BMPs to be implemented, a local agency needs to be nominated and to accept the role of lead agency for the development of a detailed Implementation Plan which includes costing and roles and responsibilities. The implementation plan should coordinate the activities of other supporting agencies and provide feedback on the performance of the plan in achieving the goals over time. Note that the plan may refer to the existing work programs of other agencies that are relevant to the goals of the TWSCMP. The BMPs are listed below and described in more detail in the body of the plan.

KMA 1: Riparian and Land Management:

- Riparian Zone BMP;
- Animal Production BMP; and
- Horticulture BMP.

KMA 2: Wastewater Management:

- Urban Stormwater BMP;
- On-site systems BMP; and
- Licensed discharges BMP (including Wastewater Treatment Plants).

Modelling scenario selection – assessment of program elements

Not all KMA program elements are capable of being assessed using catchment water quality models due to the diffuse nature of their benefits (e.g. improved agency catchment coordination), or current lack of sufficient technical or scientific data to support a modelling scenario. Consequently a shortlist of program elements was selected based on their suitability for modelling and their perceived need for assessment as considered by the Consulting Team and the stakeholder Working Group.

In total *nine management scenarios were developed and examined*. Scenario 2 examined partial and full implementations of particular management actions and so for clarity, it was grouped together to give 8 scenario groups (Table 2).

Table 2. Management scenarios

Scenario Group.	Management Scenario
	Scenario 1: Base Case, Current Management
Riparian & Land Management	Scenario 2: Implementation of Riparian Best Practice Management • Scenario 2a: Implementation of BMP (fencing and off-stream watering points) for riparian zones within grazing land use only • Scenario 2b: Implementation of BMP for riparian zones for all land uses across the catchment (excluding existing forested landuses)
	Scenario 3: Stock Exclusion Fencing Only
	Scenario 4: Calf health programs &/or exclusion of calves from riparian connected paddocks
Wastewater Management	Scenario 5: Implementation of Infrastructure Design Manual standards
	Scenario 6: Improved Management for on-site systems
	Scenario 7: Full development of unsewered properties to maximum acceptable densities under existing planning laws
	Scenario 8: Full development and improved management

For each modelling scenario the effectiveness of the identified management actions were modelled on sediment, nutrient and microbial pathogen parameters. Not all parameters are appropriate for modelling with each scenario. For example, Adenovirus concentrations are mainly a product of septic tanks and leaking sewers and so are not relevant to management actions that do not involve these issues. Table 3 shows which parameters were appropriate for modelling for particular scenarios.

Table 3. Summary of parameters of relevance to management scenarios and used in modelling and the modelling approach that could be used.

		Parameter modelled for management scenario					
No.	**Management Scenario and sub-scenario**	**Nitrogen (N)**	**Phosphorus (P)**	**Suspended solids**	**Cryptosporidium**	**Adenovirus**	**Campylobacter**
1	Base Case, Current Management	✓	✓	✓	✓	✓	✓
2	Implementation of Riparian Best Practice Management						
	Scenario 2a: Implementation of BMP (fencing and off-stream watering points) for riparian zones on Crown Frontages within cattle grazing land uses	✓	✓	✓	✓	✓	✓
	Scenario 2b: Implementation of BMP for riparian zones for Crown Frontages and Private Land for all perennially flowing streams within cattle grazing land uses	✓	✓	✓	✓	✓	✓
3	Stock Exclusion Fencing Only	✓	✓	✓	✓	✓	✓
4	Calf health programs &/or exclusion of calves from riparian connected paddocks				✓	✓	✓
5	Implementation of Infrastructure Design Manual standards	✓	✓	✓			
6	Improved Management for on-site systems	✓	✓	✓	✓	✓	✓
7	Full development of unsewered properties to maximum acceptable densities under existing planning laws	✓	✓	✓	✓	✓	✓
8	Full development and improved management	✓	✓	✓	✓	✓	✓

Modelling results

Model runs produced a time series of daily loads for each constituent for the modelled period 1973-2013. This produced files with around 14,640 cases (40 years x 365.25 days) which required some distillation in order to develop useful statistics for comparison. Loads were converted to average tonnes per month for sediments and nutrients and to organisms per month for pathogens. From an ecological and human health point of view concentrations in river water are of interest, particularly for pathogens, however these vary greatly on a daily basis due to flow variations and the local scale effects are uncertain. The most useful presentation of model results was therefore to present average monthly loads for all parameters and monthly averages of daily concentrations for pathogens.

Conclusions

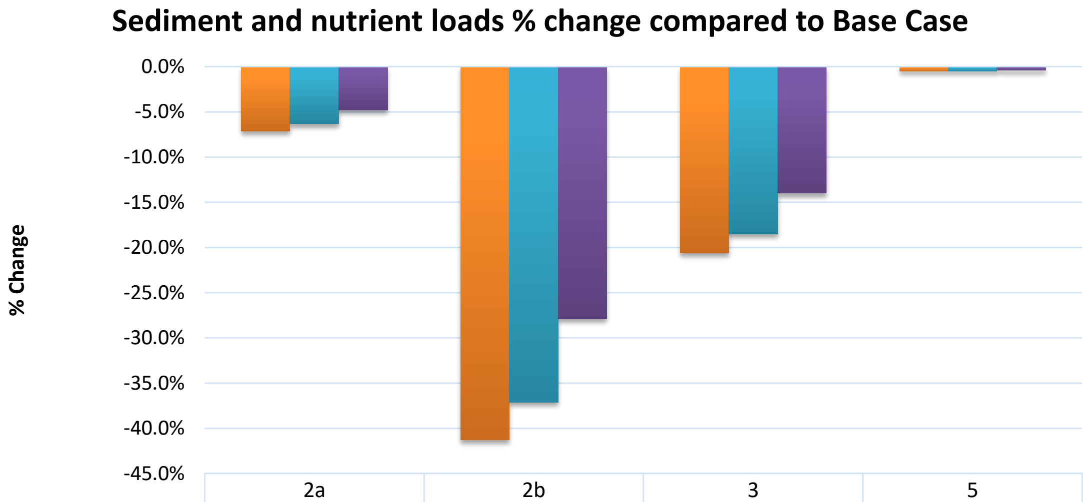
- Modelling of sediment and nutrient loads showed that implementation of riparian and landuse best practice management gave major reductions in annual transported loads of sediments and nutrients (SS up 41%, TN and TP up 37% and 28% respectively). The greater the degree of implementation and percentage of catchment waterways, the greater the reduction in loads.
- Improved stormwater management was modelled as minor improvements to urban drainage consistent with the Infrastructure Design Manual. This scenario generated little benefit due to the relatively small areas of the catchment

influenced by such changes (township zones) and the limited nature of the modelled changes in comparison to full implementation of water sensitive urban design.

- Sediment and nutrient load reductions would be likely to lead to some tangible improvements in instream water quality, but most of the benefits would be manifested downstream in the Tarwin River Estuary (Andersons Inlet). Assessment and modelling of downstream benefits was beyond the studies' scope, however reduced sediment and nutrient loads to Andersons Inlet could be expected to decrease the likelihood of excessive algal growth to the benefit of seagrass communities.

- Modelling of pathogen loads, was considered useful even though it could be argued that loads are not so closely linked to potential health impacts as concentrations. Analysis of pathogen loads indicated a dominance of the riparian management scenarios over the wastewater management scenarios for *Cryptosporidium* but the reverse for *Campylobacter* and Adenovirus.

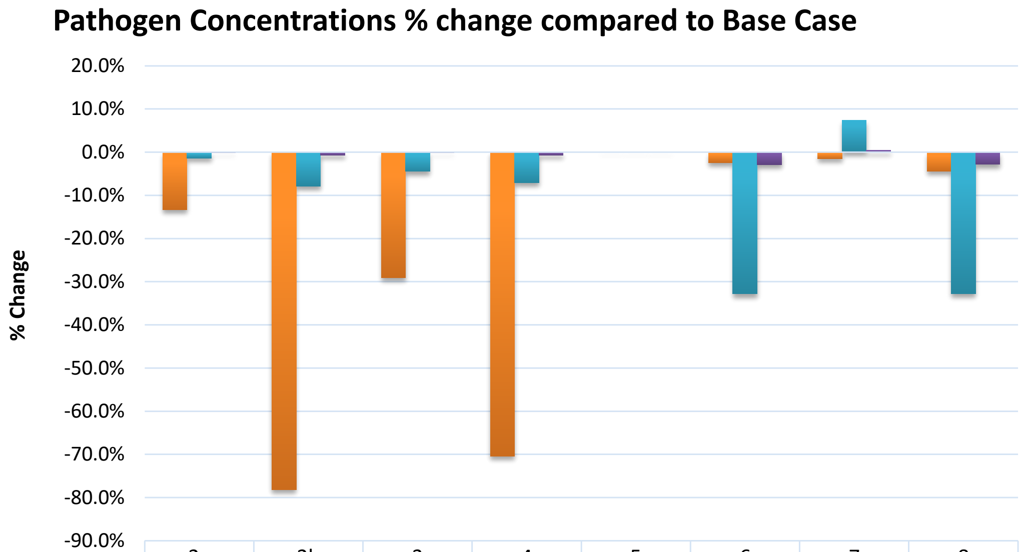
- The reasons for the dominance of wastewater management scenarios over riparian management scenarios are clear for Adenovirus, since it is not sourced from cattle, and therefore model settings did not differ between the base case and the riparian management scenarios. For *Campylobacter*, the difference could be due to uncertainty in model settings (discussed below) as the settings for the wastewater management and the riparian management scenarios were informed by different sources of evidence.



	2a	2b	3	5
Suspended Solids	-7.1%	-41.3%	-20.6%	-0.5%
Total Nitrogen	-6.3%	-37.1%	-18.5%	-0.5%
Total Phosphorus	-4.8%	-27.9%	-14.0%	-0.4%

Figure 2. Summary of percent change changes in Meeniyan average annual loads of suspended solids and nutrients for each scenario compared with the base case. For sediments and nutrients there were no significant changes for scenarios 4, 6, 7 & 8 and these have been excluded from the graph above for clarity.

- Modelling of monthly averages of daily pathogen concentrations showed a marked seasonal pattern with highest average concentrations occurring during the low flow period encompassing January, February and March. The seasonal pattern dominated the modelled results, making it difficult to differentiate between the scenarios to varying extents.
- Results of different modelling scenarios, for average monthly concentrations, also differed markedly depending on the reference pathogen with greatest differences observed for *Cryptosporidium* and to a lesser extent *Campylobacter*, while the Adenovirus modelling scenarios could not be separated without narrowing the focus to just a few months.
- Modelling settings for *Cryptosporidium* were considered to be more robust and based on a stronger evidence base than those of *Campylobacter* and Adenovirus and should be given greater weight for consideration in management responses. Estimates for *Campylobacter* runoff coefficients for the high dwelling density land uses used in the modelling were based on *E. coli* monitoring data assuming a certain ratio of *Campylobacter* to *E. coli.* This is a critical assumption for *Campylobacter* and while efforts were made to quantify the assumption based on ratios in cattle manure, there is still a significant degree of uncertainty.
- For Adenovirus, modelling at the whole of catchment scale was unable to separate the wastewater management scenarios when viewed as average monthly concentrations due to the high seasonal variation, although load-based comparisons gave a clearer separation which was more consistent with the other pathogens. Zooming in to focus on just a few months at time did show separation between the scenarios consistent with the *Campylobacter* results.
- The reason that the Adenovirus Wastewater Management Scenarios did not differ much from the base case was because that the base case runoff coefficients for grazing land uses (mostly Farming Zone) which make up nearly 80% of the catchment area are low to begin with due to the low density of on-site treatment systems and are not greatly altered in the scenarios.
- In comparison the higher dwelling density landuses (e.g. Rural Living Zone) where the changes to runoff coefficients are more significant for the different scenarios collectively only make up a small percentage of the catchment and therefore the catchment-wide effects of changes at these locations is attenuated.



	2a	2b	3	4	5	6	7	8
Cryptosporidium conc.	-13.3%	-78.1%	-29.1%	-70.4%	0.0%	-2.4%	-1.5%	-4.4%
Campylobacter conc.	-1.4%	-7.9%	-4.4%	-7.1%	0.0%	-32.8%	7.4%	-32.8%
Adenovirus conc.	-0.1%	-0.7%	-0.1%	-0.7%	0.0%	-2.9%	0.5%	-2.9%

Figure 3. Pathogen concentration changes (in %) for each scenario compared to the base case

Recommendations

Implementation of Riparian Best Practice Management across all perennial catchment waterways gave the largest reduction in average monthly *Cryptosporidium* concentrations. In contrast implementation of Wastewater Management Best Practice scenarios (largely focused on on-site systems) gave the greatest reduction in *Campylobacter* concentrations. However, since *Cryptosporidium* is much more difficult to treat than *Campylobacter*, reductions in *Cryptosporidium* are more important from a drinking water supply perspective than reductions in *Campylobacter* or other bacterial pathogens. Bacteria as a whole are more readily removed by oxidative disinfection processes (e.g. chlorination) than encysted protozoa. Furthermore, the evidence-base to support model settings is greater for *Cryptosporidium* than *Campylobacter*, so more faith can be placed in the model findings for *Cryptosporidium*. If monitoring data was available, the model settings could be calibrated to improve confidence in the magnitude of *Campylobacter* predictions. Consequently it is recommended that the results of the *Cryptosporidium* modelling be given a greater weight in management responses than the results of the *Campylobacter* modelling.

With respect to Adenovirus, the quantity of virions (i.e. individual virus particles) available in the catchment are two to three orders of magnitude less than *Cryptosporidium* and *Campylobacter,* reflecting the fact that cattle are present in high numbers across most of the catchment and are a major source of these pathogens but do not shed human-infectious viruses. It is important to note however, that virus concentrations here are reported as monthly averages of predicted daily average concentrations from the most downstream part of the catchment. In reality, virus concentrations will vary widely across locations in the catchment due to local factors such as the density and frequency of failing on-site treatment systems, the presence of urban stormwater outfalls and in the sewered areas, damaged sewer pipes.

Despite the findings of this study that cattle are the most important source of pathogens in the Tarwin Water Supply Catchment, management of on-site treatment systems and local scale factors such as setback distances to potable supply waterways, etc. are still important factors and need to be managed appropriately. Local scale (i.e. on a smaller scale than this study, e.g. ~100 hectares) modelling of on-site treatment systems will provide guidance on system design, maintenance and siting.

The findings of this study nevertheless indicate that South Gippsland Water should:

- *As a first priority emphasize improvement programs for riparian buffers and for stock health; and*
- *As a second priority support on-site wastewater management programs with an emphasis on treatment compliance programs over planning controls in relation to dwelling densities.*

The details of the proposed riparian and wastewater management programs and associated action items are described in Section 5 of this management plan. For each program it is recommended that South Gippsland Water and South Gippsland Shire initiate Implementation Working Groups consisting of relevant catchment partners and any other interested parties. The Working Groups should identify and agree on roles and responsibilities and seek resources to support implementation.

Research on pathogen fate and transport in water supply catchments is an area that has not been strongly supported by active research programs in the past, with the exception of some work overseen by Water Research Australia and its predecessor organisations in the early 2000s. Consequently there are many data gaps in this area, and future research may provide more definitive findings on the relative risks from different pathogens. While this is an issue for the National Water Industry, it is important that regional water companies, such as South Gippsland Water raise the need for such research in their dealings with relevant state and national agencies.

At a local level, in the Tarwin Water Supply catchment, routine monitoring of microbial indicator organisms such as enterococci and *E. coli* as well as targeted short-term monitoring of specific pathogens such as *Cryptosporidium*, *Campylobacter* and Adenovirus can provide stronger evidence bases for guiding decision makers.

Under the proposals for Victoria's Safe Drinking Water Regulations (DoH 2013), water businesses would be required to characterise source water risk and demonstrate that they have reliable barriers in place to effectively manage identified microbial hazards such as bacteria, viruses and protozoa in all scenarios. In the absence of monitoring data, conservative default assumptions that tend to overstate the risk would be necessary and may lead to calls for further water treatment at a significant cost. Consequently it is recommended that South Gippsland Water review its current catchment water quality monitoring programs with a view to developing a useful and effective reference database of microbiological data.

To recap, in the introduction to this plan, its purpose was to support the development of a Water Catchment Policy for the Tarwin River Water Supply Catchment. With the completion of this plan, the next stages of the Catchment Policy development can begin.

Glossary

Base case – Current conditions scenario.

DWC - Dry Weather Concentration. Water quality concentration during low flow (baseflow) events.

Constituent – a solute (e.g. nitrogen, phosphorus) or particle (e.g. suspended solids, microorganisms such as *Cryptosporidium*) that is transported from the catchment with rainfall runoff.

EMC - Event Mean Concentration. Water quality concentration during high flow events.

Functional Unit - Areas with common behaviours. In this model this represents landuse.

Scenario – Model run testing a particular management action.

SIMHYD - A 1-D hydrological (computer) model that generates streamflow from rainfall, evaporation and soil property data.

Source Model- Computer model from eWater employed to determine catchment loads and allow the user to investigate different scenarios that generate these.

Subcatchment - A subdivision of a catchment.

VWQMN - Victorian Water Quality Monitoring Network. Water Quality data collected and stored on the Victorian Data Warehouse internet site.

1 Introduction

South Gippsland Water (SGW) and South Gippsland Shire Council (SGSC) and other relevant stakeholders are preparing a Water Catchment Policy for the Tarwin River Water Supply Catchment. The Policy, which is consistent with the DEPI Guidelines for Planning Permit Applications in Open, Potable Water Supply Catchment Areas (DEPI 2012), will address land use planning issues and the cumulative impact of onsite wastewater/septic tank systems in the Tarwin River Water Supply Catchment area. The Catchment Policy will allow strategic land use planning to occur based on identification of areas of risk and the appropriate implementation of risk based management responses.

As part of the Policy development, a Catchment Land Use and Development Management Strategy (Figure 1-1) has been prepared by South Gippsland Water and South Gippsland Shire Council. The strategy outlines the process to be adopted in the development of the Catchment Policy and includes:

- Interim Assessment Guidelines which apply during the development phase of the Catchment Protection Policy; and
- Development of a Water Supply Catchment Water Quality Risk Management Plan which consists of:
    - A quantitative catchment process model; and
    - Risk management planning. This part of the plan is informed by the quantitative modelling.

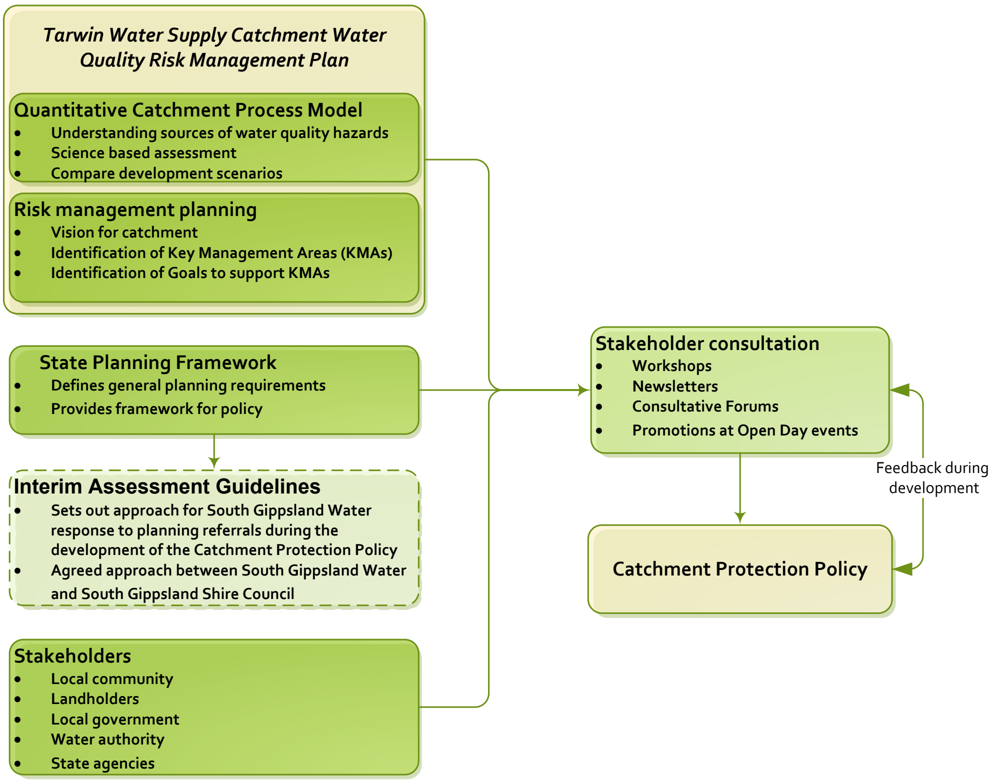


Figure 1-1. Development strategy for the Tarwin Water Catchment Policy

Ecos Environmental Consulting and Water Technology were commissioned to develop the Tarwin Water Supply Catchment Management Plan (TWSCMP) including the Quantitative Catchment Process Model and associated water quality risk management planning. The Plan is described in this report.

1.1. Background

Open and closed water supply catchments

A potable water supply catchment provides water for treatment and supply as drinking water. The Victorian DEPI Guidelines for Planning Permit Applications in Open, Potable Water Supply Catchment Areas (DEPI 2012) distinguish two types of potable water supply catchments. An 'open' catchment is where part or all of the catchment area is in private ownership and access to the catchment is unrestricted. A 'closed' catchment means that the whole of the catchment area is publicly owned and public access is prohibited.

Water corporations do not have direct control over land in open, potable water supply catchments but in order to manage risks to catchment water quality, they can influence development and land use through the strategic and statutory planning process.

The DEPI guidelines seek to protect the quality of potable water supplies, using a risk based approach, whilst facilitating appropriate development within these catchments. The guidelines set requirements for:

(1) Density of dwellings
(2) Effluent disposal and septic tank system maintenance
(3) Vegetated corridors and buffer zones along waterways
(4) Buildings and works
(5) Agricultural activities

Variations to these requirements are permitted through various mechanisms which are described in the guidelines, for example; "*Water corporations, in consultation with other stakeholders, may prepare a water Catchment Policy, water catchment risk assessment or similar project to address land use planning issues and the cumulative impact of onsite waste water/septic tank systems in a catchment area*" (DEPI 2012).

1.2. Objectives of the Tarwin Water Supply Catchment Management Plan

The development of a Tarwin Water Catchment Policy is consistent with the approach advocated by the DEPI guidelines. It is a primary objective of the TWSCMP to support the Water Catchment Policy by taking into account community interests and providing science-based guidance on catchment water quality processes. This objective was achieved by:

- Conducting a consultative process to identify issues of interest to key stakeholders;
- Undertaking water quality modelling to test management scenarios;

- Developing management scenarios consistent with requirements for drinking water supply, local government planning controls, and waterway management objectives identified by regional agencies (e.g. DEPI, CMAs etc.).

The TWSCMP is a risk-based catchment and investment strategy to direct activities aimed at protecting drinking water quality in the Tarwin River Catchment. Management issues and options identified in the plan were derived from community consultation, literature reviews and catchment modelling (conducted as part of the study).

1.2.1. Modelling objectives

An important component of the TWSCMP is the determination of the impact of land management practices in the catchment on water quality at the drinking water offtakes. Central to this component is the development of a catchment contaminant transport model. The model is able to make quantitative predictions of a range of contaminants at the offtakes and also estimate the relative proportion of contamination coming from specific sub-catchments.

The model requires the input of data describing a specific contaminant or contaminants, where the magnitude of measured values can be linked to catchment management practices. The accuracy of the modelled scenarios is determined to a significant extent by the availability of long term water quality monitoring data and also by the availability of spatial data showing the location and likely contaminants generated by land management activities.

The specific objectives of this modelling study were to:

1. Develop a quantitative water quality model based on the current condition of the Catchment;
2. Evaluate a range of broad management scenarios or possible future conditions of the catchment;
3. Indicate possible areas for further detailed investigation in accordance with the ongoing implementation of the TWSCMP; and
4. Provide scientific guidance to support future policy positions set out in the Water Catchment Policy.

1.3. Institutional Framework and the Role of the Tarwin Water Supply Catchment Management Plan

Water Corporations in rural and regional Victoria are Referral Authorities for Planning Permit applications within their areas of operation. The referral powers are set out in section 55 of the Planning and Environment Act and permit a Referral Authority to object to the proposal, in which case the responsible planning authority must refuse to issue a Permit, or otherwise provide consent with conditions, in which case the planning authority must include these conditions on any permit, if granted. Planning inconsistencies and other difficulties can arise when the water corporations, local government and other agencies and stakeholders have different interpretations of risk and of appropriate management responses.

The TWSCMP, therefore, has been prepared to provide a better understanding of risks to catchment water quality and to guide catchment management, investment and monitoring activities aimed at protecting and enhancing water quality and catchment health associated with the water supply sub-catchments in the Tarwin River Catchment.

Effective catchment management requires a whole-of-government and a whole-of-community approach. The proponent agencies for this plan, SGW and SGSC, recognise that they cannot achieve significant change on a whole-of-catchment basis by working in isolation. For this reason a project Working Group was established, comprising many organisations and individuals, so that creative partnerships could be established between groups having shared natural resource management interests and objectives (refer Section 3 for further information).

There are a number of existing natural resource management plans, initiatives and strategies established at a local, State and Federal Government level that apply to the South Gippsland Region (and therefore apply to the Tarwin River catchment). Many of these plans and strategies share common objectives.

The key natural resource management initiative in the region is the West Gippsland Regional Catchment Strategy (RCS) prepared by the West Gippsland Catchment Management Authority (WGCMA). The RCS is a statutory document under the *Catchment and Land Protection Act 1994* (CaLP Act) and provides the overarching framework for land, water and biodiversity management and conservation in the region.

The RCS lists a number of environmental plans that deal with issues such as waterways, salinity, soil erosion, invasive plants and animals, biodiversity, floodplain management and coast landscapes. Of most relevance to the TWSCMP is the Draft West Gippsland Waterway Strategy 2014-2022. Preparation of this Strategy for the West Gippsland Region is a statutory requirement for the WGCMA under the *Water Act 1989*. The strategy identifies high priority waterways requiring protective or enhancement works to protect identified values.

Similarly, the local government agencies that overlap with the Tarwin River Water Supply Catchment - SGSC, Baw Baw Shire Council and Latrobe Shire Council - have various Housing and Settlement Strategies, Municipal Domestic Wastewater Management Plans, and also oversee implementation of the State Planning Scheme in their areas of jurisdiction.

The above strategies and plans are in some cases at a high level (e.g. West Gippsland RCS), or deal with a broader range of issues across a larger area than the Tarwin Water Supply Catchment (e.g. the CMA's Waterway Strategy). Nevertheless many of these issues intersect with water supply management issues in the Tarwin River Water Supply Catchment. SGW has developed a number of management strategy documents that identify its catchment management priorities and guide its response to those priorities. These documents include:

- SGW Catchment Land Use and Development Management Strategy (sets out SGW's plans for a Water Catchment Policy and provides interim guidelines for planning referral applications);

- SGW Catchment Monitoring, Assessment and Improvement Program (CMAIP) (details SGW catchment management monitoring, assessment and improvement activities)
- SGW Water Supply Catchment Development and Land Use Guidelines (assists SGW in its assessment of planning permit applications in its open water supply catchments).

The TWSCMP will act as a reference document for SGW that will inform the direction of its Water Catchment Policy, CMAIP, and assessment of planning permit applications.

For the councils - SGSC, Baw Baw Shire, and Latrobe Shire - the TWSCMP will provide planning staff with a clearer understanding of catchment water quality issues and enable a greater degree of co-operation and understanding between SGW and the councils in relation to planning issues. Existing council planning protocols (e.g. Domestic Wastewater Management Plans) which are already focussed on public health and environmental protection such as management of on-site wastewater treatment systems, can be refined to provide more effective, efficient and appropriate responses.

For the regional agencies and industry groups – specifically WGCMA, DEPI, EPA, and the Department of Health, the VFF, GippsDairy and others - the TWSCMP provides a point of reference for understanding water supply catchment management issues where they intersect with the interests of these organisations. The presence of a dedicated water supply catchment management plan enables these organisations to more effectively consider the safety and security of regional drinking water supplies in their own planning. For example, GippsDairy and Dairy Australia already encourage good environmental practice in relation to waterway fencing to their members, so it's easy to envisage how such organisations could encourage further improvements, e.g. educating members on the management of scouring calves, one the main sources of *Cryptosporidium* in catchment waterways and which poses a risk to water supplies.

Similarly, the West Gippsland Waterway Strategy sets out the WGCMA's priorities for stream protection and restoration works. Whilst it contains comparable objectives to SGW's CMAIP, the CMA does not necessarily have the same priorities in the Tarwin River water supply catchment as SGW.

Nevertheless, this does not prevent SGW from working together with the CMA - the TWSCMP identifies the critical water quality and catchment health issues to be addressed in the Tarwin River water supply catchment, allowing SGW to partner with the CMA where the interests of the respective organisations are aligned. Similarly, this would also allow SGW to work with all other stakeholders in a similar way. A key aim of the TWSCMP is to identify opportunities for working together where shared interests can result in positive outcomes for the catchment, positive outcomes for the regional water supply, and positive outcomes for all participants in the projects and initiatives.

SGW and the 3 councils recognise that other partners in the catchment management process will have their own interests and priorities. However provided that any proposed action is consistent with the TWSCMP then SGW and the councils will work together with all partners for the benefit of the environment.

1.4. Developing the Management Plan

Catchment management is a complex area, management responsibilities are divided amongst many agencies, environmental processes are complex and occur over a large spatial area, the effects of human intervention in the catchment are diverse and environmental responses may occur rapidly or develop slowly over long time scales. Consequently, catchment management and catchment planning works best when stakeholders representing many disciplines work together.

For the management plan development process, an emphasis was placed on the involvement of stakeholders to assist in guiding the development of the plan and to ensure that the plan was consistent with the stakeholder's understanding of the main issues affecting water quality in the Tarwin catchment.

Development of the plan involved two stakeholder workshops to provide opportunities for stakeholder input and feedback, the development of linked pathogen source and hydrological models, and a final stakeholder workshop to provide comment on the draft plan. The overall process is set out graphically in Figure 1-2.

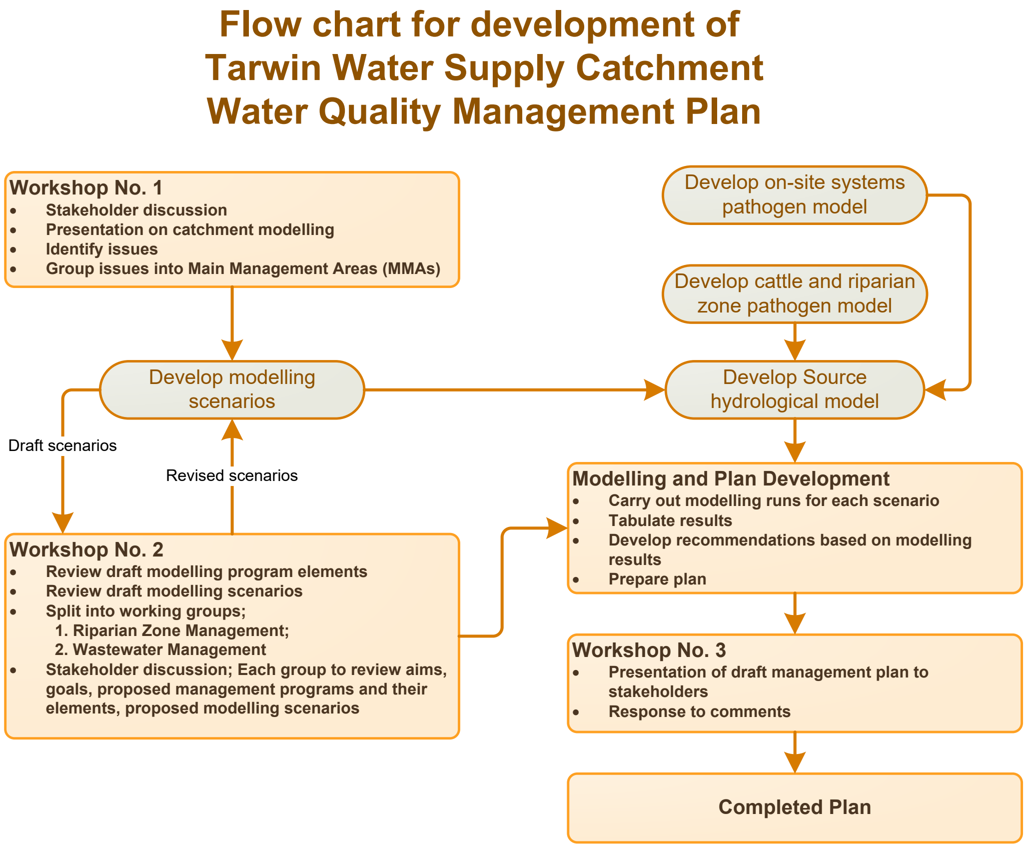


Figure 1-2. Flow chart for development of Tarwin Water Supply Catchment Water Quality Management Plan.

2 Tarwin River Water Supply Catchment description

2.1. The Tarwin Water Supply Catchment

The Tarwin River catchment ranges from an elevation of around 580 m AHD in the north to less than 100 m AHD for the lower catchment (and down to sea level at the estuary mouth at Andersons Inlet). The catchment geomorphology ranges from very hilly in the north to mildly undulating in the south (Figure 2-1).

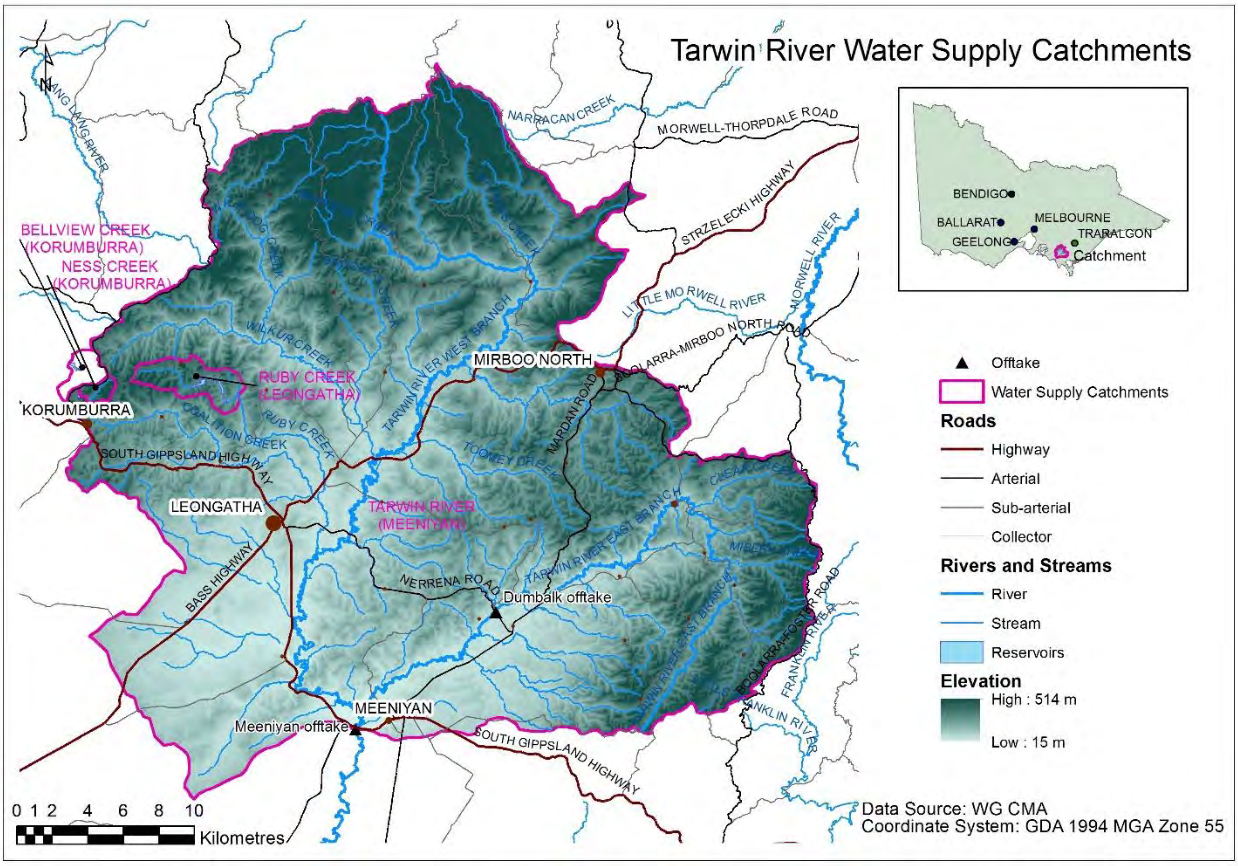


Figure 2-1. Tarwin River Water Supply Catchment Elevation.

The Tarwin Water Supply Catchment above the Meeniyan Water Supply Offtake is an open water supply catchment and consists largely of cleared grazing land, with some plantation forestry, and small regional towns. There are two water supply offtake locations supplied by large catchment areas:

(iii) Dumbalk which is supplied from the Tarwin River East Branch; and

(iv) Meeniyan which is supplied from the Tarwin River downstream of the confluence of the east and west branches (Figure 2-2).

Smaller subcatchments are located west of Korumburra (Ness Gully and Coalition Creek) and upstream of Fish Creek (Battery Creek Catchment). The Battery Creek Catchment is considered to be outside of the scope of the present study by South Gippsland Water and will not be considered further in this study.

2.1.1. Land use

Maps and tabulations of land use were calculated using the Australian Land Use Mapping (ALUM) standard (ABARES 2011) and the Victorian Land Use Information System digital data set (VLUIS 2010).

The ALUM classifications showed that almost 80% of the water supply catchment area (i.e. upstream of the Meeniyan water supply offtake) is dedicated to grazing of modified pastures (Figure 2-2, Figure 2-3, Table 2-1). It is understood that most of this land use is for grazing of dairy and beef cattle although there may be some land devoted to sheep grazing. The next most significant land uses are grazing of natural vegetation (likely to be public land reserves with a grazing lease) ~ 6.6% of the catchment; and plantation forestry, 4.4%.

Overall grazing land uses constitute 86% of the catchment area signifying the major important of this land use on water quality in the Tarwin River and its tributaries.

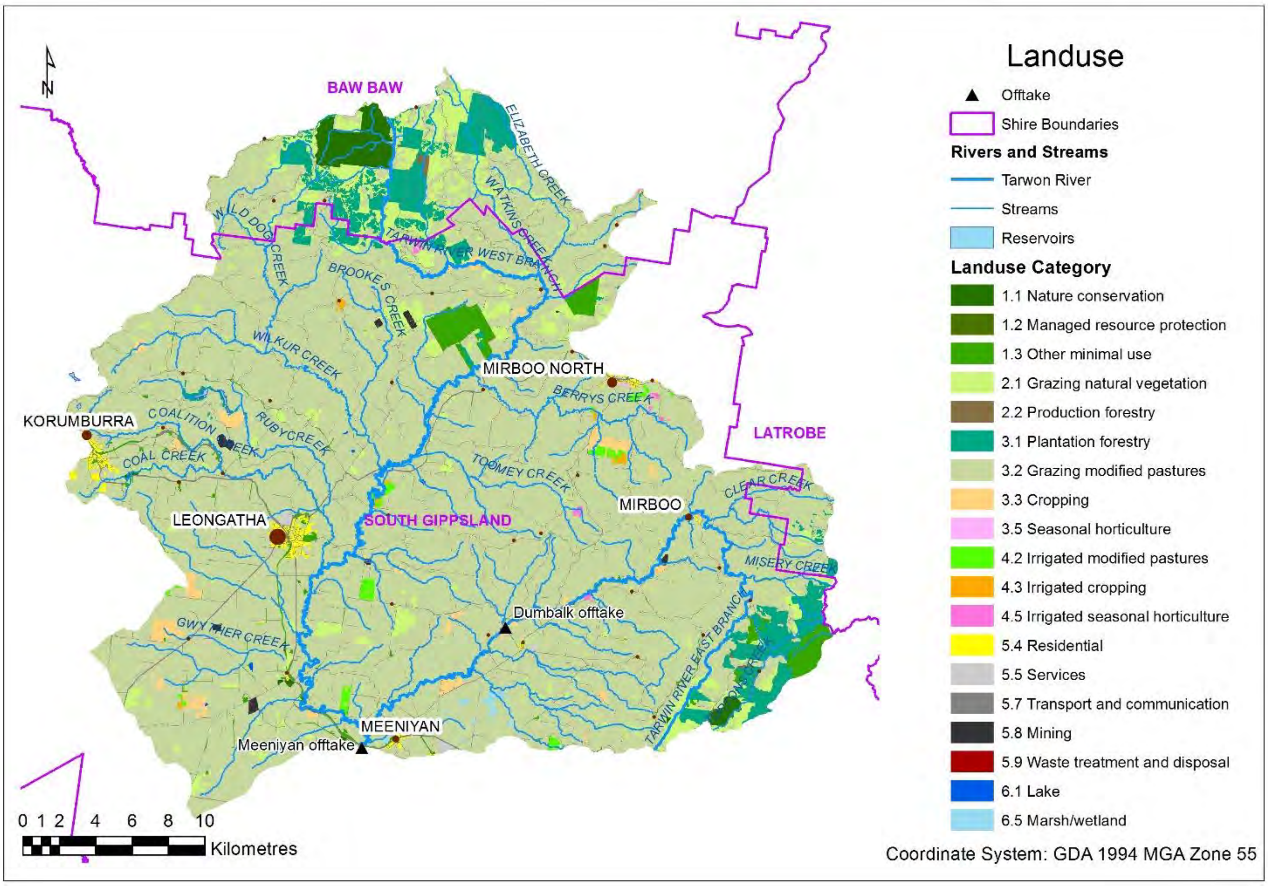


Figure 2-2. Tarwin Water Supply Catchment land use and municipal boundaries.

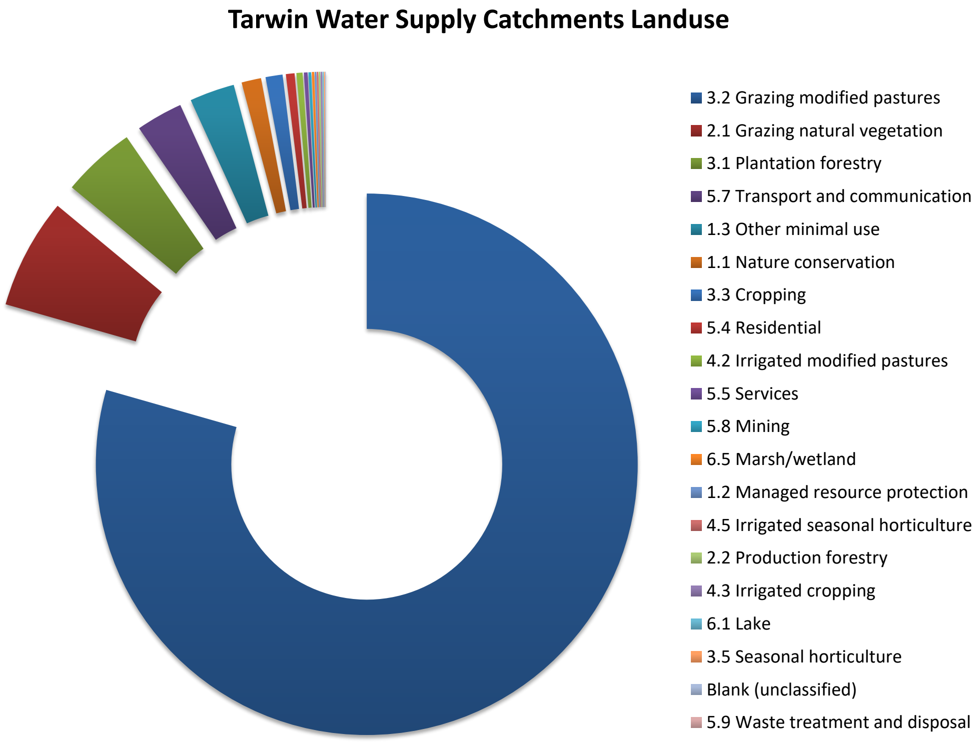


Figure 2-3. The major landuse categories by area in the Tarwin River catchment. The landuses in the key are listed in descending order of the area they cover in the catchment. Thus "grazing - modified pastures" is the dominant landuse in the catchment.

Table 2-1. Tarwin River Water Supply Catchment ALUM land use categories and their areas in hectares and as a proportion of the total.

ALUM Land Use Categories	Hectares	% of total area
3.2 Grazing modified pastures (incl. 3.2.1 Dry land dairy)	85,186.8	79.4%
2.1 Grazing natural vegetation	7,072.2	6.6%
3.1 Plantation forestry	4,700.7	4.4%
5.7 Transport and communication	2,987.3	2.8%
1.3 Other minimal use	2,875.4	2.7%
1.1 Nature conservation	1,254.1	1.2%
3.3 Cropping	1,084.7	1.0%
5.4 Residential	552.4	0.52%
4.2 Irrigated modified pastures	390.5	0.36%
5.5 Services	239.7	0.22%
5.8 Mining	176.1	0.16%
6.5 Marsh/wetland	146.1	0.14%
1.2 Managed resource protection	105.3	0.10%
4.5 Irrigated seasonal horticulture	98.8	0.09%
2.2 Production forestry	98.7	0.09%
4.3 Irrigated cropping	96.0	0.09%
6.1 Lake	74.3	0.07%
3.5 Seasonal horticulture	62.6	0.06%
Blank (unclassified)	45.5	0.04%
5.9 Waste treatment and disposal	0.3	0.0003%
Grand Total	107,247.6	100%

2.1.1.1. Average property size

A classification of property boundaries by size indicates that the most common size range in the farming zone is 60 to 400 ha. Near the township areas, there are many clusters of smaller properties less than 30 ha. In these areas it is likely that most properties have a dwelling and so the density of dwellings is likely to be less than the 1 dwelling per 40 ha DEPI guideline level for water supply catchments in many areas (Figure 2-4).

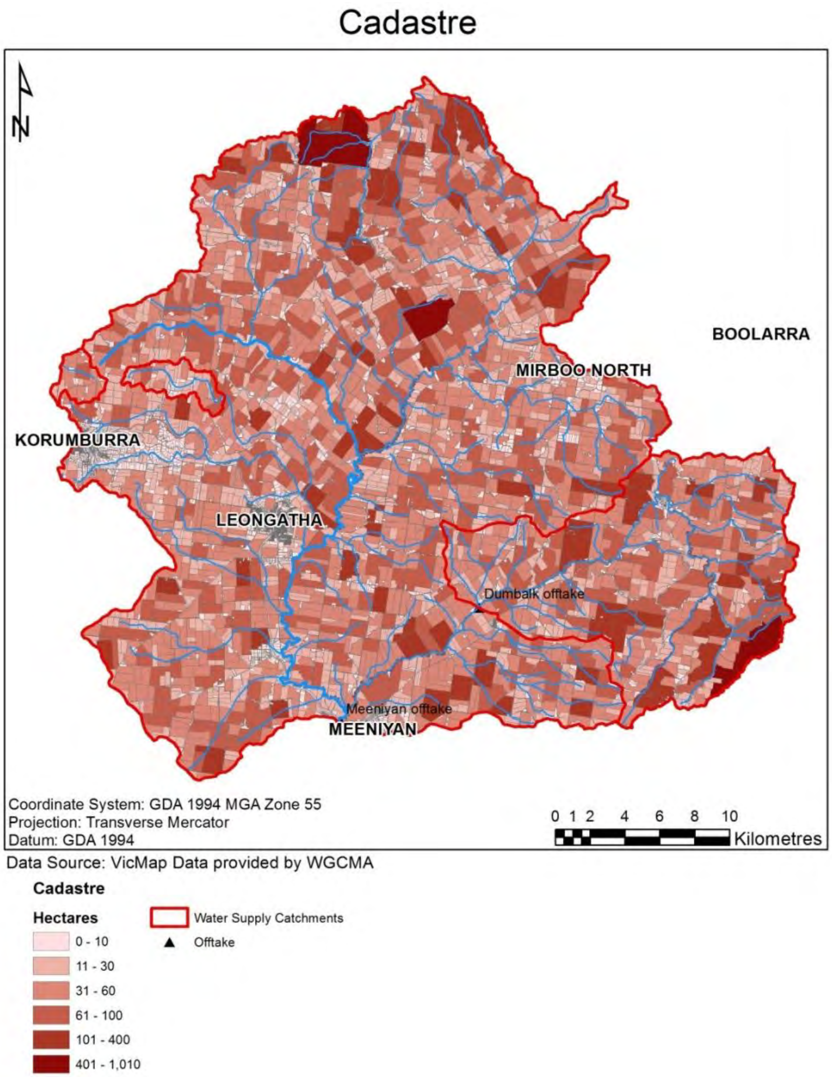


Figure 2-4. Land parcels classified by size

2.1.2. Water Supply Systems

The major towns, Korumburra and Leongatha, receive drinking water supplied through the Coalition Creek Storage network (Table 2-2). The network consists of 3 small catchments and associated storages to the north of Korumburra and on the western edge of the larger Tarwin Catchment (Figure 2-2). Leongatha receives drinking water supplies through the Ruby Creek Catchment. Ruby Creek then flows into Coalition Creek north east of Leongatha. The 3 storages are Coalition Creek Reservoir, Ness Gully Reservoir and Bellview Creek Reservoir (Appendix 1). The Bellview Creek Reservoir Catchment is part of the Bass River Catchment and is not included in this study.

The Coalition Creek Storages supply the Korumburra Water Treatment Plant (WTP). Treatment at the plant is focussed on removal of microbial pathogens and consists of primary sedimentation, coagulation, filtration and chlorination. Powdered Activated Carbon (PAC) is used to control taste and odour compounds and algal toxins when blue green algae are detected in the storages (usually in summer for short periods).

Leongatha is supplied by pipeline from the Coalition Creek Storages and via storages on Ruby Creek, Coaltin Creek, groundwater bores and the Tarwin River west branch (Appendix 1). Water treatment processes at the Leongatha WTP are similar to those at Korumburra.

Meeniyan receives drinking water from the Meeniyan WTP which treats water from the Tarwin River West Branch. The offtake location is downstream of Meeniyan and is the most downstream point in the study area. The Meeniyan WTP treatment train consists of pre-treatment, poly electrolyte coagulation, sedimentation, filtration and chlorination (Appendix 1).

The Dumbalk WTP draws water from the Tarwin River east branch upstream of Meeniyan and treats it to potable standard through pre-treatment, flocculation, clarification, filtration and chlorination (Appendix 1).

Table 2-2. Water Supply sources relevant to Tarwin Catchment Water Quality Risk Management Plan (sources: SKM (2011),(South Gippsland Water 2014)).

Centre	Population Served (Permanent)	Customers Billed	Current average raw water demand ML/yr	Supplied Water from
Korumburra	3,404	2,167	685	Coalition Creek storage. Emergency supplies for Korumburra are pumped from the Tarwin River at Koonwarra.
Leongatha, Kardella, Leongatha South, Ruby	4,921	3,054	1626	Ruby Creek, Tarwin River West Branch, Coalition Creek. Water can be supplied in extreme emergency from Coalition Creek, however emergency supplies for Leongatha would be pumped firstly from groundwater supplies from the Leongatha Groundwater Management Area.
Meeniyan	460	269	59	Tarwin River – West Branch
Dumbalk	418	102	20	Tarwin River – East Branch

1. Population Served based on ABS 2011 Census updated with a local government growth factor of 1.5% for South Gippsland Shire Council.
2. Water and Sewerage Assessments = Number of Rated Properties at June 2014.
3. The ABS method of calculation of population is based on State Suburbs and may not always reflect the exact water district.

2.2. Water quality issues in the Tarwin River Water Supply Catchment

2.2.1. On-site wastewater management

When on-site treatment systems such as domestic septic tanks or small commercial systems (e.g. Caravan Parks) fail, they may give rise to the pooling of septic effluent at the soil surface. Clogging of the septic tank disposal field reduces the capacity of the disposal field to accept otherwise normal hydraulic loadings while excessive hydraulic loadings can also cause surface ponding of effluent. During rainfall events surface effluent puddles can be entrained in stormwater runoff and transported to waterways.

Poorly sited tanks that do not comply with the Victorian EPA Code of Practice for Onsite Wastewater Management (EPA Victoria 2013) minimum setback distances or land capability requirements (e.g. located over shallow bedrock) can also pose a risk to waterways through shallow subsurface drainage.

The exposure pathway for subsurface flows begins with vertical percolation of effluent down to the water table whereupon it is entrained to flow horizontally in the direction of groundwater flow; usually downslope to the nearest waterway. Poorly operated on-site systems and poorly maintained disposal fields can have lower pathogen removal rates than well-managed systems and this increases the risks to groundwater[1].

Pathogens in septic effluent

Human infectious pathogens can be broadly classed into viruses, bacteria, protozoa and helminths. Water quality risk management is generally focussed on the first three groups only, as helminths (e.g. tape worms etc.) are not considered to be a major waterborne public health issue in Victoria. The most significant waterborne human infectious species of pathogens capable of causing gastroenteritis and in some cases further health complications (e.g. kidney failure, death) are viruses, bacteria, protozoa

Septic effluent from onsite treatment systems poses a risk to public health since human waste is the most significant source of human infectious pathogens and supports many species of pathogens among all three pathogen classes. In contrast animal manure, the other major source of pathogens in the catchment is generally only a source of a small number of bacterial and protozoan species. Nevertheless cattle can be a major source of pathogens such as *Campylobacter* and *Cryptosporidium* (see section 2.2.4).

2.2.1.1. Current wastewater management

Stormwater and groundwater quality

Historical analysis of storm water samples in Meeniyan and other towns with partial or no sewerage service has indicated very high concentrations of microbial indicator organisms like *E. coli* and nutrients (nitrogen and phosphorus) (SGSC 2012)

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[1] Note that in this study, it is assumed that the risk profile in the catchment is dominated by surface water sources and therefore on a whole catchment scale groundwater risk is not considered to be significant by comparison. The reason for this assumption is that travel times in the subsurface are relatively slow by comparison and permit significant die-off of pathogens before intersection with surface water.

Systems in use

According to SGSC'c Draft Municipal Domestic Wastewater Management Plan 2012 – 2022 (MDWMP) (SGSC 2012) the majority of on-site wastewater treatment systems (approximately 72 %) involve primary treatment only (i.e. consist of a simple one-chambered septic tank arrangement plus a disposal field) and a portion of these (14 % of the total number of on-site systems) are toilet only systems *(Draft MDWMP Table 7, page 22, SGSC 2012)*.

According to the draft MDWMP few systems installed prior to 1970 and still in use have been upgraded. These are toilet only systems, which treat only the toilet wastewater. The remaining portion of wastewater from showers, baths, basins, etc, is discharged to local creeks, rivers and ground waters via the storm water system (Draft MDWMP page 22, SGSC 2012).

Discharge of greywater to the environment means that local stormwater can be expected to have a very high nutrient and pathogen loading. Research has shown greywater pathogen concentrations can be very high (Birks and Hills 2007).

System performance and design

General design and performance standards for wastewater management systems are determined by EPA Victoria and are published in a Certificate of Approval for each system type listed on the EPA website[2] while other specifications are given in the EPA Code of Practice – Onsite Wastewater Management, Publication 891.3 (EPA Victoria 2013) and Australian Standard AS/NZS 1547:2012. On-site domestic-wastewater management (Standards Australia 2012).

The councils issue permits to install septic tank systems requiring compliance with these standards and other relevant site specific requirements.

The SGSC DWMP notes that:

Systems are generally designed to be used over a 15-25 year life cycle under typical use patterns (e.g. full occupancy). After this time the system is intended to be renewed or replaced. As many systems in use are older than 25 years, Council expects that these systems require significant works to maintain adequate treatment and operational standards.

To comply with EPA and council requirements, unless otherwise permitted, daily wastewater loads must be treated and contained within the property boundaries. While, system design considerations include the rate of waste water generation, the level of treatment required and the capacity of the soil and vegetation to treat the waste water, recent investigations by SGSC have found that, regardless of the level of treatment; the majority of township properties are still not likely to contain wastewater within property boundaries (SGSC 2012). .

Maintenance

It is an axiom that all on-site wastewater treatment systems require maintenance (e.g. periodic sludge removal and inspection every 3 years for septic tanks). Such

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[2] http://www.epa.vic.gov.au/your-environment/water/onsite-wastewater#Systems

maintenance activities must be reported to the councils. However, the councils report that very few maintenance reports are submitted annually (SGSC 2012). *The lack of reporting suggests that maintenance is not undertaken as required.*

2.2.2. Further development of unsewered residential areas

2.2.2.1. South Gippsland Shire Council Housing and Settlement Strategy

To manage predicted growth in the South Gippsland Region, South Gippsland has prepare a Housing and Settlement Strategy (HSS) to provide Council with a Shire-based integrated framework for managing the future growth and development of its settlements to 2031. The Shire is expected to grow by 1.4% per annum from 28,500 residents to 36,927 residents in 2031 (Planisphere 2013).

The following dot points provide a summary of the HSS strategic directions relevant to the Tarwin Water Supply Catchments:

- New settlements are to be encouraged to sewered townships;
- Settlement Structure Plans (SSPs) will guide development at the larger towns;
- Benefits of town-focussed growth are protection of agricultural land and environment and ability to supply services;
- For smaller unsewered settlements, development will be encouraged only within the settlement boundary. SSPs or Urban Design Frameworks (UDFs) will guide development;
- Most commercial growth will be focused on Leongatha, Korumburra and Foster[3] and industrial growth is to be concentrated in Leongatha and Korumburra;
- Low Density Residential Zone land will be focussed on the periphery of larger settlements in accordance to structure planning and access to reticulated sewer;
- Demand for land zoned RLZ (Rural Living Zone) is considered to be met by the existing supply; i.e. it seems unlikely that more land will be allocated to RLZ;
- The HSS will aim to ensure an adequate supply of urban land to reduce development pressure on agricultural land; and
- Development of connected, resilient and sustainable settlements will be a priority.

Planning zones and overlays for the Tarwin Water Supply Catchment are shown for reference in Appendix 4.

In summary, the HSS seeks to foster growth in the major towns and protect existing agricultural land. Land has been allocated for low density residential living around the larger settlements and this is where any further development of unsewered housing is likely to be contained.

2.2.2.2. Baw Baw Shire Council Settlement Management Plan

According to the Baw Baw Shire Council Settlement Management Plan (SMP), Baw Baw Shire is growing a rapid rate (BBSC 2014) with population increases between the 2006 and 2011 censuses occurring at an annual growth rate of 2.89 per cent (i.e. an increase

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[3] Note that Foster is not in the Tarwin Catchment

of 5,806 to 42,864). Forecast growth rates are projected to be between 1.7 and 2.3 percent per annum giving likely population of 71,683 residents by 2036.

Despite these recent and forecast high growth rates, actual population growth in the portion of the Tarwin Water Supply Catchment that lies within the Baw Baw Shire (see Figure 2-2) is expected to be limited due to the broad planning direction for future settlement patterns established in the SMP. These directions are:

- Directing development into the existing settlements within current urban boundaries as far as possible.
- Concentrating development in the large and medium towns along the Princes Freeway/railway corridor to take advantage of the transport connections.
- Emphasising major growth in Warragul and Drouin to optimise access to existing physical and social infrastructure, commercial and community facilities as well as available land supply.
- Restriction of growth in smaller settlements where there is limited sewerage infrastructure and/or heightened environmental risk to population, such as fire, flooding or declared water catchments.
- Definition of locations where rural housing outside towns could be supported provided there is minimal disruption to rural land uses.

Overall the SMP is expected to lead to a slowing in growth outside identified settlements due to policies that restrict the development of residential dwellings in areas predominantly intended for agricultural purposes (BBSC 2014).

2.2.2.3. Latrobe City Council settlement planning

Only a small south east portion of the Tarwin Water Supply Catchment near Boolarra South lies within the area of Latrobe City Council (LCC). LCC planning intentions for this area, which is mainly devoted to grazing agriculture have been derived from the following aims listed in the Latrobe Municipal Strategic Statement (MSS):

- To contain urban development within distinct boundaries (Clause 21.04-4 under section 21.04, Built Environment Sustainability).
- To provide for the use of land for agriculture (Clause 35.07, Farming Zone).
- To encourage the retention of productive agricultural land (Clause 35.07, Farming Zone).
- To ensure that non-agricultural uses, including dwellings, do not adversely affect the use of land for agriculture (Clause 35.07, Farming Zone).

Based on the above points, it may be expected that Latrobe City Council planning directions for the small portion of land within the Tarwin Water Supply Catchment will be consistent with those of South Gippsland Shire Council and Baw Baw Shire Council.

2.2.3. Densities of unsewered dwellings

2.2.3.1. Farming Zone

A legacy of past subdivision practice has resulted in the creation of numerous lots in the Farming Zone (FZ) less than 1000 m^2. Many of these lots were created before planning permits were required, with many being created as a result of historic road realignment practices. Changes to the Planning Scheme mean that such small lot subdivisions are unlikely to be permitted. However the legacy of smaller undeveloped lots remains.

Under the Victorian Planning Provisions (VPP) Clause 35.07-3 Subdivision (applies for all three local government areas in the Tarwin Water Supply Catchment), a permit is required to subdivide land. Each lot must be at least the area specified for the land in a schedule to the zone. If no area is specified, each lot must be at least 40 hectares.

A permit may be granted to create smaller lots if any of the following apply:

- The subdivision is to create a lot for an existing dwelling. The subdivision must be a two lot subdivision.
- The subdivision is the re-subdivision of existing lots and the number of lots is not increased.
- The subdivision is by a public authority or utility service provider to create a lot for a utility installation.

With respect to previously subdivided lots, under the current scheme:

- The minimum lot size for use and development of a dwelling in the South Gippsland Shire FZ is 1000 m^2. This is due to the presence of clay soils and often also slope constraints, so that the area required for a disposal field and the dwelling would be too great to fit on a smaller lot.
- For all current South Gippsland Shire lots > 1000 m^2 in the FZ the use and development of a dwelling is permitted provided that all other relevant matters listed in the Planning Scheme are addressed (*e.g*., waste water disposal, vegetation removal, *etc*.).
- For South Gippsland Shire any lot between 4.1 ha and 40 ha may still be suitable for the use and development of a dwelling but the local policy requires the applicant to demonstrate that a dwelling "is genuinely required to carry out a long-term agricultural activity on the land". Lots greater than 40 ha do not need to justify the use of a dwelling even if they trigger a permit for development under the FZ or some other overlay.
- To preserve farming land, for South Gippsland Shire the minimum new subdivision for any FZ property is 80 ha, so no block less than 160 ha can be subdivided. However this restriction does not apply in the Baw Baw and Latrobe Shires where the VPP specify 40 ha as the minimum lot size.
- In summary, development may occur in South Gippsland Shire:
    - On lots greater than 40 ha;
    - On lots less than 40 ha but greater than 4.1 ha subject to requirements for a planning permit and justification of dwelling need on agricultural use grounds;
    - Below 4.1 ha subject to requirements for a planning permit but generally does not require agricultural justification; and
    - Lots below 1000 m^2 are generally considered too small to effectively develop.

Note that with respect to minimum lot sizes for development SGSC's adopted Rural Land Use Strategy supports the development of new dwellings on lots under 4.1ha, and therefore is in conflict with the DEPI Guidelines for *Planning Permit Applications In Open, Potable Water Supply Catchment Areas* (DEPI 2012). The guidelines state that where a planning permit is required to use land for a dwelling or to subdivide land or where a planning permit to develop land is required pursuant to a schedule to the Environmental Significance Overlay that has catchment or water quality protection as an objective:

- the density of dwellings should be no greater than one dwelling per 40 hectares (1:40 ha); and
- each lot created in the subdivision should be at least 40 hectares in area.

However, smaller lots and higher densities may be permitted if:

- they are consistent with the local Catchment Policy. A Catchment Policy sets out measures for overall water supply catchment management and should be prepared for the catchment and endorsed by the relevant water corporation following consultation with relevant local governments, government agencies and affected persons;
- A range of other conditions are met as described in the DEPI guidelines such that the referral agencies and the council agree that the site is safe to develop and implemented a Domestic Wastewater Management Plan (DWMP).

Presently SGSC is participating in the development of a Catchment Policy and has developed a draft DWMP. As these processes are completed, the potential conflicts in planning policy may be resolved.

2.2.3.2. Future development potential

Under the current planning regime described above, the number of possible future unsewered dwellings that may be permitted in the Tarwin Water Supply Catchment can be estimated. Using GIS data supplied by SGW, SGSC and Baw Baw Shire Council, estimates of the number of current and future unsewered dwellings were made for the whole of the Tarwin Water Supply Catchment (Figure 2-5) and for the FZ (Figure 2-6) (See Appendix 8 for Planning Zones and Overlays). The Farming Zone is of interest due to the high number of lots between 1000 m^2 and 4.1 ha that under current Council planning policy may be permitted to have a dwelling.

Potential increases in the FZ planning zone are shown graphically in Figure 2-9.

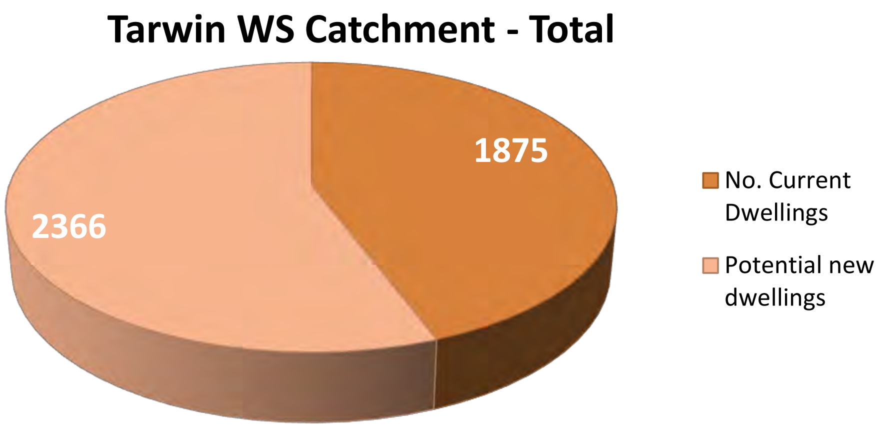


Figure 2-5. Estimated current no. of unsewered dwellings and potential new unsewered dwellings in the Tarwin Water Supply Catchment

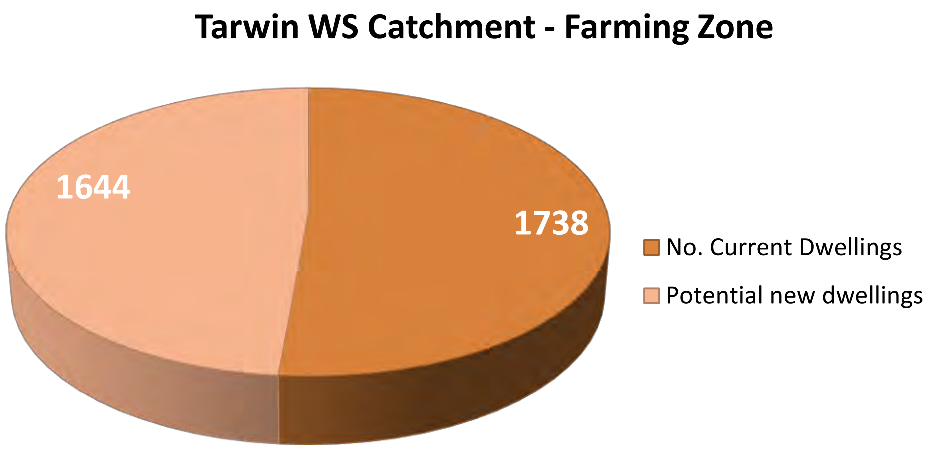


Figure 2-6. Estimated no. of potential new unsewered Farming Zone dwellings in the Tarwin Water Supply Catchment

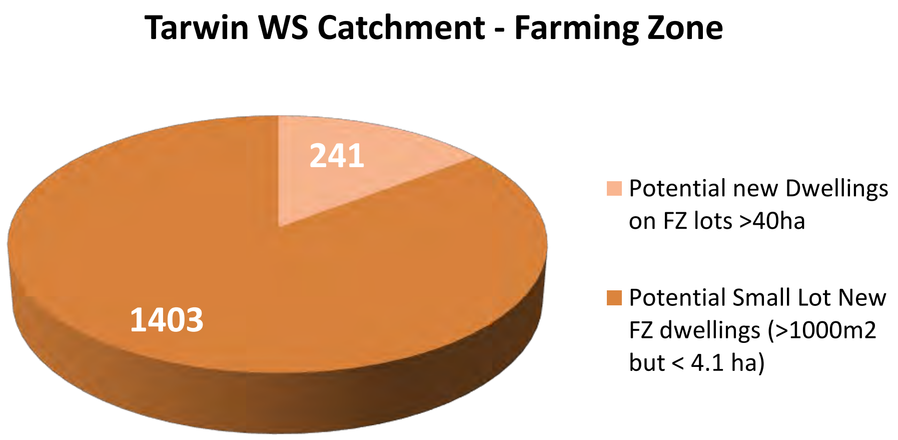
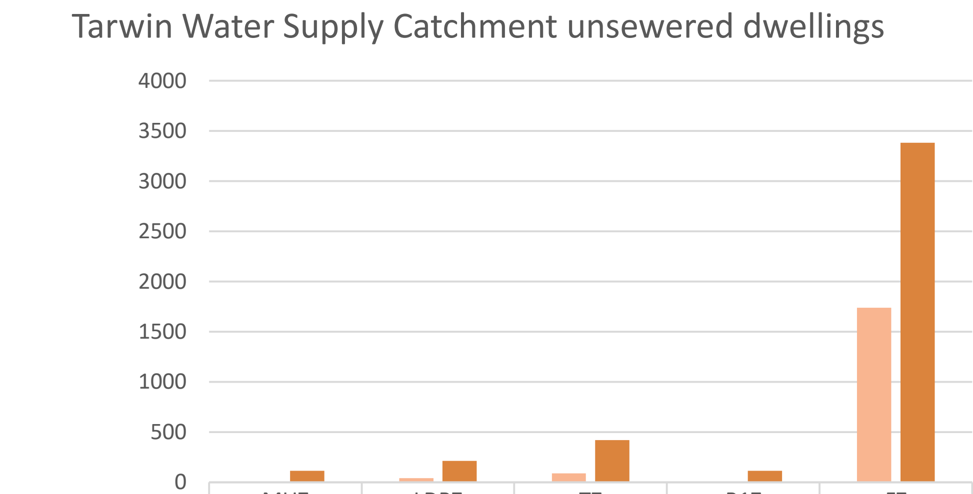


Figure 2-7. Number of lots with potential for development classified by size with respect to the DEPI 40 ha rule

2.2.3.3. Other planning zones

Apart from the Farming Zone other zones where unsewered dwellings may be permitted on lots are the RAZ (Rural Activity Zone), RLZ (Rural Living Zone), LDRZ (Low Density Residential Zone), and TZ (Township Zone). These are all in the South Gippsland Shire Council area. The total number of new dwellings possible for these zones is significant (859), but still less than the figure for FZ alone (1644) (Figure 2-8).

Currently there are approximately 1875 unsewered dwellings in the Tarwin Water supply catchment and under the current planning regime this could increase by 2366 (i.e. 126%) to around 4241 dwellings in the future.



	MUZ	LDRZ	TZ	R1Z	FZ
Current Dwellings	5	39	89	4	1738
Future Dwellings	113	213	420	113	3382

Figure 2-8. Estimates of current unsewered dwellings and potential future dwellings unsewered dwellings in the Tarwin Water Supply Catchment. 2366 new unsewered dwellings are possible.

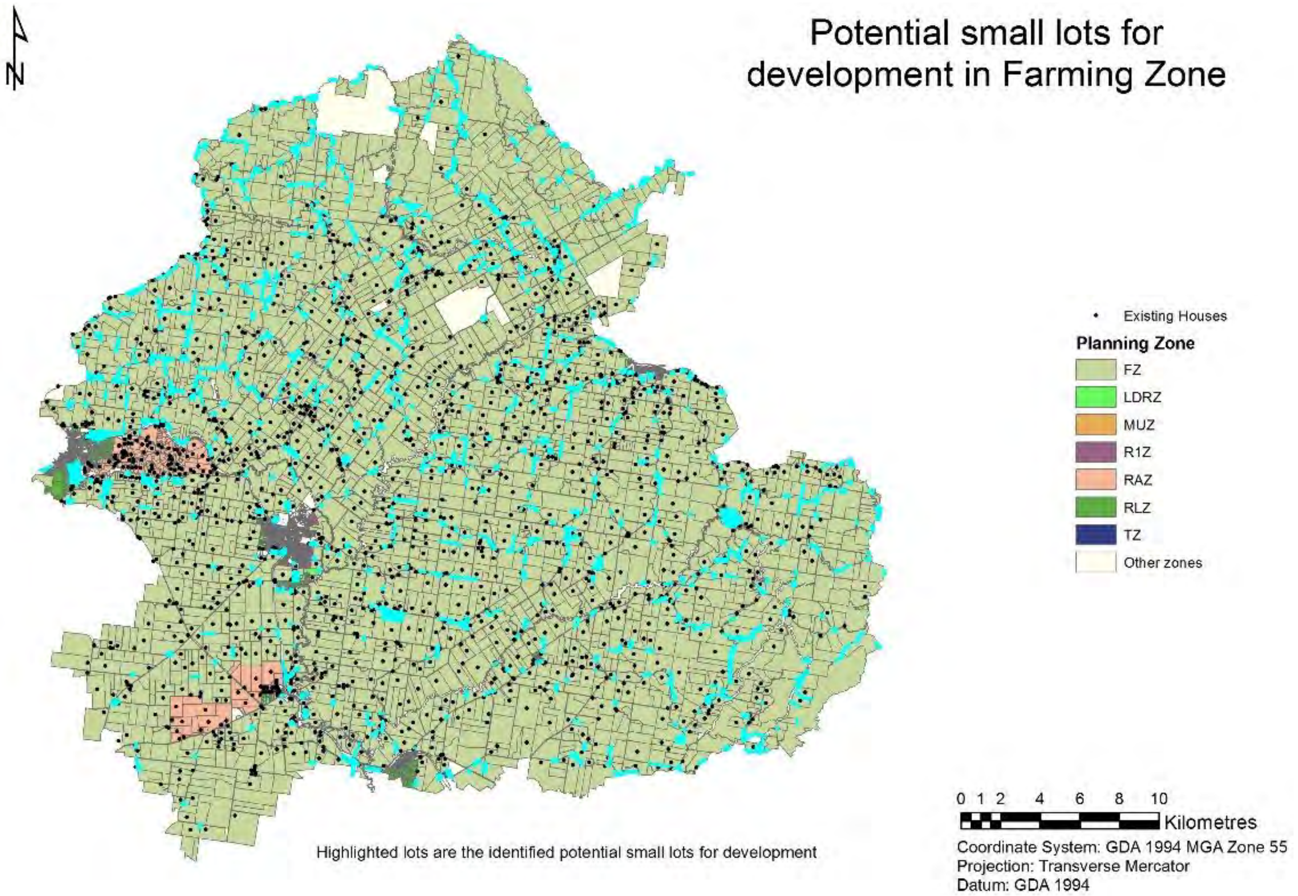


Figure 2-9. Potential small lots for development in the Tarwin Water Supply Catchment FZ planning zone.

2.2.4. Grazing pasture landuse and stock access to waterways

As noted above, grazing land uses constitute around 86% of the catchment area. Most of this is expected to be grazing cattle for milk production (i.e. dairy farms) with some beef cattle production. Cattle are a potential source of human infectious pathogenic protozoa and bacteria; in particular *Cryptosporidium parvum, Giardia duodenalis, Salmonella* spp. *Campylobacter* spp. and some pathogenic strains of *E. coli* (Billington *et al*. 2011). The pathogen of most concern is *Cryptosporidium* due to its resistance to oxidant disinfectants and greater environmental persistence compared to the indicator bacterial species, *E. coli.* The resistant oocyst stage of *Cryptosporidium's* life cycle is excreted in the manure of infected cattle and can contaminate sources of drinking water. *Cryptosporidium* oocysts are extremely hardy, easily spread via water, resistant to chlorine and are difficult to inactivate or remove from water without the use significant treatment steps such as filtration supported by effective coagulation (Billington *et al*. 2011).

According to the Australian Drinking Water Guidelines (NHMRC and NRMMC 2011), a multiple barriers approach operating from catchment to tap should be implemented to minimise the risk of contamination by *Cryptosporidium* and protection of water catchments from contamination by human and animal faeces should be a priority.

Cryptosporidium

Two species of *Cryptosporidium* can commonly infect humans (*C. hominis* and *C. parvum*), however, cattle only support *C. parvum* as well as several other *Cryptosporidium* species that do not pose a significant threat to human health (Kay et al 2012). Bovine cryptosporidiosis is mostly a disease of pre-weaned calves and infection rates and oocyst shedding rates differ greatly with the age of the cattle. It has been reported that infected calves can excrete up to 10 billion oocysts in one day (NHMRC and NRMMC 2011) but more commonly around 400 million (Davies *et al.* 2005). Adult cattle produce about 23 kg of manure per day, while calves produce around 6 kg (Ferguson 2005). Studies on how cattle drop manure show that when access is available to waterways (e.g. streams are unfenced adjacent to grazing pasture), between 0.5% and 9% of the daily manure production is deposited directly in the stream (Elliott and Harper 2011 citing McDowell *et al.* 2008).

Dairy farm management generally involves high stocking rates and concentration of manure and urine in paved areas around Milking Sheds and Feed Pads. Runoff from these areas is generally directed to effluent storage ponds which if properly managed can assist in controlling pathogen loads to streams.

South Australian studies have identified juvenile beef cattle as the major source of *Cryptosporidium* in a mixed dairy and beef catchment in the Adelaide Hills (Billington *et al*. 2011). Unlike dairy production, beef production involves the retention of young cattle on the farm for grow out hence the significance of beef production as a major *Cryptosporidium* source. Regardless of the type of cattle farming, retention of young cattle on the property and in paddocks adjacent to waterways, including areas with unfenced riparian zones poses a very high risk to the quality of catchment drinking water supplies.

2.2.5. Point source discharges

EPA licensed discharges

There are 2 small EPA Licenced Discharges in the Tarwin Water Supply Catchment, Burra Foods Pty Ltd at Korumburra and the Leongatha Wastewater Treatment Plant (WWTP) operated by South Gippsland Water. The Meeniyan WWTP discharges into the Tarwin River downstream of the town water supply offtake and therefore is considered to be out of the catchment for the purposes of this study.

The flows, nutrient and pathogen loads from the SGW WWTP and Burra Foods discharges are relatively small compared to other catchment sources and the sources are expected to have minor influence on catchment water quality. With respect to pathogens. Both the licenced discharges were included in the Source catchment water quality model described in Section 4.2.2.

3 Modelling and consultation approaches

As stated in Section 1, the Tarwin Water Supply Catchment Management Plan (TWSCMP) includes a Quantitative Catchment Process Model and associated water quality risk management planning. In some catchment management approaches, risk modelling and subsequent risk management are conducted sequentially as separate exercises. For this project they were developed in tandem and a reference Working Group of Stakeholders assisted in the development and selection of management scenarios for modelling.

3.1. Stakeholder Working Group and Workshops

The Working Group consisted of representatives from SGW and SGSC and regional stakeholders (e.g. West Gippsland CMA, DEPI, EPA, etc.); see Appendix 5.

3.1.1. First Working Group meeting

The key assumptions of the modelling were explained to the Working Group to achieve support for the model outcomes and subsequent proposed management responses.

The first meeting of the working group was at the Leongatha Project workshop on November 21st. At the first workshop, attendees were invited to join the project Working Group and help direct the modelling exercise and the development of the Tarwin Catchment WQMP.

A discussion paper was circulated prior to the workshop to assist stakeholders in their understanding of catchment issues and spatial attributes, the modelling process for the Tarwin Catchment WQMP and the WQMP objectives. The Workshop objectives included:

- Development of an understanding of the Tarwin Water Supply Catchments;
- Identification of key issues of concern relevant to water quality;
- Development of a draft vision for the catchment, and Key Management Outcomes and Goals for each outcome;
- Working Group to have an understanding of the modelling approach, including;
    - A description of the constituents for modelling: this included physical (suspended solids), chemical (nutrients, pesticides) and biological parameters (microbial pathogens);
    - model resolution, limitations and key assumptions; and
- Assisting the consultants in determining subcatchments for modelling.

The consulting team sought feedback on model assumptions from the Working Group and incorporated the responses into later versions of the discussion paper.

After some initial discussion in relation to the attributes of the Tarwin Water Supply Catchment, the working group split into two groups to discuss issues in relation to Wastewater Management and Riparian Zone and Land Management. The issues and questions identified by the two groups and the consulting team's response are listed in detail in Appendix 6 and considered in Section 5 as part of modelling scenario development.

3.1.2. Second Working Group meeting: Scenario Development

A second Working Group meeting was held at the Coal Creek Historical Village, Korumburra on the 1st of May 2014. At the meeting the Consulting Team presented the catchment model base case (current situation), and with further input from the Working Group on the day, developed a set of management scenarios for modelling. Based on the feedback from the Working Group and the Consulting Team's expertise, a suite of 9 model scenarios were agreed upon (i.e. 1 base case and 8 scenarios); See Appendix 7.

3.1.3. Compilation, analysis and presentation of modelling results

After the second workshop, the Consulting Team finalised the model scenarios and conducted the model runs for each scenario. The relevant time series of each scenario was statistically analysed and the results tabulated and written up as part of the TWSCMP report (i.e. this document). The results of each scenario were compared and contrasted to identify the magnitude of any benefits.

3.1.4. Final Working Group meeting: Presentation of draft modelling report

At the final working group meeting (21st October 2014 at SGW's offices at Foster) the Consulting Team presented the draft of the Tarwin Catchment WQMP report and sought comment from the working group on the report findings. The Consulting Team stepped through the report findings as part of a detailed presentation to assist the Working Group in understanding how the report has been constructed and how the modelling results have been derived. Following a two week period for comments, all comments were collated and the draft report revised as appropriate and a final version of the Tarwin Catchment WQMP was prepared.

4 Model setup

4.1. About the Source model and its structure

Modelling for the TWSCMP was conducted using the eWater "Source" Package (www.ewater.com.au. Source was developed to model the flow of sediment and nutrients in water catchments. However, given certain assumptions, any constituent which comes from diffuse sources within a catchment can be modelled. Within a Source model scenario, predictions can be made at any point in a river network and can be based on daily, or sub-daily, time steps.

The three major physical components of Source are sub-catchments, nodes and links.

- Sub-catchments**:** The sub-catchment is the basic spatial unit in Source; however sub-catchments are also divided into land-uses based on a common hydrological response. Within each land use, or functional unit, as it is termed, three models may be assigned - *a rainfall-runoff model, a constituent generation model and a filter model*.
- Nodes**:** represent points where flows and nutrients enter the river network, or where some process that is important for modelling, occurs (e.g. flow measurements at a stream gauge). Nodes are connected by links, forming a representation of the stream network.
- Links**:** used to join nodes and to store, route and process flow and constituents. Links represent river reaches, dams, or floodplains. Within each link, three models may be assigned - a routing model, a Source/sink model and a decay/enrichment model.

Source uses a node-link style modelling system for generating, transporting and transforming water and constituents within the major channels in a catchment (see Figure 4-1).

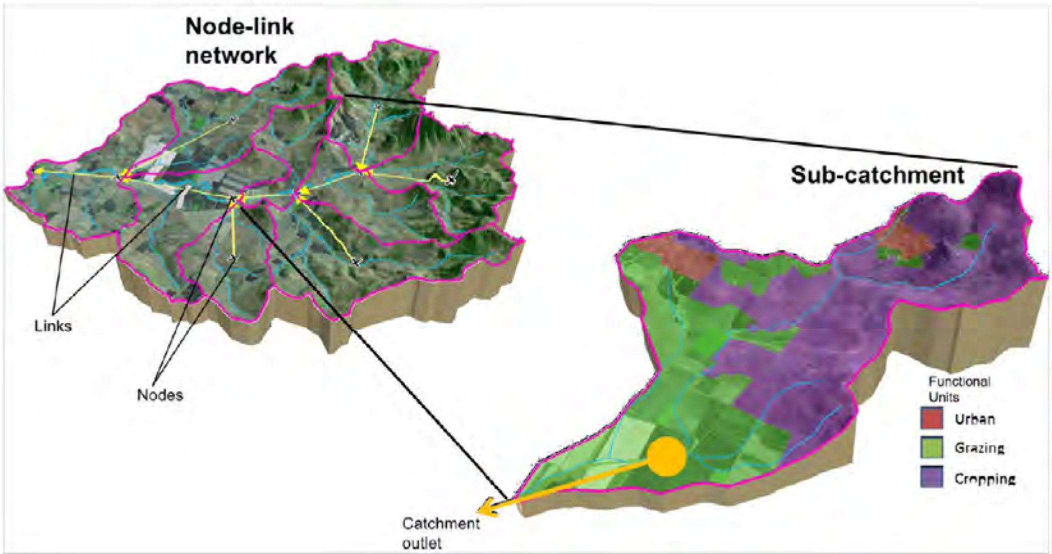


Figure 4-1. Node-link networks and sub-catchments in a Source model (www.ewater.com.au)

4.2. A description of the modelling approach

The Source Catchment Modelling Software Package consists of a number of component models that determine factors such as:

- How rainfall is accumulated and apportioned to flow across different land uses within the catchment;
- How constituents (material transported in water, e.g. nutrients, sediments, pathogens, etc.) are handled;
- Handling of dissolved (e.g. nutrients) versus particulate constituents (e.g. suspended sediments); and
- Handling of flow peaks (storm events) and base flows (dry weather flows).

The broad approach used to model different management scenarios involves alterations to settings within particular component models. For the Tarwin River Catchment Model the following component models were used to develop scenarios:

- A Constituent Generation Model that deals with Event Mean Concentrations and Dry Weather Concentrations (EMC/DWC) runoff coefficients.
- A Filter Model which reduces the amount of constituent that is generated in a Functional Unit.

4.2.1. Constituents for modelling: e.g. nutrients, microbial pathogens, pesticides, etc.

If sufficient supporting data is available almost any dissolved substance or particulate matter can be modelled. However for catchment water quality management, the constituents usually modelled are:

Nutrients:

- Total phosphorus (TP);
- Total nitrogen (TN);
- Suspended solids; and
- Pesticides (sometimes)

Microbial pathogens and indicator organisms, e.g.:

- *Cryptosporidium* (protozoan pathogen)
- *Campylobacter* (bacterial pathogen)
- *E. coli* (bacterial indicator)
- Adenovirus (viral pathogen)

Modelling of nutrients is most common, whilst modelling of pesticides and pathogens is more challenging due to inherent variability in their quantity, timing and area of application to the catchment and in their individual propensity to bind to sediment, break down, or in the case of pathogens, die off. For the Tarwin Catchment model, nutrients, suspended solids and pathogens were modelled.

4.2.2. Source outputs and scenario definition

The final outputs from Source are predictions of stream-flow and loads and concentrations of flow constituents.

An outline of the major preparatory tasks in the development of the Source model of the Tarwin River catchment is presented in Figure 4-2 and further elaborated on in the following sections.

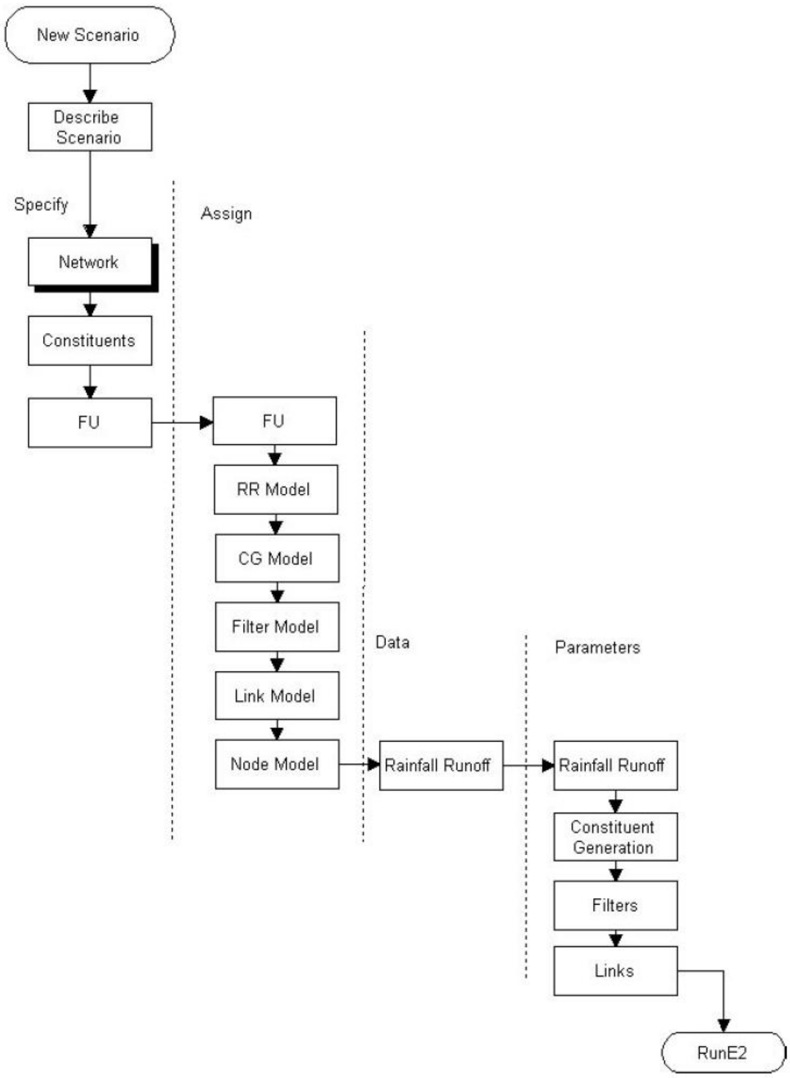


Figure 4-2. Source Scenario definition process (eWater CRC, 2007b)

4.3. Specifying network and sub-catchments

4.4. Delineation of subcatchments for modelling

Based on a 1 m digital elevation model for the catchment, a preliminary delineation of subcatchments for modelling was undertaken. Feedback from the Working Group was sought on the subcatchments delineation at the first workshop and modifications made as required. In Figure 4-3 the focus for subcatchment delineation has been on major tributaries, reservoirs and hydrological monitoring stations. Additional catchments were also provided around townships so that the data may be inquired on a finer scale in these areas.

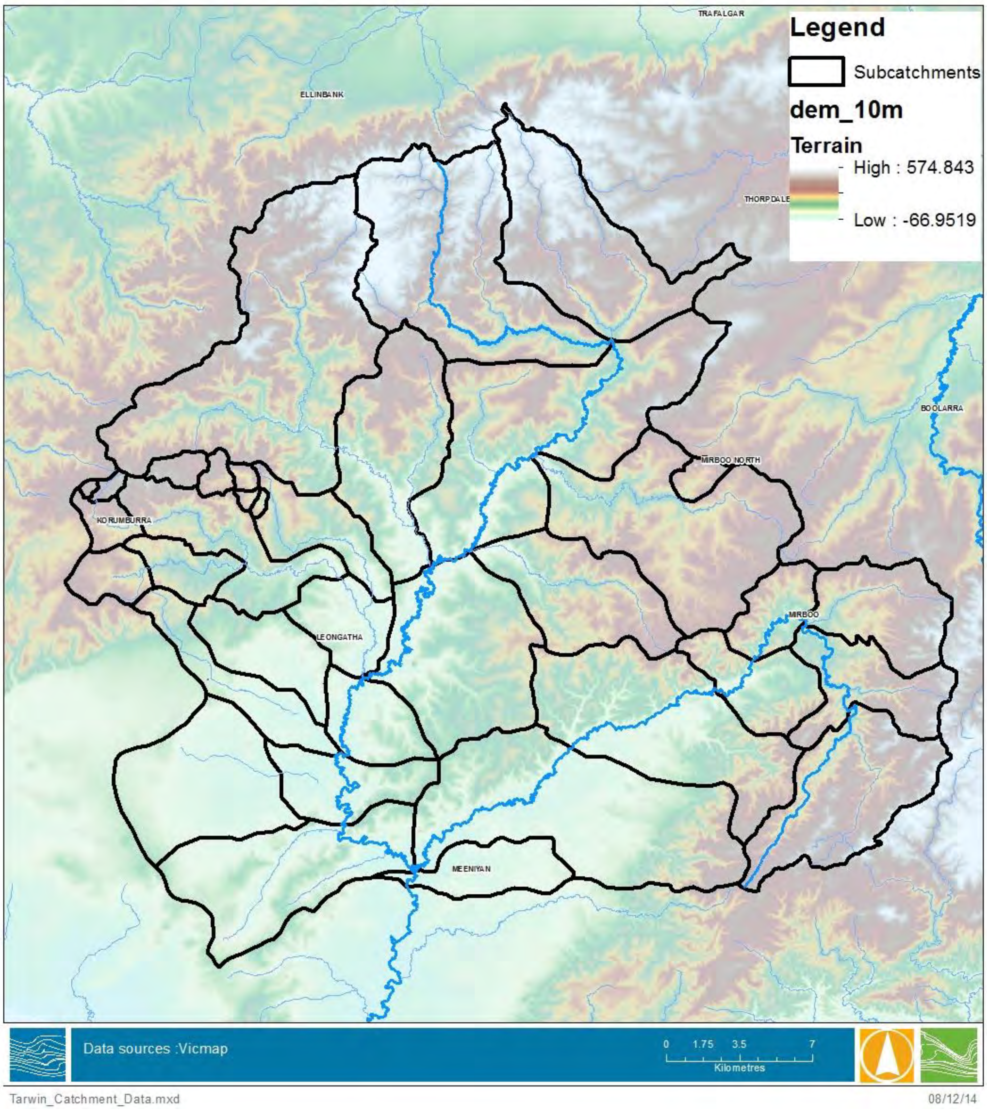


Figure 4-3. Delineation of subcatchments for modelling

Final subcatchments were established based on river watersheds, locations of calibration data, and key points of interest throughout the catchment (Figure 4-4). In Source, data can be applied to individual sub-catchments, so that breaking up the broader catchment into smaller sub-catchments allows input data to be tailored to reflect the spatial variation of values.

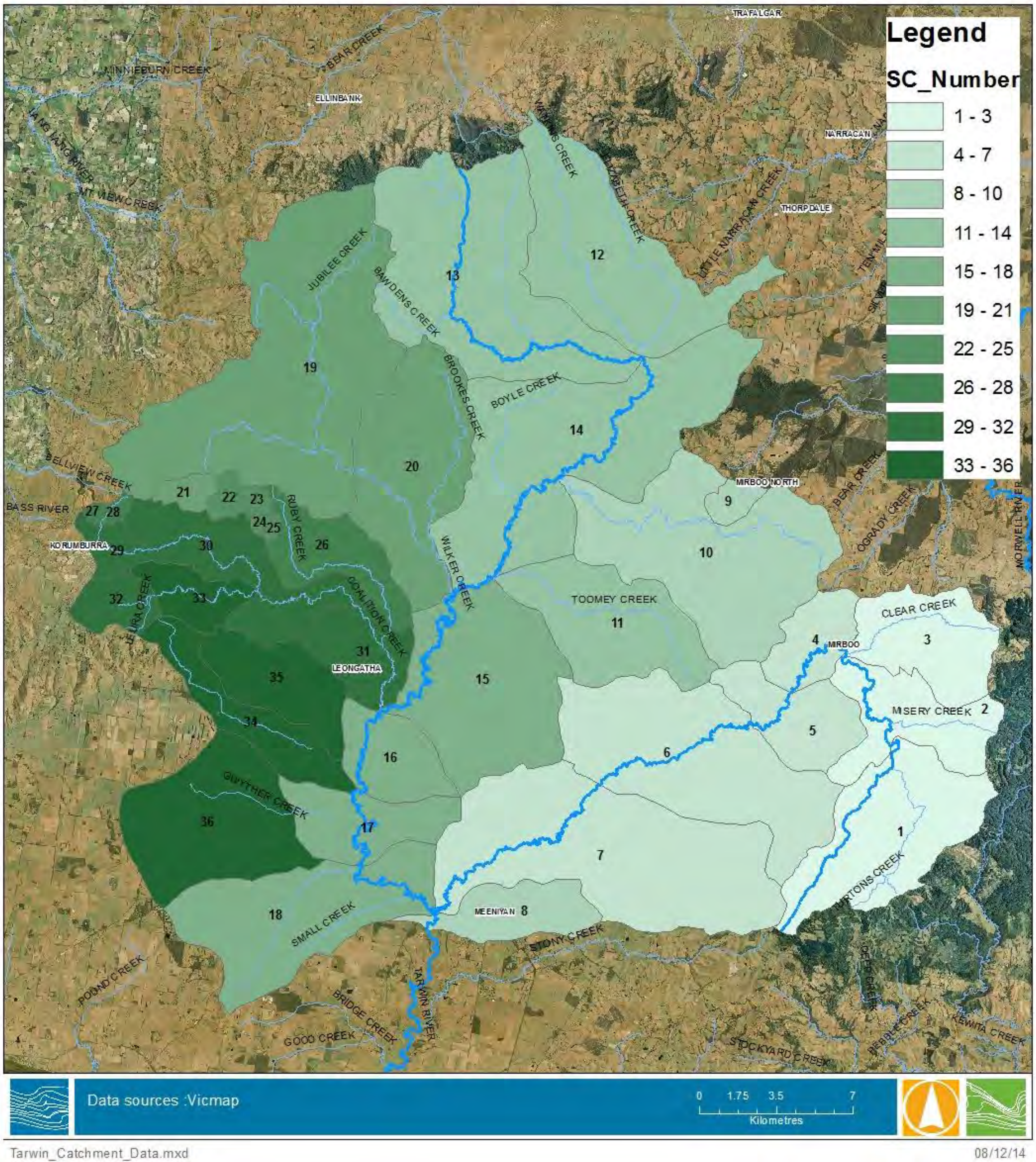


Figure 4-4. Sub-catchment boundaries for Source modelling

4.5. Specifying constituents

For this study the following constituents were chosen:

Physico-chemical attributes:

- Suspended sediments
- Nitrogen – a key nutrient for algae and vascular plants
- Phosphorous – as for nitrogen

Public health reference pathogens

- *Campylobacter* – a reference bacterial pathogen
- *Cryptosporidium* – a reference protozoan
- Adenovirus – a reference virus

4.5.1. Suspended Sediment

Elevated concentrations of suspended sediment (also known as suspended solids) are directly attributable to land use activities that reduce catchment vegetation cover or concentrate or increase runoff. Levels of suspended sediment depend on the background generation rates, the steepness of slopes, the erodibility of soils and the erosivity of weather events and the impact of agriculture and land clearance.

High concentrations of suspended solids are not only an indicator of hazardous land management practices, but they are also important because they cause high turbidities which can interfere with treatment processes at water treatment plants (where turbidity is usually monitored by on-line turbidity meters). Furthermore, suspended sediments are associated with downstream sedimentation and water quality problems including smothering of aquatic vegetation and habitat of aquatic fauna such as fish

Eroding stream banks are also an important source of sediments in many catchments, however for this study they could not be assessed due to the lack of a detailed inventory of such sources.

4.5.2. Nutrients

The nutrients nitrogen and phosphorus are important stimulants of plant growth and when in excess may promote blooms of macroalgae or harmful microalgae such as blue-green algae.

Both nitrogen and phosphorous occur naturally in soils. However, Australian soils are naturally depleted in nutrients and the rate of nutrient leaching from pristine environments is relatively low (Letcher *et al.* 1999). Elevated levels of nutrient are commonly attributed to increased human activity in catchments.

Newham and Drewry (2006) note that many studies have focussed on the nature and mechanism of nutrient loss from agricultural soils, with a particular emphasis on dairy pasture. In comparison to dryland grazing, dairy pastures are often treated with chemical fertilisers and have higher stocking rates of cattle. Consequently, nutrient runoff, particularly phosphorus is higher on such pastures.

The physical state of different forms of nutrients affects their transport mode, with dissolved forms of nitrogen and phosphorus typically exported at much greater rates than particulate forms. Particulate forms are also more likely to be trapped by natural catchment filters such as riparian vegetation. A significant portion of soil phosphorus is bound to sediments particles so that as sediment transport occurs, usually under high rainfall events, particulate phosphorus is transported as well. In this study, management scenarios for nutrients were largely based on past empirical studies and therefore did not make any assumptions about the form of the nutrients.

4.5.3. Waterborne pathogens

There are around 150 gastrointestinal pathogens that can be classified as waterborne and therefore pose a risk to water supplies. These pathogens may be broadly separated into viruses, bacteria, protozoa (single-celled parasites) and helminths (intestinal worms) (Table 4-1).

Table 4-1. Common water-related pathogens (adapted from WHO 2011) where ingestion by drinking will generally result in gastrointestinal illness of varying degrees and in some cases serious health complications up to and including death.

Taxon	Common water-related pathogens
Bacteria	*Campylobacter* spp., *E. coli, Salmonella* spp., *Shigella* spp., *Vibrio cholerae, Yersinia* spp.
Viruses	Adenovirus, Astrovirus, Enterovirus, Hepatitis A Virus, Hepatitis E Virus, Noroviruses, Adenoviruses, Sapovirus, Rotavirus
Protozoa and Helminths	*Cryptosporidium parvum, C. hominis, Dracunculus medinensis, Entamoeba histolytica, Giardia intestinalis, Toxoplasma gondii.*

Selecting reference pathogens for modelling

Modelling all of the known waterborne pathogens would be impractical and for many there would be inadequate data to produce a practically meaningful model. Fortunately, any one pathogen tends to arise from, and behave in, ways that are similar to many others. Therefore, WHO (2011) describes the use of reference organisms in which one organism is selected to be representative, typically conservatively, for many others in a broad class pathogens. Suitable reference organisms are those that have:

- high relative source abundance; and
- high relative resistance to removal and inactivation.

These two factors combined mean a reference organism would be expected to provide a dominant contribution to the total pathogen load for which the pathogen group is representative. The reference organisms used in this study are the protozoan *Cryptosporidium*, the bacteria *Campylobacter*, and Adenovirus. The justification of the use of these organisms is summarised in Table 4-2 below.

Table 4-2. Waterborne reference pathogens used in this study and their significance in water supplies (adapted from WHO 2011).

Pathogen	Health Significance	Persistence in water supplies	Resistance to chlorine	Relative infectivity	Important animal source	Likely source in Tarwin River Catchment
Bacteria: *Campylobacter jejuni, C. coli*	High	Moderate	Low	Moderate	Yes	Cattle, other livestock, unsewered dwellings, leaking sewers
Virus: Adenovirus	High	Long	Moderate	High	No	Unsewered dwellings, leaking sewers
Protozoa: *Cryptosporidium parvum, C. hominis*	High	Long	High	High	Yes	Cattle, other livestock, unsewered dwellings, leaking sewers

4.6. Specifying functional units

A functional unit in Source is an area with similar water quality and runoff characteristics. For this study we have selected landuse as the functional unit. A significant number of landuses exist throughout the catchment and therefore where there is insufficient water quality literature to support different values, and where the landuse is minimal compared to the other landuses within the catchment, these have been lumped into a single category.

Functional Units developed for this study include:

- Forestry
- Grazing < 4.1 hectares (representing small lot holdings in Farming Zone which are expected to include a dwelling in most cases)
- Grazing – Cattle
- Grazing – Other Livestock
- Reserves
- Roads
- Rural Living (zoned as rural residential or rural living)
- Urban Sewered (Township Zone)
- Urban Unsewered (Township Zone)

Functional units within the model were also based on the outcomes to be achieved in the study, with higher definition of landuses in urban and peri-urban areas in order to assess the effects of development (with associated septic tanks).

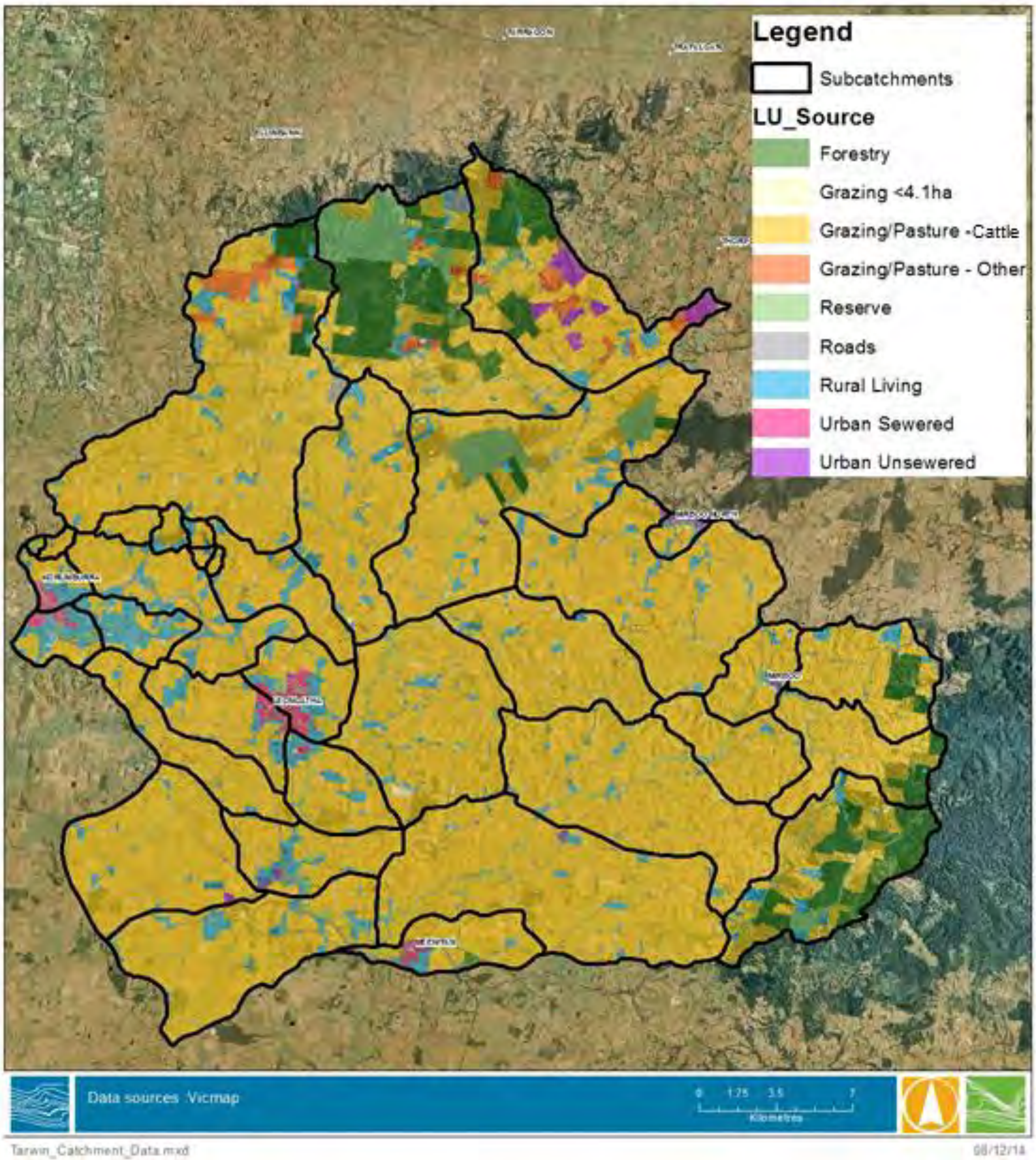


Figure 4-5. Functional units developed for Source catchment modelling.

4.7. Choice of rainfall-runoff model

Source contains two rainfall-runoff models, AWBM and SIMHYD. SIMHYD was selected for this model due to the ability to automatically calibrate the model to observed data.

SIMHYD is a daily conceptual rainfall-runoff model that estimates daily stream flow from daily rainfall and areal Potential Evapotranspiration (PET) data. The model contains 3 stores for interception loss, soil moisture and groundwater and has 7 parameters (see Figure 4-6).

The relative sensitivity of parameters varies between catchments but, generally, the model is most sensitive to the recession constants and the base flow index (see Table 4-3).

Table 4-3 Default values for the SIMHYD Model

Parameter Description	Units	Default	Minimum	Maximum
Baseflow Coefficient	None	0.3	0.0	1.0
Impervious Threshold	None	1	0	5
Infiltration Coefficient	day^{-1}	200	0	400
Infiltration Shape	None	3	0	10
Interflow Coefficient	day^{-1}	0.1	0.0	1.0
Pervious Fraction	None	0.9	0.0	1.0
Rainfall Interception Store Capacity	mm	1.5	0.0	5.0
Recharge Coefficient	day^{-1}	0.2	0.0	1.0
Soil Moisture Store Capacity	mm	320	1	500

Box 4-1. SIMHYD Model Details

During the model runtime daily rainfall first fills the interception store, which is emptied each day by evaporation. The excess rainfall is then subjected to an infiltration function that determines the infiltration capacity. The excess rainfall that exceeds the infiltration capacity becomes infiltration excess runoff. Moisture that infiltrates is subjected to a soil moisture function that diverts the water to the stream (interflow), groundwater store (recharge) and soil moisture store. Interflow is first estimated as a linear function of the soil wetness (soil moisture level divided by soil moisture capacity). The equation used to simulate interflow therefore attempts to mimic both the interflow and saturation excess runoff processes (with the soil wetness used to reflect parts of the catchment that are saturated from which saturation excess runoff can occur).

Groundwater recharge is then estimated, also as a linear function of the soil wetness. The remaining moisture flows into the soil moisture store.

Evapotranspiration from the soil moisture store is estimated as a linear function of the soil wetness, but cannot exceed the atmospherically controlled rate of Areal Potential Evapotranspiration. The soil moisture store has a finite capacity and overflows into the groundwater store. Base flow from the groundwater store is simulated as a linear recession from the store.

The model therefore estimates runoff generation from three sources – infiltration excess runoff, interflow (and saturation excess runoff) and base flow.

eWater CRC, 2007a

Calibration was undertaken by adjusting parameters within the modelling program Rainfall Runoff Library (RRL). This program compares observed rainfall, evaporation and runoff time series and determines the SIMHYD parameters which best match the data sets. Optimisation was undertaken to primarily match the baseflows, with the modelled and observed datasets being compared by the Root Mean Square Error (RMSE) and the difference in runoff (%). A correlation of 0.65 was achieved between the observed and modelled data sets, representing an average to good correlation. Flows generated at the key points throughout the catchment were checked to ensure the model was generating suitable flows.

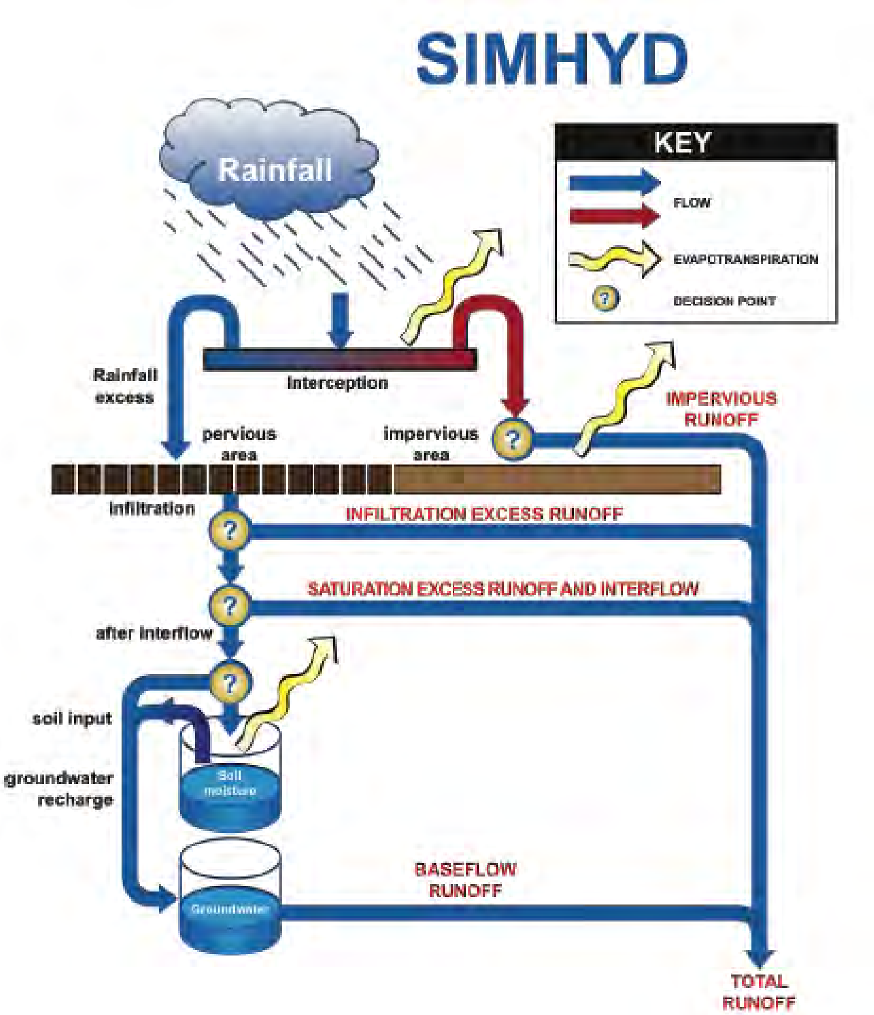


Figure 4-6 Structure of the SIMHYD model (www.eWater.com.au)

4.8. Assigning constituent generation models

Source provides a small number of options in terms of constituent generation models. The model chosen to use for all constituents is a model that predicts dry weather concentrations (DWC) and event mean concentrations (EMC). Source requires estimates of generation rates for each constituent in DWC and EMC and these were developed from the literature and from local water quality monitoring data.

4.9. Assigning filter models

Filter models are used to show the effect on constituent generation of filtering structures within a catchment and may be used to develop scenarios where variations in the filtering capacity of various functional units may be compared. In the Tarwin River Catchment

Model, filter models were used in a modelling scenario focussed on riparian best practice management (See section 3).

4.10. Assigning link models

Links in-stream

Link models allow the user to model changes in constituent concentrations during travel through the catchment. Each constituent can be assigned an in-stream processing model. While generation rates of the constituents in this study have been estimated from the gross outputs from each land use, inclusion of link models allows the modeller to alter the attenuation of constituents through in-stream processes and thus extends the value of the model for developing new scenarios.

The links were used in the model to delay the flows to match observed data sets and replicate the time of concentration for the catchment.

4.11. Assigning node models

Nodes are a special case of network features, and are used to model major management features such as input of load data from a Source external to the catchment, or sources which do not fall within the defined functional units. In this model the wastewater treatment plant outfalls were included as nodes, representing the sediment, nutrient and pathogen concentrations entering the river at this location.

4.12. Rainfall-runoff model data input

The Source model runs on a daily timestep and hence daily rainfall and evaporation data was sourced.

Available data sets need to be processed into a continuous and overlapping time-series that, as near as possible, reflects the spatial heterogeneity of the whole catchment. Source allows each sub-catchment to have a separate rainfall and evapotranspiration data set.

While the model does not need observed stream flow data to run, observed (gauged) stream flow data can be used to calibrate the model outputs.

4.12.1. Data availability

There were a number of rainfall data sets available from throughout the catchment (Table 4-4) and only one evapotranspiration data set was available. Two rainfall stations were chosen to represent the difference in rainfall observed in the lowland and highland areas: Leongatha South Gippsland Water (85049) for lowland, and Foster (Post Office) (85029) for highland. These sites represented locations with the same average rainfall value for the region and consistent long term data sets. Note that Foster is located outside of the catchment, however a comparison of rainfall was made to other stations in the Tarwin River highland region and there was a close correlation. This site was chosen due to the length of consistent record.

Evaporation records at Korumburra were used as it is the only site within the catchment (see Table 4-5).

By examining the length of these records it was determined that all rainfall and evaporation series were coincidental over the period from 1/08/1973 to 31/08/2013.

Table 4-4. Weather stations with available rainfall data

Site No.	Name	Year of first record	Year of last record	Mean Annual Rainfall (mm)	Highland / Lowland
85099	Pound Creek	2007	2014	871	Lowland
85137	Tarwin Lower (Riverside)	1885	2014	940	Lowland
85028	Fish Creek	1928	2014	1026	Highland
85183	Buffalo	1969	2014	970	Lowland
85295	Stony Creek	1993	2014	960	Lowland
85178	Koonwarra (Leongatha South)	1969	2014	952	Lowland
85049	Leongatha Sth Gippsland Water	1896	2014	952	Lowland
85045	Korumburra	1900	2014	1210	Highland
85045	Korumburra Sth Gippsland Water	1973	2014	1056	Highland
85308	Thorpdale Peak	2009	2014	891	Highland
85282	Mirboo North Water Board	1899	2014	1024	Highland
85030	Boolarra South	2002	2014	1165	Highland
85227	East Tarwin (Mirboo Pastoral Company)	1971	2014	1114	Highland
85029	Foster (Post Office)	1884	2014	1099	Highland

Table 4-5. Nearby weather stations with available pan evaporation data

Site No.	Name	Year of first record	Year of last record
85200	Korumburra Sth Gippsland Water	1973	2013

Rainfall was applied to the lowland and highland subcatchments as shown in Figure 4-7. This ensured that the topographical effects on rainfall (and consequently runoff) were considered in the model.

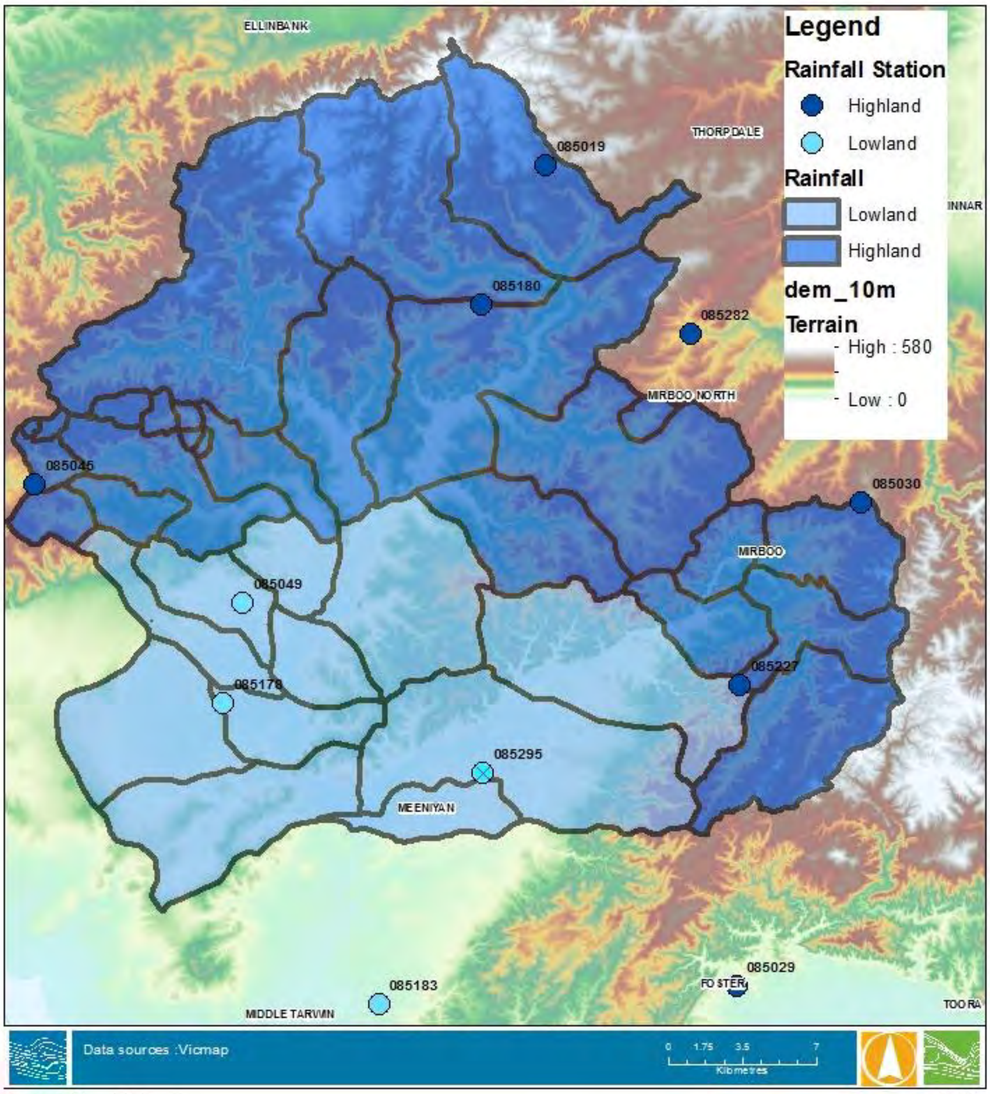


Figure 4-7. Application of rainfall data to subcatchments

4.12.2. Stream flow data

Stream flow data have been collected at a number of gauges in the Tarwin River catchment. Data suitable for calibration of the Source flow model was available at seven gauges:

- 227228 - Tarwin River East Branch @ Mirboo
- 227226 – Tarwin River East Branch @ Dumbalk North
- 227227 – Wilkur Creek @ Leongatha
- 227202 – Tarwin River @ Meeniyan
- 227266 - Tarwin River @ Koonwarra
- 227264A – Coalition Creek @ Spencers Road Bridge Leongatha North
- 227249A – Ruby Creek @ David Webb's Property

Data from the above sites were downloaded from the Victorian Data Warehouse or were provided by South Gippsland Water. The location of the sites is shown in Figure 4-8, showing a good distribution of validation points throughout the catchment.

Figure 4-8. Monitoring station locations stream flow data used in this study

4.13. Water Quality model data input

Water Quality data was available at two locations throughout the catchment. This data was collected as a grab sample on a monthly basis and hence could not be used as a time series input to our model. Instead the grab sample values were compared against the modelled concentrations (derived from the EMC/DWC values).

Data suitable for calibration of the Source flow model was as follows:

- 227227 – Wilkur Creek @ Leongatha
- 227202 – Tarwin River @ Meeniyan

The location of the sites is shown in Figure 4-9. Fortunately a site was available at the catchment outlet and hence the overall nutrient load at this point could be verified.

Figure 4-9. Monitoring station locations of water quality data used in this study

4.14. Assigning rainfall-runoff model parameters

Rainfall-runoff model parameters were assigned through a calibration procedure (described later in this report).

4.15. Assigning constituent generation parameters

4.15.1. Suspended Solids & Nutrients

Broad generation rates in kg/ha/yr for a range of parameters were taken from the Corner Inlet DSS Project (2008) as the catchment is adjacent to the current study. There were also a number of sites within the catchment where these values were recorded.

Values were modified from the Corner Inlet (2008) values to match observed values throughout the catchment, while keeping within the literature values (as shown in Appendix 4).

4.15.2. Pathogen generation rates

Determination of generation rates for pathogens is an active area of research and relevant estimates of generation rates for specific land uses and for both low flow and event conditions are still quite rare. A report on research conducted by CRCWQT (2007) provided some useful estimates of DWC and EMC for a range of land uses. This data has been used to inform the EMC/DWC values in conjunction with values derived for the Wilsons River Study Ecos Environmental Consulting (2009). More importantly, two quantitative models (one for cattle and one for on-site treatment systems) were developed as part of this study to provide estimates of pathogen loads generated in each subcatchment for each modelling scenario. The models are described in Appendix 9 Pathogen Fate Modelling. The predicted pathogen loads were used to derive appropriate runoff coefficients for pathogens and provided an additional level of confidence in the coefficients.

4.15.3. Base Case DWC/EMC Values

The base case management scenario is the current management regime. Modelling of other scenarios consists of applying systematic changes to runoff coefficients for particular land uses, or filters to particular Functional Units. The base case runoff coefficient table is shown in Table 4-6. The table presents Dry Weather Concentrations (DWC) and Event Mean Concentrations (EMC) for a series of land uses for each modelled constituent.

Table 4-6. DWC and EMC values for Base Case (Current Management)

Landuse	Suspended solids (mg/L)		TN (mg/L)		TP (mg/L)		Campylobacter (orgs/L)		Cryptosporidium (orgs/L)		Adenovirus (orgs/L)	
	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC
Forest	10	100	0.3	1	0.05	0.3	0.3	23	0.02	0.02	0	0
Grazing < 4.1ha	10	140	0.2	2.5	0.04	0.5	0.35	5.6	6.6	12	0.37	8.73
Grazing - Cattle	10	200	0.3	2.2	0.08	0.5	0.35	5.6	6.6	12	0.01	0.26
Grazing – Other Livestock	10	150	0.3	2.2	0.04	0.5	0.35	26.5	0.05	0.45	0.01	0.28
Reserve	5	40	0.008	0.9	0.02	0.09	0.3	0.7	0.02	0.02	0	0
Roads	10	100	0.3	2.3	0.1	0.3	0.3	23	0.02	0.02	0	0
Rural Living	10	110	0.3	2	0.1	0.25	19.3	165	0.18	16.05	0.4	8.7
Urban Sewered	11	90	0.5	2	0.1	0.25	3.6	150	0.16	20	1	10
Urban Unsewered	11	90	0.5	2	0.1	0.25	24	257	2.41	25.8	2	21

4.16. Assigning node parameters

There are 3 sewered towns in the Tarwin Water Supply Catchment (Table 4-7). Treated sewage effluent discharged to waterways is a potential source of pathogens and nutrients. Pathogen concentrations are generally controlled to a significant degree by disinfection steps in the treatment processes while nutrients may be controlled to a lesser degree.

The quality and quantity of effluent discharged to each waterway has been considered in the model. As shown in Table 4-7 only the Leongatha Wastewater Treatment Plan

(WWTP) discharges into the Tarwin Water Supply Catchment, with Meeniyan discharging downstream of the offtake point and Korumburra discharging to Foster Creek (outside the catchment). The Leongatha WWTP discharges to Little Ruby Creek.

Table 4-7. Sewage treatment services summary Tarwin Water Supply Catchment.

Centre	Population Serviced	Sewerage Customers Billed	Discharge in Tarwin Catchment?
Korumburra	3,348	1,822	No
Leongatha	4,762	2,810; also includes Steam Condensate Wastewater	Yes
Meeniyan	451	229	No

(Source: South Gippsland Water 2013)
Note that a small portion of Korumburra lies outside the Tarwin water supply catchment

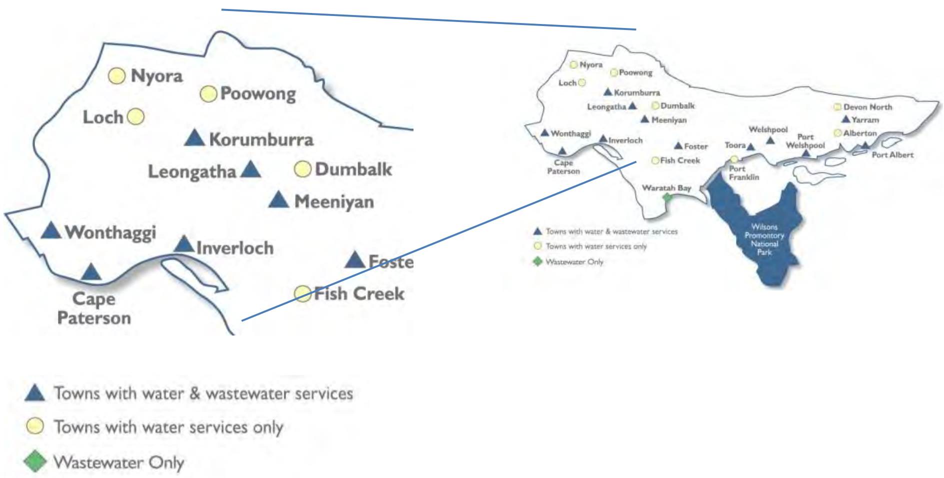


Figure 4-10. Water and wastewater service status for towns in the Tarwin Catchment area (Source: www.sgw.com.au).

South Gippsland Water is working towards recycling sewage treatment plant (STP) effluent although current rates of recycling are relatively low compared with water authorities in dryer parts of Victoria (Table 4-8).

Table 4-8. Wastewater reused by South Gippsland Water in 2009/10, extract from SKM (2011)

Wastewater Treatment Plant	Discharge Volume (ML/yr)	Target Discharge Quality	Current Treated Wastewater Use	Plan for reuse
Leongatha	547	Class B	Discharge to Inland Waters. <1ML reused from standpipe.	Reuse Water available at treatment plant stand pipe. Potential reuse for Golf Club or pasture irrigation, environmental flow to Little Ruby Creek

South Gippsland Water provided data on measured concentrations collected on an ad-hoc basis between 2009 and 2014. The average value was determined and applied as a constant due to a lack of further data delineation. Note that pathogens were not monitored and hence typical values were selected based on the treatment type[4]. Average yearly flows were applied to the model where available (Table 4-9), and the average of these values was applied outside the range 2005-2014.

Table 4-9. Average concentrations applied to the model

Item	Value
TSS	9.25 mg/L
TP	0.28 mg/L
TN	4.6 mg/L
Campylobacter	70 orgs/L
Adenovirus	80 orgs/L
Cryptosporidium	20 orgs/L

4.17. Runoff model calibration

Calibration is the process of refining model parameter values, so that model outputs are as close as possible to observed conditions. While model performance would be improved through calibration for all variables, the key driver of contaminant loads is stream flow, and it is also the only variable with detailed observed time series data available for calibration. Thus, the most important aspect of Source calibration was to calibrate stream flow.

There are limits to the goodness of fit that can be achieved with rainfall-runoff models. Typically, achieving a good fit to one part of the hydrograph will come at the cost of a poorer fit elsewhere. There are a number of ways to calibrate, with the preferred one being to fit the model as best as possible to part of the gauged record, and then validate its performance on the remainder of the record. This can be problematic if the record contains trends of declining or increasing runoff over time.

In the case of Tarwin River streams, the model was calibrated using the Rainfall Runoff Library (RRL). The Dumbalk gauge was selected for calibration as it gave the best parameter fit across the catchment and had the longest consistent record. The calibrated model was then applied to the rest of the catchment and the model fit to the gauged data reported. Values applied to the model are shown in Table 4-10.

Upon beginning the calibration procedure, it was apparent that the SIMHYD model would provide a reasonably close model fit to the daily data, however all components would not be able to be matched. The main calibration issue was that compared to the gauged data the modelled event hydrographs was lower in peak magnitude (Figure 4-11). The mean flow rate and correlation are provided in Table 4-11, where a peak correlation of 0.647 was achieved.

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[4] i.e. 95th percentile sewage pathogen concentration data from the Australian Guidelines for Water Recycling (NHRMC 2006) and assuming a 2 log reduction through the treatment plant.

Table 4-10 Parameter values for runoff model

Parameter	SIMHYD
Baseflow Coefficient	0.27
Impervious Threshold	4.79
Infiltration Coefficient	177
Infiltration Shape	0.24
Interflow Coefficient	0.0117
Pervious Fraction	0.98
Rainfall Interception Store Capacity	4.99
Recharge Coefficient	0.57
Soil Moisture Store Capacity	150

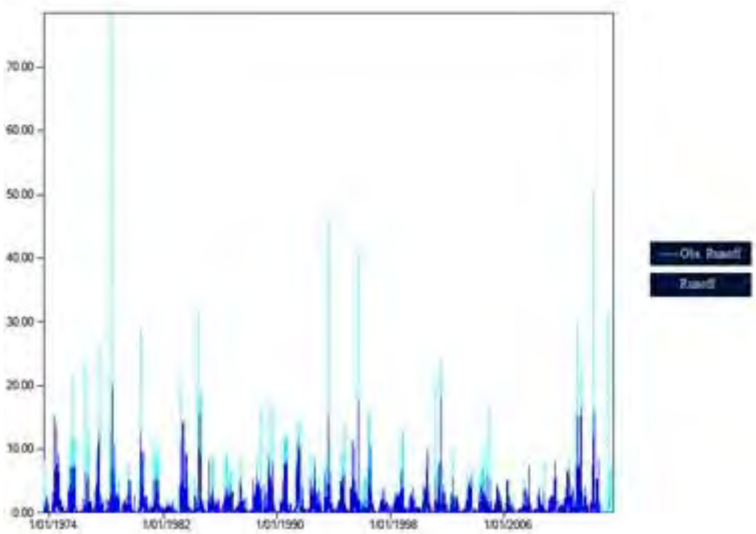

Figure 4-11 Discharge over the calibration period for observed flows at Tarwin River @ Dumbalk versus modelled flows.

Table 4-11 Performance of model calibration– annual flow

Scenario	Mean annual flow (m3/s)	Standard Deviation	Correlation coefficient of annual discharge - scenario vs observed	Relative Difference in flow (%)
Gauged	0.751	1.407		
SIMHYD	0.739	1.839	0.647	1.627%

4.18. Runoff model verification

Having established that the SIMHYD model produced the best fit to observed runoff data at Tarwin River @ Dumbalk, the model was verified by comparing modelled flows with observed flows at other gauges within the catchment.

The model performance was assessed by comparing modelled against observed:

- mean annual discharge,
- daily flow duration curves.

Flows at the model outlet are presented in the main body of the report, with all calibration sites presented in Appendix 2.

4.18.1. Mean annual discharge

Mean annual discharge was adequately predicted by SIMHYD, where the modelled value fell between the ranges of observed flow for all sites (see Appendix 2). The observed flow is actually the calculated flow based on the comparison of the water level to the stage-discharge curve at the gauge, hence why a range is appropriate. As shown in Figure 4-12 the mean annual flow at the outlet is 21.3 ML/d higher than the mean observed flow, although this is within the range of quoted values for the site.

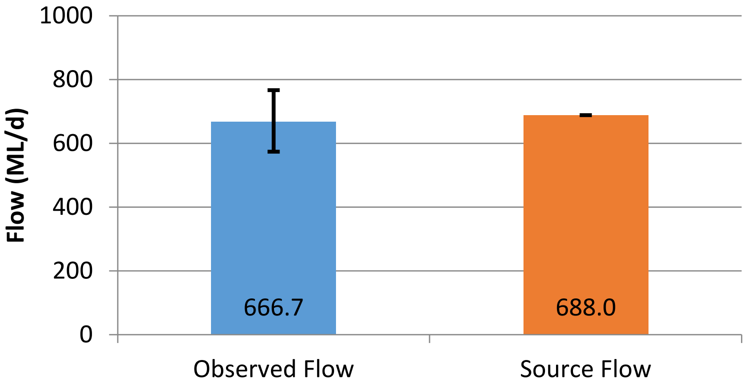

Figure 4-12 Mean Annual Discharge - Meeniyan

4.18.2. Daily flow duration curves

The models generally matched the medium and low flows, while underestimating the highest flow peaks. At Meeniyan, however, the low flows were overestimated with a good match throughout the medium and high flow range (Figure 4-13).

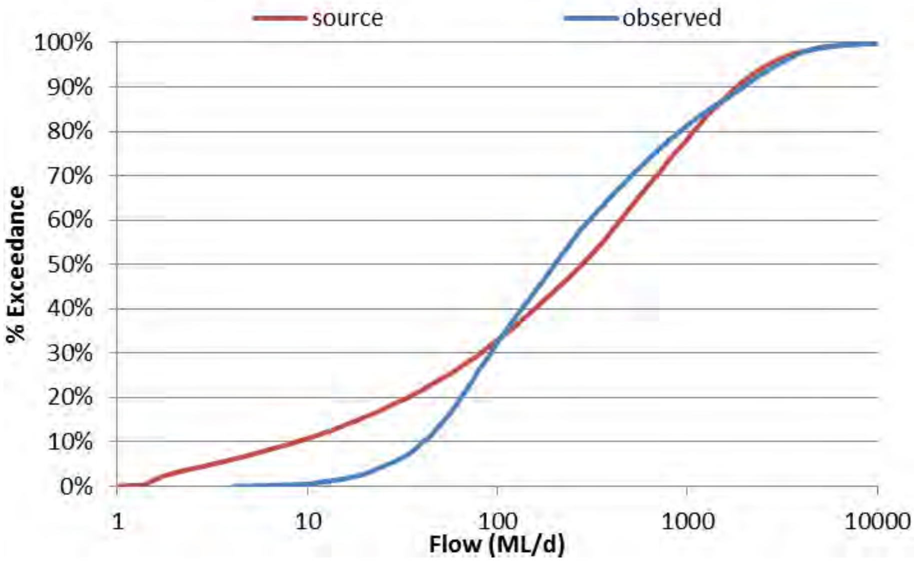

Figure 4-13 Flow duration curves for observed daily flows at Meeniyan versus modelled flows

4.18.3. Extractions

A number of water extractions occur throughout the catchment for bulk entitlements. The model was modified to include these storages and extractions in order to match the observed flows (Figure 4-14). Further details about the storages and systems are provided in Appendix 1.

Flows from the river were extracted based on a series of rules, which relate to:

- Capacity of the system
- Supply restrictions (low flow and peak supply)
- Water Demand

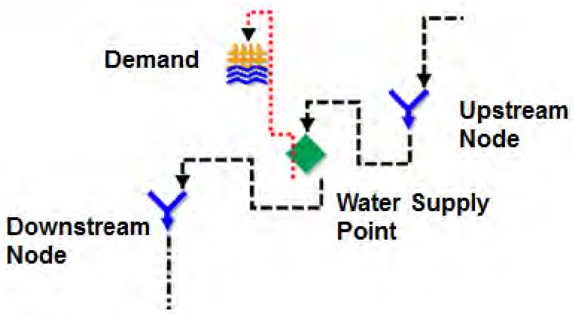

Figure 4-14 Source model schematic of extractions

The modelled extractions compared to the expected extractions is shown in *Table 4-12*. The model provided a good calibration to the expected extraction points.

Table 4-12 Extraction Calibration

Town	Modelled Extraction (ML/yr)	Expected Extraction (ML/yr)
Dumbalk	17.2	17
Meeniyan	70.1	65
Coalition Creek	488.3	621
Leongatha	1839.3	1893
Koonwarra	811.4	Unknown (max 1000)

4.18.4. Conclusion – runoff model verification

The SIMHYD model was validated for the Tarwin River catchment at sites with available gauged flow data. The model provided satisfactory predictions across the catchment. The validation sites covered a range of sub-catchment areas and were spread throughout the catchment. The Source model predicts annual flows very well, but is not as good with daily flows. In general, the model under-estimates the flood peaks, predicts a higher duration of low flows, and provides a reasonable estimation of the mid-range flows. *Thus, it is concluded that from the perspective of discharge, the model is suitable for predicting contaminant loads at the monthly time-step, but peak daily loads will be underestimated*. Of course, the veracity of these predictions also relies heavily on the appropriateness of the functions relating contaminant concentration to discharge as a function of land use.

4.19. Water Quality model verification

The time series of concentrations generated within the model was compared to grab sample values at Meeniyan and Leongatha. Generally water quality data is notoriously hard to calibrate to as the concentrations can change significantly between sampling periods due to a range of factors. The observed values do, however, provide a good range of values likely to be observed at each site which the model has tried to match. Note that only TSS, TN and TP values could be compared as pathogens have not been monitored in the catchment. Nevertheless, pathogen data from similar interstate catchments (Deere *et al.* 2005) indicated that the Tarwin Source Model provides good estimates of pathogen loads.

4.19.1. Leongatha Verification

The modelled TSS, TN and TP values were compared to sampled concentrations at the Wilkur Creek @ Leongatha site. The contributing catchment is predominantly cattle grazing.

The modelled concentration of Suspended Solids in the baseflow was a good match to observed data, as shown in Figure 4-15. The model has underestimated some of the higher concentrations observed in events, however the model is only supposed to provide the event mean concentration rather than the peak so the TSS values in the event were considered appropriate.

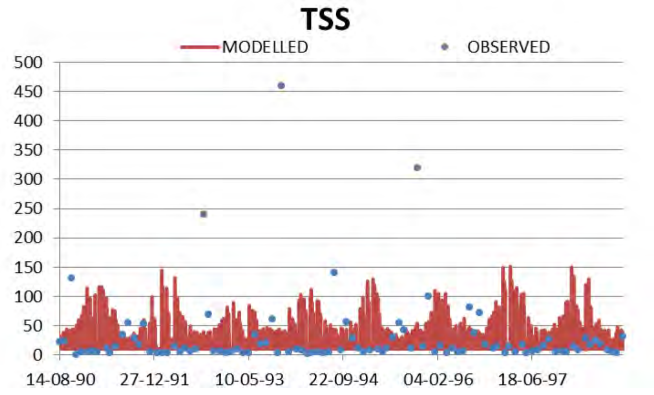

Figure 4-15 Suspended Solids – Leongatha

The Total Phosphorus verification (Figure 4-16) provided a reasonably close fit to the observed data, with most of the peak values obtained. The DWC values for this site were likely to be slightly higher than observed, however the calibration at Meeniyan was preferentially chosen to ensure the entire catchment verification was more accurate.

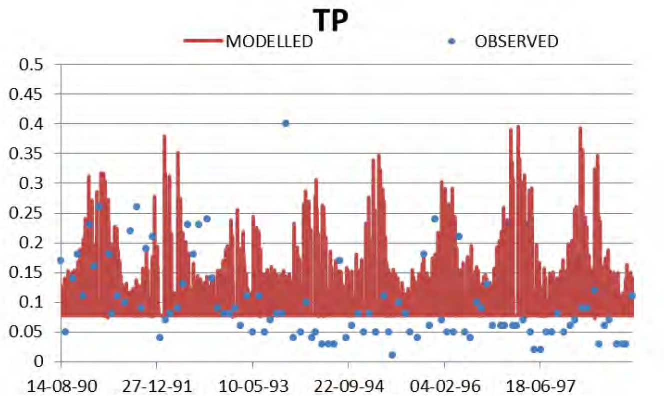

Figure 4-16 Total Phosphorus – Leongatha

The Total Nitrogen calibration at this site was not strong, with the model not being able to achieve the minimum and maximum values observed at this site (Figure 4-17). EMC and DWC values were not modified to represent this trend as this pushed the values significantly outside the literature values for the grazing landuse, which was considered inappropriate for the catchment.

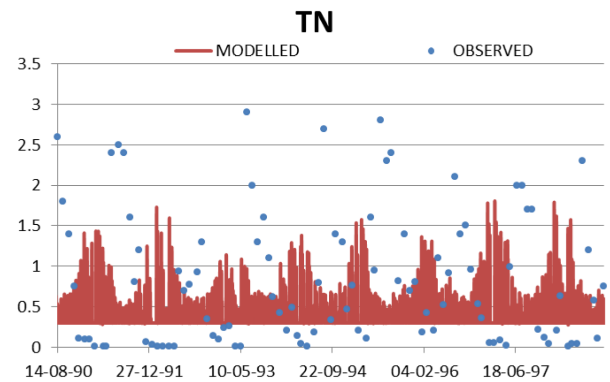

Figure 4-17 Total Nitrogen - Leongatha

4.19.2. Meeniyan Verification

The modelled values were also compared to the outlet point for the catchment, where a monitoring site exists on the Tarwin River at Meeniyan.

As per the Leongatha site the Suspended Solids verification was a good fit to the data, with the baseflows well matched, and most event concentrations achieved (Figure 4-18). Some higher values were observed, however most events were in the 75 -150mg/L range.

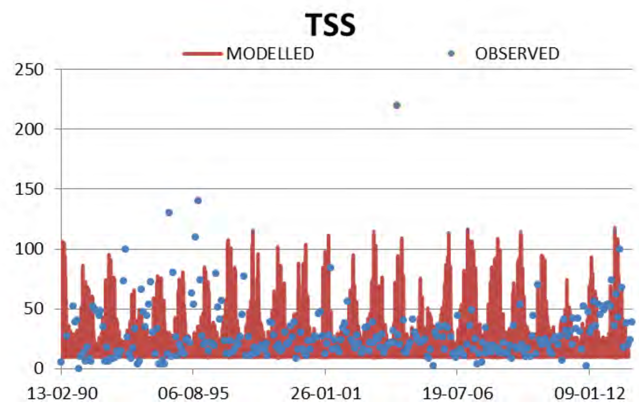

Figure 4-18 Suspended Solids – Meeniyan

The Total Phosphorus concentrations were also well matched at the outlet, with most peaks and baseflows matched by the modelled data (Figure 4-19).

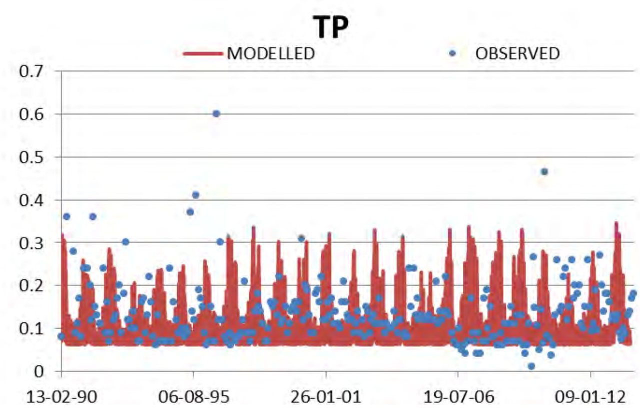

Figure 4-19 Total Phosphorus – Meeniyan

The Total Nitrogen concentrations for the catchment were generally matched in magnitude, however the lowest concentrations were not achieved (Figure 4-20). Most grazing related landuses were assigned a DWC of 0.3mg/L which has shifted the models concentration prediction for the baseflows to this level.

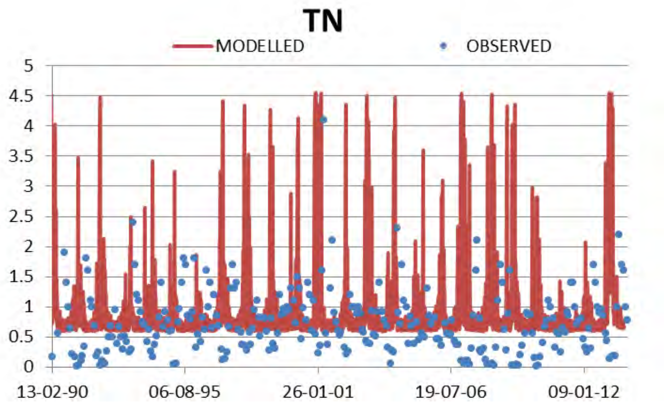

Figure 4-20 Total Nitrogen – Meeniyan

The nutrient loads at Meeniyan were compared to determine if the overall load from the model matched with loads observed at this point. Note that the load at Meeniyan was not provided, hence the grab sample concentrations were multiplied by the flow measurement for that day. The flow reading was not necessarily taken at the same time as the grab sample.

As shown in Table 4-13 the sediment and nutrient loads predicted by the model provide a relatively good fit compared to observed values. TSS and TP loads are slightly below observed values, but well within the same order of magnitude.

Table 4-13. Nutrient Loads at Meeniyan

Load	Observed at Meeniyan	Modeled at Meeniyan
Flow (ML/d)	678	688
TSS (kg/d)	19428	12481
TN (kg/d)	489	503
TP (kg/d)	90	59

4.19.3. Conclusion – water quality model verification

The EMC/DWC model was validated for the Tarwin River catchment at sites with available water quality sample data. The model provided satisfactory predictions across the catchment, and particularly at the outlet point at Meeniyan.

The Source model predicts the loads very well and provides the right order of magnitude concentrations throughout the time series. Due to the variable nature of water quality concentrations, and the ability to only change two parameters (EMC & DWC) this was considered to be a good fit.

5 Key Management Areas and related programs

The focus of the TWSCMP is to identify and describe a plan for the management actions that are necessary to protect water quality within the Tarwin River Water Supply Catchment. Although the TWSCMP and the Tarwin Catchment Water Supply Protection Policy will largely be vehicles for the harmonisation of environmental management and environmental planning processes between South Gippsland Water and South Gippsland Shire Council, the plan and policy will play an important role in informing other agencies and catchment stakeholders of the objectives of the SGW and SGSC in relation to catchment protection and the statutory planning process.

The plan and policy will seek to identify and support catchment management and catchment protection measures relevant to water quality that are the responsibility of other agencies. In such cases a cooperative relationship will be sought with the other agencies to help them achieve their goals.

Plan development

As described in section 3.1 the development of the TWSCMP plan involved two stakeholder workshops to provide opportunities for Working Group input and feedback, the development of linked pathogen source and hydrological models, and a final stakeholder workshop to provide comment on the draft plan (see also Figure 1-2). There were two important outcomes from the first workshop; 1) the development of a vision statement which described the Working Group's vision for the Tarwin Water Supply Catchment with reference to water quality and ecosystem health, and 2) the development of key management areas and associated supporting goals. The vision, KMAs and goals were further refined by the Working Group in the second workshop (along with the modelling scenarios) and are described below.

5.1. Vision and Key Guiding Principles and Key Management Areas (KMA's)

In order to address the hazards to water quality in the Tarwin River catchment, the Working Group developed the following vision for the catchment:

Vision for the Tarwin River Water Supply Catchment

"Our vision is for the Tarwin Water Supply Catchment to have productive and sustainable communities and healthy ecosystems that provide clean water."

The Working Group also developed guiding principles to ensure the vision's fulfilment:

Guiding Principles to ensure the visions fulfilment

> *"The vision will be fulfilled by supporting and promoting a culture of sustainable development and cooperation and focussing on mutually beneficial outcomes through the implementation of the best and/or most appropriate management practices. We will identify and progressively work through the challenges to achieve our long-term goals."*

To meet these guiding principles two Key Management Areas (KMA's) were identified for the Plan, reflecting the main focus and actions required, in order to work towards and achieve our Vision. Targets or benchmarks to strive for can be set based on the aim and goals of these KMA's. Furthermore, our overall performance and progress towards achieving the goals can be measured and reported on, with actions for improvement or adjustment recommended where necessary.

Six Goals have been identified, three under each KMA, based on the values to protect and challenges associated with achieving our Vision. These goals support the specific aims we have identified for each KMA.

Our Key Management Areas:

1. Riparian and Land Management — Goals 1, 2 & 3
2. Wastewater Management — Goals 4, 5 & 6

The generic framework used for the Tarwin Water Supply Catchment Management Plan is set out in Figure 5-2.

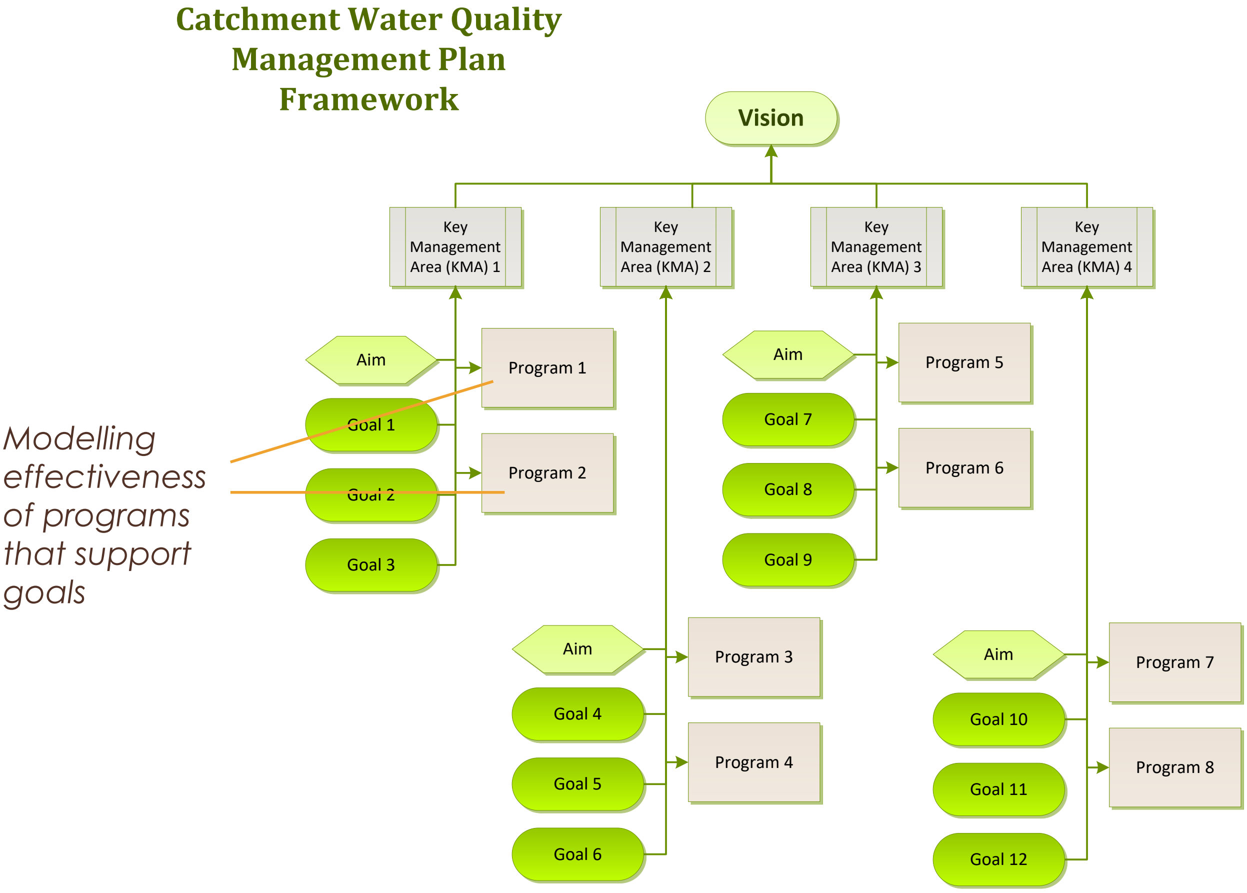

Figure 5-1: Generic framework adapted for a water supply catchment management plan. Modelling focusses on assessing the effectiveness of programs that support goals. The plan for the Tarwin Water Supply Catchment is shown schematically in Figure 5-2.

5.1.1. Best Management Practice Programs

A series of Best Management Practice (BMP) actions that support the goals of the KMAs are identified below. These BMPs are aspirational and are described only briefly here. For BMPs to be implemented, a local agency needs to be nominated and to accept the role of lead agency for the development of a detailed Implementation Plan which includes costing and roles and responsibilities. The implementation plan should coordinate the activities of other supporting agencies and provide feedback on the performance of the plan in achieving the goals over time. Note that the plan may refer to the existing work programs of other agencies that are relevant to the goals of the TWSCMP.

5.1.2. KMA 1: Riparian and Land Management

Our Aim:

> Protect water quality in the Tarwin River Water Supply Catchment through the protection and restoration of riparian vegetation and control of stock access.

Our Goals:

Goal 1: Protect water quality in the Tarwin River and its tributaries by restoring and conserving riparian buffer zones.

Goal 2: Control loads of sediments, nutrients and pathogens to waterways by excluding stock from waterways except under licenced conditions for controlled grazing.

Goal 3: Provide landholders and management agencies with a clear definition of the waterways that are to be managed for water supply protection.

Programs and their key elements:

Riparian Zone BMP[5]

- For effective pathogen control communicate to stakeholders including government and industry that juvenile cattle (< 12 months) are preferably excluded from controlled grazing in riparian zones (this would be voluntary) but that exclusion of pre-weaned calves should be mandatory.
- Prepare a research update for stakeholders in relation to waterborne human pathogens excreted by stock (focus on pathogens significant in the Victorian context). This task to assist in creating and supporting industry awareness.
- Establish and maintain fenced riparian buffer strips on all perennial catchment waterways (raising awareness with farmers with properties along the smaller tributaries will be important).
- Seek development of best practice guidance for design and management of riparian buffers. Design should take into account tendency of cows to seek shade and shelter and to graze near to waterways and that areas of bare ground such as gateways, water troughs and feeding areas need to be located well beyond the buffer (see Aarons and Gourley 2012).
- In the interim provide guidance on minimum requirements for buffer strips to protect water quality (it is assumed that this will entail a minimum of 20 m of stock exclusion fencing and grass, shrubs or trees)[6].
- Establish off-stream water points with shade available to encourage livestock to stay away from riparian areas in hot weather.
- Support DEPI and West Gippsland CMA in the management of Crown Frontage Licences and Riparian Management Licences.
- Encourage awareness and compliance with Victorian Riparian Grazing Guidelines (DEPI 2013).
- Seek revision/augmentation to the Victorian Riparian Grazing Guidelines to incorporate information about pathogen control in water supply catchments.

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[5] Note: Excludes in-stream habitat although there are expected to be benefits to instream values due to improvements in water quality and physical habitat for aquatic fauna such as fish and aquatic insects, etc.

[6] At present the best or most appropriate buffer strip configuration can't be specified with certainty for Tarwin catchment streams due to lack of available research data. General comments are to have a buffer width of 10 to 20 m which may consist of grasses, trees and shrubs and protected by cattle exclusion fencing. Controlled grazing should be considered in the drier months only so as to reduce soil damage, control fire risk, and supplement farm production. Feed pads and offstream watering points should be located at appropriate distances from waterways to reduce or minimise the contribution of drainage from such sites.

- Work with DEPI and West Gippsland CMA to identify and map waterway riparian reaches that are priorities to be managed for water supply protection. Make this information available to the relevant landholders in an appropriate form (e.g. clear and easy to access, embedded with information to encourage landholder support for riparian protection, etc.)
- Develop an education and investment program that encourages landholders to fence off Priority riparian zones (see previous point) on private land (i.e. non-crown frontage).
- Track and report on success of riparian protection programs in the Tarwin Water Supply Catchment.

Key partners: DEPI, WGCMA, EPA, VFF, SGW, SGSC, Baw Baw SC, Landcare, other relevant community and industry associations and landholders.

Actions: South Gippsland Water and South Gippsland Shire to initiate a Riparian and Land Management Implementation Working Group. The Working Group would ideally consist of the above catchment partners and any other interested parties. The Working Group should identify and agree on roles and responsibilities and seek resources to support implementation.

Animal Production BMP - elements

Includes Cattle (Beef and Dairy) Production and other animal production

- Encourage awareness and use of the Dairy Self-Assessment Tool (DairySAT) on the Dairy Australia website (www.dairyaustralia.com.au)
- Encourage good herd health through support for Dairy Australia's herd health awareness and educational resources, particularly for calves. Prevent scouring calves from having direct access to waterways.
- Support local programs for Bovine Johnes Disease (BJD) control as these will also assist in varying degrees in controlling other bovine pathogens that can infect humans (e.g. *Cryptosporidium parvum*, *E. coli* O157, etc.). Relevant programs include:
    - National Dairy BJD Assurance Score (voluntary, risk-based trading system, based on self-assessment, for farmers to better manage the risk of BJD)
    - 3-Step Calf Plan (A voluntary, industry-driven program containing three essential steps for minimising the spread of BJD)
    - Johne's Disease Calf Accreditation Program (JDCAP) (managed by DEPI)
    - Beef Only (a market assurance program for beef cattle to provide assurance that they are low risk of BJD)
    - CattleMAP (Johne's Disease Market Assurance Program for cattle: a voluntary, industry-driven, national program to identify, protect and promote herds that have a low risk of being infected with BJD).
- All dairy farms to follow the Victorian Guidelines for the Management of Dairy Effluent as described in the 2008 DairyGains publication (DEPI and DairyGains 2008). Farms that conform to the effluent management guidelines are expected

to meet EPA compliance requirements. EPA is responsible for enforcement (but note that EPA does not consider monitoring as its responsibility). Management of dairy effluent could also be considered under the Wastewater Management KMA.

- Raise awareness amongst catchment residents, government agencies, emergency services and local businesses that they are living in a water supply catchment.
- Recognise and encourage Best Management Practices, including whole farm planning and biocide (i.e. herbicides, insecticides etc.) and nutrient management to reduce runoff.
- Focus on land management support by undertaking the following:
    - Encourage Best Management Practices to maximise soil retention;
    - Encourage rotation grazing of pasture; and
    - Encourage appropriate stocking rates to minimise erosion.
- Encourage use of appropriately sited and constructed feedpads where supplemental feeding is used on dairy farms. A feedpad is an enclosed area where dairy cattle are provided with a portion of their daily feed requirement as hay, silage, grain or mixed feed for all or part of the year.
- Establish riparian zones (links to Riparian BMP).
- Encourage better drainage of driveways and access roads.
- Prevent run-off from animal wash-down areas from entering waterways.
- Discourage the dumping of dead livestock in waterways.
- Encourage appropriate storage and disposal of chemicals.

Key partners: Same as for Riparian Zone BMP

Horticulture BMP

- Raise awareness amongst catchment residents, government agencies, emergency services and local businesses that they are living in a water supply catchment.
- Recognise and encourage Best Management Practices, including whole farm planning and biocide and nutrient management to reduce runoff;
    - Support fertiliser management to avoid over use of fertiliser.
- Focus on land management support by undertaking the following:
    - encourage Best Management Practices to maximise soil retention;
    - on land that is being spelled from horticulture;
        - encourage rotation grazing of pasture; and
        - encourage appropriate stocking rates to minimise erosion.
- Establish and manage riparian buffers (see Riparian Program).
- Continue support for Forestry best practice (see Codes of Practice governing forestry and plantation management).

Key partners: Same as for Riparian Zone BMP

5.1.3. KMA 2: Wastewater Management

Our Aim:

Ecologically sustainable development that minimises transport of contaminants to waterways, and supports good water quality and stream health in the Tarwin River Water Supply Catchment.

Our Goals:

Goal 4: Protect water quality in the Tarwin River and its tributaries by improving the quality of wastewater discharge and reducing the quantity of surface water discharge.

Goal 5: Manage and reduce loads of pathogens and nutrients from on-site wastewater management systems.

Goal 6: Minimise adverse impacts on waterways through continuous improvement in stormwater management and recycling.

Programs and their key elements:

Urban Stormwater BMP

- Raise awareness amongst catchment residents, government agencies, emergency services and local businesses that they are living in a water supply catchment;
- Encourage use of Infrastructure Development Manual (IDM) in urban areas;
- Encourage recycling of urban stormwater;
- Appropriate sewage treatment systems in place for all major towns.

On-site systems BMP

- Encourage compliance with the Victorian EPA Code of Practice for On-site Wastewater Management (891.4);
- Develop program to phase out non-conforming older systems and upgrade to new conforming systems;
- Undertake a detailed local scale study of alternative systems to provide better guidance on long-term sustainability with respect to pathogen and nutrient control and failure rates. Issue revised guidance informed by the study;
- Audit existing on-site systems for compliance with Septic Tank Code of Practice in relation to allowed setbacks.
- Develop a Tarwin River Water Supply Catchment Policy; and
- Support South Gippsland Shire Council, Baw Baw Shire Council and Latrobe Shire Council in the development and implementation of their Domestic Wastewater Management Plans (DWMP); The goals associated with these strategies are:
    - Capture on-site wastewater management systems installation and maintenance data to guide decision making.
    - Plan for the long term sustainability of townships through appropriate development controls of land and infrastructure.

- Effective utilisation of legislation to implement improved management of on-site wastewater systems.
- Provide fair, accurate and accessible information on good wastewater management principles, practices and improvement options.
- To ensure risks from wastewater management are minimised through behavioural change and compliance with performance standards.

Further details of the strategies and their associated actions are to be developed in the DWMP.

Licensed discharges BMP (including WWTPs)

- Encourage industry to apply EPA Victoria water conservation hierarchy (reduce, reuse recycle) to their wastewater discharges (http://www.epa.vic.gov.au/your-environment/water/reusing-and-recycling-water);
- Continued compliance with Licence conditions for EPA licensed discharges.

Key partners: DEPI, EPA, WGCMA, SGW, SGSC, Baw Baw SC, Latrobe SC, Property Owners and Residents

Actions: South Gippsland Water and South Gippsland Shire to initiate a Wastewater Management Implementation Working Group. The Working Group should consist of the above catchment partners and any other interested parties. The Working Group should identify and agree on roles and responsibilities and seek resources to support implementation.

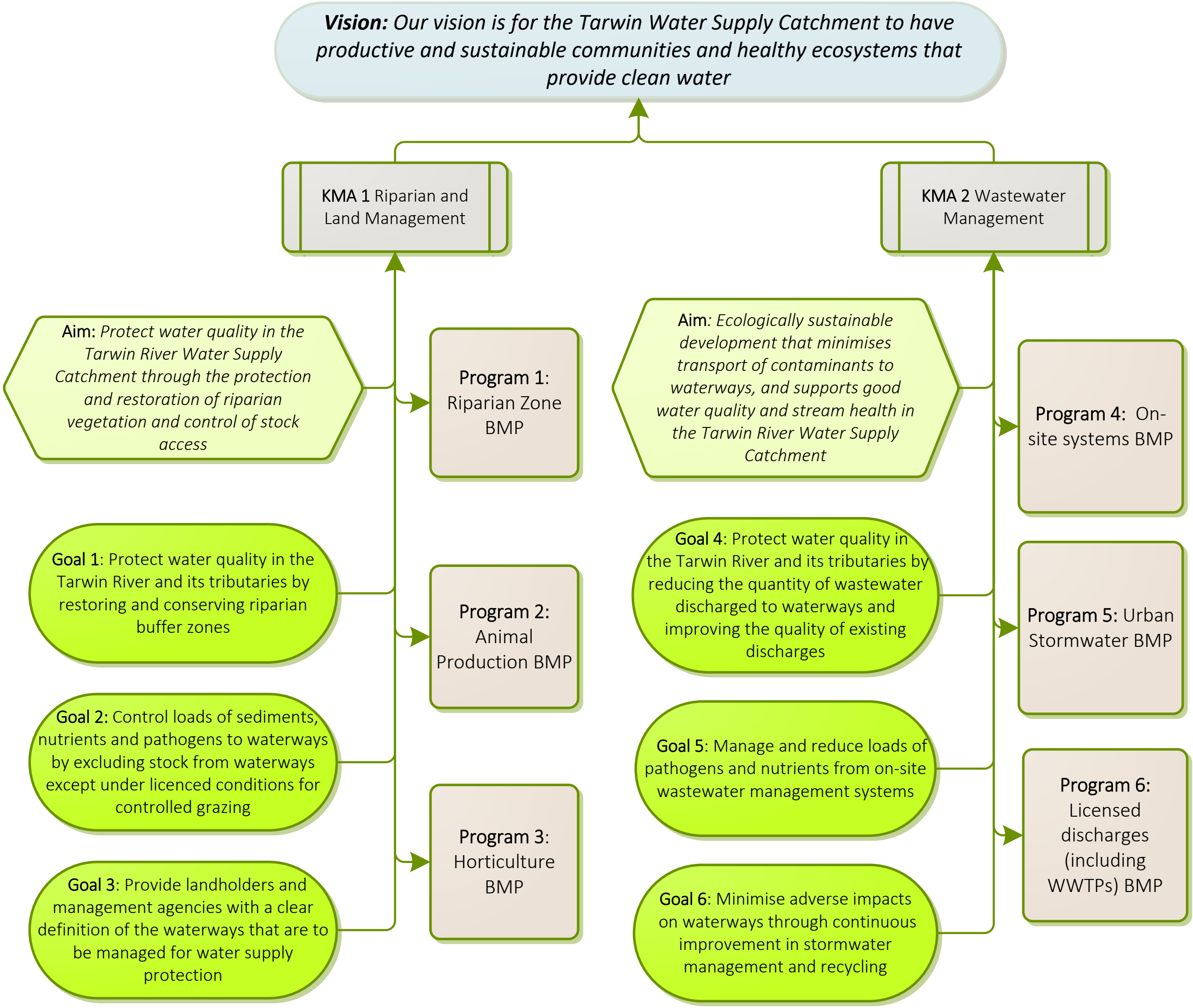


Figure 5-2. Tarwin Water Supply Catchment Management Plan Framework.

6 Management scenarios for modelling

6.1. Modelling approaches

The broad approach used to model different management scenarios involved alterations to settings within particular component models. For the Tarwin River Catchment Model the following component models were used to develop scenarios:

- Conversion of area from one functional unit to another within the subcatchment.
    - E.g. where more dense development occurs the appropriate area of Rural Living is converted to Urban Sewered/Unsewered.
- A Constituent Generation Model that deals with runoff coefficients.
    - Constituents are applied to Functional Units (FU) (i.e. a discrete land use within a modelled sub-catchment
    - Changing constituent values is one way of running different modelling scenarios. For example, the nitrogen coefficient for grazing under standard grazing management practices may be 2 times higher than under best practice. A modelling scenario may then involve conducting a program to implement best practice grazing management in selected sub-catchments and compare the results to the current management scenario.
- A Filter Model which reduces the amount of constituent that is generated in a FU.
    - There are a number of filter models available in Source but the most appropriate for the Tarwin River Catchment is the Percentage Removal model. This model involves the application of a constant removal coefficient to the constituent load passing with baseflow (slow flow) and surface (quick) flow. Baseflow and quickflow can have different percentage removal coefficients. Quickflow typically only occurs during heavy rainfall events when the soil is saturated.
    - Scenarios can be developed using filtering: e.g. assuming that a healthy riparian zone will improve contaminant retention, the restoration of the riparian zone for selected landuses could be modelled by changing the value of the Filter coefficient for each FU.
    - The default filter model (pass-through of catchment constituents) was used for current management.

6.2. Scenario selection

Not all program elements are capable of being assessed using catchment water quality models due to the diffuse nature of their benefits (e.g. improved agency catchment coordination), or current lack of sufficient technical or scientific data to support a modelling scenario. Consequently a shortlist of program elements listed in Section 5 above were selected based on their suitability for modelling and their perceived need for assessment as considered by the Consulting Team and the Tarwin River Catchment Working Group.

In total *nine management scenarios were developed and examined*. Some scenarios were partial or full implementations of particular management actions and so for clarity, these were grouped together to give 8 scenario groups (Table 6-1). The scenarios are described in more detail in the following sections.

Table 6-1. Management scenarios

Scenario Group.	Management Scenario
	Scenario 1: Base Case, Current Management
Riparian & Land Management	Scenario 2: Implementation of Riparian Best Practice Management • Scenario 2a: Implementation of BMP (fencing and off-stream watering points) for riparian zones within grazing land use only • Scenario 2b: Implementation of BMP for riparian zones for all land uses across the catchment (excluding existing forested landuses)
	Scenario 3: Stock Exclusion Fencing Only
	Scenario 4: Calf health programs &/or exclusion of calves from riparian connected paddocks
Wastewater Management	Scenario 5: Implementation of Infrastructure Design Manual standards
	Scenario 6: Improved Management for on-site systems
	Scenario 7: Full development of unsewered properties to maximum acceptable densities under existing planning laws
	Scenario 8: Full development and improved management

Not all parameters are appropriate for modelling with each scenario. For example, Adenovirus concentrations are mainly a product of septic tanks and leaking sewers and so are not relevant to management actions that do not involve these issues. Table 6-2 shows which parameters are appropriate for modelling for particular scenarios.

Table 6-2. Summary of parameters of relevance to management scenarios and used in modelling and the modelling approach that could be used.

		Develop model scenarios by altering			Parameter relevant to management scenario?					
No.	**Management Scenario and sub-scenario**	**Area of the functional unit**	**EMC/DWC coefficients**	**Filters**	**Nitrogen (N)**	**Phosphorus (P)**	**Suspended solids**	**Cryptosporidium**	**Adenovirus**	**Campylobacter**
1	Base Case, Current Management				✓	✓	✓	✓	✓	✓
2	Implementation of Riparian Best Practice Management									
	Scenario 2a: Implementation of BMP (fencing and off-stream watering points) for riparian zones on Crown Frontages within cattle grazing land uses			✓	✓	✓	✓	✓	✓	✓
	Scenario 2b: Implementation of BMP for riparian zones for Crown Frontages and Private Land for all perennially flowing streams within cattle grazing land uses			✓	✓	✓	✓	✓	✓	✓
3	Stock Exclusion Fencing Only			✓	✓	✓	✓	✓	✓	✓
4	Calf health programs &/or exclusion of calves from riparian connected paddocks		✓					✓	✓	✓
5	Implementation of Infrastructure Design Manual standards			✓	✓	✓	✓			
6	Improved Management for on-site systems		✓		✓	✓	✓	✓	✓	✓
7	Full development of unsewered properties to maximum acceptable densities under existing planning laws	✓			✓	✓	✓	✓	✓	✓
8	Full development and improved management	✓	✓		✓	✓	✓	✓	✓	✓

6.3. Management scenarios model settings

6.3.1. Scenario 1: Base Case (Current Management)

Management Scenario 1, current management, formed the base case for comparison with all other scenarios. DWC and EMC concentrations for the base case scenario are detailed in Table 6-3 below.

Table 6-3. DWC and EMC values for Scenario 1: Base Case (Current Management)

Landuse	Suspended solids (mg/L)		TN (mg/L)		TP (mg/L)		Campylobacter (orgs/L)		Cryptosporidium (orgs/L)		Adenovirus (orgs/L)	
	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC
Forest	10	100	0.3	1	0.05	0.3	0.3	23	0.02	0.02	0	0
Grazing < 4.1ha	10	140	0.2	2.5	0.04	0.5	0.35	5.6	6.6	12	0.37	8.73
Grazing - Cattle	10	200	0.3	2.2	0.08	0.5	0.35	5.6	6.6	12	0.01	0.26
Grazing – Other Livestock	10	150	0.3	2.2	0.04	0.5	0.35	26.5	0.05	0.45	0.01	0.28
Reserve	5	40	0.008	0.9	0.02	0.09	0.3	0.7	0.02	0.02	0	0
Roads	10	100	0.3	2.3	0.1	0.3	0.3	23	0.02	0.02	0	0
Rural Living	10	110	0.3	2	0.1	0.25	19.6	165	0.18	16.05	0.4	8.7
Urban Sewered	11	90	0.5	2	0.1	0.25	3.6	150	0.16	20.0	1	10
Urban Unsewered	11	90	0.5	2	0.1	0.25	24	257	2.41	25.8	2	21

6.3.2. Scenario 2. Implementation of Riparian Best Practice Management

Scenario 2 involved the implementation of Best Practice Management (BMP) for riparian zones. This is a common restoration activity in many catchment water quality improvement programs. The aim of establishing vegetated riparian buffers strips along catchment streams is to attenuate fluxes of contaminants (particularly nutrients and pathogenic microorganisms) between the source and stream through 1) trapping particles with which the contaminants are commonly associated and 2) filtration as surface water infiltrates the upper soil layers (Kay *et al.* 2007).

The scenario assumes that the riparian zone, land management and horticultural management BMPs are in place and that being the case, that there would be great filtration of surface runoff and retention of cattle faecal material and associated pathogens.

Two versions of the scenario were modelled:

- *Scenario 2a*: Implementation of BMP (fencing and off-stream watering points) for riparian zones on Crown Frontages within cattle grazing land uses only; and
- *Scenario 2b*: Implementation of BMP for riparian zones for Crown Frontages and Private Land for all perennially flowing streams within cattle grazing land uses.

The method used for modelling the implementation of the Riparian BMP was filtering (see section 6.1 above). A summary of the filters applied for Scenarios 2a and 2b are shown in Table 6-4.

Table 6-4. Summary of Scenario 2 changes compared with the base case

Landuse	Scenario	
	2a	2b
Forest	No Filter	No Filter
Grazing < 4.1ha	**Filter Applied**	**Filter Applied**
Grazing - Cattle	**Filter Applied**	**Filter Applied**
Grazing – Other Livestock	No Filter	No Filter
Reserve	No Filter	No Filter
Roads	No Filter	No Filter
Rural Living	No Filter	No Filter
Urban Sewered	No Filter	No Filter
Urban Unsewered	No Filter	No Filter

Filtering using the percentage removal method involves the assignment of different filters for slow flow and quick flow (i.e. overland flow) as well as different values of these attributes for different parameters. The scientific literature was reviewed to determine appropriate filter settings for all parameters (Table 6-6). The literature did not distinguish between slow and quick flow for the nutrient parameters and suggested a minimal difference for the pathogen parameters.

Other assumptions were as follows:

- It was assumed that there was no current implementation of Riparian BMP within the grazing land use the base case. Note that although there is some recent implementation, little data is available on this at present (WGCMA data suggests about 4% coverage at present[7]), thus the overall effect is expected to be small relevant to the large areas where there is no implementation of Riparian BMP. Current Crown Frontage coverage for the catchment is estimated at about 6.2% (Table 6-5).

  Table 6-5. Crown Frontage Statistics for the Tarwin Water Supply catchment tabulated using GIS. Small streams have a minimum catchment area of 20 ha

	Total km	% covered	km not covered
Tarwin River	154.4	95.3%	7.3
Streams	638.9	9.5%	578.8
Small streams	2,587.7	0.0%	2,586.9
Grand Total	3,381	6.2%	3,173

- The riparian zone has not been explicitly modelled as a separate landuse within the Tarwin River Source model as a current riparian zone GIS layer does not yet

[7] It is important to note the amount of voluntary fencing of waterways undertaken by landholders. It is difficult to include these in the model as they are an unknown quantity. Inspection of catchment aerial photography indicated that additional fencing was limited, nevertheless, it is possible that more waterways are currently fenced than assumed in the model and as such the benefits of new fencing may be slightly overstated. This comment applies mainly to scenario 2b.

exist. Such a layer would need to be developed based on ground survey in conjunction with aerial photography.

- Riparian filters are applied only to the Grazing < 4.1ha and the Grazing/Pasture functional units. No EMC/DWC changes are modelled.
- The percentage-removal efficiency of Adenovirus was assumed to be the same as *Cryptosporidium* due to a lack of any research on this matter. Dai and Boll (2003) showed that encysted life history stages of *Cryptosporidium* and *Giardia* do not attach to natural soil particles. Their findings suggest that, when cysts have been entrained in overland flow (i.e., runoff), they will travel freely in the water and not as part of the particulate sediment load.
- The published literature provides a wide range of filtration effects for sediments, nutrients and pathogens. In general the sediment and nutrient literature is more extensive and robust. Nutrient reduction values chosen for the modelling were consistent with the literature and with observed water quality data based on the author's experience. The pathogen literature is more limited and mainly focuses on the fate of bacterial indicators through buffer strips of limited widths. For the current study we used relatively high removal rates based on the results of our pathogen fate modelling (see Appendix 9) and informed by empirical pathogen monitoring data from similar cattle grazing catchments in the Adelaide Hills of South Australia (Deere *et al.* 2005).

Table 6-6. Summary of published riparian filter strip filtration efficiencies for sediments, nutrients and microorganisms and assumed efficiencies for this study.

Reference	TN	TP	SS	E coli	Faecal coliforms	Streptococci (S), Enterococci (E)	Campylobacter	Cryptosporidium	Adenovirus	Comments
Coyne *et al.* (1998)			96%	75%	75%	68% (S)				4.5 m grass filter strips
Coyne *et al.* (1998)			98%	91%	91%	74% (S)				9m grass filter strips
Daniels and Gilliam (1996)	50%	50%	50-80%							Distance unclear, possibly similar to Coyne *et al.*
Fajardo *et al.* (2001)	97-99%				64-87%					Grass filter strips ~ 3 m
Schmitt *et al.* (1999)		55-79%	76-93%							Biocides also measured with dissolved forms removed much less efficiently. Filter strips 7 to 15 m. Trees and shrubs planted in strips did not improve efficiency over grass
Tate *et al.* (2000)										Study dissolved nutrients and suspended solids in runoff experiments on irrigated pasture. Did not find significant removal of nutrients. SS removal was significant

Reference	TN	TP	SS	E coli	Faecal coliforms	Streptococci (S), Enterococci (E)	Campylobacter	Cryptosporidium	Adenovirus	Comments
Line (2003)					65%	57% (E)				Implementation of cattle exclusion BMP and 7.5 years of monitoring (fencing and alternate water supply)
Young *et al.* (1980)	84%	83%	67-79%							Cropped buffer strips on a 4% slope
Tate *et al.* (2004)								90%		Small scale experimental plots
Assumed reductions for this study	48%	35%	50%				99.83% EMC 99.99% DWC	99.75% EMC 99.86% DWC	99.75% EMC 99.86% DWC	

6.3.3. Scenario 3: Stock Exclusion Fencing Only

This scenario was requested by the Working Group to examine the possible water quality benefits of a low cost fencing option. The option involves erection of basic fencing just to prevent stock access to the waterway and would not include any revegetation works in the riparian zone. As livestock access to the waterway is the major concern for pathogens this would allow a greater amount of works to be undertaken for the same amount of money. Since the Source model cannot directly model the effect of cattle defecating in the water, the Cattle Pathogen Fate model (Appendix 9) was used to determine the likely difference in the filtration efficiencies that would give the same effect as fencing out cattle and preventing direct defecation to the waterway.

The base case model was therefore modified to include reduced efficiency filters (as shown in Table 6-7).

Table 6-7. Summary of stock exclusion fencing efficiencies for sediments, nutrients and microorganisms.

	TN	TP	SS	*Campylobacter*	*Cryptosporidium*	Adenovirus
Assumed reductions for this study	17.5%	24%	25%	33.86% EMC 98.08% DWC	0.85% EMC 44.74% DWC	0.85% EMC 44.74% DWC

6.3.4. Scenario 4: Calf health programs &/or exclusion of calves from riparian connected paddocks

Implementation of a BMP for calf heath was modelled for Scenario 4. These practices included cattle herd health management to reduce infection rates of *Cryptosporidium* in juvenile cattle. Scouring calves suffering from cryptosporidiosis are a key source of *Cryptosporidium* oocysts in streams draining agricultural land. This scenario differs from the previous scenario which was focussed only on the riparian zone. It was assumed that a herd health program would have a high efficiency and therefore loads of *Cryptosporidium* and *Campylobacter* would be significantly reduced.

The Cattle Pathogen Fate model (Appendix 9) was used to determine the reduced load of pathogens available in each subcatchment compared to the base case. This was done by reducing the modelled value of pathogen concentration in cattle manure at 10% of the value used for the base case. It is assumed that an effective herd health program should have an impact of this order.

Scenario 4 is modelled as a change to the EMC/DWC parameters for pathogens as shown in Table 6-8.

Table 6-8. Summary of Calf Heath Programs efficiencies for pathogens (not adenovirus does not differ between the base case and Scenario 4.

Landuse	*Campylobacter* (orgs/L)		*Cryptosporidium* (orgs/L)		Adenovirus (orgs/L)	
	DWC	EMC	DWC	EMC	DWC	EMC
Grazing < 4.1ha – Base case	0.35	5.6	6.6	12	0.37	8.73
Grazing < 4.1ha – Scenario 4	0.035	0.56	0.66	1.2	0.37	8.73
Grazing/Pasture – Base case	0.35	5.6	6.6	12	0.01	0.26
Grazing/Pasture – Scenario 4	0.035	0.56	0.66	1.2	0.01	0.26

6.3.5. Scenario 5: Implementation of Infrastructure Design Manual standards

Urban stormwater is commonly characterised as having high contaminant concentrations. This may include contaminants such as heavy metals and petroleum hydrocarbons but attention is most commonly focussed on nutrients and pathogens. Control measures seek to improve stormwater quality through implementation of water sensitive urban design (WSUD) features. These include water quality treatment features, source controls and reduction of flow (Table 6-9) (NSW DEC 2006). Other WSUD measures include water conservation, stormwater reuse, redirection of flows and improved construction site environmental management.

Table 6-9. Summary of WSUD Measures

Water quality treatment	Source controls	Reducing flows
Wetlands and ponds Bioretention Sand / inorganic filtration Litter Control Hydrocarbon separators Gross Pollutant Traps Swales Buffer Strips	Site design Road design Industry operations Maintenance practices	Rooftop controls Stormwater Reuse Onsite Detention Tanks Detention Basins Infiltration Systems Porous Pavement Landscaping

For this scenario, it is assumed that implementation of the design standards specified in the IDM (Infrastructure Design Manual; CGB *et al.* 2013) will lead to improvements in stormwater quality. The IDM is a document that sets out the basic standards for urban stormwater management for regional Victorian towns and cities. It does not specify a standard fully consistent with water sensitive urban design (WSUD). The Working Group considered that the full implementation of WSUD standards would be unrealistic in the medium term future (e.g. next 25 years).

The modelled reductions in this scenario have been estimated based on assumed implementation of the IDM in urban sewered areas along with some elements of WSUD (see Table 6-10), and about 50% adoption of the IDM in unsewered areas urban areas.. The exact nature of the practices are not explicitly assessed.

To implement the scenario within the catchment model, filters for urban landuses were applied. The assumed reductions for each of the parameters are listed in Table 6-11.

Table 6-10. Indicative levels of pollutant retention for different stormwater treatment measures (Source: NSW DEC 2006)

Stormwater treatment measure	Suspended solids	Total phosphorus	Total nitrogen	Turbidity	*E. coli*
Gross Pollution Trap	0–70%	0–30%	0–15%	0–70%	Negligible
Swale	55–75%	25–35%	5–10%	44–77%	Negligible
Sand filter	60–90%	40–70%	30–50%	55–90%	25–95% (up to 1.5 $\log_{10}$)
Bioretention system	70–90%	50–80%	30–50%	55–90%	58–90% (up to 1 $\log_{10}$)
Pond	50–75%	25–45%	10–20%	35–88%	40–98% (0.5–2 $\log_{10}$)
Wetland	50–90%	35–65%	15–30%	10–70%	5–99% (up to 2 $\log_{10}$)

Table 6-11. Filters applied to Scenario 5. Implementation of Best Management Practice for Urban Stormwater Management

Reference	TN	TP	SS
Assumed reductions for this study – Urban Sewered	45%	45%	80%
Assumed reductions for this study – Urban Unsewered	22.5%	22.5%	40%

6.3.6. Scenario 6: Improved Management for on-site systems

In section 2.1.1 the prevalence of on-site wastewater treatment systems in the Tarwin Water Supply catchment was documented. According to SGSC'c Draft Domestic Wastewater Management Plan (DWMP) (SGSC 2012) the majority of on-site wastewater treatment systems involve primary treatment only (approximately 72 %) and approximately 14 % are toilet only systems, which treat only the toilet wastewater (i.e. blackwater). For this 14 % of systems, the remaining portion of wastewater from showers, baths, basins, etc., is discharged to local creeks, rivers and ground waters via the storm water system (SGSC 2012).

In the Farming Zone grazing lands, *Cryptosporidium* and *Campylobacter* loads are dominated by cattle sources and the additional contributions of these pathogens from septic tanks is unlikely to be significant. However since human viruses generally only arise from human sources such as septic effluent, improved management of on-site wastewater systems is expected to significantly reduce virus loads wherever on-site systems occur, including the large areas of Farming Zone land that makes up the Tarwin Water Supply Catchment. The reduction in virus loads is modelled using the reference virus for this study, Adenovirus.

Since the catchment consists of highly productive land with a relatively high rainfall, average land parcels sizes are relatively small compared to drier, less productive parts of Victoria. Consequently the dwelling density is relatively high for farming land and so this scenario examines the possible benefits to catchment water quality of improved management of the existing on-site systems.

Improved management assumes that there is an increase in compliance with the EPA Code of Practice for Onsite Wastewater Management.

This scenario was modelled as a reduction in the EMC/DWC values for each of the reference pathogens in rural living and urban unsewered land uses for viruses in the grazing land uses (changes from the basecase are highlighted in Table 6-12).

Table 6-12. Summary of EMC/DWC values for on-site systems efficiencies for sediments, nutrients and microorganisms.

Landuse	Suspended solids (mg/L)		TN (mg/L)		TP (mg/L)		*Campylobacter* (orgs/L)		*Cryptosporidium* (orgs/L)		Adenovirus (orgs/L)	
	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC	DWC	EMC
Forest	10	100	0.3	1	0.05	0.3	0.3	23	0.02	0.02	0	0
Grazing < 4.1ha	10	140	0.2	2.5	0.04	0.5	0.35	5.6	6.6	12	**0.015**	**0.349**
Grazing - Cattle	10	200	0.3	2.2	0.08	0.5	0.35	5.6	6.6	12	**0**	**0.01**
Grazing – Other Livestock	10	150	0.3	2.2	0.04	0.5	0.35	26.5	0.05	0.45	**0**	**0.011**
Reserve	5	40	0.008	0.9	0.02	0.09	0.3	0.7	0.02	0.02	0	0
Roads	10	100	0.3	2.3	0.1	0.3	0.3	23	0.02	0.02	0	0
Rural Living	10	110	0.3	2	0.1	0.25	**0.18**	**4.199**	**0.018**	**0.421**	**0.015**	**0.346**
Urban Sewered	11	90	0.5	2	0.1	0.25	3.6	150	0.16	20	1	10
Urban Unsewered	11	90	0.5	2	0.1	0.25	**0.96**	**10.29**	**0.096**	**1.032**	**0.079**	**0.849**

6.3.7. Scenario 7: Full development of unsewered properties to maximum acceptable densities under existing planning laws

In section 2.2.3 evidence was presented for an increase in the abundance of unsewered housing within the Tarwin Water supply catchment. To model the effect of changes in densities of unsewered housing, the runoff coefficients in Table 6-12 were revised up or down in accordance with density changes of unsewered housing.

In practice this was achieved in the modelling scenarios by changing the nominated landuse. For example, if a particular area was expected to undergo rural intensification, it would be reclassified to the next most intensive landuse. A more specific example would be changing a landuse from Rural Living to Urban (sewered or unsewered depending on the township), or from Grazing Cattle to Rural Living.

As shown in Table 6-13 an area multiplier was employed to match the predicted density of houses (and septic systems) per catchment. For example if the density in the catchment increases for the Rural Living functional unit the appropriate area would be swapped to Urban Unsewered using the following formula:

*Area Swap = maximum property size * number of new unsewered dwellings * area multiplier to take into account the housing densities for each functional unit*.

The resultant area swaps are shown in Table 6-14. No EMC or DWC changes have been applied.

Table 6-13. Summary of rules for area swaps between subcatchments.

Land use	1 septic tank per area	Septics/ha	Area multiplier	Land use change
FZ	80.0	0.013	0.013	FZ to Rural Living
LDRZ	0.4	2.5	0.115	LDRZ to urban unsewered
RLZ	1.0	1.0	0.046	RLZ to urban unsewered
TZ	0.03	33.33	1.533	TZ to urban unsewered
Rural living	1.1	0.95		
Urban unsewered	0.05	21.75		

Table 6-14. Summary of area swapped between subcatchments.

Subcatchment	River basin	Area swap Grazing Cattle -> Rural Living	Area swap Rural Living -> Urban Unsewered	Area swap Rural Living -> Urban sewered
1	Tarwin River East Branch	110.7		
2	Tarwin River East Branch us Mirboo	62.7		
3	Tarwin River East Branch us Mirboo	62.7		
4	Tarwin River East Branch us Mirboo	62.7		
5	Tarwin River East Branch	110.7		
6	Tarwin River East Branch	110.7		
7	Tarwin River West Branch	40.8	6.6	
8	Tarwin River	70.4	10.8	
9	Berrys Creek	57.3		1.4
10	Berrys Creek	57.3		1.4
11	Toomey Creek	65.2		
12	Watkins Creek	145.1		
13	Tarwin River West Branch	40.8		
14	Tarwin River West Branch	40.8		
15	Tarwin River West Branch	40.8		
16	Tarwin River West Branch	40.8		1.6
17	Tarwin River West Branch	40.8	0	31.7
18	Tarwin River West Branch	40.8		
19	Wilkur Creek	158.7		3.8
20	Wilkur Creek	158.7		
21	Ruby Creek	7.4		5.4
22	Ruby Creek	7.4	0	
23	Ruby Creek	7.4	0	
24	Ruby Creek	7.4	0	
25	Ruby Creek	7.4		
26	Coalition Creek ds flow station	21.5		
27	Tarwin River West Branch	15		
28	Ness Creek	4.2		
29	Coalition Creek	22.3	8.7	

Subcatchment	River basin	Area swap Grazing Cattle -> Rural Living	Area swap Rural Living -> Urban Unsewered	Area swap Rural Living -> Urban sewered
30	Coalition Creek	22.3		1.9
31	Coalition Creek ds flow station	21.5		1
32	Coalition Creek	22.3	7.4	0.4
33	Coalition Creek	22.3		0.4
34	Little Ruby Creek	20.5		
35	Little Ruby Creek	20.5	11.7	
36	Tarwin River West Branch	40.8		1.6

6.3.8. Scenario 8: Full development and improved management

Scenario 8 combines the effects of Scenarios 6 and 7, i.e. all current unsewered dwellings are modelled as being managed under best practice. Firstly this means that failure rates should be greatly reduced and much less effluent should be available for wash off. Secondly all development that is allowed under current planning laws is permitted to take place and densities of unsewered dwellings increase greatly (currently around 1875 unsewered dwellings increasing by around 2366 (i.e. 126%) to around 4241 dwellings in the future – see Sections 2.2.3.1 and 2.2.3.2).

Since Scenario 8 combines the effects of Scenarios 6 and 7 the EMC/DWC modifications in Scenario 6 and the area swaps shown in Scenario 7 were applied. Through this we were able to reflect a change in density and a change in management in the Source model.

7 Results and discussion

7.1. Data analysis and reliability

Model runs produced a time series of daily loads for each constituent for the modelled period 1973-2013. This produced files with around 14,640 cases (40 years x 365.25 days) which required some distillation in order to develop useful statistics for comparison. Loads were converted to average tonnes per month for sediments and nutrients and to organisms per month for pathogens. From an ecological and human health point of view concentrations in river water are of interest, particularly for pathogens, however these vary greatly on a daily basis due to flow variations and the local scale effects are uncertain. The most useful presentation of model results was therefore to present average monthly loads for all parameters and monthly averages of daily concentrations for pathogens. These data are further described and discussed below.

7.1.1. Load results

Model results are shown in Figures 6-1 to 6-6. Due to the use of the average monthly load statistic and the fact that the Tarwin River Catchment model is hydrologically based, each constituent has the same average annual pattern of loads. There is a marked wet (June to November) and dry season (December to March) with maxima and minima occurring in August and February respectively. Average monthly load ranges are as follows:

- Suspended solids: 120-840 tonnes
- Total Nitrogen: 2-18 tonnes
- Total Phosphorus: 0.4 to 4 tonnes
- *Cryptosporidium*: 19.5 x 10^9 to 25 x 10^{10} oocysts per month
- *Campylobacter*: 18.5 x 10^9 to 1.35 x 10^{12} cells per month
- Adenovirus: 4 x 10^9 to 9 x 10^9 virions per month

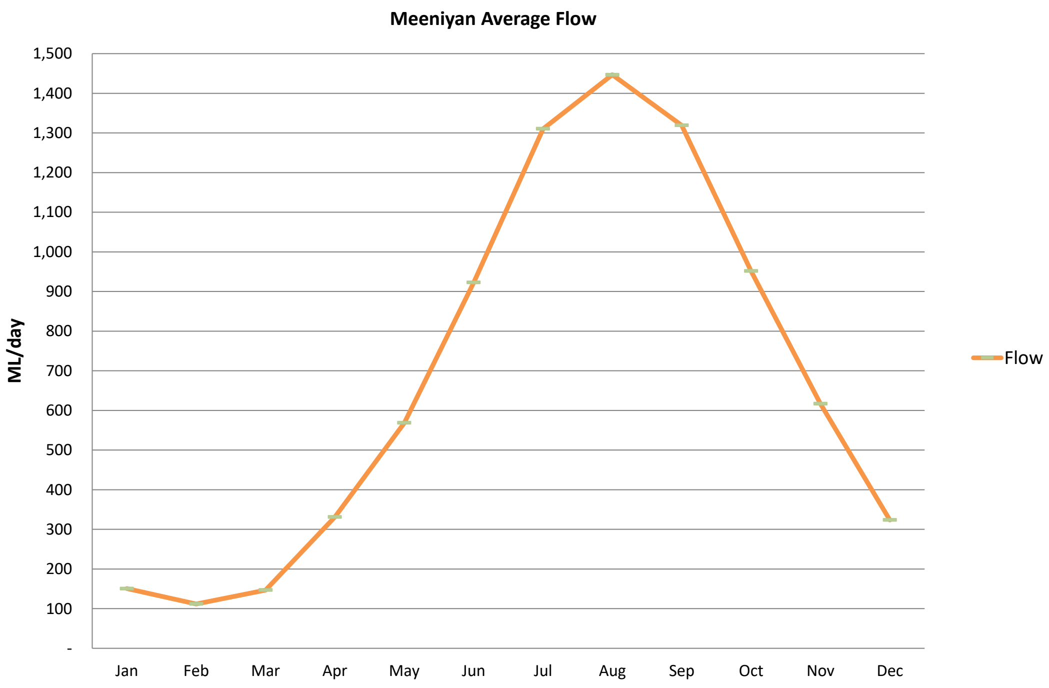


Figure 7-1. Base Case model results: average monthly flow for the Tarwin River at Meeniyan.

7.2. Scenarios

In this section a broad comparison of the scenarios is presented at the Meeniyan offtake. Modelling scenarios are summarised in Table 7-1 for ease of reference while the results are presented in graphical formats in Figure 7-2 to Figure 7-8. Monthly values at the three water supply offtakes (i.e. Leongatha, Dumbalk and Meeniyan) are provided in Appendix 3.

Table 7-1. Summary of modelled scenarios

Scenario	Description
Scenario 1	Base Case
Scenario 2a	Riparian BMP on Crown Frontages Only
Scenario 2b	Riparian BMP for riparian zones for Crown Frontages and Private Land for all perennially flowing streams
Scenario 3	Stock exclusion fencing only
Scenario 4	Calf health programs and/or exclusion of calves from riparian connected paddocks
Scenario 5	Implementation of Infrastructure Design Manual standards as a minimum for Urban Stormwater
Scenario 6	Improved Management of Septic Tanks
Scenario 7	Full development with current management
Scenario 8	Full development with improved management

7.2.1. Sediments and nutrient loads

Modelling results for suspended solids, total nitrogen and total phosphorus predicted significant reductions from the base case for the Scenarios that explicitly involved fencing out of livestock and establishing vegetated riparian buffers (Figure 7-2, Figure 7-3, Figure 7-4, Figure 7-5). Scenario 2a involves application of best practice riparian management to Crown Frontages only, while Scenario 2b involves applying best practice to all streams with catchment areas greater than 20 ha. Scenario 2a gives a moderate decrease in monthly loads, while 2b gives a major decrease, particularly in the winter months. Scenario 3 is similar to Scenario 2b but assumes an unmanaged riparian buffer of minimal size; it predicts loads that are intermediate between 2a and 2b.

Implementation of the Riparian and Land Management BMP for all catchment waterways (i.e. Scenario 2b) is an aspirational target and modelling indicates the magnitude of the benefits that can be expected. In the near term the benefits will be nearer to those predicted by scenarios 2a and 3.

The lower cost fencing option considered under Scenario 3 would lead to significant sediment and nutrient load reductions if implemented on perennial waterways. However it could be argued that a mix of better fencing and riparian zone establishment (i.e. a blend of 2a and 2b) albeit over less of the catchment waterways could achieve the same or better effect. Such an approach is likely to better cater to the reality that not all landholders will have the resources or interest to improve and protect the riparian lands on their properties.

On-site wastewater treatment system management scenarios were not explicitly modelled for sediments and nutrients as the quantities of effluent involved at the catchment scale were not considered significant enough to influence nutrient loads within the range of model sensitivity. As a result, these scenarios (6, 7 and 8) do not differ from the base case. Scenario 4 (management of calf health and waterway access) did not involve changes to nutrient and sediment model settings so it also did not differ from the base case. Scenario 5 (stormwater management) involved such small benefits, it is not distinguishable from the base case. This is due to the relatively small areas of the catchment influenced by such changes (township zones) and the limited nature of the modelled changes in comparison to full implementation of water sensitive urban design.

Despite the model findings in relation to on-site wastewater treatment system management, there may be local stream reaches that are nutrient enriched during low flow periods and the impacts of effluent from failing on-site treatment systems should not be discounted in such situations. Local scale modelling, and/or field monitoring of high risk areas could be employed to better understand these risks. A similar consideration applies to stormwater management in the township areas.

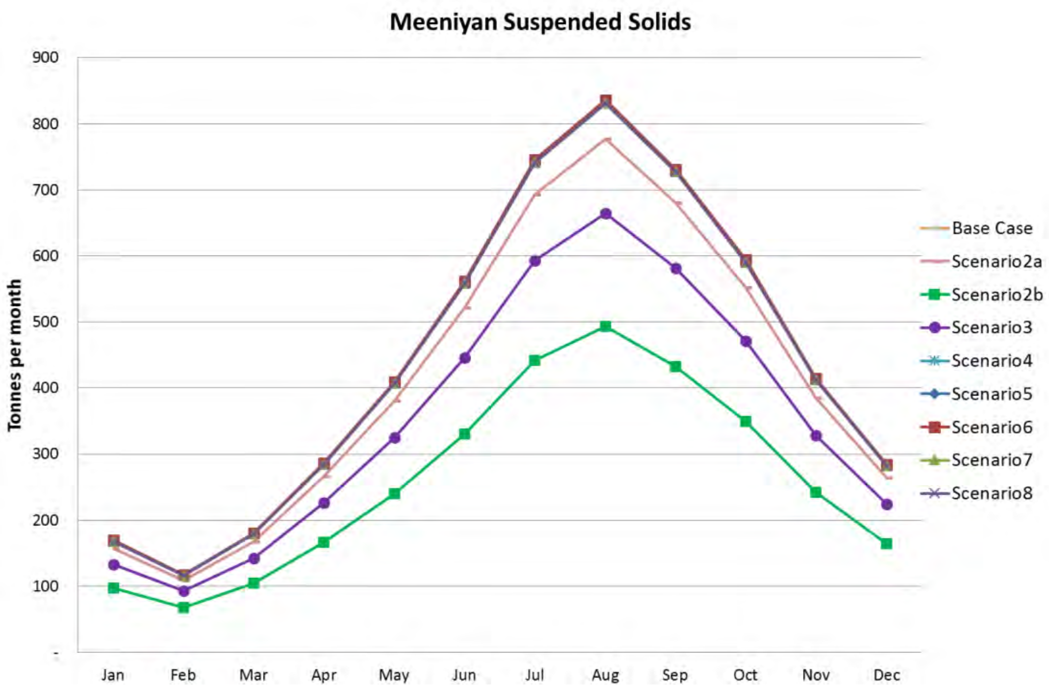


Figure 7-2. Model results: average monthly Suspended Solids load for the Tarwin River at Meeniyan

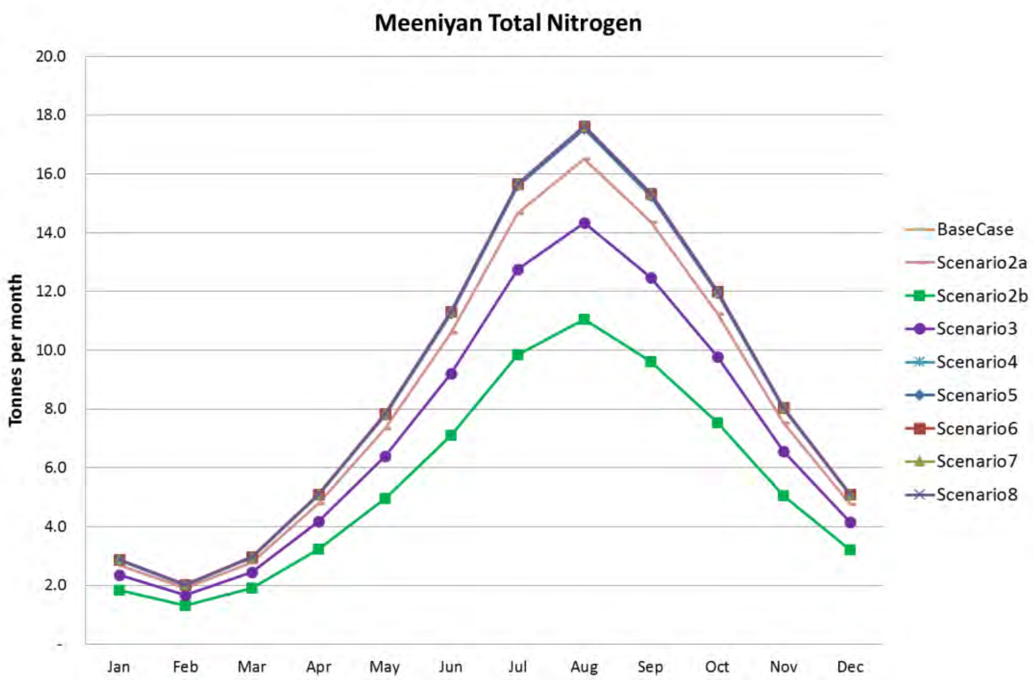


Figure 7-3. Model results: average monthly Total Nitrogen load for the Tarwin River at Meeniyan

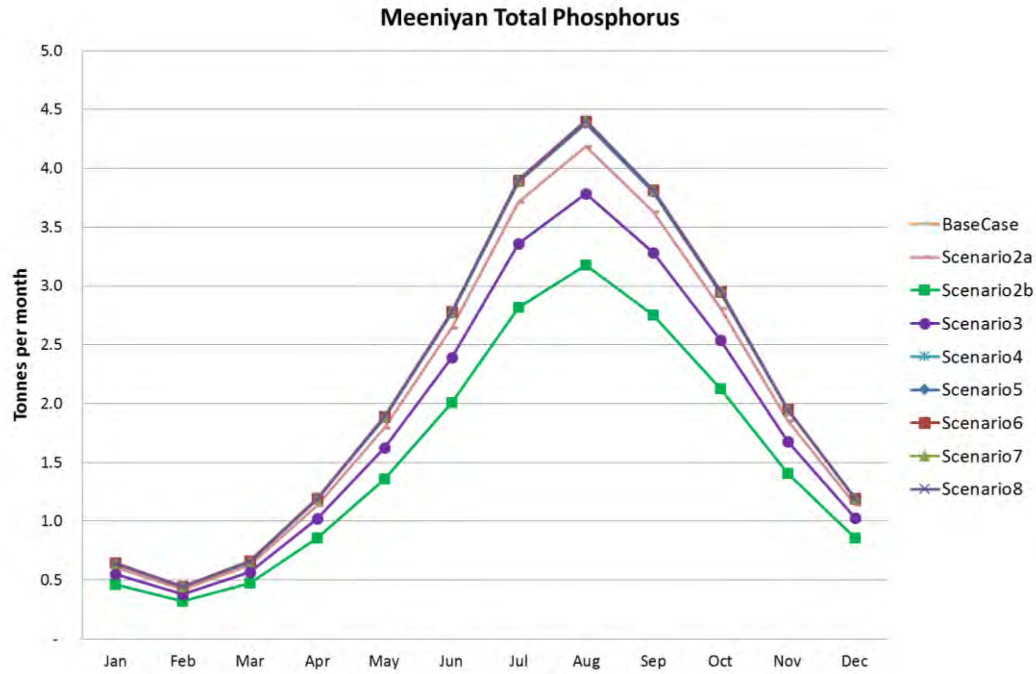
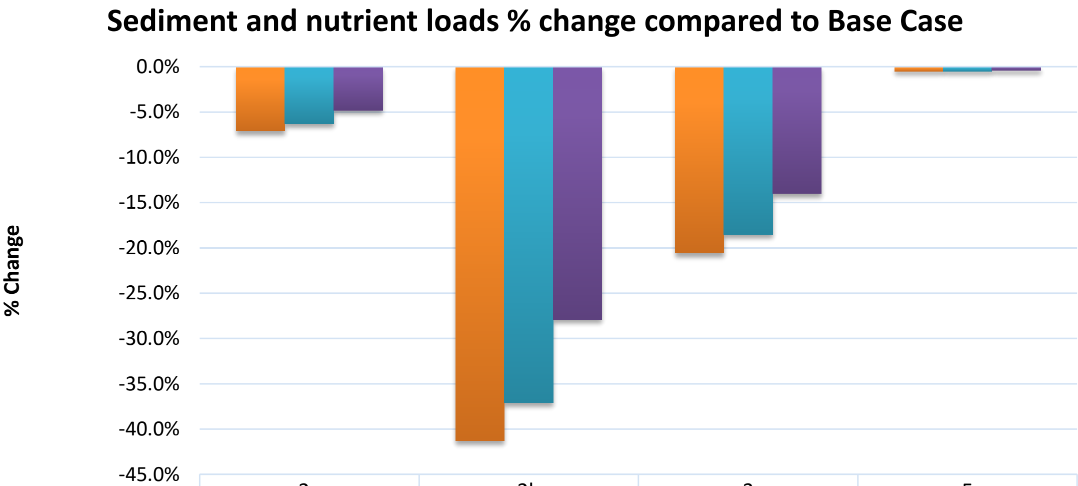


Figure 7-4. Model results: average monthly Total Phosphorus load for the Tarwin River at Meeniyan



	2a	2b	3	5
Suspended Solids	-7.1%	-41.3%	-20.6%	-0.5%
Total Nitrogen	-6.3%	-37.1%	-18.5%	-0.5%
Total Phosphorus	-4.8%	-27.9%	-14.0%	-0.4%

Figure 7-5. Summary of percent change changes in Meeniyan average annual loads of suspended solids and nutrients for each scenario compared with the base case. For sediments and nutrients there were no significant changes for scenarios 4, 6, 7 & 8 and these have been excluded from the graph above for clarity.

The benefits of reduced suspended solids loads and reduced nutrient loads for the Tarwin Catchment are summarised in Table 7-2. The main beneficiaries are the instream aquatic ecological communities in the catchment waterways and the ecological communities of the Tarwin River estuary (i.e. Andersons Inlet) downstream. Since downstream effects are beyond the scope of this study, a full assessment of the benefits of sediment and nutrient load reductions to the estuary is not possible but Valiela *et al.* (1997) showed that nitrogen loadings of greater than about 100-200 kg ha^{-1} yr^{-1} led to almost complete dominance by macroalgae of some Northern Hemisphere coastal systems. With respect to the Tarwin River, the nutrient loadings to Andersons Inlet have not been studied, however, the data presented here could be used to inform a nutrient budget for the Inlet which could be used to assist in its management.

Table 7-2. Environmental consequences or benefits of predicted scenarios for suspended solids and nutrients.

Constituent	Consequences/benefits of predicted scenarios
Suspended Solids	Reduced sedimentation of upstream stream reaches with benefits to aquatic macroinvertebrates and fish. Reduced sedimentation downstream in lowland and floodplain sections of stream. If excessive this can cause changes to stream channel morphology through increased bank erosion. Reduced sedimentation of estuarine reaches downstream. Reduced turbidities in estuarine waters and reduced smothering of seagrass beds. Phosphorus is usually transported to attached particulates, so reductions in suspended solids will reduce phosphorus load as well.
Total Phosphorus	Reduced instream loads of total phosphorus may provide some reductions in instream concentrations which could reduce periphyton growth rates but the greatest effects are usually observed in downstream storages or estuaries. In these habitats, phosphorus stimulates algal growth and may lead to blooms of harmful or nuisance microalgae or blooms of filamentous macroalgae. In estuaries it is often thought that nitrogen is the limiting nutrient but in many estuarine systems phosphorus can be limiting.
Total Nitrogen	Reductions in nitrogen loads will have similar effects to those described for phosphorus above. In addition, since nitrogen is often the limiting nutrient in estuaries, significant reductions in nitrogen loadings are generally associated with marked ecological changes such as recovery of seagrass communities and improved spawning success of estuarine fish species.

7.2.2. Pathogens

The Source model produces load data for pathogens which, it could be argued, is not so closely linked to potential health impacts as concentrations since loads are heavily determined by rainfall and river flow both of which also act to dilute pathogen concentrations. Nevertheless, it is informative to view the load graphs for each pathogen for each scenario to gain an understanding of the relative effects of the different scenarios on pathogen mobilisation and transport (Figure 7-6, Figure 7-7, and Figure 7-8). The graphs show a similar pattern to the sediment and nutrient graphs with the exception of Scenario 4 (Calf health management) for *Cryptosporidium* and Scenarios 6 & 8 for *Campylobacter* and Adenovirus. Scenario 4 produced greatly reduced loads of *Cryptosporidium* oocysts while Scenarios 6 & 8 had a similar effect on *Campylobacter* and Adenovirus.

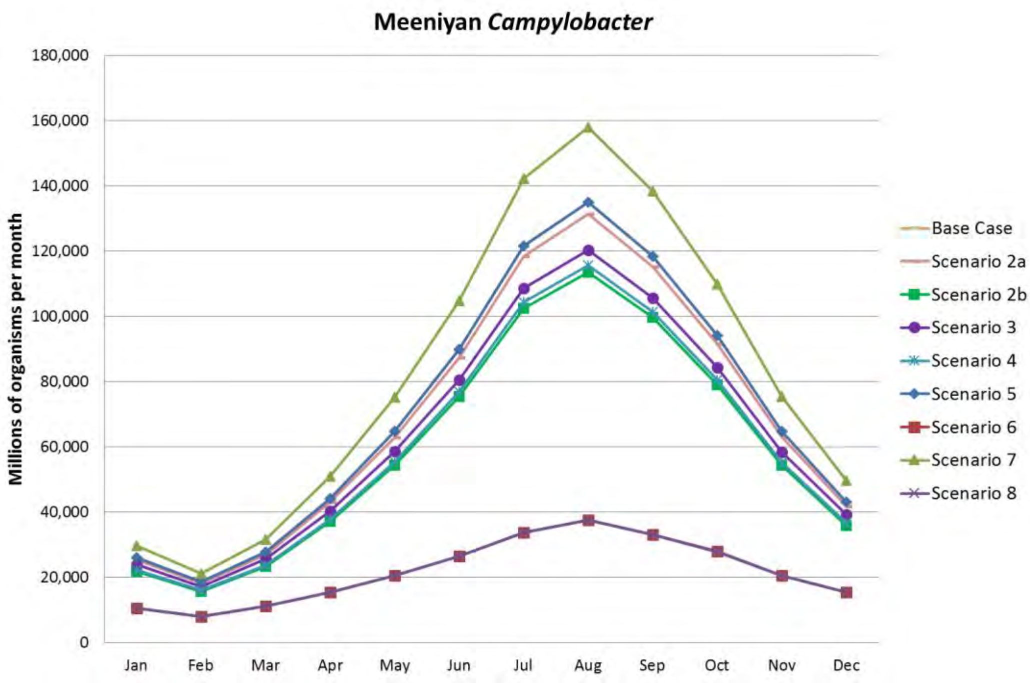


Figure 7-6. Model results: average monthly Campylobacter *load for the Tarwin River at Meeniyan (Base Case is obscured by Scenario 5).*

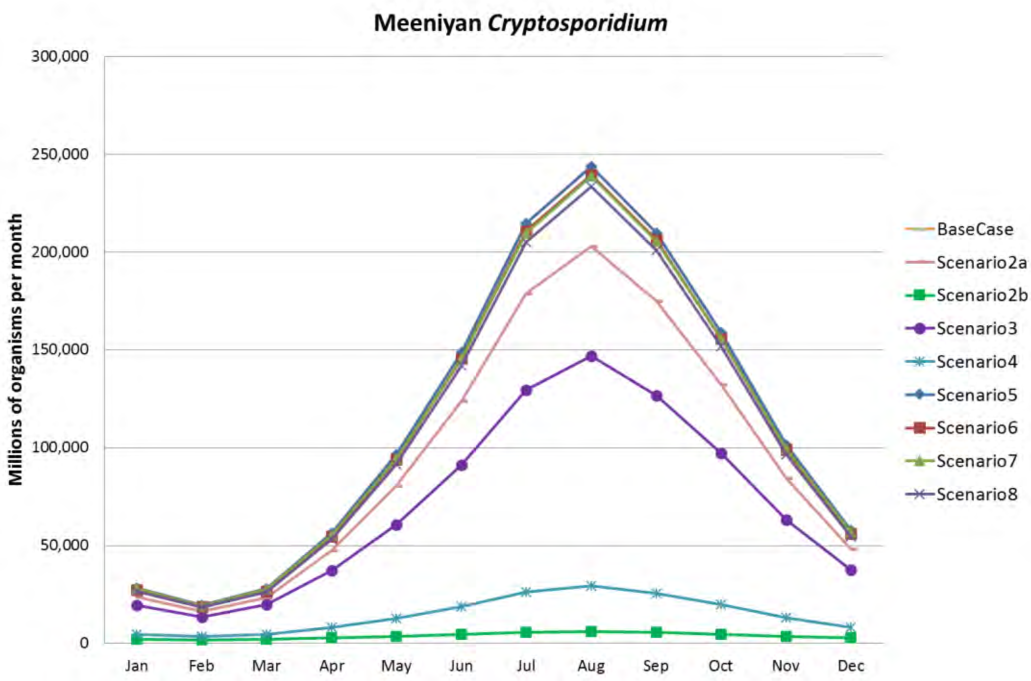


Figure 7-7. Model results: average monthly Cryptosporidium *load for the Tarwin River at Meeniyan. (Base Case is obscured by Scenario 5).*

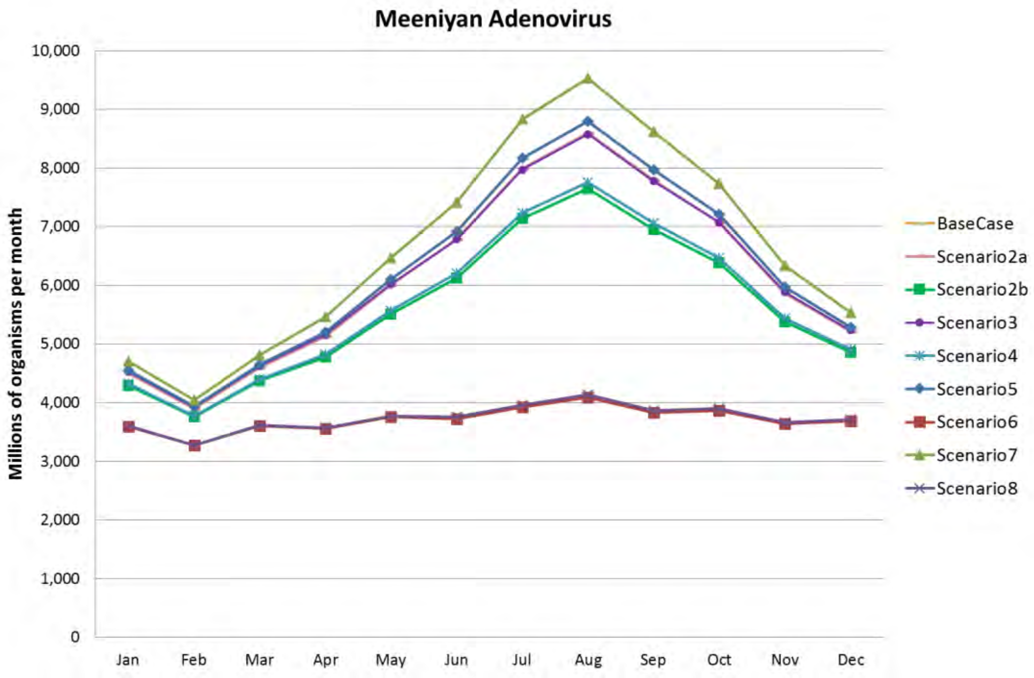


Figure 7-8. Model results: average monthly Adenovirus load for the Tarwin River at Meeniyan. (Base Case is obscured by Scenario 5).

7.2.2.1. Pathogen concentrations

Pathogen concentrations showed a marked seasonal pattern with highest concentrations occurring during the flow period encompassing January, February and March. The seasonal pattern dominated the modelled results, making it hard to differentiate between the scenarios. Scenario results also differed markedly depending on the reference pathogen with greatest differences observed for *Cryptosporidium* and to a lesser extent *Campylobacter*, while the Adenovirus modelling scenarios could not be separated without narrowing the focus to just a few months.

Campylobacter

For *Campylobacter*, the Wastewater Management BMP Scenarios 6 and 8 gave a marked improvement in average concentrations (Figure 7-9) compared to the base case while Scenario 7 (increased development, current management) gave a slightly worse result. Comparing the concentration results (Figure 7-9) to the load results (Figure 7-6) shows that the scenarios are more separated when viewed as loads but much less so when viewed as concentrations.

A surprising finding for predicted average *Campylobacter* concentrations is that the Riparian BMP Scenarios did not show much separation. The reason for this appears to be that the base case *Campylobacter* runoff coefficients for Rural Living, Urban Sewered and Urban Unsewered land uses were set at a relatively high level (165, 150 and 257 orgs/L). Due to the absence of microbiological monitoring data for the Tarwin Catchment, these coefficients were based on a similar study undertaken by Ecos for the Wilsons

River Catchment in Northern New South Wales (Ecos Environmental Consulting 2009). The Wilsons River Catchment is similar to the Tarwin Catchment in terms of topography, small farm lot size, the presence of cattle and urban stormwater from several villages and small towns in the catchment. *E .coli* water quality monitoring showed many spikes in concentrations including numbers as high as 19,000 MPN[8] per 100 ml. Assuming a ratio of 1:1000 *Campylobacter* to *E. coli* this gives an event concentration of 190 *Campylobacter* orgs/L (see Appendix 10, calculated from cattle manure data). Runoff coefficient values for the urban and semi-urban land uses were derived using this approach (see Table 6-3).

For the Riparian Management Scenarios, runoff coefficient values for *Campylobacter* were derived from the Cattle Pathogen Model (Appendix 9) and changed from the base case to the relevant scenarios by applying percentage reduction filters (described in Section 6.3.2). The different approaches used to model the Riparian Management scenarios compared to the Wastewater Management scenarios accounts for the marked separation of onsite system management Scenarios 6, 7 and 8 over the riparian and other scenarios for *Campylobacter* concentrations.

In summary, *Campylobacter* runoff coefficients and filters used in the model have been set with the best available evidence however uncertainty remains high and the relative difference between the riparian management and wastewater management scenarios for *Campylobacter* is likely to be more marked than modelling results suggest. If water quality monitoring data was available for the Tarwin Catchment for *Campylobacter*, it could be used to calibrate the model and allow a better estimate of the relative difference between the riparian management and wastewater management scenarios.

More importantly, regardless of the different methods used to derive the riparian management and wastewater management for *Campylobacter* modelling results, seasonal flow change is the dominant factor determining *Campylobacter* concentrations in the Tarwin River at Meeniyan. At low flows, dilution impacts are reduced and there is an approximate 5-fold increase in average monthly *Campylobacter* concentrations across the scenarios (Figure 7-9).

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8 MPN = most probable number, a method used to enumerate microorganisms in environmental samples

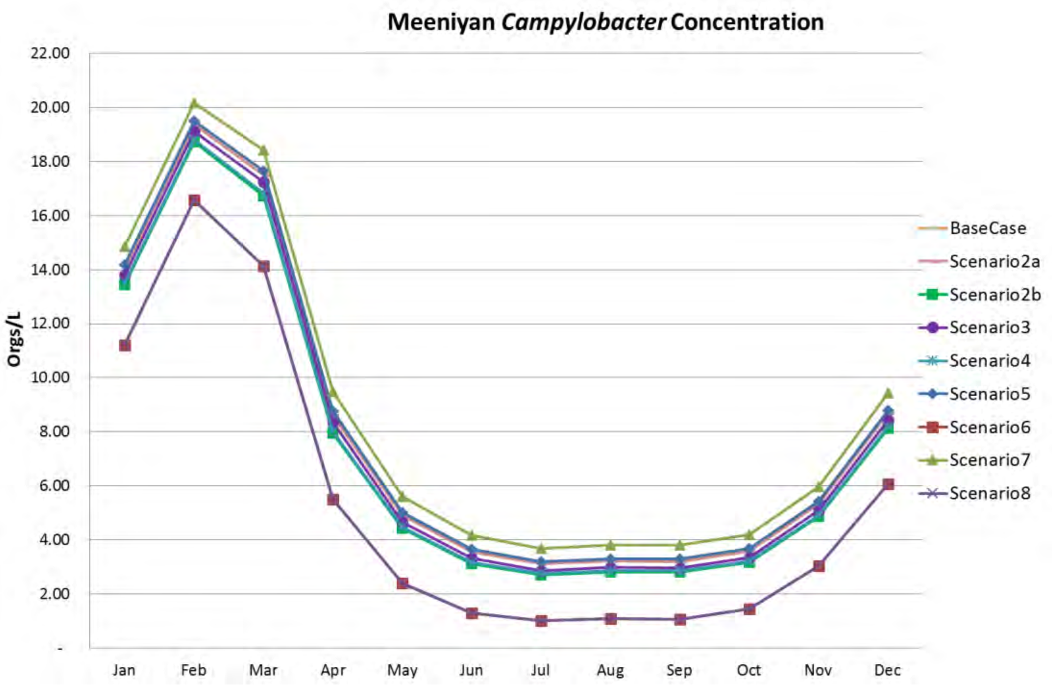


Figure 7-9. Model results: average monthly Campylobacter *concentration for the Tarwin River at Meeniyan. (Base Case is obscured by Scenario 5).*

Cryptosporidium

The amount and quality of available reference data to support settings for runoff coefficients and filters for *Cryptosporidium* was much greater than for *Campylobacter*. Consequently the results of *Cryptosporidium* modelling were both more intuitive and can be viewed with much greater confidence than can those for *Campylobacter*. Published reference data from cattle grazing catchments near Adelaide (Deere *et al.* 2005; Bryan *et al.* 2009b; Bryan *et al.* 2009a) and the CRC for Water Quality and Treatment report by Roser and Ashbolt (2007) was used to calibrate the model results for *Cryptosporidium*.

Predicted average monthly concentrations for *Cryptosporidium* strongly separated out the riparian management scenarios from other scenarios. The base case and the wastewater management scenarios tended to clump together indicating that management of cattle manure loads to waterways, cattle access to the waterways and calf health were the dominant factors determining waterway concentrations of *Cryptosporidium*. Seasonal flow changes also had a significant impact, but unlike *Campylobacter* did not override the difference between modelled scenarios. From the base case to the best performing scenario (2b) there was a reduction in average monthly *Cryptosporidium* concentrations (Figure 7-10) of about 5 oocysts/L. Note that the Tarwin Catchment Source model over-estimates the frequency of low flows (see Figure 4-13) to a certain extent, so the magnitude of the seasonal differences in concentration is possibly not as marked as has been modelled.

In summary, the *Cryptosporidium* modelling indicates that managing calf health and implementing riparian best practice management across the catchment provide the greatest improvements in *Cryptosporidium* concentrations compared to the base case.

Furthermore, due to the large proportion of the catchment devoted to cattle grazing the impacts of increased numbers of on-site systems (to the extent modelled) is difficult to discern. The Tarwin Source model is a whole of catchment model and averages out the effects of local impacts. In reality the daily concentrations of *Cryptosporidium* in the Tarwin catchment waterways will vary to a much greater degree than is shown in the modelling results due to local factors, but overall should reflect the proportional reductions as modelled, particularly at the most downstream catchment location (i.e. the Meeniyan water supply offtake).

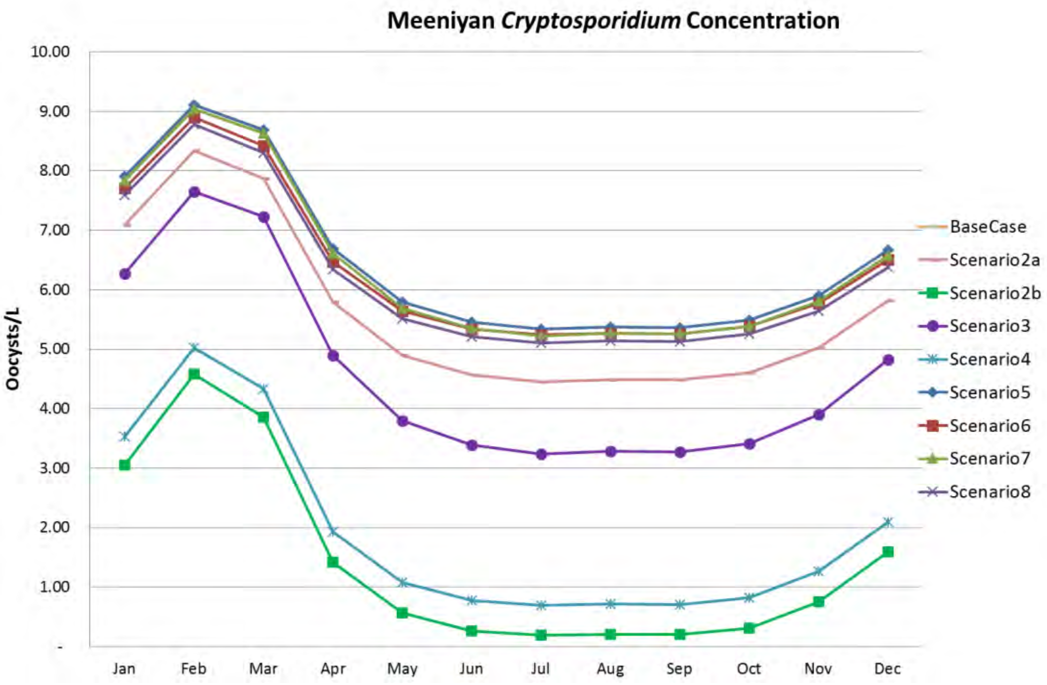


Figure 7-10. Model results: average monthly Cryptosporidium *concentration for the Tarwin River at Meeniyan (Base Case is obscured by Scenario 5).*

Adenovirus

Adenovirus was only modelled from human sources in the catchment and therefore is not influenced by the riparian and cattle management scenarios (2a, 2b, 3, and 4) which did not differ from the base case. Scenario 5 involved minor improvements to stormwater management in built areas which accounted for only a small percentage of the catchment. Consequently it did not differ significantly from the base case for Adenovirus.

Scenarios 6, 7 and 8 also did not significantly differ from the base case despite large reductions in runoff coefficients modelled for Scenarios 6 and 8 (e.g. compare Table 6-3 and Table 6-12) and the changes of land use that were applied for Scenarios 7 and 8. The reason for such minor differences is that the base case runoff coefficients for grazing (i.e. Farming Zone) land uses which make up nearly 80% of the catchment area (see Figure 2-3 and Table 2-1) are low to begin with due to the low density of on-site treatment systems and are not greatly altered in the scenarios. The other landuses where the changes to runoff coefficients are more significant for the different scenarios collectively only make up a small percentage of the catchment. Consequently seasonal variation in flow is the dominant factor affecting virus concentrations in the Tarwin Catchment.

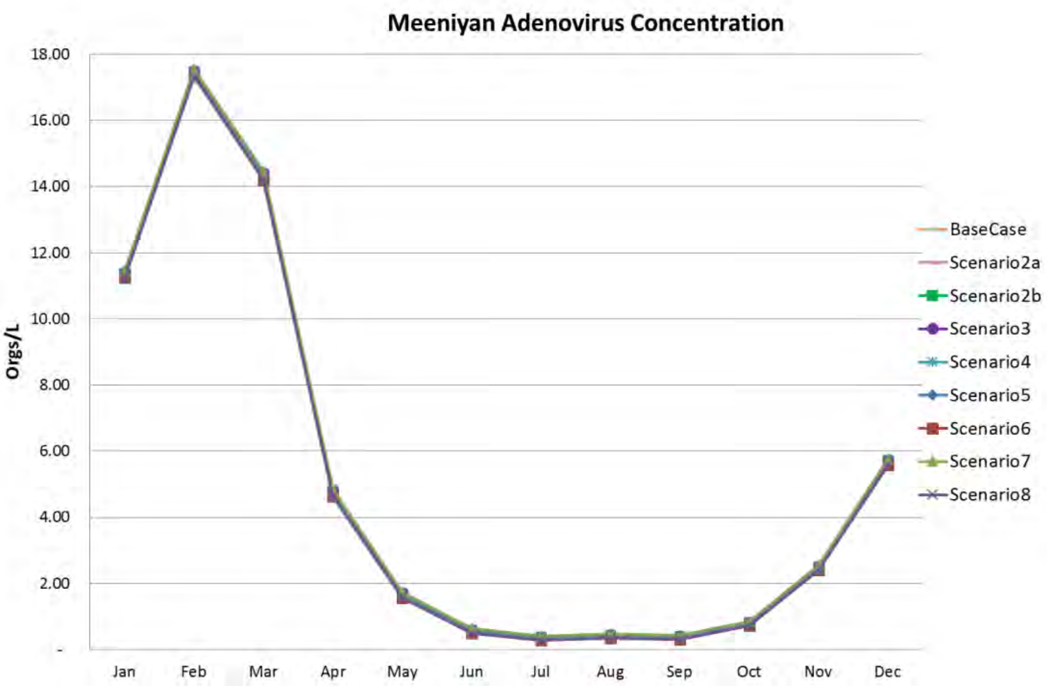


Figure 7-11. Model results: average monthly Adenovirus concentration for the Tarwin River at Meeniyan

Zooming in to focus on the winter months and the wastewater management scenarios only (Figure 7-12) shows that there is a marked difference in predicted average Adenovirus concentrations between Scenarios with the pattern consistent with those observed for *Campylobacter*. However the changes are relatively small.

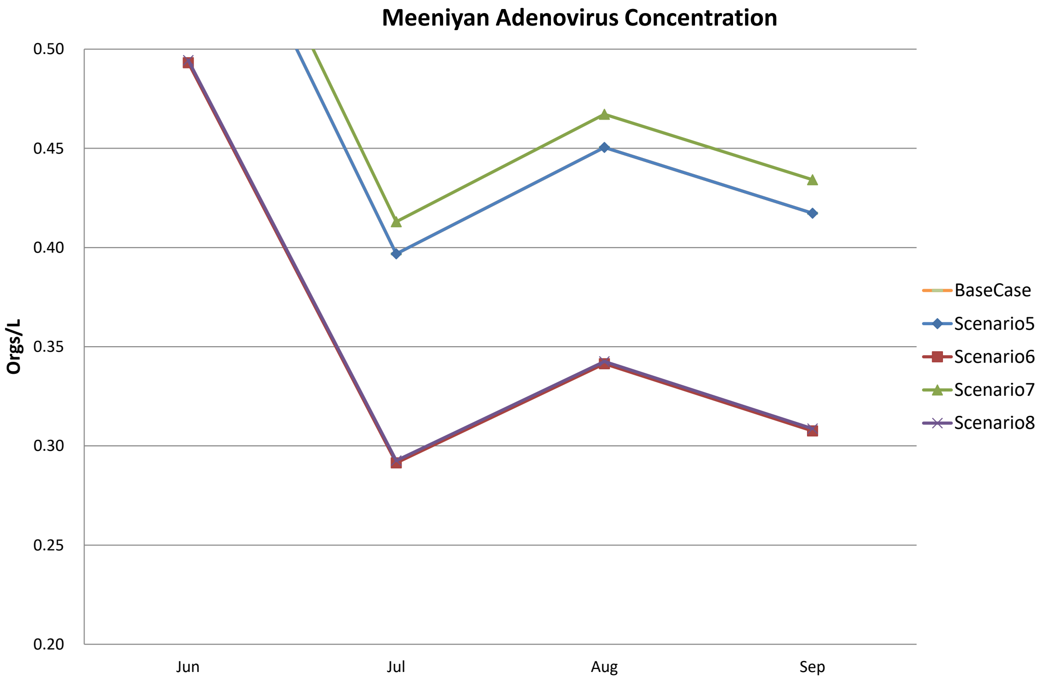


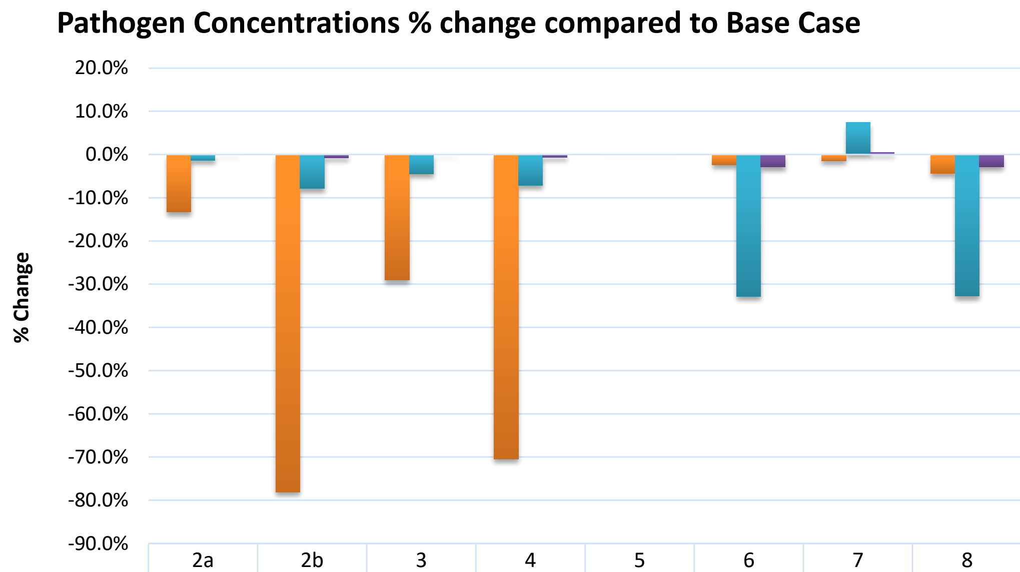
Figure 7-12. Model results: average monthly Adenovirus concentration for the Tarwin River at Meeniyan: Winter Months close up for wastewater management scenarios only. (Base Case is obscured by Scenario 5).

Pathogen concentrations summary

Predicted average concentrations for riparian and cattle health management scenarios 2a, 2b, 3 and 4 for *Cryptosporidium* were between around 13 and 79% lower than the base case but were less marked for *Campylobacter* (1.4 to 7.9%) (Figure 7-13). Catchment-wide implementation of fenced and vegetated riparian buffer zones gave the greatest reduction in *Cryptosporidium* concentrations, followed by implementation of calf health management programs. In contrast, low cost fencing with minimal vegetation management was predicted to be only half as effective.

The results of *Campylobacter* modelling differed markedly from *Cryptosporidium.* For *Campylobacter* the predicted changes for the wastewater management scenarios excluding scenario 5, (i.e. 6, 7 and 8) were greatest (7 to 32 %) whereas for *Cryptosporidium* they were less marked (Figure 7-13). The differences stem from the use of different sources of information to inform model settings for *Campylobacter* and highlight the need to have water quality monitoring data to better calibrate the model for this reference pathogen. A critical assumption is the ratio of *Campylobacter* to *E. coli* which was used to set wastewater management scenario runoff coefficients for *Campylobacter.* If the ratio is lowered one order of magnitude from 1:1,000 to 1:10,000 the *Cryptosporidium* and *Campylobacter* modelling results would be consistent across all scenarios.

Adenovirus is only sourced from humans and therefore was not greatly influenced by the riparian and cattle management scenarios (Figure 7-13). Wastewater Management Scenarios did not significantly differ from the base case as most of the unsewered dwellings are dispersed throughout the grazing land uses (i.e. Farming Zone) which make up most of the catchment. The higher dwelling density land uses (e.g. Rural Living Zone, etc.) only make up a small percentage of the catchment and therefore the catchment-wide effects of changes at these locations is attenuated.



	2a	2b	3	4	5	6	7	8
Cryptosporidium conc.	-13.3%	-78.1%	-29.1%	-70.4%	0.0%	-2.4%	-1.5%	-4.4%
Campylobacter conc.	-1.4%	-7.9%	-4.4%	-7.1%	0.0%	-32.8%	7.4%	-32.8%
Adenovirus conc.	-0.1%	-0.7%	-0.1%	-0.7%	0.0%	-2.9%	0.5%	-2.9%

Figure 7-13. Pathogen concentration changes (in %) for each scenario compared to the base case

8 Conclusions and Recommendations

In this section the results of modelling are drawn on to support a series of conclusions with respect to the main sources of risk to drinking water supplies in the Tarwin Catchment and recommendations are made to support future catchment improvement and protection measures including the Tarwin Catchment Protection Policy.

Conclusions

- Modelling of sediment and nutrient loads showed that implementation of riparian and landuse best practice management gave major reductions in annual transported loads of sediments and nutrients (SS up 41%, TN and TP up 37% and 28% respectively). The greater the degree of implementation and percentage of catchment waterways, the greater the reduction in loads.
- Improved stormwater management was modelled as minor improvements to urban drainage consistent with the Infrastructure Design Manual. This scenario generated little benefit due to the relatively small areas of the catchment influenced by such changes (township zones) and the limited nature of the modelled changes in comparison to full implementation of water sensitive urban design.
- Sediment and nutrient load reductions would be likely to lead to some tangible improvements in instream water quality, but most of the benefits would be manifested downstream in the Tarwin River Estuary (Andersons Inlet). Assessment and modelling of downstream benefits was beyond the studies' scope, however reduced sediment and nutrient loads to Andersons Inlet could be expected to decrease the likelihood of excessive algal growth to the benefit of seagrass communities.
- Modelling of pathogen loads, was considered useful even though it could be argued that loads are not so closely linked to potential health impacts as concentrations. Analysis of pathogen loads indicated a dominance of the riparian management scenarios over the wastewater management scenarios for *Cryptosporidium* but the reverse for *Campylobacter* and Adenovirus.
- The reasons for the dominance of wastewater management scenarios over riparian management scenarios are clear for Adenovirus, since it is not sourced from cattle, and therefore model settings did not differ between the base case and the riparian management scenarios. For *Campylobacter*, the difference could be due to uncertainty in model settings (discussed below) as the settings for the wastewater management and the riparian management scenarios were informed by different sources of evidence.
- Modelling of monthly averages of daily pathogen concentrations showed a marked seasonal pattern with highest average concentrations occurring during the low flow period encompassing January, February and March. The seasonal pattern dominated the modelled results, making it difficult to differentiate between the scenarios to varying extents.

- Results of different modelling scenarios, for average monthly concentrations, also differed markedly depending on the reference pathogen with greatest differences observed for *Cryptosporidium* and to a lesser extent *Campylobacter*, while the Adenovirus modelling scenarios could not be separated without narrowing the focus to just a few months.
- Modelling settings for *Cryptosporidium* were considered to be more robust and based on a stronger evidence base than those of *Campylobacter* and Adenovirus and should be given greater weight for consideration in management responses. Estimates for *Campylobacter* runoff coefficients for the high dwelling density land uses used in the modelling were based on *E. coli* monitoring data assuming a certain ratio of *Campylobacter* to *E. coli.* This is a critical assumption for *Campylobacter* and while efforts were made to quantify the assumption based on ratios in cattle manure, there is still a significant degree of uncertainty.
- For Adenovirus, modelling at the whole of catchment scale was unable to separate the wastewater management scenarios when viewed as average monthly concentrations due to the high seasonal variation, although load-based comparisons gave a clearer separation which was more consistent with the other pathogens. Zooming in to focus on just a few months at time did show separation between the scenarios consistent with the *Campylobacter* results.
- The reason that the Adenovirus Wastewater Management Scenarios did not differ much from the base case was because that the base case runoff coefficients for grazing land uses (mostly Farming Zone) which make up nearly 80% of the catchment area are low to begin with due to the low density of on-site treatment systems and are not greatly altered in the scenarios.
- In comparison the higher dwelling density landuses (e.g. Rural Living Zone) (where the changes to runoff coefficients are more significant for the different scenarios) collectively only make up a small percentage of the catchment and therefore the catchment-wide effects of changes at these locations is attenuated.

Recommendations

Implementation of Riparian Best Practice Management across all perennial catchment waterways gave the largest reduction in average monthly *Cryptosporidium* concentrations. In contrast implementation of Wastewater Management Best Practice scenarios (largely focused on on-site systems) gave the greatest reduction in *Campylobacter* concentrations. However, since *Cryptosporidium* is much more difficult to treat than *Campylobacter*, reductions in *Cryptosporidium* are more important from a drinking water supply perspective than reductions in *Campylobacter* or other bacterial pathogens. Bacteria as a whole are more readily removed by oxidative disinfection processes (e.g. chlorination) than encysted protozoa. Furthermore, the evidence-base to support model settings is greater for *Cryptosporidium* than *Campylobacter*, so more faith can be placed in the model findings for *Cryptosporidium*. If monitoring data was available, the model settings could be calibrated to improve confidence in the magnitude of *Campylobacter* predictions. Consequently it is recommended that the results of the *Cryptosporidium* modelling be given a greater weight in management responses than the results of the *Campylobacter* modelling.

With respect to Adenovirus, the quantity of virions (i.e. individual virus particles) available in the catchment are two to three orders of magnitude less than *Cryptosporidium* and *Campylobacter,* reflecting the fact that cattle are present in high numbers across most of the catchment and are a major source of these pathogens but do not shed human-infectious viruses. It is important to note however, that virus concentrations here are reported as monthly averages of predicted daily average concentrations from the most downstream part of the catchment. In reality, virus concentrations will vary widely across locations in the catchment due to local factors such as the density and frequency of failing on-site treatment systems, the presence of urban stormwater outfalls and in the sewered areas, damaged sewer pipes.

Despite the findings of this study that cattle are the most important source of pathogens in the Tarwin Water Supply Catchment, management of on-site treatment systems and local scale factors such as setback distances to potable supply waterways, etc. are still important factors and need to be managed appropriately. Local scale (i.e. on a smaller scale than this study, e.g. ~100 hectares) modelling of on-site treatment systems will provide guidance on system design, maintenance and siting.

The findings of this study nevertheless indicate that South Gippsland Water should:

- *As a first priority emphasize improvement programs for riparian buffers and for stock health; and*
- *As a second priority support on-site wastewater management programs with an emphasis on treatment compliance programs over planning controls in relation to dwelling densities.*

The details of the proposed riparian and wastewater management programs and associated action items are described in Section 5 of this management plan. For each program it is recommended that South Gippsland Water and South Gippsland Shire initiate Implementation Working Groups consisting of relevant catchment partners and any other interested parties. The Working Groups should identify and agree on roles and responsibilities and seek resources to support implementation.

Research on pathogen fate and transport in water supply catchments is an area that has not been strongly supported by active research programs in the past, with the exception of some work overseen by Water Research Australia and its predecessor organisations in the early 2000s. Consequently there are many data gaps in this area, and future research may provide more definitive findings on the relative risks from different pathogens. While this is an issue for the National Water Industry, it is important that regional water companies, such as South Gippsland Water raise the need for such research in their dealings with relevant state and national agencies.

At a local level, in the Tarwin Water Supply catchment, routine monitoring of microbial indicator organisms such as enterococci and *E. coli* as well as targeted short-term monitoring of specific pathogens such as *Cryptosporidium*, *Campylobacter* and Adenovirus can provide stronger evidence bases for guiding decision makers.

Under the proposals for Victoria’s Safe Drinking Water Regulations (DoH 2013), water businesses would be required to characterise source water risk and demonstrate that they have reliable barriers in place to effectively manage identified microbial hazards such as bacteria, viruses and protozoa in all scenarios. In the absence of monitoring data, conservative default assumptions that tend to overstate the risk would be necessary and may lead to calls for further water treatment at a significant cost. Consequently it is recommended that South Gippsland Water review its current catchment water quality monitoring programs with a view to developing a useful and effective reference database of microbiological data.

To recap, in the introduction to this plan, it was stated that its purpose was to support the development of a Water Catchment Policy for the Tarwin River Water Supply Catchment. With the completion of this plan, the next stages of the Catchment Policy development can begin.

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Appendix 1. Victorian Waterway Management Strategy, Comment on Relevant Policy Sections

9.1. Riparian Zone Management

The Victorian Waterway Management Strategy Riparian Chapter sets out current roles and responsibilities for riparian zone management in Victoria. The Department of Environment and Primary Industries (DEPI) is responsible for Crown Frontages including:

- administration
- licensing for riparian management and for grazing; and
- ensuring compliance with licence conditions.

The DEPI also has a direct on-ground responsibility for unlicensed Crown frontages and some other categories of frontage. Furthermore, the DEPI provides funding for riparian management programs through the catchment management authorities (CMAs).

The CMAs are primarily responsible for the maintenance and improvement of most riparian land through partnerships with adjoining landholders. However, waterway managers typically do not have any direct land management responsibilities for either private or Crown riparian land.

Policy 9.1 – Assisting land holders to manage the riparian zone

Policy 9.1 describes the Victorian Government's approach to achieve its objective for riparian management on both public and private land. The approach is to assist landholders (and other public land managers) to maintain or improve the condition of the riparian land typically through support for fencing, revegetation and vegetation enhancement, weed management and the provision of offstream stock watering infrastructure.

The policy states that wherever possible, riparian management should deliver multiple benefits, including the provision of:

- agricultural values such as:
    - controlled grazing
    - access to water for stock
- water quality benefits, particularly by considering areas upstream of drinking water offtakes or reservoirs
- Other important values including biodiversity conservation, public access and recreational use, cultural heritage and carbon sequestration.

From the perspective of South Gippsland Water, this means:

- that stock access to waterways will occur but under controlled circumstances; and
- that protection of water used for drinking water is a recognised component of the riparian management policy.

Policy 9.4 – Protection of water assets from fire

In relation to Policy 9.4, water authorities (i.e. South Gippsland Water) should ensure that the CFA and DEPI have the appropriate information on the important water authority assets (e.g. offtake points, pumping stations, Water Treatment Plants), that the asset precinct has appropriate signage and access for firefighters.

Policy 9.5 – Allowing controlled grazing

Policy 9.5 states that In general, controlled grazing will be allowed on Crown frontages and private riparian land subject to riparian management agreements if it:

- is environmentally beneficial
- is acceptable as a management tool and/or
- does not compromise:
    - environmental, social, cultural or economic values of the riparian land
    - downstream environmental, social, cultural or economic values.

DEPI has prepared a decision support tool and guidelines to be used to assist implementation of the policy on controlled grazing (ref).

The outcome of this policy is that the CMA will allow controlled grazing on most Crown Frontages.

Policy 9.6 – Management of controlled grazing in riparian zones

Policy 9.6 states that stock will not be banned catchment-wide from drinking water catchments. However, reducing stock access, especially juvenile stock, to priority waterways upstream of drinking water offtakes by fencing riparian land will be undertaken by agencies (including waterway managers and water corporations) as part of their on-ground management programs. For Crown frontages, this is to be assisted by the conversion of traditional agricultural licences to riparian management licences (which provide for the issue of a licence to take and use water for stock at an off-stream watering point).

The DEPI Controlled Grazing Guidelines specify the conditions under which controlled grazing can occur. ‘Control’ means permitting a known population of livestock to graze in a defined area, at a specified time, for a specified duration (DEPI 2013). In practice determination of these factors is complex due to the wide variation in riparian zone vegetation and bank and soil physical characteristics. With respect to water quality, controlled grazing will greatly reduce the amount of time stock will have access to a waterway and is expected to greatly reduce nutrient and pathogen loads to streams.

The CMA will determine the nature of the controlled grazing allowed on Crown Frontages in conjunction with landholders as part of the conditions of Crown Frontage licences.

Where possible licence conditions in the Tarwin Water Supply Catchment should consider the following points:

- juvenile stock, particularly juvenile cattle pose the greatest risk from pathogen loads due to their much higher prevalence of infection. Pre-weaned calves (1-3 months) pose the greatest risk followed by post-weaned calves (3-12 months).

Consequently it is preferable that adult cattle (> 12 months) are used for controlled grazing with the numbers of post-weaned calves kept to a minimum.

- Pre-weaned calves should never be used for controlled grazing and preferably should never be allowed on to paddocks adjacent to riparian land or major drainage lines due to the very high concentrations of pathogens in their faeces. See Appendix 9 for a description of cattle pathogen infection rates.

Policy 9.7 – Riparian zone width on Crown Frontages

It is assumed that the CMA will manage the relationship with the landholder and specify appropriate licence conditions. However a key detail of Policy 9.7 with respect to water quality impacts is the requirement for riparian land fenced for riparian management purposes to be at least 20 m wide on average from the top of the bank and no narrower than 10 m in any one place. Vegetated 20 m buffers from top of the bank can be expected to yield significant water quality benefits. Stock exclusion will also greatly reduced pathogen and nutrient loads.

9.2. Water Quality

Policy 10.1 – State Environment Protection Policy, Waters of Victoria

Policy 10.1 of the Victorian Waterway Management Strategy identifies the State Environment Protection Policy (Waters of Victoria) (abbreviated as WoV SEPP) as the key statutory framework for managing surface water quality. The WoV SEPP specifies beneficial uses that must be protected and this includes “Water for human consumption after appropriate treatment” (i.e. raw drinking water). This highlights the need for priority to be given to the protection of water supply catchments.

Policy 10.2 – Regional Waterway Strategies and recognition of the Water Supply Catchment areas.

Under Policy 10.2 Regional Waterway Strategies will identify priority waterways where environmental, social, cultural or economic values are threatened by poor water quality. These strategies should clearly identify drinking water catchments as a major beneficial use and the water authority and local government should be considered as important stakeholders involved in the production of the strategy. With respect to the Tarwin Water Supply Catchment, the preparation of a Catchment Protection Policy and a supporting Catchment Management Plan (developed from the perspective of South Gippsland Water and South Gippsland Shire Council) should be considered as a significant contribution to the development of a regional waterway strategy for the Tarwin Catchment.

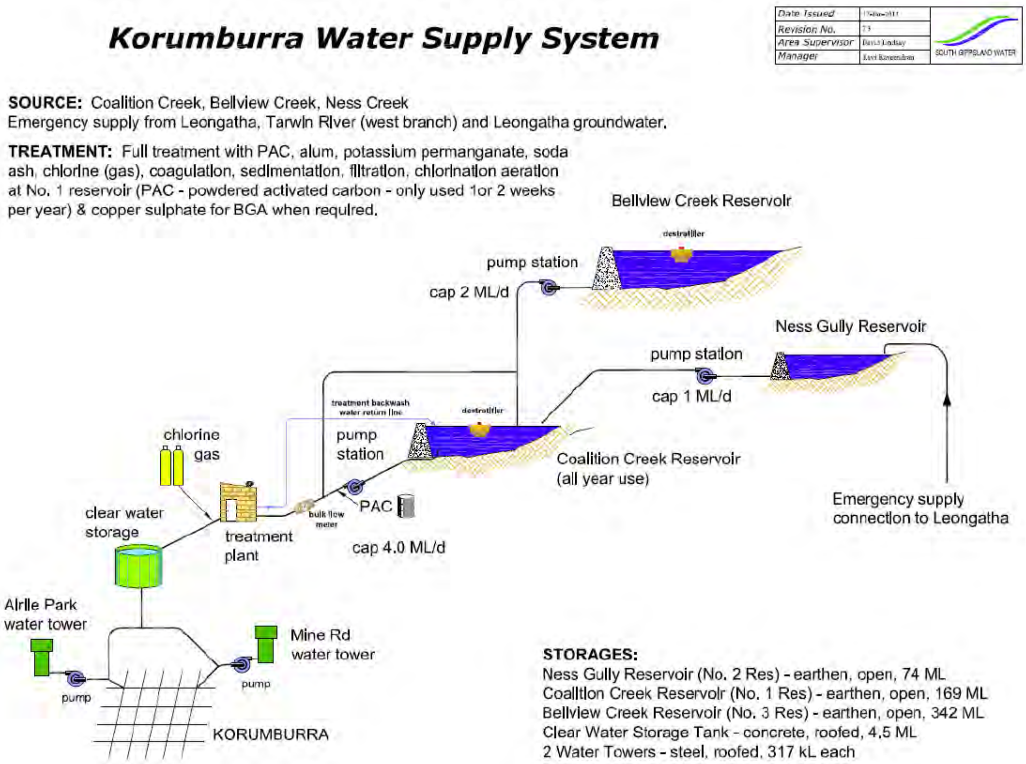
Policy 10.5 – Management of diffuse and point source pollution

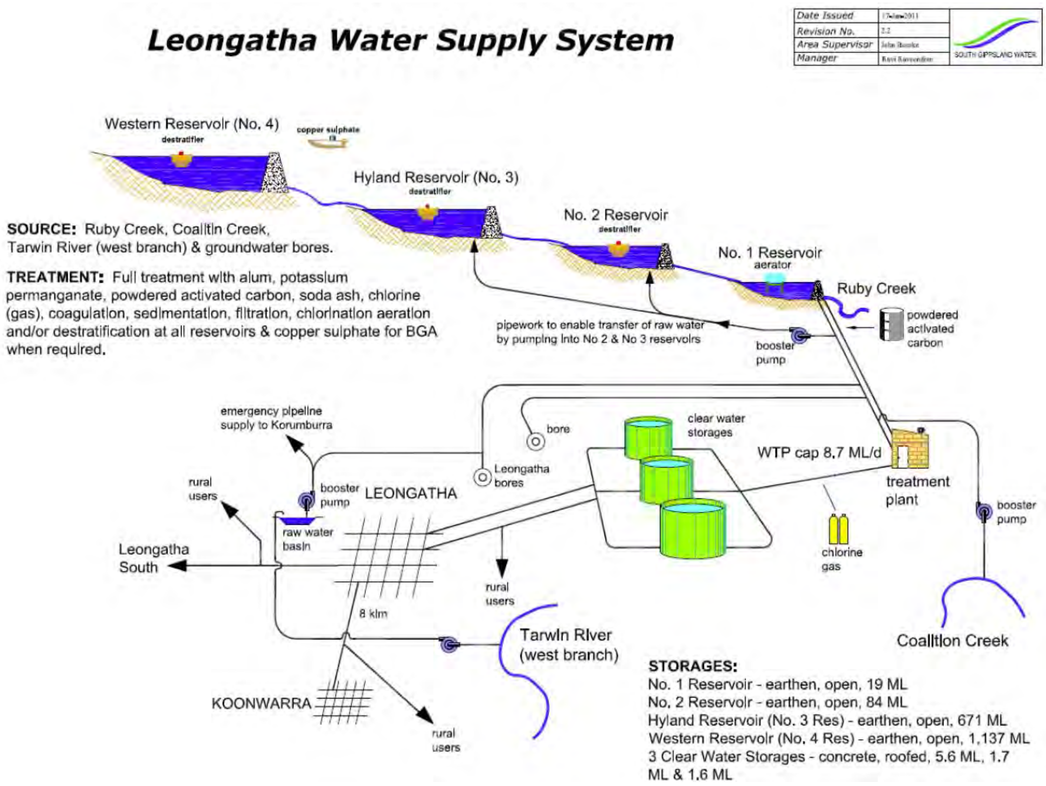
Policy 10.5 states that the Department of Environment and Primary Industries and the Environment Protection Authority Victoria will encourage best management practices and specific management activities to reduce both diffuse and point sources of pollution to waterways.

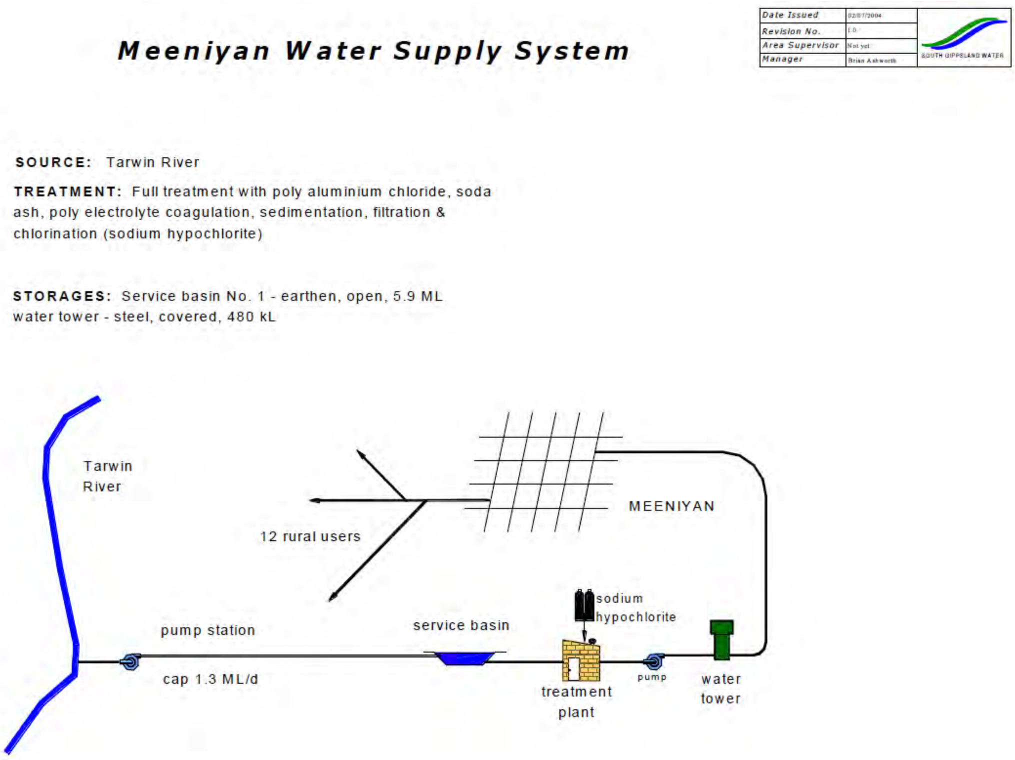
This policy supports the aims of South Gippsland Water, South Gippsland Shire and Baw Baw Shire in seeking best practice for riparian zones and land management in the Tarwin Water Supply Catchment.

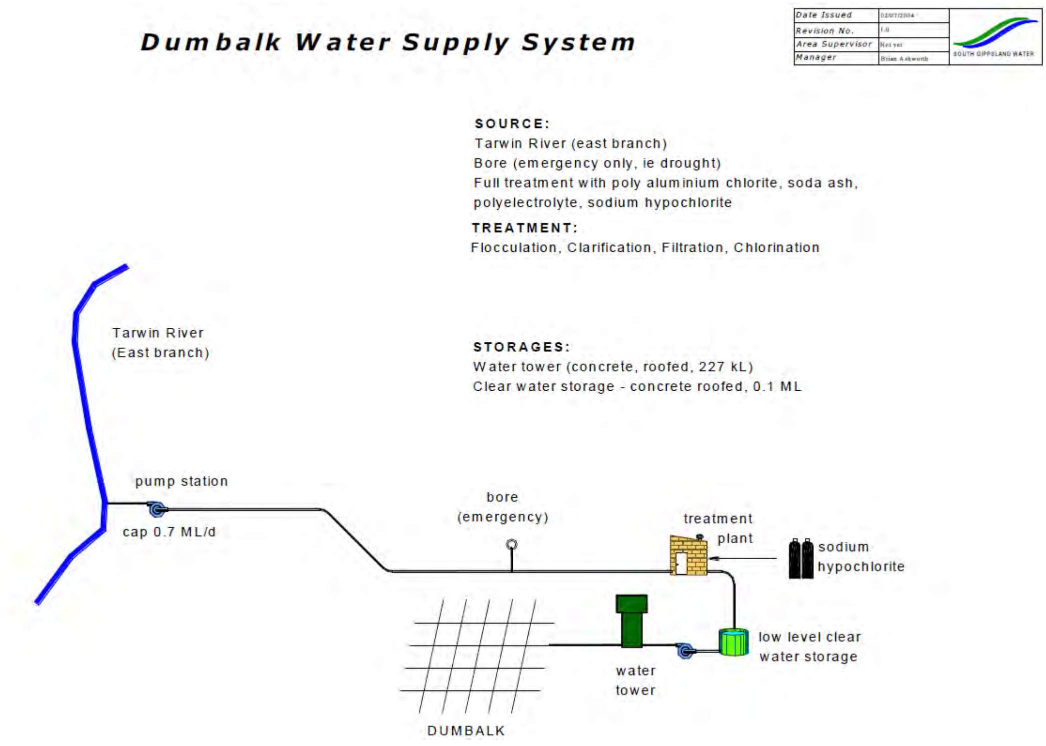
Appendix 1 - Tarwin Catchment Water Supply System Schematics

Source: Water Supply Demand Strategy (SKM 2011).




Leongatha Water Supply System
Date Issued
Revision No.
Area Supervisor
Manager
SOUTH GIPPSLAND WATER
Western Reservoir (No. 4)
destratifier
copper sulphate
Hyland Reservoir (No. 3)
destratifier
No. 2 Reservoir
destratifier
No. 1 Reservoir
aerator
Ruby Creek
SOURCE: Ruby Creek, Coalition Creek, Tarwin River (west branch) & groundwater bores.
TREATMENT: Full treatment with alum, potassium permanganate, powdered activated carbon, soda ash, chlorine (gas), coagulation, sedimentation, filtration, chlorination aeration and/or destratification at all reservoirs & copper sulphate for BGA when required.
pipework to enable transfer of raw water by pumping into No 2 & No 3 reservoirs
booster pump
powdered activated carbon
emergency pipeline supply to Korumburra
bore
clear water storages
WTP cap 8.7 ML/d
rural users
booster pump
LEONGATHA
Leongatha bores
treatment plant
booster pump
raw water basin
Leongatha South
chlorine gas
rural users
8 klm
Tarwin River (west branch)
Coalition Creek
KOONWARRA
rural users
STORAGES:
No. 1 Reservoir - earthen, open, 19 ML
No. 2 Reservoir - earthen, open, 84 ML
Hyland Reservoir (No. 3 Res) - earthen, open, 671 ML
Western Reservoir (No. 4 Res) - earthen, open, 1,137 ML
3 Clear Water Storages - concrete, roofed, 5.6 ML, 1.7 ML & 1.6 ML


Meeniyan Water Supply System
Date Issued
Revision No.
Area Supervisor
Manager
SOUTH GIPPSLAND WATER
SOURCE: Tarwin River
TREATMENT: Full treatment with poly aluminium chloride, soda ash, poly electrolyte coagulation, sedimentation, filtration & chlorination (sodium hypochlorite)
STORAGES: Service basin No. 1 - earthen, open, 5.9 ML
water tower - steel, covered, 480 kL
Tarwin River
MEENIYAN
12 rural users
sodium hypochlorite
pump station
service basin
cap 1.3 ML/d
treatment plant
pump
water tower



Supply System	Towns Supplied	Current average raw water demand (ML/yr)[1]
Northern Towns		
Little Bass River	Poowong, Loch, Nyora	264
Coalition Creek	Korumburra	621
Ruby Creek	Leongatha, Koonwarra	1,893
Southern Towns		
Lance Creek	Wonthaggi, Cape Paterson, Inverloch	1,706
Central Towns		
Tarwin River East Branch	Dumbalk	17
Tarwin River	Meeniyan	65
Deep Creek/Foster Dam	Foster	140
Battery Creek	Fish Creek	136
Agnes River	Toora, Welshpool, Port Welshpool, Port Franklin, Barry Beach Port	564
Eastern Towns		
Tarra River	Yarram, Alberton, Port Albert, Devon North	560
	TOTAL	5,966

(1) Estimated at current level of population and industrial development over a long-term climate sequence (typically 40+ years) to account for differences in water demand in wet, average and dry years

Figure 9-1 Water Supply Systems Managed by South Gippsland Water

Source	Maximum annual volume (ML/yr)	Maximum diversion rate (ML/d)	Minimum passing flows
Little Bass River	420	2.7	Minimum of 0.5 ML/d or natural flow
Coalition Creek storage		4.8	Minimum of 0.6 ML/d or natural flow
Ness Creek	1,000	1.6	Minimum of 0.6 ML/d or natural flow
Bellview Creek		3.0	Minimum of 1.0 ML/d or natural flow
Ruby Creek	2,476	17.3	Minimum of 0.5 ML/d or natural flow
Coalition Creek at Spencers Road		6.0 (May-Nov)	Minimum passing flow 10 ML/d
Tarwin River West Branch at Koonwarra	1,800	10.0 (May-Nov) 5.0 (Dec-Apr)*	Minimum passing flow 90-100 ML/d Minimum passing flow 15-20 ML/d
Lance Creek	3,800	35	100 ML/yr when Lance Creek storage greater than 3000 ML at 1st December. No daily minimum passing flow.
Powlett River	1,800	10	As per Table 3-2. Winterfill diversions only.
Tarwin River at Dumbalk	100	0.72	No minimum passing flows
Tarwin River at Meeniyan	200	1.3	No minimum passing flows
Deep Creek	326	3.5	Minimum of 0.2 ML/d or natural flow
Battery Creek	251	1.0	No minimum passing flows
Agnes River	1,617	4.8	Minimum of 1.0 ML/d or natural flow
Tarra River	853	As per Table 3-3.	As per Table 3-3.
TOTAL	14,643		

*Summer diversion only available until 30 June 2015 as an interim measure

Figure 9-2 Bulk Entitlements held by South Gippsland Water

Appendix 2 – Hydrology Calibration

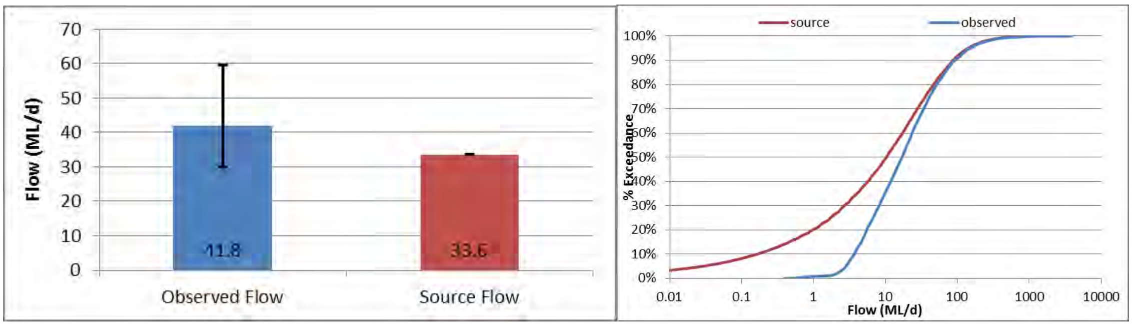


Figure 9-3. Mean Annual Discharge & Exceedence Curve – Mirboo

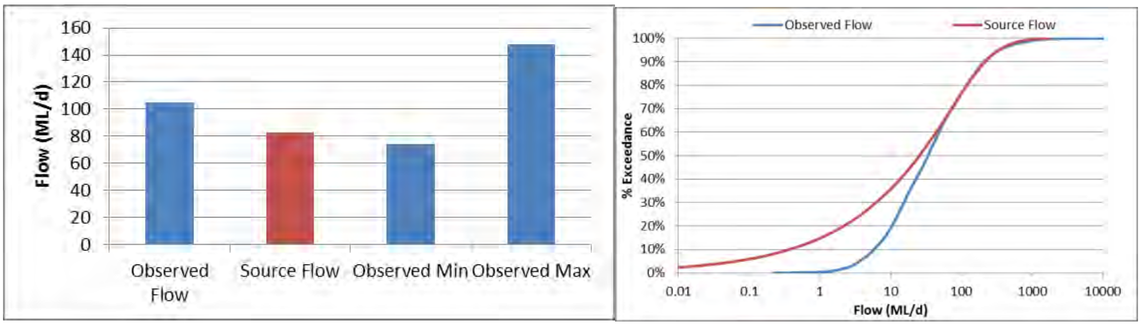


Figure 9-4. Mean Annual Discharge & Exceedence Curve – Dumbalk North

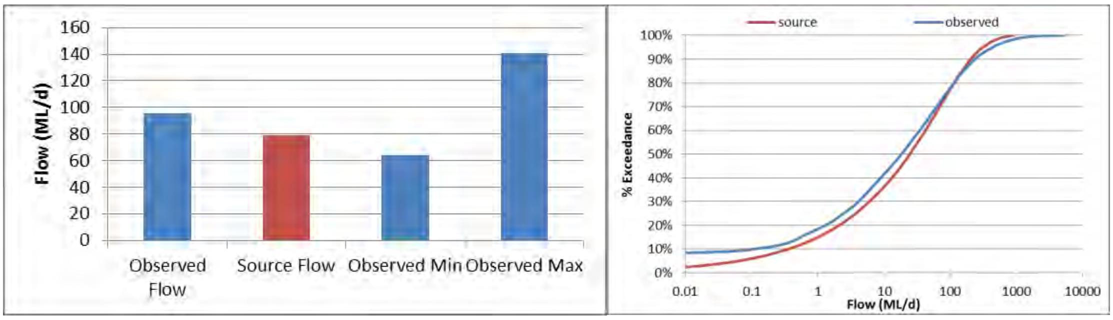


Figure 9-5. Mean Annual Discharge & Exceedence Curve – Leongatha

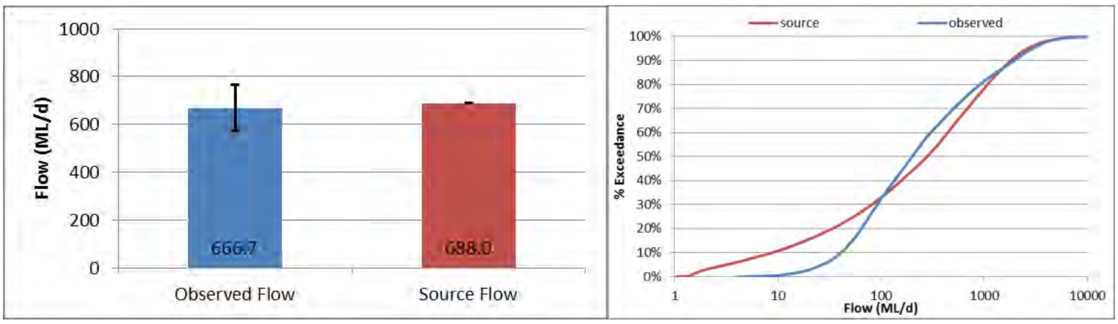


Figure 9-6. Mean Annual Discharge & Exceedence Curve – Meeniyan

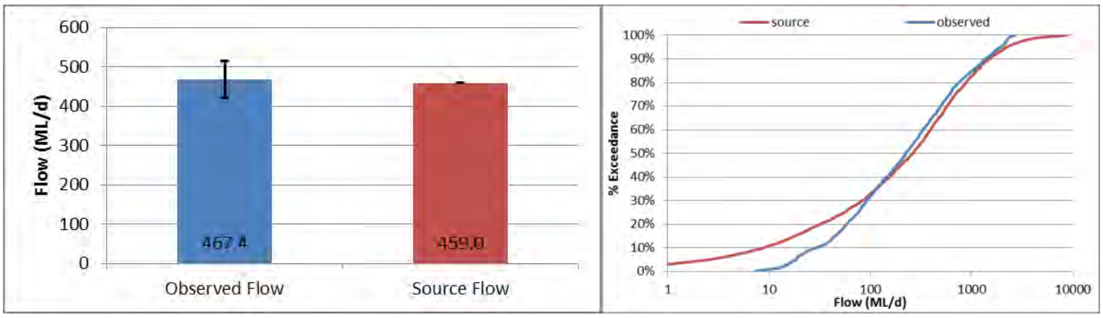


Figure 9-7. Mean Annual Discharge & Exceedence Curve – Koonwarra

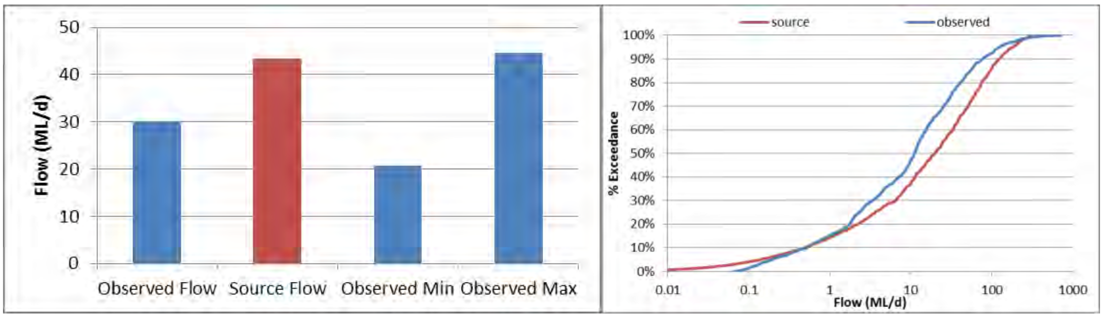


Figure 9-8. Mean Annual Discharge & Exceedence Curve – Coalition Creek

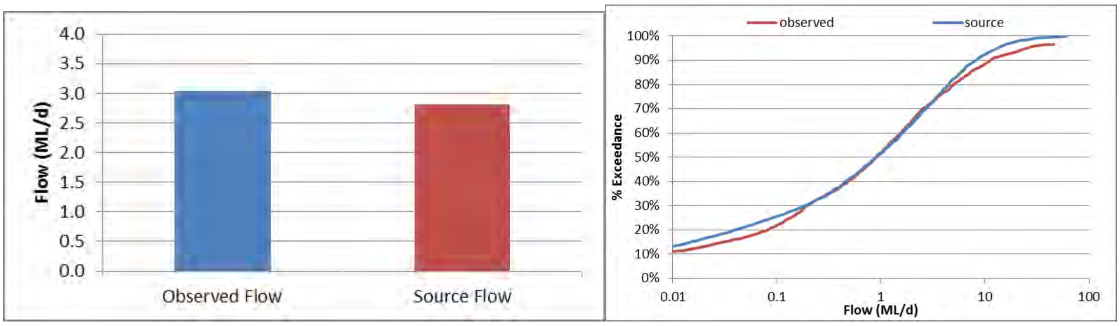


Figure 9-9. Mean Annual Discharge & Exceedence Curve – Ruby Creek

Appendix 3 – Loads at Offtakes throughout catchment

Scenario 1 *Base Case*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	498.3	17.9	0.3	0.1	2015.1	2606.7	75.8	43.7	0.7	0.0	0.0	182.9	177.8	7.0	4670.0	169.3	2.9	0.6	26075.7	28433.1	4552.1
Feb	330.5	11.9	0.2	0.0	1338.3	1729.3	50.3	29.0	0.5	0.0	0.0	125.2	119.0	4.8	3162.2	117.6	2.0	0.4	18650.6	19464.9	3935.1
Mar	566.2	20.9	0.3	0.1	2346.4	2977.2	88.5	49.6	0.9	0.0	0.0	223.0	209.2	8.7	4549.9	180.6	3.0	0.7	27761.0	27952.1	4647.2
Apr	1250.4	33.6	0.6	0.1	3857.2	6213.9	138.6	128.9	2.2	0.0	0.0	565.2	530.4	21.7	9938.2	286.9	5.1	1.2	44231.8	56490.0	5205.0
May	2223.7	49.1	0.9	0.2	5740.7	10745.8	198.5	331.9	5.2	0.1	0.0	1386.1	1292.9	52.8	17631.9	409.8	7.8	1.9	64737.4	96326.0	6102.8
Jun	3459.8	67.3	1.3	0.3	7985.1	16460.6	268.2	473.0	7.4	0.1	0.0	1957.2	1898.2	73.4	27682.4	561.5	11.3	2.8	89824.4	148613.1	6917.6
Jul	5032.9	89.6	1.9	0.5	10731.2	23703.8	352.1	623.4	9.4	0.2	0.0	2489.8	2479.1	91.7	40622.1	745.2	15.7	3.9	121569.1	214472.0	8167.1
Aug	5257.3	92.5	1.9	0.5	11098.8	24730.5	363.1	644.7	9.3	0.2	0.0	2493.6	2535.2	90.5	45936.5	835.4	17.6	4.4	134962.2	243837.2	8796.8
Sep	4625.7	82.7	1.7	0.4	9903.5	21797.1	325.4	583.7	8.2	0.2	0.0	2220.3	2282.2	79.6	39578.5	731.3	15.3	3.8	118287.3	209732.2	7967.0
Oct	3295.1	64.4	1.3	0.3	7636.1	15685.6	256.7	441.0	6.2	0.1	0.0	1663.3	1713.4	59.6	29498.7	593.9	12.0	3.0	94136.4	158829.9	7213.4
Nov	2052.0	44.5	0.8	0.2	5217.8	9894.4	179.7	270.7	3.8	0.1	0.0	1017.5	1042.7	36.7	18503.8	414.9	8.0	2.0	64830.9	101315.0	5971.6
Dec	1040.7	28.0	0.5	0.1	3218.0	5174.0	115.7	91.3	1.4	0.0	0.0	357.4	361.0	13.3	10034.5	284.7	5.1	1.2	43133.4	57728.1	5280.9

Scenario 2a *Riparian BMP on Crown Frontages Only*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	498.3	15.6	0.2	0.1	1876.2	1761.5	66.6	43.7	0.6	0.0	0.0	175.3	109.8	6.4	4670.0	156.9	2.7	0.6	25344.6	23894.7	4508.2
Feb	330.5	10.3	0.2	0.0	1246.0	1168.6	44.2	29.0	0.4	0.0	0.0	120.0	73.6	4.4	3162.2	109.0	1.9	0.4	18145.2	16409.2	3904.7
Mar	566.2	18.1	0.3	0.1	2184.4	2012.7	77.8	49.6	0.7	0.0	0.0	213.8	129.5	8.0	4549.9	167.6	2.8	0.6	26996.0	23576.0	4600.5
Apr	1250.4	29.2	0.5	0.1	3595.5	4182.3	122.0	128.9	1.8	0.0	0.0	542.8	328.1	20.0	9938.2	266.4	4.8	1.1	43004.7	47390.8	5133.0
May	2223.7	42.8	0.8	0.2	5356.5	7216.2	174.9	331.9	4.3	0.1	0.0	1332.7	799.9	48.8	17631.9	380.8	7.3	1.8	62969.7	80541.9	6002.5
Jun	3459.8	58.8	1.2	0.3	7456.0	11039.5	236.6	473.0	6.1	0.1	0.0	1881.2	1171.7	67.7	27682.4	521.8	10.6	2.6	87364.8	123918.7	6782.1
Jul	5032.9	78.3	1.7	0.4	10025.7	15883.7	310.9	623.4	7.8	0.2	0.0	2393.1	1527.6	84.5	40622.1	693.2	14.7	3.7	118310.2	178878.0	7991.2
Aug	5257.3	80.9	1.7	0.4	10369.8	16570.0	320.6	644.7	7.8	0.2	0.0	2397.0	1560.0	83.4	45936.5	776.7	16.5	4.2	131274.7	203018.7	8599.2
Sep	4625.7	72.3	1.5	0.4	9252.1	14606.6	287.3	583.7	6.9	0.1	0.0	2135.0	1403.1	73.4	39578.5	680.1	14.3	3.6	115079.6	174846.8	7794.1
Oct	3295.1	56.3	1.1	0.3	7129.9	10520.3	226.5	441.0	5.1	0.1	0.0	1599.3	1053.2	54.9	29498.7	551.8	11.2	2.8	91526.8	132369.5	7070.5
Nov	2052.0	38.8	0.7	0.2	4869.0	6643.2	158.4	270.7	3.2	0.1	0.0	978.2	641.3	33.8	18503.8	385.2	7.5	1.9	63011.4	84542.5	5869.8
Dec	1040.7	24.4	0.4	0.1	2999.6	3482.5	101.8	91.3	1.2	0.0	0.0	343.0	222.4	12.2	10034.5	263.9	4.8	1.1	41886.3	48245.7	5208.7

Scenario 2b *Riparian BMP for riparian zones for Crown Frontages and Private Land for all perrenially flowing streams*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	498.3	10.9	0.2	0.0	1599.9	80.9	47.7	43.7	0.4	0.0	0.0	163.9	7.8	5.5	4670.0	97.5	1.8	0.5	21839.6	2116.6	4296.9
Feb	330.5	7.2	0.1	0.0	1062.5	53.8	31.7	29.0	0.3	0.0	0.0	112.3	5.5	3.8	3162.2	67.7	1.3	0.3	15713.5	1661.3	3757.5
Mar	566.2	12.7	0.2	0.1	1862.2	94.8	55.7	49.6	0.5	0.0	0.0	200.0	9.9	6.9	4549.9	104.2	1.9	0.5	23282.2	2242.2	4372.5
Apr	1250.4	20.6	0.4	0.1	3075.2	142.9	87.8	128.9	1.3	0.0	0.0	509.3	24.8	17.5	9938.2	166.9	3.2	0.9	37045.9	2907.2	4781.8
May	2223.7	30.3	0.6	0.2	4592.6	198.0	126.5	331.9	3.0	0.1	0.0	1252.6	60.5	42.8	17631.9	240.3	4.9	1.4	54389.2	3691.1	5514.3
Jun	3459.8	41.9	0.9	0.2	6403.9	260.6	171.7	473.0	4.3	0.1	0.0	1767.1	82.1	59.2	27682.4	330.6	7.1	2.0	75515.6	4545.6	6128.0
Jul	5032.9	56.0	1.2	0.3	8623.0	334.7	226.2	623.4	5.4	0.1	0.0	2248.1	100.3	73.8	40622.1	441.4	9.8	2.8	102523.5	5643.2	7138.6
Aug	5257.3	57.9	1.3	0.4	8920.5	344.1	233.4	644.7	5.4	0.1	0.0	2252.2	97.1	72.7	45936.5	493.7	11.0	3.2	113506.3	6163.9	7645.2
Sep	4625.7	51.7	1.1	0.3	7957.0	309.7	209.0	583.7	4.8	0.1	0.0	2007.0	84.4	64.0	39578.5	432.4	9.6	2.8	99565.2	5509.7	6956.8
Oct	3295.1	40.1	0.8	0.2	6123.5	249.8	164.3	441.0	3.6	0.1	0.0	1503.4	63.1	47.9	29498.7	349.2	7.5	2.1	78958.2	4739.3	6380.0
Nov	2052.0	27.5	0.5	0.2	4175.6	178.7	114.6	270.7	2.2	0.0	0.0	919.3	39.2	29.5	18503.8	242.7	5.1	1.4	54274.2	3619.5	5379.6
Dec	1040.7	17.2	0.3	0.1	2565.5	119.3	73.3	91.3	0.8	0.0	0.0	321.3	14.5	10.6	10034.5	164.7	3.2	0.9	35931.1	2863.1	4861.9

Scenario 3 *Stock exclusion fencing only*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	498.3	14.4	0.2	0.1	1811.4	1773.7	73.5	43.7	0.6	0.0	0.0	171.4	112.2	6.8	4670.0	133.4	2.4	0.6	23975.8	19657.4	4530.8
Feb	330.5	9.6	0.2	0.0	1203.0	1177.1	48.8	29.0	0.4	0.0	0.0	117.5	75.4	4.7	3162.2	92.6	1.7	0.4	17211.6	13603.7	3920.8
Mar	566.2	16.8	0.3	0.1	2111.2	2037.5	86.0	49.6	0.7	0.0	0.0	209.5	133.1	8.4	4549.9	142.4	2.4	0.6	25622.1	19740.0	4626.8
Apr	1250.4	27.1	0.5	0.1	3422.9	3982.2	132.7	128.9	1.7	0.0	0.0	531.4	334.6	21.1	9938.2	226.9	4.2	1.0	40325.9	37093.8	5158.7
May	2223.7	39.7	0.8	0.2	5040.3	6644.9	187.8	331.9	4.1	0.1	0.0	1304.5	813.1	51.3	17631.9	325.1	6.4	1.6	58517.8	60590.4	6018.9
Jun	3459.8	54.6	1.1	0.3	6956.1	9968.5	251.4	473.0	5.8	0.1	0.0	1838.6	1184.1	71.1	27682.4	446.1	9.2	2.4	80610.1	91141.5	6784.2
Jul	5032.9	72.8	1.5	0.4	9291.2	14155.5	327.6	623.4	7.4	0.1	0.0	2336.3	1535.9	88.7	40622.1	593.3	12.8	3.4	108648.2	129365.7	7970.1
Aug	5257.3	75.2	1.6	0.4	9601.7	14743.3	337.4	644.7	7.4	0.2	0.0	2337.8	1561.8	87.4	45936.5	664.6	14.3	3.8	120313.2	146741.7	8573.3
Sep	4625.7	67.2	1.4	0.4	8577.4	13026.0	302.8	583.7	6.5	0.1	0.0	2081.0	1400.2	76.9	39578.5	581.9	12.5	3.3	105626.6	126605.7	7775.0
Oct	3295.1	52.3	1.1	0.3	6654.1	9506.2	240.8	441.0	4.9	0.1	0.0	1558.8	1050.8	57.5	29498.7	471.5	9.8	2.5	84313.5	97226.0	7070.9
Nov	2052.0	36.0	0.7	0.2	4576.6	6100.7	169.9	270.7	3.0	0.1	0.0	953.7	640.8	35.4	18503.8	328.8	6.6	1.7	58363.2	63248.5	5883.0
Dec	1040.7	22.6	0.4	0.1	2856.1	3317.4	110.8	91.3	1.1	0.0	0.0	334.8	224.6	12.9	10034.5	224.7	4.2	1.0	39174.1	37702.7	5233.7

Scenario 4 *Calf health programs and/or exclusion of calves from riparian connected paddocks*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	498.3	17.9	0.3	0.1	1640.9	329.7	50.4	43.7	0.7	0.0	0.0	165.8	24.6	5.7	4670.0	169.3	2.9	0.6	22258.4	4708.7	4321.9
Feb	330.5	11.9	0.2	0.0	1089.7	218.8	33.5	29.0	0.5	0.0	0.0	113.6	16.7	3.9	3162.2	117.6	2.0	0.4	16003.8	3414.7	3774.9
Mar	566.2	20.9	0.3	0.1	1910.1	378.7	58.9	49.6	0.9	0.0	0.0	202.3	29.6	7.1	4549.9	180.6	3.0	0.7	23724.8	4773.7	4399.4
Apr	1250.4	33.6	0.6	0.1	3152.6	741.3	92.8	128.9	2.2	0.0	0.0	514.9	74.6	17.9	9938.2	286.9	5.1	1.2	37757.1	8188.3	4823.2
May	2223.7	49.1	0.9	0.2	4706.4	1238.3	133.5	331.9	5.2	0.1	0.0	1265.9	182.0	43.8	17631.9	409.8	7.8	1.9	55414.7	12826.2	5572.0
Jun	3459.8	67.3	1.3	0.3	6560.8	1858.7	181.1	473.0	7.4	0.1	0.0	1785.9	261.2	60.6	27682.4	561.5	11.3	2.8	76935.0	18757.0	6205.5
Jul	5032.9	89.6	1.9	0.5	8832.3	2640.4	238.6	623.4	9.4	0.2	0.0	2272.1	334.9	75.5	40622.1	745.2	15.7	3.9	104414.2	26247.0	7239.6
Aug	5257.3	92.5	1.9	0.5	9136.8	2750.2	246.1	644.7	9.3	0.2	0.0	2276.1	337.6	74.4	45936.5	835.4	17.6	4.4	115636.5	29614.1	7758.3
Sep	4625.7	82.7	1.7	0.4	8150.3	2429.7	220.4	583.7	8.2	0.2	0.0	2028.2	301.2	65.5	39578.5	731.3	15.3	3.8	101423.8	25658.8	7056.0
Oct	3295.1	64.4	1.3	0.3	6273.6	1772.5	173.4	441.0	6.2	0.1	0.0	1519.2	225.9	49.0	29498.7	593.9	12.0	3.0	80464.0	19939.7	6461.7
Nov	2052.0	44.5	0.8	0.2	4278.9	1136.9	121.0	270.7	3.8	0.1	0.0	929.1	138.1	30.2	18503.8	414.9	8.0	2.0	55320.7	13254.5	5437.7
Dec	1040.7	28.0	0.5	0.1	2630.1	617.6	77.4	91.3	1.4	0.0	0.0	324.9	48.7	10.9	10034.5	284.7	5.1	1.2	36644.0	8271.0	4903.0

Scenario 5 *Implementation of Infrastructure Design Manual standards as a minimum for Urban Stormwater*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	498.3	17.9	0.3	0.1	2015.1	2606.7	75.8	43.7	0.7	0.0	0.0	182.9	177.8	7.0	4670.0	168.5	2.9	0.6	26075.7	28433.1	4552.1
Feb	330.5	11.9	0.2	0.0	1338.3	1729.3	50.3	29.0	0.5	0.0	0.0	125.2	119.0	4.8	3162.2	117.0	2.0	0.4	18650.6	19464.9	3935.1
Mar	566.2	20.9	0.3	0.1	2346.4	2977.2	88.5	49.6	0.9	0.0	0.0	223.0	209.2	8.7	4549.9	179.8	3.0	0.7	27761.0	27952.1	4647.2
Apr	1250.4	33.5	0.6	0.1	3857.2	6213.9	138.6	128.9	2.2	0.0	0.0	565.2	530.4	21.7	9938.2	285.5	5.1	1.2	44231.8	56490.0	5205.0
May	2223.7	49.0	0.9	0.2	5740.7	10745.8	198.5	331.9	5.2	0.1	0.0	1386.1	1292.9	52.8	17631.9	407.7	7.8	1.9	64737.4	96326.0	6102.8
Jun	3459.8	67.3	1.3	0.3	7985.1	16460.6	268.2	473.0	7.4	0.1	0.0	1957.2	1898.2	73.4	27682.4	558.5	11.2	2.8	89824.4	148613.1	6917.6
Jul	5032.9	89.5	1.9	0.5	10731.2	23703.8	352.1	623.4	9.4	0.2	0.0	2489.8	2479.1	91.7	40622.1	741.0	15.6	3.9	121569.1	214472.0	8167.1
Aug	5257.3	92.5	1.9	0.5	11098.8	24730.5	363.1	644.7	9.3	0.2	0.0	2493.6	2535.2	90.5	45936.5	830.7	17.5	4.4	134962.2	243837.2	8796.8
Sep	4625.7	82.7	1.7	0.4	9903.5	21797.1	325.4	583.7	8.2	0.2	0.0	2220.3	2282.2	79.6	39578.5	727.2	15.2	3.8	118287.3	209732.2	7967.0
Oct	3295.1	64.4	1.3	0.3	7636.1	15685.6	256.7	441.0	6.2	0.1	0.0	1663.3	1713.4	59.6	29498.7	590.6	11.9	2.9	94136.4	158829.9	7213.4
Nov	2052.0	44.5	0.8	0.2	5217.8	9894.4	179.7	270.7	3.8	0.1	0.0	1017.5	1042.7	36.7	18503.8	412.7	8.0	1.9	64830.9	101315.0	5971.6
Dec	1040.7	28.0	0.5	0.1	3218.0	5174.0	115.7	91.3	1.4	0.0	0.0	357.4	361.0	13.3	10034.5	283.3	5.1	1.2	43133.4	57728.1	5280.9

Scenario 6 *Improved Management of Septic Tanks*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	498.3	17.9	0.3	0.1	929.7	2535.0	2.9	43.7	0.7	0.0	0.0	24.1	170.5	0.3	4670.0	169.3	2.9	0.6	10550.1	27370.9	3596.6
Feb	330.5	11.9	0.2	0.0	617.6	1681.7	1.9	29.0	0.5	0.0	0.0	16.5	113.9	0.2	3162.2	117.6	2.0	0.4	7998.8	18728.8	3273.7
Mar	566.2	20.9	0.3	0.1	1088.0	2893.0	3.4	49.6	0.9	0.0	0.0	29.4	199.9	0.3	4549.9	180.6	3.0	0.7	11146.2	26772.4	3606.8
Apr	1250.4	33.6	0.6	0.1	1663.3	6091.6	5.1	128.9	2.2	0.0	0.0	71.7	507.2	0.8	9938.2	286.9	5.1	1.2	15475.4	54738.9	3560.4
May	2223.7	49.1	0.9	0.2	2333.3	10582.1	7.2	331.9	5.2	0.1	0.0	171.8	1236.5	2.0	17631.9	409.8	7.8	1.9	20557.0	93962.6	3754.6
Jun	3459.8	67.3	1.3	0.3	3101.8	16251.4	9.6	473.0	7.4	0.1	0.0	243.2	1821.9	2.8	27682.4	561.5	11.3	2.8	26483.3	145548.7	3725.0
Jul	5032.9	89.6	1.9	0.5	4018.4	23441.9	12.5	623.4	9.4	0.2	0.0	307.9	2386.3	3.5	40622.1	745.2	15.7	3.9	33805.5	210552.4	3921.7
Aug	5257.3	92.5	1.9	0.5	4135.6	24462.3	12.9	644.7	9.3	0.2	0.0	306.4	2445.6	3.4	45936.5	835.4	17.6	4.4	37570.6	239524.8	4090.2
Sep	4625.7	82.7	1.7	0.4	3715.8	21554.4	11.6	583.7	8.2	0.2	0.0	270.2	2204.4	3.0	39578.5	731.3	15.3	3.8	33171.9	205907.1	3826.9
Oct	3295.1	64.4	1.3	0.3	2971.5	15484.9	9.2	441.0	6.2	0.1	0.0	202.5	1655.3	2.2	29498.7	593.9	12.0	3.0	27896.9	155638.1	3868.5
Nov	2052.0	44.5	0.8	0.2	2108.7	9747.2	6.5	270.7	3.8	0.1	0.0	124.4	1006.5	1.4	18503.8	414.9	8.0	2.0	20513.3	99006.8	3637.9
Dec	1040.7	28.0	0.5	0.1	1388.6	5071.9	4.3	91.3	1.4	0.0	0.0	45.8	347.6	0.5	10034.5	284.7	5.1	1.2	15401.1	56055.7	3692.0

Scenario 7 *Full development with current management*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	497.7	17.7	0.3	0.1	2654.6	2532.9	102.2	43.4	0.7	0.0	0.0	222.8	170.2	8.5	4669.5	168.0	2.9	0.6	29733.2	28017.5	4704.2
Feb	330.1	11.7	0.2	0.0	1762.9	1680.4	67.9	28.8	0.5	0.0	0.0	152.7	113.9	5.9	3161.8	116.7	2.0	0.4	21169.4	19186.9	4040.5
Mar	565.5	20.6	0.3	0.1	3087.6	2894.5	119.4	49.4	0.9	0.0	0.0	272.0	200.4	10.5	4549.2	179.2	3.0	0.7	31648.1	27558.5	4813.0
Apr	1249.0	33.1	0.6	0.1	5151.1	6006.0	187.0	128.2	2.1	0.0	0.0	675.8	507.8	25.7	9936.7	284.8	5.1	1.2	50990.7	55483.4	5465.7
May	2221.2	48.5	0.9	0.2	7752.1	10354.9	267.8	330.8	5.1	0.1	0.0	1613.2	1243.3	60.7	17629.0	407.2	7.8	1.9	75136.0	94415.5	6472.9
Jun	3455.9	66.7	1.3	0.3	10869.2	15834.5	361.9	471.2	7.3	0.1	0.0	2267.2	1823.7	83.6	27677.7	558.3	11.3	2.8	104725.2	145518.3	7417.7
Jul	5027.2	88.7	1.9	0.5	14697.7	22776.2	475.3	620.8	9.2	0.2	0.0	2892.3	2376.0	104.6	40615.3	741.3	15.7	3.9	142255.1	209799.8	8828.7
Aug	5251.4	91.7	1.9	0.5	15213.3	23759.5	490.1	641.9	9.2	0.2	0.0	2902.4	2428.4	103.4	45928.9	831.2	17.6	4.4	158024.8	238600.3	9532.1
Sep	4620.5	81.9	1.7	0.4	13559.5	20945.3	439.2	581.3	8.1	0.2	0.0	2585.3	2186.2	91.1	39571.9	727.5	15.3	3.8	138434.9	205206.0	8613.3
Oct	3291.4	63.8	1.3	0.3	10391.0	15089.9	346.5	439.2	6.1	0.1	0.0	1937.4	1643.4	68.4	29494.0	590.5	12.0	3.0	109841.8	155546.5	7738.2
Nov	2049.7	44.0	0.8	0.2	7053.2	9532.2	242.5	269.7	3.7	0.1	0.0	1189.6	1000.5	42.3	18500.9	412.4	8.0	2.0	75334.9	99309.9	6338.9
Dec	1039.5	27.7	0.5	0.1	4296.9	5001.1	156.1	90.7	1.4	0.0	0.0	429.9	344.9	15.8	10033.1	282.7	5.1	1.2	49708.8	56732.0	5533.1

Scenario 8 *Full development with Improved Management*

	Dumbalk							Leongatha							Meeniyan						
Month	Dumbalk Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Meeniyan Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)	Leongatha Flow (ML/m)	Suspended Solids BC t/month	TN BC t/month	TP BC t/month	*Campylobacter* BC (millions of organisms per month)	*Cryptosporidium* BC (millions of organisms per month)	Adenovirus BC (millions of organisms per month)
Jan	497.7	17.7	0.3	0.1	923.5	2419.5	3.9	43.4	0.7	0.0	0.0	23.6	160.7	0.3	4669.5	168.0	2.9	0.6	10550.7	26721.9	3605.5
Feb	330.1	11.7	0.2	0.0	613.5	1605.1	2.6	28.8	0.5	0.0	0.0	16.1	107.3	0.2	3161.8	116.7	2.0	0.4	7998.8	18288.0	3279.9
Mar	565.5	20.6	0.3	0.1	1080.8	2761.3	4.6	49.4	0.9	0.0	0.0	28.8	188.4	0.4	4549.2	179.2	3.0	0.7	11148.0	26119.2	3616.5
Apr	1249.0	33.1	0.6	0.1	1650.8	5813.3	7.1	128.2	2.1	0.0	0.0	70.3	479.0	1.0	9936.7	284.8	5.1	1.2	15468.6	53356.9	3575.8
May	2221.2	48.5	0.9	0.2	2313.9	10097.8	10.0	330.8	5.1	0.1	0.0	168.9	1176.1	2.3	17629.0	407.2	7.8	1.9	20535.0	91559.8	3776.9
Jun	3455.9	66.7	1.3	0.3	3074.1	15506.9	13.3	471.2	7.3	0.1	0.0	239.0	1733.8	3.2	27677.7	558.3	11.3	2.8	26443.4	141832.6	3755.7
Jul	5027.2	88.7	1.9	0.5	3980.3	22367.4	17.3	620.8	9.2	0.2	0.0	302.3	2266.8	4.0	40615.3	741.3	15.7	3.9	33738.0	205106.9	3962.6
Aug	5251.4	91.7	1.9	0.5	4096.1	23341.0	17.8	641.9	9.2	0.2	0.0	300.8	2322.7	3.9	45928.9	831.2	17.6	4.4	37493.1	233432.1	4135.7
Sep	4620.5	81.9	1.7	0.4	3680.8	20566.5	16.0	581.3	8.1	0.2	0.0	265.3	2094.3	3.4	39571.9	727.5	15.3	3.8	33106.0	200622.3	3866.7
Oct	3291.4	63.8	1.3	0.3	2945.0	14775.6	12.8	439.2	6.1	0.1	0.0	199.0	1574.3	2.6	29494.0	590.5	12.0	3.0	27852.6	151705.3	3900.5
Nov	2049.7	44.0	0.8	0.2	2091.0	9301.1	9.0	269.7	3.7	0.1	0.0	122.2	957.1	1.6	18500.9	412.4	8.0	2.0	20489.9	96522.5	3660.1
Dec	1039.5	27.7	0.5	0.1	1378.2	4840.1	5.9	90.7	1.4	0.0	0.0	44.8	328.0	0.6	10033.1	282.7	5.1	1.2	15394.5	54698.6	3707.0

Appendix 4 – Literature Values for EMC/DWC

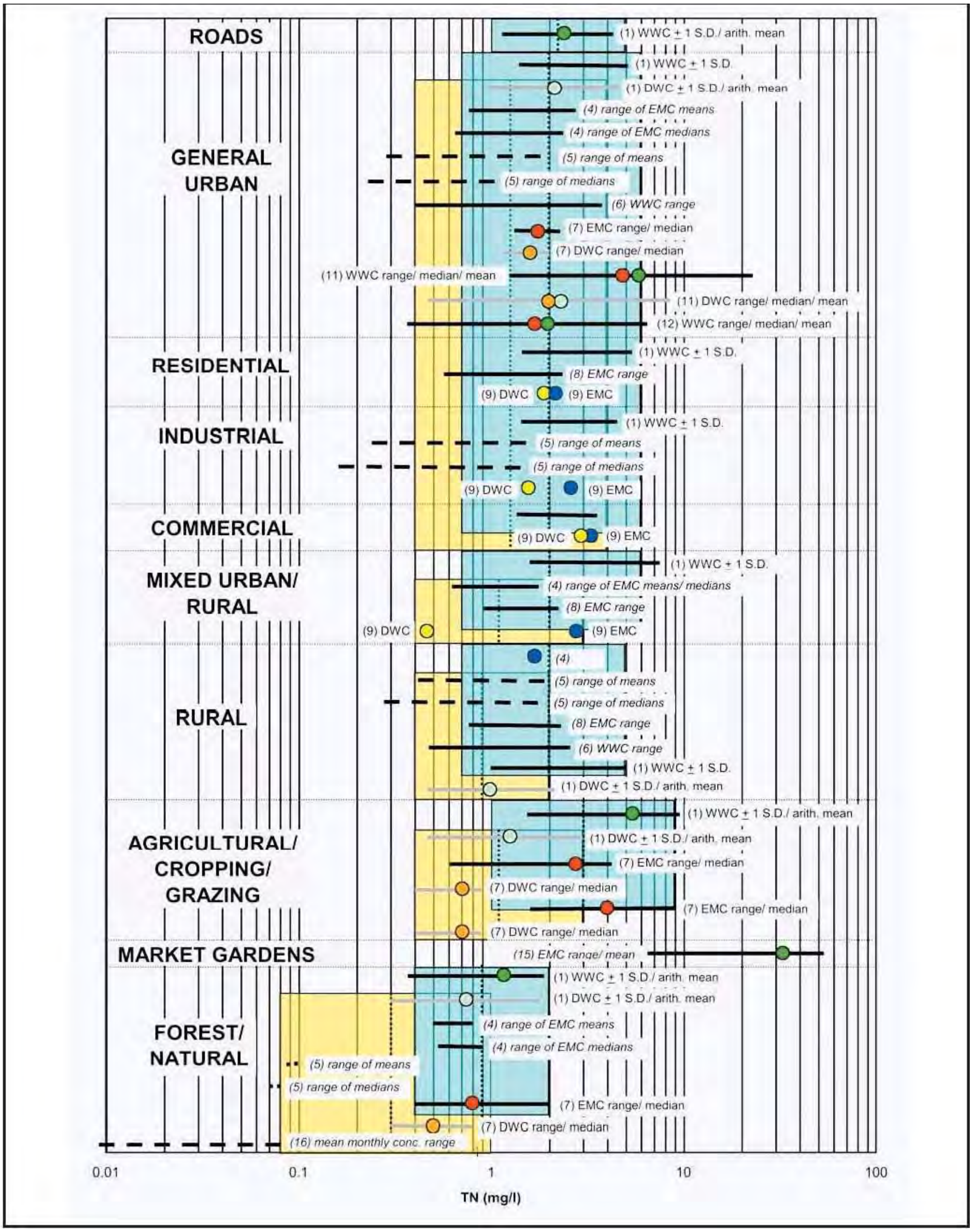


Figure 9-10. Total Nitrogen, where yellow shaded is the DWC recommended range and blue shaded is the EMC recommended range (From Fletcher et al, 2004)

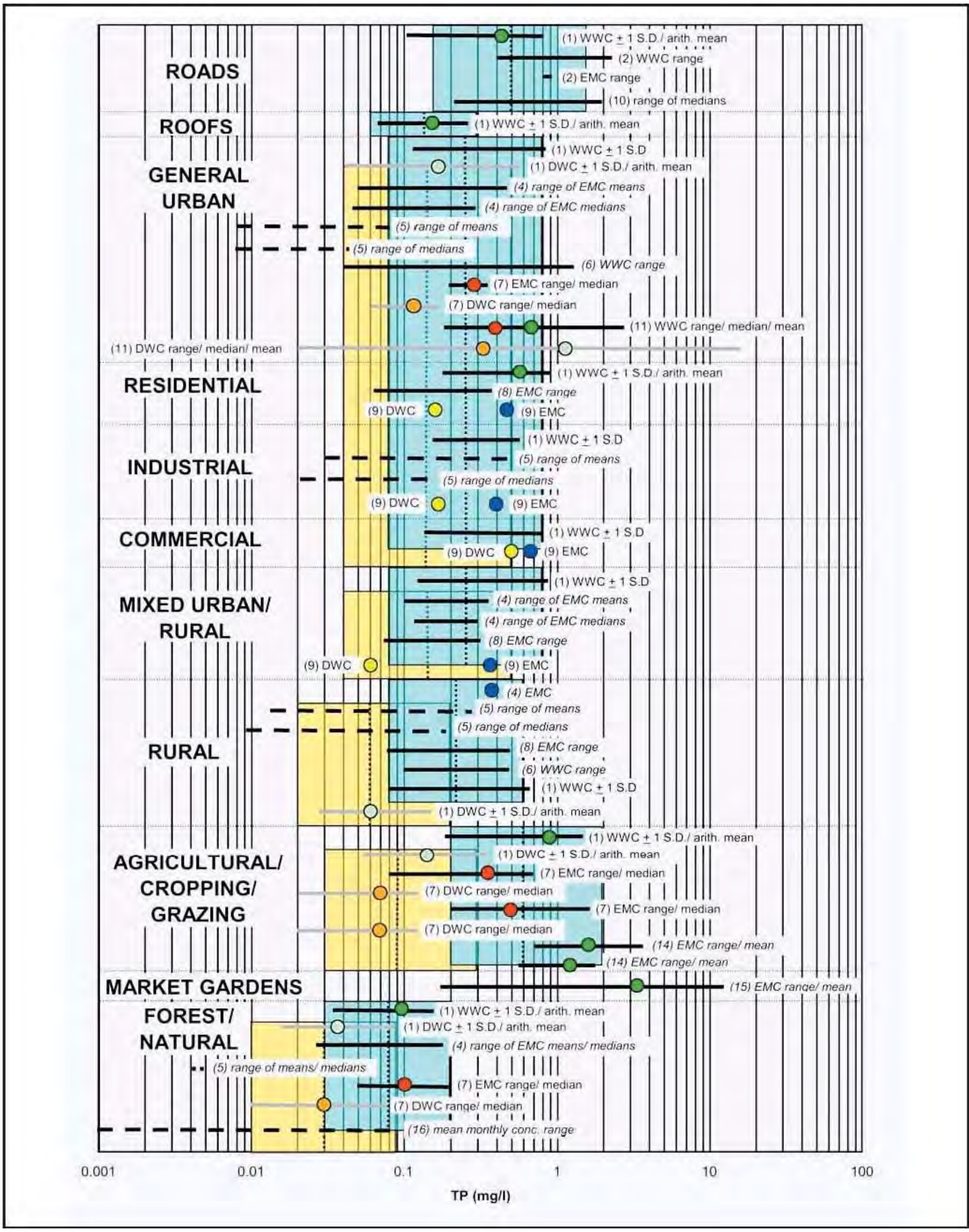


Figure 9-11. Total Phosphorus, where yellow shaded is the DWC recommended range and blue shaded is the EMC recommended range (From Fletcher et al, 2004)

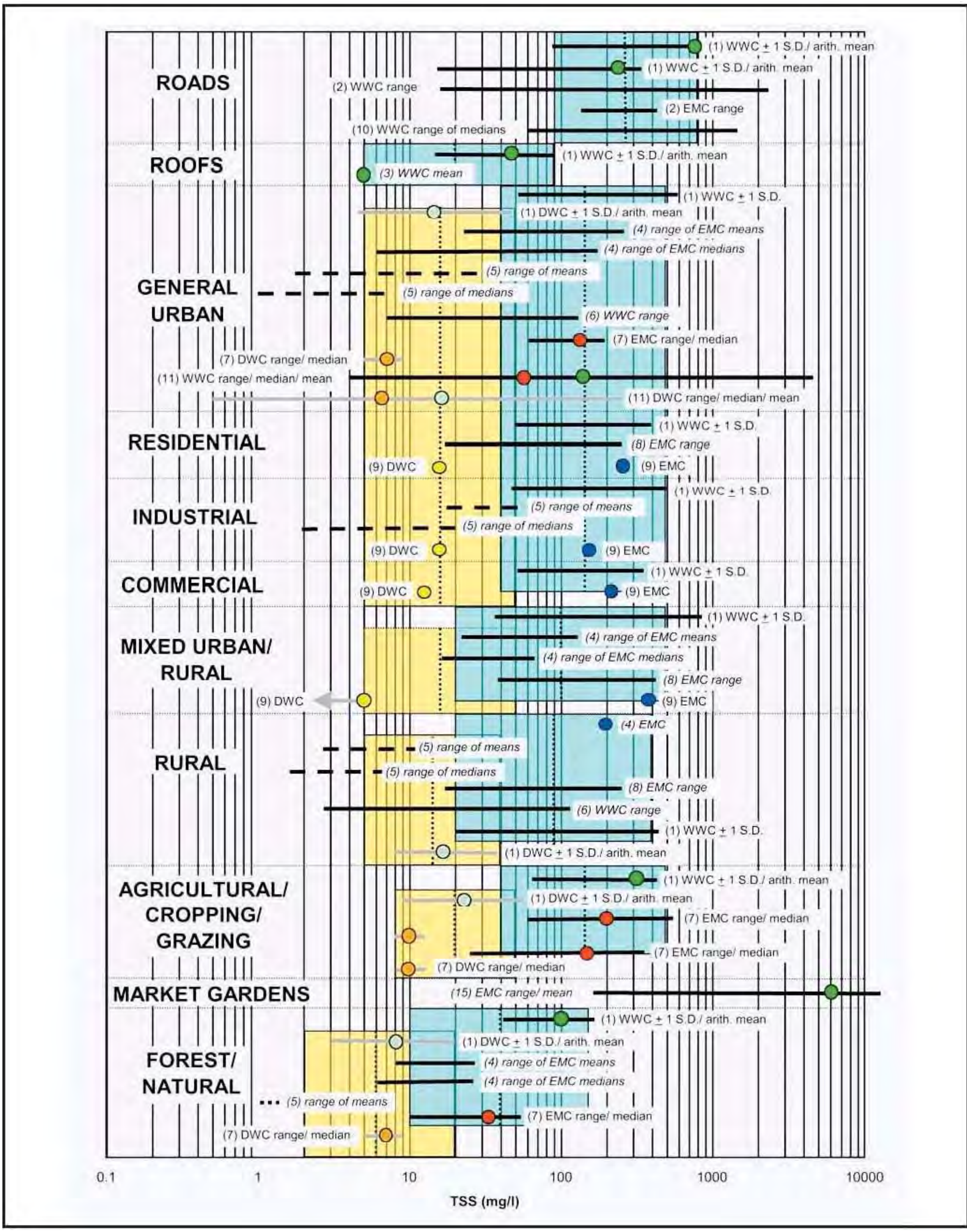


Figure 9-12. Total Suspended Solids, where yellow shaded is the DWC recommended range and blue shaded is the EMC recommended range (From Fletcher et al, 2004)

Appendix 5 – Catchment Management Plan Working Group Members

Table 9-1. Working Group

Attendees	Area	Company	Work-shops
Adam Dunn	Statutory Planning Manager	West Gippsland CMA	2
Benita Kelsall	DEPI	Department of Environment and Primary Industries	2
Bimal Narayan	Planner	Baw Baw Shire	1
Brett Vurlow	Environment Coordinator	South Gippsland Water	2
Bryan Chatelier (apology)	Water Quality Manager	South Gippsland Water	1
Bryan Sword	Manager Planning and Environmental Health	South Gippsland Shire Council	1&2
Craig Wilson	Catchment Planning	West Gippsland CMA	1
Dan Garlick	Catchment Planning and Delivery Unit Manager	West Gippsland CMA	2
Danielle Douglas (apology)	Strategic Planning Officer	Latrobe City Council	1
David Esmore	Environmental Health Officer (EHO)	Baw Baw Shire	1&2
David Sheehan	Team Leader - Water Regulation	Water Program | Health Protection Branch | Department of Health	1
David Stork	Environmental Water	West Gippsland CMA	1&2
Dr.David Nash	Scientist DPI Ellinbank	Department of Environment and Primary Industries	1
Fiona Pfeil	Catchment Officer	Gippsland Water	2
Gillian Hayman (apology for workshop 2)	Natural Resource Management (Dairying for Tomorrow) coordinator	Gippsdairy	1
Helen Oates	Policy Officer	Water Program I Health Protection | Department of Health	2
Jenny O'Sullivan	Coordinator	South Gippsland Landcare Network	2
Jodie Smith	Dairy audit Officer	EPA	1&2
John Lambert	Waste Water Officer	South Gippsland Shire Council	1&2
Ken Griffiths	Strategic Planner	South Gippsland Shire Council	1&2
Kerry Matthews	Water Resources Coordinator	South Gippsland Water	1&2
Malcolm Cox	Beef Consultant	Farm Dynamics	2
Michelle Dickson	River Health	West Gippsland CMA	1
Nick Dudley	Catchment Planning	Department of Environment and Primary Industries	1&2
Ravi Raveendran	Manager Operations	SGW	2
Robyn Duffy	Environmental Health Officer (EHO)	Baw Baw Council Shire	2
Sarah Salmons	Water Quality Coordinator	South Gippsland Water	2
Tim Brown	EHO Coordinator	South Gippsland Shire Council	1
Todd Haughton	Planning Manager-Gippsland	HVP	1
Nick O'Connor	Consultant	Ecos Environmental Consulting	1&2
Tracy Clark	Consultant	Ecos Environmental Consulting	1&2
Sarah Law	Consultant	Water Technology	1&2
Warwick Bishop	Consultant	Water Technology	2

Appendix 6 – Issues identified and discussed by the Working Group during the First Workshop

Riparian Zone Management

Table 9-2. Riparian Zone Management

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
Riparian Management Issues			
Existing investment			
Landcare land stewardship program – assisting landholders to manage properties sustainably	We would need specific information on type of actions usually implemented and proportion of properties involved in each sub-catchment. May be best to document at a general level and use to support modelling assumptions at a similarly general level.	Identify relevant Landcare contact and discuss land stewardship program over phone	Deferred for discussion at second workshop. Could aim to link Landcare Programs to Catchment BMPs
Dairy Australia holds data for Gippsland area on riparian management by dairy farms (e.g. % of fencing etc.)	Depending on level of detail, such data could be used to support modelling assumptions about current levels of waterway protection and also to assist in generating realistic future management scenarios	Contact Gillian Hayman (Gippsdairy) on availability of data	Contacted. Gillian provided helpful reference material.
Forestry code may refer to riparian – limits on machinery (5 m no activity, 25 m limited activity)	Confirmation of areas under forestry and types of management will be useful to determine influence on water quality. May assist in selecting appropriate runoff coefficients. Excerpts from Code of Practice are in tables below. Different buffer and filter strip distances apply for different site conditions	Check available land use data and/or contact HPV for details on local production	Obtained forestry land use information from VLUIS GIS data. For modelling use Code of Practice as a guide for setting up model parameters
Query - will riparian zone improve water quality?	Riparian zone is considered important for modelling. Literature searches will inform this component of modelling. There is recent (2013) research on effectiveness for pathogens (e.g. Wilkes et al. 2013)	Conduct lit search. Check with David Sheehan (Dept of Health) who mentioned he has contacts with Canadian research team	Contacted. David forwarded copies of relevant research papers
Fencing of cattle			
How effective?	Fencing will prevent faecal loads direct to water so is expected to be helpful for pathogens control, but for nutrients the effects may be less clear. Fencing also protects in-stream ecological values which are not being modelled in this study. Modelling may assist in defining the answer to a degree. There is also recent Canadian research on buffer strips mentioned above.	Ecos and Water Tech to consider approach based on literature search.	Literature search conducted. Good recent publications provided direction for model input and assumptions. See body of report for details.
Separate filtration effect from fencing effect	The point being made here is that filter or buffer strips have an effect independent of fencing. Although, how likely is it for there to be unfenced waterways adjacent to cattle grazing pasture that have functioning filter strips? Information on the proportion of fenced vs unfenced cattle grazing in the catchment would be useful. Runoff coefficients weighted according to fencing and filter strip prevalence could be used to assess different scenarios. Model accuracy may be good for monthly loads but not so good for daily estimates.	Ecos and Water Tech to consider approach based on literature search.	As above.
For young cattle, dairies tend to "shed" young cattle, but beef cattle not so – so beef cattle could be a more	Check with Dairy Australia on standard practices for management of young cattle. If there is a difference in practice between dairy cattle and beef cattle, this could be modelled for pathogens using different	Contact Gillian Hayman (Gippsdairy) for details of current practices	Contacted. Gillian provided helpful reference material.

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
significant source	runoff coefficients (these would need to be estimated) for each land use, or else weighted according to the proportion of dairy vs beef. We would need to be able to distinguish between dairy and beef land use which may not be possible.		
South Australian study (ask Gillian)	Gillian Hayman mentioned a South Australian study on management of cattle and waterways	Contact Gillian Hayman (Gippsdairy)	Gillian provided link to study. Study included in literature review.
South Gippsland tends to be a beef cattle farming area, older cattle bought in to fatten up	Noted. For modelling it could be assumed that pre-weaned calves make up a lower proportion of stock than might be expected. This could justify the use of lower pathogen loadings to waterways while for nutrient loadings sourced from cattle it may not make so much difference.	Speak with Gillian Hayman and DEPI regional staff to document local practices.	Contacted. Gillian provided helpful reference material.
Aim to keep cattle out of creek	Early view based on workshop discussion about sources of pathogens to waterways. Also provides benefits in terms of protection of instream habitat values.	No action	No action
WG CMA may have data on % of fencing	West Gippsland CMA may have data on % streams fenced. For modelling, this could be useful in determining the allocation of runoff coefficients.	Contact WGCMA to enquire about availability of such data.	WGCMA was contacted regarding this data set. Information was provided to the study team after the 2nd workshop.
Note in hilly country – lots of small feeder streams, not fenced (probably not practical), these would generate runoff	Smaller, ephemeral drainage lines would not be practical to fence. To the extent that such drainage lines are vegetated, they could act like filter strips. When modelling, assumptions are made about the area of catchment above a point that will generate persistent flowing water. Generally it is set to a few hundred ha or more and will coincide more or less with the formation of true persistent drainage lines. Standard fencing practices, where they are applied, may miss a small portion of the drainage lines where they begin.	Guidance on fencing for waterway protection could address this issue. To be considered when setting assumptions for modelling. Could test sensitivity on modelling results. If sensitive, then seek more accurate description of current practice.	Considered in modelling.
CMA study on Tarwin Catchment (ask Michelle)	WG CMA may have another study on nutrients and landuse for the Tarwin Catchment.	Contact Michelle Dickson at WGCMA for further information	Report provided by Michelle. RMCG Pty Ltd (2011) Sediments, nutrients and their impacts in the Tarwin River catchment- a review of available information. Consultant's report to the West Gippsland CMA.
Recent changes to landuse, less dairy in hills, increase in seasonal horticulture (eg. snow peas)	Need to seek latest land use GIS data	Contact DEPI to enquire about more recent land use data	Latest GIS land use data obtained from Victorian Land Use Information System (VLUIS).
Increase in hobby farm-type owners – absentee landlords, more likely to overgraze	Difficult issue to capture via modelling. Its not likely that we will have information on which farms are hobby farms. However, a scenario could be modelled that showed the effects of assuming a large increase in hobby farms and assumed slightly higher sediment and nutrient runoff coefficients for hobby farms compared to regular farms. Results would be indicative rather than definitive. May be better to model on a small scale through a separate exercise	Suggest recognition of this issue in reporting but do not consider for modelling at this stage due to lack of supporting data. Perhaps an issue for regional organisations to tackle (e.g. Landcare, DEPI, etc).	No further action.
Some sheep production in catchments – need to consider (eg. lambs)	Supporting data on pathogens is available for sheep, and its thought that nutrient loadings exist. Location of sheep grazing in catchment could need to be	Unless sheep production is greater than a few percent of catchment area or	For modelling purposes it was assumed that sheep production was negligible.

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
	determined. Alternatively, estimates of proportions of properties dedicated to sheep grazing could be used to produce weighted average runoff coefficients. If proportion of properties with sheep is low, the model is unlikely to be sensitive to it for nutrients and sediments and probably likewise with respect to pathogens.	highly localised, it's probably not worth distinguishing from cattle. Action: check the more recent Land use data then decide on approach to be taken.	Land use data for the Baw Baw Shire distinguished sheep grazing properties (around 5% of the shire area within the Tarwin Catchment) but no distinction was made for the South Gippsland Shire portion of the catchment which constitutes about 80% of the catchment.
Possibly some free-range piggeries	Similar approach as for sheep.	See above.	Due to small no. of piggeries and lack of information on location, these were assumed to have negligible discernable affect compared to cattle grazing (i.e. they may have a local impact, but not so important at whole catchment scale).
Need to state limitations to model accuracy	It is expected that broad land changes should be able to be modelled successfully. For smaller changes to areas of land use it will be more difficult to discern differences.	Assumptions and limitations will be documented	Modelling assumptions documented in report
Forestry – timber corps advise water authority of pesticide spraying, less data on sediment runoff	Check with South Gippsland Water (SGW) on their monitoring. Decision made at workshop to exclude pesticide fate modelling from the study. Nevertheless, pesticide use and monitoring will remain a topic of interest to South Gippsland Water (SGW).	Check with SGW on their WQ monitoring.	Done. Data supplied and used to inform modelling.
U.S. evidence- conservation measures sometimes lead to worse outcomes – eg cattle seeking shade in new riparian zone increasing pathogen loads to water	Interesting point to consider when describing best practice management.	Contact David Nash at DEPI for further info on this study	Contacted. Link to reference supplied. Considered in Riparian BMPs.
Sediment management roads – issue for forestry and greater catchment	Review literature and forestry codes of practice on this topic to ensure use of appropriate runoff coefficients for roads – seek local data.	Lit review and check of regional data	Lit review conducted. Findings used to support model assumptions.
Soils in catchment	Soils will affect type of runoff, check for local data	Literature review	Lit review conducted. Findings used to support model assumptions.
DPI 2012 – landuse data	Noted earlier	As above, contact DEPI to enquire about more recent land use data	Addressed above with VLUIS data.
Fenced waterway data – in GIS Most of works from CMA – Dairying for Tomorrow has captured what private have undertaken	WG CMA has GIS data on fencing works. Dairying for Tomorrow also has data	Contact WGCMA and Dairying for Tomorrow to request data	WGCMA Contacted. Referred to VLUIS data. Gillian Hayman also provided reference to Dairy industry data.
Limited riparian for horticulture	Assume that this point means riparian zones in horticultural areas are limited	Noted	No action required.
Horticulture needs to be split – high and low density	Assume this means high and low intensity. e.g. active tilling for annual crops versus tree production?	Investigate horticultural land uses in the catchment further.	VLUIS GIS landuse data used to identify horticultural areas.
* Reporting – make sure the sensitivity and accuracy of the data is obvious and doesn't quote levels of accuracy not supported by data	Point noted.	All assumptions will be listed and sensitivity analyses conducted for key input parameters during model setup to	Action: as stated at left.

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
		assist in identifying level of sensitivity in model.	
EPA licenced discharges (Jodie) – other sources	Food processors and WWTPs have discharge points. This data is important for the model. Key factors are daily discharge rates and quality of discharge in relation to nutrients, sediments and pathogens.	Contact EPA and SGW for further information.	SGW provide information on its discharges. EPA website now lists key data on all licensed discharges and was the source of data used in the study
• Burra foods – Coalition Creek – historical data available (David) 0 expansion since • Murray Goulburn – has raw data, data from David • Townships	These are some of the potential point sources. Townships will be covered as a source of stormwater.	Noted	SGW provided historical water quality data
Dot points of where dairy farms are – SGW	SGW has some data which may be helpful in assigning land use. However it is noted that in later discussion there was preference for pooling cattle production (i.e. not distinguishing between beef and dairy).	Discuss data with SGW and consider its utility.	As requested by working group, dairy farms were not identified separately from other cattle production.
Physical outcomes for riparian zones to give information when looking at planning and compliance – how do you ensure….	Sentenced not finished, but assume it means: how do you ensure compliance?. Compliance rates can only be confirmed by periodic auditing; checking for condition of riparian zone and fencing. How this should be managed is beyond the scope of these notes and would likely be a sensitive issue. To be discussed with stakeholders at next working group meeting.	For modelling scenarios we would be assuming some level of uptake of Best Practice Management. It was not captured in the meeting notes, but there was a comment from someone about recent Victorian Dairy BMP material. This will be followed up.	Literature search conducted on BMPs for dairy. Recent research published by Sharon Aarons and Cameron Gourley of DEPI, Ellinbank Research Centre.
Issues	**Summary of above issues by Working Group at Workshop**		
• Modelling limitations and sensitivity ○ Open ○ data gaps, how critical	Need to be clear about model limitations and sensitivity of the model. This includes highlighting data gaps.	Point noted. All assumptions will be described in the supporting documentation for modelling.	See model setup description in report
• Fenced vs unfenced riparian zones and buffer zones / modified management (forestry, horticulture, other)	The benefits of fencing should be assessed. Also the presence of buffer zones with respect to other non-grazing landuses.	Seek best available GIS data on land use and extent of fencing to support model	Assumptions on fencing described in report. Modelling using filter controls
• Landuse – definition within agriculture landuse (cow or not)	Look for clear definitions of land use; in particular its probably best to distinguish between the presence of cattle versus absence rather than distinguish between say, Dairy and Beef	As above	Modelling necessarily involves lumping similar land uses together as runoff coefficients for each modelled constituent are not available for every land use. See report for details.
• Sediment generation ○ roadways (unsealed) ○ gullies ○ instream ○ buffers – recommended best practice	Sediment sources to be clearly documented in model. Seek local data to support runoff coefficients in model where possible.	Noted.	Sediment sources documented and described in report.
Goals for Riparian Management			
• No animals in the waterway	Goals to be reviewed and possibly wording revised	Review goals and seek	Draft Goals developed and

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
• Clear definition of waterways • Limiting sediment loads to the waterways • Implement riparian chapter of Victorian Waterway Strategy	to more clearly capture intent	support from Working Group for any changes	comment from Working Group sought.

Wastewater Management

Table 9-3. Wastewater Management

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
Wastewater Management Issues			
Density of development – differences between high density nodes and widespread low density on overall water quality?	Other things being equal, the loading to the subcatchment node (a point at which the model gives predictions on loads and concentrations) will depend on the runoff coefficient allocated to the type of land use. There will be a trade-off between dwelling density and area in terms of impact at a node. The model will not be able to distinguish small differences (but these are less important anyway).	Go ahead with modelling, consider sensitivity testing (artificially boosting/decreasing housing densities, etc.) to get an idea of model accuracy.	Sensitivity testing done in model setup
Monitoring and compliance of installation and maintenance	Modelling could test implementation of a best practice management regime for onsite systems. This would assume a lower failure rate. Experience from previous modelling indicates that the changes would have to be large to detect at the catchment scale for both nutrients and pathogens. Smaller scale spreadsheet modelling may assist here.	Model with appropriate assumptions for failure rates etc.	See report for description of modelling assumptions and sensitivity analysis.
Types of systems			
• older split systems (blackwater contained, greywater direct output)	Source modelling will most likely to be too coarse to detect differences between systems. However, smaller-scale spreadsheet modelling could assist in providing guidance here.	Consider simple spreadsheet model of hypothetical area for guidance here.	Not modelled with Source. Could be modelled using a spreadsheet model at a smaller spatial scale and using a hypothetical area containing say 50 dwellings and making assumptions on treatment performance, failure rates, and quantity of effluent available for transport to waterways in the event of failure. Since this is an industry issue perhaps it could be funded through an industry agency such as the Victorian Water Industry Association.
• 1° all onsite containment	Evidence is mounting that simple primary systems are more reliable (i.e. less chance of failure) despite that fact they require more land.	As above	
• 2° systems	Secondary (aerated) systems appear to have higher failure rates	As above	
• recent systems 2030 (Baw Baw)	This refers to higher quality sand filter systems which produce a better quality of effluent. As before, Source is unlikely to be able to distinguish performance differences at the catchment scale, but smaller scale modelling may. 2030 refers to system performance and Baw Baw shire is encouraging use of such systems	As above	
Age and management of existing systems	This is a general comment: older systems may be where most failures occur. System management is probably limited. Depending on the area and system density. Source modelling could be used to assess remediation and improved management, otherwise smaller scale spreadsheet modelling could be used to provide guidance.	As above	
Council's database of permits – issued by time	This data could be useful if assumptions about system performance with age can be verified	Contact council for copy of data (privacy requirements may mean	GIS data provided by South Gippsland Shire and Baw Baw Shire Councils

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
		that the data has to be edited beforehand to remove id. Info)	
SGSC MDWMP (Municipal Domestic Water Management Plan)	Plan may provide guidance on developing appropriate modelling scenarios.	Review plan	Draft MDWMP 2014 reviewed. Reported statistics tabulated and used to support model settings. See text in report for detail.
EPA's Certificates of Approval – effluent objectives met	Not sure what this can offer but we can review EPA certified systems.	Review EPA approved systems	Too many systems to distinguish. See spreadsheet model described in report.
Soil types	Different soil types are listed in soil mapsheets at VRO (Vic Resources Online). Soil data will be reviewed for use in determining runoff coefficients	Review soil data. Consider use of GIS query tools to assist in developing appropriate functional unit layer for modelling.	Infiltration parameters were chosen to represent the average soil conditions within the catchment. These parameters were calibrated to the gauged flows to develop the rainfall-runoff relationship
Impacts – different terrain affecting runoff	Slopes will influence runoff.	Consider settings within Source model	The impacts of terrain were included in the rainfall files (higher rain in hilly areas) and the lowland areas had a flow lag applied to match the timing at gauging stations
Drainage – 2 sewered towns (Korumburra and Leongatha)	Sewered towns will be allocated stormwater-based runoff coefficients. Either local data or other good quality data from the Australian Stormwater Recycling Guidelines will be used. WWTP outfalls will also be considered as point source inputs in the model.	Data sources and assumptions to be documented as part of modelling.	Town stormwater flows included in model setup. See report for description.
Stormwater systems – Dumbalk and Mirboo North	Unsewered towns will be assumed to have poorer water quality. Runoff coefficients will be adjusted accordingly. A lit search will support this	Review literature and available monitoring data	As above. Different runoff quality assumed for unsewered towns
Where we expect development to occur – estimate future impacts of wastewater systems, type installed	Effects of increased development density can be assessed with Source model. Modelling of system types is likely to be through the use of smaller scale spreadsheets if project resources can support this.	Develop future development layers in accordance with local Govt Planning Strategies	Future development layers developed in GIS and used to assign different values to selected areas as part of scenario modelling. See report for details.
LCA – soil type info – recommendations (issues with quality of LCAs)	Land Capability Assessments – quality of LCAs is not something that can be modelled. For the management plan, however, recommendations can be made in relation to LCA standards	Possibility of dealing with this in the management plan or the Catchment Protection Policy	Not considered in modelling.
Code of Practice – EPA 891.3 (Feb 13) re setbacks	Assume this means assessing compliance with setbacks including understanding the extent of compliance of older systems to the newer EPA guidelines. Issue needs clarification with Council	Contamination Risks are increased with reduced setbacks. If data was available for the extent of compliance/non-compliance with setbacks, it could be used to justify particular model assumptions and scenarios.	For the base case, only a moderate level of compliance was assumed
Model existing domestic impact – what level of detection: is there an impact now known (identifiable) as	South Gippsland Water water quality monitoring data may provide some guidance. The base case modelling scenario will also seek to predict the existing conditions. Definitive evidence of human	Proceed with modelling pathogens and nutrients for base case. Consider model sensitivity and need	Issue evaluated as part of base case sensitivity. See report for description.

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
human in current catchments?	impacts (pathogens) would require virus testing or testing for particular strains of bacteria.	for smaller scale spreadsheet modelling if necessary.	
Have data on compliance, inspection data (John SGSC)	This data may help inform model assumptions about nutrient and pathogen loadings in unsewered areas	Contact John Lambert at SGSC to discuss availability of data	Discussed with John. Concluded that the data is not comprehensive enough nor in an appropriate form e.g. not collated, not in electronic form) to contribute to setup of modelling scenarios. No further action.
SGW did compliance assessments when sewering (Meeniyan)	As above	As above	See above.
EPA assessment on how different on-site treatment plants work (Sarah West)	Follow up on this with EPA (Sarah West). Note comments above about Source model sensitivity limitations to detect differences between different systems	EPA approved systems listed on EPA website. Concluded that if it's not approved, then it's probably not compliant. Possibly better considered as part of smaller scale modelling.	SG Shire Council advice is that there are many older poorly performing systems in the catchment; non-EPA approved systems would be part of this number. These factors were considered in the setting of the runoff coefficients for unsewered land use and the consideration of potential improvements (as modelling scenarios)
Urban stormwater from sewered areas			
- Other contaminants – effect of oils and hydrocarbons on the effectiveness of the treatment plant, e.g. truck washes connected to stormwater, triple interceptors	This could be an issue for the EPA. Surfactants can be toxic to aquatic biota. Truck wash surfactants are quite strong. Ideally truck wash runoff should be routed to sewer. Need some more information on what is meant here. Is it that fats, oils and grease (FOG) will end up in stormwater due to effect of surfactants on triple interceptors? Such organics will not be modelled by the Source Model but management may be discussed in the overall Catchment Policy.	Seek clarification from SGSC.	Discussed with SGSC. Not considered for modelling. This is more of an issue for EPA compliance monitoring.
WWTP discharge – Leongatha – point source / runoff from discharge field	WWTP discharges will be considered as point source inputs of nutrients and pathogens into the Source Model. Runoff from wastewater irrigated land can also be considered if area irrigated is significant.	Seek information on WWTP effluent management from South Gippsland Water	SGW provided information on WWTP discharges. Data used in modelling.
WQ sampling downstream of Meeniyan prior to sewering (SGSC Callum and Skye) – some high *E. coli* and temperatures	South Gippsland Shire Council may hold some WQ data for the Tarwin River d/s of Meeniyan. This data could be used to inform stormwater component of Source Model.	Contact SGSC to discuss availability of data	Data provided by and SGW and used in modelling.
Q: from SGSC re viruses from human impacts			
• Are we having an impact now? (current)	The base case will attempt to make predictions about current impacts. As discussed above, depending on the areas covered, it may be difficult to detect differences between different management scenarios at the catchment level.	Proceed with modelling pathogens and nutrients for base case. Evaluate performance of base case on this issue.	See model base case description in report.
• If we fully develop, will we have an impact? (worst case)	These situations may be considered for scenarios with the Source model. A smaller scale spreadsheet model may also assist in guiding management.	Evaluate sensitivity in base case model	Evaluated in model scenario

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
• What is the impact if we ensure all systems are upgraded and maintained? (best case)	See last point above	As above	As above.
Stormwater discharge – crypto around townships, campylobacter?	This can be considered in the Source Model. If there is an absence of local water quality data, the Australian Guidelines for Stormwater Recycling have data that can be used to support modelling.	Check with SGSC and SGW on available WQ data. Also check with Health Dept.	No local data. See report for data sources used to support modelling.
Point sources within subcatchments – downstream of township - town management of stormwater and development design	Townships can be considered as diffuse source inputs of stormwater rather than point source inputs. Any industrial discharges must be considered as point sources.	Proceed with modelling as part of base case	Town stormwater considered in modelling as a diffuse source. EPA licensed discharges considered as point sources where these occur.
What potential for improvement if bring older systems up to current standards?	See above for system comparisons	See above (i.e. evaluate in source model and/or assess using smaller scale spreadsheet model)	See modelled scenario in Source. Finer details could be addressed in a spreadsheet model as described above (not included in this part of the project).
Govt money has sewered Meeniyan, some may be available for another town, eg Loch, Poowong (both of these towns are outside the study catchment)	Depending on modelling outcomes there may be evidence to support sewering of smaller towns. The issue may be taken up in the development of the Catchment Policy	No action at this stage	No Action.
At treatment (Water Treatment Plant Issues)			
• use of alternative water supply?	Understand these questions to be: Should South Gippsland Water: use an alternative water supply?; increase treatment at plant?; consider giving up protecting 100% of water supply catchment given the water is used for only a small number of people. These are all fairly weighty debating points that won't be answered by the Source modelling exercise. SGW may consider addressing these discussion topics in the development of the Catchment Policy	No action at this stage	No Action.
• increase treatment at plant?			
• protecting 100% of water for use of small number of people			
SGSC – histories of when put in, 60% not looked at since installation, extrapolate failure rates	SGSC has data on installation dates of on-site systems. This data could be used to determine failure rates.	Contact SGSC to discuss availability of data	Addressed earlier. Data not considered suitable. Captured in modelling through assumptions of on-site system performance.
SGSC – survey through Meeniyan 2004, quite high failure rates, higher level of failure expected there than at Dumbalk, monitoring stormwater systems	This data could be used to support modelling assumptions.	Contact SGSC to discuss availability of data	As above.
Current practices			
Land capability assessment	These points all relate to current practices and direction of likely future practices. Catchment scale modelling is probably not appropriate to examine these issues. Small scale spreadsheet modelling of a hypothetical area devoted to best practice management of onsite systems versus current management could help provide evidence to inform the debate.	Spreadsheet modelling is not covered in the current modelling project budget at this stage.	As described earlier, not modelled with Source. Could be modelled using a spreadsheet model at a smaller spatial scale and using a hypothetical area containing say 50 dwellings and making
1° or 2° treated effluent systems – to meet EPA guidelines			
SGW asking for 2° treated in higher density areas			
Don't run general (proactive) compliance checks – reaction			

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
to complaints			assumptions on treatment performance, failure rates, and quantity of effluent available for transport to waterways in the event of failure. Since this is an industry issue perhaps it could be funded through an industry agency such as the Victorian Water Industry Association.
Efficacy of 2 treatment? – looking at systems which are more effective and require less maintenance			
• SGSC encourage sand filter over aerated 2 treatment • If aerated 2 treatment – LPED (more robust, less likely to clog up)			
Looking at more failsafe systems – because have no proactive compliance			
Sediment through system clogs up pressure subsurface irrigation system so some then cut and hose the effluent			
Like to be able to enforce 3 monthly maintenance check			
Baw Baw get a lot of sandfilters in, ½ go to pressure fed below ground irrigation, ½ go to trenches			
Issues	**Summary of above issues by Working Group at Workshop**		
• What is the effect of different development densities?	Refers to different development densities of unsewered housing. Can be modelled if differences in densities and areas developed are large. Smaller scale, spreadsheet-based modelling may be required to provide guidance in the comparison of moderate density differences or relatively few ha are being modelled compared to size of catchment (86,000 ha).	To be considered in modelling	Modelled scenarios will include the effects of different development densities
• Effect of monitoring and compliance on performance of on-site systems? (see structure plans for industrial)	Similar to point above. May be modelled successfully using Source model, but there may be a need for some additional smaller scale modelling as well.	Consider in Source model and evaluate sensitivity	Source model used to assess effects of different performance levels at the catchment scale. This could be augmented by finer scale modelling as a follow up.
• Performance of different on-site systems – there could be some clustering of older systems	See point above	As above.	As above
• Impact of different terrains on runoff	Could possibly be considered in modelling, but further investigation required to be certain. Slopes will affect runoff.	To be considered in modelling	The impacts of terrain were included in the rainfall files (higher rain in hilly areas) and the lowland areas had a flow lag applied to match the timing at gauging stations
• Performance of sewered vs unsewered townships	Can be modelled using Source Model	To be considered in modelling	Addressed in scenario modelling
• Assessment of future development			
• Effects of WWTPs including runoff from discharge			

Program/item/Data	Relevance to Tarwin WS Catchment Modelling and WQ Plan	Action	Outcome
• Effects of sewering other towns?			
• [Feedlots could be an industrial use]	Could be considered as a scenario for testing if required.	Suggest this is beyond the scope of the current modelling exercise as it involves the evaluation of a particular proposal.	Not included in current scope. No further action.
Goals			
• Identify appropriate pro-active septic tank management regime for the catchment	Goals to be reviewed and possibly wording revised to more clearly capture intent	Review goals and seek support from Working Group for any changes	Draft Goals developed and comment from Working Group sought.
• Identify appropriate level of development (residential or otherwise) to protect water supply (the appropriate levels of development are likely to be area specific)			

Appendix 7 – Notes from Second Workshop

Riparian Zone Management

Table 9-4. Notes from Second Workshop: Riparian Management Group

Working Group Comments	Response/comment
Vision & Guiding Principles	
• In general the group was happy with the wording of the vision and guiding principles. They noted they are very broad and aspirational however appropriate for the study.	Noted
• One wording change (or removal) was the "working space"	Noted, changes made as requested
• *We will identify and progressively work through the challenges to achieve our long-term goals.* – this statement was considered to be too broad to achieve commitment. Working together will be an important step but there will need to be money and programs in place to support these goals.	No alternative was offered and there was no request for change from the other group, so in the absence of a better alternative we decided to leave this as is
• The term sustainable development should be used instead of sustainability in many cases	Noted, changes made to guiding principles to reflect this.
General Comments	
• There are possibly two scenarios to consider when looking at riparian works:	
➢ Fencing just to exclude stock – this would be a lower grade fence just to prevent stock and would not include any revegetation works in the riparian zone. As livestock in the creek are the major concern for pathogens this would allow a greater amount of works to be undertaken for the same amount of money. If necessary grass planted to provide buffer.	Stock exclusion reduces direct loads to streams (i.e. no DWC load, but similar EMC load) since cattle cannot access the water. This would mean the model Dry Weather Concentration (DWC) runoff coefficient should be set to zero when riparian zone fences are in place. The Event Mean Concentration (EMC) runoff coefficient remains the same as this is the pathogen load from manure on the paddocks that is transported by rainfall. It is assumed that fencing alone without effective buffer vegetation will not change this value. In reality there would be some vegetation present due to exclusion of cattle and thus reduced grazing pressure.
➢ Fencing to exclude stock and riparian works – Providing additional waterway health benefits and nutrient reductions as a result of the vegetation.	Fencing with vegetated buffers will reduce EMC pathogen, N, P, & SS transport (and to some extent DWC). Grassed buffers will also achieve this, but do not provide much in the way of bankside and in-stream habitat nor so much protection from bank erosion. Course Woody Debris (CWD) is also beneficial for bank protection and in-stream habitat, but we are not modelling these benefits.
• The group also discussed whether SGW cares about a healthy ecosystem or just the nutrient/sediment/pathogen load at the extraction points. If so do we need trees or would a grass buffer be sufficient? Kerry mentioned it is within SGW's sustainability strategy to provide ecological sustainability and hence would be seeking a good outcome for the creek as well.	See response above. Ecological sustainability is also desirable but is not being modelled here.
• A comment was made by Council about a known Anthrax site on the Tarwin River. In this area waterway works and development is not approved. This can be taken into account with the scenarios (i.e. no assumed works in the vicinity) but the report should also mention areas of biological risk and that specific management actions need to be undertaken. Council providing data about where the anthrax occurred.	SGSC did provide data on Anthrax risk sites but these are limited in extent and not considered to have any effect at the sub-catchment/catchment scale of the current Tarwin WS Catchment model. DEPI oversees Anthrax risk issues and has issued a Guidance note for this (See 2012 Ag Note).
• Due to the limited area of this landuse it was agreed that a scenario looking into BMP for horticulture would be less valuable than other scenarios. Most of the horticulture is around Dumbalk, with some opportunistic horticulture throughout the catchment.	Agreed. Low priority for modelling. No horticulture scenario at this stage.
• If some of these works need to just be tested on a case study area the Ruby Creek catchment is grazing with no riparian works.	Noted. If smaller scale follow up work is required, this catchment could be considered.
Scenario: Implementation of BMP for riparian zones (Crown Frontages only)	

Working Group Comments	Response/comment
• There were no major concerns with the crown frontage data provided in the presentation	Noted.
• To the group's knowledge there was unlikely to be much of the crown land currently fenced	Noted and confirmed by subsequent GIS data provided by West Gippsland CMA.
• Crown land vs private is of interest due to the ability to undertake the works	Noted. This can be tested through the modelling scenarios.
Scenario: Implementation of BMP for riparian zones (Crown Frontages and private land)	
• It isn't common practice in this area to graze within the fenced off areas due to the high stocking rates and local conditions. There has been a local study about this. It was also noted that a high vegetation regeneration is observed in this region which could help to limit planting costs for riparian works	Noted. Cost-benefits need to be assessed at the planning stage for implementation. Assessing costs, except in a very general sense to avoid unrealistic modelling scenarios, is beyond the scope of the current project.
• West Gippsland CMA to provide stream frontages work in GIS format	Done, data received.
• Standard practice by the CMA is 10m fencing width with vegetation and grass	Noted. It is understood that vegetation and grass means some replanting is taking place.
Scenario: Implementation of "Improved Grazing Management" on 90% of all grazing properties	
• We had a significant discussion about the management of wet soils and onsite practices. The group suggested a change of this scenario to be called on farm management. This would include:	Noted. Change made as suggested.
➢ Wet soil management – i.e. the use of feed pads and associated effluent storage	Use of feedpads should protect soil around the site and lead to better quality runoff from site compared to wet damaged soil. Assuming that feedpad management is consistent with best practice, effluent storage should also assist with improving quality of runoff water. From a perspective of modelling environmental impacts a feedpad can be considered the same as a dairy shed.
➢ Effluent management – impacts of onsite effluent storage failure on the pathogen loads	Effluent storages would be a point source. Unfortunately we do not have data on the locations of effluent ponds.
• In terms of the effluent management it was discussed this could be modelled as a 10% improvement on current practices (as it is assumed 90% compliance at the moment). This would take into account farms with:	Improved pond management can only assess this on a catchment wide-basis by lowering runoff coefficients a small amount. This is difficult as the relationship between point sources and land use runoff coefficients is highly situation specific and will in any event be dominated by catchment runoff. A model scenario testing the difference between effluent pond compliance of 90% (current) to 100% future is unlikely to yield satisfactory results unless modelled explicitly (i.e. effluent ponds treated as point sources and their locations and discharge rates known for each subcatchment).
➢ No effluent management system	
➢ Not well managed systems	
➢ Good systems that fail	
• It was noted that hobby farms had the worst practices and least likely to have appropriately managed the site compared to the larger and more well established sites.	The effects of hobby farms can't be modelled without explicit information on their number, location and type of land use activity (current and future). Considered beyond the scope of current project, however could be considered at the Catchment Policy development stage by South Gippsland Water and the Councils.
• Feedpad guidelines are available – which would be a good reference for this scenario	Noted. The guidelines were obtained and reviewed. The guidelines provide guidance on design and management. As noted above, from a perspective of modelling environmental impacts a feedpad can be considered the same as a dairy shed. The guidelines provide advice on appropriate siting; location remote from waterways and effective effluent management are important.
• There is also a large potential to improve management practices with this scenario	Noted.
• Melbourne Water provides incentives for similar schemes – through effluent management and feed pads. Maybe this is something SGW could consider if it makes a significant difference to the pathogen loads.	Something like can be assumed as part of a scenario for improved management. However, the cost-benefit aspects would need to be considered during the implementation/response planning stage.
• A point was brought up from Council about the planning implications for medium sized lots. Planners recommend to landowners that small scale agriculture is required for these medium lots (size to be confirmed with council). This is likely to	See comment above, beyond scope of current project

Working Group Comments		Response/comment
	be contributing to the water quality issues as these are often not well looked after	
•	It was noted that the management practices are currently being checked on an ad-hoc basis and usually only reactionary due to limited resources	Noted. This is a general comment about resourcing and could be taken up during the catchment policy development stage.

Wastewater Management

Table 9-5. Notes from Second Workshop: Wastewater Management Group

Working Group Comments		Response/comment
Modelling Scenario: implementation of BMP [most appropriate management] for On-site Systems		
•	Now (what is the impact of the existing number of wastewater systems with their existing failure rate?)	These points were all incorporated into the modelling scenario
•	Now with improved management (what is the impact if the existing wastewater systems have a reduced failure rate through improved management?)	
•	All developed (what is the impact if the catchment is fully developed and the new wastewater systems have the same failure rate as current)	
•	All developed with improved management (what is the impact of the increased number of wastewater systems if all systems have reduced failure rate through improved management?	
Types of systems		
•	Are there different coefficients for primary, secondary and tertiary onsite systems?	No, systems are modelled as runoff coefficients
•	What are the failure rates for each of the primary, secondary and tertiary systems	Q. what is meant by tertiary on site system – higher treatment?). Currently we have no data on different failure rates.
•	If primary fails the result is primary effluent, if secondary fails the result is primary effluent, if tertiary fails the result is primary effluent (but worse because the field is closer to the surface) –	Noted. This may be a policy decision based on some level of science and council's experience. Fines for unreported failures. Hold random inspections.
•	May need to tweak subcatchments to slope to modify impacts of wastewater system failure	While slope is incorporated into the Digital Elevation Model used by Source, in general the model does distinguish between individual septic tank locations and site-specific risk. This would require a separate more localised study.
•	What is the best practice for on-site systems? - cost vs improvement Higher treatment is higher cost and higher maintenance (and potentially higher chance of failure) Need land capability assessment – this may require a targeted model after this broad scale model.	Best practice is specified by Australian Standards and EPA code of Practice. Any additional requirement would be focused on maintenance frequency to minimise risk of failure leading to surface ponding of effluent
•	Check that there may be a report by Dr Dan Deere regarding cost vs improvement for onsite wastewater systems	Emailed Dan requesting a copy if such a report existed, but according to Dan there is no such report.
•	Is the base case currently showing acceptable water quality? What level of management is required to maintain the status quo?	Discussed in report
Scenario: dwelling densities increased to permitted levels under the current planning laws		
•	Farming Zone small blocks –old road reserves, land locked, slope or size may mean they can't have an onsite wastewater system	Selected 1000 m^2 as the minimum lot size
•	[John and Brian] minimum FZ size for a house would be 1000 m^2 (500 m^2 is historical) as with the slope and clay soils, the area required for the disposal field wouldn't fit on the block with the buildings as well.	Confirmed that minimum FZ size for a house would be 1000 m^2 (500 m^2 is historical)
•	Minimum subdivision for any FZ property in South Gippsland Shire is 80 ha blocks, so no block less than 160 ha can be subdivided (this is not the case in Baw Baw Shire)	Point noted in report and in modelling
Scenario: implementation of BMP for urban stormwater		
•	Old urban stormwater is likely to the stay the same	Noted – full implementation of WSUD was not modelled
•	Model new as improved	Noted
•	Baw Baw Shire in Tarwin has no stormwater	Noted

Working Group Comments	Response/comment
• Can be expensive	Noted
• Drainage study done for Leongatha	Brian supplied a copy
• Future development – Korumburra and Leongatha – structural plans	Pdfs of plans and maps downloaded
• Rezoning currently underway : some farming to future residential (sewered)	SGSC subsequently supplied GIS update
• Main Issue: Availability of data to inform the modelling for cost: benefit (particularly for onsite wastewater systems)	Noted

Appendix 8 – Tarwin Water Supply Catchment: planning zones and overlays

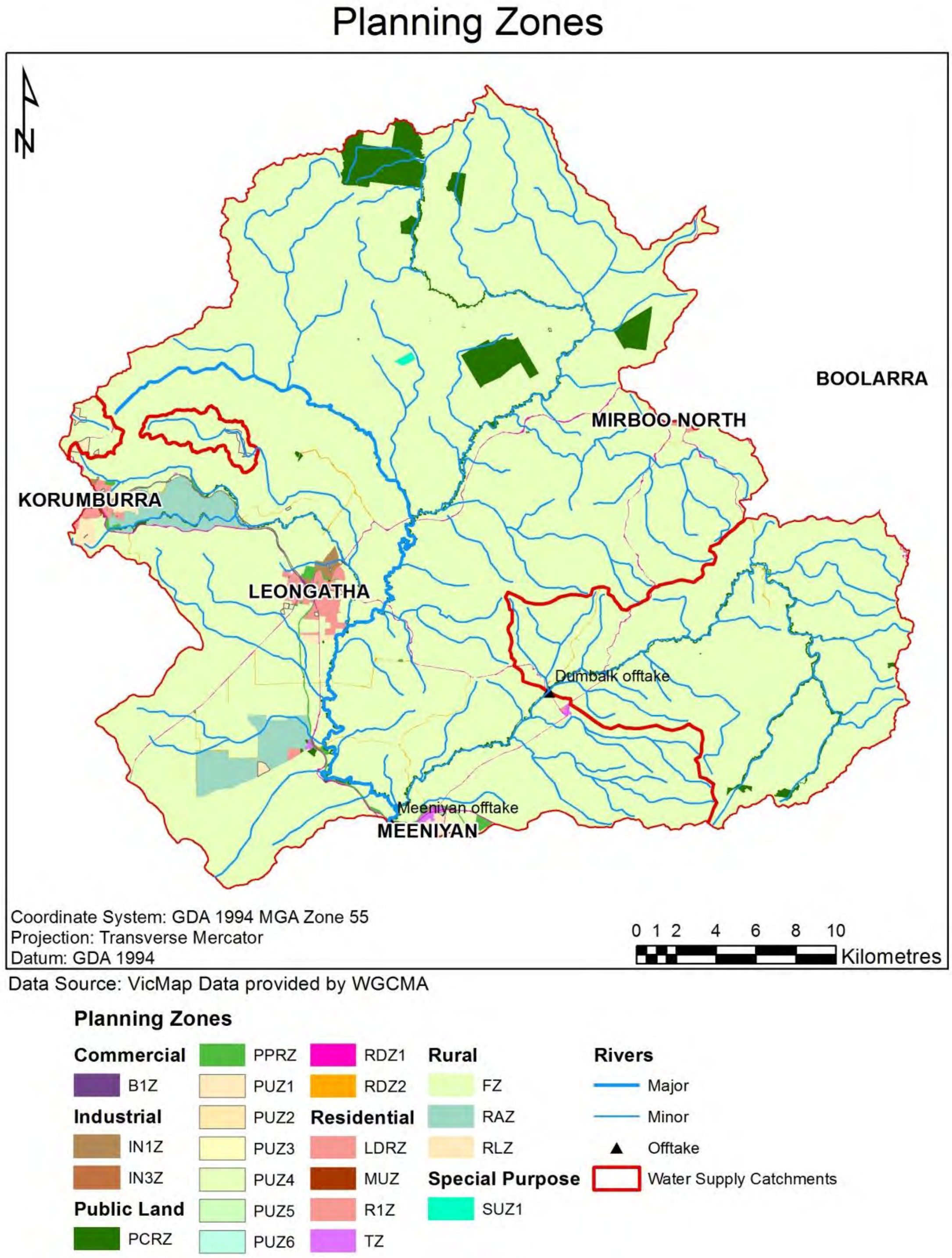


Figure 9-13. Tarwin Water Supply Catchments Planning Zones

Table 9-6. Key to planning zones

Category	Code	Planning Zones Name	Local Government Area
Commercial	B1Z	Commercial 1 Zone	South Gippsland
Industrial	IN1Z	Industrial 1 Zone	South Gippsland
	IN3Z	Industrial 3 Zone	South Gippsland
Public Land	PCRZ	Public Conservation and Resource Zone	South Gippsland, Baw Baw
	PPRZ	Public Park and Recreation Zone	South Gippsland
	PUZ1	Public Use Zone: Service and Utility	South Gippsland
	PUZ2	Public Use Zone: Education	South Gippsland
	PUZ3	Public Use Zone: Health and Community	South Gippsland
	PUZ4	Public Use Zone: Transport	South Gippsland
	PUZ5	Public Use Zone: Cemetery/Crematorium	South Gippsland
	PUZ6	Public Use Zone: Local Government	South Gippsland
	RDZ1	Road Zone: Category 1 Road	South Gippsland, Baw Baw, Latrobe
	RDZ2	Road Zone: Category 2 Road	South Gippsland
Residential	LDRZ	Low Density Residential Zone	South Gippsland
	MUZ	Mixed Use Zone	South Gippsland
	R1Z	Residential Zone 1	South Gippsland
	TZ	Township Zone	South Gippsland
Rural	FZ	Farming Zone	South Gippsland, Baw Baw, Latrobe
	RAZ	Rural Activity Zone	South Gippsland
	RLZ	Rural Living Zone	South Gippsland
Special Purpose	SUZ1	Special Use Zone: Earth and Energy Resources Industry	South Gippsland

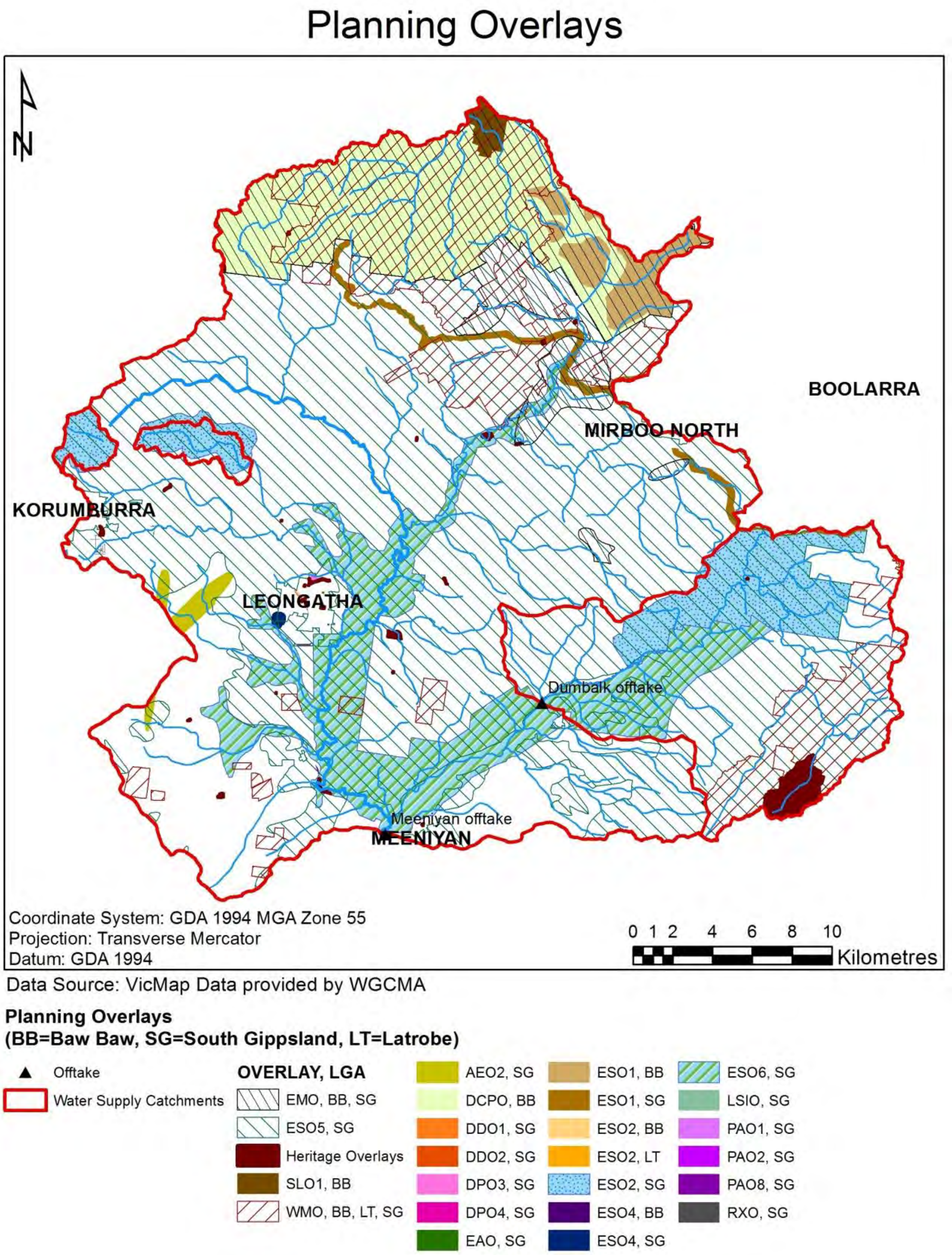


Figure 9-14. Tarwin Water Supply Catchment Planning Overlays

Table 9-7. Key to planning overlay codes

Code	Planning Overlays	Local Government Area
AEO2	Airport Environs Overlay 2	South Gippsland
DCPO	Development Contributions Overlay	Baw Baw
DDO1	Design and Development Overlay 1: Township Approach	South Gippsland
DDO2	Design and Development Overlay 2: Burchell Lane Industrial Precinct	South Gippsland
DPO3	Development Plan Overlay 3: Murray Goulburn Leongatha Factory	South Gippsland
DPO4	Development Plan Overlay 4: LDRZ Development Plan - Simons Lane	South Gippsland
EAO	Environmental Audit Overlay	South Gippsland
EMO	Erosion Management Overlay	South Gippsland, Baw Baw
ESO1	Environmental Significance Overlay 1: High Quality Agricultural Land	Baw Baw
ESO1	Environmental Significance Overlay 1: Areas of Natural Significance	South Gippsland
ESO2	Environmental Significance Overlay 2: Water Catchment Areas	South Gippsland, Baw Baw, Latrobe
ESO4	Environmental Significance Overlay 4: Protection of Giant Gippsland Earthworm and Habitat Areas	Baw Baw
ESO4	Environmental Significance Overlay 4: Sewage Treatment Plant and Environs	South Gippsland
ESO5	Environmental Significance Overlay 5: Areas Susceptible to Erosion	South Gippsland
ESO6	Environmental Significance Overlay 6: Areas Susceptible to Flooding	South Gippsland
HO189	Heritage Overlay: Old Ferndale School No 3571	Baw Baw
HO193	Heritage Overlay: Seaview Hall	Baw Baw
HO212	Heritage Overlay: Strezlecki Railway Embankment at Strezlecki	Baw Baw
HO263	Heritage Overlay: Childers Primary School No 2350 (former)	Baw Baw
HO264	Heritage Overlay: St Stephen's Church of England (former)	Baw Baw
HO265	Heritage Overlay: Childers Methodist Church (former)	Baw Baw
HO10	Heritage Overlay: Knox's Rockhill Farm Complex	South Gippsland
HO102	Heritage Overlay: Merrena Public Hall	South Gippsland
HO11	Heritage Overlay: Turton's Creek Goldfield	South Gippsland
HO112	Heritage Overlay: Stony Creek Mechanic's Institute & Free Library	South Gippsland
HO113	Heritage Overlay: Strezlecki Avenue of Honour	South Gippsland
HO137	Heritage Overlay: Wooreen Avenue of Honour	South Gippsland
HO138	Heritage Overlay: Part Leongatha Secondary College	South Gippsland
HO18	Heritage Overlay: Korumburra Railway Station Complex	South Gippsland
HO22	Heritage Overlay: Mirboo on Tarwin Hall	South Gippsland
HO23	Heritage Overlay: Allambee East Cemetery	South Gippsland
HO24	Heritage Overlay: Allambee Sth State School No 3075 (former)	South Gippsland
HO26	Heritage Overlay: Leongatha Sth State School No 3251 (former)	South Gippsland
HO28	Heritage Overlay: Berry's Creek Honour Avenue	South Gippsland
HO3	Heritage Overlay: Mossvale Park	South Gippsland
HO32	Heritage Overlay: Dollar State School No 3473 (former)	South Gippsland
HO48	Heritage Overlay: Kardella Avenue of Honour	South Gippsland
HO49	Heritage Overlay: Boer War Memorial Oak Trees	South Gippsland
HO5	Heritage Overlay: Part of Korumburra Railway Station Complex	South Gippsland
HO51	Heritage Overlay: Three Railway Bridges over Tarwin River	South Gippsland
HO52	Heritage Overlay: Cluarie	South Gippsland
HO53	Heritage Overlay: Korumburra Post & Telegraph Office	South Gippsland
HO54	Heritage Overlay: Coal Creek Heritage Park	South Gippsland
HO59	Heritage Overlay: Korumburra Strezlecki Memorial	South Gippsland
HO6	Heritage Overlay: Leongatha Mechanic's Institute & Free Library (former)	South Gippsland
HO61	Heritage Overlay: Korumburra Baptist Church	South Gippsland
HO64	Heritage Overlay: Springdale	South Gippsland
HO65	Heritage Overlay: South Gippsland Water Purification Plant	South Gippsland
HO66	Heritage Overlay: Koorooman Avenue of Honour	South Gippsland
HO67	Heritage Overlay: Leongatha Railway Station	South Gippsland
HO68	Heritage Overlay: Leongatha Strezlecki Memorial	South Gippsland
HO69	Heritage Overlay: Canary Island Palms	South Gippsland
HO7	Heritage Overlay: Memorial Hall & Woorayl Shire Offices (former)	South Gippsland
HO70	Heritage Overlay: Leongatha Court House (former)	South Gippsland
HO71	Heritage Overlay: Leongatha Post & Telegraph Office	South Gippsland
HO72	Heritage Overlay: Leongatha Secondary College	South Gippsland

Code	Planning Overlays	Local Government Area
HO76	Heritage Overlay: Leongatha Showgrounds Grandstand and Gates	South Gippsland
HO77	Heritage Overlay: Leongatha World War 1 Memorial Avenue of Honour	South Gippsland
HO8	Heritage Overlay: Leongatha Butter and Cheese Faactory (former)	South Gippsland
HO88	Heritage Overlay: Railway Bridge over Tarwin River	South Gippsland
HO9	Heritage Overlay: Hayes' (PA Dunne's) Store (former)	South Gippsland
HO90	Heritage Overlay: Meeniyan Public Hall	South Gippsland
HO91	Heritage Overlay: Meeniyan & Stony Creek World War 1 Memorial	South Gippsland
LSIO	Land Subject to Inundation Overlay	South Gippsland
PAO1	Public Aquisition Overlay 1: SGSC - Road widening and aquisition	South Gippsland
PAO2	Public Aquisition Overlay 2: VicRoads - Roadworks	South Gippsland
PAO8	Public Aquisition Overlay 8: VicRoads - Proposed highway improvements	South Gippsland
RXO	Road Closure Overlay	South Gippsland
SLO1	Significant Landscape Overlay 1: Strezlecki Ranges	Baw Baw
WMO	Bushfire Management Overlay	South Gippsland, Baw Baw, Latrobe

Appendix 9 – Pathogen Fate Modelling

Cattle pathogen load model

Cattle are a potential source of pathogenic protozoa and bacteria. In the cattle pathogen load model the risks from such sources is modelled using *Cryptosporidium* (protozoa) and *Campylobacter* (bacteria).

For modelling purposes it was assumed that the Grazing Landuse in the Farming Zone was continuously devoted to grazing of beef cattle and stocking rates were based on standard economic stocking practices. Stocking rates were calculated using advice and calculator tools from the Meat and Livestock Australia website (Meat and Livestock Australia 2013a; Meat and Livestock Australia 2013b). Cattle manure production rates were sourced from Ferguson (2005).

Cryptosporidium

Two species of *Cryptosporidium* can commonly infect humans (*C. hominis* and *C. parvum*), however, cattle only support *C. parvum* as well as several other *Cryptosporidium* species that do not pose a significant threat to human health (Kay et al 2012).

C. parvum consists of many strains including a number that are adapted to infect humans. In estimating concentrations of human infectious *C. parvum* in cattle manure the ratio of infectious to non-infectious strains needs to be considered since reported concentrations of *C. parvum* oocysts do not typically distinguish between the different strains (Santín et al 2008).

Key model parameters were *C. parvum* oocyst concentrations in cattle manure, prevalence of infection and proportion of *C. parvum* oocysts that were human infectious, and inactivation rates in manure (Table 9-8). Since bovine cryptosporidiosis is mostly a disease of pre-weaned calves and infection rates and oocyst shedding rates differ greatly with the age of the cattle, different parameter values were used for pre-weaned (0 to 3 months) and post-weaned calves (3-12 months) and for adult cattle (> 12 months).

Oocyst concentrations in manure gradually decline after deposition with the rate of decline greatly influenced by temperature. In the model, inactivation rates were applied to manure that accumulated on the grazing pasture between rainfall events.

Table 9-8. Model parameters for Cryptosporidium and Campylobacter and Cattle stocking rates

Model parameter	Source
Protozoa: *Cryptosporidium parvum*	
Cattle manure loads	
Cryptosporidium concentration/g manure - infected calves	(Davies et al 2005a)
Cryptosporidium concentration/g manure - infected adult (heifer, steer, cow or bull)	(Davies et al 2005a)
Cryptosporidium prevalence - pre-weaned calves (1-3 months)	(Santín et al 2008)
Cryptosporidium prevalence - post-weaned calves (3-12 months)	(Santín et al 2008)
Cryptosporidium prevalence - adult	(McBride et al 2012)
Cryptosporidium human infectious proportion (*C. parvum*) - pre-weaned calves (1-3 months)	(Santín et al 2008)
Cryptosporidium human infectious proportion (*C. parvum*) - post-weaned calves (3-12 months)	(Santín et al 2008)
Cryptosporidium human infectious proportion (*C. parvum*) - adult (considered >12 months)	(Santín et al 2008)
Inactivation rates in cattle manure	
Inactivation coefficient - K	(Davies et al 2005a)
Inactivation formula: $N_t = N_0 \times 10^{-KT}$ [derived from formula = log10(N_t/N_0)= -KT] – different coefficients for infected calves and infected adults (where N_t = estimated concentration after inactivation, N_0 = concentration at time = 0, and T = temperature in °C)	(Davies et al. 2005a; Davies et al. 2005b)
Bacteria: *Campylobacter jejuni*	
Cattle manure loads	
Campylobacter concentration/g manure - infected calf	(Atwill et al. 2012; McBride et al. 2012)
Campylobacter concentration/g manure - infected adult (heifer, steer, cow or bull)	(Atwill et al. 2012; McBride et al. 2012)
Campylobacter prevalence - calf	(Kay et al 2012)
Campylobacter prevalence - adult	(Kay et al 2012)
Campylobacter human infectious proportion - calf and adult	(Kay et al 2012)
Inactivation rates in cattle manure	(Sinton et al 2007b)
Inactivation coefficient - K	(Sinton et al 2007b)
Inactivation formula: see formula used for *Cryptosporidium*	(Davies et al. 2005a; Davies et al. 2005b)
Cattle stocking rates and manure production and transport	
Area of cattle grazing	Measured using GIS land use layer for catchment
Cattle manure production rate per day - adult	(Ferguson 2005) citing (Dorner et al 2004)
Cattle manure production rate per day - calf	(Ferguson 2005) citing (Dorner et al 2004)
Stock density - adult	(Meat and Livestock Australia 2013a; Meat and Livestock Australia 2013b)
Stock density - calf	Calculated estimate based on proportion of yearling stocking
Proportion of calves classified as pre-weaned calves (1-3 months)	(Santín et al 2008)
Proportion of calves classified as post-weaned calves (3-12 months)	(Santín et al 2008)
Manure deposition rates in stream	(Elliott and Harper 2011) citing (McDowell and et al. 2008)

Campylobacter

*Campylobacter*s are frequently shed in the faeces of domestic and wild mammals and wild birds. Cattle are a well-established source of *Campylobacter jejuni* with infection and shedding rates being highest in calves compared to adult cattle (Kay *et al.* 2012).

Campylobacter loads from cattle are also high since cattle are common in agricultural landscapes and excrete large quantities of manure. Although potentially shed in large quantities, the survival rates of *Campylobacter*s in the environment is generally much less than the protozoans and viruses considered in this study and even *E. coli*, as they are more susceptible to die-off due to UV light and warm temperatures (Sinton et al 2007a).

On-site treatment systems model

Humans, by definition, support the widest range of human infectious organisms and human faecal material is considered to be a source of each the pathogens modelled in this study. Failing on-site treatment systems (e.g. septic tanks) are a potential source of human pathogens when effluent pools at the surface where it can be mobilised in rainfall runoff or where it affects shallow groundwater in porous streamside alluvial soils.

From a council perspective on-site treatment systems are deemed to have "failed" and will be subject to compliance action where they do not meet performance standards. Councils also consider the following as indicators of system failure (SGSC 2012):

- Proximity to identified faecal contamination in storm water systems; and
- Emergence of wastewater from adjacent embankments

The on-site systems pathogen model was used to predict subcatchment loads of *Cryptosporidium*, *Campylobacter* and Adenovirus arising from failing on-site treatment systems in the catchment.

Effluent pathogen concentrations

Concentrations of reference pathogens in septic effluent were obtained from the scientific literature (Table 9-10). For viruses, literature values are generally based on DNA studies that use Polymerase Chain Reaction (PCR) as a technique to amplify tiny amounts of viral DNA into detectable quantities. However the PCR technique will also amplify DNA from non-viable virions (individual virus particles) that would not cause infection. Therefore a correction factor must be applied to account for the ratio between PCR Detectable Units (PDU) and Infectious Units (IU). For the on-site treatment systems model IUs were considered to represent individual virions. The studies of de Roda Husman *et al.* (2008) and Rutjes *et al.* (2009) provided guidance on the selection of appropriate ratios of PDU to IU.

The concentration of pathogens in septic effluent from single-dwelling on-site systems depends on the recent infection history of the household residents and is highly variable. For commercial systems servicing a large number of people, effluent pathogen concentrations are more consistent and reflect average rates of prevalence in the community. Since the average concentration of many individual septic tanks would be similar to domestic sewage and due to the difficulty in estimating concentrations for individual tanks, estimates of pathogen concentrations for individual septic tanks was based on literature values for town sewage (Table 9-9).

Table 9-9. *Pathogen loads per L of sewage effluent (for on-site treatment systems failure effects)*

Pathogen	Source
Adenovirus PDU per L of sewage effluent	(Fong et al 2009)
Cryptosporidium oocysts per ml of sewage effluent (*hominis* and *parvum*)	(Rose et al 2004)
Campylobacter jejuni cells per ml of sewage effluent	(Jones 2001)

A variety of environmental mechanisms can cause the reduction of pathogens in surface water including damage to cellular biochemistry by UV light, or free radicals, reactions to naturally occurring antibiotic compounds, predation by heterotrophic microorganisms and invertebrates, dilution due to flushing from upstream flows, and other factors. The most important factor is UV light which inactivates microorganisms by damaging their nucleic acid, thereby preventing them from replicating. A microorganism that cannot replicate cannot infect a host (US EPA 2006).

Empirical inactivation rates for viral and bacterial reference pathogens used in the on-site treatment systems model have been established for freshwater (Table 9-10). The inactivation rates are largely determined by exposure times to UV light, however warmer water temperatures also increase inactivation rates presumably by speeding up rates of temperature dependent microbial and biochemical reactions.

Table 9-10. Viral and bacterial reference pathogen inactivation rate coefficients for freshwater. T_{90} = days for 90% reduction in abundance.

Parameter	T_{90} days	Inactivation rate coefficient: K	Source
Adenovirus	40	0.025	(World Health Organization 2009) citing (Enriquez et al 1995)
Campylobacter - Summer	0.8	1.250	(Sinton et al 2007a)
Campylobacter - Winter	1.58	0.633	

Inactivation rate coefficient K = $(\log_{10}(N_t/N_0)/-t)$ where N_t = concentration at time t and N_0 = initial concentration.

Cryptosporidium

Peng et al. (2008) evaluated the effect of temperature on inactivation of *Cryptosporidium parvum* oocysts in water, soils, and faeces. Based on inactivation coefficient (K) values obtained from studies with temperatures in the range of 4 to 37°C, which covers most situations in the aquatic environment, Peng et al. proposed that the relationship between K and temperature can be represented by an exponential function, as follows:

$$K_T(T) = K_4\, e^{\lambda(T-4)}$$

where K_4 and K_T are the die-off rate coefficients at 4°C and temperature T, respectively, and λ is a dimensionless modifier of temperature (Table 9-11).

Table 9-11. Cryptosporidium inactivation rates in freshwater (river water)

Medium	K4 (day-1)	λ	T (°C)	KT	Source
River water	0.0093	0.095	20	0.0425	(Peng et al 2008)

Appendix 10 – Estimating *Campylobacter* concentrations as a ratio to *E. coli* concentrations

Calculations for cattle manure

Average calculated from a lognormal distribution

Campylobacter concentration/g manure - infected calf (N_0)	80000	no.g-1	Estimated from spread of study findings reported by McBride *et al.* (2012) table A10.1, see also Atwill *et al.* (2012)
Campylobacter concentration/g manure - infected adult (heifer, steer, cow or bull) (N_0)	600	no.g-1	

E. coli concentration/g manure - infected cattle (calf) (N_0)	64,500,000	no.g-1	Estimated from NSW Animal Faecal Survey (Table a1) by Davies *et al.* (2005a)
E. coli concentration/g manure - infected cattle (heifer, steer, cow or bull) (N_0)	5,500,000	no.g-1	

Ratio

Calf	0.124%	Assume most *Campylobacter* and *E. coli* come from calves
Adult	0.011%	

Example

Observed	*E.coli*	1000	no. L
Predicted	*Campylobacter*	**1.240**	no. L