SINCLAIR KNIGHT MERZ
SKM

Moorabool River Water Resource Assessment

FINAL REPORT

- Final 1
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Executive Summary

This project

This project was initiated by the Corangamite Catchment Management Authority (CCMA) in recognition of the Moorabool River as a stressed river. The objectives of the project are to:

- estimate the impact of water use and entitlement (full uptake of licenses) on "natural" flow conditions;
- provide an assessment of water requirements for human uses and the environment;
- identify options for improving streamflow for the environment; and
- evaluate and recommend options to achieve the environmental flow requirements.

A Technical Reference Group and a Community and Stakeholder Reference Group was established to review and discuss findings and outcomes from this study.

This Report

The project was divided into three stages.

- Background Stage — Collation and assessment of background information
- Stage A — Catchment modelling and identification of options to enhance environmental flows
- Stage B — Assessment and shortlisting of options

This Final Report consolidates the work of all three stages and includes all information contained in the earlier Background Report and Stage A Report.

BACKGROUND

The Catchment

The Study Area

The Moorabool River Catchment covers an area of approximately 2000 km^2 extending from the Great Dividing Range near Ballarat to the Barwon River, south west of Geelong (SRW, 1997). The east and west branches of the Moorabool River rise in the southern ranges of the Wombat State Forest. Each branch flows in confined valleys to their confluence near Meredith (CCMA, 2000b). Below the confluence of the upper branches, the Moorabool River continues to flow through a tightly confined valley that broadens downstream but occasionally narrows markedly to its confluence with the Barwon River at Fyansford near Geelong.

Land Use

Approximately 75 per cent of the Moorabool River catchment is used for agriculture. Most (99%) of this agricultural land is used for dryland farming. It consists of sheep and cattle grazing, although cereal production is also important (SRW, 1997). In the upper reaches of the catchment, (upstream of Lal Lal Reservoir) beef cattle are grazed and irrigated vegetables (potatoes) are grown (Zampatti and Grgat, 2000). Further south, sheep grazing and cropping dominate with some viticulture around Bannockburn and vegetable growing between Batesford and Fyansford (SRW, 1997; Zampatti and Grgat, 2000).

Water Resource Management

Water in the Moorabool catchment is drawn upon for many uses, including:

- supply to the townships of Ballarat and Geelong;
- groundwater pumping;
- interception by farm dams;
- private diversions.

Some users are subject to constraints such as those set out in Bulk Entitlements (i.e. volumes of extraction and passing flow requirements) applying to urban extraction, as well as various restriction rules applying to both urban and rural diverters.

Hydrology

Flow in most parts of the catchment is highly modified. The existence of a number of major storages, in conjunction with significant extraction, has reduced the magnitude, variability and frequency of downstream flows. The reach between Lal Lal Reservoir and She Oaks Weir is used as a conduit to transfer water in summer, resulting in artificially high flows at this time of year.

Environmental Assets

Environmental assets in the Moorabool River catchment include a number of native freshwater fish species such as the Victorian *Flora and Fauna Guarantee Act 1988* listed Australian Grayling. The highest diversity of native freshwater fish species occurs downstream of Batesford and only one native fish species has been recorded on the west (Mountain Galaxias) and east (Short-finned Eel) branches. The condition of riparian vegetation in the Moorabool Catchment ranges from extensively cleared in the upper reaches to more densely scattered native remnants in the mid and lower reaches. Lack of streamside vegetation and invasion by exotic species such as willows and Gorse have been identified as significant issues in the catchment. Water quality in the catchment is monitored by the Victorian Water Quality Monitoring Network and Barwon Water. Results indicate high nutrient concentrations throughout the catchment, and high electrical conductivity in the lower reaches from groundwater inflow. Macroinvertebrate communities in the vicinity of She Oaks appear to be indicative of moderate environmental condition.

Socio-Economic Assets

Economic assets include water supply for farming, towns and industry. The region also attracts tourism, as well as value adding agricultural industries. Towns in the region also provide 'lifestyle' properties for city dwellers.

There are a range of social assets in the catchment including recreational assets such as parks, picnic areas, lookouts, swimming holes, fishing areas and wineries. There are also assets with heritage value such as historic bridges. The catchment has a high aesthetic value for its residents and visitors.

Key Issues in the Catchment

- Over-allocation of water;
- Significant and increasing urban water use;
- Impact of farm dams on flows;
- Impact of groundwater extraction on flows;
- Suitability of passing flows specified in existing Bulk Entitlements;
- Protection of remaining areas with significant environmental values in the catchment.

Climate Change

The study investigated catchment behaviour under both current climatic conditions and under projected climate change conditions. Based on work by CSIRO, the projected impact of climate change in the Moorabool Basin in 30 years time is a 1.5% reduction in annual rainfall and a 7.7% increase in annual evaporation. Modelling has shown that this will result in a reduction in inflows of 9%, an increase in urban demands of 4.5% and an increase in irrigation demands of 11%.

Groundwater and Surface Water Interaction

It is understood that there is extensive groundwater use in the upper west part of the catchment. The degree to which this affects surface water flows was considered as part of this study.

The assessment indicated strong interaction between surface water and groundwater in the upper west Moorabool catchment. Groundwater was found to contribute a large proportion of the baseflow to streams. On the basis of this work, it was assumed for modelling purposes that 60% of groundwater extractions come from baseflow in the Moorabool River.

It should be noted that new (higher) metered usage data for 2002/03 became available after this assessment was completed. This data does not change the fundamental conclusions of this report.

Farm Dam Impacts

It was found that farm dams, defined in this study as dams in the landscape not licensed as winterfill storages, were also impacting on inflows. Aerial photos show a large number (and hence volume) of farm dams spread throughout the catchment. The following table summarises the distribution of farm dams in the catchment.

- **Summary of Farm Dams**

Subarea	Catchment Area (km²)	Number of Farm Dams	Volume of Dams (ML)
Upstream of Moorabool Reservoir	29	65	146
Upstream of Moorabool Channel / pipeline	45	238	1,323
Between Moorabool and Lal Lal Reservoir	42	190	904
Tributaries upstream of Lal Lal Reservoir	174	1,283	3,686
Upstream of Korweinguboora and Bostock Reservoir	127	398	1,009
Between Lal Lal Reservoir, Bostock Reservoir and Morrisons	218	672	3,109
Between Morrisons gauge and Batesford gauge	537	1,927	4,224
TOTAL	**1,172**	**4,773**	**14,401**

This information was used to model the impact of farm dams on inflows throughout the catchment. The results of this work were included in the catchment model.

CATCHMENT MODELLING

The REALM Model

The resource allocation model (REALM) simulates the distribution of water within a system on a daily, weekly or monthly timestep. The model is capable of simulating all elements of a system including storages, river reaches, pipes and channels, urban demands and restriction policies, irrigation demands including allocation policies, rainfall and evaporation effects on storage and river losses. REALM can incorporate complex system operating rules such as storage targets, multi-year caps and capacity sharing.

SKM

A REALM model of the Moorabool system was developed to determine current and natural flows to assist with environmental flow recommendations, and to "test" the impact of flow improvement options.

SKM had previously built a weekly model of the Moorabool system for Southern Rural Water (SRW). As part of this project, the period of record was updated to 2002 and more detail was added to the model configuration. These additions included the representation of the impact of farm dams and groundwater extractions on streamflow and the addition of the weirs below She Oaks. Key assumptions incorporated in the modelling include the assumption that all onstream storages pass summer flows.

The updated model was calibrated to recorded data, and then used to generate "base case" results. The base case is defined as the system operating under current operating rules, with demands at current level of development, over the 1965 to 2002 climatic period. The resulting average annual demand supplied is shown below.

- **Summary of Supplied Demands (from base case REALM model)**

Demands	Average Annual Supplied Demand (ML)
Central Highlands Water	16,619
Farm dams	12,262
Barwon Water	7,637
Groundwater	1,248*
Private Diverters	1,168
TOTAL	**38,934**

* estimated current impact on surface water

Current and Natural Flows

Outputs from the REALM model were used to derive current and natural flows at key locations. Weekly model output was converted to a daily timestep by using the pattern of flows recorded historically. These flows were used to help develop environmental flow recommendations.

A 92% security of supply (defined as percentage of years without restrictions) was determined for Central Highlands Water (CHW), while a 94% security of supply was calculated for SRW (defined as percentage of restricted demand supplied). Security of supply could not be calculated for Barwon Water as restriction rules were not included in the model. This was because the restriction rules for Barwon Water depend on water available in both the Moorabool and the Barwon catchments. The Barwon catchment is not included in the model.

Environmental Flow Requirements

Environmental flow requirements have been determined for the four reaches in the Moorabool River. The reaches are:

- Reach 1 – Bostock Reservoir downstream to the confluence with the west Moorabool River;
- Reach 2 – West Moorabool River between Moorabool and Lal Lal Reservoirs;
- Reach 3 – West Moorabool River below Lal Lal Reservoir to She Oaks;
- Reach 4 – Moorabool River below Sharp Road She Oaks.

The FLOWS method was used for the development of the recommendations for environmental flows, which are linked to a series of environmental objectives for each reach. The environmental flow recommendations are summarised in the following table, with the detailed objectives and rationale in the body of the document. Flow recommendations are developed for each of the critical flow components in each reach.

- **Summary of environmental flow requirements**

Reach	Cease to Flow	Summer Low	Summer Fresh	Winter Low	Winter Fresh	Winter High
Reach 1	Max 2 times for 30 days	NR	> 2 ML/day, min 2 times for 10 days	8 ML/day – Jun - Nov	> 37 ML/day, min 2 times for 10 days	> 641 ML/day, annual for 1 - 3 days
Reach 2	Max 2 times for 8 days	4 ML/day – Dec - May	> 7 ML/day, min 4 times for 7 days	22 ML/day – Jun - Nov	> 40 ML/day, min 3 times for 10 days	> 525 ML/day, annual for 1 - 2 days
Reach 3	Annual for 10 days	20 ML/day – Dec - May	> 31 ML/day, 3 times for 10 days	83 ML/day – Jun - Nov	> 146 ML/day, 2 times for 5 days	> 3000 ML/day, annual for 1 - 2 days
Reach 4	NR	21 ML/day – Dec - May	> 32 ML/day, 3 times for 10 days	86 ML/day – Jun - Nov	> 162 ML/day, 3 times for 10 days	> 3000 ML/day, annual for 1 - 2 days

NR – no recommendation was made, because flow component not relevant

Ramp rate recommendations are provided as a factor of the previous days flow. For example a recommended rate of rise of 1.3 stipulates that flow on a given day should not exceed 1.3 times the previous day’s flow. The recommended ramp rates should be applied to any change in flow, including changes from high to low flow seasons, freshes and high flows. The recommended ramp rates for the Moorabool are rise of 1.3 and fall of 0.8.

SKM

Options for Improving Streamflow

Two tasks were undertaken to determine options for improving streamflow. Firstly, a range of criteria were developed against which different options could be measured. These criteria were sent to the Technical Reference group for comment, and were discussed for approval by the Community and Stakeholder Reference Group. Once the 6 criteria were adopted, reference group members were asked to give a weighting to each criteria to indicate its relative importance. The following table summarises the weightings assigned by the reference groups.

- **Criteria Prioritisation**

Criteria	Weighting (/100)
1. Protect and improve the riverine environment	26.8
2. Maintain security of supply for users	21.0
3. Minimise financial cost	10.3
4. Add value to the region	9.7
5. Ensure long-term viability	21.4
6. Have no impact outside the catchment	10.9

Secondly, a brainstorming meeting was held to come up with ideas for enhancing flows. These ideas were discussed at a meeting of both reference groups and a shortlist of 10 "A" options was agreed on for assessment. The following table summarises these options.

- **A Options**

No	Description
25	Encourage conjunctive use
27	Reallocation from savings due to demand management across all consumptive users other than the environment
1	Enhance flows passed downstream from major storages
2	Connect Barwon Water to the Upper Werribee system and buy/trade back some of their share of Lal Lal
3a	Find an augmentation option for Ballarat and get back part of Moorabool or Lal Lal Reservoir: - Bores (west of Ballarat)
8	Buy back licences/sleepers
20	Transfer Ballarat Sth recycled water into Moorabool Basin
23	Farm dams to pass summer flows
26	Potable Water substitution for Ballarat
28	Environmental Water Allocation

ASSESSMENT OF OPTIONS

Option Assessment

Each option was investigated in terms of its:

- Impact on security of supply;
- Environmental costs and benefits;
- Socio-economic costs and benefits;
- Financial costs and benefits.

Results of these investigations were used to score each option between 0 and 1 for each of the 6 criteria. The weightings given above were used to obtain a single representative figure for each option.

The options were then ranked in two ways, first based on the weighted single figure, and second by using dominance theory (i.e. the number of criteria for which the option ranked highly).

- **Ranked Options**

Option		Weighted Ranking	Dominance Ranking	Average Ranking
23	Farm dams to pass summer flows	1	1	1
27	Shared savings	2	4	3
3a	Ballarat bores	3	3	3
25	Conjunctive use	7	2	4.5
2	Connect to Upper Werribee	4	5	4.5
28	Environmental water allocation	5	8	6.5
	Base Case	6	9	7.5
8	Buy back licences / sleepers	9	7	8
26	Ballarat potable water substitution	10	6	8
1	Environmental flows	8	11	9.5
20	Ballarat Sth recycled water	11	10	10.5

Conclusions

In summary:

- Implementing the environmental flow requirements reduces security of supply, mostly for sources supplied from Lal Lal Reservoir and downstream;

- Implementing options to improve environmental flows makes small improvements to system performance but are not able to restore the current (base case) security, or supply full environmental flows recommendations;
- All options are very similar in terms of environmental benefits;
- There is real potential to achieve environmental flow benefits in the upper catchment;
- Positive recreation and aesthetic values result from most options, negative impacts on wineries in the lower catchment for some options;
- All options are of relatively high cost (well above the cost of permanent water);
- Results are driven by the scoring of the subjective criteria.

If further investigation into these options is undertaken it is recommended that more work be done in consultation with the community to refine the weighting and scoring of the more subjective criteria. It is also recommended that a realistic upper limiting cost be established to eliminate expensive options.

Future Work

A range of work is described in Section 15 regarding improving and refining the system model. Work is also recommended relating to the improvement and furthering of option assessment. These include:

- Assessment of B options
- Re-run Option 28 with a different set up
- Reconciliation of weightings for criteria 1 and 2 - The difference of opinion between interest groups in regard to the first two criteria is not unexpected, but should be recognised as a potential stumbling block in getting stakeholder agreement on actions. It is recommended that as part of any future work some further discussion is undertaken with stakeholders on the relative importance of these criteria in an attempt to reduce the disparity in weightings.
- Scenario modelling using combined options - The aim of this task would be to attempt to achieve security and environmental flow targets by combining options. This was discussed with Stakeholders at the October 2003 meeting and the following targets were suggested:

Environmental Flows	95% achieved at upper catchment sites
	60% achieved at lower catchment sites
Demand Security	90% of current demand supplied (Target A)
	Current security minus 5% (Target B)

- Refinement of weightings and scoring for subjective criteria 4 and 6 - As the results for the highest ranking options is similar for the easily quantified criteria such as security, the final ranking is being driven by the weight and scoring given to more subjective criteria. If further investigation into these options is undertaken it is recommended that more work be done in consultation with the community to refine the weighting and scoring of the more subjective criteria.

- Establishment of an upper limiting cost - The costings for each of the options assessed were consistently high. It is recommended that a realistic upper limiting cost be established to eliminate expensive options.
- Winter Fresh for Reach 1 – this was specified incorrectly in the REALM model and should be corrected as part of any future work. It should be noted that this will not effect the option assessment at the relative differences between options would be the same.

1. Introduction

There is an increasing awareness in water resource management of the need to incorporate the environmental requirements of ecosystems into the water resource planning process. Implementation of the 1994 Council of Australian Governments (COAG) agreement ensured the environment was seen as a legitimate water user. Further to this, the Victorian River Health Strategy (NRE, 2002b) provides a framework that aims to maintain and, where possible, restore the environmental values of rivers and wetlands, whilst recognising existing entitlements.

Environmental flows are often considered to be flows that maintain the natural variability in stream discharge. They are important for both ecological and geomorphological processes such as the removal of nutrients and sediment from catchments, life history strategies and subsequent recruitment of native fish, macrophyte and macroinvertebrate species (NRE, 2002a). Alterations to natural flow regimes can have a significant impact on riverine ecosystems and the determination of environmental water requirements is a key part of the water resource planning process.

The Moorabool River is considered one of the most heavily committed and therefore flow stressed rivers in Victoria due to the high competition between utilitarian and environmental needs for water. The Moorabool River is the primary source of water for Ballarat and a major source of water for Geelong and surrounding areas. There are also numerous on-stream and off-stream farm dams located in the upper catchment and licensed diversions in the lower catchment including some from a series of on-stream weirs. There is extensive use of groundwater in the upper catchment. As demands on the resource increase, the deficiencies of the current system of water allocation have become apparent and the impacts on the health of the Moorabool River have become more significant.

A streamflow management plan process was initiated for the Moorabool Catchment a number of years ago but was halted. A background paper was produced as part of that study in which an assessment of the environmental water requirements of the Moorabool River was undertaken. It specified minimum environmental flows on the Moorabool River above Lal Lal Reservoir and at Batesford near the junction of the Barwon River. Meeting the recommended environmental flows was found to significantly affect the reliability and quantity of supply to consumers, indicating that the water in Moorabool Basin is already over-committed.

In light of this information, the Corangamite Catchment Management Authority (CCMA) initiated the Moorabool River Catchment Project after receiving funding under the National Action Plan (NAP) Priority Project. The NAP Priority Action Project is made up of four major sub-projects, the water resource assessment, lower Moorabool on-stream storage investigation, upper catchment on-stream storage assessment and high priority riparian re-vegetation program. This report relates specifically to the water resource assessment project.

The objectives of the project are to:

- estimate the impact of use and entitlement on 'natural' flow conditions;
- provide an assessment of environmental and user needs;
- identify options for improving streamflow; and
- evaluate and recommend options to achieve the environmental flows required.

The development of options relies on a review of previous water resource investigations undertaken in the Moorabool River Catchment and consultation with stakeholders and relevant water authorities to:

- characterise the major environmental assets, social assets, infrastructure and current land use in the catchment;
- summarise existing limits on water use and passing flow requirements;
- review and quantify water use and licensed volumes;
- assess the likely effects of climate change on demands and streamflows in relation to the provision of environmental flows;
- examine interactions between groundwater and surface water;
- review, refine and update the previous REALM model;
- determine the downstream effects of farm dam impacts on streamflows;
- assess the current and natural flows; and
- determine desirable environmental flows.

Communication Arrangements

Two reference groups have been established by the CCMA for this project. The Technical Reference Group was established to review the technical details of work undertaken. A Community and Stakeholder Reference Group was also set up to ensure the needs and wants of all stakeholders are taken into account.

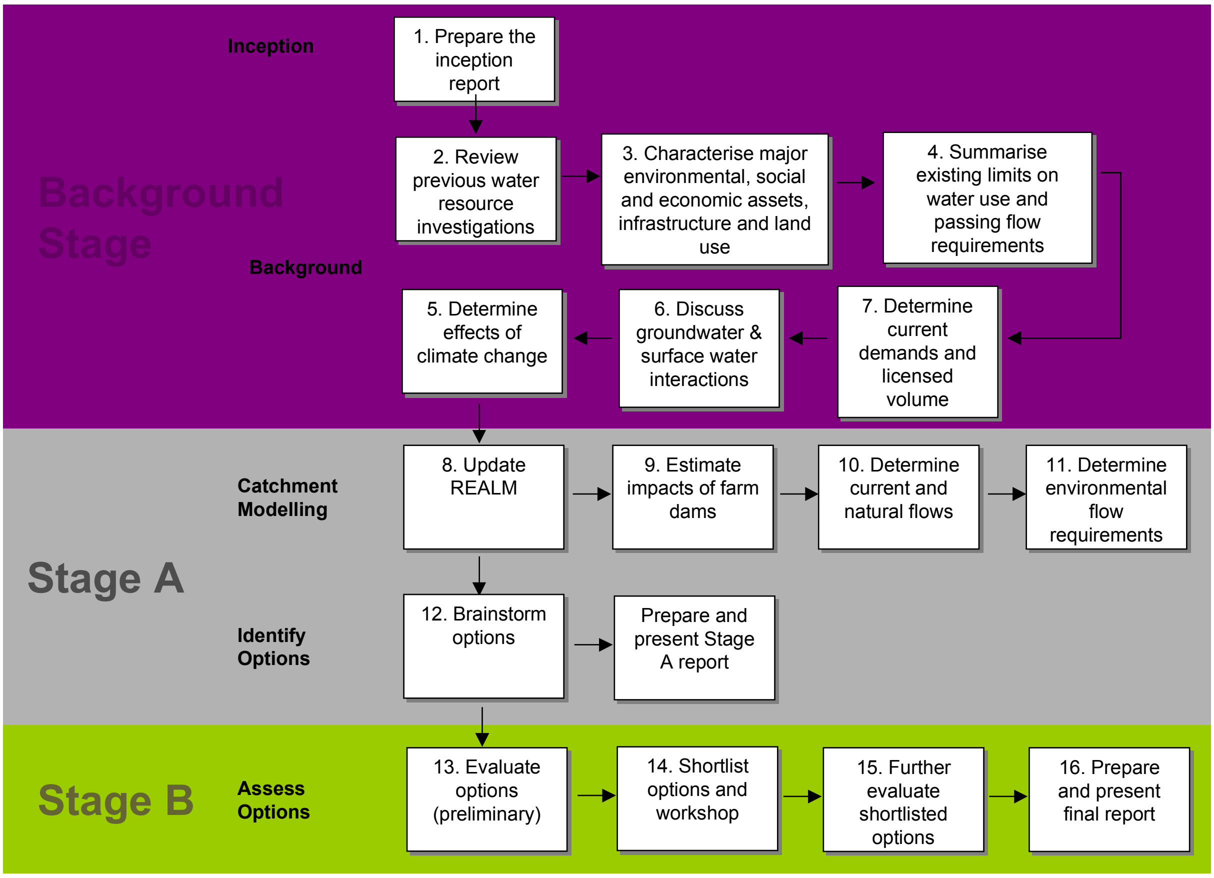
This Project

The project was split into three stages, as shown in Table 1-1 and Figure 1-1.

Table 1-1: Project Stages

Stage	Description	Output
Background	Collation and assessment of background information	Background Report
Stage A	Catchment modelling and identification of options to enhance environmental flows	Stage A Report
Stage B	Assessment of options	Final Report

Figure 1-1: Project Stages



Accordingly this report is also broken up into three sections. The first section, “Background”, identifies and reviews the available background information on the catchment including environmental and social values in the study area. It assesses critical knowledge gaps and considers key issues for determining the environmental water requirements of the study area.

The second section, “Stage A”, includes the details and results of system modelling and the determination of environmental flows, along with suggested options to enhance environmental flows, and criteria that could be used to assess these options.

The third section of the report, “Stage B”, contains results of the option assessment, recommendations arising from this study and a discussion of future work.

BACKGROUND

2. The Moorabool River Catchment

2.1 Study Area

The Moorabool River Catchment covers an area of approximately 2000 km^2 extending from the Great Dividing Range near Ballarat to the Barwon River, south west of Geelong (SRW, 1997). The east and west branches of the Moorabool River rise in the southern ranges of the Wombat State Forest. Each branch flows in confined valleys to their confluence near Meredith (CCMA, 2000b). Below the confluence of the upper branches the Moorabool River continues to flow through a tightly confined valley that broadens downstream but occasionally narrows markedly to its confluence with the Barwon River at Fyansford near Geelong (Figure 2-1).

2.2 Landuse

Within the Corangamite Region, the majority of land associated with each waterway is used for agriculture (Table 2-1). The agricultural enterprises are dairy, beef, cereals, sheep, egg and poultry farming. In comparison to other waterways in the region, land associated with the Moorabool River has the highest percentage of minimal use (mainly crown land) and one of the lowest for forestry.

- **Table 2-1 Percent landuse per waterway in the Corangamite Region (CCMA, 2002).**

Land use	Moorabool River	Barwon River	Lake Corangamite	Otway Coast
Nature conservation	4.5	2.0	12.0	14.5
Minimal use (mainly crown land)	11.7	3.0	1.5	8.3
Forestry	3.3	9.0	2.5	22.4
Livestock grazing	39.1	42.3	38.9	26.5
Dryland agriculture	33.7	35.9	43.0	26.6
Irrigated agriculture	0.4	0.5	0.6	0.4
Built environment	7.3	6.8	1.1	0.6
Water	0	0.3	0.4	0.2
TOTAL	100	100	100	100

In the Moorabool River Catchment approximately 75 % of the total area is used for agriculture, most of which (99%) is dryland farming (Table 2-2). It consists of sheep and cattle grazing, although cereal production is also important (SRW, 1997). In the upper reaches of the catchment (upstream of Lal Lal Reservoir) beef cattle are grazed and irrigated vegetables (potatoes) are grown (Zampatti and Grgat, 2000). Further south, sheep grazing and cropping dominate with some viticulture around Bannockburn and vegetable growing between Batesford and Fyansford (SRW, 1997; Zampatti and Grgat, 2000).

Table 2-2 Landuse data for the Moorabool River Catchment (Land and Water Australia, 2002).

Land use	Area (ha)
Non-agricultural area	47,191
Agricultural area	176,081
Irrigated agricultural area in 1996/97	1,760
Dryland agricultural area in 1996/97	174,322
TOTAL	233,272

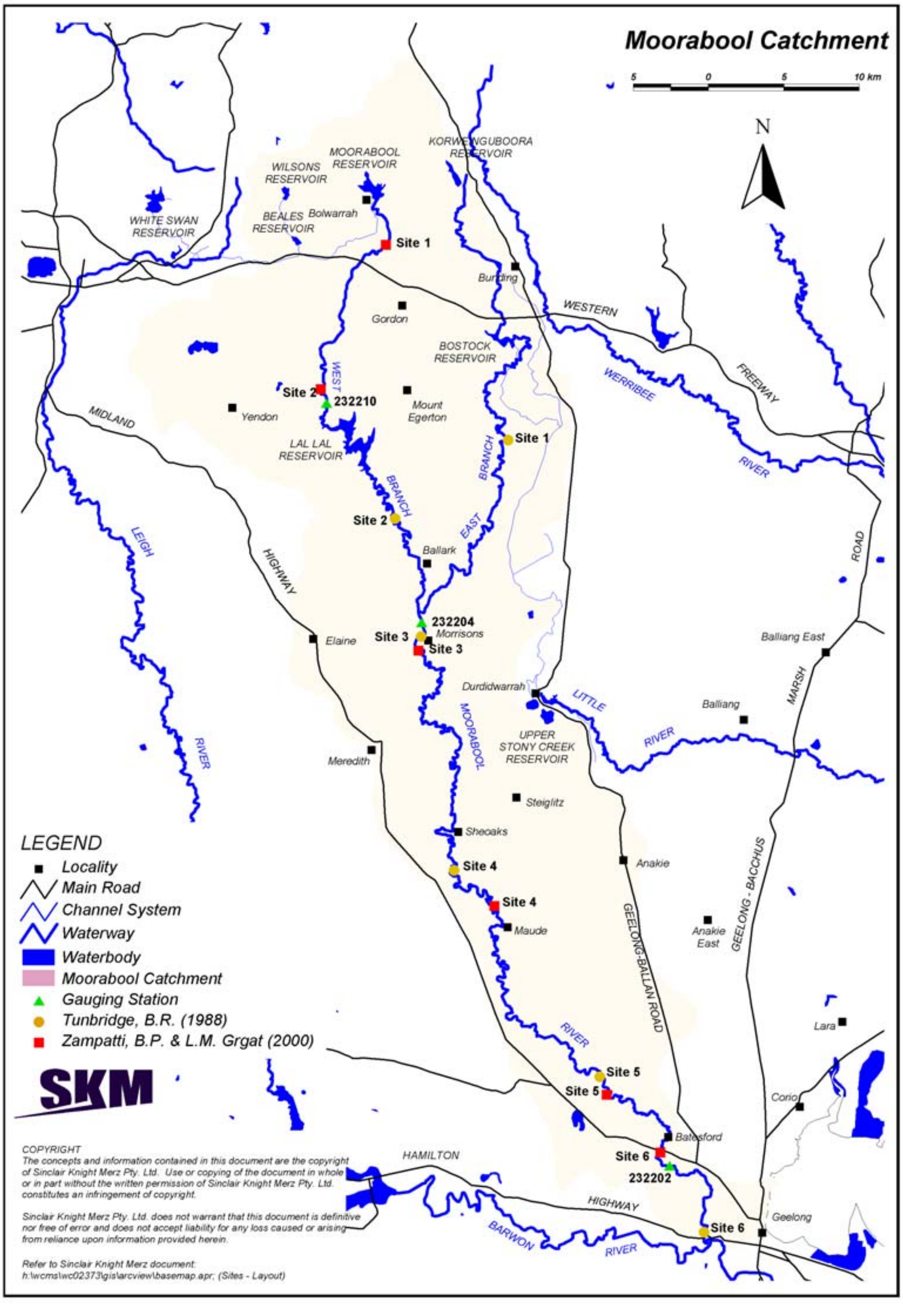


Figure 2-1 Moorabool River Catchment showing location of stream gauging stations and previous environmental flow assessment sites.

2.3 Water Resource Management

2.3.1 System Infrastructure and Operation

There are three major storages on the headwaters of the Moorabool River. They are the Moorabool Reservoir (capacity = 6,740 ML) and Lal Lal Reservoir (capacity = 59,550 ML) on the West Moorabool River and Bostock Reservoir (capacity = 7,460 ML) on the East Moorabool River. The smaller Korweinguboora Reservoir (capacity = 2,091 ML) is also located on the headwaters of the East Moorabool River (Figure 2-1).

On the East Moorabool River, releases from Korweinguboora Reservoir flow eight kilometres down the river to Bolwarra Weir. At Bolwarra Weir, the flow is diverted into the Ballan Channel that carries the water 37 kilometres to the Upper Stony Creek Reservoirs. Water from Bostock Reservoir is transferred to the Upper Stony Creek Reservoirs via the 10 kilometre Bostock Channel that connects with the Ballan Channel. Water is supplied by a gravity pipeline from the Upper Stony Creek Reservoirs to Geelong (Montpellier Basins) and Bannockburn district via the She Oaks Weir, Moorabool Water Treatment Plant, and the She Oaks-Montpellier Pipeline.

In the West Moorabool system, flows are diverted from Moorabool Reservoir through a pipeline and open channel system to White Swan Reservoir, the major offstream storage for Ballarat. The channel also collects water released from Wilsons and Beales Reservoirs (1013 ML and 415 ML respectively) which are small storages located in the upper reaches of Lal Lal Creek, a tributary of the West Moorabool River. The pipeline and channel also have the facility to collect flow from a number of watercourses that intersect them. Water from White Swan is treated and supplied to a regional water supply system known as the Ballarat Water supply System. This includes Ballarat, Creswick, Ballan, and a large number of small towns up to 50 km from Ballarat.

Lal Lal Reservoir is located on the West Moorabool River south east of Ballarat. It is the largest reservoir in the basin and its resources are shared by Barwon Water and Central Highlands Water. The storage is managed by Central Highlands Water. The stored water is shared between the Ballarat Water Supply System and systems operated by Barwon Water that include Geelong and smaller towns including Meredith, Lethbridge and Bannockburn. The reservoir is managed on a capacity share system in accordance with the Bulk Entitlements of the two authorities. Central Highlands Water is entitled to two-thirds of the yield for supply to the Ballarat System, and Barwon Water is entitled to the remaining third.

Central Highlands Water operates a water treatment plant at the Lal Lal Reservoir from which treated water is pumped into the Ballarat system to supplement the supply from White Swan Reservoir. A separate supply is pumped from the Moorabool River about 20 km downstream of Lal Lal Reservoir by Barwon Water to the Meredith treatment plant to serve the towns between Meredith and Geelong.

The confluence of the east and west Moorabool systems is just north of Morrisons township. She Oaks Weir is the first major weir below this confluence. Water released from Lal Lal Reservoir is diverted at She Oaks Weir and pumped to the Moorabool water treatment plant. It is then piped 37 km in the She Oaks – Montpellier Transfer Main to the Montpellier service basin. This water is blended with the Barwon Water supply at Montpellier Basins and supplied to customers in Geelong and northern towns such as Lara, Anakie, and Staughton Vale.

The key infrastructure assets involved in the operation of the system are summarised in Table 2-3.

Table 2-3 Key Infrastructure assets related to Moorabool Basin.

Infrastructure type	Name	Capacity	Other comments
Storage	Bostock Reservoir	7,500 ML	Constructed 1875, enlarged 1954* **Authority** - Barwon Water
Weir	Bolwarra Weir	122 ML	**Authority** - Barwon Water
Storage	Korweinguboora	2,091 ML	Constructed 1910* **Authority** - Barwon Water
Storage	Lower Stoney Creek	267 ML	**Authority** - Barwon Water
Weir	She Oaks Weir	150 ML	**Authority** - Barwon Water
Storage	Upper Stoney Creek	3,443 ML	**Authority** - Barwon Water
Storage	Upper Stoney Creek	2,345 ML	**Authority** - Barwon Water
Storage	Upper Stoney Creek	3,706 ML	**Authority** - Barwon Water
Storage	Beales Reservoir	415 ML	**Authority –** Central Highlands Water
Storage	Kirks Reservoir+	400 ML	**Authority –** Central Highlands Water
Storage	Gong Gong Reservoir+	1902 ML	**Authority –** Central Highlands Water
Storage	Pincotts Reservoir+	218 ML	**Authority –** Central Highlands Water
Storage	Moorabool Reservoir	6,737 ML	Constructed 1915* **Authority –** Central Highlands Water
Storage	Wilsons Reservoir	1,013 ML	**Authority –** Central Highlands Water
Storage	White Swan Reservoir	14,325 ML	Constructed 1952* **Authority –** Central Highlands Water
Storage	Lal Lal Reservoir	59,549 ML	Jointly managed by Barwon Water and Central Highlands Water. Constructed 1972*
Pumping station	She Oaks	65 ML/d	-
Pumping station	Meredith		-
Water Treatment Plant	Lal Lal		Supplying Ballarat water supply system** which includes Ballarat and towns within a 50km radius. **Process –** Dissolved air flotation filtration **Authority –** Central Highlands Water
Water Treatment Plant	White Swan		Supplying Ballarat water supply system** which includes Ballarat and towns within a 50km radius.

SKM

Infrastructure type	Name	Capacity	Other comments
			Process – Dissolved air flotation filtration **Authority –** Central Highlands Water
Water Treatment Plant	Moorabool WTP	65 ML/d	Supplied from She Oaks Reservoir and Lower Stoney Creek Reservoir supplying Montpellier Basins. **Process –** dissolved air flotation filtration. **Authority –** Barwon Water
Water Treatment Plant	Meredith	2.5 ML/d	**Process –** Microfiltration **Authority** - Barwon Water
Pipes	Moorabool Pipeline	15 ML/d	**Authority –** Central Highlands Water
Channels	Moorabool Channel	140 ML/d	**Authority –** Central Highlands Water
	Ballan Channel	35 ML/d	**Authority** - Barwon Water
	Bostock Channel	27 ML/d	**Authority** - Barwon Water

* Source: Water Victoria - A Resource Handbook (Department of Water Resources Victoria, 1989)
+ These storages are not within the Moorabool Basin however are part of the supply system sourced from the basin
**The system stretches from Ballan in the east to Skipton in the west and from Creswick South to Rokewood. In the event of a failure of one of the two plants serving the Ballarat system the other plant can supply the full industrial and domestic demand of the system, providing a valuable emergency back up.

2.3.2 Bulk Entitlement Operating Rules

The Bulk Entitlement (BE) requirements (for the riverine environment and downstream users) influence the operation of the Moorabool system. The BE specifies a maximum volume of extraction, a passing flow, and where appropriate a maximum rate of extraction. BEs exist for the Upper West Moorabool System, Lal Lal Reservoir, She Oaks Weir, Meredith Pump Station and the Upper East Moorabool System and are provided below.

Bulk Entitlement Volumes

Upper West Moorabool System – 10,500 ML/yr
Lal Lal Reservoir (Barwon Water) – 21,000 ML over 3 years
Lal Lal Reservoir (Central Highlands Water)- 42,000 ML over 3 years
She Oaks Weir – 6,000 ML over 3 years
Meredith Pump Station – 600 ML/yr
Upper East Moorabool System – 9,000 ML/yr

Bulk Entitlement Maximum Extraction Rates

Upper West Moorabool System – 140 ML/d to White Swan Reservoir, 12 ML/d to Wallace Township
She Oaks Weir – 65 ML/d

Bulk Entitlement Passing Flow Requirements

Upper West Moorabool System - the lesser of 3 ML/d downstream of Moorabool Reservoir or gauged inflow to Moorabool Reservoir;

Lal Lal Reservoir - The lesser of 20 ML/d or inflow downstream of Lal Lal Reservoir reduced to 5 ML/d when the 24 month cumulative inflow to Lal Lal Reservoir drops below the 90th percentile exceedence value

She Oaks Weir - The lesser of 40 ML/d downstream of She Oaks or local inflow between Lal Lal, Bostock and She Oaks.

Meredith Pump Station –if local inflow between Lal Lal, Bostock and Meredith is less than 0.5 ML/d then passing flow = 0, if local inflow between Lal Lal, Bostock and Meredith is between 0.5 ML/d and 10 ML/d then passing flow = 0.34 + (0.33 * local inflow) ML/d, if local inflow > 10 ML/d then passing flow = 10 ML/d

Upper East Moorabool System – At Korweinguboora and Bolwarra Weir, passing flow is the lesser of Korweinguboora inflow and 0.6 ML/d (Dec to Mar), 0.4 ML/d (Apr, May, Oct, Nov), or 0.1 ML/d (Jun to Sep). At Bostock Reservoir, passing flow is the lesser of flow into Bostock and 1.2 ML/d (Dec to Jul), or 0.8 ML/d (Aug to Nov).

2.3.3 Urban Restriction Rules

Central Highlands Water

The total volume in all Ballarat storages triggers restrictions in Ballarat. The triggers for restrictions are summarised in Table 2-4 below.

- **Table 2-4: Ballarat Trigger for Restrictions (Total volume in store, ML)**

Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	29008	27585	26396	25331	24436	24085	24302	25428	27459	29200	30259	30097
2	23914	22966	22173	21463	20866	20632	20776	21563	22881	24042	24748	24640
3	18820	18346	17949	17594	17296	17179	17251	17645	18304	18884	19237	19183
4	13726	13726	13726	13726	13726	13726	13726	13726	13726	13726	13726	13726

Barwon Water

As Geelong is supplied from both the Barwon and Moorabool catchments, triggers for restriction depend on the resource available from both these sources. It should be noted that as the Barwon River is not included in the Moorabool model it is difficult to predict when restrictions would occur. Therefore for modelling purposes the Geelong demand supplied from Moorabool River is unrestricted.

SKM

2.3.4 Licensed Diversions

Private Diverter water use involves direct pumping from waterways or storage of water from a stream for the purpose of irrigation of pasture or crops. Various conditions on water use are enforced by Southern Rural Water (SRW) when issuing their various licenses (Table 2-5).

Table 2-5 Licence types and descriptions

Licence type	Description and conditions
Direct pumping licence	A licence issued by the authority for the take and use of water directly from a stream. Licences state the maximum area to be irrigated and the annual extraction volume and maximum daily extraction rate. The use of these licences is subject to specific conditions including (but not limited to) adequate flows.
Winter-fill storage	Issued for filling of on-stream and off-stream dams during May to October inclusive. On-stream dams must have compensation pipes to pass summer flows, but these are often inoperable (SRW, 1997).
Stock and domestic	(where crown frontage exists) – Nominal 2.2 ML/a allocated for household purposes, watering animals or irrigation of garden. Water not to be used for commercial purposes.

The majority of private diverter licences are concentrated in three regions within the catchment: between Moorabool and Lal Lal Reservoirs on the West Moorabool River, on Lal Lal Creek and its tributaries, and downstream of She Oaks after the confluence of the east and west branches of the Moorabool River.

The total licensed volumes by licence types within the Moorabool River Catchment is shown in Table 2-6. The number of licences issued in the basin by licence type and river reach is shown in Table 2-7.

Table 2-6 Licence types and volumes in the Moorabool River Basin

Licence type	Number of licences	Total volume of licences (ML)
Winter-fill - onstream	31	796.0
Winterfill – offstream	11	507.5
Direct irrigation	62	1282.3
Domestic and stock	25	55.0
Commercial & Industrial	6	48.9
TOTAL	135	2689.7

▪ **Table 2-7 Private licensed diverters in the Moorabool Basin by reach**

		Licensed Volume (ML)				
		Commercial	Domestic and Stock	Industrial	Winterfill – offstream	Direct & onstream winterfill
Below she oaks	above Batesford	2.2	19.8	43.0	265.0	713.0
	below Batesford	3.7			3.2	147.5
tribs btwn she oaks and Batesford		0.0	0.0	0.0	190.0	0.0
mainstream lal lal to she oaks		0.0	19.8	0.0	0.0	0.0
tribs lal lal to she oaks		0.0	4.4	0.0	0.0	0.0
mainstream btwn lal lal and mbool		0.0	2.2	0.0	0.0	88.9
tribs above lal lal		0.0	8.8	0.0	49.3	925.9
tribs btwn lal lal and mbool		0.0	0.0	0.0	0.0	12.0
above mbool		0.0	0.0	0.0	0.0	162.0
above wilsons		0.0	0.0	0.0	0.0	27.0
trib of pincotts		0.0	0.0	0.0	0.0	2.0
TOTAL VOLUME		**5.9**	**55.0**	**43.0**	**507.5**	**2078.3**

2.3.5 Southern Rural Water Restriction Rules

A rostering system and restrictions have been developed by SRW and are in place for all direct pumping downstream of She Oaks Weir. This aims to ensure that there is a small passing flow in the lower basin and that there is equitable use of the water by the downstream users. Restrictions that occur for private diverters are shown in Table 2-8.

▪ **Table 2-8: SRW Triggers for Private Diverter Restrictions**

Restriction Level	Trigger	Allocation(% of licence volume)
Stage 1	Flow < 10 ML/d at Batesford	100%
Stage 2	Flow < 8 ML/d at Batesford	75%
Stage 3	Flow < 6 ML/d at Batesford	50%
Stage 4	Flow < 4 ML/d at Batesford	25%
Ban	Flow < 2 ML/d at Batesford	0%

Winter-filling of dams is not permitted at flows less than or equal to 12 ML/d.

2.3.6 Total diversions

The updated REALM model estimates that at the current level of development, the average annual water use in the Moorabool Basin is around 39,000 ML. Urban authorities and private diverters use around 25,500 ML of this. A further 12,300 ML is intercepted by unlicensed farm dams in the catchment, while groundwater extraction reduces baseflow in streams by 1,200 ML/yr.

SKM

Figure 2-2: Spilt of Water Usage

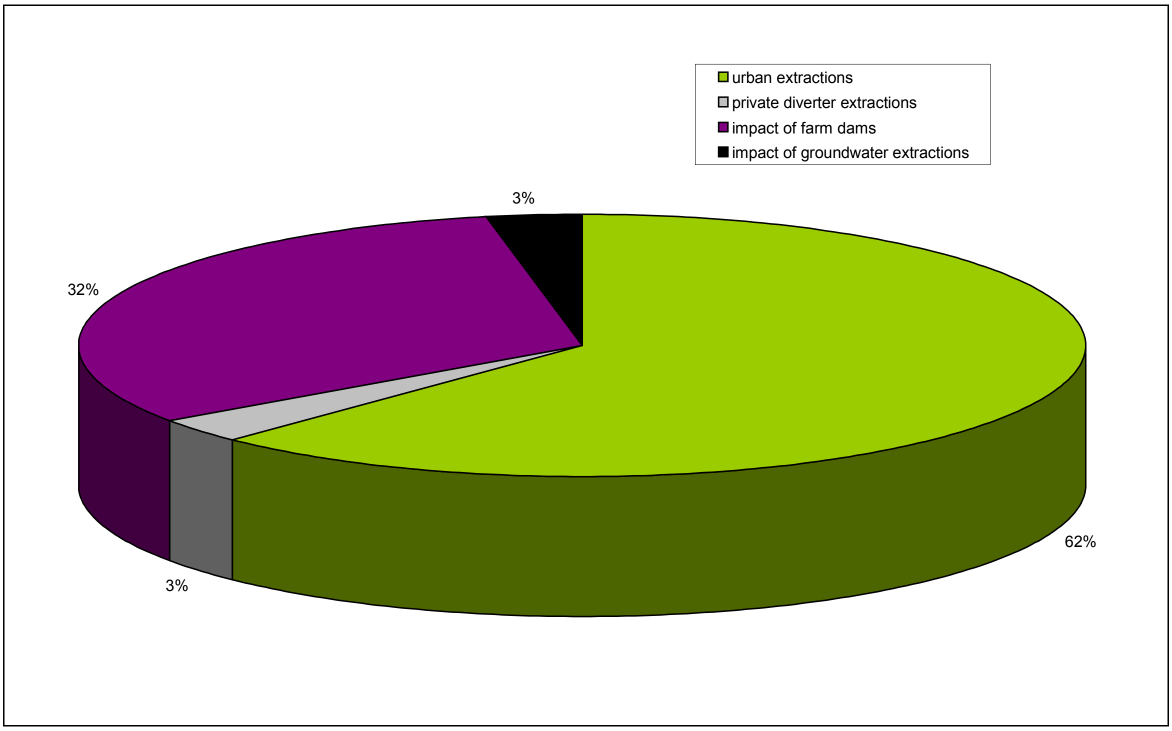


Table 2-9 compares current usage to licensed and BE volumes.

Table 2-9: Current usage, licensed volume and BE volumes

Diverter	Current use (Avg annual, ML)	BE Volume (ML)	Licensed Volume (ML)
Upper West Moorabool (CHW)		10,500	
Lal Lal Reservoir (CHW)		14,000	
CHW total	**16,600**	**24,500**	
Lal Lal Reservoir (BW)		7,000	
She Oaks (BW)		2,000	
Meredith (BW)		600	
Upper East Moorabool (BW)		9,000	
BW Total	**7,600**	**18,600**	
Private Diverters (surface water)	**1,200**		**2,700**
Private Diverters (groundwater)	**1,200***		**3,960*+**
Farm Dams	**12,300**		**0**
TOTAL	**38,900**	**49,760**	

* estimated current impact on surface water, + licensed vol = 6600 ML

2.4 Climate

Rainfall and evaporation data throughout the catchment was required for modelling purposes. The characteristics of that data are described in Table 2-10.

- **Table 2-10: Summary of Climatic Data Characteristics**

Station	Mean Annual Rainfall 1965-2002 (mm)	Minimum Annual Rainfall 1965-2002 (mm)	Maximum Annual Rainfall 1965-2002 (mm)
Beales Reservoir	867	497	1218
Moorabool Reservoir	973	498	1359
Durdidwarrah	716	363	1229
Station	**Mean Annual Evaporation 1965-2002 (mm)**	**Minimum Annual Evaporation 1965-2002 (mm)**	**Maximum Annual Evaporation1965-2002 (mm)**
Moorabool Reservoir	1217	988	1762
White Swan Reservoir	1230	964	1855
Durdidwarrah	1045	831	1480

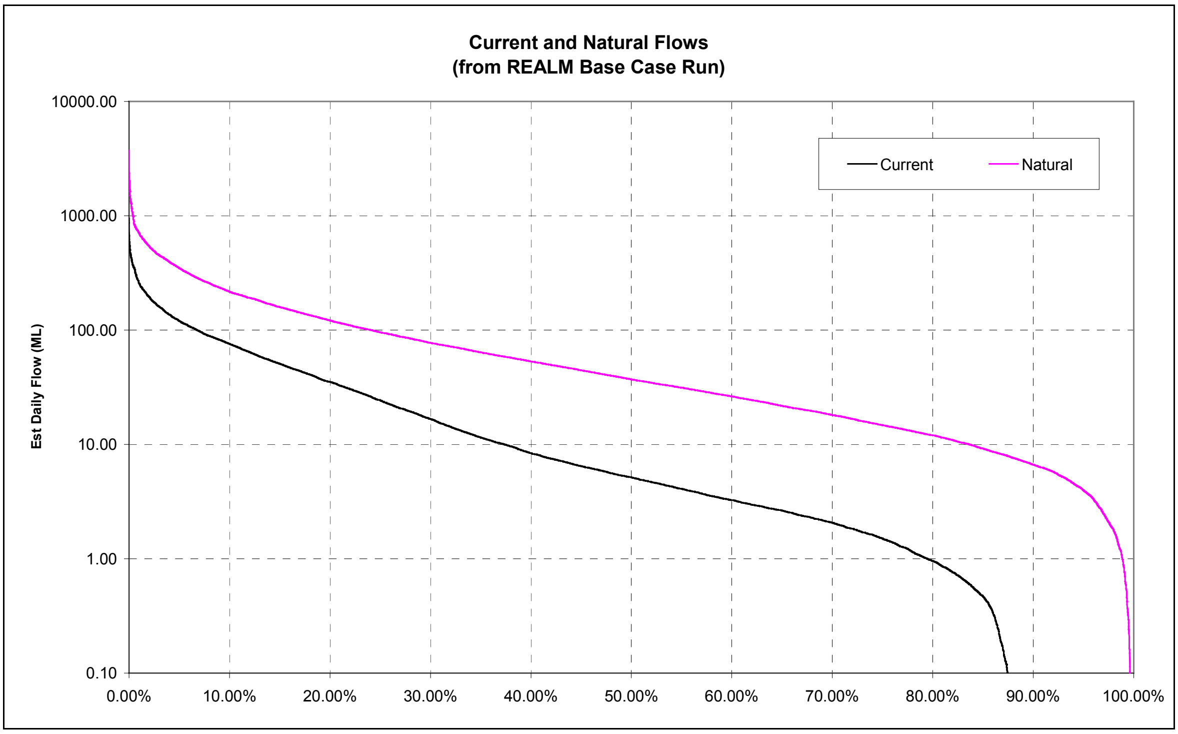
2.5 Hydrology

The Moorabool River Basin covers an area of around 2,225 km^2 ranging from the Great Dividing Range near Ballarat to the Port Phillip and Corio bays. The River originates in the Wombat State Forest ranges and flows south through the flat western basalt plain and meets the Barwon River at Geelong. The mean annual flow at Batesford, the most downstream gauging station in the basin (232202), is 53,300 ML (1965-2002). The upper portion of the Moorabool Basin includes the East and the West branches of the Moorabool River. The confluence of these two branches is located just north of Morrisons. Streamflow data from five stream gauging stations in the catchment show that a high proportion of the catchment yield is derived from the northern third of the catchment with the lower two thirds producing a lower yield. High flow months are July through to November with the peak flows observed in the months from August to October. The lowest flow months are December to April.

2.5.1 West Moorabool River

In the West Moorabool River upstream of Lal Lal Reservoir, current level of development demands result in a median flow of approximately 8 ML/d, compared with 36 ML/d under natural conditions (Figure 2-3). The flow exceeded 80% of time (an indicative low flow) has dropped from 15 ML/d to 1 ML/d. The stream now ceases to flow around 12% of the time, whereas under natural conditions it would not have dried up. These changes to the flow regime are due to harvesting of water in urban storages and farm dams, private diverter usage and groundwater usage.

It should be noted that since this figure was produced these flows have now changed slightly due to alterations to inflows and the base case REALM model outlined in Section 8.10.

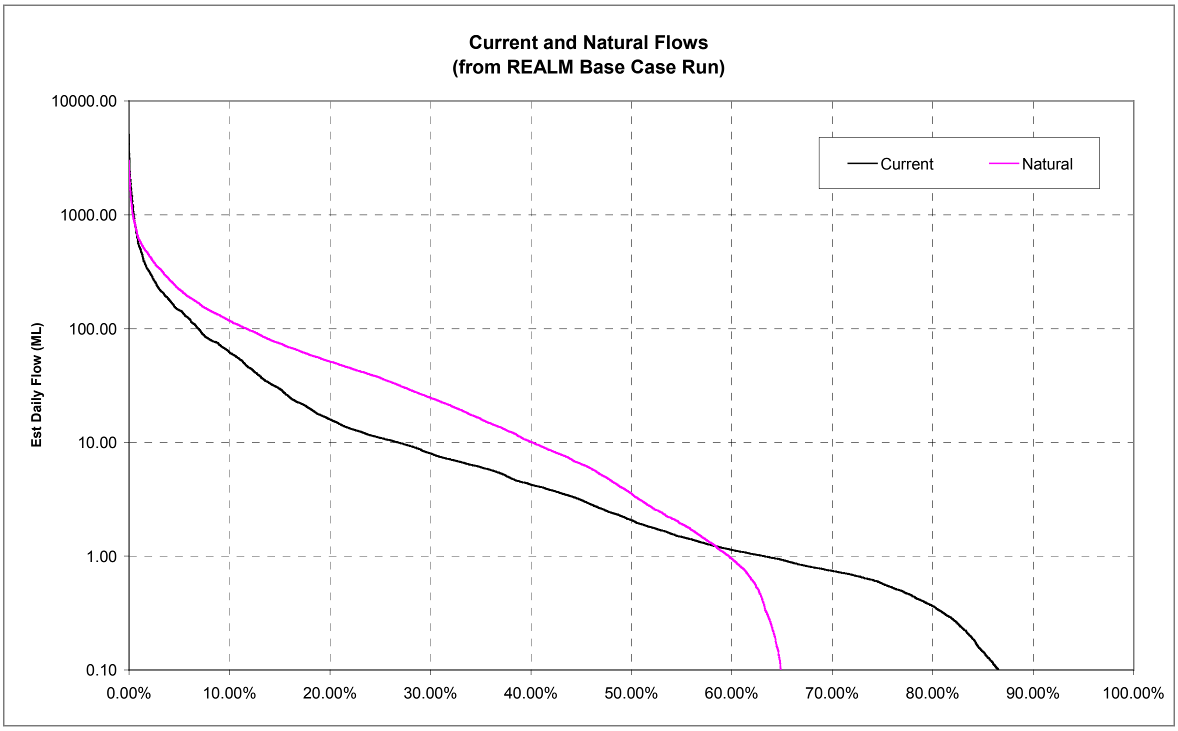


- **Figure 2-3 Moorabool River flow into Lal Lal over period Jan 1965 to Dec 2002**

2.5.2 East Moorabool River

In the East Moorabool River downstream of Bostock Reservoir the REALM model results in a median flow of approximately 3 ML/d, compared with 2 ML/d under natural conditions. The flow exceeded 80% of time (a indicator of low flow) has increased from 0 ML/d to 0.3 ML/d. The stream now ceases to flow around 13% of the time, whereas under natural conditions it would have dried up 35% of the time. Reduced flow magnitude is due to harvesting of water in urban storages and farm dams impacts. The decrease in cease to flow times is due to passing flow releases at the storages and occasional small spills.

It should be noted that since this figure was produced these flows have now changed slightly due to alterations to inflows and the base case REALM model outlined in Section 8.10.



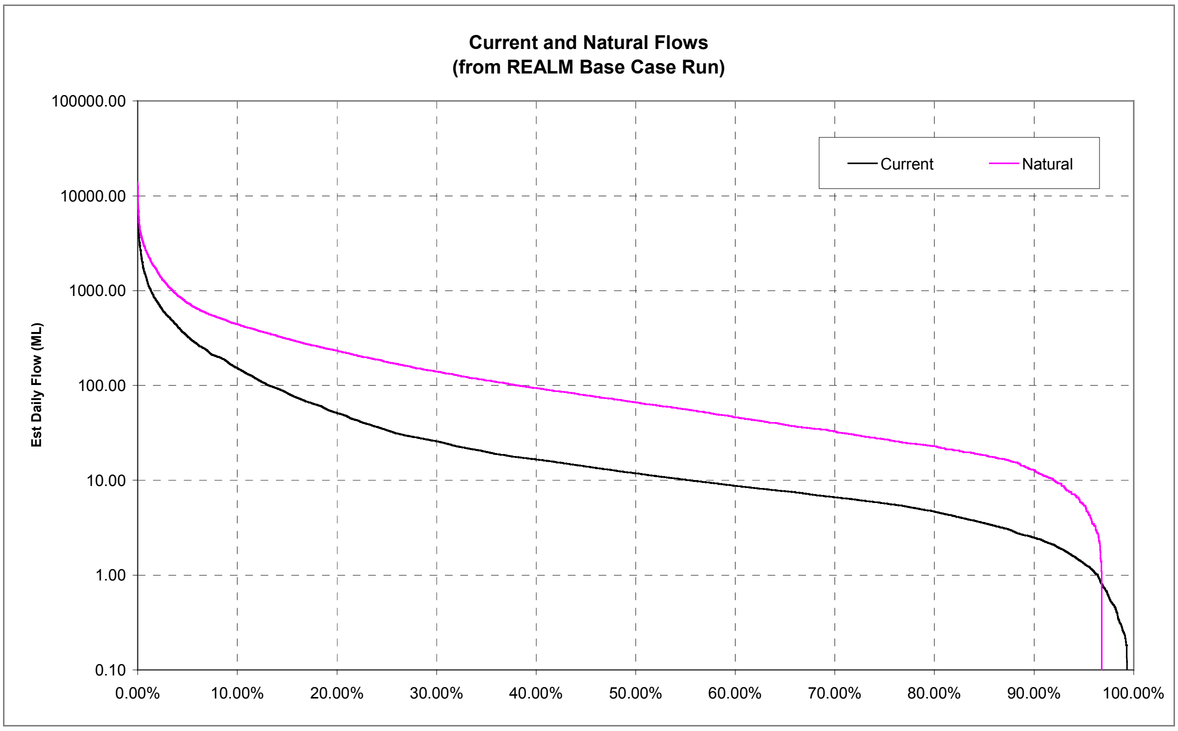
- **Figure 2-4: East Moorabool River flow d/s Bostock over period Jan 1965 to Dec 2002**

2.5.3 Moorabool River below She Oaks

In the Moorabool River below She Oaks, demands at current level of development result in a median flow of approximately 12 ML/d, compared with 65 ML/d under natural conditions. The flow exceeded 80% of time has dropped from 22 ML/d to 5 ML/d. There is little change to the percentage of time the stream ceases to flow, however current cease to flow is slightly higher than natural due to small spills.

The local catchment below Lal Lal experiences an artificial flow regime (high flows in summer) and decreased hydrological variability due to its use to transfer water from Lal Lal to She Oaks.

It should be noted that since this figure was produced these flows have now changed slightly due to alterations to inflows and the base case REALM model outlined in Section 8.10.

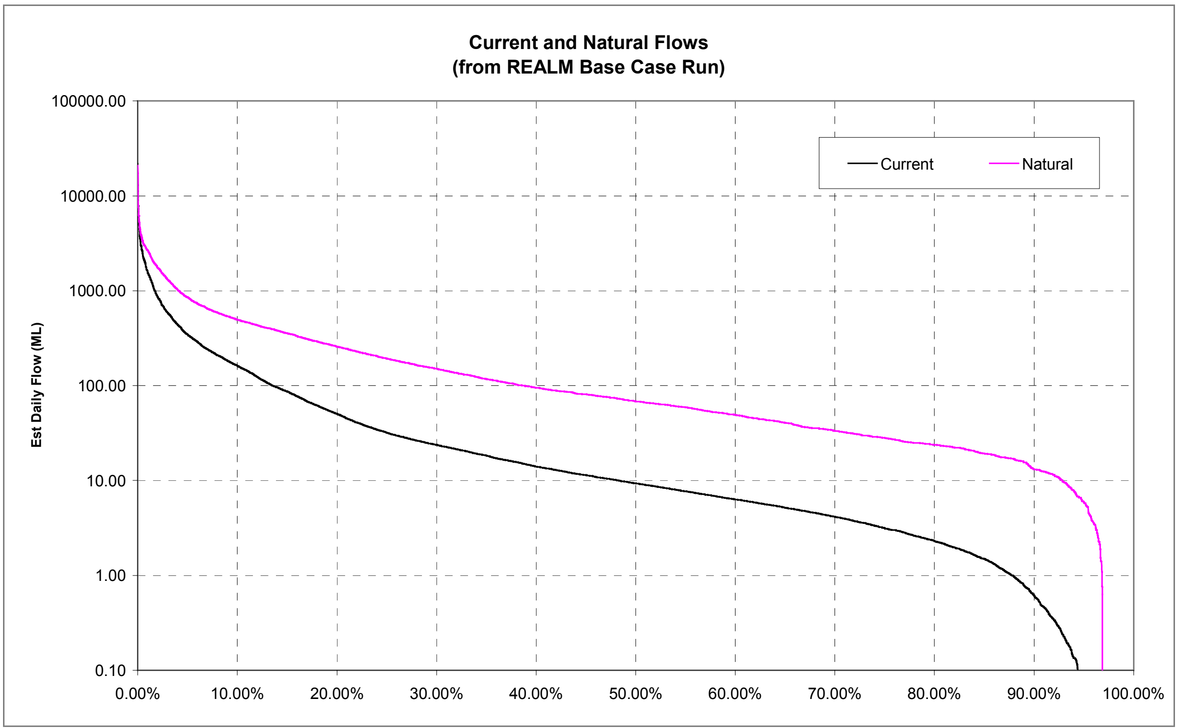


▪ **Figure 2-5: Moorabool River d/s She Oaks over period Jan 1965 to Dec 2002**

2.5.4 Moorabool River Below Batesford

Below Batesford the median flow in the Moorabool River has dropped from 90 ML/d to 10 ML/d. The 80th percentile exceedence flow has reduced from 24 ML/d to 2 ML/d (Figure 2-6). There is a slight increase in the frequency of cease to flow events.

It should be noted that since this figure was produced these flows have now changed slightly due to alterations to inflows and the base case REALM model outlined in Section 8.10.



■ **Figure 2-6 Moorabool River flow at Batesford over period Jan 1965 to Dec 2002**

2.5.5 The Sustainable Diversion Limit

There is debate surrounding the quantity of water that may be harvested in a sustainable manner during the wetter months. Sinclair Knight Merz have carried out a statewide estimation (SKM, 2002a) of the amount that can be harvested catchment wide in the winter months (July to October inclusive). This is known at the Sustainable Diversion Limit (SDL). The SDL provides a conservative estimate of limits to extraction. The SDL for the Moorabool River has been determined to be 3,482 ML/yr (SKM, 2002a). The base case REALM model indicates that the average current diversion (including the effect of harvesting at storages) over these months is 38,000 ML/yr indicating the system is substantially over developed.

The hydrology of the Moorabool River is discussed in more detail in Section 10.

2.6 Environmental assets

Environmental assets of a waterway are either threatened species or processes listed under state and federal agreements for protection or considered 'of value' by the community. Their existence requires that appropriate water quality and quantity be provided to maintain and improve the health and sustainability of aquatic ecosystems. Managing surface water, groundwater and land management in an integrated way may protect these values.

Environmental values in the Moorabool River Catchment were identified from background reports and Natural Resource and Environment (NRE) database outputs of flora and fauna in the catchment. The CCMA also identified stakeholders in the catchment and SKM contacted a selection (Appendix A).

2.6.1 Geomorphology

Riparian clearing and willow establishment appear to be widespread along the Moorabool River and will inevitably lead to changes in channel form. Craigie *et al*. (2002) highlight a number of areas where the river, and its tributaries, is actively adjusting through bed and bank erosion.

The upper reaches of the West Moorabool River are prone to moderate bank and bed instability (CCMA, 2000b). The channel also appears to have contracted below the reservoirs and there is potential for channel adjustment due to the highly regulated flow in this reach.

The main stem of the Moorabool River is also prone to avulsion with a number of anabranches and oxbow lakes present on the floodplain. According to Craigie *et al*. (2002), willow encroachment on the channel and floodplain clearing are increasing the risk of further avulsions of the contemporary river course. Widening and deepening may be accelerated due to sustained high flows from Lal Lal to She Oaks for Geelong's water supply.

Downstream of Batesford, the river has been extensively modified through realignment and concrete lining during the 1930s and the 1980s to allow the development of a large limestone quarry (Craigie *et al.*, 2002). The highly regulated nature of the stream flow and the presence of many small weirs that have been constructed over the past 50 years will further complicate adjustment processes (Zampatti and Grgat, 2000). It may also give rise to alternatively wider and narrower channel reaches with upstream sediment deposition and localised erosion (or perhaps channel contraction) downstream.

The East Moorabool River is impounded by Korweinguboora Reservoir, Bostock Dam and several minor storages, which have altered the flow regime and sediment transport processes downstream (Craigie *et al.*, 2002). Craigie *et al*. (2002) noted that channel contraction processes were evident in the reach downstream of Bostock Dam, including invasion of woody vegetation into the stream channel and colonisation of the stream bed by Cumbungi (*Typha sp*.). The valley form alternates from narrow and gorge-like to wide with broad floodplains (Craigie *et al.*, 2002).

2.6.2 Water Quality

Water quality can be characterised by a large variety of parameters, many of which are important to the ecological condition of a waterway. At the same time the Moorabool River Catchment is widely recognised as a valuable resource for drinking water, agriculture and recreation. Key parameters for the monitoring of water quality include salinity, dissolved oxygen, nutrients, pH and turbidity. These parameters are important due to the variety of potential impacts they can pose to the ecosystem and water users. For example, low levels of dissolved oxygen can restrict aerobic respiration of aquatic biota, which can lead to mortalities of such organisms. High turbidity levels can restrict the use of water for irrigation as a result of clogged pumps. In addition, high nutrient levels can result in algal blooms that may interfere with the treatment processes and make the water unsuitable for human consumption.

Water quality in rivers is influenced by the condition of the inputs and runoff from the surrounding land. In light of this, a Draft Water Catchment Protection Policy (CHW, 2003) has been prepared on behalf of the four water authorities in the Moorabool Shire. The Catchment Policy aims to provide landowners, the local council and other stakeholders with a clear understanding of what activities are considered acceptable in the catchment for reducing the risk to water quality. The policy will ensure that; water authorities adopt a clear and consistent approach to assessing planning applications, provide assistance to applicants who are considering making an application for planning permit and reduce the time taken to consider applications by ensuring that all relevant information is lodged with the council (CHW, 2003).

Good water quality is an essential requirement for the habitat and life cycle requirements of native fish species. Various species have specific tolerance limits to chemical and physical water criteria. The five key water quality parameters for instream biota are dissolved oxygen, temperature, salinity, turbidity, pH, nutrients and toxins. Changes in these parameters are often brought about by clearing of riparian vegetation, access of stock to streams and changes to the flow regime.

Water quality in the Moorabool River is monitored at six stations as part of the Victorian Water Quality Monitoring Network (VWQMN) (DSE, 2003) (Table 2-11). Barwon Water also monitors water quality at the Bostock Reservoir outlet upstream of the stream gauge on the East Moorabool River to ensure the quality of supply to Geelong (Table 2-12). Due to data availability, this section will primarily be based on summary water quality statistics from the west branch at Batesford, Morrisons and Lal Lal Reservoirs (Figure 2-1; Table 2-13; Table 2-14; Table 2-15). No water quality data exists for the VWQMN stations on the East Moorabool River at Bolwarrah weir or Barkstead. Therefore additional reviews on water quality in the catchment have been used to assist in the interpretation of water quality in the Moorabool River.

- **Table 2-11 Victorian Water Quality Monitoring Network stations.**

Station number	Location
232201	East Moorabool downstream of Bolwarrah weir
232202	Moorabool River @ Batesford
232204	Moorabool River @ Morrisons
232207	East Moorabool River @ Barkstead
232210	Moorabool River West @ Lal Lal
232211	Moorabool River West @ Mt. Doran

Water quality data for three stations have been compared with the draft State Environment Protection Policy (SEPP) objectives (EPA, 2001) and the Australian and New Zealand Environment Conservation Council (ANZECC) water quality guidelines (ANZECC, 2000) to assess compliance (Table 2-15; Table 2-14; Table 2-13). The draft SEPP objectives set out guidelines and indicators that describe the environmental quality required to protect the beneficial uses of Victoria's water environments.

Nutrients

High values of nitrogen and/or phosphorus produce nutrient enrichment, increasing plant and animal biomass, benefiting certain species and potentially altering species diversity and abundance in affected systems. Eutrophication (excessive nutrient enrichment) may result if nutrient levels get sufficiently high and other conditions (eg. temperature) are favourable. Under eutrophic conditions, water can become anoxic, and turbidity becomes high, potentially leading to algal blooms and fish kills (OCFE, 1988).

Total nitrogen concentrations have exceeded the draft SEPP objective of ≤ 0.60 mg/L at all three VWQMN monitoring stations. Since 1992, 75th percentile concentrations have also been higher at Lal Lal in comparison to Batesford. Cottingham (1995) suggested that runoff from agricultural and urban areas was the most likely source of nutrients in the Moorabool system, as there are no major point source discharges.

Two significant algal blooms have also occurred in the Moorabool Reservoir (May 1980 and September 1991) and have caused problems by depleting oxygen downstream of the reservoirs, smothering other plants and clogging waterways (Barwon Moorabool Corangamite Waterway Management Consultative Action Team, 1995).

Downstream of Bostock Reservoir total phosphorus concentrations have exceeded the draft SEPP objective of ≤ 0.04 mg/L six of the seven years monitored since 1996 (Table 2-12).

The CCMA has identified the specific need to address the issue of nutrient impacts to the waterways through the Corangamite Nutrient Management Plan (CCMA, 2000a).

Salinity

Electrical conductivity (EC) is a short-cut measure for estimating the concentration of total dissolved salts and therefore salinity (Boulton and Brock, 1999). High EC can threaten the survival of native flora and fauna as well as affect the use of the water for drinking and irrigation. Aquatic flora and fauna species are adapted to tolerate a certain range of salinity. Conditions outside this tolerable range can exclude or lead to mortalities of any sensitive species. The impact of saline conditions on aquatic vegetation and macroinvertebrates can lead to reduced overall biodiversity and limit the availability of food resources (OCFE, 1988). There are a number of factors that may contribute to high EC. However, if EC is already moderate, evaporation can increase the EC by removing a large proportion of water while leaving the dissolved salts. Electrical conductivity may also rise due to the passage of highly saline surface or groundwater into the river.

Analyses conducted by Zampatti and Grgat (2000) at Batesford, Morrisons and Lal Lal show that EC is highest in the lower reaches of the river where median values range between 1300 to 1600 µS/cm (Zampatti and Grgat, 2000).

The draft SEPP objective has also been exceeded for nine years at Batesford and ten years at Morrisons since 1992 (Table 2-15; Table 2-14). In the lower reaches of the river at Batesford, median EC values increase from December to August and decrease (900 µS/cm) during the high flow period of September to December (Zampatti and Grgat, 2000). In the middle sections of the river, EC values are generally constant (400 to 500 µS/cm) with the exception of a small peak that occurs during June and July. At Lal Lal, median EC concentrations are low and range between 250 to 450 µS/cm (Zampatti and Grgat, 2000).

Saline pools may occur in the lower sections of the Moorabool River from saline groundwater intrusion during periods of low flow (Bennett, 1994). However, they did not appear to be an issue at the environmental flow sites monitored by Zampatti and Grgat (2000). On the other hand trend analysis conducted by Barton (2000), showed that electrical conductivity in the East Moorabool River was increasing over the period of 1995 to 2000. Low flow conditions were thought to be responsible for this, along with saline groundwater intrusion (Barton, 2000). At the Bostock Reservoir outlet electrical conductivity complied with four of the six years monitored, a 75th percentile maximum of 617 µS/cm in 2000 (Table 2-12).

pH

Catchment mineralogy, vegetation, biological productivity and flow characteristics influence the pH of waterbodies. The acidity of a waterway is measured by its pH. Reduced pH values are associated with more acidic conditions in a river. The chemical properties of water can also be altered by the pH. Spawning failure and diminished hatching success for fish that has been associated with pH values less than 6.0 (ANZECC, 2000). Decreased pH has been shown to reduce the abundance, biodiversity and species composition of macroinvertebrate communities (Boulton and Brock, 1999).

The median monthly pH ranges are similar at all the monitored reaches in the Moorabool River and range from 6.9 to 7.9. However, the draft SEPP objective for the 25th percentile has been exceeded on two occasions (Batesford in 1992 and Lal Lal in 1995).

High pH values were recorded at Bostock Reservoir (mean = 8.53; n = 120) and were shown to increase markedly over a five year period to the year 2000 (Barton, 2000). In 2002, pH complied with all draft SEPP objectives (Table 2-12).

Turbidity

Turbidity is the cloudy appearance of water due to suspended material. Increased turbidity limits light penetration of the water column thereby reducing the growth of aquatic flora and impeding the feeding of visual predators, such as some fish species. High turbidity can also smother habitat areas in a stream, blanketing out the light and reducing habitat complexity.

Turbidity levels at Batesford and Lal Lal vary considerably between years and have been shown to increase significantly during the high flow period (Zampatti and Grgat, 2000). Conversely, since 1992 turbidity levels at Morrisons have complied with the draft SEPP objective of ≤ 10 NTU.

Fletcher (1998) analysed water quality parameters above and below Lal Lal Reservoir and found that from 1976 to 1992 there were significantly lower levels of turbidity below the Reservoir. He concluded this reduction in turbidity was the result of a settling effect leading to a reduction in the volume of the storage over time. Trend analyses conducted by Barton (2000) show that turbidity concentrations have generally decreased at Morrisons since 1980.

On the East Moorabool River, turbidity levels at Bostock Reservoir were shown to increase during the drought period. Barton (2000) attributed this to the fact that the water level of Bostock Reservoir was slowly decreasing over time as the drought progressed and sediments from the bottom of the reservoir were becoming more prevalent in the out going water. However streamflow and turbidity were not found to be statistically related by Barton (2000), although graphically, it was shown that increased flow resulted in increased turbidity levels. Turbidity at the Bostock Reservoir outlet ranged from a low 75% percentile of 5.7 NTU to a maximum of 17.3 NTU in 2002 (Table 2-12).

Dissolved oxygen

The concentration of oxygen dissolved within the water column can be affected by natural and human activities including bacterial activity in enriched sediments and pollutants (OCFE, 1988). Dissolved oxygen is also highly variable temporally and spatially and the data from spot samples must be considered with caution. Low dissolved oxygen can be expected in slow moving or still waters, while dissolved oxygen concentrations can increase in the presence of aquatic macrophytes or turbulence as a result of mixing with the atmosphere. Low dissolved oxygen concentrations can be harmful to aquatic biota, as it is required for aerobic respiration.

Dissolved oxygen concentrations have exceeded the ANZECC (2000) water quality guideline over the monitoring period at all sites. Dissolved oxygen concentrations vary depending on the seasons. In the Moorabool River dissolved oxygen concentrations are lowest from November to March and highest during June to August (Zampatti and Grgat, 2000). Downstream of She Oaks, low flows have caused low dissolved oxygen concentrations that have the potential to be lethal to fish (Zampatti and Grgat, 2000).

Low dissolved oxygen can also be a significant problem below reservoirs and is the result of very cold water released from outlets low in the reservoir's wall. Fletcher (1998) found that temperature and flow were strongly negatively correlated above Lal Lal Reservoir, but positively correlated below. This indicates that the temperature of water entering Lal Lal Reservoir (from Moorabool Reservoir) decreases with increasing flow.

On numerous occasions, dead fish have been identified below Lal Lal Reservoir (P. Toohey *pers. comm.*). Whether this is the result of low dissolved oxygen concentrations is unknown.

Dissolved oxygen in the East Moorabool River was not studied by Barton (2000) due to a lack of data.

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Table 2-12 Water quality data for the East Moorabool River at the Bostock Reservoir outlet.

Year	TP (mg/l)		EC (µS/CM)		pH				Turbidity (NTU)	
	75th %ile	SEPP ≤0.04	75th %ile	SEPP ≤500	25th %ile	SEPP ≥ 6.5	75th %	SEPP ≤8.3	75th %ile	SEPP ≤10
1996	0.04	X	270	✓	6.8	✓	7.0	✓	10.8	X
1997	0.03	✓	290	✓	7.0	✓	7.4	✓	5.7	✓
1998	0.10	X	400	X	7.2	✓	7.7	✓	7.9	✓
1999	0.10	X	562	✓	7.5	✓	7.8	✓	12.3	X
2000	0.05	X	617	X	7.4	✓	7.8	✓	17.5	X
2001	0.05	X	465	✓	6.9	✓	7.3	✓	12.0	X
2002	0.06	X	545	X	7.4	✓	7.6	✓	17.3	X

✓ - SEPP or ANZECC water quality objective met.
TP – total phosphorus, EC – electrical conductivity

Table 2-13 Water quality data for the Moorabool River at Lal Lal (232210).

Year	TN (mg/l)		TP (mg/l)		EC (µS/CM)		pH				Turbidity (NTU)		DO (mg/l)	
	75th %ile	SEPP ≤0.60	75th %ile	SEPP ≤0.04	75th %ile	SEPP ≤500	25th %ile	SEPP ≥ 6.5	75th %	SEPP ≤8.3	75th %ile	SEPP ≤10	50th %ile	ANZECC ≥6
1992	1.40	X	0.03	✓	425	✓	ID		ID		12.0	X	10.3	✓
1993	1.46	X	0.04	X	385	✓	ID		ID		14.1	X	10.5	✓
1994	1.07	X	0.03	✓	448	✓	7.1	✓	7.6	✓	9.9	✓	ID	
1995	1.88	X	0.03	✓	448	✓	6.9	✓	7.8	✓	7.0	✓	ID	
1996	1.48	X	0.06	X	343	✓	ID		ID		11.3	X	ID	
1997	1.55	X	0.05	X	565	X	7.4	✓	7.6	✓	13.3	X	ID	
1998	ID		ID		ID		ID		ID		ID		ID	
1999	0.95	X	0.05	X	663	X	7.5	✓	7.7	✓	ID		ID	
2000	ID		ID		ID		ID		ID		ID		ID	
2001	1.09	X	0.05	X	490	✓	7.6	✓	7.9	✓	9.2	✓	10.2	✓
2002	0.95	X	0.04	X	638	X	7.5	✓	7.9	✓	7.8	✓	7.8	✓

✓ - SEPP or ANZECC water quality objective met.
ID- -Insufficient data.
TN – total nitrogen, TP – total phosphorus, EC – electrical conductivity, DO – dissolved oxygen

■ **Table 2-14 Water quality data for the Moorabool River at Morrisons (232204).**

Year	TN (mg/l)		TP (mg/l)		EC (μS/CM)		pH				Turbidity (NTU)		DO (mg/l)	
	75th %ile	SEPP ≤0.60	75th %ile	SEPP ≤0.04	75th %ile	SEPP ≤500	25th %ile	SEPP ≥ 6.5	75th %	SEPP ≤8.3	75th %ile	SEPP ≤10	50th %ile	ANZECC ≥6
1992	1.03	X	0.02	✓	853	X	ID		ID		6.8	✓	9.7	✓
1993	1.07	X	0.02	✓	493	✓	ID		ID		5.9	✓	9.6	✓
1994	0.87	X	0.02	✓	535	X	7.2	✓	7.8	✓	4.7	✓	ID	
1995	0.95	X	0.02	✓	538	X	7.2	✓	7.5	✓	3.7	✓	9.7	✓
1996	1.10	X	0.02	✓	613	X	ID		ID		4.5	✓	ID	
1997	1.08	X	0.02	✓	590	X	7.4	✓	7.6	✓	1.8	✓	9.0	✓
1998	0.78	X	0.01	✓	520	X	7.4	✓	7.8	✓	1.3	✓	9.2	✓
1999	0.61	X	0.01	✓	833	X	ID		ID		1.1	✓	8.5	✓
2000	0.65	X	0.03	✓	1525	X	7.2	✓	7.5	✓	3.9	✓	7.8	✓
2001	0.69	X	0.02	✓	1025	X	7.8	✓	7.8	✓	2.4	✓	9.5	✓
2002	0.66	X	0.02	✓	1450	X	7.5	✓	7.8	✓	2.5	✓	7.9	✓

✓ - SEPP or ANZECC water quality objective met.
ID – Insufficient data.
TN – total nitrogen, TP – total phosphorus, EC – electrical conductivity, DO – dissolved oxygen

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■ **Table 2-15 Water quality data for the Moorabool River at Batesford (232202).**

Year	TN (mg/l)		TP (mg/l)		EC (µS/CM)		pH				Turbidity (NTU)		DO (mg/l)	
	75th %ile	SEPP ≤0.60	75th %ile	SEPP ≤0.04	75th %ile	SEPP ≤500	25th %ile	SEPP ≥6.5	75th %	SEPP ≤8.3	75th %ile	SEPP ≤10	50th %ile	ANZECC ≥6
1992	0.96	X	0.04	X	1325	X	6.4	X	7.0	✓	20.5	X	9.4	✓
1993	1.25	X	0.05	X	1500	X	ID		ID		16.6	X	9.8	✓
1994	0.71	X	0.02	✓	1525	X	ID		ID		2.0	✓	9.1	✓
1995	0.92	X	0.35	✓	1725	X	ID		ID		4.2	✓	10.2	✓
1996	1.03	X	0.04	X	2000	X	7.6	✓	7.7	✓	13.0	X	ID	
1997	0.72	X	0.03	X	1533	X	7.6	✓	7.9	✓	ID		8.6	✓
1998	ID		ID		ID		ID		ID		ID		ID	
1999	0.86	X	0.06	X	ID		7.2	✓	7.7	✓	1.5	✓	7.3	✓
2000	1.27	X	0.07	X	2600	X	7.3	✓	7.7	✓	17.0	X	6.7	✓
2001	ID		ID		1850	X	ID		ID		ID		ID	
2002	0.92	X	0.05	X	2600	X	7.4	✓	7.6	✓	1.5	✓	6.9	✓

✓ - SEPP or ANZECC water quality objective met.
ID – Insufficient data.
TN – total nitrogen, TP – total phosphorus, EC – electrical conductivity, DO – dissolved oxygen

2.6.3 Biota

Fish

The diversity and distribution of native freshwater species from the Moorabool River Catchment were identified from the Victorian Fish Database (NRE, 2003a) and comprehensive fish surveys. The first survey was undertaken by the then Department of Conservation, Forests and Land in 1986-1987 (Tunbridge, 1988) and was followed by two more comprehensive surveys by NRE (Arthur Rylah Institute) in October 1998 (Zampatti and Grgat, 2000). The objective of the surveys was to assess the conservation values of the Moorabool River in light of water utilisation activities. In particular Raadik and Koster (2000) assessed the distribution of fish fauna below and above the barriers in the Moorabool River system and commented on the construction of fishways and recommendations to improve fishway efficiency. Zampatti and Grgat (2000) assessed the environmental values of the Moorabool River as a component of the Moorabool River SMP. Each survey involved sampling from six locations. The sampling locations differed in that Zampatti and Grgat (2000) chose to sample at two sites upstream of Lal Lal Reservoir (Figure 2-1).

Overall, twelve native freshwater fish species have been recorded in the Moorabool River system (Table 2-16). All were recorded by Zampatti and Grgat (2000) in 1998. One species, the Australian Grayling (*Prototroctes maerena*), is listed as vulnerable in Victoria, listed under the Victorian *Flora and Fauna Guarantee Act 1988* (*FFG Act 1988*), listed as vulnerable under the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (*EPBC Act 1999*) and listed on the 2002 IUCN Red List of Threatened Species. Surveys indicate that Australian Grayling has been recorded near the junction of the Moorabool and Barwon Rivers (downstream of Batesford) in 1998 and as far upstream as Meredith prior to 1976 (McDowall, 1976). Australian Grayling are diadromous, spending larval life in the sea and returning to the rivers during spring, at about six months of age (McDowall, 1996a). Australian Grayling have become extinct in a major part of its range attributable to the construction of dams and weirs restricting migration to estuarine waters, and the alteration of natural stream flow and temperature regimes (McDowall, 1996a). For this reason, together with the uncertainty of movement of Australian Grayling into the Moorabool system (Tunbridge *pers. comm*. cited in Bennett, 1994), recommended that water should be present in the lower Moorabool at all times.

- **Table 2-16 Native and exotic fish species recorded from the Moorabool River system (NRE, 2003a; Zampatti and Grgat, 2000).**

Scientific name	Common name	Conservation status	Migratory	Last observed
Gadopsis marmoratus	River Blackfish	Common	N	1998
Galaxias maculatus	Common Galaxias	Common	Y	1998
Galaxias olidus	Mountain Galaxias	Common	N	1998
Galaxias truttaceus	Spotted Galaxias	Common	Y	1998
Philpnodon grandiceps	Flat-headed Gudgeon	Common	N	1998
Anguilla australis	Short-finned Eel	Common	Y	1998
Mordacia mordax	Short-headed Lamprey	Common	Y	1998
Prototrocetes maraena	Australian Grayling	Vulnerable	Y	1998
Retropinna semoni	Australian Smelt	Common	N	1998
Nannoperca australis	Southern Pygmy Perch	Common	N	1998
Pseudaphritis urvillii	Tupong	Common	Y	1998
Pseudogobius sp. 9	Blue-spotted Gobby	Common	N	1998

Five other diadromous species that require passage between freshwater and saltwater have been recorded in the Moorabool River catchment and include Common Galaxias (*Galaxias maculatus*), Spotted Galaxias (*Galaxias truttaceus*), Short-finned Eel (*Anguilla australis*), Short-headed Lamprey (*Mordacia mordax*) and Tupong (*Pseudaphritis urvilli*). Surveys indicate that Short-finned Eel are widespread throughout the catchment, being found in all reaches, while the other species have a distribution restricted to sites downstream of Batesford. Zampatti and Grgat (2000) attributed this to the presence of barriers to fish migration. Short-headed Lamprey was first recorded in the Moorabool

River in 1998. These species prefer still gently flowing streams and rivers, although Short-finned Eel can also occur in lakes and swamps and Tupong often remain buried among rocks and logs.

Non-migratory species that have been recorded in the Moorabool Catchment include River Blackfish (*Gadopsis marmoratus*), Southern Pygmy Perch (*Nannoperca australis*) and Australian Smelt (*Retropinna semoni*). River Blackfish and Australian Smelt have a wide distribution in the Moorabool River that extends from the junction with the Barwon River to the junction with Coolebarghurk Creek (running up past Meredith) (NRE, 2003a). On the other hand, Southern Pygmy Perch have not been recorded upstream past Bannockburn. Australian Smelt are most common in still and gently flowing waters but have been recorded in fast flowing waters (Allen *et al.*, 2002). They occur as large schools in mid-water or near the surface (McDowall, 1996b). River Blackfish inhabit a variety of stream types compared to Southern Pigmy Perch that are commonly found in small, slow-flowing systems (Koehn and O'Connor, 1990). Both prefer abundant cover such as snags and submerged vegetation and are susceptible to increased sediment loads in streams and removal of woody debris and degraded riparian vegetation (Doeg and Koehn, 1994; Koehn and O'Connor, 1990).

One native fish species, Mountain Galaxias (*Galaxias olidus*) has been recorded upstream of Lal Lal Reservoir on the west branch in 1998 and as far downstream as She Oaks on the main stem in 1987. Mountain Galaxias occur primarily in small streams and sometimes small tarns and ponds, at higher elevations where water temperatures remain cool in summer (McDowall and Fulton, 1996). There it is found in small, loose shoals mostly in pools and runs, but it may be solitary among substrate rocks and around stream margins (McDowall and Fulton, 1996).

Blue-spotted Gobby (*Pseudogobius sp. 9*) were first recorded in the Moorabool River in 1998 (Zampatti and Grgat, 2000). However, their exact distribution in the catchment is unknown. Blue-spotted Gobby are common in protected estuaries and coastal lakes and can be very abundant over muddy to sandy substrates or where aquatic vegetation is thick (Larson and Hoese, 1996).

The fish community of the Moorabool River contains a number of native fish species including the *FFG Act 1988* listed Australian Grayling. The highest diversity of native freshwater fish species occurs downstream of Batesford and only one native fish species has been recorded on the west (Mountain Galaxias) and east (Short-finned Eel) branches. Several of the native species are known to be sensitive to the environmental disturbances that have occurred in the Moorabool River, particularly sedimentation, desnagging, riparian degradation, flow regulation and the construction of dams and weirs.

Macroinvertebrates

Macroinvertebrates are often used as indicators of river health due to their sensitivity to changes in catchment use, pollution and habitat preference. In addition, macroinvertebrates break down organic matter and provide a food source for many animals higher up in the food chain (eg. fish, birds and platypus).

Macroinvertebrate data in the Moorabool River Catchment was assessed from one EPA site on the Moorabool River at She Oaks on Sharp Road (003257-OLT) and five Index of Stream Condition (ISC) sites (one on the west branch, three on the east branch and one on the main stem).

Two habitats (edge/pool, kick/riffle) were sampled from the EPA site in the autumn and spring of 1998 and 2000. The results of the combined data from the two seasons were compared against the draft State Environmental Protection Policy (SEPP) macroinvertebrate objectives (EPA, 2001) for regions classed as cleared hills and coastal plains (Table 2-17).

The indicators met all the respective draft SEPP objectives and well exceeded the number of families and key families typically found in streams of this region (Table 2-17). This indicates that in general, at this site, the macroinvertebrate community diversity is high and is not limited by habitat availability or water quality.

AUSRIVAS predicts the macroinvertebrates which should be present in specific stream habitats under reference conditions (EPA, 2000) whereas SIGNAL scores provide an indication of the level of pollution, based on the types of invertebrate families collected at that site (Chessman, 1999).

Table 2-17 Macroinvertebrate ratings for edge and riffle habitats in 1998 and 2000 and their compliance with SEPP objectives (EPA, 2001).

Year	Habitat	AUSRIVAS		SIGNAL		Number of families		Number of key families combined habitat	
		She Oaks Rating	SEPP Objective	She Oaks Rating	SEPP Objective	She Oaks Rating	SEPP Objective	She Oaks Rating	SEPP Objective
1998	Edge	1.06	0.85	5.71	5.5	31	26	29	22
1998	Riffle	0.95	0.82	5.63	5.5	29	23		
2000	Edge	0.96	0.85	5.53	5.5	40	26	32	22
2000	Riffle	1.05	0.82	5.71	5.5	27	23		

Aquatic life scores provided from five ISC sites were based on a combination of SIGNAL and AUSRIVAS indices. SIGNAL scores ranged from less than three at a reach on the east branch to greater than six at reaches on the west branch and main stem of the Moorabool River. AUSRIVAS scores at all reaches, except two of those of the east branch, were below the objective for regions classed as cleared hills and coastal plains (Table 2-18). The overall aquatic life score combines the AUSRIVAS and SIGNAL results into a single number out of 10.

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■ **Table 2-18 Macroinvertebrate ISC and corresponding AUSRIVAS and SIGNAL scores (DSE, 2003 #47).**

Site	Reach	ISC Aquatic life	AUSRIVAS	SIGNAL
Moorabool River	1	8	0.59-0.4	>6
West Moorabool River	6	8	0.59-0.4	>6
East Moorabool River	10	5	0.59-0.4	<3
East Moorabool River	11	9	>0.8	5-6
East Moorabool River	13	8	>0.8	4-5

The common decapod species of Yabby, Yarra Spiny Cray, Burrowing Cray and Freshwater Shrimp have also been recorded from the Moorabool River system (NRE, 1999b). Raadik and Koster (2000) also caught the Southern Victorian Spiny Cray at four sites between Batesford and She Oaks weir in 1998.

In general, macroinvertebrate communities in the Moorabool River Catchment appear to be indicative of moderate environmental condition. The major issues for macroinvetebrates in the catchment is the lack of habitat due to the alternation of flow regimes (ie. riffles) and instream vegetation (ie. macrophytes), sedimentation and water quality. The occurrence of SIGNAL scores that conform to EPA standards at all sites, except two sites suggest that lack of habitat rather than water quality is the key factor limiting aquatic macroinvertebrates in the catchment.

Birds

Floodplains and coastal wetlands within the Moorabool River catchment are likely to provide important habitat for water dependent birds in the area. A total of 11 Victorian threatened water dependent bird species have been recorded within the Moorabool River catchment downstream of Moorabool Reservoir and Bostock Reservoir (NRE, 1999b) (Table 2-19). This list includes the critically endangered Little Egret (*Ergetta garzetta*) and Intermediate Egret (*Ardea intermedia*) and the endangered Great Egret (*Ardea alba*). Five species are listed under the *FFG Act 1998*. The Great Egret is also declared internationally significant by the Japan and Australia Migratory Bird (JAMBA) and China and Australian Migratory Bird (CAMBA) Agreements.

■ **Table 2-19 Threatened Victorian water dependent bird species recorded within the Moorabool River catchment (NRE, 1999b).**

Scientific name	Common name	Conservation Status	FFG[1]	JAMBA/ CAMBA[2]	Last observed[3]
Porzana pusilla	Baillon's Crake	Vul	L		1985
Grus rubicunda	Brolga	Vul	L		1992
Platalea regia	Royal Spoonbill	Vul			1995
Egretta garzetta	Little Egret	CEn			2000
Ardea intermedia	Intermediate Egret	CEn	L		2001
Ardea alba	Great Egret	End	L	J, C	2001
Nycticorax caledonicus	Nankeen Night Heron	Vul			2001
Anas rhynchotis	Australasian Shoveler	Vul			2001
Aythya australis	Hardhead	Vul			2001
Oxyura australis	Blue-billed duck	Vul	L		2000
Biziura lobata	Musk Duck	Vul			2000

[1] Victorian conservation status: End-endangered; Vul-vulnerable; CEn-critically endangered;

[2] FFG Act 1988 L-listed;

[3] Treaties: C-CAMBA; J-JAMBA

Water dependent birds will be strongly influenced by the condition of weir pools and freshwater and coastal lakes associated with hydrological inputs from the Barwon River catchment and Moorabool River. In recognition of this, two separate studies were undertaken by the Warrnambool Institute of Advanced Education in 1988 to determine the inflow and discharge requirements of Reedy Lake and Lake Conneware (cited in Bennett, 1994). Recommendations arising from the study included flows to maintain adequate water quality in the estuary system, with particular respect to salinity (cited in Bennett, 1994). However, the study gave no indication as to the source of the flows required to meet the recommendations, or investigated the effects on the biota of issues such as reduced area flooded or flooding frequency or duration which is critical to maintaining Ramsar values in Reedy Lake.

Mammals

The Platypus (*Ornithorhynchus anatinus*) has been recorded throughout the Moorabool River catchment. Numerous specimens were collected in recent fish surveys of the system (Zampatti and Grgat, 2000). However the exact location of these specimens is unknown. There have been no recorded sightings of the Platypus in the reach between Moorabool and Lal Lal Reservoirs for approximately the last five years (P. Toohey *pers. comm.).*

Riparian and instream flora

The condition of riparian vegetation in the Moorabool catchment ranges from extensively cleared in the upper reaches to more densely scattered native remnants in the mid and lower reaches. Lack of streamside vegetation and invasion by exotic species such as willows (*Salix spp*.) and Gorse (*Ulex europaeus*) has been identified as significant issues in the catchment (CCMA, 2000b).

Riparian vegetation has many important roles such as acting as a filter for nutrients before they reach the waterway, as a source of organic inputs into the stream (leaves, trees and logs), providing habitat for native fauna and contributing to bank stability.

In the upper reaches of the Moorabool River (between Moorabool and Lal Lal Reservoirs) riparian vegetation is degraded due to extensive clearing and unrestricted cattle access. Remaining vegetation consists of River Red Gums (*Eucalyptus camaldulensis*) scattered amongst willows and pasture grasses. Willows are a significant problem below the reservoirs and form obstructions that cause bank erosion and impede channel conveyance (CCMA, 2000b).

The mid reaches of the Moorabool River riparian environments are, in general, less disturbed than upstream of Lal Lal Reservoir (Zampatti and Grgat, 2000). In some areas between Morrisons and Meredith excellent stands of native remnant riparian vegetation consisting of River Red Gum, Silver Wattle (*Acacia dealbata*) and Woolly Tea-tree (*Leptospermum lanigerum*) remain (CCMA 2000b). However, Zampatti and Grgat (2000) did note some considerable riparian clearing (probably due to mining activities) and instream degradation in the vicinity of Morrisons.

In the lower reaches downstream of She Oaks weir, the Moorabool River broadens to more extensive floodplain. Here dense strands of willow dominate the streamside vegetation along with an undergrowth of blackberries (*Rubus spp*.), pasture grasses and exotic creepers (Zampatti and Grgat, 2000). Native trees and shrubs such as River Red Gum, Blackwood (*Acacia melanoxylon*) and Tea-tree also occur, but the riparian width is rarely more than one mature tree wide (CCMA, 2000b).

On the other hand, few studies have been undertaken on the East Moorabool River. However Craigie et al. (2002) for the Stream Assessment Project, provided an environmental score of 'low' based on the current condition of stream stability, in-stream habitat and riparian zone. This was due to extensive clearing and exotic and indigenous vegetation (eg. willows) encroachment into the channel (Craigie *et al.,* 2002). The East Moorabool Gorge contains significant areas of remnant grasslands.

The aquatic macrophyte community in the Moorabool River was characterised by Zampatti and Grgat (2000) as containing species common to lentic (non-flowing) water bodies (eg. Elodea (*Elodea canadensis*) and Duck Weed (genera unknown)) especially in the lower reaches downstream of She Oaks. Floating Azolla (*Azolla* sp.) in pools, woody debris along the bank edges, leaf litter and willow root mats were also common at field assessment sites (Zampatti and Grgat, 2000). Zampatti and Grgat (2000) noted that whist these species colonise rivers during the low flow period, during higher flows they were not displaced. Whilst aquatic macrophytes are important habitat for fish and macroinvertebrates, high densities of aquatic macrophytes may also be detrimental to aquatic fauna by causing low levels of dissolved oxygen, particularly overnight and in the early morning (Zampatti and Grgat, 2000).

In addition to instream and riparian species identified by recent site visits, a database search of the catchment revealed seven Victorian threatened water dependent flora species present (NRE, 2003b) (Table 2-20). Of particular interest is the identification of Yarra Gum (*Eucalyptus yarraensis*). This poorly known species whose distribution appears to have been much fragmented by the clearing of native habitat has a Victorian conservation status of 'poorly known' and a national listing of 'rare' (Jeanes, 1996; NRE, 2003b).

- **Table 2-20 Threatened instream and riparian species recorded within the Moorabool River catchment (NRE, 2003b).**

Scientific name	Common name	AROT	VROT
Craspedia paludicola	Swamp Billy-buttons		v
Helichrysum aff. reutidolepos	Pale Swamp Everlasting		v
Senecio psilocarpus	Swamp Fireweed	V	v
Xerochrysum palustre	Swamp Everlasting	V	V
Callitriche palustris	Swamp Water-starwort		k
Eucalyptus yarraensis	Yarra Gum	R	k
Thelymitra circumsepta	Naked Sun-orchid		e

V Vulnerable in Australia: not presently Endangered but at risk of disappearing from the wild over a longer period (20 to 50 years) through continued depletion.
R Rare in Australia: rare but overall not currently considered Endangered or Vulnerable.
v Vulnerable in Victoria: rare, not presently endangered but likely to become so soon due to continued depletion;
k Poorly known and suspected, but not definitely known, to belong to any of categories x, e, v or r within Victoria.
e Endangered in Victoria: rare and at risk of disappearing from the wild state if present land use and other causal factors continue to operate.

2.6.4 Wetlands

Several wetlands were identified in the Moorabool River catchment following a study undertaken to assess the conservation values of lakes and wetlands in the south western region of Victoria (cited in Bennett, 1994). The significant 'artificial' wetlands identified were Lal Lal, Bostock, Korweinguboora and Moorabool Reservoirs (cited in Bennett, 1994). Although the values or ecological consequences of an altered flow regime have not been described for any of the reservoirs, Bennett (1994) suggested that they were singled out due to their size, potential drought refuge and rarity.

Also identified in the study was the Reedy Lake/Lake Connewarre complex of the lower Barwon River. Reedy Lake is a freshwater wetland system which is fed by overflows and regulated inputs from the Barwon River (Parks Victoria, 2000). Reedy Lake also has a regulated outlet allowing the control of water levels to Lake Connewarre. The Moorabool River contributes water to the Barwon River estuary which is important to the health of Lake Connewarre and associated wetlands, and to the availability of water for regulating levels in Reedy Lake (Bennett, 1994). The mean annual flow of the Moorabool River at the Batesford gauging station over the period 1969 to 2000 is 20%, compared to the Barwon River at Pollocksford which is 80%.

Therefore these wetlands will be affected by any environmental flow decisions made upstream in the Moorabool River and need to be considered as part of this project. They have already been considered as part of the Moorabool SMP process, whereby an objective has been set to 'promote appropriate flow regimes required by downstream wetlands and the Barwon River estuary'. However, they were not considered in the assessment of the environmental flow requirements for the Moorabool River. An environmental flows study for the Barwon and Leigh Rivers is currently in preparation and will address the water requirements of the wetlands.

The ecological consequences of an altered flow regime have been described for Reedy Lake and Lake Connewarre in the *Draft Strategic Management Plan for the Port Philip Bay and Bellarine Peninsula Ramsar site* (Parks Victoria, 2002). However, the water requirements of the wetlands were not discussed but cited earlier in Bennett (1994). Water requirements were based on flows to ensure adequate water quality in the system and conditions for maintaining existing fish populations in the lakes following investigations by Tunbridge (1988) and the Warrnambool Institute of Advance Education in 1988 (cited in Bennett, 1994). A water level management plan has also been prepared for Reedy Lake and aims to provide a framework for managing the water regime to protect the ecological and social values and functions of the lower Barwon River system (Parks Victoria, 2000). This involves actively managing water levels to control Carp (*Cyprinus carpio*) and more closely resemble the natural seasonal filling and drying cycle of the lake (Parks Victoria, 2002).

Reedy Lake and Lake Connewarre are recognised as Wetlands of International Importance (Parks Victoria, 2002). They form part of the Port Philip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site that also includes parts of the shoreline, intertidal zone and adjacent wetlands of western Port Philip Bay, extending from Altona south to Limeburners Bay (Parks Victoria, 2002).

Lake Connewarre is one the most significant wetland areas for swans, ducks, grebes and coots in terms of numbers and diversity (Parks Victoria, 2002). It also contains the most important known wintering sites for the critically endangered Orange-bellied Parrot (*Neophema chrysogaster*) and a number of other migratory waders listed under the CAMBA and JAMBA treaties (Parks Victoria, 2002). Lake Connewarre also provides rearing, spawning and nursery habitat for various freshwater and estuarine species such as the Short-finned Eel, Tupong and Short-headed Lamprey (Tunbridge, 1988). Of particular interest is that Australian Grayling are thought to potentially use the lake, as they require brackish conditions during their life cycle (Tunbridge, 1988).

The site also has high vegetation richness with 137 native plants being recorded. It contains the most extensive example of *Wilsonia* herblands and *Distichlis* grassland (Frazier, 2002). Lake Connewarre plays an important role in absorbing and recycling sediment, nutrient and other pollutants from the Barwon River catchment. Subsequently, this improves water quality and flows in the lower Barwon River and adjacent coastal waters for tourism and recreational value (Parks Victoria, 2002).

Reedy Lake is the largest freshwater lake in central Victoria and has outstanding value due to its large size (approximately 550 ha), floristic richness, structural diversity and the presence of restricted plant species and associations (Frazier, 2002; Parks Victoria, 2000). It is also listed on the Register of the National Estate as part of the Lake Connewarre State Game Reserve (Parks Victoria, 2000). More than one hundred bird species have been recorded in the wetland. Of these, seven are listed under the *FFG Act 1988*, nineteen under CAMBA and seventeen under JAMBA, including the Little Tern (*Sterna albifrons*), White-bellied Sea-eagle (*Haliaeetus leucogaster*) and Great Egret (*Ardea alba*) (NRE, 1999a). Two significant fish species, the Yarra Pygmy Perch (*Nannoperca obscura*) and Australian Grayling have also been recorded in the lake (NRE, 1999a).

The site also supports one of the best examples of freshwater marsh vegetation in Victoria (Parks Victoria, 2000) and the globally threatened plant Cover Glycine (*Glycine latrobeana*) (Frazier, 2002; Genrke and Harris, 2001).

2.6.5 Weirs

Downstream of She Oaks a number of weirs have been constructed over the past 50 years. The weirs create pools upstream allowing licensed diverters to extract water. Many of these weirs act as barriers to native fish migration, prevent spawning and therefore isolate communities within a river reach. The exact number and location of these barriers will be confirmed as well as options regarding their removal and/or modification in the Lower Moorabool On-stream Storage Investigation Project conducted as part of the Moorabool River Catchment project.

2.6.6 Environmental flow requirements in the Moorabool River

Three studies have provided environmental flow recommendations for the Moorabool River (Bennett, 1994; Tunbridge, 1988; Zampatti and Grgat, 2000) (Table 2-21). While the method for determining the recommendations may differ, the basic objective of the studies generally remains the same – to ensure the consumptive use of water has a minimal impact on, or risk to, the environment (Bennett, 1994).

Environmental flows are often considered to be flows that maintain the natural variability in stream discharge. They are important for both ecological and geomorphological processes such as to remove nutrients and sediment through and from the catchments and support life history strategies and subsequent recruitment of native fish, macrophyte and macroinvertebrate species (NRE, 2002a).

The first environmental flow recommendations provided by (Tunbridge, 1988) were the result of a study carried out to assess the conservation and recreational values in the Moorabool River. Therefore an ‘environmental flow study’ as such, was not carried out for the Moorabool River due to its ‘low angling and conservation value and its past record of flow regulation’ which would ‘make it unrealistic to impose a strict environmental flow regime’ (Tunbridge, 1988). Nethertheless, a visual assessment of fish habitat was undertaken for flows at three reaches in the catchment; West

Moorabool River below Lal Lal Reservoir (55 ML/d), East Moorabool River below Bostock Reservoir (0.14 ML/d) and Moorabool River below She Oaks (11 ML/d) (Tunbridge, 1988). Final flow recommendations were based on the protection of fish habitat in pools, the maintenance and spawning of Brown Trout (*Salmo trutta*) and for aesthetic purposes. The East Moorabool River and the reach below She Oaks were not included in the final flow recommendations. However, it was intended that the flows recommended above She Oaks should also be applied to the lower Moorabool River (Tunbridge *pers. comm*. cited in Bennett, 1994) and that a further reduction from 0.14 ML/d was not advisable (Tunbridge, 1988).

- **Table 2-21 Flow recommendations for the Moorabool River from previous studies.**

Recommended by	Downstream of Moorabool Reservoir	Downstream from Lal Lal Reservoir	Morrisons	Morrisons to She Oaks	Downstream of She Oaks
Tunbridge, 1988	N/S	5 ML/d (freshening flow) even when releases for water diversion are not required	N/S	15 ML/d during May and June	N/S
Bennett, 1994	N/S	Minimum flow of 19.7 ML/d*	Minimum flow of 40 ML/d*	N/S	N/S
Zampatti and Grgat, 2000	2 ML/d or natural	N/S	N/S	N/S	10 ML/d or natural

N/S-Not Specified. The Bulk Entitlement includes the recommended 20 ML/d except during the extended dry periods.
* Specified in Bulk Entitlement (2.3).

The second environmental flow recommendation provided by Bennett (1994) was based on the findings of Tunbridge (1988) and an analysis of water quality data, with particular reference to salinity. A minimum flow of 19.7 ML/d or the natural flow, whichever was smaller was specified below Lal Lal Reservoir. However, a constant minimum release of this magnitude was discounted for the reason that it would significantly impact on Ballarat's and Geelong's current rights to water (Bennett, 1994). No further recommendations were made. However, the bulk entitlement states that the recommended 20 ML/d downstream of Lal Lal Reservoir to be reduced to 5 ML/d during extended dry periods. A minimum flow of 40 ML/d was also provided at Morrisons by Bennett (1994), as there were indications if this minimum flow was provided water quality would be adequate to sustain instream biota. This subsequently led to an inclusion in the Bulk Entitlement of 40 ML/d downstream of She Oaks.

The third recommendation provided by Zampatti and Grgat (2000) was the result of an assessment of environmental flow requirements for the Moorabool River as part of the SMP process. Three reaches were identified in the catchment (downstream of Moorabool, downstream of Lal Lal and downstream of She Oaks). Within these reaches, comprehensive fish surveys were undertaken at six sites to determine the distribution of fish in the Moorabool River catchment and assess the amount of habitat available to River Blackfish at flows that occurred on particular sampling dates. Flow recommendations were based on the assessment of fish habitat, along with investigations of water quality and current and natural flow regimes for the summer/autumn low flow period only. A minimum flow of 2 ML/d was recommended below Moorabool Reservoir and 10 ML/d downstream of She Oaks (Zampatti and Grgat, 2000). Zampatti and Grgat (2000) did not recommend minimum flows from Morrisons to She Oaks as there are no private diverters in this reach and therefore it was beyond the scope of the SMP process. However, the reach is used as a conduit during the summer period when discharges are commonly greater then 20 ML/d. It is also subject to a reversed flow regime with elevated flows over the summer and autumn period and low flows over the winter period.

Flow recommendations were made with the aim of meeting the environmental management objectives that were proposed by the Moorabool River SMP Working Group (Zampatti and Grgat, 2000). However, not all management objectives were addressed in the report and the link between the objectives and recommended flows was not clearly defined. In particular, no recommendations were provided for the volume or duration of ‘flushing flow’ and ‘high flow’ regimes. Flushing flow is important for the maintenance or improvement of water quality and high flows effectively wet and connect most habitats within the main channel (NRE, 2002a). In addition, the relationship between physical processes and these flows was not investigated in this study or those conducted previously. Physical processes include the natural movement of sediment downstream and prevention of the unnatural encroachment of vegetation into the streambed.

To ensure that the minimum flow requirements recommended as environmental flows can be met, it is important to first identify the magnitude of streamflows what would have occurred within that system under the natural conditions (ie. in the absence of licensed diverters, farm dams and water supply reservoirs). Zampatti and Grgat (2000), modelled flow duration curves for the Moorabool system in an undeveloped state. However, it is unclear whether an assessment of farm dam impacts was considered. This could have a significant bearing on the environmental flows recommended.

Flow recommendations by Zampatti and Grgat (2000) were also not provided for the Reedy Lake/Lake Connewarre complex of the lower Barwon River. Although it may have been seen to be beyond the scope of the Moorabool River environmental flows assessment, an environmental management objective was set by the Moorabool River SMP working group that ‘minimum flows were recommended with the aim of meeting the environmental management objectives’ (Zampatti and Grgat, 2000). However, the environmental flow requirements failed to address this issue or even knowledge its existence.

This project also does not provide flow recommendations specifically for the Reedy Lake/Lake Connewarre complex. However, the wetlands have been identified as an area containing significant ecological value that requires management of the water regime to maintain those values. Environmental flows have been recommended for the Moorabool River that are important for both ecological and geomorphological processes. In doing so, it is envisaged that if appropriate environmental flows are delivered to the Moorabool River reaches, appropriate environmental flows will also be delivered to the wetlands downstream. However, other factors such as regulators and environmental flows in the Barwon River play an important role.

The modified Instream Flow Incremental Method (IFIM) was used to determine the minimum environmental flow requirements provided for the upper and lower Moorabool by Zampatti and Grgat (2000). This method aims to relate potential habitat availability (ie. riffles and pools) to adult and juvenile River Blackfish. Minimum environmental flows were based on the proviso that riffle habitat would be lost in upstream and downstream reaches when flows were below 2 ML/d and 10 ML/d respectively. At sites upstream of Lal Lal Reservoir, for which the upper Moorabool recommendation was provided, discharges of less than 1 ML/d 'led to rapid losses in potential habitat' (Zampatti and Grgat, 2000). However, 2 ML/d was recommended even though only three discharges at each site were experienced. The measured discharges ranged from 0 ML/d to 0.4 ML/d and 5.8 ML/d to 7.3 ML/d. Therefore no discharges were measured between 0.4 ML/d and 5.8 ML/d. A similar scenario was experienced for the recommendations provided for sites on the lower Moorabool. The measured discharges ranged from 0.1 ML/d to 6.1 ML/d and 14.9 ML/d to 26.3 ML/d. No discharges were therefore measured between 6.1 ML/d and 14.9 ML/d, the range in which the flow recommendation exists.

The method used for the previous determination of environmental flows had significant limitations (NRE, 2002a). Consequently the transparency and robustness of the outcomes could be questioned. There was little predictive capacity and the recommendations were based on the flows observed. In addition, the premise behind the method relied on fish habitat data for one species studied in another region of Victoria. There was no mention of geomorphological condition or issues in the catchment, in response to river regulation.

Since the completion of these studies a new method for determining environmental water requirements was developed in 2002. Named 'FLOWS,' it aims to provide a standard scientific approach of flow requirements for river systems that can be used across the state (NRE, 2002a).

In recognition of this, Sinclair Knight Merz undertook a brief field assessment of the Moorabool River in an attempt to fill some of the gaps identified from previous studies and confirm previous findings. The brief field assessment undertaken by an Environmental Flows Technical Panel (EFTP) was a two stage process. Firstly, the EFTP visited numerous sites along the Moorabool River including those previously visited by Zampatti and Grgat (2000) and Tunbridge (1988). While in the field, the environmental management objectives proposed by the SMP were reviewed to consider any additional information collected on site. The second stage of the field assessment was to visit the reaches for which environmental flow recommendations by Zampatti and Grgat (2000) exist. The reaches identified were downstream of Moorabool Reservoir and downstream of She Oaks. An additional reach for which a flow recommendation by Zampatti and Grgat (2000) was not provided for was also visited. The reach from below Lal Lal Reservoir to She Oaks was considered in this project as the aim was to address water resource options throughout the catchment. Sites selected at the bottom of each reach were the subject of a field based assessment as per the FLOWS method (NRE, 2002a). Field sheets were completed to identify environmental assets and selected cross sections were sketched. Discussions between members of the EFTP at each site lead to the identification of flow components required to maintain the environmental assets.

2.7 Socio-economic Assets

2.7.1 Introduction

This section describes the major socio-economic assets within the Moorabool River Catchment that are of relevance to the provision of environmental flows. Although environmental flows are primarily concerned with the amount of water required to sustain aquatic ecosystems with a minimum risk of degradation, it is proposed that the strategies for the delivery of environmental flows acknowledge the socio-economic uses of the river to increase returns to all stakeholders.

This section identifies the socioeconomic uses of the Moorabool River Catchment, cataloguing key socioeconomic uses spatially and seasonally. Where appropriate, estimates of user numbers and origins are presented with the intention of indicating the flows required for the continuation of these uses.

Process

Due to the relative novelty of cataloguing the socio-economic values of water catchments and impacts upon these catchments were ascertained by a three-stage investigation. These stages were:

- A review of existing strategies and plans, including the Municipal Strategic Statements of relevant Shires and City Councils;
- Discussions with key representatives from the Department of Primary Industries, Water Authorities and Local Governments; and
- A review of council and water authority publications on the internet and elsewhere.

The investigation focussed on the key uses of the Moorabool River Catchment - reservoirs, farmers' weirs, on-stream and the wider catchment.

To understand these use areas and the assets associated with them, this section is split into three sections:

1) Current socio-economic situation;
2) Current socio-economic assets; and
3) Qualitative assessment of required flows and impacts from changed conditions.

SKM

2.7.2 Current socio-economic situation

The Moorabool River Basin is located within the Corangamite Region. There are four basins within this region – Moorabool, Barwon, Lake Corangamite, and Otway Coast. The Colac-Otway, Golden Plains and Surf Coast shires sit within this catchment, as does the Borough of Queenscliff, most of the cities of Ballarat and Greater Geelong and parts of the Shires of Corangamite, Moorabool and Moyne.

The Corangamite Region has a population of some 325,000 people and current growth trends indicate that it will grow by 40,000 to 80,000 over the next twenty years (CCMA, 2002).

Over time there has been a structural change occurring in the population, as a result of improved road and rail transport within and outside the area. This infrastructure has encouraged more people to relocate from Melbourne to either Geelong or Ballarat and commute to the city centre for work. These new 'migrants' are a mix of people who come from a wide range of socio-economic backgrounds. It is expected that specific groups such as retirees will continue to move to the Corangamite area for lifestyle reasons. In the towns of Anglesea, Lorne and Apollo Bay for instance, the resident population is expected to rise from 4,000 to 11,000 over the next 20 years as a result of this trend.

On account of these changes, the populations living in Ballarat and Geelong and adjoining towns is expected to increase. At the same time, it is expected that there will be a decline in the population in the rural shires. Thus, over time a shift to increased urbanisation is anticipated (Table 2-22). The Municipal Strategic Statements of the local municipalities support this shift, by not encouraging urban growth outside of town boundaries.

- **Table 2-22 Population projections for the Corangamite Region 2006 to 2021 (CCMA, 2002).**

Shire	2006	2011	2021	15 yr change (2006 to 2021)	% change
Ballarat	83,035	84,566	87,748	4,713	+5.7
Colac-Otway	20,631	20,643	20,836	205	+1.0
Corangamite	13,218	12,594	11,578	-1,640	-12.4
Golden Plains	15,340	16,248	18,478	3,138	+20.5
Greater Geelong	197,509	202,887	211,313	13,804	+7.0
Moorabool	8,337	8,684	9,443	1,106	+13.3
Queenscliff	3,598	3,610	3,604	6	+0.2
Surf Coast	20,879	22,210	24,947	4,068	+19.5
Total	**362,546**	**371,442**	**387,947**	**25,401**	**+7.1**
Victoria Total	4,946,688	5,099,070	5,359,116	412,428	+8.3
Regional Victoria	1,342,141	1,367,751	1,424,238	82,097	+6.1

The local population within the Moorabool catchment is ageing as a result of a number of factors including fewer births per person and a net arrival of retirees (Table 2-23). It is projected that by 2006 the region will contain some 76,000 people aged 60 years and over and by 2021 it is predicted that there will be 112,000 people aged 60 years and over.

- **Table 2-23 Age distribution of the population of the Corangamite Region (CCMA, 2002).**

Age Group	2006	2011	2016	2021	15 yr change (over the years 2006 to 2021)	% change
0 – 19	94,622	90,300	86,510	84,927	-9,695	-10.6
20 – 39	93,008	93,937	94,569	94,179	1,171	+1.3
40 – 59	98,616	99,626	98,456	96,850	17,66	-1.8
60 – 79	59,349	68,145	79,031	89,624	30,275	+53.7
80 +	16,951	19,434	21,241	22,367	5,416	+29.4
Total	**362,546**	**371,442**	**379,807**	**387,947**	**25,401**	**+7.1**

Employment

The unemployment rate within the Corangamite Region ranges from 3.1 per cent to 10 per cent in the different statistical local areas (SLA) within it (Table 2-24). A relatively high proportion of self-employed farmers and the relatively low level of income in those areas could explain the low unemployment rate in some areas. These figures may mask a significant level of under-employment. The figures also reflect the trend for young people and people who have been unable to find employment locally to leave these areas and move to the city areas (such as Ballarat) in search of work.

- **Table 2-24 Labour force for the different statistical local areas within the Corangamite Region (DEWR, 2002)**

SLA Name	Unemployment	Unemployment Rate (%)	Labour Force
Corangamite	300	3.1	9,675
Golden Plains	309	4.2	7,435
Colac-Otway	464	4.3	10,766
Greater Geelong	682	4.5	15,094
Surf Coast	435	4.7	9,295
Moorabool	735	5.9	12,544
Ballarat	4243	10	42,302

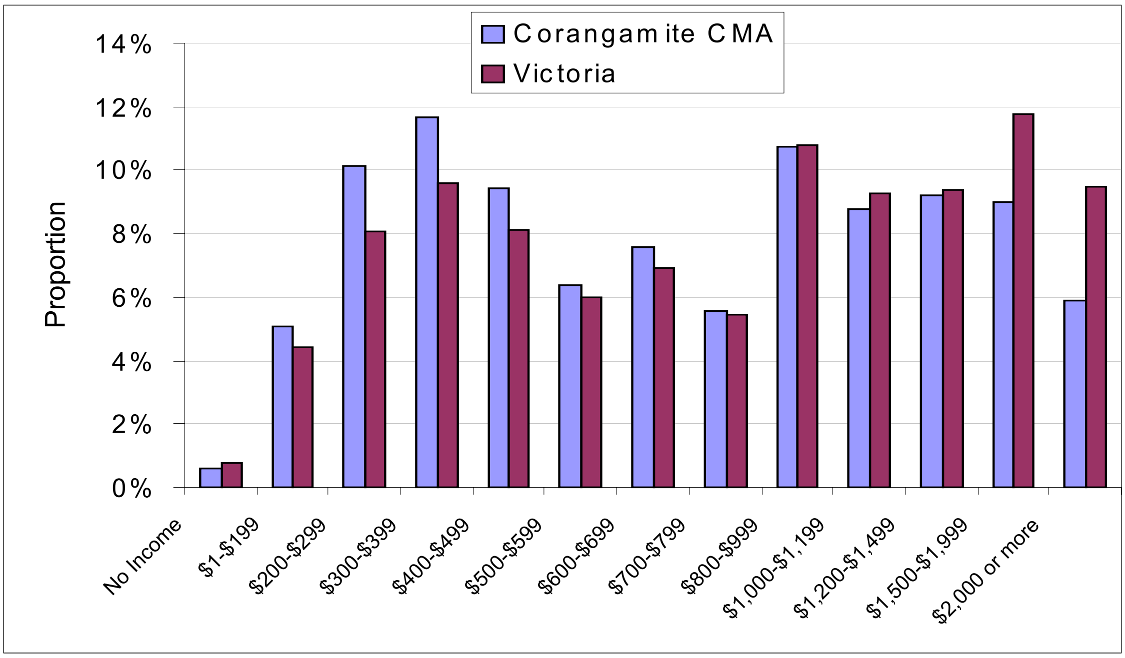
The three main industries of the region are agriculture (the most dominant), forestry and tourism. The main agricultural enterprises in the Corangamite Region are dairy, beef, cereals, sheep and intensive agricultural industries (egg producers and poultry farming). The dairy and beef industries are currently intensifying and expanding output (dairying in particular). In the future, agricultural industries are expected to intensify their production. This forecast is based on the expectation that rising land prices surrounding Melbourne will lead to the relocation of these industries to cheaper and greenfields sites within the region. Forestry (in particular wood chips) has been a strong industry in the Corangamite Region. In the future a shift toward more agroforestry is anticipated.

The other main industry of the Corangamite Region is tourism. The Great Ocean Road, Ballarat, Geelong and the Bellarine Peninsula are all major tourist attractions. The growth in tourism is significant, with the Great Ocean Road averaging an annual growth rate of 15 per cent (in visitor numbers) over the past few years. In addition to these tourist attractions, the Corangamite Region is also experiencing increases in rural tourism, wine tourism and food tourism.

Weekly Income

The median weekly income across the Corangamite CMA is lower than the Victorian average, with residents more commonly in lower income brackets and fewer in high income brackets than the prevailing Victorian average (Figure 2-7).

- **Figure 2-7 Weekly wage for persons aged 15 years and over (Source: ABS 2002).**



Profile of the Moorabool River Basin

Approximately 75 per cent of the total land area in the Moorabool River Basin is used for agriculture – almost all of which is unirrigated (as discussed below in the land use section). The Moorabool River Basin was ranked 147 for its contribution to national 1996/97 profit at full equity (Land and Water Australia, 2002). In 1996/97 the Moorabool River Basin had a profit at fully equity of $1.3 million. Also, during this period the government provided over $2.7 million in support. Irrigated agriculture had a considerably higher five year profit at full equity compared to dryland agriculture (Table 2-25). The data indicates that the Moorabool River Catchment is heavily reliant on government support (Table 2-25).

- **Table 2-25 Value of production (Land and Water Australia, 2002).**

Measure of Production	Value
1996/97 gross revenue ($'000)	40,672
1996/97 variable costs ($'000)	13,020
1996/97 fixed costs ($'000)	26,336
1996/97 profit at full equity ($'000)	1,316
1996/97 government support ($'000)	2,720
1996/97 economic returns ($'000)	-1,404
5 yr (1992/93 – 1996/97) gross revenue ($'000)	44,391
5 yr (1992/93 – 1996/97) total costs ($'000)	39,382
5 yr (1992/93 – 1996/97) profit at full equity ($'000)	5,009
Irrigated agriculture 5 year profit at full equity ($'000)	5,258
Dryland agriculture 5 year profit at full equity ($'000)	-249
Minimum area of basin needed to produce 80 % of profit at full equity within basin (ha)	293

The two closest cities to the Moorabool River Catchment are Ballarat and Geelong. Both receive water from the Moorabool River Catchment and have a variety of uses for the catchment, including economic and social. The following will very briefly discuss these two cities.

Ballarat

Ballarat is experiencing a change in its mix of dominant industries. Agriculture and minerals-based resources have been the main providers within the region and now, manufacturing, tourism, health, community services, education and retailing are the city's key industries. New industries such as information technology are also emerging (City of Ballarat, 2002).

Agriculture is still significant, but not as significant as in the past. In 1997, agricultural production was valued at almost $27.5 million (the main industries: pigs, potatoes and wool). These agricultural industries supply to value-adding industries such as McCain Foods and Japanese noodles located in the region (City of Ballarat, 2002).

The manufacturing sector represents 19 per cent of the Ballarat workforce and is the city's largest generator of job opportunities (City of Ballarat, 2002).

Tourism is important to Ballarat. Given the city's close proximity to Melbourne, it has been more successful as a day-visit destination than for overnight stays. There were 1,230,000 day trip visitors to Ballarat during 2000. The City is seeking ways to increase the number of overnight visitors from 608,000 overnight trips (in 2000 calendar year) in order to increase the economic benefits of tourism

(City of Ballarat, 2002). The main tourist attractions for Ballarat are its history related to the Goldfields.

Housing demand

The Department of Infrastructure has estimated that more than 6,000 new households will be built in Ballarat over the next 20 years (City of Ballarat, 2002). This is a result of both lifestyle moves from elsewhere (net immigration) and the result of the fast rail project which is expected to reduce the commute between Ballarat and Melbourne to 60 minutes. The growth in population has already increased the pressure of lifestyle residential development around towns on the Western Freeway, such as Gordon and Ballan.

Water demand

The regional water supply systems for Ballarat receive almost 100% of their water supply from the Moorabool Catchment, with a small contribution from the adjacent upper Leigh River. In 2000/01 Ballarat required some 12,152 ML for 39,981 services. Of the total water used in the town, 68 per cent was for residential use and 3 per cent for non-residential use with the remainder for concessions. In 2000/01 CHWA diverted water under bulk entitlements. These were:

- Upper West Moorabool System released 9,855 ML; and
- Lal Lal- Central Highlands Water released 6,667ML.

Due to the extreme drought conditions, water over and above passing flows was released from the Upper West Moorabool System and Lal Lal by Central Highlands Water. These were provided to ensure the West Moorabool River downstream of the reservoir maintained a flow of at least 1 ML a day to meet the requirements of downstream stock and domestic users and environment needs (CHRWA, 2002).

Geelong

Geelong is the largest regional centre in the State of Victoria, with an estimated population of 190,000.

Over 80,000 people are employed in Geelong. The main industry is in the 'tertiary production' sector, including construction, retail, transport, government, finance and health (Table 2-26).

- **Table 2-26 Employment by industry in Geelong (City of Greater Geelong, 2003).**

Industry structure	Percent of the work force
Primary (agriculture and mining)	2%
Secondary (manufacturing)	20%
Tertiary (construction, retail, transport, government, finance and health)	66%
Service (accommodation, restaurants, personal services)	10%

Like Ballarat, Geelong is experiencing an increase in net migration with people choosing to live in Geelong for lifestyle reasons and commute to Melbourne for work.

Tourism is a significant industry for Geelong. It is the gateway to the Great Ocean Road and given its close proximity to Melbourne there is a high proportion of day visitors (2,062,000 day trip visitors). The quality of accommodation within the area also encourages overnight stays (773,000 overnight trips). The key aspect of tourism that interacts with the Moorabool River Catchment is winery touring and access to the Brisbane Ranges National Park and then further to the Lerderderg State Park.

A third of the water consumed in Greater Geelong is sourced from Moorabool River Catchment. Due to the integrated system operated by Barwon Water, in some years no water is sourced from Moorabool River Catchment as all has been supplied from the Barwon System. This has been due to:

- The lack of treatment of Moorabool water before the end of 2001,
- Previously adopted high salinity standards for supply, and
- The occurrence of high salinity from the Western branch of the Moorabool River when there is no release from Lal Lal Reservoir (P. Northey Barwon Water *pers. comm.*).

Geelong demand is 36,000 ML per year on average with the majority of the water going to residential use (62%), 23% for industrial and the remaining 15% for commercial uses. The Moorabool River Catchment usually supplies a slightly higher proportion of the industrial demand due to its location in the northern part of Geelong.

2.7.3 Projected land use change

The threats to the agricultural economy in the Moorabool River Catchment are the same as for the rest of Australia: uneconomically small farm sizes, declining country town populations and an ageing population. In the future, agricultural industries are expected to intensify production, which is at least partially the result of rising land values. As a result of consolidation into larger properties, larger herds, more mechanisation and more use of feed, production from local dairy farms is expected to double over the long term (10-20 years). Cropping systems are expected to become more intensive as more producers adopt raised bed cropping. Intensive agricultural industries such as egg producers, poultry farmers and piggeries are expected to move from their present locations around Melbourne and Geelong, to the Surf Coast and Golden Plains due to the rising demand for residential land surrounding Melbourne. Horticulture and viticulture will continue to expand and seek out land that has suitable water, soil and is close to transport and labour.

Forestry (in particular wood chips) has been a strong industry in the within the catchment. In the future there is expected to be a move toward more agroforestry.

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Salinity

The future of the Moorabool River Catchment is expected to be impacted by dryland salinity in the next twenty years. This rise in dryland salinity will increase annual local infrastructure costs (Table 2-27).

- **Table 2-27: Salinity – the costs (Land and Water Australia, 2002).**

Area where dryland salinity caused yield loss in 2000 (ha)	1,129
Area where dryland salinity may cause yield loss in 2020 (ha)	10,871
Limiting factor gross benefit ($'000)	15,705
Impact cost of dryland salinity to agriculture from 2000 to 2090 ($'000)	373
Local infrastructure cost of salinity and water table rise 2000 ($'000/yr)	295
Local infrastructure cost of salinity and water table rise 2020 ($'000/yr)	1,446
Present value of increase in local infrastructure costs from salinity and rising water tables from 2000 to 2020 ($'000)	6,384
Downstream costs (estimated)	
1 % increase in salt loads ($'000)	-
5 % increase in salt loads ($'000)	-
10 % increase in salt loads ($'000)	-
1 % increase in turbidity ($'000)	84
5 % increase in turbidity ($'000)	415
10 % increase in turbidity($'000)	812
1 % increase in sediment loads ($'000)	23
5 % increase in sediment loads ($'000)	58
10 % increase in sediment loads ($'000)	100

There is also an increasing prevalence of urban development within the catchment. This development is associated with people seeking a 'lifestyle' change and requiring smaller 'hobby farm' size farm developments that are generally not economically viable. These developments are occurring throughout the catchment but within the lower and upper regions of the catchment primarily. In the lower regions, developments are spreading north from Geelong up to Steiglitz Road, whereas the upper regions of the catchment are spreading east from Ballarat, around Mount Egerton, towards Lal Lal Reservoir from the Lal Lal township and around Gordon. However, local planning initiatives such as the Local Planning Policy Framework and Environmental Significant Overlay 1 in the Moorabool Shire Planning Scheme is restricting these lifestyle developments.

2.7.4 Socio-economic assets

The Moorabool River Catchment is a significant socioeconomic asset to the Region. Historically it formed the 'road' to development of the Moorabool Valley with industries such as tin and gold mining and more recently has facilitated the development of sand mining and viticulture expansion.

However, its current degraded state has reduced the utilisation of the river by the catchment and wider community. The more significant issues raised have been:

- Weed proliferation along river and creek banks;
- Poor water quality (eg. high salinity levels);
- Limited water security (eg. no flow or slow water flow throughout the year); and
- Limited access to the River (it is estimated that only 40 per cent of river bank is crown land) (A. Bishop, *pers. comm.* 7 Feb 2003)

No *social* values for access or use of the water in the Moorabool River appear to be included in the overall allocation process.

The socioeconomic assets that the Moorabool River currently provides to its region are significant but under-utilised. The four main user groups that use the Moorabool River Catchment are:

- The wider **Community**, including the wider local, regional and wider community of users;
- **Economic development**, including tourism and value adding agricultural industries (eg. Artificial Insemination Piggery Centre);
- **Urban development**, including township development and expanding 'lifestyle' properties; and
- **Farmers and irrigators**, including all farmers and irrigators who use the river for both direct pumping for winter water storage or on an as needs basis.

These four groups have overlapping but particular uses for the Moorabool River Catchment and each use has associated assets. Table 2-28 displays the four user groups and the types of uses and activities they have for the Moorabool River Catchment.

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▪ **Table 2-28 Activities and uses of the Moorabool River Catchment.**

User groups \ Use areas	Reservoirs	Farmers' Weirs	On-stream	Weir catchment
Community	Fishing Picnics Walking	Fishing Swimming	Swimming Fishing Canoeing	Sightseeing Historical development Aesthetics
Economic Development	Water security and supply	-	Water security and supply	Tourist development
Urban development	Diversions	-	Diversions	Aesthetics
Farmers and Irrigators	Regulation of flow	Water security	Allocations Diversions	-

The activities that occur in the Moorabool River Catchment have been further divided into four categories. The categories reflect the location or type of extractive (or non-extractive) use that may occur, and include:

- Reservoirs, which are controlled by the Water Authorities;
- Farmer's weirs, which include all on stream storage facilities that have been constructed;
- On stream diversions, which does not include on-stream storage, but is for direct diversions; and
- Wider catchment, including the broader regional land area within the catchment.

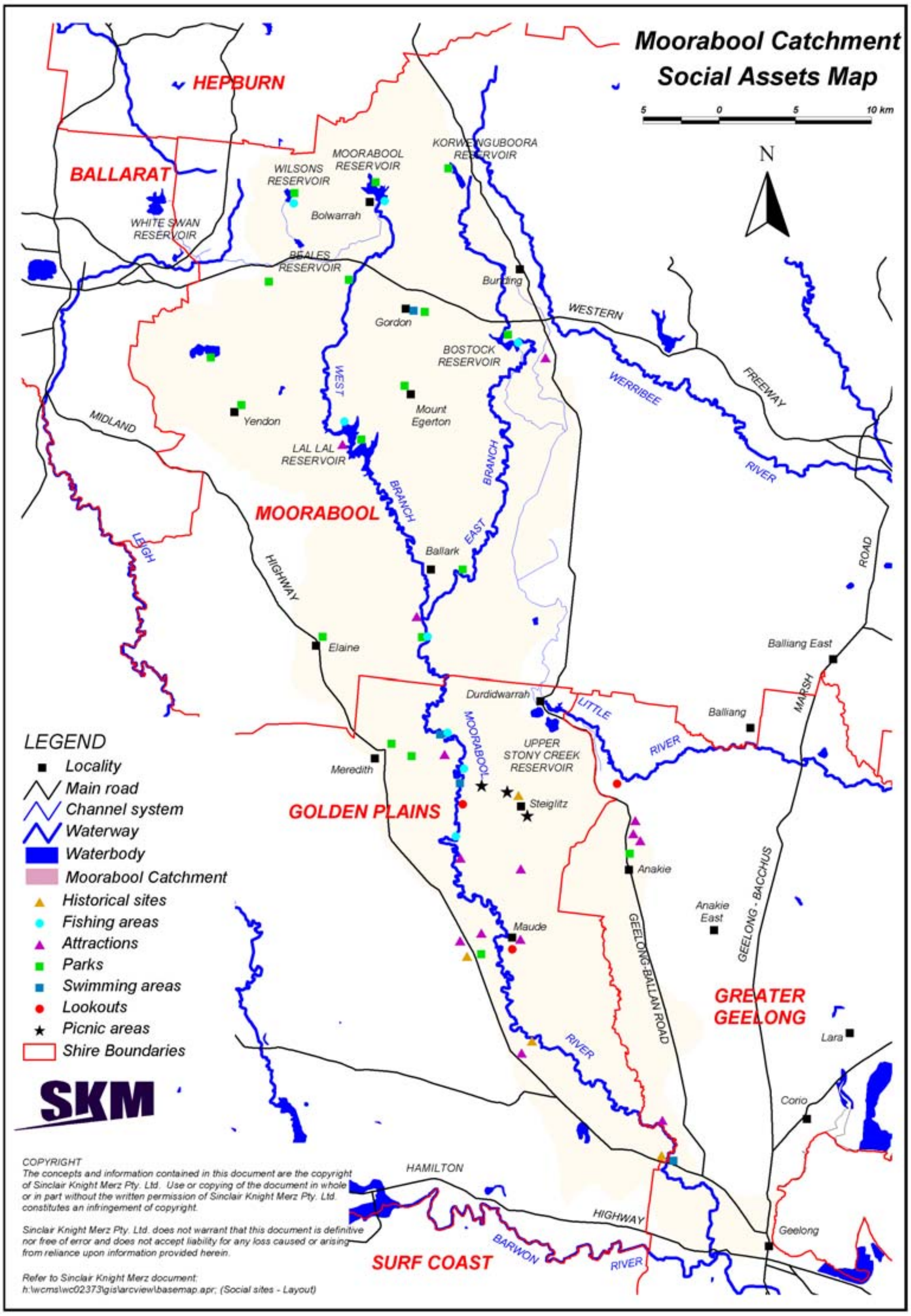
The differentiation of these use areas has been done to link in with other parts of the water resource assessment, as there is considerable overlap between user groups activities and areas of use.

The majority of community or social uses of the catchment are recreational, occurring in reservoirs and on-stream (Table 2-28). It has been revealed that at various times the Moorabool River have had a variety of social uses, including:

- Swimming
- Picnicking
- Fishing
- Horseriding
- Mountain biking
- Gold fossicking
- Gem fossicking
- Kayaking
- Bird watching
- Camping
- Bushwalking
- Aesthetic/Sightseeing

Most of the users are locals or have local knowledge and originate from Ballarat, Geelong or Melbourne (C. Worell, *pers. comm.* 7 Feb 2003). There has been minimal promotion of the river and its uses to the wider public and they are not included within the broader tourist promotion of the region. The majority of use occurs during the summer months.

A social assets map has been compiled that categorises uses from various sources including discussions with stakeholders, Municipal Strategic Plans, web sites for Parks Victoria, local shires and Tourism Victoria (Figure 2-8).



- **Figure 2-8 Social assets in the Moorabool River Catchment.**

Table 2-29 List of Social Assets in Moorabool River Catchment.

Area	Asset type	Name or Description
Steiglitz	Picnic area	Bert Boardman Recreation Areas
	Picnic area	The Crossing Picnic Area
	Picnic area	Old Mill Camp
	Lookout	Red Break Track
	Historic	Whole town has historic overly
	Swimming area	Access to Moorabool River
	Lookout	Eagles Point, large white cliffs
Gordon	Park	Recreation Reserve
	Swimming Area	Local Pool
Meredith	Park	Picnic area, toilets, golf course
	Park	Meredith State Forest
	Swimming Area	Swimming access to river
	Fish	Camping and fishing facilities
	Attraction	Meredith Education Area
	Fish	Between Slate Quarry and Steiglitz Rd
Lethbridge	Park	Lake Reservoir
	Attraction	Lethbridge winery
	Historic	Historic bridge
Anakie	Attraction	Del Rios Vineyard
	Attraction	Straughton Value Vineyard
	Attraction	Mount Anakie Winery
	Park	Fairy Park
Bannockburn	Attraction	Clyde River Winery
	Historic	Russells Bridge
Batesford	Swimming area	In the river
	Historic	Blue Stone Bridge
	Attraction	Jindalee Estate Winery
Maude	Attraction	Amietta Vineyard and Winery
	Attraction	Tarcoola Estate Winery
	Lookout	Back of recreation reserve, view down Gully
Wilsons Reservoir	Fishing	Fishing in reservoir
Lal Lal Reservoir	Attraction	Lal Lal Falls
Bostock Reservoir	Fishing	Fishing in reservoir (reservoir stocked)
	Park	Park and picnic facilities around reservoir
Moorabool Reservoir	Fishing	Fishing in reservoir (reservoir stocked)
	Park	Park and picnic facilities around reservoir
Bradshaw	Attraction	Ballan Mineral Springs
Korweinguboora	Park	Korweinguboora Recreation Reserve
Wallace	Park	Wallace Recreation Reserve
Mt Egerton	Park	Mt Egerton Recreation Reserve

Area	Asset type	Name or Description
Yendon	Park	Yendon Recreation and Tennis Reserve
Navigators	Park	Navigators Community Centre and Recreation Reserve
Bungaree	Park	Bungaree Recreation Reserve
Morrisons	Park	Morrisons Recreation Reserve
	Attraction	Gem and Gold Fossicking at the mouth of the Dolly's Ck
	Fishing	Fishing in the River
Sheoaks	Attraction	Tammaroo Wildlife Park
	Fishing	Camping and fishing
	Attraction	Rapids downstream from Sharpes Bridge
Ballark	Park	Bungal State Forest
	Park	Borheneyghurk Common

Some notable facets of social dependence on the river include:

- There is an environmental overlay (Moorabool Municipal Strategic Statement, ESO3) over the Moorabool River that is purely enacted for scenic value;
- The Moorabool River is the only swimming area apart from Geelong in the Lower Catchment and Ballarat and Gordon in the Upper Catchment;
- Many 'old time' farmers continue to live in the Moorabool River Catchment due to its spectacular scenery and aspect, and the 'vision' they retain of it twenty years ago;
- Camping areas around Slate Quarry Rd, Coopers and Sharps Rd all require permits that enforce a chemical toilet to be taken in and removed; and
- Although most of the River is only accessible through private land there is a perception by some members of the community that access for fishing or swimming is easily granted by private landholders.

Economic development initiatives require water security and supply to enable stable and long term capital investment. The main areas where security is needed is from the reservoirs and consequently the Water Authorities and on-stream diversions. It is noted that the majority of economic development is occurring in the lower catchment primarily between the Midland Highway and the Moorabool River between Batesford and Meredith. It is the lower part of this area that has been experiencing no-flow periods which are a problem for future development initiatives which require a secure water supply.

Urban development is dependent on water supplied from the Water Authorities for the residential development and from the on-stream diversion for the lifestyle properties. Due to the Bulk Water Entitlements that the water authorities are allowed there is no perceived issues of security of supply for the residential expansion. T he lifestyle expansion has been curtailed by council's adherence to maintaining larger block sizes through Moorabool Planning Scheme and the catchment policy issued by Barwon Water, Central Highlands water, Southern Rural Water and Western Water to protect the catchments in Moorabool from inappropriate development. However the most significant issues from this type of development and associated users are:

- proliferation of on-farm dams on the smaller properties;
- greater demand on winter flow to ensure re-fill of on-farm dams;
- decreased run-off into the River due to increased off-stream storage dams; and
- increased nutrient run-off from septic tank seepage and marginal farming practices.

The main groups of water users in the Moorabool River Catchment are farmers and irrigators, and their main areas of use are on-stream weirs, reservoirs, on-stream diversions and in the upper reaches, ground water. The main source of use downstream is through on-stream diversions, however there are a number of weirs and ground water pumps constructed by farmers in the Upper Catchment around Lal Lal Reservoir. The relationship between ground water and surface water is further explored in the ground water investigations (later section). All of these areas are important to the security and supply of water for production purposes in the Moorabool River Catchment. The problem of over allocation affects all uses, especially the downstream irrigators who have experienced periods of no flow and minimal flow.

2.7.5 Flow requirements

The specific flow requirements for each group are discussed below. There is no quantitative data about the impact of a marginal change in flow. This section highlights the key issues that each group has expressed with respect to the flow of the Moorabool River.

Community

Current community uses are highly dependent on water availability and the seasonality of their use. Use by the local community has reduced considerably over the last ten years due to the unpredictability of the water supply and therefore its ‘unappealing’ nature. Requirements from the community users are:

- Increasing the flow of water down the River to ensure a more appealing habitat for the development of fisheries and native flora and fauna attractions;
- Decreasing the weeds and reeds in the river to enable core uses (eg. canoeing over longer stretches);
- Ensuring year round security of supply to enable the development of ‘natural’ swimming holes and attractions; and
- Improving quality of water to attain safe drinking standards and continue social camping areas.

Economic development

The introduction of more intensive agricultural land practices (eg. viticulture and large piggeries) is also producing numerous land-use and resource-use issues for the catchment. These higher value industries are more water intensive and rely not only on security of supply but can also be significantly impacted by duration of supply shortfalls. Some are also highly susceptible to polluted run-off. Many of the newer value-adding establishments are concentrated in the lower catchment and are hence more concerned with security of supply and predictability of shortages.

Tourism has been highlighted as one of the biggest growth industries for the region. Its future depends on the pro-active sourcing of complimentary tourist attractions, activities and accommodation. There has already been concern expressed about value-adding agricultural industrial development which may not complement the tourist industry. Requirements for economic development are:

- Increasing the continuous flow of water down the River, to ensure a lively habitat for the development of fisheries and native flora and fauna attractions;
- Ensuring security of supply, in summer, to enable the development of 'natural' swimming holes and attractions; and
- Improving quality of water to attain safe drinking standards and continue social camping areas.

Urban development

The concern with increased urban development is the demand and impact on resources – such as land and water. An increase in the size of the population will mean that there is increased demand for drinking water and increased potential for pollution. Urban development throughout the catchment requires increased water quantity and maintenance of current quality. However, current endeavours by the water authorities (eg. Barwon Water's Water Resources Development Plan, draft indicates that more efficient water practices will halve demand from the expected 1.3% per year growth). The growth in peri-urban development or lifestyle development will have two proposed impacts on the catchment:

- increased construction of dams on properties will decrease the quantity of water into the waterway; and
- increased septic tank construction will potentially increase the nutrient load entering the waterway.

These impacts will be felt throughout the whole catchment as much of the peri-urban development is occurring around Mount Egerton and the urban development is focused on Ballarat in the Upper Catchment.

Farmers and Irrigators

The key concern for farmers and irrigators is the security of supply and supply shortfalls. This is becoming more prevalent with higher value crops and farming practices being dependant on regular and known water supply and use. The social implications for the increased dependence are being felt through land management practices and river restoration. These issues are being addressed by fencing off streams from stock and planting shelterbelts and buffer strips separating intensive agriculture. Requirements from the farmers and irrigator users are, as related to crop or production type:

- security of supply;
- minimise duration of supply shortfalls; and
- clarification of extraction (in-stream, on-stream and ground water).

2.7.6 Conclusion

The socio-economic environment within the Moorabool catchment is changing as more city dwellers are lured into the area to work and commute or retire. The overall trend within the catchment is for the population to continue to grow and for dominant land uses to move towards consolidated primary agricultural enterprises and more intensive production techniques.

These changes give rise to concerns on the part of the users of river flows, who wonder whether their access and security of supply will be maintained into the future. There appears to be a heightened appreciation of the needs of a sustainable riparian zone and river, and the benefits that such sustainability bring – both financially and socially/economically.

Overall, recent and ongoing socio-economic changes within the catchment represent a major break with the past and indicate that optimal management of water resources within the catchment will continue to become more important (and possibly more complex) as finite water resources are pursued by a larger number of users.

3. Reaches in the Moorabool River

Four reaches have been identified in the Moorabool River catchment following an assessment of the current flow regimes and ecological and social values of the region. The four reaches are from:

- East Moorabool River Bostock Reservoir to the confluence with west Moorabool River;
- Moorabool to Lal Lal Reservoirs;
- Lal Lal Reservoir to Sharp Road, She Oaks;
- Sharp Road, She Oaks downstream to the confluence with the Barwon River.

The current condition and issues within each of the reaches will be discussed below.

3.1 Reach 1 – East Moorabool River Bostock Reservoir to the confluence with the west Moorabool River

Hydrology

- Extended low median flow
- Decreased cease to flow events

Geomorphology

- The highly regulated nature of the stream flow has altered the sediment transport process downstream (Craigie *et al*., 2002). Craigie *et al.* 2002 noted that channel contraction processes were evident in the reach downstream of Bostock Reservoir, including invasion of woody vegetation into the stream channel and colonisation of the stream bed by Cumbungi. The valley form alternates from narrow and gorge-like to wide with broad floodplains (Craigie *et al*., 2002).

Water quality

- There are no VWQMN water quality gauging stations.
- Barwon Water monitors water quality at the Bostock Reservoir outlet. Results from this station and analysis and trends by Barton (2000) indicate that from 1995 to 2000 electrical conductivity increased during low flow conditions due to groundwater intrusion. High pH values (mean = 8.53) increased markedly over a five year period to the year 2000 and turbidity at Bostock Reservoir increased during drought due to a decreasing water level and therefore of sediment in the outgoing water. Total phosphorus concentrations have exceeded the draft SEPP objective of ≤ 0.04 mg/L six of the seven years monitored since 1996.
- No dissolved oxygen data readily obtained.

Biota

- Short-finned Eel is the only native fish species recorded in 1981 at Bolwarrah and downstream of Bostock Reservoir in 1988 by Tunbridge (1988).

Social assets

- Wallace – Recreation Reserve
- Mount Egerton Recreation Reserve
- Ballark – Bungal State Forest and Borhereyghurk

3.2 Reach 2 – Moorabool to Lal Lal Reservoirs.

Hydrology

- Extended low flow season.
- Decreased inflow into Lal Lal Reservoir due to farm dam impacts.
- Proliferation of farm dams in upper catchment.

Geomorphology

- Channel is contracted below the reservoirs and there is potential for channel adjustment due to the highly regulated flows.

Water quality

- Two algal blooms have occurred in the Moorabool Reservoir during 1980 and 1991.
- Total nitrogen and total phosphorus concentrations have exceeded all draft SEPP objectives since 1992 (except total phosphorus in 1994 and 1995). Dissolved oxygen complied for the four years in which percentiles could be calculated (1992-93, 2001-02). Turbidity and total phosphorus complied with the draft SEPP objectives four out of the eight and three out of the nine years for which monitoring was undertaken.

Biota

- Riparian vegetation is degraded due to extensive clearing and unrestricted cattle access. Remaining vegetation consists of River Red Gums scattered amongst willows and pasture grasses.
- Exotic fish species dominate. Only one native fish species, Mountain Galaxias, has been recorded.

Social assets

- Fishing in the Moorabool and Lal Lal Reservoirs.
- Park and picnic facilities surrounding the reservoirs.
- Lal Lal falls.

3.3 Reach 3 – Lal Lal Reservoir to Sharp Road, She Oaks

Hydrology

- Reversal of seasonal flow pattern and decrease in flow variability.

- Constant high flows, as this reach is used as a conduit for delivering water to She Oaks weir and subsequently Geelong.
- No licensed diverters.

Geomorphology

- Prone to avulsion with a number of anabranches and oxbow lakes present on the floodplain. Willow encroachment on the channel and floodplain clearing are increasing the risk of further avulsions of the contemporary river course.
- Widening and deepening may be accelerated due to sustained high flows from Lal Lal Reservoir to She Oaks.

Water quality

- Trend analyses conducted by Barton (2000) show that turbidity concentrations have generally decreased at Morrisons since 1980.
- Total nitrogen and electrical conductivity measurements have exceeded the draft SEPP objectives for the last 11 years (except 1993 for EC). On the other hand, total phosphorus, turbidity and dissolved oxygen have complied.

Biota

- Between Morrisons and Meredith the most extensive area of remnant riparian vegetation remains and exists of River Red Gum, Silver Wattle and Woolly Tea-tree.
- Short-finned Eel and non-migratory fish species such as River Blackfish, Australian Smelt and Southern Pygmy Perch are abundant.
- Macroinvertebrate community diversity is high and exceeded all draft SEPP (EPA, 2001) AUSRIVAS and SIGNAL objectives.

Social assets

- Fishing and swimming in the Moorabool River.
- Bungal State Forest.
- Camping.
- Morrisons Recreation Reserve.

3.4 Reach 4 – Sharp Road She Oaks downstream to the confluence with the Barwon River.

Hydrology

- Decreased median flow and cease to flow periods
- Constant low flows
- Large extractions by licensed diverters.

Geomorphology

- Downstream of Batesford, , the river has been extensively modified through realignment and concrete lining during the 1930s and the 1980s to allow the development of a large limestone quarry (Craigie *et al.*, 2002)
- The highly regulated nature of the stream flow and the presence of many small weirs that have been constructed over the past 50 years will further complicate adjustment processes (Zampatti and Grgat, 2000). It may also give rise to alternatively wider and narrower channel reaches with upstream sediment deposition and localised erosion (or perhaps channel contraction) downstream.

Water quality

- Dissolved oxygen can be potentially low due to extended periods of low flow. This has the potential to be lethal to native fish. However at Batesford, (VWQMN station 232202) dissolved oxygen has met the ANZECC (2000) guideline value since 1992.
- The draft SEPP objectives for total nitrogen and electrical conductivity have been exceeded for the last eleven years. Median EC values increase from December to August and decrease during the high flow period (Zampatti and Grgat, 2000).

Biota

- The highest diversity of native freshwater fish species occurs towards the bottom of this reach at Batesford and the community is dominated by migratory species, including the vulnerable *FFG Act 1988* listed Australian Grayling.

Social assets

- Attraction: Rapids on the Moorabool River downstream of Sharps Bridge.
- Attraction: Numerous wineries
- Camping and fishing at She Oaks.

4. Summary of key issues in the Moorabool Catchment

Although the Moorabool River is recognised as one of the most flow stressed rivers in Victoria, there are still significant environmental values in some parts of the catchment, particularly in the mid to lower reaches. These values include native fish of high conservation value such as the Australian grayling and some areas of remnant vegetation. The riparian values, predominantly in the upper catchment, are significantly degraded as a result of grazing and land use change. Although exotic species, both aquatic and terrestrial, are significant components of the communities in some reaches, native species are still abundant in other reaches. Overall there is potential for an ecological response with the provision of appropriate environmental flows although the system is currently in a continuing state of degradation.

The main water storages in the Moorabool system are Korweinguboora, Bostock, White Swan, Moorabool and Lal Lal Reservoirs. These reservoirs supply water to Geelong and Ballarat. There are a significant number of farm dams in the basin, substantial groundwater use in the upper west part of the catchment, as well as extraction by private diverters predominantly above Lal Lal Reservoir and below She Oaks Weir.

As a result of water resource development in the catchment, there have been significant impacts on the natural streamflow of the Moorabool River. These impacts vary in different reaches of the River. In the upper catchment the natural flows are significantly reduced as a result of the urban water supply storages, groundwater use, farm dams impacts and winter fill extraction.

Bulk Entitlement passing flow rules for the urban storages allow low inflows (up to a set threshold) to be passed through. However inflows exceeding the passing flows are generally caught in the storage and are either consumed or released at a later date. Also, inflows to storages have been decreasing independent of climatic influences due to activities in the catchments upstream.

Downstream of Lal Lal Reservoir there is an increased flow in summer as releases are made for the urban supply to Geelong which is extracted at She Oaks Weir. Further downstream of the main areas of extraction by private diverters, the flow is once again significantly reduced.

Throughout the catchment, farm dams are having a significant impact on inflows to the river. Farm dam usage removes water from the system before other users can gain access. There are more than 4,000 dams in the catchment and these have an estimated volume of some 14,400 ML. It has also been estimated that since 1965 there has been a 150% growth in the volume stored by farm dams. In the past there has been little or no control over dam construction and the proliferation of farm dams has affected the available stream yield.

It is estimated that groundwater use in the upper west catchment is resulting in direct baseflow reduction in the stream. For every megalitre of water pumped from groundwater it is estimated that baseflow in the stream is reduced by 0.6 ML. There is a strong link between surface water and groundwater and while this link has been understood for some time, it has not previously been quantified. Clearly significant groundwater/surface water interaction exists within the Bungaree WSPA (the upper west part of catchment) such that increasing groundwater usage in the Bungaree WSPA is very likely to further reduce in streamflow. The current usage is about 33% of Permissible Annual Volume (PAV). If usage increases up to the PAV then further reduction in streamflow is highly likely.

One of the major issues in the catchment is the high degree of allocation relative to the available resource. There are many competing needs in the catchment, all with a valid claim to water. The extent of allocation is such that there is a degree of overlap between bulk entitlements, private diverter licences, farm dam usage and groundwater licences. Historic changes in the catchment including the construction of both urban supply dams and farm dams, increasing groundwater use, the introduction of bulk entitlements and passing flows etc. has also lead to users of the available resource being affected.

Because of the competition for water in the catchment, a significant dry period can lead to crisis where river health and some user groups are particularly affected. Groundwater users in the upper catchment areas and farm dams across the catchment are satisfied first. Water available to other users is reduced with increased groundwater and farm dam use.

The conversion of the entitlements held by Central Highlands Water and Barwon Water into bulk entitlements have involved some increases to passing flow rules generally with the express purpose of providing improved environmental flow. However, in the case of Moorabool Reservoir, the change was from a compensation or fixed delivery to the lesser of a minimum flow or natural inflow to storage. This change, in combination with reduced storage inflows due to upstream activities, has had an impact on downstream users and river health. Flows in this reach have also been influenced by the dry climatic sequence since the bulk entitlement was enacted.

Barwon Water would normally not wish to rely on water from Lal Lal Reservoir in the summer due to the salinity pickup downstream of the storage. However, in extended dry periods in the Barwon catchment, Barwon Water must draw on its reserves in Lal Lal Reservoir. Given the current lack of total resource and aided by the new Moorabool Treatment Plant, Barwon Water now routinely use a "shandy" of East and West Moorabool River water rather than using water from Lal Lal Reservoir as a last resort. Therefore, high summer flows in the river between Lal Lal Reservoir and She Oaks Weir can now be expected in most years.

Prior to 2001, all water supplied to Geelong from the Moorabool catchment was untreated. Therefore, Barwon Water preferred to use water from the Barwon system where possible and, as a result, the Moorabool was considered in some respects to be a secondary resource.

Barwon Water had previously aimed to provide water with a salinity of not greater than 400EC to its Geelong customers. This also restricted to some extent the amount of West Moorabool water that could be used (Moorabool water was and still is shandied with Barwon water at Montpellier distribution basin in Geelong). A constant release out of Lal Lal Reservoir can keep the water harvested from the West Moorabool to about 1000EC. With no release, salinity can get as high as 1800EC. Barwon Water's adopted salinity standard is now 600EC (still well within the WHO guidelines of 1000EC). Therefore, salinity is not considered to be an issue in terms of future usage of the West Moorabool resource.

The threats to the agricultural industry are the same as for the rest of Australia, uneconomic farm sizes, declining country town populations and an ageing population. In the future, agricultural industries will intensify production, which is partially the result of rising land values. As a result of consolidation into larger properties, larger herds, more mechanisation and more use of feed, production from dairy farms is expected to double. Horticulture and viticulture will continue to expand into areas close to transport and labour and with suitable water and soil. The major change issues in this area are likely to be rural-residential and general urban growth, both of which are already occurring. If links to Melbourne improve there may be growth in town's periphery to Ballarat as well as within Ballarat itself.

Continued growth is expected in both the urban and rural sectors. Urban growth will be steady but may accelerate with improved transport linkages. Rural growth could also occur but will be limited by the availability of water.

There has been a lot of development in this catchment over recent times, and this development has occurred without a full understanding of the complex interaction of the physical links between farm dams, groundwater and surface water runoff. Unfortunately this development has occurred when there has not been one coordinating body to control the linkages and complex interactions between the competing users. The catchment is now in a stressed condition and will need a considerate and cooperative approach by a number of different stakeholders to resolve the issues.

5. Climate Change

5.1 Introduction

Since the industrial revolution the concentration of carbon dioxide in the earth's atmosphere has increased from a background level of 280 ppm to the current level of 370 ppm (Whetton et al, 2002). This has led to an enhanced green house effect, which has been characterised by rising global temperatures. The future expected rate of warming is uncertain; predictions are dependent upon future emission rates. However, the Intergovernmental Panel on Climate Change has predicted that global temperatures will increase by between 1.4 and 5.8 °C by the year 2100, relative to 1990 levels (Whetton et al, 2002).

Global warming will influence future global rainfall and evaporation patterns, which in turn will impact upon streamflows and demands. Global warming therefore is an important consideration in the long-term management of water resources in Australia. It is an especially important consideration in relation to the Moorabool Catchment, as water resources in the Moorabool River are already heavily committed. A future reduction in average streamflows and increase in demands would have severe environmental and economic impacts. Task 6 of the Project Proposal has recognised this, and has identified a need to assess the likely effects of climate change on demands and streamflows in relation to the provision of environmental flows.

The simulation of future climate systems is problematic. Whetton et al (2002) investigate future climate conditions as simulated by eight Global Climate Models (GCMs), including DAR60, a limited area model developed by the CSIRO. Model results were found to vary considerably from model to model and also from season to season. However, the projected global warming predicted by DAR60 lies within the predicted range identified by the Intergovernmental Panel on Climate Change (Whetton et al, 2002) and due to its ability to model climate at a fine spatial scale, its predictions are suitable for consideration in region-specific water resource impact studies.

The DAR60 model has simulated a global warming of 1.1°C by the year 2030 (Whetton et al, 2002, p.25). Changes to the pattern of seasonal rainfall within Victoria are presented within Whetton et al (2002) in units of percent change per degree C. DAR60 simulates a reduction in annual rainfall ranging between 0 and 2 percent per degree C within the Moorabool Catchment. Summer and autumn rainfalls are predicted to also decrease within this range. Spring rainfalls are predicted to decrease within the range of 2 and 5 percent per degree C. In winter, the Moorabool Catchment straddled two different categories of rainfall change. The simulation predicted that the upper half of the catchment would decrease within the range of 0 and 2 percent per degree C, while the lower half would increase by 0 and 2 percent.

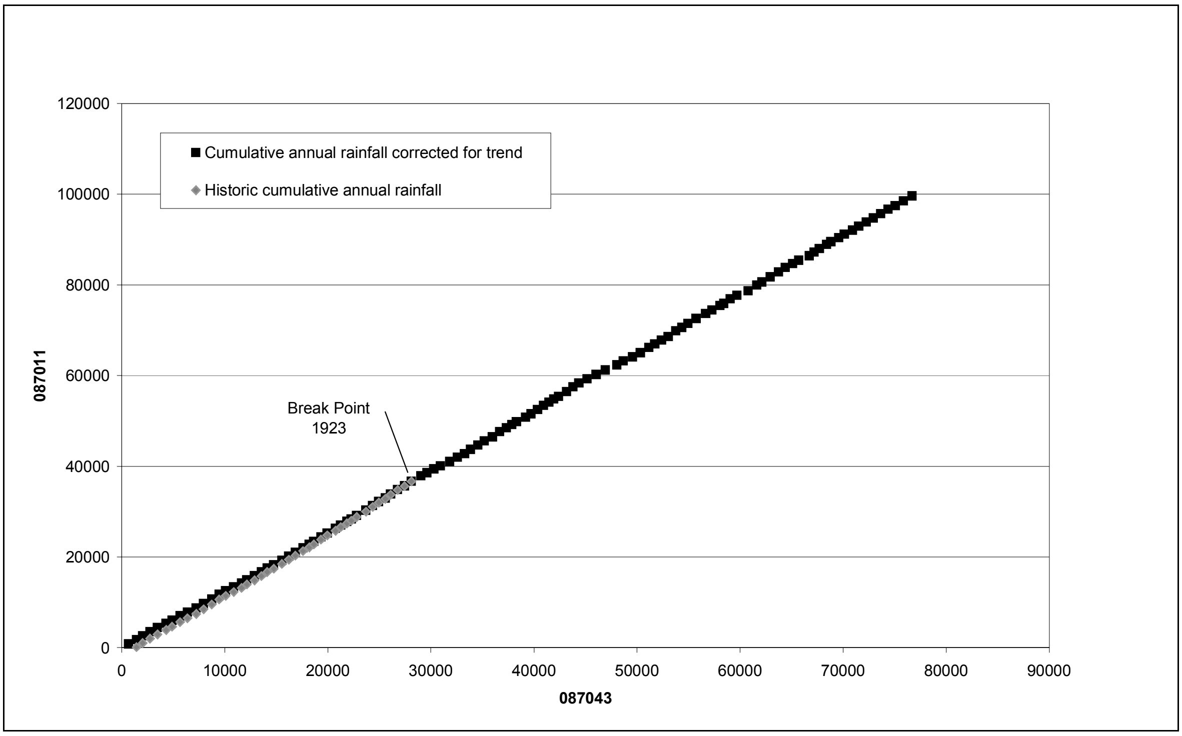
Similarly, changes to potential evaporation in Victoria are presented within Whetton et al (2002) in units of percentage change per degree C of global warming. Within the Moorabool Catchment, the DAR60 model simulates an increase in evaporation ranging between 6 and 8 percent.

For the purpose of this project, an existing rainfall-runoff model is used as a test case for the Moorabool Catchment, in order to assess the potential impact of global warming. As part of the "Development of a weekly REALM Model of Moorabool River" project (SKM, 2002c), HYDROLOG was used to simulate inflows into the Moorabool-White Swan System. HYDROLOG is a conceptual based lumped parameter model for the estimation of runoff. The model was calibrated using the monthly inflows estimated by Rigby (1994). A daily rainfall series for Beales Reservoir (087011) and monthly regional evaporation data were used as inputs. Modified climatic inputs will be used to simulate 2030 levels of global warming. The resulting change to annual streamflow will be calculated.

5.2 Method

The original HYDROLOG simulation period ranged between 1st Jan-1941 and 31st Dec-1990. However, the available rainfall record at Beales Reservoir is considerably longer than this. Daily rainfall recordings commence in 1881 and the site is still in operation today. In order to take advantage of the full period of data available, and to test the HYDROLOG model over a greater range of climatic events, a test was completed in order to validate the quality of the rainfall data.

The Bureau of Meteorology has advised that the rainfall series at Meredith (087043) is a series of high quality and represents a stationary time series uninfluenced by random or systematic errors (Nicholls, 2001). A double mass curve (cumulative annual rainfall at Meredith versus cumulative annual rainfall at Beales Reservoir) was constructed. A break in slope (indicating trend) was detected and, although the suspected trend in rainfall data was very small (4.4%), the earlier part of the rainfall record at Beales Reservoir was modified to eliminate this trend. The following curve depicts the corrected cumulative annual rainfall series at Beales Reservoir versus that of Meredith:



■ **Figure 5-1: Double Mass Curve of Rainfall Data**

In order to generate a rainfall series that simulated the average, worst case and best case climatic effects of global warming, the corrected rainfall series at Beales Reservoir was multiplied by a set of factors. These factors were derived by use of the average maximum and minimum percent change in seasonal rainfall per degree C global warming for the Moorabool Catchment, as simulated by the CSIRO DAR60 global climate model. 2030 levels of global warming were assumed. As mentioned above, the DAR60 model has simulated a rise in global temperatures of 1.1 °C by the year 2030, relative to 1990 levels (Whetton et al, 2002).

■ **Table 5-1: Climatic change in the Moorabool Catchment**

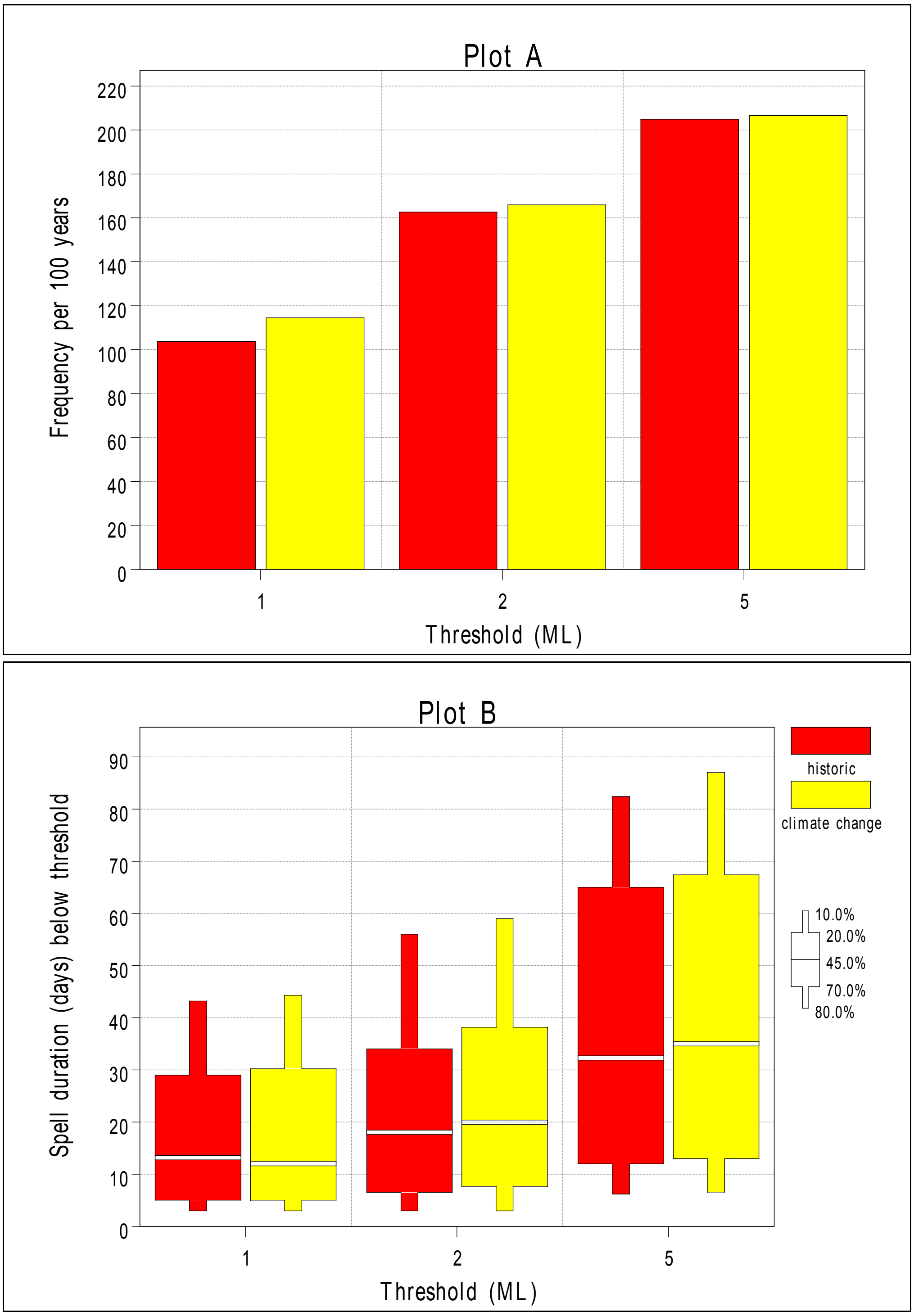
	Percentage change per °C global warming		
Rainfall	**Average**	**Best Case**	**Worst Case**
Summer	-1	0	-2
Autumn	-1	0	-2
Winter	0	+2	-2
Spring	-3.5	-2	-5

HYDROLOG also requires monthly evaporation data. Rates of evaporation under 2030 levels of global warming were derived by multiplying the mean monthly evaporation figures obtained form the earlier REALM study by factors derived from the maximum and minimum expected change in annual evaporation for the Moorabool Catchment, as simulated by the DAR60 model (SKM, 2000a).

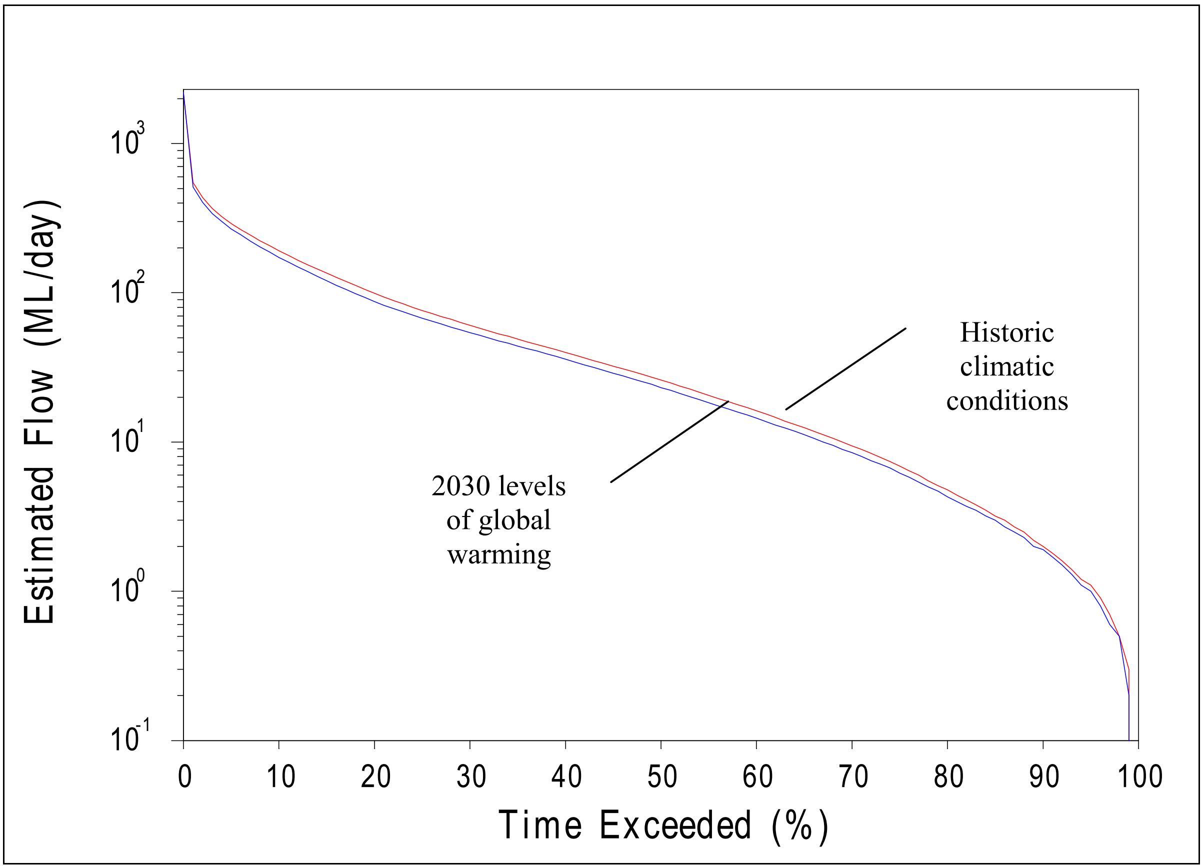
5.3 Results

HYDROLOG was used to estimate daily streamflows, during the period of 1st Aug 1881 to 28th Feb 2002, using historic climatic data and data modified to simulate 2030 levels of global warming as inputs. Under best case scenario conditions, the average estimated annual inflows for 2030 levels of global warming were approximately 97% of inflows for historic climatic conditions. For the worst case scenario, annual inflows were 86% of inflows under historic conditions and for average predicted levels of global warming, the estimated annual inflows were approximately 91% of inflows for historic climatic conditions. The mean daily inflow for historic climatic conditions was 69 ML, compared to 63 ML for average 2030 levels of global warming.

Global warming also influenced the distribution of inflows. For historic climatic conditions 31% of estimated inflows were under 10 ML/day. There were 196 spell events of less than 2 ML/day, which lasted on average 22.8 days. For average 2030 levels of global warming, 33% of estimated inflows were under 10 ML/day and there were 200 spell events of less than 2 ML/day, which lasted on average 24.3 days. The effect of global warming on the frequency and duration of low flows is illustrated by Figure 5-2. Figure 5-3 illustrates the slight shift in the exceedance duration curve caused by global warming.

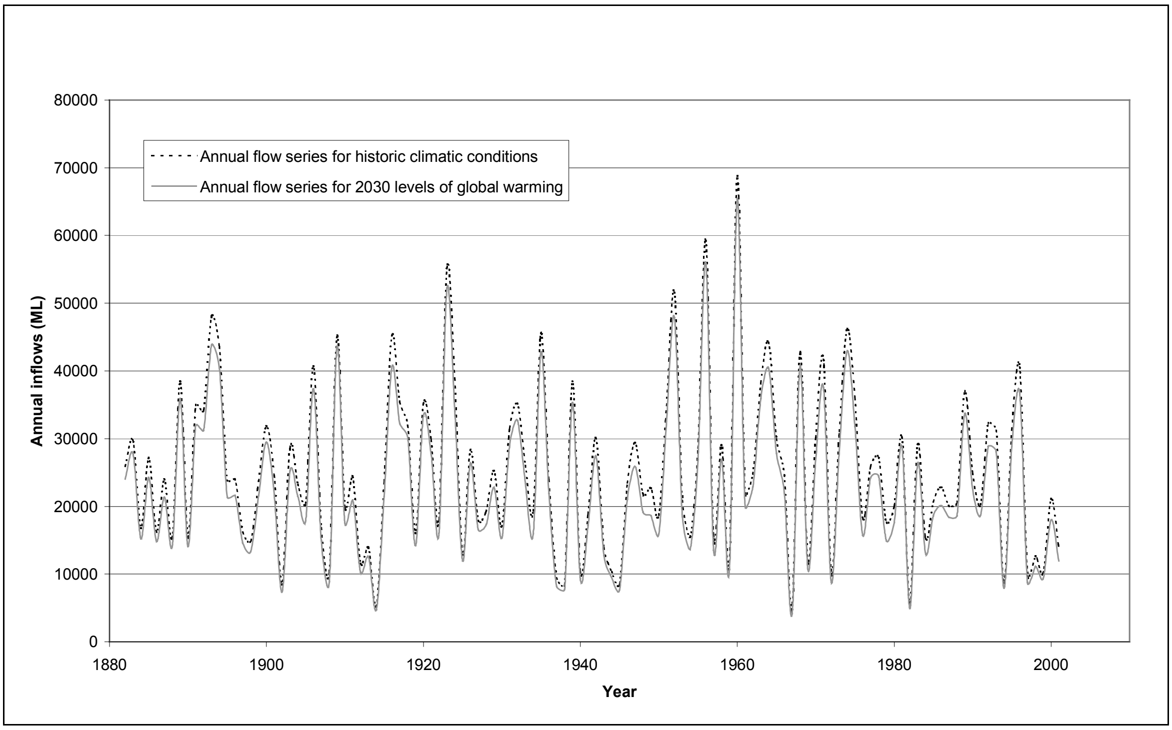


■ **Figure 5-2: Frequency of inflows below 1 ML/day, 2ML/day and 5ML/day per 100 years (Plot A) and Duration of inflows below 1 ML/day, 2ML/day and 5 ML/day (Plot B) for estimated historic flows and estimated flows for 2030 levels of global warming**



▪ **Figure 5-3: Exceedence Duration Curve for historic climatic conditions and 2030 levels of global warming**

The following figure illustrates the effect of global warming upon the simulated annual inflows to the Moorabool-White Swan System.



▪ **Figure 5-4: Annual estimated flow series for historic climatic conditions and 2030 levels of global warming**

Lower streamflows in the Moorabool Catchment and increased irrigation demands caused by both a reduction in rainfall and likely increased crop water demands suggest that global warming may be a consideration in the assessment of water resources and sustainability in the Moorabool Catchment. The impacts of global warming on the Moorabool Catchment will be further investigated by SKM in a later stage of this project. All climatic time series, PRIDE demands and streamflows will be modified to simulate 2030 levels of global warming and used as input into the REALM model.

5.4 Results of REALM Run

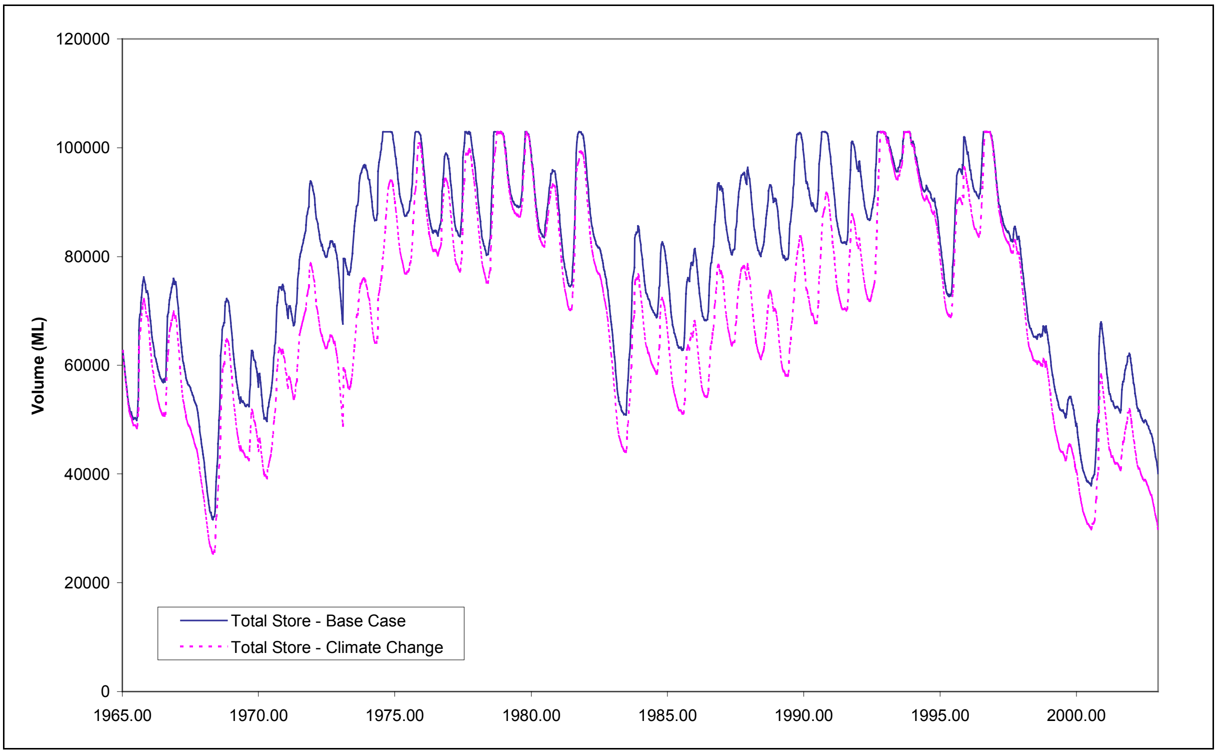
A REALM run was carried out to assess the impacts of climate change. To set up this run model inputs were adjusted as follows:

- Inflows – decreased by 9% based in results presented above;
- Climatic inputs – rainfall decreased by 1.5%, evaporation increased by 7.7%;
- Urban demands – rederived at current level of development but with adjusted climatic data, temperature increased by 1.1°C. Average demand increase was 4.5%;

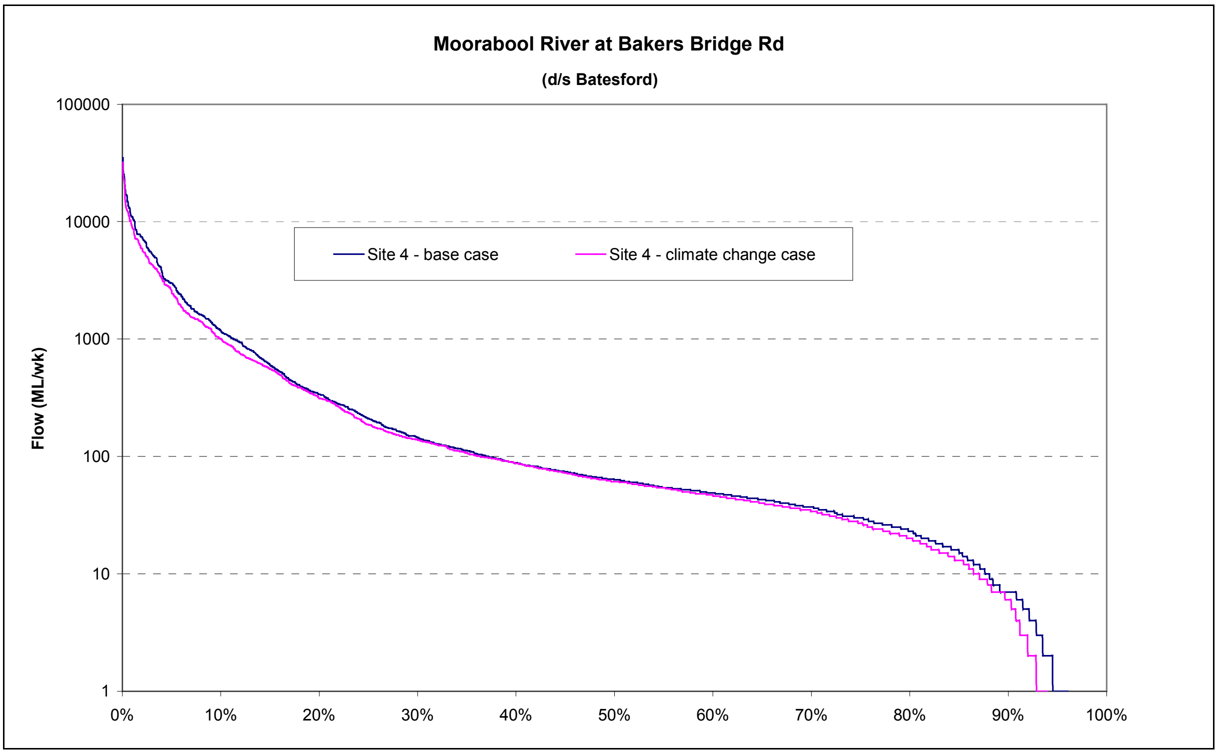
- Irrigation demands – demands factored up by 11.4%. This factor was derived by re-running PRIDE for irrigators on tributaries upstream Lal Lal at current level of development but with climatic inputs adjusted as above;
- Impact of groundwater extraction – current level of development impacts factored up as per irrigation demands;
- Impact of farm dams – current level of development impacts increased by 3.2%. This was based on re-running the TEDI model for irrigators on tributaries upstream Lal Lal with climatic inputs adjusted as above.

The difference in system behaviour is illustrated in Figure 5-5. Climatic effects, lower inflows and higher demand mean that total storage at the end of the climate change run is 10,600 ML less than the revised base case, an average reduction of 280 ML/yr. The average annual flow downstream of Batesford (Figure 5-6) reduces 15% from 31,700 ML/yr to 27,100 ML/yr. The average annual supplied demand increases from 25,500 ML to 26,200 ML.

- **Figure 5-5: Comparison of Storage Behaviour under Climate Change**



▪ Figure 5-6: System Outflow under Climate Change



6. Groundwater and Surface Water Interaction

Measurable reduction in inflows to Moorabool Reservoir has occurred in the Devil Creek sub-catchment in the north-eastern part of the Moorabool catchment and downstream the Moorabool River has run dry since approximately 1993/1994. Possible causes of these reductions include groundwater extractions, onstream storages and farm dams. The principal objective of this part of the study is to assess the significance of groundwater and surface water interactions, quantify the baseflow component of the Moorabool River and thereby determine impacts on the stream from groundwater users. The full investigation into groundwater and surface water interaction is presented in Appendix B.

The scarcity of near stream groundwater data proved a major limitation in being able to evaluate groundwater and surface water interaction. Measured and synthesised streamflow in the Moorabool River was processed to obtain an estimate of the baseflow component. These estimates used in conjunction with cross-sectional hydrological assessments along the Moorabool River formulated predictions of streamflow changes in the creek arising from groundwater use upstream of the Lal Lal Reservoir.

The baseflow analyses indicated that the baseflow contribution in the upper catchment (upstream of Moorabool Reservoir) is in the order of 50 to 60 % of the total flow. An assessment of the components of the groundwater cycle showed evidence of a strong one to one to one to four relationship between groundwater and surface water where the impact of increased groundwater usage is expected to affect the baseflow component by between 25% and 100%. The mid-point of the range, representing groundwater discharge influence of 60 %, should be adopted in subsequent modelling of streamflow losses. Given this strong relationship between groundwater and surface water in the study area groundwater pumping was concluded to result in a short term (months) change in storage, a medium term (years) reduction in baseflow and a long term (decades) reduction in aquifer throughflow, that is causing down catchment impacts.

Although the Devils Creek sub-catchment comprises just 4% or the study area, it contains 15% of the total allocations. The reduction in the baseflow component from increased extraction is therefore likely to be greater and more immediate than other areas of the catchment.

Lower baseflow contributions determined in the middle catchment, upstream of Lal Lal, in the order of 30 to 40 % combined with negligible groundwater allocations along this reach suggest usage impacts here are not currently significant.

Insufficient reliability of streamflow data downstream of Morrisons and inadequate groundwater data precluded any meaningful evaluation of the relationship between groundwater and surface water in the lower catchment. Groundwater usage in this part of the catchment is negligible and is not currently believed to affect baseflow to the Moorabool River where it occurs between the Lal Lal Reservoir and Batesford.

Recommendations made on the basis of this assessment involve further investigation to better define the components of the groundwater cycle in order to re-visit it in say five years.

7. Catchment Farm Dam Impacts

7.1 The TEDI Model

The impact that unlicensed farm dams have on inflows to a stream can be estimated by using the Tool for Estimating Dam Impacts (TEDI). For this study the catchment was broken up into a number of subareas, and the TEDI model was used to determine the impact of farm dams in each area. An estimate of historic farm dam impacts was required to assist with the calculation of model inflows. Farm dam impacts at current level of development were also required for input to the base case run. This scenario was run both with and without the influences of climate change.

7.2 TEDI Model Input Data

The model inputs for each subarea were:

- Inflows adjusted to add back estimated historic private diverter extractions and the effects of on-stream dams.
- The total volume of farm dams in the each subcatchment;
- The threshold dam volume between stock and domestic and irrigation dams;
- Irrigation demand patterns and annual demand volumes;
- Stock and domestic annual demand volumes;
- Monthly rainfall and evaporation data;
- The proportion of farm dam volume withdrawn each year as annual demand (demand factor);
- Farm dam size distribution; and
- Upstream catchment areas for farm dams of 5 ML and 100 ML in size.

The derivation of each of these inputs are discussed in more detail below.

7.2.1 Subcatchments for Farm Dam Modelling

The Moorabool catchment was spilt as shown in Table 7-1.

Table 7-1 Subcatchments for Farm Dam Impact Modelling

Description	Inflow Subcatchment(s)
Upstream of Moorabool Reservoir	F1
Upstream of Wilsons/Beales Reservoir, Fellmongers Creek, unregulated tributaries upstream of CHW (Moorabool) Channel, Leigh Creek, Giles Creek, Clarkes Creek, and Whisky Creek upstream of CHW (Moorabool) pipeline.	F2,3,4,5b
West Moorabool River between Moorabool Reservoir & Lal Lal Reservoir	F5a
Tributaries upstream of Lal Lal Reservoir	F6
Upstream of Korweinguboora Reservoir & Bostock Reservoir	F7,8
Between Lal Lal Reservoir, Bostock Reservoir & Morrisons gauge	F9
Between Morrisons gauge & Batesford gauge	F10 & 11

7.2.2 Adjusted inflows

Inflows calculated as described in Section 8.6 were used. For the climate change case, inflows were reduced by 9% as indicated in Section 5.3.

7.2.3 Volume of farm dams

The surface area of farm dams in each catchment was determined from aerial photos. The source, date and extent of the aerial photography used is shown in Figure 7-1.

The area of each dam was converted to a volume using the following relationship (Good & McMurray, 1997):

$$V = A^{1.4}/22727 \quad (1)$$

Where volume is in ML and area is in m².

Subsequent to the release of the Stage A report, a new volume versus surface area relationship was developed as part of the sustainable diversion limits study (SKM, 2003c). The new relationship predicts volumes that are higher than those derived using Equation 1 above. It is recommended that use of this revised relationship be considered as part of any future work in this catchment.

Areas are summarised in Table 7-2.

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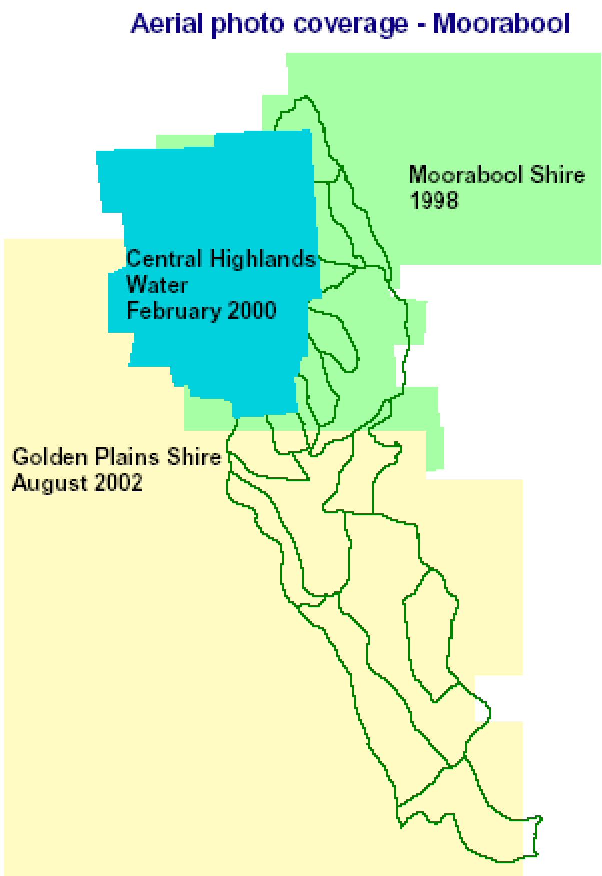
- **Table 7-2 Volume of Farm Dams**

Subarea	Catchment area (km²)	Number of dams	Total volume of dams (ML)	Volume of winterfill dams (ML)	Volume of catchment dams (ML)
u/s Moorabool Reservoir	29	65	308	162	146
u/s Beales Res, Unreg Tribs u/s chl, Whisky Ck u/s pipe	45	238	1,362	39	1,323
Btwn Mbool Res. & Lal Lal Res.	42	190	904	0	904
Tribs. U/s of Lal Lal Res.	174	1,283	4,612	925.9	3,686
u/s Korweinguboora & Bostock	127	398	1,009	0	1,009
btwn Lal Lal, Bostock and Morrisons	218	672	3,109	0	3,109
btwn Morrisons & Batesford	537	1,927	4,650	426.2	4,224
TOTAL	**1,172**	**4,773**	**15,954**	**1,553.1**	**14,401**

- **Figure 7-1: Extent of aerial Photography**



7.2.4 Volume of Farm Dams in 1965

The volume of farm dams in 1965 was estimated using data from a report prepared by GHD for the Department of Water Resources Victoria in 1987 (GHD, 1987). The report provided estimates of total farm dam volumes and numbers at various times between 1970 and 1985 in the West Moorabool River catchment. The trend in this historic data was linearly extrapolated back to 1965, and ahead to 2002.

It was found that the 2002 estimate of dam numbers using linear extrapolation was much lower than that obtained from GIS analysis. This underestimate is consistent with a counting method used in the 1987 report which does not include small dams, those less than approximately 0.6 ML. However, although dams less than 0.6 ML account for about 25% of the *number* of dams, they only account for about 3% of the total dam volume. Therefore the difference in the two estimates for dam numbers in 2002 is not considered significant for the purposes of this study.

The extrapolation of historic data showed that there were 982 more dams in 2002 than in 1965. GIS analysis shows that currently there are 1649 dams, therefore there were approximately 670 dams in 1965, a proportional decrease of around 40%.

Assuming that the distribution of farm dam sizes in 1965 was similar to the present, it follows that the volume of farm dams in 1965 was approximately 40% of the current volume.

7.2.5 Threshold dam volume

In the TEDI model it is assumed that dams larger than a given threshold volume are used for irrigation, and those smaller are used for domestic and stock. Different demand patterns are applied to the two different dam types. For this study, it was assumed that this threshold volume was 5 ML (Simone Wilkinson pers. com.). This is consistent the threshold volume used in GHD (1987), and with more recent findings developed as part of the Sustainable Diversion Limits Study currently being undertaken for DSE (SKM, 2003b).

7.2.6 Irrigation demands

The within year pattern of irrigation demands were estimated using PRIDE, a model which calculates daily, weekly or monthly irrigation demand based on rainfall, evaporation, temperature, crop types, and crop areas. The monthly demands calculated in PRIDE were averaged over the study period to produce average monthly proportions. These proportions are given in Table 7-3 for each catchment area.

- **Table 7-3 Irrigation Demand Patterns Adopted (% of annual water use)**

Catchment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
u/s Moorabool Reservoir	31.8%	31.5%	24.1%	0%	0%	0%	0%	0%	0%	0%	0.7%	12.0%
U/s Beales Res, Unreg, Tribs u/s chl, Whisky Ck u/s pipe	31.9%	31.5%	24.1%	0%	0%	0%	0%	0%	0%	0%	0.6%	11.9%
Btwn Mbool Res. & Lal Lal Res.	31.7%	31.5%	24.2%	0%	0%	0%	0%	0%	0%	0%	0.6%	11.9%
Tribs. U/s of Lal Lal Res.	29.7%	28.4%	21.0%	1.4%	0.2%	0%	0%	0%	0.2%	0.9%	3.4%	14.7%
u/s Korweinguboora & Bostock	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%
btwn Lal Lal, Bostock and Morrisons	28.9%	25.3%	15.8%	2.4%	0.2%	0%	0%	0%	0.1%	1.0%	6.3%	19.9%
btwn Morrisons & Batesford	28.9%	25.3%	15.8%	2.4%	0.2%	0%	0%	0%	0.1%	1.0%	6.3%	19.9%

7.2.7 Stock and domestic demands

Farm dams which are used for stock and domestic supply were assumed to have constant demand throughout the year, ie. 8.3% of annual demand each month.

7.2.8 Rainfall and evaporation

Rainfall and evaporation data is used to represent climatic effects on the water in store. Data were obtained for a number of gauges across the study area.

Any long term trends in the rainfall data were identified with double mass curves against Bureau of Meteorology high quality rainfall stations, and then removed. Infilling of rainfall and evaporation data was completed using linear regression with nearby gauges.

Climate data for each catchment was determined either using a single nearby gauge, or using Thiessen polygons to create a weighted average of several nearby gauges. The data used for each catchment is given in Table 7-4 below.

- **Table 7-4 Adopted Rainfall and Evaporation**

Catchment	Rainfall	Evaporation
u/s Moorabool Reservoir	087045 (Moorabool Res)	087045 (Moorabool Res)
U/s Beales Res, Unreg, Tribs u/s chl, Whisky Ck u/s pipe	087011 (Beales Res)	087011 (Beales Res)
Btwn Mbool Res. & Lal Lal Res.	087045 (Moorabool Res)	087045 (Moorabool Res)
Tribs. U/s of Lal Lal Res.	087011 (Beales Res)	087011 (Beales Res)
u/s Korweinguboora & Bostock	087045 (Moorabool Res)	087045 (Moorabool Res)
Btwn Lal Lal, Bostock and Morrisons	087045 (Moorabool Res) * 0.454 + 087011 (Beales Res) * 0.536 + 087046 (Scotsburn-Mt Bunninyong) * 0.01	087045 (Moorabool Res)
Btwn Morrisons & Batesford	087045 (Moorabool Res) * 0.454 + 087011 (Beales Res) * 0.536 + 087046 (Scotsburn-Mt Bunninyong) * 0.01	087045 (Moorabool Res)

For the climate change scenario, rainfall and evaporation data was adjusted as described in Section 5.3.

7.2.9 Demand Factor

The demand factor represents the proportion of each dam's volume that is used each year. A large domestic and stock dam might only have 20% of its volume used each year, whereas a small irrigation dam might fill and be emptied several times over.

Calculating the demand factor is difficult, and determining a reliable estimate is outside the scope of this study. Therefore, based on previous studies and advice from CCMA (Simone Wilkinson pers, com.) it has been assumed that the full volume of each dam is used each year, which corresponds to a demand factor of 1.

Subsequent to the release of the Stage A report, work done as part if the Sustainable Diversion Limits Study (SKM, 2003b) indicated a demand factor of 0.84 for irrigation dams and 0.5 for D&S dams in Victoria. It is recommended that the use of these reduced factors be considered as part of any future work in this catchment.

7.2.10 Farm dam size distribution

The distribution of farm dam sizes within each catchment has been calculated from GIS interpretation of aerial photos. The distribution for each catchment is given below. As can be seen from the tables, the greatest number of dams are small, but the greatest proportion of volume is contributed by the few large farm dams.

- **Table 7-5 Farm Dam Size Distributions (by Volume)**

Volume Range(ML)	0.0 - 0.1	0.1 - 0.2	0.2 - 0.5	0.5 – 1.0	1.0 – 3.0	3.0 – 5.0	5.0 – 10.0	10.0 – 50.0	50 - 100	100 - 2000
u/s Moorabool Reservoir	0.31%	0.26%	0.54%	0.55%	7.82%	2.56%	15.5%	43.2%	29.2%	0%
U/s Beales Res, Unreg, Tribs u/s chl, Whisky Ck u/s pipe	0.20%	0.31%	0.95%	0.85%	4.62%	6.12%	4.72%	33.3%	38.1%	10.9%
Btwn Mbool Res. & Lal Lal Res.	0.16%	0.55%	1.47%	1.89%	4.14%	2.93%	14.3%	44.6%	14.7%	15.3%
Tribs. U/s of Lal Lal Res.	0.33%	0.66%	2.13%	2.33%	4.13%	2.44%	8.03%	20.8%	18.4%	40.7%
u/s Korweinguboora & Bostock	0.27%	0.86%	4.04%	5.75%	8.06%	3.32%	7.41%	25.1%	23.9%	21.3%
btwn Lal Lal, Bostock and Morrisons	0.16%	0.55%	2.14%	2.89%	5.21%	1.28%	3.87%	7.72%	6.48%	69.7%
	0.44%	1.02%	3.84%	4.93%	7.22%	3.79%	8.15%	16.5%	3.52%	50.6%

SKM

- **Table 7-6 Farm Dam Size Distributions (by Number)**

Volume Range(ML)	0.0 - 0.1	0.1 - 0.2	0.2 - 0.5	0.5 – 1.0	1.0 – 3.0	3.0 – 5.0	5.0 – 10.0	10.0 – 50.0	50 - 100	100 - 2000
u/s Moorabool Reservoir	38%	8%	8%	5%	18%	8%	0%	3%	11%	2%
U/s Beales Res, Unreg, Tribs u/s chl, Whisky Ck u/s pipe	26%	12%	16%	8%	14%	9%	0%	8%	4%	3%
Btwn Mbool Res. & Lal Lal Res	14%	17%	22%	12%	10%	11%	1%	4%	9%	1%
Tribs. U/s of Lal Lal Res.	28%	16%	24%	12%	9%	3%	1%	2%	4%	1%
u/s Korweinguboora & Bostock	11%	15%	30%	21%	14%	4%	0%	2%	3%	1%
btwn Lal Lal, Bostock and Morrisons	12%	17%	30%	19%	15%	2%	0%	2%	2%	0%
btwn Morrisons & Batesford	19%	17%	29%	17%	11%	2%	0%	2%	3%	0%

7.2.11 Farm Dam Subcatchment Areas

The representative catchment areas for 5ML and 100 ML dams (A_5, A_{100}) have been estimated using equations and values derived in SKM (2003).

- **A_5 (km²) = 1.31 - 315.48 x Stream Density (m/km²)** **(2)**
- **A_{100} (km²) = 1.6** **(3)**

where Stream Density = density of streams in 1:25k state topographic data

Table 7-7 below gives the farm dam subcatchment areas for each catchment.

- **Table 7-7 Farm Dam Subcatchment Areas**

Catchment	Stream Density (m/km^2)	A_5 (km^2)	A_{100} (km^2)
u/s Moorabool Reservoir	0.00092	1.02	1.6
U/s Beales Res, Unreg, Tribs u/s chl, Whisky Ck u/s pipe	0.00117	0.94	1.6
Btwn Mbool Res. & Lal Lal Res.	0.00105	0.98	1.6
Tribs. U/s of Lal Lal Res.	0.00126	0.91	1.6
u/s Korweinguboora & Bostock	0.00192	0.71	1.6
btwn Lal Lal, Bostock and Morrisons	0.00176	0.76	1.6
btwn Morrisons & Batesford	0.00172	1.02	1.6

7.3 Results of TEDI Modelling

7.3.1 Historic Farm Dam Impacts

An estimate of historic farm dam impacts was required to add back to system inflows to derive natural inflow to the system.

The TEDI model was run from 1965 to 2002 with 1965 demand levels. The average annual impact of farm dams on streamflows in each catchment is given in Table 7-8 below. These impacts were linearly combined with the impacts at 2002 level of development to derive a time series of estimated historic farm dam impacts.

- **Table 7-8 Average Annual Farm Dam Impact (1965 development levels)**

Catchment	Total Volume of Catchment Dams (ML)	Average Annual Impact of Dams (ML)	Ratio (Dam Vol / Impact)
u/s Moorabool Reservoir	59	68	1.15
U/s Beales Res, Unreg, Tribs u/s chl, Whisky Ck u/s pipe	535	582	1.09
Btwn Mbool Res. & Lal Lal Res.	365	394	1.08
Tribs. U/s of Lal Lal Res.	1,489	1,521	1.02
u/s Korweinguboora & Bostock	408	427	1.05
Btwn Lal Lal, Bostock and Morrisons	1,256	639	0.51
Btwn Morrisons & Batesford	1,707	1,401	0.82

7.3.2 Current Level of Development Farm Dam Impacts

Current level of development farm dam impacts are required to include in the base case REALM model.

To derive these impacts the TEDI model was then run from 1965 to 2002 with 2002 demand levels. The average annual impact of farm dams on streamflows in each catchment is given in Table 7-9 below.

SKM

- **Table 7-9 Average Annual Farm Dam Impact (2002 development levels)**

Catchment	Total Volume of Catchment Dams (ML)	Average Annual Impact of Dams (ML)	Ratio (Dam Vol / Impact)
u/s Moorabool Reservoir	146	171	1.17
U/s Beales Res, Unreg, Tribs u/s chl, Whisky Ck u/s pipe	1,323	1,471	1.11
Btwn Mbool Res. & Lal Lal Res.	904	953	1.05
Tribs. U/s of Lal Lal Res.	3,686	3,559	0.97
u/s Korweinguboora & Bostock	1,009	1,052	1.04
btwn Lal Lal, Bostock and Morrisons	3,109	1,508	0.49
btwn Morrisons & Batesford	4,224	3,502	0.83

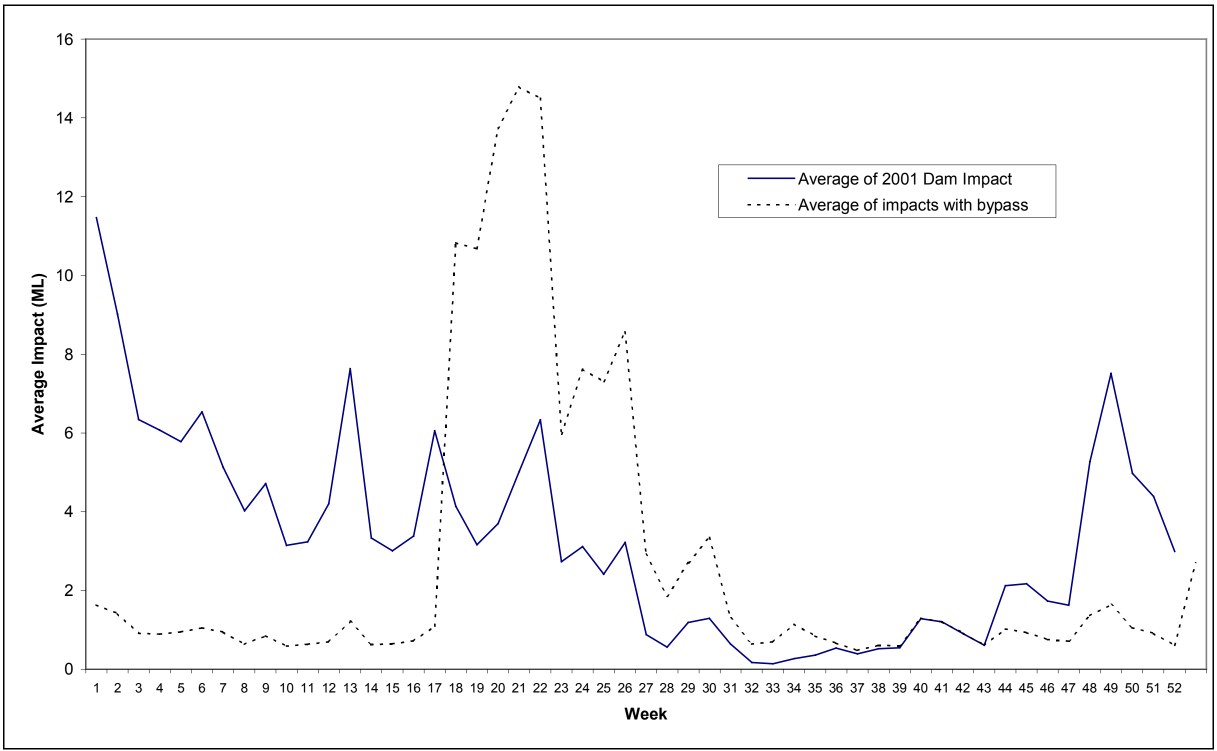
7.3.3 Farm Dam Impacts under Climate Change

A climate change REALM model run was undertaken (refer Section 5.4). The impact of farm dams subject to climate change was required as an input to this run. To determine this, climatic inputs to the TEDI run for farm dams above Lal Lal were adjusted to reflect predicted climate change levels in 30 years. Under this scenario it was found that farm dam impacts increased by 3.2%.

7.3.4 Farm Dam Impacts with Summer Bypass

Option 23 (refer Section 13.9) required the assessment of farm dam impacts if they were required to pass summer flows. The following plot illustrates the shift in the timing of impacts as a result of this change.

- **Figure 7-2: Impact of Farm Dams above Moorabool Reservoir**

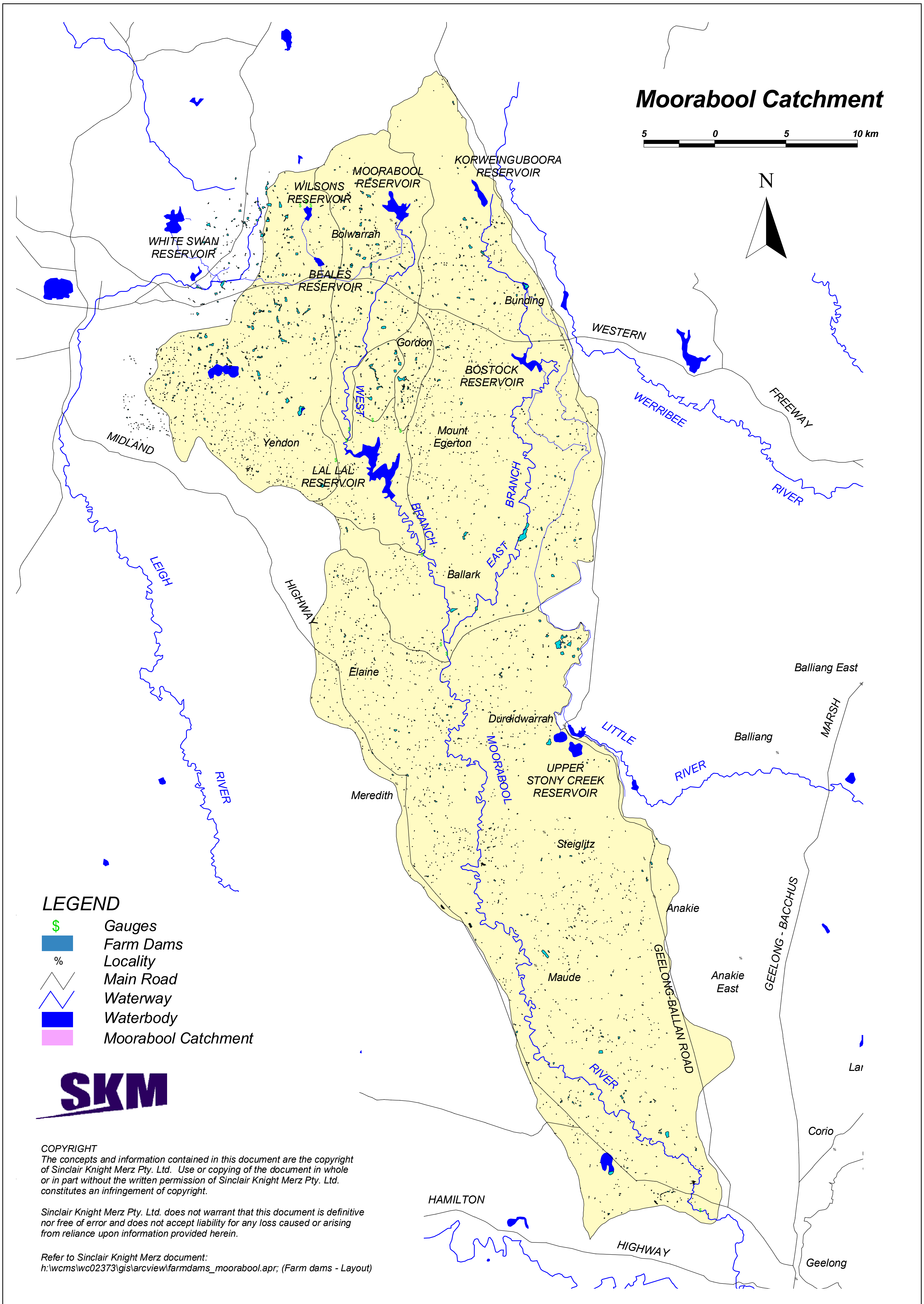


7.4 Confidence Limits

The GIS process used to identify farm dams was estimated to be 98% accurate when directly compared to aerial photos.

According to SRW records 7,950 ML of farm dams have been licensed in the Moorabool catchment. By comparison, of dams larger than 5 ML from the GIS data gives a total volume of 13,500 ML. Given that not all dams greater than 5 ML would be used for irrigation, and the fact that not all irrigation dams would be registered yet, the difference in these figures is not felt to be of concern.

This is also supported by other evidence. The GIS layer of farm dams was examined and some ground proofing done by CCMA staff. No discrepancies were found in this limited sample.



Refer to Sinclair Knight Merz document:
h:\wcms\wc02373\gis\arcview\farmdams_moorabool.apr; (Farm dams - Layout)

STAGE A - Catchment modelling and identification of options to enhance environmental flows

8. Review and Update of the Moorabool River REALM Model

8.1 Background

The weekly Moorabool model was first developed by Sinclair Knight Merz in late 1998 as part of the Moorabool River SFMP. Later scenario modelling for the SFMP was undertaken (December 2000) and included model runs to examine the effect of different environmental flow rules and rural restriction policies on the security of supply. Inflows upstream of Moorabool Reservoir were also examined to look at trends and farm dam impacts in July 2001.

SKM also built a weekly model of the Lower Barwon River to assist with the Barwon SFMP in 2001. It incorporated outputs from both the weekly Moorabool model and the daily Upper Barwon Model (held by Barwon Water). The Moorabool River below Batesford was incorporated into the Lower Barwon model as this reach is not included in the Moorabool River REALM model. This information has now been included in the Moorabool REALM model as part of this project.

The monthly REALM model of the Ballarat System was originally developed in 1995 (HydroTechnology). This model has been used repeatedly since then to carry out a range of analyses for CHW. Most recently (in 2000) drought response modelling was undertaken. Elements of this model have been incorporated into the Moorabool model as part of this project to better represent the CHW system.

In addition to these changes, a number of other modifications were made to the REALM model. These include:

- Improving the representation of on-stream storages in the Lower Moorabool River. This involved splitting inflows and demands along reaches, and adding individual storages to the REALM model.
- The examination and refinement of losses in the model, particularly downstream of Moorabool Reservoir and Lal Lal Reservoir.
- Extending the period of record of model inputs (currently January 1965-June 1998) to include the most recent critical drought years (up to Dec 2002).
- Adding in farm dam impacts
- Adding in the effects of groundwater interaction and extraction where appropriate.
- Incorporating the most up to date operating rules and restriction policies used.

Once these changes were made, the model was calibrated over the most recent period for which historic data was available.

The calibrated model was then used to come up with a base case model. This incorporated current level of development demands and current operating rules. Current operating rules were derived in discussion with CHW, BW and SRW. The impact of farm dams and groundwater extraction was incorporated into the base case.

8.2 Data Collection and Preparation

The model requires flow, demand and climatic inputs. To assist with the derivation of these inputs, a range of raw data was collected.

8.2.1 Rainfall

Rainfall data was required for farm dam impact modelling, demand modelling, rainfall-runoff modelling and for representing rainfall effects on storages. Stations used were:

- **Table 8-1: Rainfall Data**

Station number	Site Description	Period of record
087000	Anakie	1889 – present
087002	Bacchus Marsh	1880 – 1962
087009	Bannockburn Post Office	1898 – present
087011	Beales Reservoir	1881 – present
087021	Durdidwarrah	1874 – present
087034	Lovely Banks Reservoir	1877 – present
087042	Meredith Post Office	1887 – present
087045	Moorabool Reservoir	1912 – present
078046	Scotsburn (Mount Buninyong)	1856 – present
087067	Wilsons Reservoir	1896 – present
089001	Ballarat Gardens	1881 – 1995

8.2.1.1 Detrending Rainfall Data

Rainfall was checked for trend by plotting a double mass curve of cumulative annual rainfall against cumulative annual rainfall at the nearest high quality rainfall site. High quality rainfall sites are identified by the Bureau of Meteorology and represent a stationary time series uninfluenced by random or systematic error (Nicholls, 2001). A break in slope in the double mass curve indicates a trend in the observed rainfall. Trends were removed by adopting the slope of the most recent period. The high quality rainfall sites used for the purpose of this task were Lovely Banks Reservoir (087034), Meredith (087043) and Beaufort Post Office (089005). Adjustments made are summarised in Table 8-2. Plots of adjusted double mass curves are found in Appendix C.

- **Table 8-2- Summary of Rainfall Detrending**

Station number	Period of adjustment to remove trend	Factor applied
087000	1892 to 1923	1.070
	1924 to 1963	1.153
087002	1889 to 1924	0.857
	1925 to 1949	0.921
087009	No correction required	
087011	1882-1923	0.954
087021	1888 to 1928	1.049
087034	No correction required	
087042	No correction required	
087045	1912 to 1943	1.130
087046	1882 to 1899	1.101
087067	1896 to 1951	1.044
089001	1883 to 1916	1.052
	1917 to 1945	1.145

8.2.1.2 Infilling and Disaggregation of Rainfall Data

The greater part of the rainfall data was prepared using the method outlined in Porter and Ladson (1993). This method uses the weighted average of daily rainfall recorded at nearby stations to estimate missing periods of record. In some cases additional data preparation was performed in order to extend the period of the available record to February 2003:

- Accumulated data was disaggregated, by dividing the recorded rainfall evenly over the period of accumulation.
- Infilling was completed by regression against nearby stations. Regression equations used for infilling and plots of regressions are provided in Appendix D and are sourced from SKM (2000a).

8.2.1.3 Preparation of rainfall data that simulates 2030 levels of global warming

An assessment of the impact of climate change will be carried out as part of this project. Therefore alternative climatic, demand and streamflow series are required. DAR60, the CSIRO limited area climate model, has simulated a global warming of 1.1°C by the year 2030 relative to 1990 levels (Whetton et al, 2002, p. 25) as presented in Section 5 of this report. Furthermore, DAR60 simulates a reduction in annual rainfall ranging between 0 and 2 percent per degree °C within the Moorabool catchment. Summer and autumn rainfalls were predicted to also decrease within this range. Spring rainfalls are predicted to decrease within the range of 2 and 5 percent per degree °C. In winter, the Moorabool catchment straddled two different categories of rainfall change. The simulation predicted that the upper half of the catchment would decrease within the range of 0 and -2 percent per degree °C, while the lower half would increase by between 0 and +2 percent.

In order to investigate the effect of global warming on streamflow in the Moorabool catchment, each rainfall series was modified to simulate 2030 levels of global warming. Rainfall series were multiplied by a set of seasonal factors, derived by use of the average maximum and minimum percent change in seasonal rainfall per degree °C global warming. These factors are shown in Table 8-3.

- **Table 8-3 - Rainfall change in the Moorabool catchment under 2030 levels of global warming**

Season	Average percentage change	Seasonal factor
Summer	-1.10	0.989
Autumn	-1.10	0.989
Winter	0.00	1.000
Spring	-3.5	0.962

8.2.2 Evaporation

Evaporation data was required for demand modelling and for representing rainfall effects on storages. Stations used were:

- **Table 8-4 - Evaporation data**

Station number	Site description	Period of record
087021	Durdiwarrah	Sep 1971 – Jul 2000
087023	Geelong Salines	Jan 1965 – present
087045	Moorabool Reservoir	Sep 1971 – present
089048	White Swan Reservoir	Sep 1971 – present

8.2.2.1 Detrending Evaporation Data

Although it is possible for systematic or random error to influence evaporation data, it is not possible to detrend evaporation series as the Bureau of Meteorology has not identified evaporation sites of high quality. However, unlike rainfall, evaporation rates generally do not vary considerably within a single region.

8.2.2.2 Infilling of evaporation data

The greater part of the evaporation data was prepared using the method described by Porter and Ladson (1993). This method uses the weighted average of daily evaporation recorded at nearby stations to estimate missing periods of record. However it was necessary to perform additional data preparation in order to extend the period of the available record to December 2002:

- Cumulative evaporation data was disaggregated by dividing the recorded evaporation evenly over the period of accumulation.

- Data was infilled using regression against nearby stations. Equations used for infilling and plots of regressions are given in Appendix D and are sourced from, SKM (2000a).

8.2.2.3 Preparation of evaporation data that simulates 2030 levels of global warming

The DAR60 global climate model has simulated an increase in evaporation rates of between 6 and 8 percent per degree °C global warming for the Moorabool catchment (Whetton et al., 2002). In order to prepare evaporation data that simulates 2030 levels of global warming, the completed evaporation series were multiplied by a factor of 1.077.

8.2.3 Temperature

Temperature data was required to predict urban demands. Stations used were:

- Table 8-5 - Temperature data

Station number	Site description	Period of record
087021	Durdiwarrah	Jan-1965 – Jul-2000
089002	Ballarat Aerodrome	Jan-1957 – present

8.2.3.1 Infilling of Temperature data

The temperature series were infilled by regression against each another. Equations used for infilling and plots of regression are given in Appendix D.

8.2.3.2 Preparation of temperature data to simulate 2030 levels of global warming

The DAR60 model has simulated a global warming of 1.1°C by the year 2030 (Whetton et al, 2002, p. 25). In Victoria, the pattern of warming is predicted to vary, with inland regions experiencing higher rates of warming relative to coastal areas. For the Moorabool region, the DAR60 model has simulated an increase in summer temperatures of approximately 0.95 °C per degree °C global warming and an increase in winter temperatures of approximately 0.75 °C per degree °C global warming. Warming is predicted to affect both the daytime maximum and the nightly minimum temperatures. As the degree of summer and winter warming is approximately equal to the global rate of warming, and considering the uncertainty involved in estimating such a factor, the global rate of warming was adopted to simulate 2030 levels of warming for the Moorabool catchment.

Temperature series which simulate 2030 levels of warming were prepared by adjusting the existing temperature series by 1.1 ºC.

8.2.4 Streamflow

Gauged streamflow data was used both to derive inflows and to calibrate the REALM model. Table 8-6 lists the stream gauging stations used and describes the application of each in the development of the Moorabool REALM model.

■ **Table 8-6: Streamflow Data Required**

Station Number	Description	Application
232202	Moorabool River at Batesford	Estimate inflows for the lower Moorabool River. Calibrate REALM Model.
232204	Moorabool River at Morrisons	Estimate inflows for the lower Moorabool River. Calibrate REALM Model
232210	Moorabool River West Branch at Lal Lal	Estimate inflows between Lal Lal Res., Bostock Res. and gauge 232204. Calibrate REALM Model
232211	Moorabool River West Branch at Mount Doran	Estimate inflow below Lal Lal Reservoir Calibration of REALM Model
232213	Lal Lal @ Bungal Dam	Estimate inflow to Lal Lal Reservoir Calibration of REALM Model
232214	Black Ck U/S Bungal Dam	Estimate inflow to Lal Lal Reservoir Calibration of REALM Model
232215	Woollen Ck U/S Bungal Dam	Estimate inflow to Lal Lal Reservoir Calibration of REALM Model
232223	Frawley Ck U/S Wilsons Reservoir	Estimate inflow to Wilsons Reservoir
232224	Slater Ck U/S Wilsons Reservoir	Estimate inflow to Wilsons Reservoir
	Devils Ck u/s Moorabool Reservoir	Estimate inflow to Moorabool Reservoir
	West Moorabool River u/s Moorabool Reservoir	Estimate inflow to Moorabool Reservoir

8.2.5 Operational data (storage records, channel flows, consumption, etc)

Information on spills from reservoirs, storage volumes, reservoir releases and stream diversions were also required to derive inflows and to calibrate the REALM model. Data was provided by the relevant urban water authorities. This information supplemented other data previously provided for the Moorabool Streamflow Management Plan project. Table 8-7 and Table 8-8 summarise the data supplied by the water authorities.

■ **Table 8-7: Summary of Data Supplied by Barwon Water**

Location	Description	Timestep	Period
Korweinguboora Res.	Historic storage volumes	Daily	7/96 to 6/03
	Spills	Daily	7/96 to 6/03
	Releases to river	Daily	7/96 to 6/03
Bolwarra Weir	Diversions to Ballan Ch.	Daily	7/96 to 6/03
Bostock Res.	Historic storage volumes	Daily	7/96 to 6/03
	Spills	Daily	7/96 to 6/03
	Releases to river	Daily	7/96 to 6/03
	Releases to Ballan Ch.	Daily	7/96 to 6/03
	Supply to Ballan	monthly	7/83 to 6/96
She Oaks	Pumping data	monthly	7/96 to 6/02
Meredith	Pumping data	monthly	7/95 to 6/02

Table 8-8: Summary of Data Supplied by Central Highlands Water

Location	Description	Timestep	Period
Lal Lal Reservoir	Historic storage volumes	Daily	1/1/96 to 18/02/03
	Passing flow / scour releases	Daily	1/1/96 to 18/02/03
	Releases to Geelong	Daily	1/1/96 to 18/02/03
	Lal Lal rainfall	Daily	1/1/96 to 18/02/03
	Lal Lal evaporation	Daily	1/1/96 to 18/02/03
Wilsons Reservoir	Historic storage volumes	Daily	11/96 to 2/03
	Rainfall	Daily	11/96 to 2/03
Beales Reservoir	Historic storage volumes	Daily	11/96 to 2/03
	Rainfall	Daily	11/96 to 2/03
Kirks Reservoir	Historic storage volumes	Daily	11/96 to 2/03
	Rainfall	Daily	11/96 to 2/03
Gong Gong Reservoir	Historic storage volumes	Daily	11/96 to 2/03
Pincotts Reservoir	Historic storage volumes	Daily	11/96 to 2/03
Moorabool Reservoir	Historic storage volumes	Daily	11/96 to 2/03
	Rainfall	Daily	11/96 to 2/03
	Evaporation	Daily	11/96 to 2/03
	Releases to pipe	Daily	11/96 to 2/03
	Passing flow releases	Daily	11/96 to 2/03
West Moorabool River	Flows	Daily	11/96 to 2/03
Devils Ck	Flows	Daily	11/96 to 2/03
Whiskey Ck	Flows	Daily	11/96 to 2/03
	Spills	Daily	11/96 to 2/03
Fellmongers Ck	Flows	Daily	11/96 to 2/03
Clarkes Ck	Flows	Daily	11/96 to 2/03
	Spills	Daily	11/96 to 2/03
Flood gate	Spills	Daily	11/96 to 2/03
White Swan Channel		Daily	11/96 to 2/03
Moorabool Channel		Daily	11/96 to 2/03
White Swan Reservoir	Historic storage volumes	Daily	11/96 to 2/03
	Rainfall	Daily	11/96 to 2/03
	Evaporation	Daily	11/96 to 2/03
Ballan	Consumption data	Daily	7/98 to 2/03

8.2.6 Rural demands, culture, metering, licence info, survey data

In order to calibrate the irrigation demand prediction model PRIDE, information on private diverter culture type, crop area and consumption was required. Survey data was available from previous work carried out by SRW. This was supplemented by metered consumption data and the most recent listing of licence holders provided by SRW.

8.3 Derivation of Demands

There is significant recorded demand data available in the catchment for urban extractions. Recorded rural demands are more difficult to find and some infilling was needed.

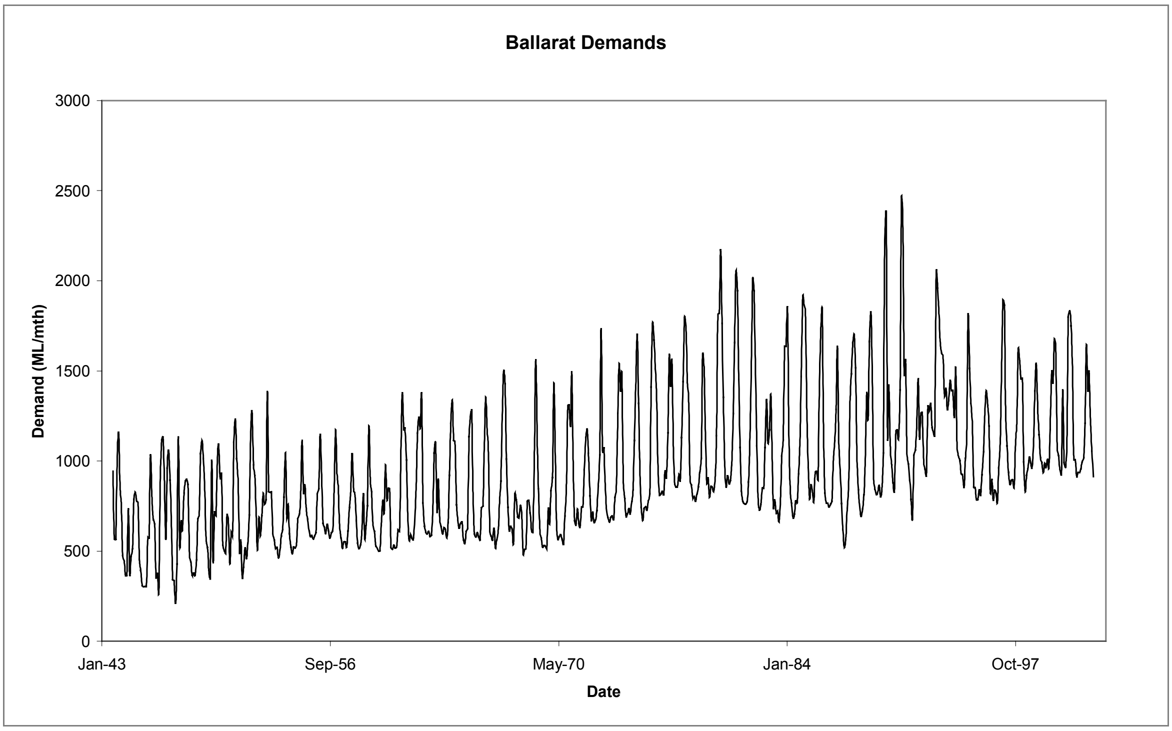
Where historic demands are not recorded, a prediction of demands is required to assist with inflow derivation and model calibration. Demands at current level of development were required for input to the base case run.

8.3.1 Urban Demands

8.3.1.1 Ballarat

Previously, demands at Ballarat had been predicted by regression with climate data. As part of this project this regression was refined using more recent recorded data. Historic consumption data is available from 1943 to date (Figure 8-1).

- **Figure 8-1: Ballarat Historic Monthly Consumption**

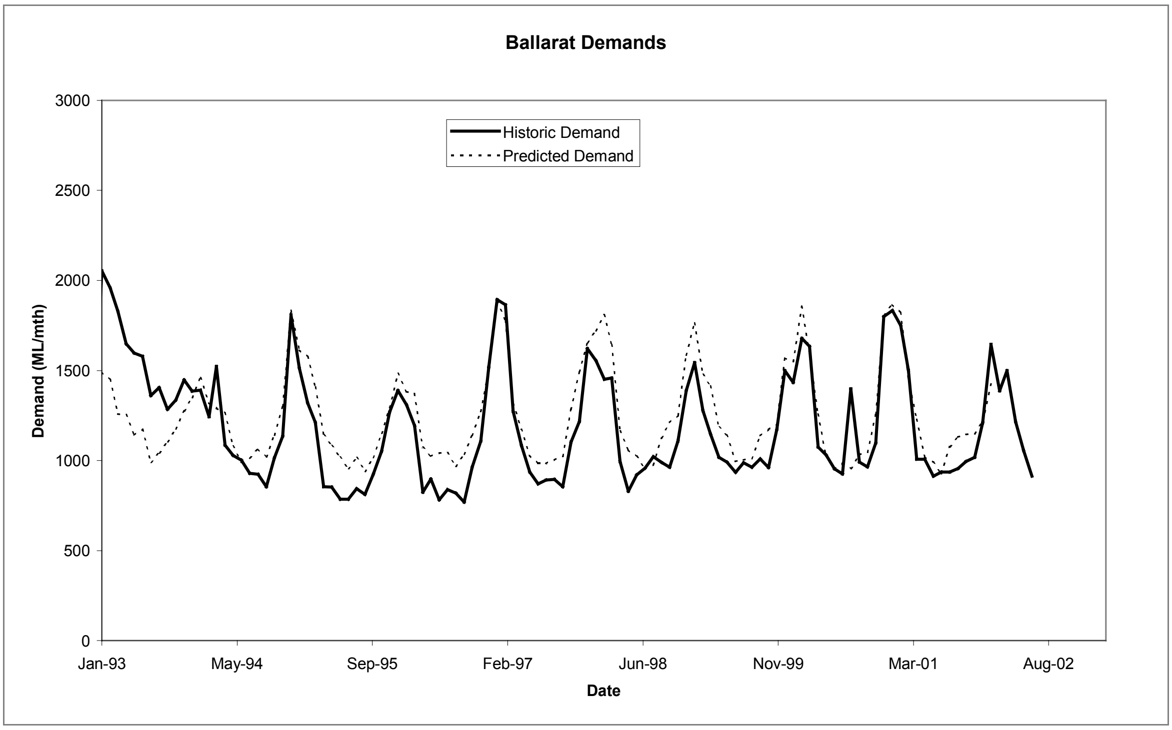


To reproduce recent consumption behaviour, the model fit was carried out on the period from 1993 to date. For accuracy of fit, periods of restriction during this time (August 2000 to November 2000, November 2002 to date) were removed from the data set. The model was fitted to monthly data (Figure 8-2) and the regression equation converted to weekly. This equation was used to derive demands at current level of development for input to the REALM model.

- **monthly** demand = 7.7*evap + 555 - 214cos(mth*pi/6) (4)
- **weekly** demand = 7.7*evap +128 - 49.38cos(wk*pi/26) (5)

where evap = evaporation at White Swan Reservoir (087048)

- **Figure 8-2: Regression to Predict Ballarat Demand**



8.3.1.2 Geelong

Approximately one third of the total Geelong supply is taken from the Moorabool catchment. Some is taken from the East Moorabool storages, Bostock Reservoir and Korweinguboora Reservoir via the Stoney Creek reservoirs, while the remainder is taken from Barwon Waters' share of Lal Lal Reservoir via the She Oaks pump station. The REALM model is configured in such a way that an estimate of extraction at She Oaks and extraction from Stoney Creek reservoirs is required.

As mentioned in Section 2.3.3, without modelling the Barwon catchment as well, it is difficult to determine the supply from the Moorabool catchment in any given year as it is dependant on the water available in the Barwon catchment and decisions made by the Barwon Water operators.

Therefore on the advice of Barwon Water staff it was assumed that at current level of development 3000 ML/yr would be extracted at She Oaks, and 4000 ML/yr be extracted from the Stoney Creek Reservoirs. The within-year pattern of the most recent available water year (1998/99) was applied to this demand.

Subsequent to this figure being adopted for the base case and scenario modelling, BW staff advised that in future usage in the catchment is likely to increase to 8-10,000 ML/yr. The ratio of usage from the East and West Moorabool is also likely to change, with greater use of Lal Lal water in the future.

It is recommended that any changes to Moorabool usage by BW be reassessed before any future work is undertaken.

8.3.1.3 Ballan, Bungaree, Wallace, Gordon and Mt Egerton

In July 1998 a new water treatment plant and pipeline was commissioned to supply the townships of Ballan, Bungaree, Wallace, Gordon and Mt Egerton with water from the Lal Lal Reservoir.

Prior to July 1998, the water supplied to the townships of Ballan, Bungaree, Wallace, Gordon and Mt Egerton was sourced from a number of locations.

Ballan, pre July 1998 - Prior to the commissioning of the new water treatment plant, the Ballan supply was sourced from a combination of the Bostock Reservoir and the Colebrook Reservoir.

Bungaree and Wallace, pre July 1998 - Bungaree and Wallace were originally supplied from the Moorabool channel, among other sources.

Gordon and Mt Egerton, pre July 1998 - Gordon and Mt Egerton were originally supplied from groundwater bores. Pump meters were read on an annual basis and available records begin in June 1986.

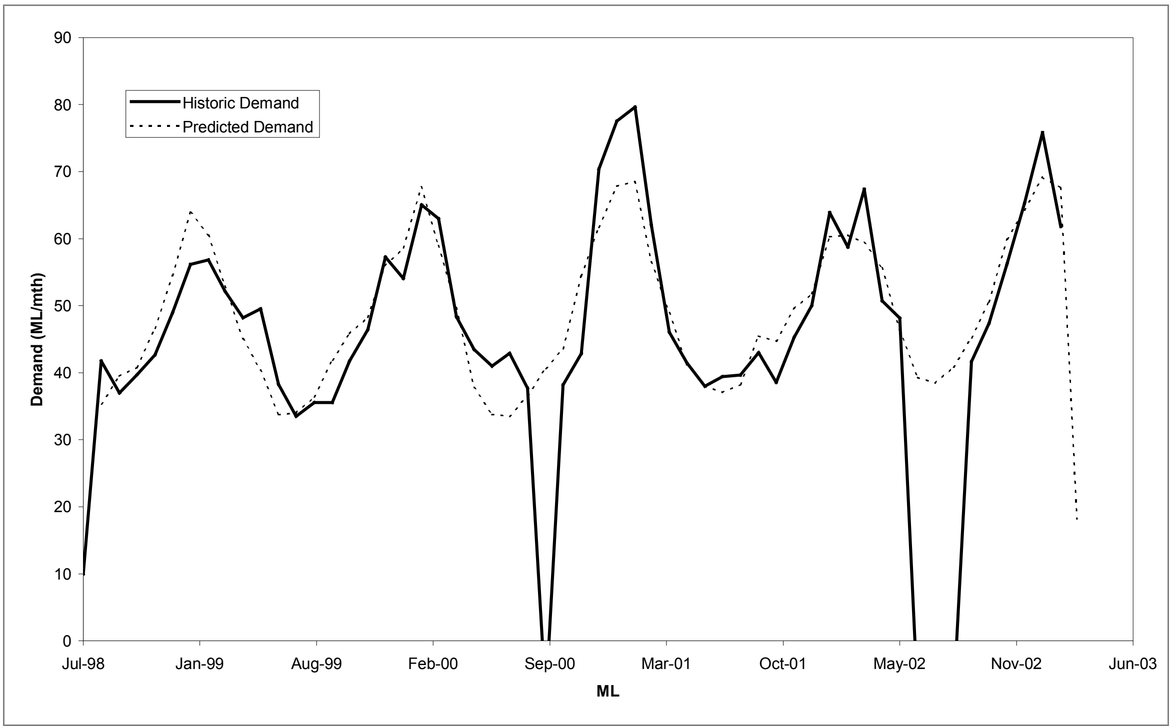
The periods when restrictions were imposed upon Ballan and district were identical to the periods when restrictions were applied to Ballarat: August 2000 to November 2001 and November 2002 to the present day. The Generalised Additive Model was used to generate the following monthly linear regression:

- **monthly** **demand = 1.7*time + 1.9*temp + 10.4** **(6)**
- **weekly** **demand = 0.39*time + 0.44*temp + 2.4** **(7)**

Where time = the decimal month where August 1998 is assigned a value of zero
temp = the monthly average daily maximum temperature at the Ballarat Aerodrome (089002)

The time component was set equal to 2003 in order to generate current level of development demands for input to the REALM model.

■ **Figure 8-3: Regression to Predict Ballan, Bungaree, Wallace, Gordon and Mt Egerton Demand**



* Times of zero demand indicate missing data

8.3.1.4 Meredith

Water is extracted directly from the Moorabool River to supply the town of Meredith. The extracted water is stored in a town storage facility, but the storage is so small that it can be assumed that, for any single month, the extracted volume is equal to the consumed volume.

Electronic pumping records exist for the Meredith demand, beginning in August 1988 to the present day. Meredith experienced the same periods of restrictions as the greater Geelong area: October 1967 to August 1968, September 1982 to June 1983 and February 1998 to June 2001.

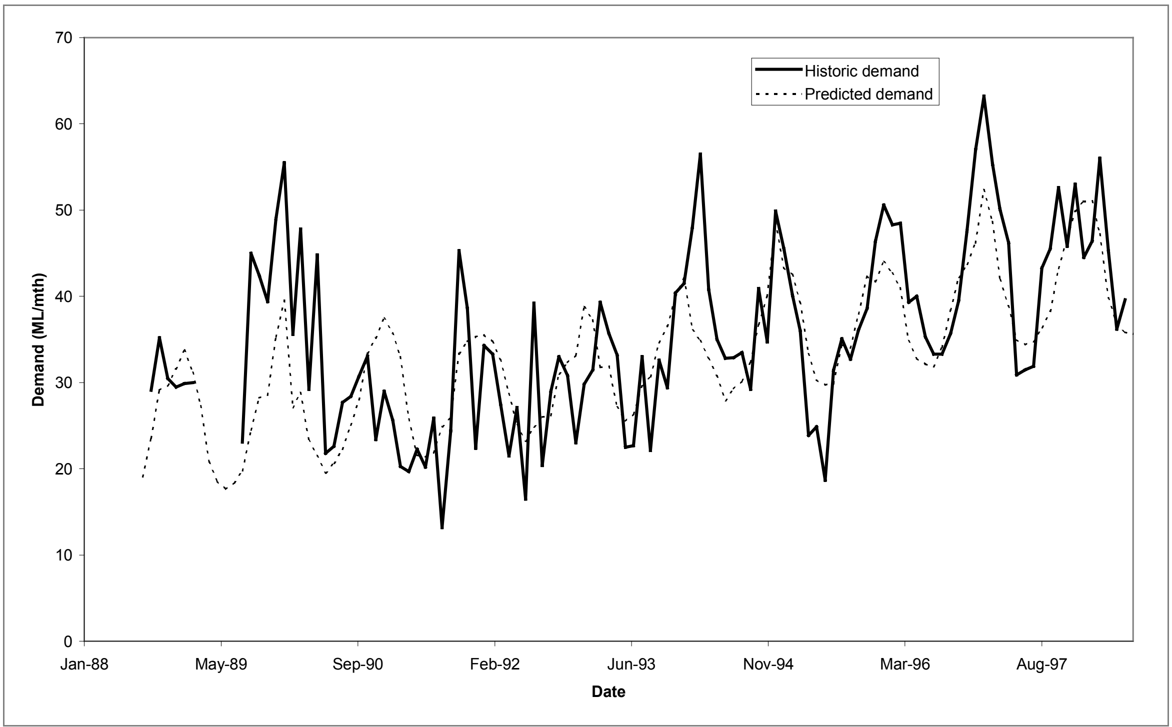
The Generalised Additive Model (GAM) was used to fit the following monthly linear regression to the Meredith Demand.

- **monthly** **Demand (ML) = 2.00*Time + 0.13*Evap + 12.70** **(8)**
- **weekly** **Demand (ML) = 0.46*Time + 0.13*Evap + 2.93** **(9)**

Where time = the decimal month where November 1988 is assigned a value of zero

Evap = the monthly evaporation at Durdidwarrah (station number 087021)

▪ **Figure 8-4: Regression to Predict Meredith Demand**



8.3.2 Private Diverter Demands

As for other demand series, historic private diverter demands were required to assist with inflow derivation and model calibration. Current level of development demands were required for input to the base case.

For accuracy of modelling, demands were split into the following reaches:

■ **Table 8-9: Private Diverter Demand Split**

No	Description	No	Description
1	mainstream lal lal to she oaks	9	Mattheys to Maddens
1b	tribs lal lal to she oaks	9w	from Maddens Weir
2	mainstream btwn lal lal and mbool	10	Maddens to Buchters
3	tribs above lal lal	10w	from Buchters Weir
4	tribs btwn lal lal and mbool	11	Buchters to Hills
5a	above mbool	11w	from Hills Weir
5b	above wilsons	12	Hills to Mitchells
5c	trib of pincotts	12w	from Mitchells Weir
6	She Oaks to Spillers Weir	13	Mitchells to Joaquin
6w	from Spillers Weir	13w	from Joaquin Weir
7	Spillers to Caprons	14	d/s Joaquin
7w	from Caprons Weir	15	d/s Batesford
8	Caprons to Mattheys	16	tribs btwn she oaks and Batesford
8w	from Mattheys Weir		

The modelling of each private diverter licence type is discussed in more detail below.

8.3.2.1 Domestic and Stock, Commercial and Industrial

Licence details for these demand types are summarised in Table 8-10. There is no metering data available for these demands. Therefore current use is assumed to be equal to licensed volume, distributed evenly throughout the year. Historic usage is assumed equal to current usage.

■ **Table 8-10: Summary of D&S, Commercial and Industrial Licences**

Demand reach		Licensed Volume (ML)		
		Commercial	D&S	Industrial
1	mainstream lal lal to she oaks	0.0	19.8	0.0
1b	tribs lal lal to she oaks	0.0	4.4	0.0
2	mainstream btwn lal lal and mbool	0.0	2.2	0.0
3	tribs above lal lal	0.0	8.8	0.0
6	She Oaks to Spillers Weir	2.2	4.4	37
7	Spillers Weir to Caprons Weir	0.0	13.2	0.0
8w	Out of Mattheys Weir	0.0	0.0	4
15	Below Batesford	3.7	2	2.2
TOTAL VOLUME (ML)		5.9	54.8	43.2
Number of licences		3	25	3

8.3.2.2 Offstream Winterfill

Licence details for these demand types are summarised in Table 8-11. There is no metering data available for these demands. Therefore current use is assumed to be equal to licensed volume, distributed evenly over the winterfill period of May to October. Historic usage is assumed equal to current usage.

Table 8-11: Summary of Offstream Winterfill Licences

Demand reach		Licensed Volume (ML)
6	She Oaks to Spillers Weir	65
7	Spillers to Caprons weir	22
8	Caprons to Mattheys Weir	124
8w	Out of Mattheys Weir	54
15	Below she oaks – below Batesford	3.2
16	tribs btwn she oaks and Batesford	190
1	mainstream lal lal to she oaks	0
1b	tribs lal lal to she oaks	0
2	mainstream btwn lal lal and mbool	0
3	tribs above lal lal	49.3
4	tribs btwn lal lal and mbool	0
5	above mbool	0
5b	above wilsons	0
5c	trib of pincotts	0
TOTAL VOLUME (ML)		507.5
Number of licences		11

8.3.2.3 Onstream Winterfill and Direct Diverters

Onstream winterfill storages were to be explicitly included in the model. Both onstream winterfill and direct diverters were modelled as direct irrigation. Diverters were split into the relevant reaches using property title information and advice from Simone Wilkinson of the CCMA. Licensed volumes for each reach are summarised in Table 8-12.

■ **Table 8-12: Summary of Onstream Winterfill and Direct Irrigation Licences**

Demand reach		Licensed Volume (ML)
2	mainstream btwn lal lal and mbool	88.9
3	tribs above lal lal	925.9
4	tribs btwn lal lal and mbool	12.0
5	above mbool	162.0
5b	above wilsons	27.0
5c	trib of pincotts	2.0
6	She Oaks to Spillers weir	36.9
6w	Out of Spillers Weir	48.3
7	Spillers to Caprons	128
7w	Out of Caprons Weir	49.7
8	Caprons to Mattheys	32.3
8w	Out of Mattheys Weir	50
9w	Mattheys to Maddens	164
10	Maddens to Buchters	25
10w	Out of Buchters Weir	34.5
11	Buchters to Hills	12
11w	Out of Hills Weir	37.3
12w	Hills to Mitchells	18
13	Mitchells to Joaquin	12.4
13w	Out of Joaquins Weir	52.3
14	Joaquin to Batesford	12.3
15	below Batesford	147.5
TOTAL VOLUME (ML)		2078.3
Number of licences		92

Direct irrigation demands were predicted using the PRIDE model (HydroTechnology, 1995). PRIDE uses historic rainfall and evaporation, combined with crop factors and several other parameters to predict a theoretical unrestricted irrigation crop water requirement. Crop factors are used to reflect the growth cycle of a particular crop.

SRW conducted a survey of irrigators covering the period 1993/94 to 1997/98. Metered consumption data was available for the 2001/02 water year. The PRIDE model was calibrated using crop areas and crop types from survey, together with surveyed and metered consumption data. Crop area and consumption data used for calibration are included in Appendix E.

The general, the approach for calibration was to assume that the recent metered data was most accurate. Crop areas were derived for the metered year to give a sensible ML/ha for that crop, whilst checking against the most recent crop area data from survey (97/98). Indicative values of crop water use were:

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Potatoes	3 ML/ha	Lucerne/pasture	4.6 ML/ha
Vines	2.5 ML/ha	Vegetables	6 ML/ha
Trees	7 ML/ha		

Historic periods of restriction by SRW (16/10/99 – 17/7/00, 6/12/00 – 8/5/01, Jan 02 - Jul 02, 4/9/02 – date) were taken into consideration as part of the calibration process.

Calibration plots fore each sub-area are included in Appendix E.

Historic Demands

Diversions in the upper West part of the catchment are predominantly for growing potatoes. In order to determine an historic trend in water use for potatoes, advice was sought from McCains in Ballarat (Milton Rodder pers. comm.). Based on this advice an historic trend was assumed of approximately half current usage levels between 1965 and 1985, increasing linearly to current usage levels from 1985 to date. This trend was used to derive a time series of historic demand for all subcatchments where potatoes were the dominant crop.

Little information was available regarding historic trends for diverters in the lower Moorabool River. Therefore it was assumed that historic demands were equal to demands at current level of development.

Current Level of Development Demands

To determine demands at current level of development, PRIDE was run with crop areas determined for the 2001/02 water year (from calibration) for all years from 1965 to date. Cameron Welsh of SRW and Simone Wilkinson of CCMA provided advice regarding which licences were currently being used.

8.3.3 Private Rights

The Water Act (1989) states that the occupiers of land that includes the river, or that runs up to its banks, have the right to take water for domestic and stock use. Domestic and stock use is defined as consisting of:

- Household use,
- Watering of pets and stock,
- Watering of 1.2 ha for fire prevention,
- Watering of a kitchen garden.

The size of the kitchen garden that can be watered depends on the water source and when the allotment was alienated from the Crown.

Table 8-13: Size of Private Right Kitchen Garden

Date of allotment alienation from the Crown	Water Source		
	Surface water only	Surface and groundwater	Groundwater only
Before Dec 15 1886	1.2 ha	1.2 ha	0.4 ha
After Dec 15 1886	0.1 ha	0.4 ha	0.4 ha

Assuming D&S use of 2.2 ML, 5 ML for fire prevention, and 6 ML/ha for the kitchen garden, total potential use per household for each case can be calculated as shown below.

Table 8-14: Estimated Private Right Water Use

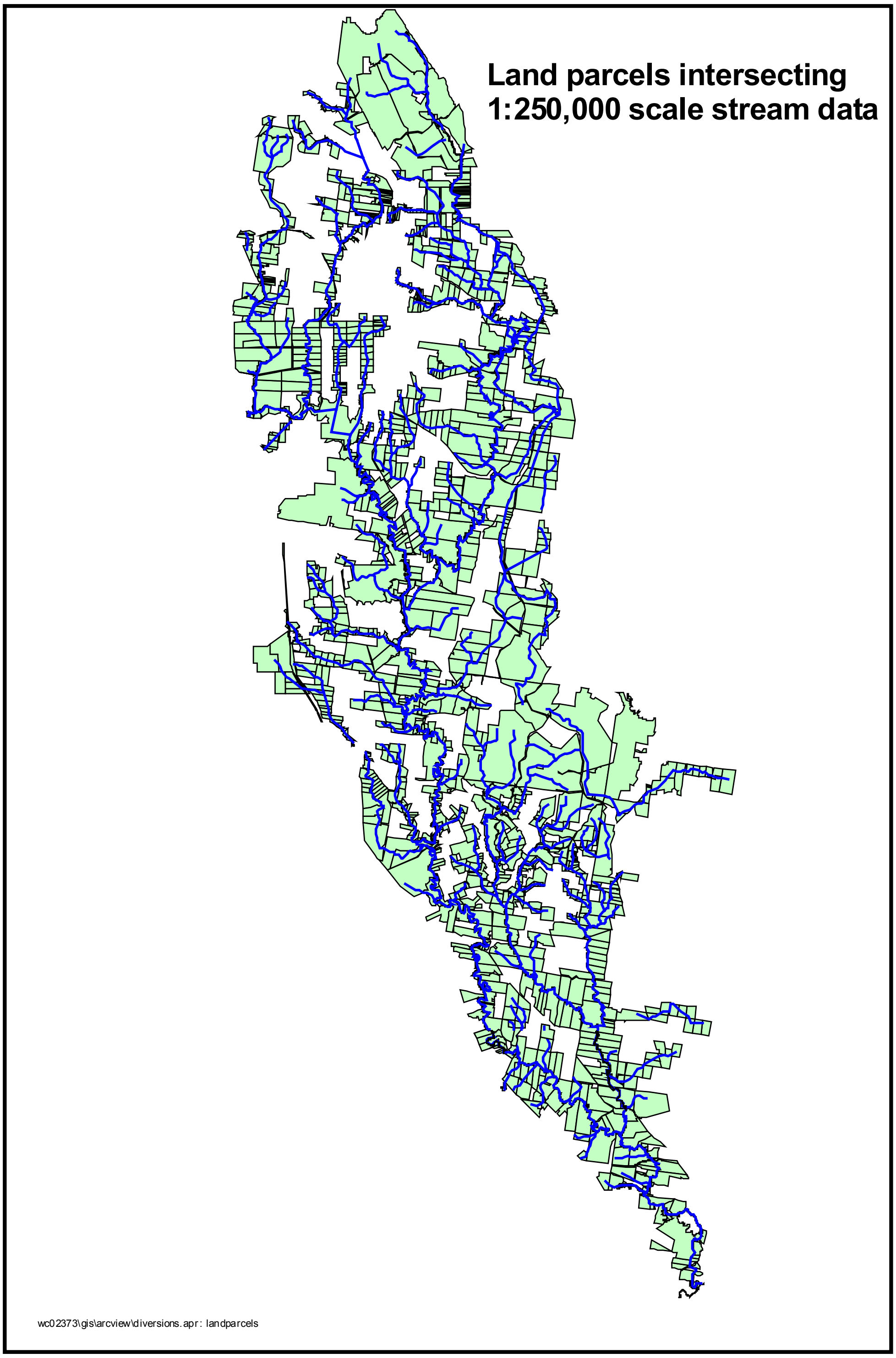
Date of allotment alienation from the Crown	Water Source		
	Surface water only	Surface and groundwater	Groundwater only
Before Dec 15 1886	7.2+7.2 = 14.4 ML	7.2+7.2 = 14.4 ML	7.2+2.4 = 9.6 ML
After Dec 15 1886	7.2+0.6 = 7.8 ML	7.2+2.4 = 9.6 ML	7.2+2.4 = 9.6 ML

From GIS information, the number properties (identified by property number) that abut or contain streams in the Moorabool catchment were estimated. 755 unique properties were identified by property number, along with 476 properties with an unspecified property number, giving a total of 1231 properties (see Figure 8-5).

Therefore the volume of private rights in the Moorabool could in the order of 12,000 ML. Anecdotal evidence suggests however that current usage is well below this volume.

It should be noted that the private right usage is not explicitly represented in the REALM model but is indirectly included in the derivation of inflows and losses.

To fully understand all uses in the catchment there would be benefit in seeking a greater understanding of the magnitude of private rights, their current usage and their likely future usage as part of future work.



- **Figure 8-5: Land Parcels abutting Streams in the Moorabool Catchment**

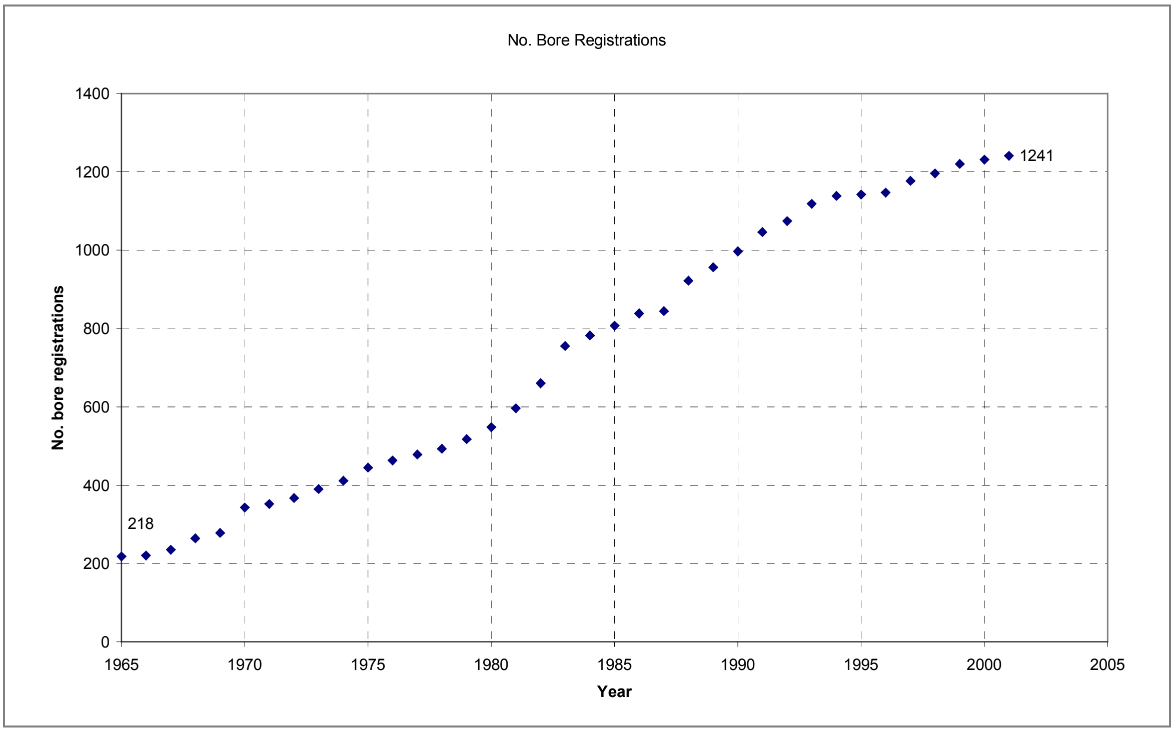
8.4 Impact of Groundwater Extraction on Inflows

An estimate of the historic impact that groundwater pumping has had on streamflow was required to estimate natural flows. The impact of groundwater pumping at the current level of development was required for input to the base case model.

As part of this project, a detailed study of the interaction between surface water and groundwater was undertaken (refer Section 6). As a result of the findings of this work, it was assumed that 60% of the groundwater extracted came from baseflow in the stream.

A time series of historic groundwater extraction was determined using the pattern of crop water requirements for potatoes, with an annual trend applied equivalent to the number of bores registered in that year (as shown in Figure 8-6). This series was adjusted so that annual usage in the 2001/2002 water year was equal to metered data (Table 8-15).

▪ **Figure 8-6: Historic bore registrations**



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■ **Table 8-15: Groundwater Use 2001/2002 Water Year**

Inflow Reach	Description	Extraction 2001/2002 (ML)
F1	Upstream of Moorabool Reservoir	490.1
F2a	Upstream of Wilsons Reservoir	144.3
F2b	Between Wilsons and Beales Reservoir	155.3
F3a	Fellmongers Ck	117.2
F3b	Unregulated tributaries above Moorabool Channel	312.7
F4a	Leigh Ck	49.1
F4b	Giles Ck	95.2
F4c	Clarkes Ck	19.0
F5a	West Moorabool River between Moorabool Reservoir and Lal Lal Reservoir	347.6
F5b	Whiskey Ck	110.2
F6	Lal Lal Reservoir tributaries	477.7
	TOTAL	2318.5

A time series of current level of development groundwater extraction was determined using the pattern of crop water requirements for potatoes, without an annual trend applied, adjusted so that annual usage in the 2001/2002 water year was equal to metered data.

As data on groundwater interactions is scant outside the Bungaree WSPA, only subcatchments with this area had groundwater influences applied.

It should be noted that subsequent to this analysis, metered 2002/03 groundwater usage figures became available for Bungaree. Usage was around 3750 ML in that year. It is recommended that as part of any future work a check should be made on the implications and persistence of this higher usage figure.

8.5 Impact of Farm Dams on Inflows

The impact of farm dams on inflow was taken into account when model inflows were calculated. They were also included in the REALM model run as "demands" at current level of development. Details are given in Section 7.

8.6 Derivation of Model Inflows

Inflows to the model are summarised in Table 8-16.

■ **Table 8-16: Moorabool REALM Model Inflows**

Inflow No	Description
1	Moorabool Reservoir Inflow
2a	Wilsons Reservoir Inflow

2b	Beales Reservoir Inflow
3a	Fellmongers Creek
3b	Unregulated tributaries above Moorabool Channel
4a	Leigh Creek
4b	Giles Creek
4c	Clarkes Creek
5a	West Moorabool River between Moorabool Reservoir and Lal Lal Reservoir
5b	Whiskey Creek above Moorabool Pipeline
6	Tributary inflows to Lal Lal Reservoir
7	Korweinguboora Reservoir Inflow
8	Bostock Reservoir Inflow
9	Moorabool River inflow between Lal Lal Reservoir, Bostock Reservoir and Morrisons gauge
10	Moorabool River inflow between Morrisons gauge and She Oaks Weir
11	Moorabool River inflow between She Oaks Weir and Batesford gauge
12	Inflow to Stoney Creek reservoirs

8.6.1 Moorabool Reservoir Inflow

This inflow was derived by a combination of a weekly water balance on Moorabool Reservoir (i.e. inflow = change in storage + outflow – rainfall + evap) and sum of gauged inflows upstream (Devils Creek and West Moorabool River).

Storage outflow is calculated by adding spill data to estimated flow passing through the Moorabool Basin. Level data is available at the basin, and this has been converted to flow using a rating table provided by CHW.

The upstream gauges used for sum of inflows are poorly rated at high flows, while the water balance on storage sometimes produced “negative” inflows at times of low flow (refer Figure 8-7). Therefore the water balance calculation was used most of the time, with the sum of inflows calculation used when the water balance gave a negative result.

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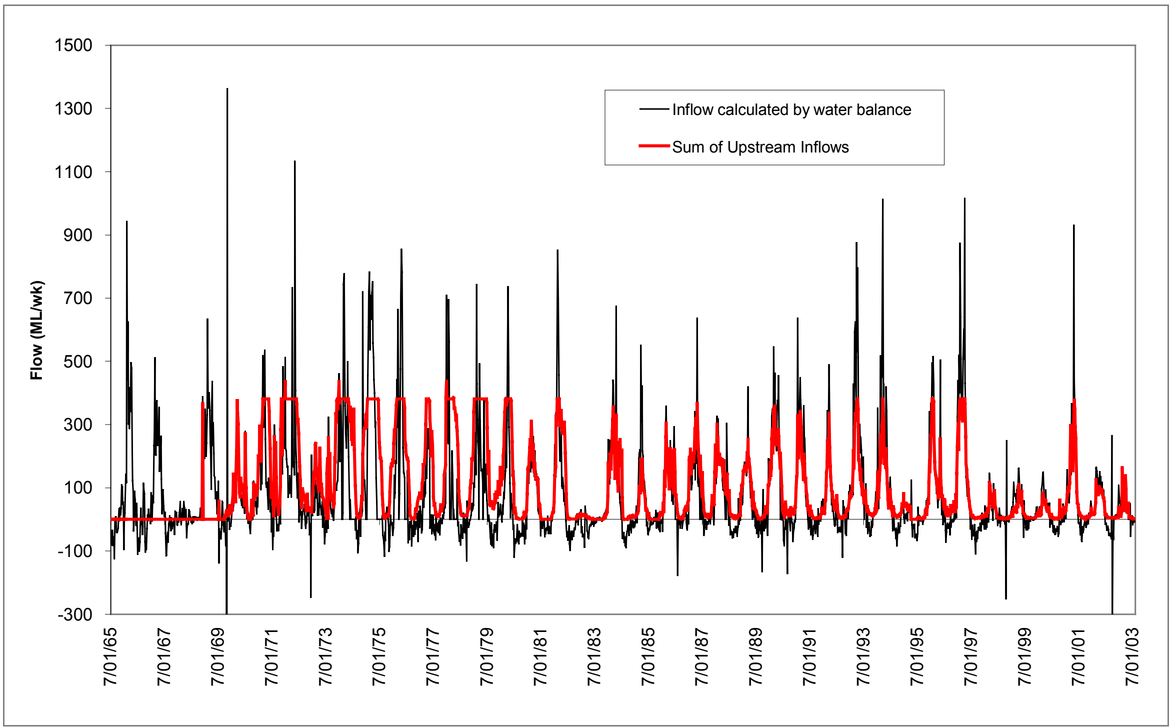
- **Figure 8-7: Moorabool Reservoir Inflow**



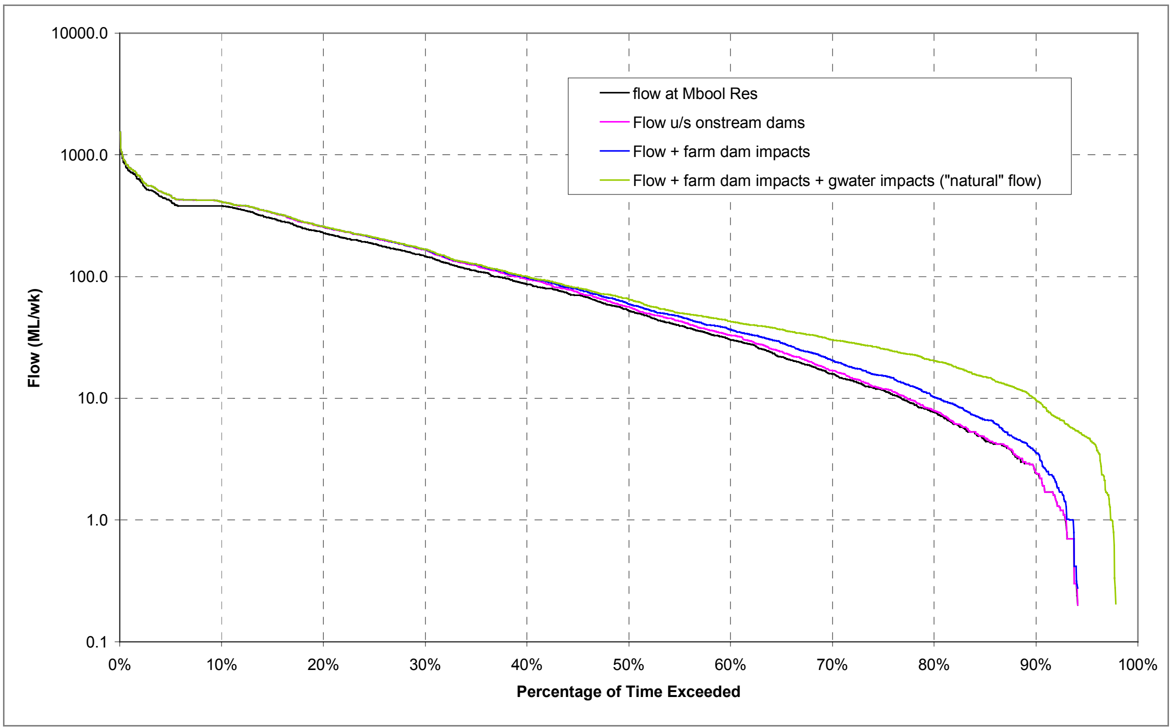
This calculation gave a time series of flows reaching the storage. It is recognised however that there are activities in the catchment upstream that have affected these flows.

There are a number of onstream storages on Devils Ck and Musk Ck, with a total licensed volume of 162 ML. The inflow upstream of these storages was calculated by determining the effect these storages were having on flow and then adding this effect back to the calculated inflow. The effect was calculated by running the time series of inflow through the storages, allowing them to be affected by diversions, rainfall and evaporation, and then spilling downstream.

Flows in this catchment are also impacted by 146 ML of farm dams (refer Section 7) and 490 ML (2001/02) of groundwater extractions (refer Section 0). These impacts were also added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

The magnitude of these various impacts is illustrated by Figure 8-8.

- **Figure 8-8: Inflow to Moorabool Reservoir**



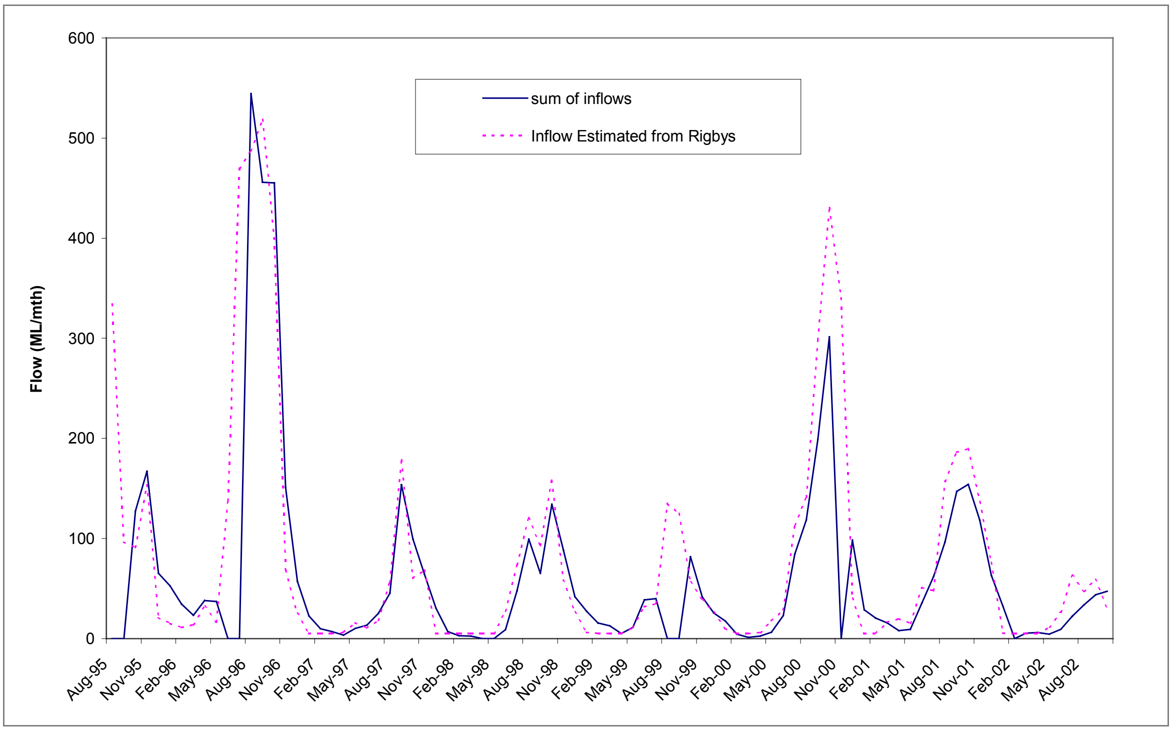
8.6.2 Wilsons Reservoir Inflow

CHW calculate a monthly total inflow to their system by summing usage, losses, spills, and change in storage. This method is commonly referred to as Rigbys calculation. It includes all inflows above Moorabool Channel and Moorabool Pipeline.

Short term gauged flow data is available on Frawleys, Slaters and Mahers creeks upstream of Wilsons Reservoir. This information was used to predict inflows as a function of Rigbys total inflow. Data could then be extended back to 1965 for input to the REALM model.

- **Monthly Inflow = 0.065 * Rigbys Inflow + 5** **(10)**
- **Weekly Inflow = 0.065 * Rigbys Inflow + 1.15** **(11)**

- **Figure 8-9: Fit of Regression to Extend Wilsons Reservoir Inflow Calculation**



As for inflows to Moorabool Reservoir, there are a number of onstream storages above Wilsons Reservoir, with a total licensed volume of 27 ML. Flows are also impacted by farm dams (refer Section 7) and groundwater extractions (refer Section 0). These impacts were added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

8.6.3 Beales Reservoir Inflow

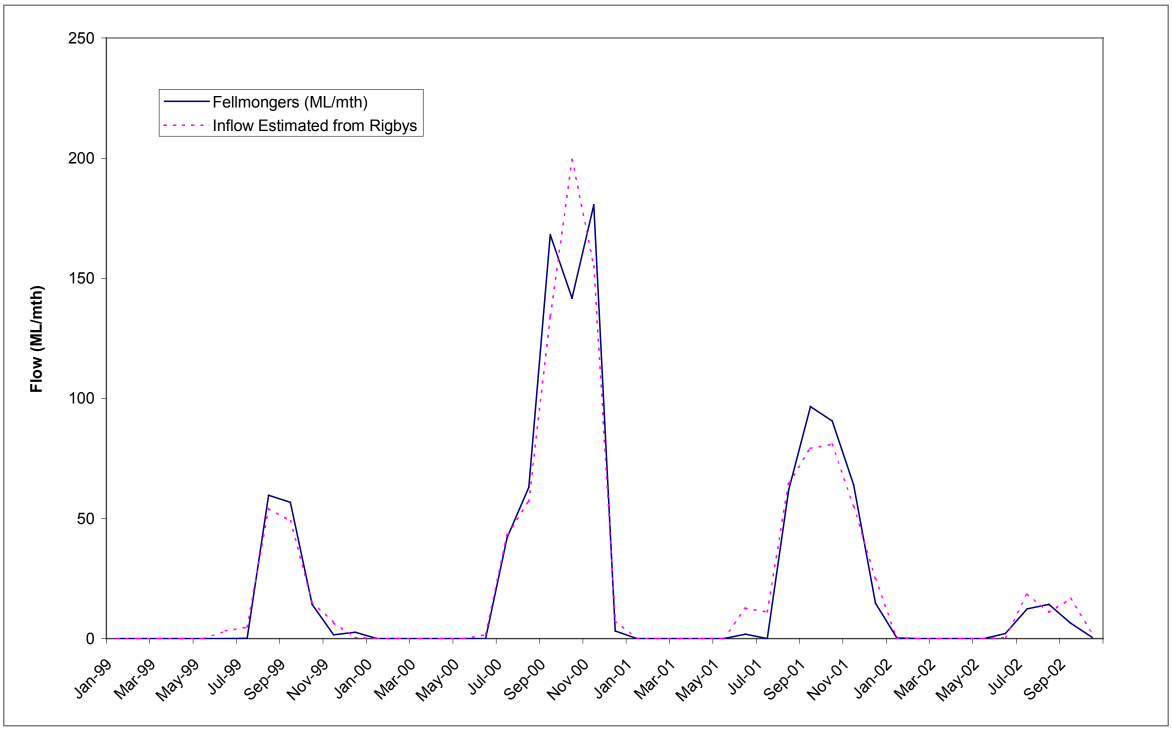
There was insufficient data available at Beales reservoir to calculate inflows by water balance. It was decided in consultation with CHW at this inflow could be approximated as 50% of Wilsons Reservoir inflow.

8.6.4 Fellmongers Creek

As for Wilsons Reservoir there is short term gauged data available for Fellmongers Ck. Again this flow was predicted as a function of Rigbys inflow to extend it back to 1965.

- **Monthly Inflow = 0.032 * Rigbys Inflow – 10** **(12)**
- **Weekly Inflow = 0.032 * Rigbys Inflow – 2.3** **(13)**

■ **Figure 8-10: Fit of Regression to Predict Fellmongers Ck flow**



Flows are impacted by groundwater extractions (refer Section 0), however the impact of farm dams could not be calculated as this inflow is not part of the Moorabool catchment. Groundwater impacts were added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

It should be noted that Fellmongers Creek is not in the Moorabool basin but is included in the model as it does contribute to CHW supply to Ballarat.

8.6.5 Unregulated tributaries above Moorabool Channel

This inflow was calculated as the balance of the total Rigbys inflow.

■ **Inflow = Rigbys inflow – Moorabool Res Inflow – Wilsons Res Inflow - Beales Res Inflow- Fellmongers Ck – Leigh Ck – Giles Ck – Clarkes Ck – Whiskey Ck** **(14)**

Flows in this catchment are also impacted by farm dams (refer Section 7) and groundwater extractions (refer Section 0). These impacts were also added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

Subsequent to the release of the Stage A report CHW advised that the seepage component of Rigbys inflow should be excluded from the unregulated tributary calculation. This adjustment was made and this inflow was used for the revised base case (refer Section 8.10) and for scenario modelling (refer Section 13).

8.6.6 Leigh Creek

Due to lack of data at this site, this inflow was calculated by transposing Giles Ck inflow using the ratio of their respective catchment areas.

- **Inflow = A_{Leigh}/A_{Giles} * Giles Ck** **(15)**

It should be noted that Leigh Creek is not in the Moorabool basin but is included in the model as it does contribute to CHW supply to Ballarat.

8.6.7 Giles Creek

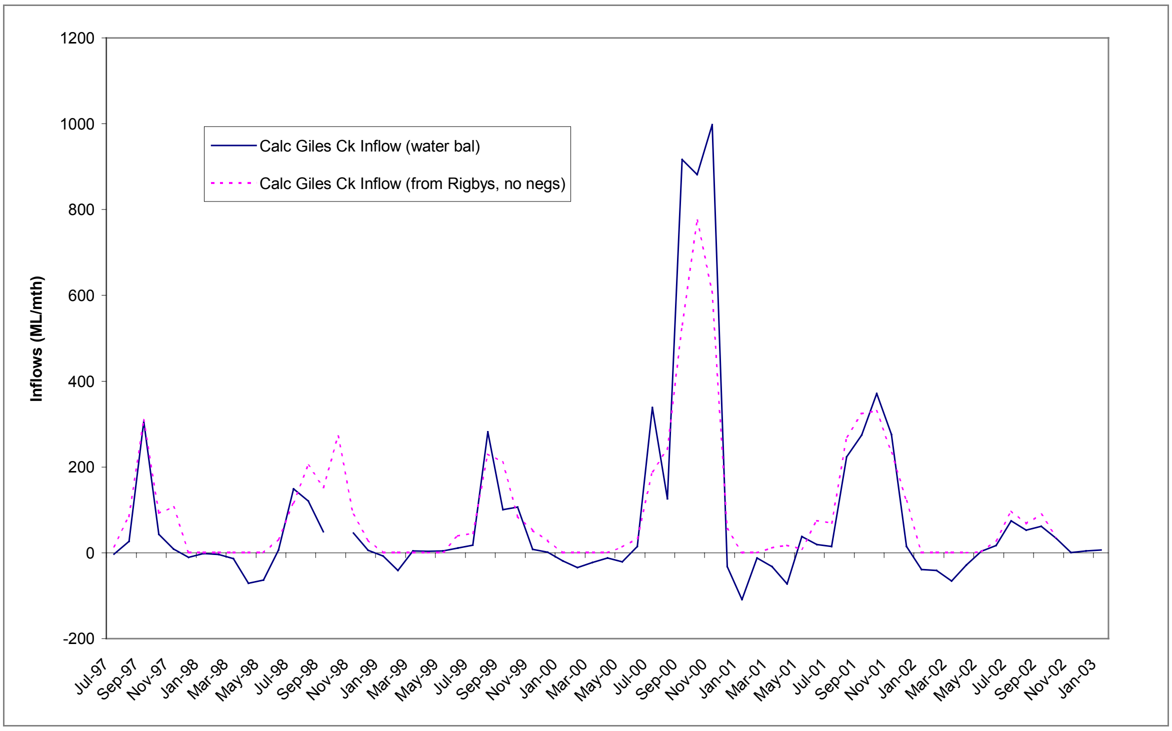
As for Wilsons Reservoir and Fellmongers Ck there is short term gauged data available for Giles Ck. Inflow above Moorabool Channel can be calculated by adding passing flow to flow down the channel.

- **Inflow = inflow to channel + passing flow** **(16)**
- **Where passing flow = "Giles Ck (ML/d)" data from CHW** **(17)**
- **inflow to channel = Swan Channel Gauge - white swan channel (i.e. Old Gauge) (18)**

Again this flow was predicted as a function of Rigbys inflow to extend it back to 1965.

- **Monthly Inflow = 0.12 * Rigbys Inflow – 10** **(19)**
- **Weekly Inflow = 0.12 * Rigbys Inflow – 2.3** **(20)**

■ **Figure 8-11: Fit of Regression to Predict Giles Ck Inflow**



Flows are impacted by groundwater extractions (refer Section 0), however the impact of farm dams could not be calculated as this inflow is not part of the Moorabool catchment (only farm dams on aerial photos within the Moorabool catchment were digitised). Groundwater impacts were added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

It should be noted that Giles Creek is not in the Moorabool basin but is included in the model as it does contribute to CHW supply to Ballarat.

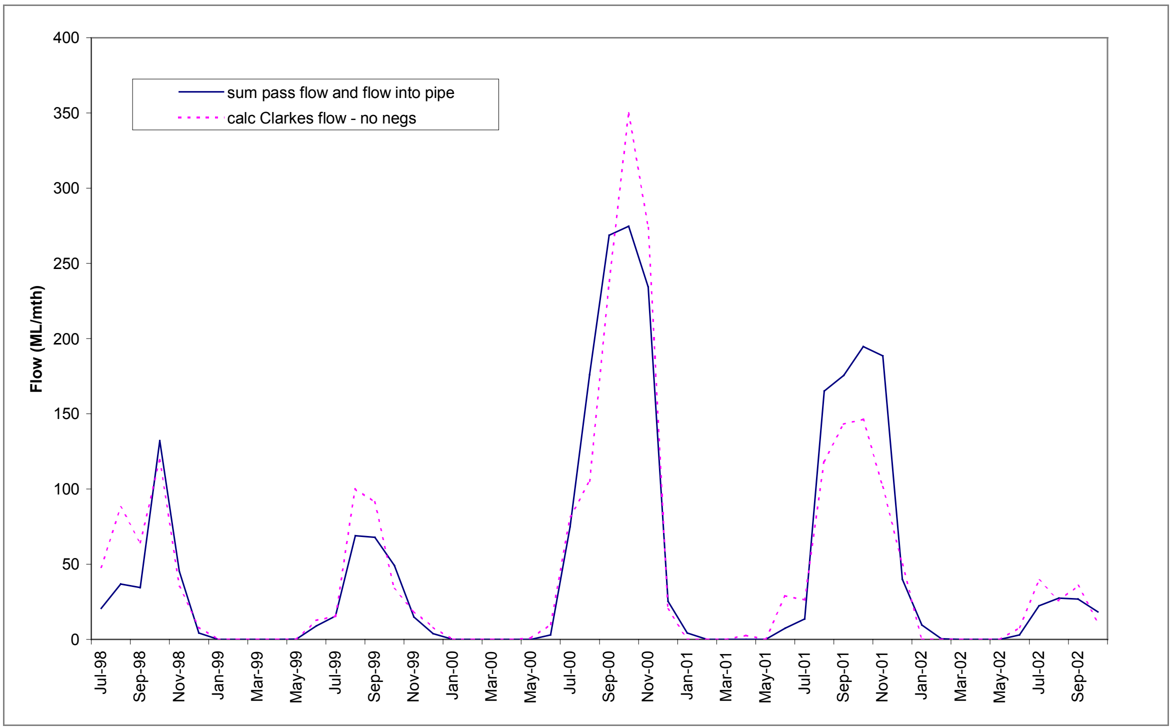
8.6.8 Clarkes Creek

As for Wilsons Reservoir, Fellmongers Ck and Giles Ck there is short term gauged data available for Clarkes Ck. Inflow can be calculated by adding passing flow to pipe inflow. Pipe inflow occurs at two locations. Unfortunately gauging only picks up flow at one of these locations. To allow for inflow at the other location, the calculated inflow for this catchment was increased by 20%.

- **Inflow = inflow to pipe (2 locations) + passing flow (21)**
- **Inflow = 1.2 * (inflow to pipe (1 location) + passing flow) (22)**
- **Where passing flow = "Clarkes pass flow (ML/d)" data from CHW (23)**
- **inflow to pipe (1 location) = "Clarkes Creek Diversion Pipe In" data from CHW (24)**

- **Monthly Inflow = 0.055 * Rigbys Inflow – 10** **(25)**
- **Weekly Inflow = 0.055 * Rigbys Inflow – 2.3** **(26)**

- **Figure 8-12: Fit of Regression to Predict Clarkes Ck Inflow**



It should be noted that Clarkes Creek is not in the Moorabool basin but is included in the model as it does contribute to CHW supply to Ballarat.

8.6.9 West Moorabool River between Moorabool Reservoir and Lal Lal Reservoir

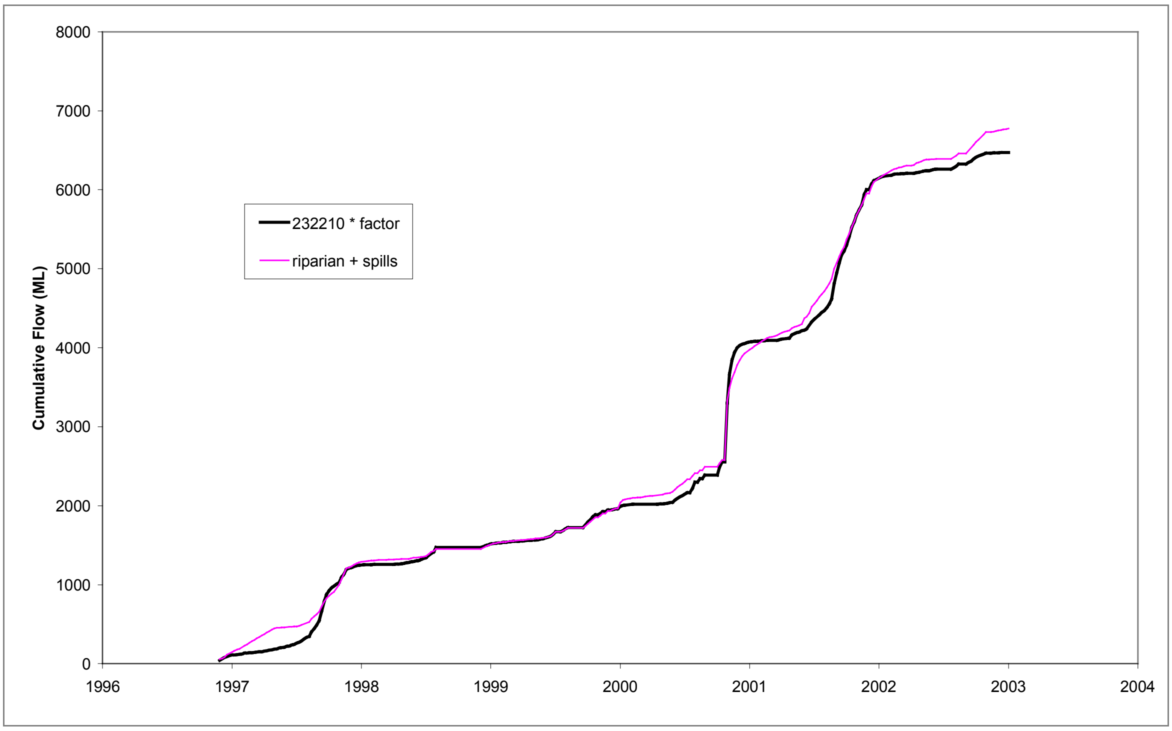
This inflow was calculated by water balance between upstream and downstream gauged data

- **Inflow = 232210 –Moorabool Res riparian release - Moorabool Res spills - whisky ck spills + historic diversions** **(27)**

Some of these inputs needed to be extended to cover the period 1965 to date. Flow at 232210 was predicted as a function of combined riparian releases plus spills, and vice versa.

- **232210 = (riparian+spills)/0.45** **(28)**
- **riparian+spills = (232210) * 0.45** **(29)**

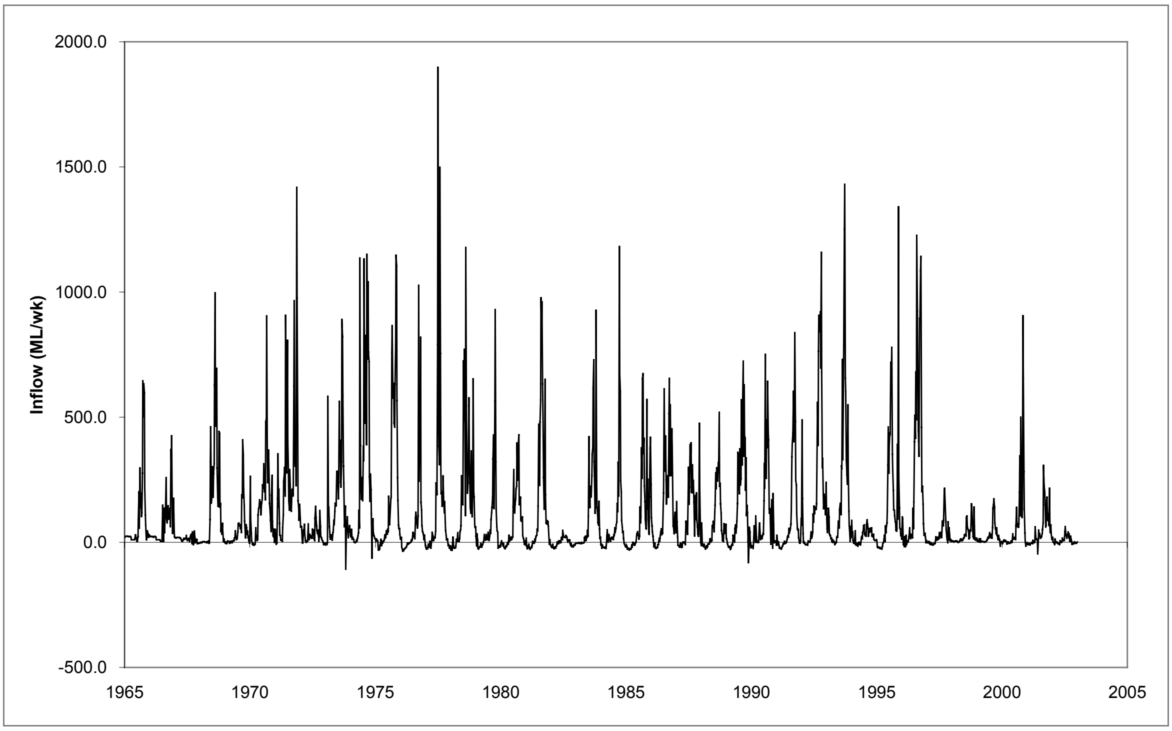
■ **Figure 8-13: Regression to infill and extend 232210**



Moorabool Reservoir spill data was available over the full period or record required. Moorabool riparian releases and Whiskey Creek spills were estimated by disaggregating Rigbys estimates of these series from monthly to weekly.

Estimates of historic D&S and direct irrigator diversions were added back to the flow.

■ **Figure 8-14: Inflow between Moorabool Reservoir and Lal Lal Reservoir**



As can be seen from Figure 8-14, negative inflows regularly result from this calculation, indicating a significant loss (or unaccounted for use such as private right extraction). Therefore a loss function was derived for this reach.

■ **Loss (% of upstream flow) = 0.45 * upstream flow when u/s flow <= 40 ML/wk** **(30)**

Estimated historic losses were then added back to the original inflow calculation.

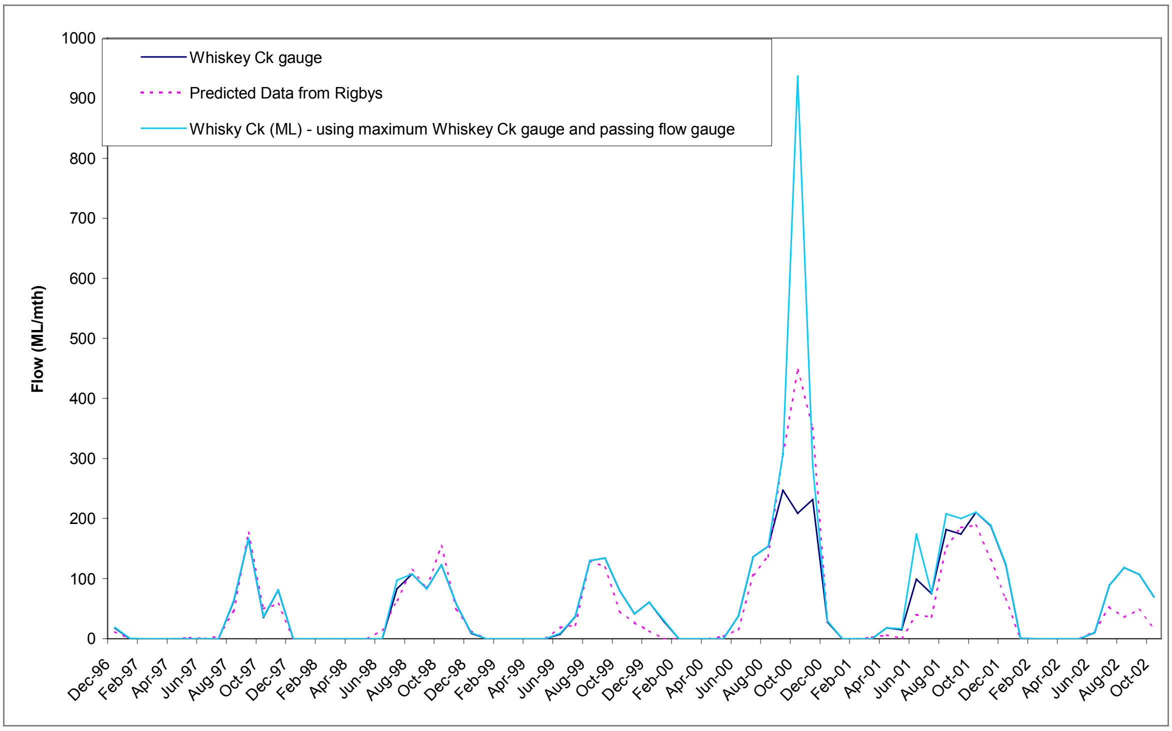
■ **Inflow = 232210 –Moorabool Res riparian release - Moorabool Res spills - whisky ck spills + historic diversions + historic losses** **(31)**

Flows in this catchment are also impacted by farm dams (refer Section 7) and groundwater extractions (refer Section 0). These impacts were also added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

8.6.10 Whiskey Creek above Moorabool Pipeline

Limited gauged data is available for Whiskey Creek both above the CHW offtake and spilling below the offtake. As can be seen from Figure 8-15, spill data sometimes exceeds flow data recorded upstream. Therefore the maximum recorded at these two gauges was adopted. The data series was extended back to 1965 using Rigbys inflow.

- **Figure 8-15: Whiskey Creek Inflow**



- **Monthly Inflow = 0.07 * Rigbys Inflow – 10** **(32)**
- **Weekly Inflow = 0.07 * Rigbys Inflow – 2.3** **(33)**

Flows in this catchment are also impacted by farm dams (refer Section 7) and groundwater extractions (refer Section 0). These impacts were also added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

8.6.11 Tributary inflows to Lal Lal Reservoir

This inflow was calculated by water balance, taking the sum of the downstream gauges, adding back historic diversions and subtracting CHW flood gate spills

- **Inflow = 232213 + 232214 + 232215 – flood gate spills + historic diversions** **(34)**

Flood gate spills were extended by disaggregating Rigbys estimate of spills from monthly to weekly. Significant periods of record were also missing for the gauges 232213, 232214 and 232215.

As part of previous work (SKM, 2000a) total inflow to Lal Lal Reservoir had been extended by fitting the HYDROLOG rainfall-runoff model. Inflow could be estimated using this series where appropriate.

- **Inflow = Total Lal Lal Inflow (HYDROLOG) - 232210 – flood gate spills (35)**

This relationship was used to extend the first calculation prior to the commencement of gauged data.

There are a number of onstream storages in this catchment, with a total licensed volume of 926 ML. The inflow upstream of these storages was calculated by determining the effect these storages were having on flow and then adding this effect back to the calculated inflow. The impact was calculated by running the time series of inflow through the storages, allowing them to be affected by diversions, rainfall and evaporation, and then spilling downstream.

Flows in this catchment are also impacted by farm dams (refer Section 7) and groundwater extractions (refer Section 0). These impacts were also added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

8.6.12 Korweinguboora Reservoir Inflow

It was proposed to estimate the complete time series of inflows to Korweinguboora Reservoir by carrying out a water balance between the change in storage volume and the sum of the releases, net evaporation and spills. However, Barwon Water advised that the recorded spill data was inaccurate and could not be used to accurately estimate inflows to the storage. Subsequently, the inflows to Korweinguboora Reservoir were estimated using a combination of the water balance approach, at times when the reservoir was not spilling, and other methods during periods of spill.

When Neither Storage is Spilling

The water balance computations were based on the following equation:

- **Inflows = $S_e - S_s + R + E$ (36)**

Where:

S_e = Storage volume at the end of the week
S_s = Storage volume at the start of the week
R = Releases from storage
E = Net evaporation from storage (evaporation minus rainfall)

The recorded storage volume and reservoir release data was supplied by Barwon Water. The net evaporation depth from the storage was calculated using rainfall and evaporation data observed at climate station 087045 (Moorabool Reservoir). The surface area at each time step was calculated using the surface area versus storage volume rating table derived in the study of the Moorabool and Barwon Inflows (HydroTechnology, 1995).

Negative inflows, calculated via the water balance approach, were relatively small and were assumed to be the result of inaccuracies associated with the estimation of evaporation and the measurement of storage volumes. All negative inflows were set to zero.

When Korweinguboora only is Spilling

When Korweinguboora is spilling and Bostock is not, the calculated Bostock inflow was split between the two storages by the ratio of catchment area

- **Korweinguboora Inflow = 32/117 * Bostock Inflow (37)**

Sometimes change in storage or net evap + release records at Korweinguboora indicated an inflow greater than that calculated using equation 37. In these cases the maximum value was used. Whenever this substitution was made the corresponding Bostock inflow figure was also adjusted to maintain water balance.

When Bostock and Korweinguboora are Spilling

When both storages were spilling, total flow at Bostock was calculated by water balance with downstream gauges and calculated inflows.

- **Bostock Flow = 232204 – 232211 – est inflow btwn Lal Lal, Bostock and 232204 (38)**

This total flow was then spilt between Korweinguboora and Bostock on the basis of catchment area.

As with the previous case, sometimes change in storage or net evap + release records at Korweinguboora indicated an inflow greater than that calculated using equation 37. In these cases the maximum value was used. Whenever this substitution was made the corresponding Bostock inflow figure was also adjusted to maintain water balance.

Aerial photographs indicate there are few farm dams above Korweinguboora Reservoir. Therefore it was assumed they had no impact on inflow to the storage. Due to the sparse bore distribution and lack of data to determine possible impacts on baseflow, the effect of groundwater extractions was only modelled above Lal Lal Reservoir (refer Section 0).

8.6.13 Bostock Reservoir Inflow

Inflow calculations for Bostock Reservoir were similar to that used for Korweinguboora Reservoir. Again, recorded spill data was inaccurate.

When Neither Storage is Spilling

The water balance computations were based on equation 36.

When Bostock only is Spilling

When Bostock is spilling and Korweinguboora is not, Bostock inflow was calculated using equation 38.

Sometimes change in storage or net evap + release records at Bostock indicated an inflow greater than that calculated using equation 38. In these cases the maximum value was used. Whenever this substitution was made the corresponding Korweinguboora inflow figure was also adjusted to maintain water balance.

When Bostock and Korweinguboora are Spilling

When both storages were spilling, total flow at Bostock was calculated by water balance with downstream gauges and calculated inflows using equation 38.

This total flow was then spilt between Korweinguboora and Bostock on the basis of catchment area.

- **Bostock Inflow = 85/117 * total Bostock Inflow** **(39)**

As with the previous case, sometimes change in storage or net evap + release records at Bostock indicated an inflow greater than that calculated using equation 39. In these cases the maximum value was used. Whenever this substitution was made the corresponding Korweinguboora inflow figure was also adjusted to maintain water balance.

Due to the sparse bore distribution and lack of data to determine possible impacts on baseflow, the effect of groundwater extractions was only modelled above Lal Lal Reservoir (refer Section 0). Flows in this catchment are impacted by farm dams (refer Section 7). These impacts were also added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

8.6.14 Moorabool River inflow between Lal Lal Reservoir, Bostock Reservoir and Morrisons gauge

Inflows to this reach were calculated by water balance. Two different calculations were used.

Bostock not spilling

- **Inflows = 232204 - 232211 –Bostock Passing Flows** **(40)**

Flow at 232211 was infilled and extended by regression against 232210 and 232204. Regressions were carried out using data before Lal Lal Reservoir was in place, and high flows at 232204 (>3000 ML/wk) showed a bias and so were excluded from the regression.

Figure 8-16: Regression between 232211 and 232210

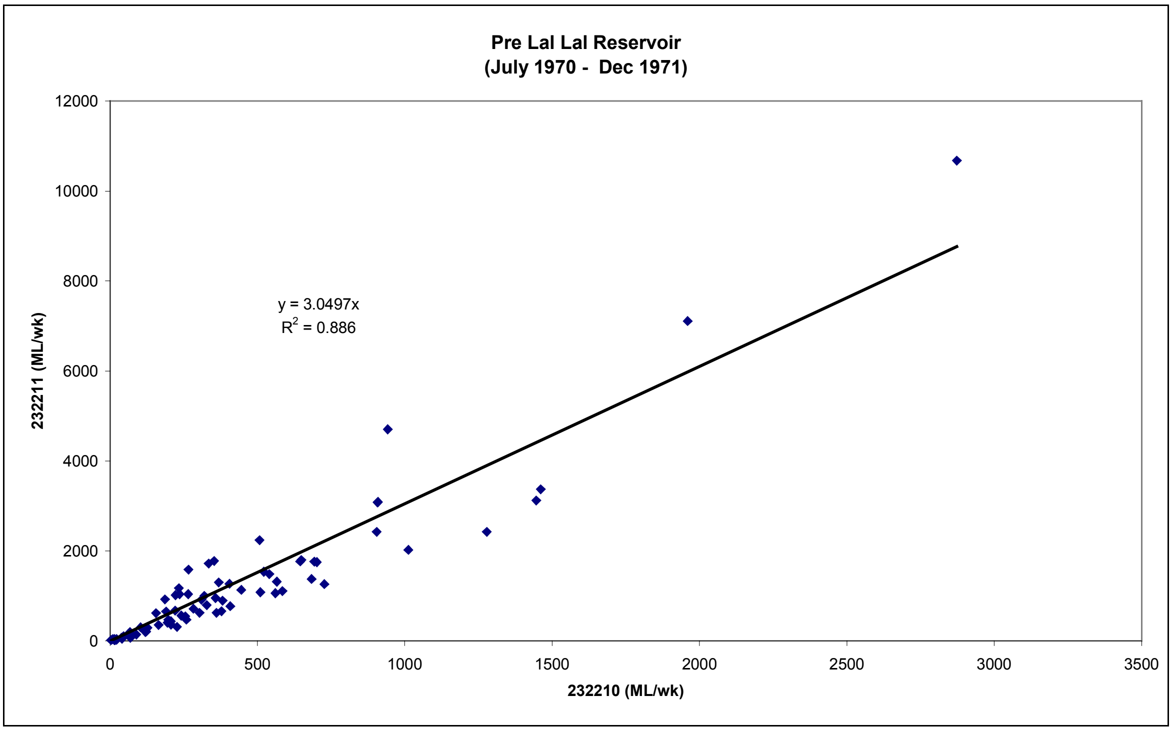
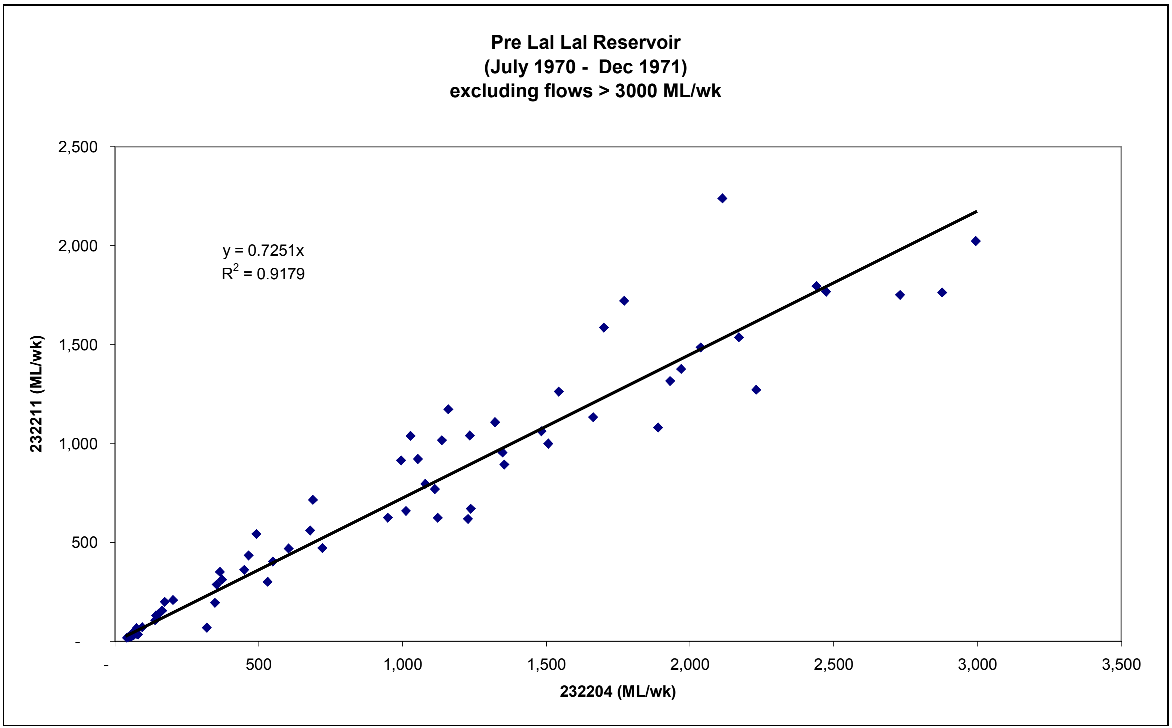


Figure 8-17: Regression between 232211 and 232204

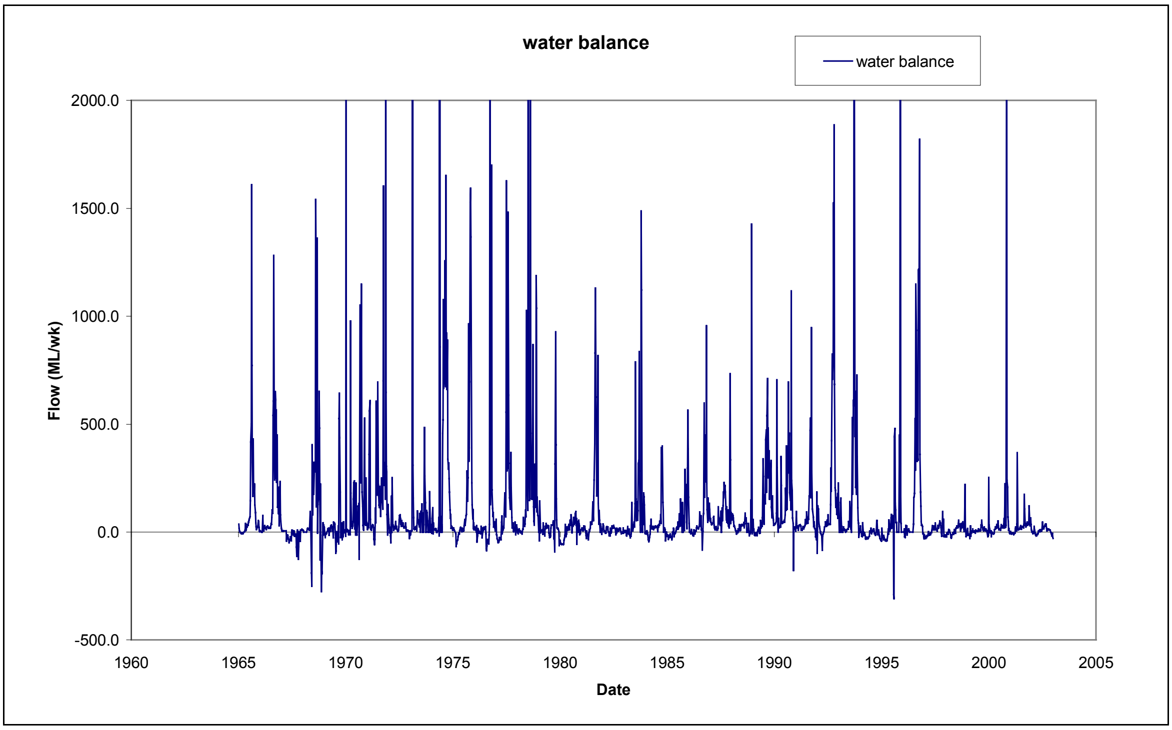


Bostock Spilling:

When Bostock Reservoir was spilling inflow was estimated by transposing inflow estimated for the lower catchment between 232204 and 232202 on the basis of catchment area.

- **Inflows = 172/539 * inflow estimated between 232204 and 232202** **(41)**

Where
172 = area (km²) between Lal Lal Reservoir, Bostock Reservoir and Morrisons gauge
539 = area between 232204 and 232202



Some negative inflows resulted from this calculation, indicating a loss (or unaccounted for use such as private right extraction) in this reach. A loss prediction equation was derived as a function of upstream flow.

- **Loss (% of upstream flow) = 0.15 * upstream flow when u/s flow <= 600 ML/wk** **(42)**

Estimated historic losses were then added back to the original inflow calculation.

Due to the sparse bore distribution and lack of data to determine possible impacts on baseflow, the effect of groundwater extractions was only modelled above Lal Lal Reservoir (refer Section 0). Flows in this catchment are impacted by farm dams (refer Section 7). These impacts were also added back to the flow to get the best estimate of "natural" flow for input to the REALM model.

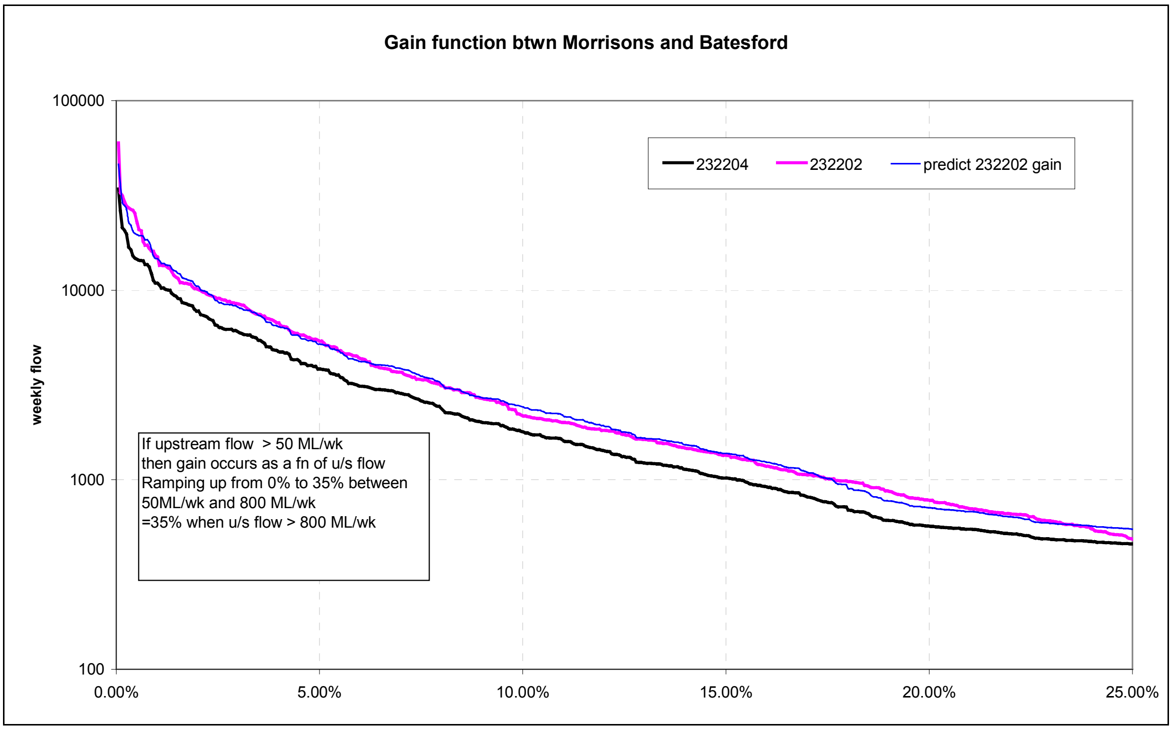
8.6.15 Moorabool River inflow between Morrisons gauge and She Oaks Weir, and between She Oaks Weir and Batesford

These two inflows were calculated as a single flow series and then spilt for input to REALM.

A "gain function" was derived by comparing recorded flows at 232204 with recorded flows at 232202. A good match could be obtained using the following relationship

- **if upstream flow at 232204 < 50 ML/wk**
  Gain = 0
- **if upstream flow at 232204 is between 50 and 800 ML/wk**
  Gain = 0 to 35% of upstream flow increasing linearly
- **if upstream flow at 232204 > 800 ML/wk**
  Gain = 35% of upstream flow (43)

- **Figure 8-18: Predicting gain between 232204 and 232202**



Due to the sparse bore distribution and lack of data to determine possible impacts on baseflow, the effect of groundwater extractions was only modelled above Lal Lal Reservoir (refer Section 0). Flows in this catchment are impacted by farm dams (refer Section 7). These impacts were also added back to the flow to get the best estimate of "natural" flow.

For input to the model, this inflow was split 50:50 upstream and downstream of She Oaks Weir.

As the system of weirs and extractions in this reach is complex, the loss (or unaccounted for use such as private right extraction) between 232204 and 232202 was determined using the REALM model. Refer section 8.8 for details.

- **Mid December (week 51) to end the of March (week 13)**
  loss (% flow u/s 232202) = (4wk net evap)/(max 4wk net evap) * flow u/s 232202*100
- **Start of April to (week 14) Mid December (week 12)**
  loss = 0 **(44)**

Where 4wk net evap = sum 4wk Durdiwarrah evap - sum 4wk Durdiwarrah rainfall.

8.6.16 Inflow to Stoney Creek Reservoirs

The natural inflows to the Stony Creek Reservoirs were estimated by undertaking a daily water balance using estimates of recorded inflows to the storage and diversions from the eastern branch of the Moorabool River. The water balance equation is described below.

- **Inflows = US1 + US2 – BstkCh – BallCh** **(45)**

Where:

US1 = Recorded inflows to Upper Stony Creek Reservoir No.1
US2 = Recorded inflows to Upper Stony Creek Reservoir No.2
BstkCh = Recorded releases to the Bostock Channel
BallCh = Recorded diversions to the Ballan Channel (via Bolwarra Weir)

The recorded inflow data to the Upper Stony Creek Reservoirs was not available for the period prior to June 1985. The inflow series estimated using the water balance approach could therefore only be derived for the period June 1985 to June 1998.

To derive an inflow series for the full period of interest, commencing in 1965, a HYDROLOG rainfall-runoff model was calibrated against the estimated water balance inflows.

8.6.17 Summary of Inflows

The mean annual flow of all inflows to the model is summarised in Table 8-17.

Table 8-17: Summary of Model Inflows

Inflow	Mean Annual Flow (ML)
Moorabool River	
Korweinguboora Reservoir Inflow	5,099
Bostock Reservoir Inflow	12,101
Moorabool Reservoir Inflow	7,403
West Moorabool River between Moorabool Reservoir and Lal Lal Reservoir	7,067
Whiskey Creek above Moorabool Pipeline	1,827
Unregulated tributaries above Moorabool Channel	6,754
Tributary inflows to Lal Lal Reservoir	17,337
Wilsons Reservoir Inflow	1,774
Beales Reservoir Inflow	735
Moorabool River inflow between Lal Lal Reservoir, Bostock Reservoir and Morrisons	7,806
Moorabool River inflow between Morrisons gauge and She Oaks Weir	5,797
Moorabool River inflow between She Oaks Weir and Batesford gauge	7,125
Total	**80,825**
Leigh River Catchment	
Giles Ck	2,562
Leigh Ck	961
Clarkes Ck	1,337
Fellmongers Ck	783
Total	**5,643**
Stoney Ck Catchment	
Stoney Creek	476
Total	**476**
SYSTEM TOTAL	**86,944**

8.7 Changes to the REALM Model

Changes to the existing REALM model were mostly to add detail. Groundwater and farm dam demands were included. The full CHW system above Lal Lal Reservoir was added to the model. Also, the eight weirs below She Oaks were added. Actual storages were included to represent onstream private diverters.

Following discussion with SRW and CCMA staff it was decided to assume that all onstream storages including the weirs downstream of She Oaks Weir pass summer flows. It is understood that in practice this is not the case for every single storage, however it was felt that most diverters did comply with this rule.

Full details of the system can be obtained from the system listing included in Appendix F.

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- **Table 8-18: Weirs Below She Oaks**

Weir	Capacity (ML)
Spillers Weir	25
Caprons weir	37
Mattheys Weir	36
Maddens Weir	14
Buchters Weir	23
Hills Weir	21
Mitchells Weir	16
Madden-Joaquin Weir	40

8.7.1 Operating Rules

All Bulk Entitlement passing flows were included in the model (refer Section 2.3.2).

Specific operating rules (as defined in the Ballarat Drought Response Plan) were also included for the CHW system to dictate whether White Swan Reservoir or Lal Lal Reservoir should be used to supply Ballarat. These rules were

- **Table 8-19: CHW Storage Operating Rules to Supply Ballarat**

Volume in Store (all CHW storages excluding Lal Lal)	Take from White Swan Reservoir	Take from Lal Lal Reservoir
> 8,218 ML	80%	20%
Between 6,545 ML and 8,218 ML	50%	50%
Between 5,471 ML and 6,545 ML	0%	100%
Less than 5,471 ML	Reserve volume	

Rules adopted for the Barwon Water system were to keep Stoney Creek Reservoirs as full as possible and drawdown Korweinguboora Reservoir as first preference.

8.7.2 Restriction Rules

Restriction rules applied are defined in Section 2.3.3.

Urban demand can be split into a restrictable and a non-restrictable component. The restrictable demand is defined as the total demand minus water required for in-house use. For Ballarat, in-house use was assumed to be 208 ML/wk. The model requires values for the assumed reduction in restrictable urban demand due to restrictions. The values adopted was as used for the Ballarat Drought Response Plan.

■ **Table 8-20: Ballarat Reduction in Demand due to Restrictions**

Restriction Level	Reduction in Restrictable Demand
1	50%
2	80%
3	95%
4	100%

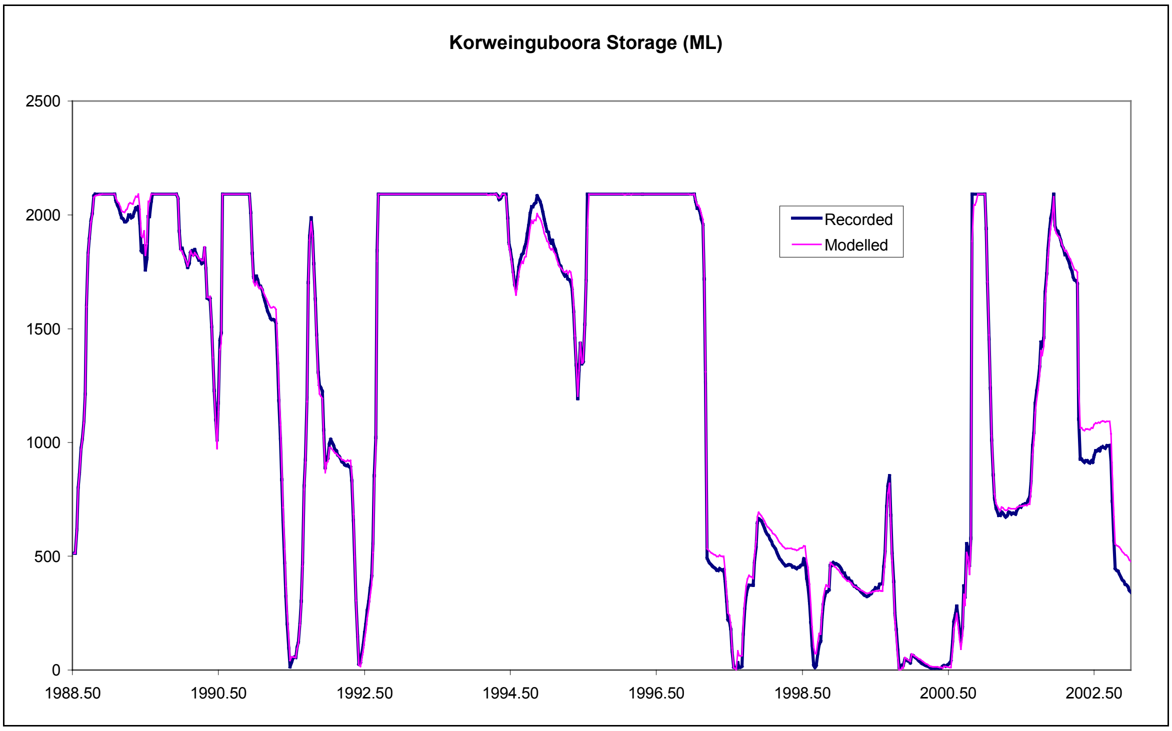
8.8 Calibration

The aim of calibration is to verify model setup and inflows. The REALM model was calibrated in sections using the longest period of historic record available for that section. Storage traces or recorded flow data were used to verify model inputs.

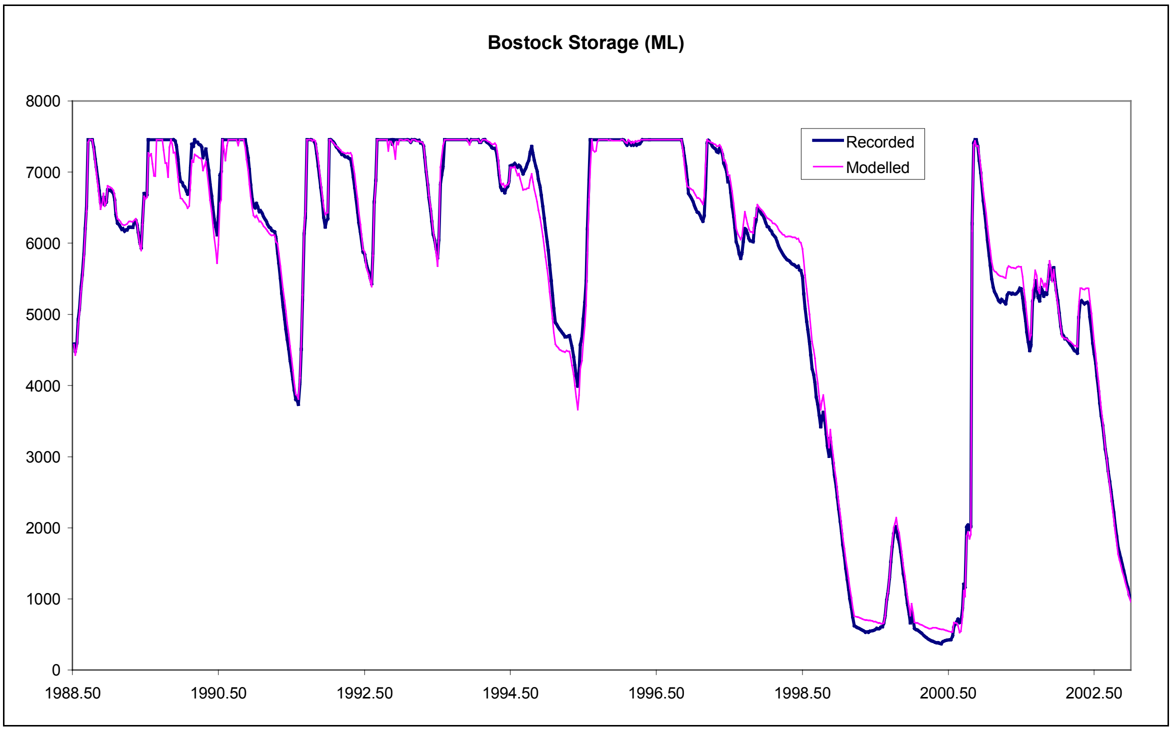
8.8.1 East Moorabool River Calibration

Historic extractions and releases at Bolwarra Weir and Bostock Reservoir were input to the model to carry out this calibration. Figure 8-19 and Figure 8-20 show the degree of calibration for Korweinguboora and Bostock reservoirs.

■ **Figure 8-19: Korweinguboora Reservoir calibration**



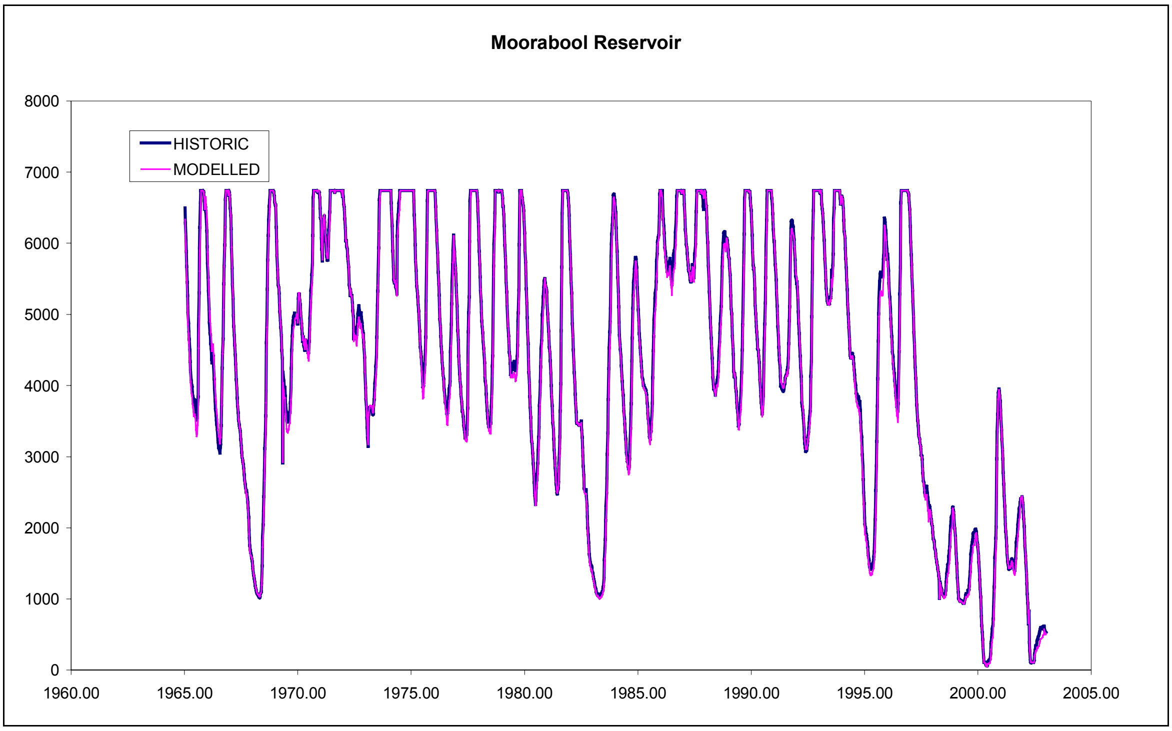
▪ **Figure 8-20: Bostock Reservoir calibration**



8.8.2 Moorabool Reservoir Calibration

Historic releases from Moorabool Reservoir were used to carry out this calibration. Figure 8-21 shows the calibration at Moorabool Reservoir.

■ **Figure 8-21: Moorabool Reservoir calibration**

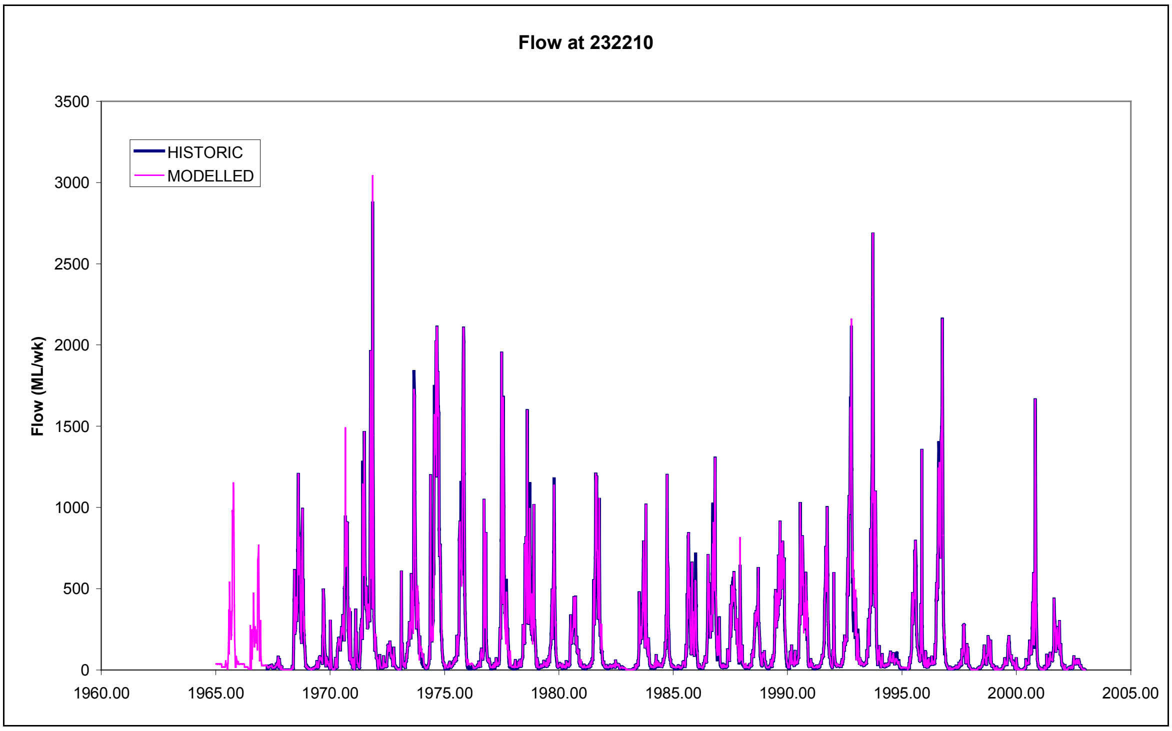


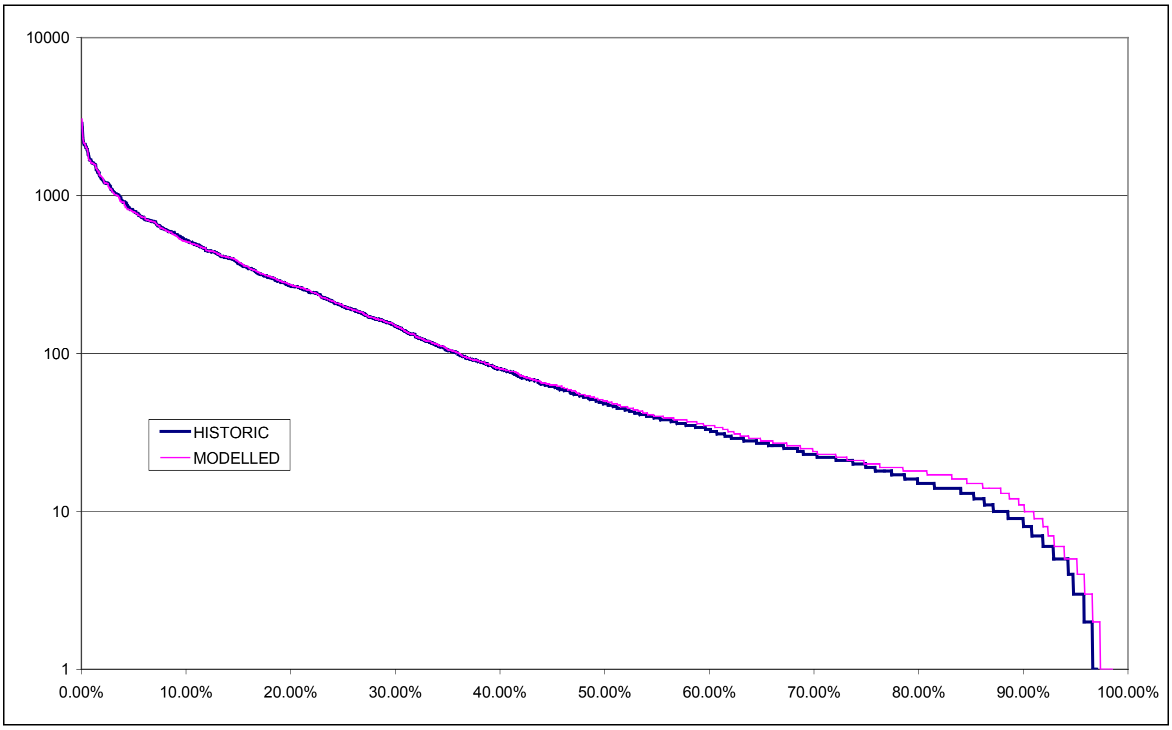
8.8.3 Inflow to Lal Lal Calibration

West Moorabool River above Lal Lal (232210)

An estimate of historic releases from Moorabool Reservoir to West Moorabool River and historic spills at Whiskey Creek were used for this calibration, as shown in Figure 8-22.

- **Figure 8-22: West Moorabool River at Lal Lal (232210) Calibration**

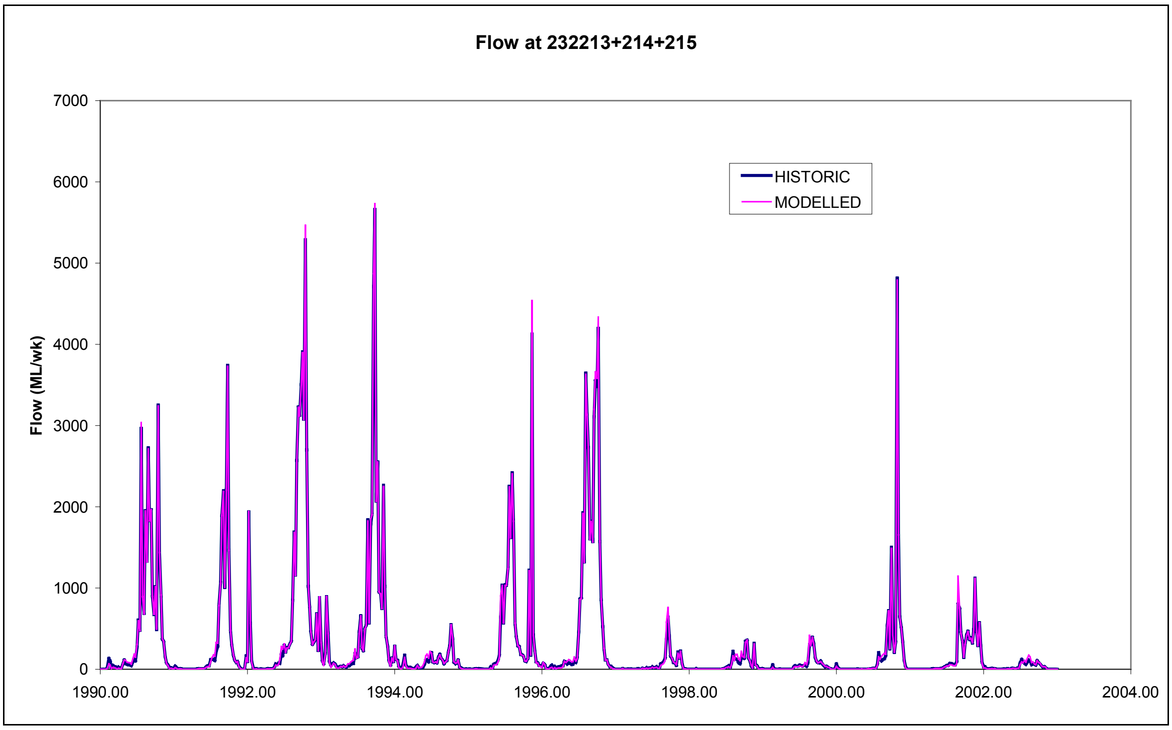


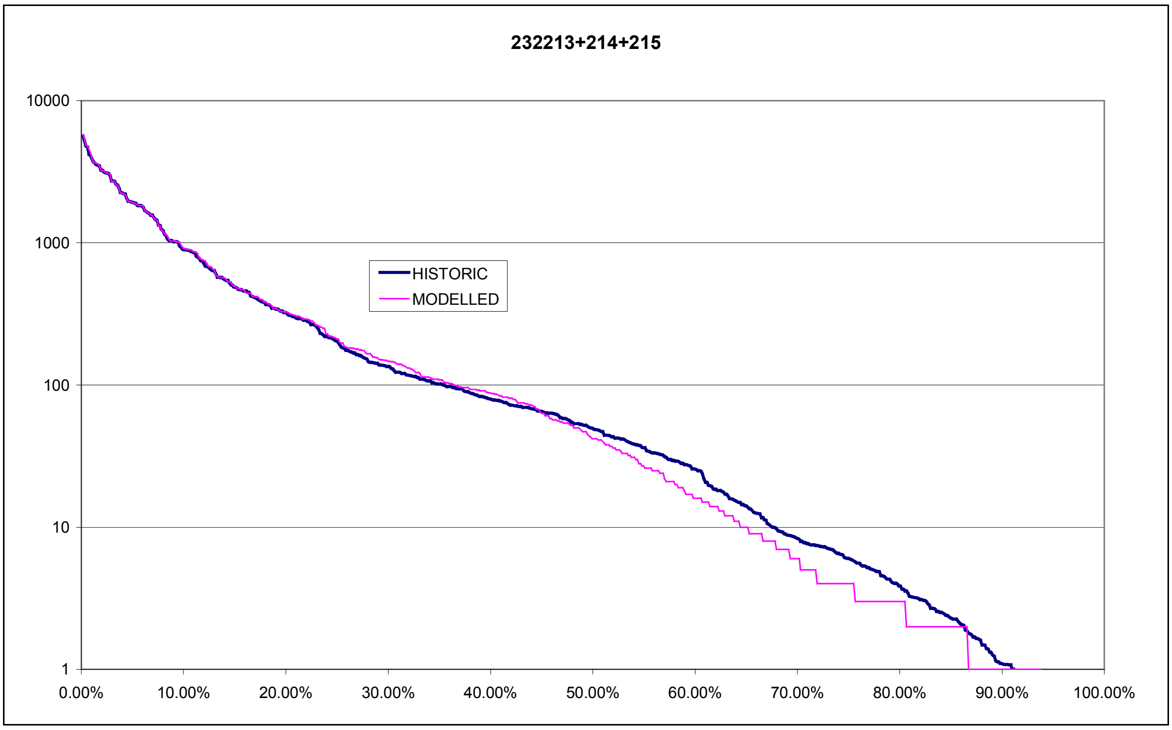


Lal Lal tributary inflows (232213+232214+232215)

An estimate of historic flood gate spills was used for this calibration. Slight mismatches in low flows (Figure 8-23) are most likely due to the simplified representation in the model of onstream storages in this reach.

- **Figure 8-23: Lal Lal Tributaries (232213+232214+232215) Calibration**

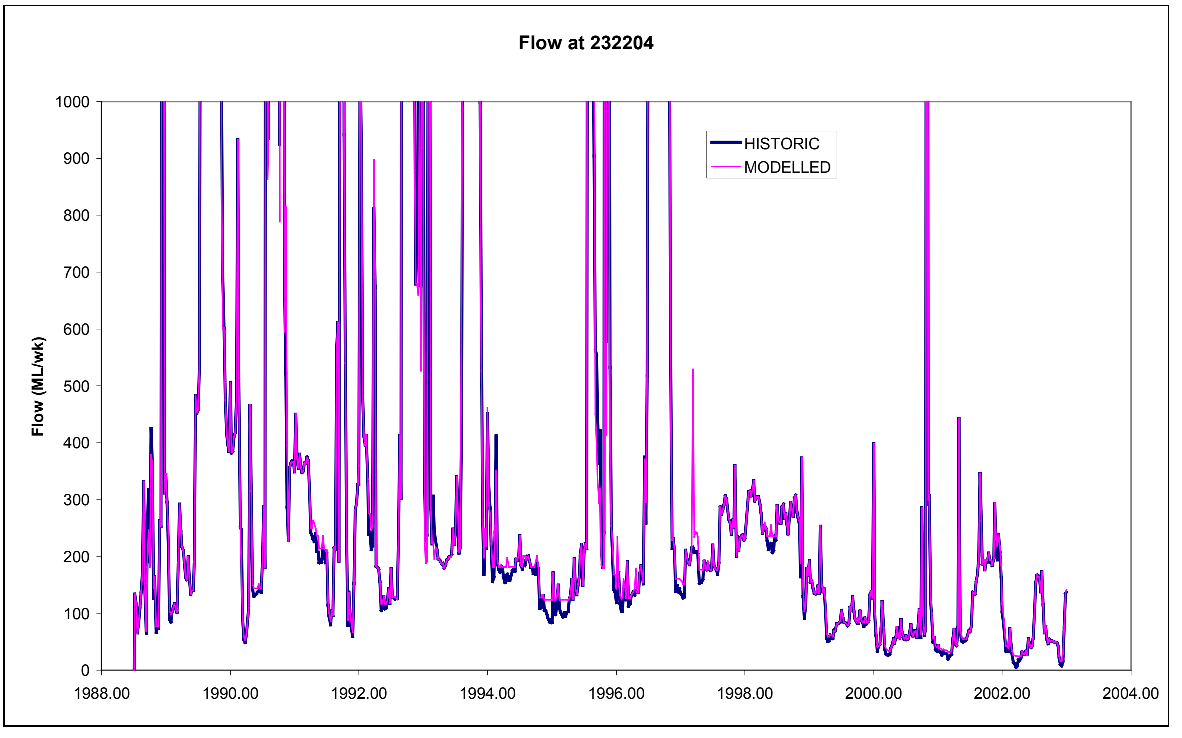


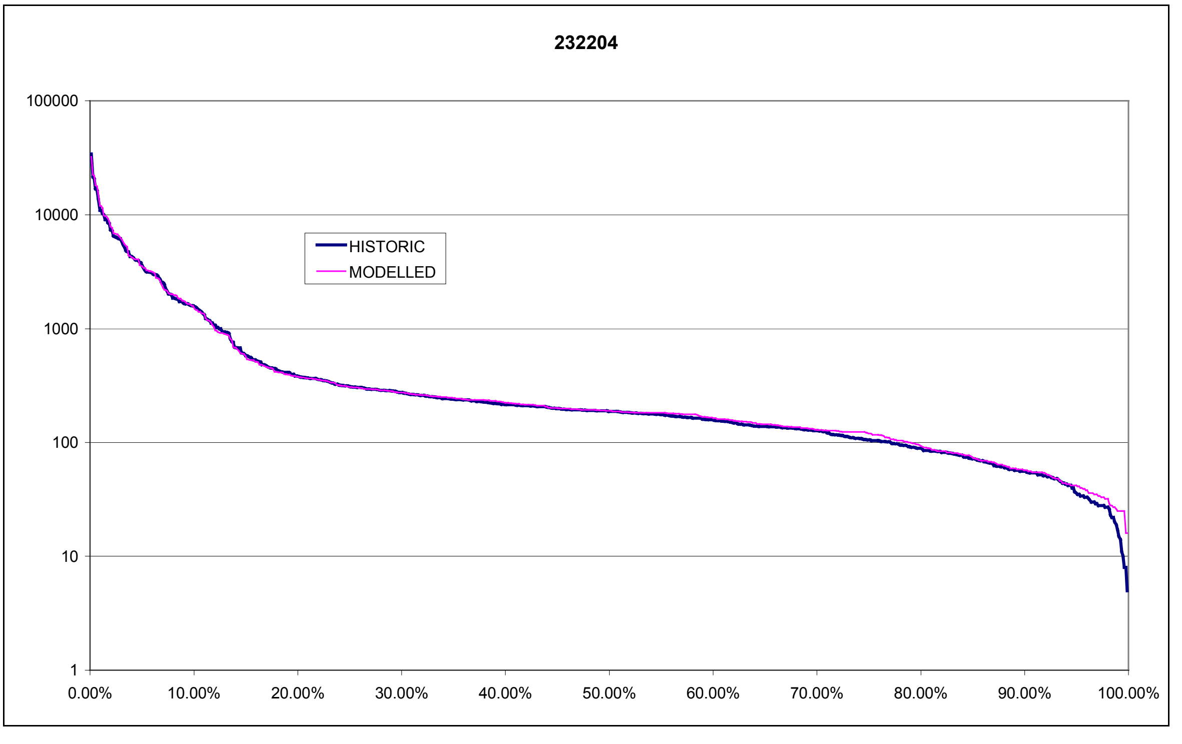


8.8.4 Moorabool River at Morrisons Calibration

Historic flow at 232211 and historic pumping at Meredith was used for this calibration shown in Figure 8-24.

▪ Figure 8-24: Moorabool River at Morrisons (232204) Calibration

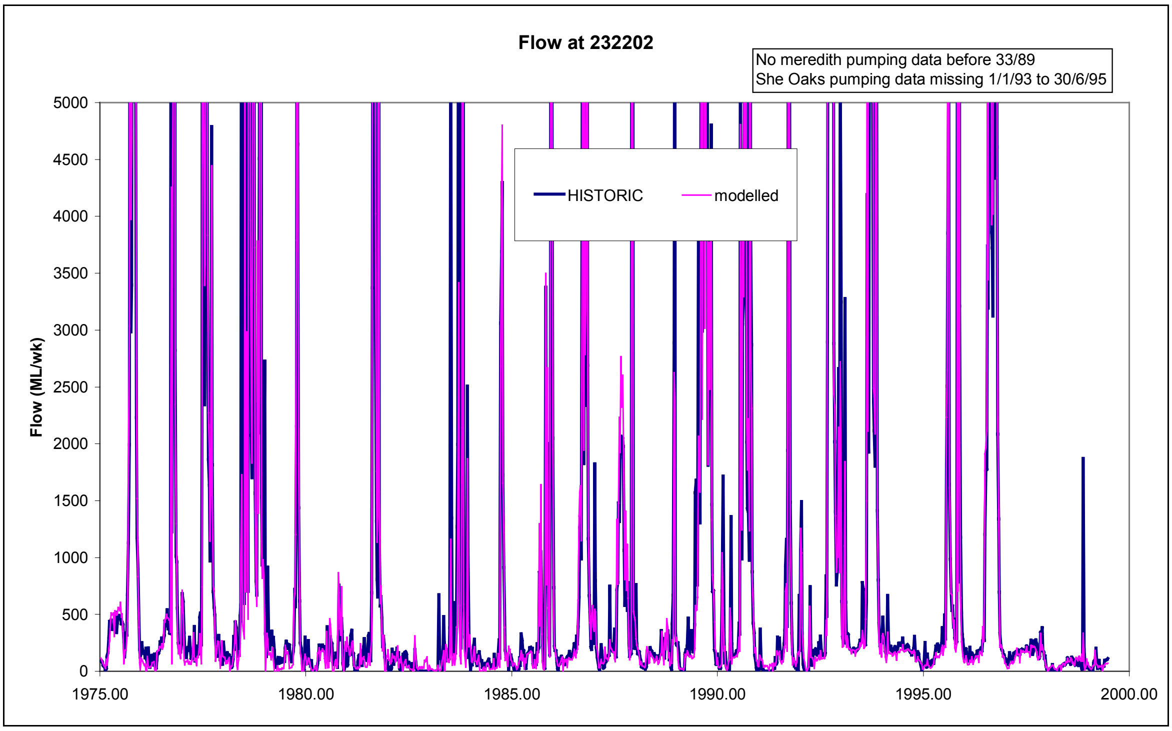


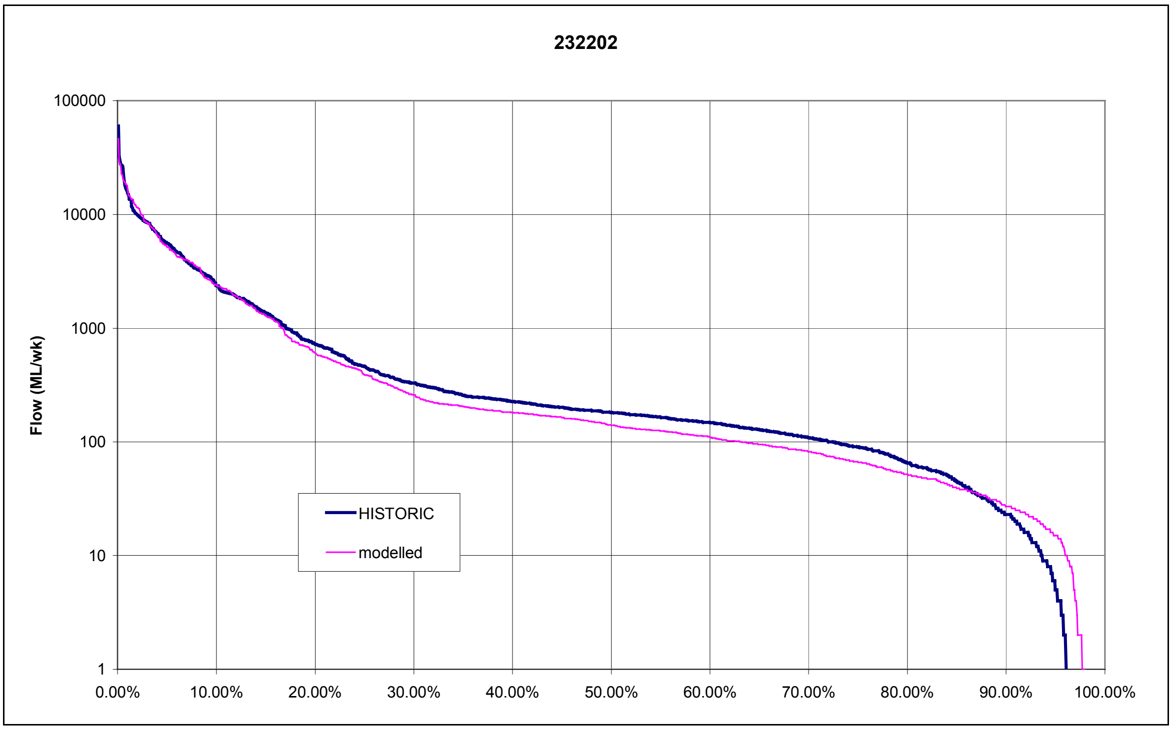


8.8.5 Moorabool River at Batesford Calibration

Historic flow at 232210 and historic pumping at Meredith and She Oaks was used for this calibration. As can be seen from Figure 8-25, there is a general underestimate of flows below 1000 ML/wk. A better fit could be obtained by altering the loss function, however the adopted fit better reproduced flows in drought times (1982/83 and recent years).

▪ Figure 8-25: Moorabool River at Batesford (232202) Calibration





8.9 The Base Case Model

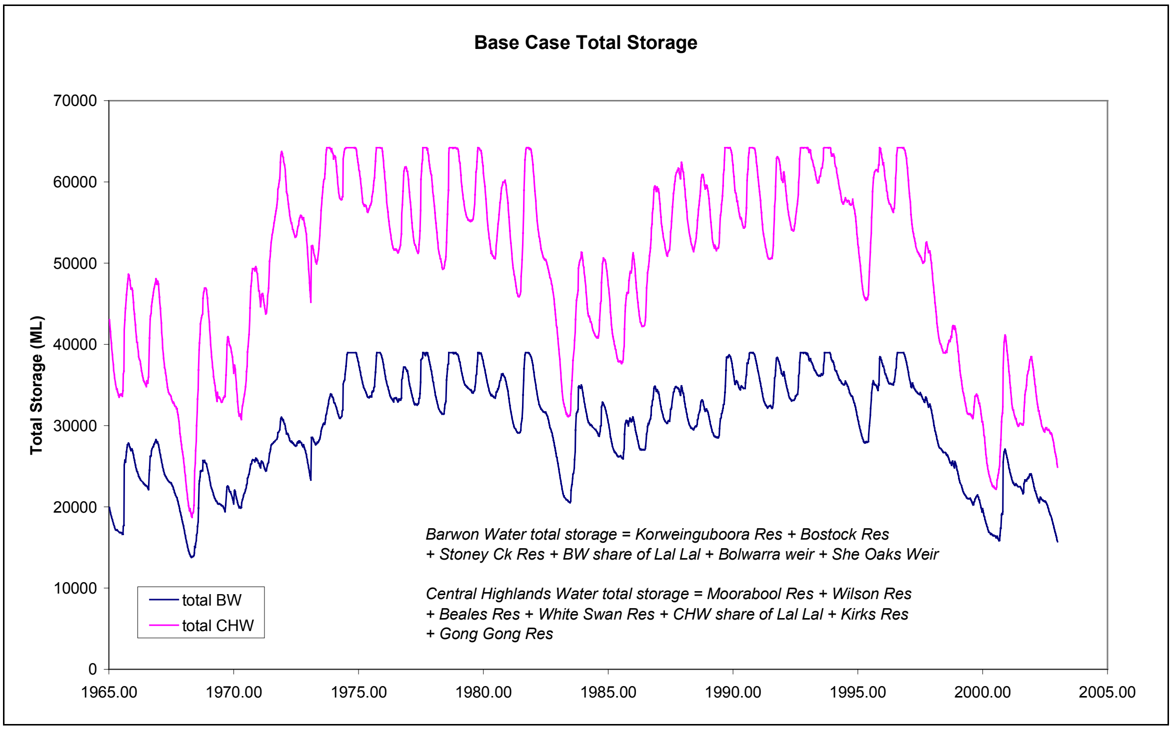
To carry out the base case run demands at current level of development and all current operating rules were input. Key results are summarised below.

- **Table 8-21: Base Case Demands**

	Average Annual Unrestricted Demand (ML)	Average Annual Restricted Demand (ML)	Average Annual Supplied Demand (ML)	Average Annual Shortfall (ML)
Barwon Water	7,637	7,637	7,637	
Central Highlands Water	16,807	16,619	16,619	
PDs	2,228	1,242	1,168	73
Groundwater	1,681*	1,681*	1,248*	
Farm dams	12,425	12,425	12,262	
TOTAL	40,777	39,603	38,934	73

* estimated current impact on surface water

- **Figure 8-26: Base Case Total Storage**



The effect of demands, evap, losses, storage, etc on flows in the river can be shown by calculating at the difference between the amount of water that flows into the river and what flows out the bottom, allowing for the change in the amount of stored water over the whole run. This calculation is shown in Table 8-22, and graphically in Figure 8-27.

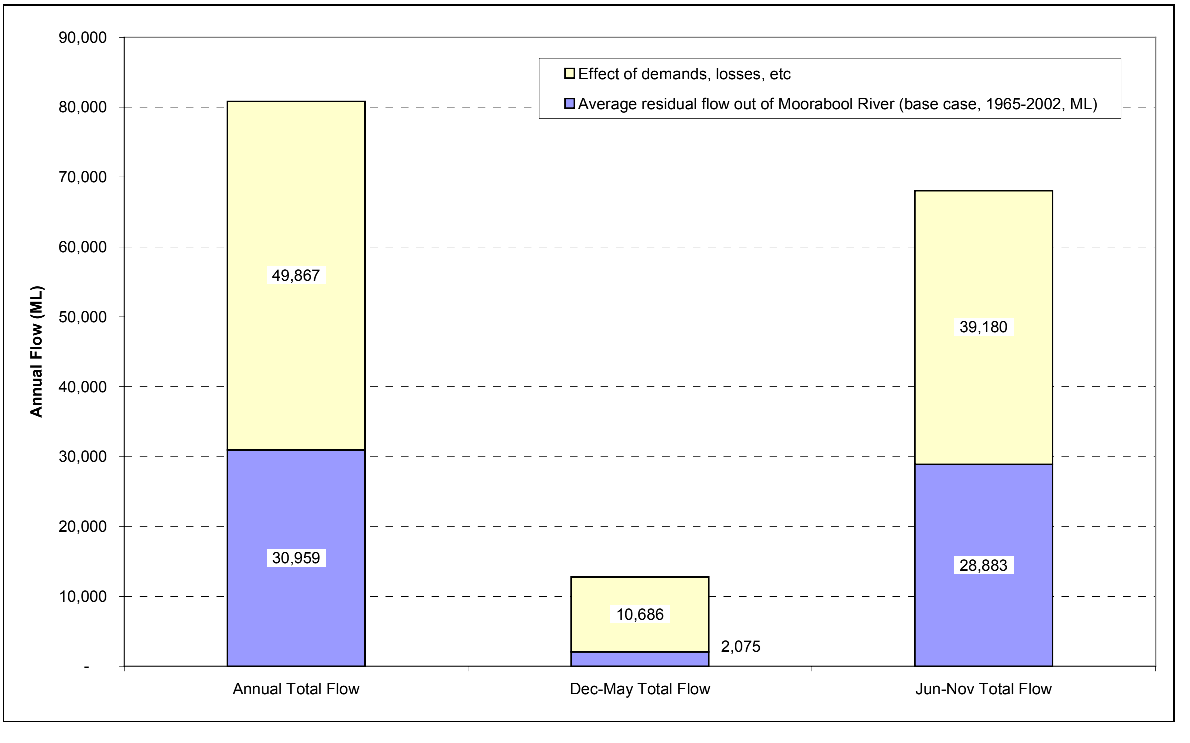
Water that flows out the bottom of the system is made up of passing flow releases and unregulated water, that is water that cannot be stored because it either flowed into the river downstream of a storage, or was spilled from full storages.

The results shown here are averages over the whole model run. Values very considerably from year to year, as shown in Figure 8-28. The lowest inflow year occurs in 1982/83, with inflow of 14,129 ML. Residual flow in that year was 2,975 ML. The lowest residual flow year was 1999/2000, with a residual flow of 1,808 ML. Inflow in that year was 21,759 ML.

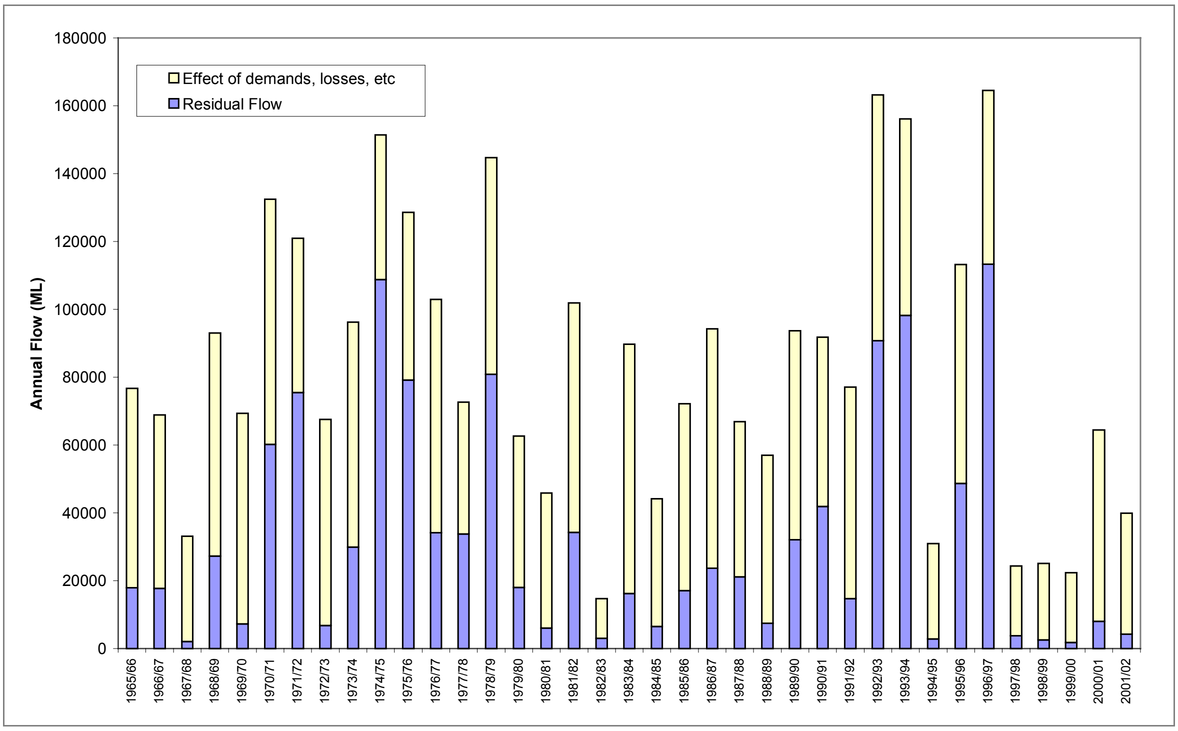
- **Table 8-22: Calculation of Effect of Demands, Losses, Evap, Storage, etc**

No	Description	Average Annual (ML)	Average Dec-May (ML)	Average Jun-Nov (ML)
(1)	Total inflow Moorabool River (base case, 1965-2002, ML)	80,825	12,761	68,063
(2)	Flow out the bottom of the system (base case, 1965-2002, ML)	31,573	2,383	29,191
(3)	Change in storage over whole run (base case, ML)	-23,368		
(4)	Change in storage per year (base case, ML) = **(3)**/38	-615	-307	-307
(5)	Flow plus change in storage (Residual flow, ML) = **(2)+(4)**	30,959	2,075	28,883
(6)	Effect of demands, losses, evap, storage, etc = **(1)–(5)**	49,867	10,686	39,180

- **Figure 8-27: Base Case Residual Flows**



■ **Figure 8-28: Base Case Residual Flows Each Year**



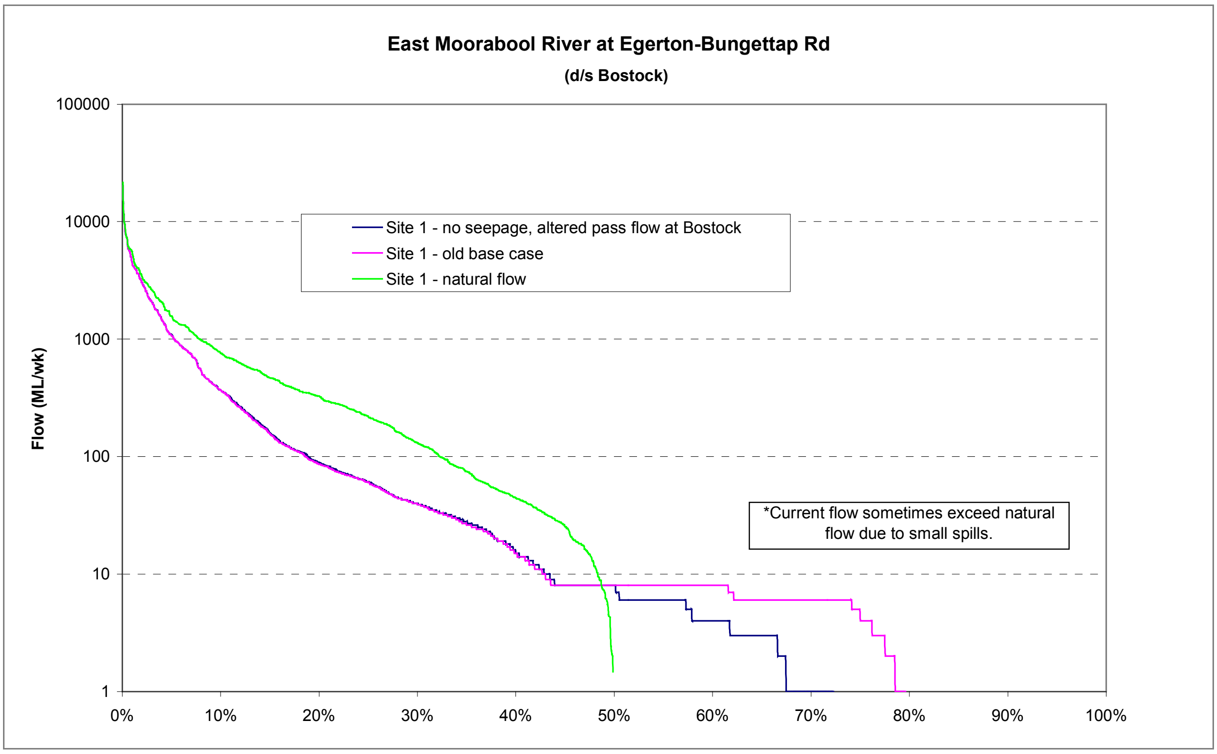
8.10 The Revised Base Case

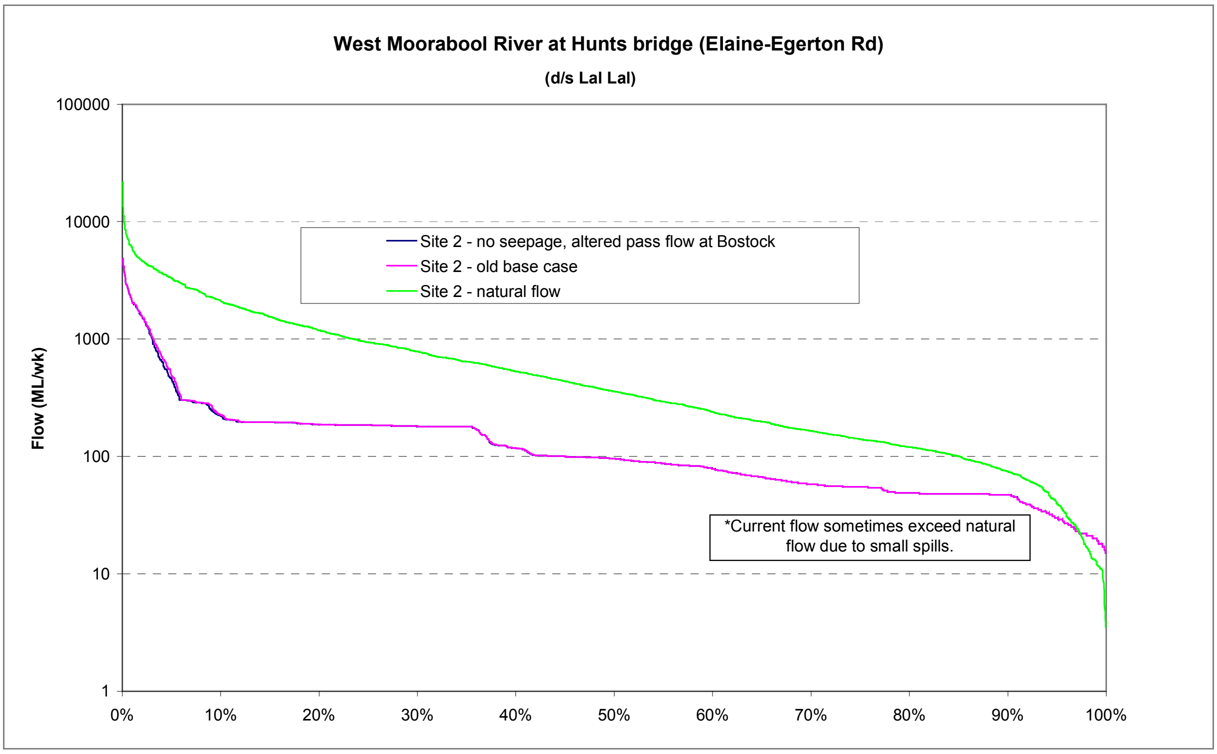
Subsequent to the release of the Stage A Report, a decision was made by DSE to alter the modelled passing flow rule at Bostock so that transfers from Korweinguboora were not included in the Bostock inflow for the purposes of determining the passing flow requirement. In addition, on advice from CHW, seepage data was excluded from the calculation of the UNREG TRIB inflow above Moorabool Channel. This model became the revised base case and was used as the basis for the models used to test scenarios. As shown in the following plots, there was little difference between the old and new base cases, and so base case results presented in earlier sections of this report have not been replaced with the revised base case results.

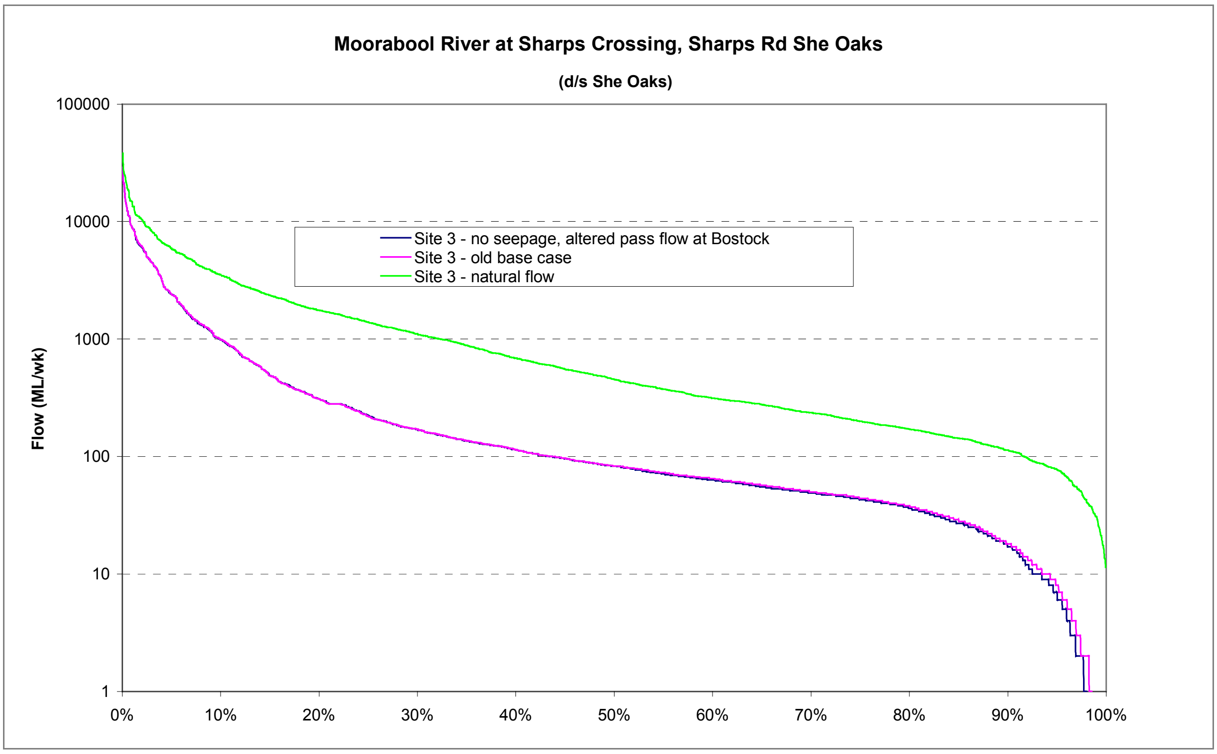
For site 1 (downstream of Bostock) current flows are reduced in the new base case but are still greater than the natural flows at the extreme end of the curve. This is due to small spills occurring when there is zero natural inflow. The same thing happens to a much smaller degree at site 2 downstream of Lal Lal.

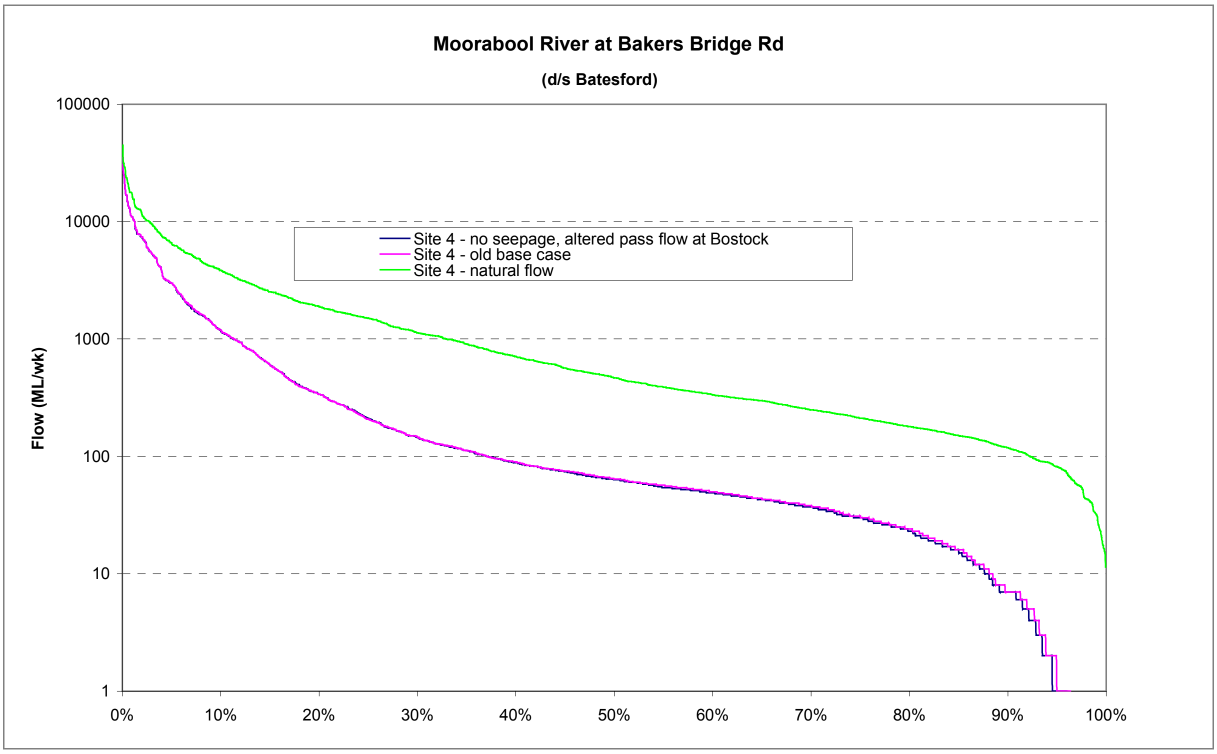
The natural flows at site 5 (upstream of Lal Lal) show a "step" in the flow duration curve. This is due to the loss function in the upstream reach only applying to flows < 20 ML/wk. This step is smoothed out when flows are converted to daily timestep by method of fragments.

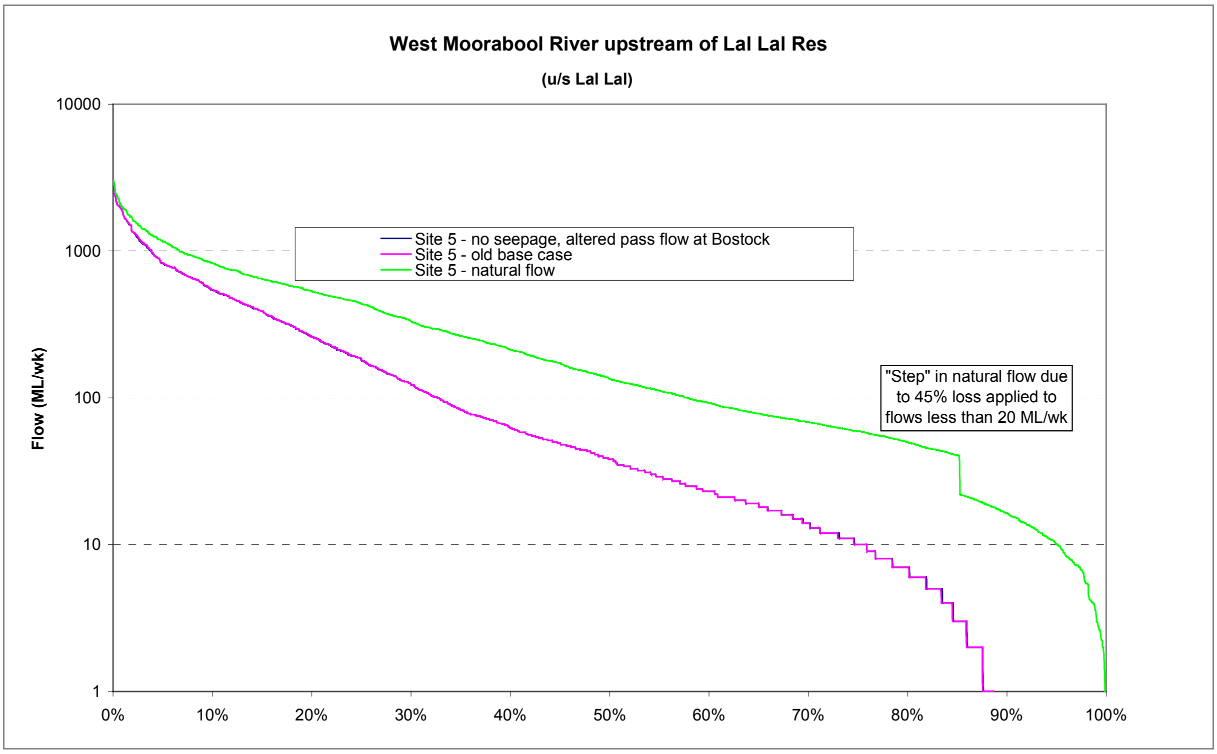
▪ Figure 8-29: Comparison between Old and Revised Base Cases






Moorabool River at Sharps Crossing, Sharps Rd She Oaks
(d/s She Oaks)
Site 3 - no seepage, altered pass flow at Bostock
Site 3 - old base case
Site 3 - natural flow
Flow (ML/wk)
100000
10000
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Moorabool River at Bakers Bridge Rd
(d/s Batesford)
Site 4 - no seepage, altered pass flow at Bostock
Site 4 - old base case
Site 4 - natural flow
Flow (ML/wk)
100000
10000
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%



8.11 Results with Urban Demands Increased to BE Volume

As part of the Sustainable Diversion Limits study currently being undertaken by SKM, the REALM model was run with urban demands increased to Bulk Entitlement (i.e. maximum usage) volume. To do this, demands were factored up such that the maximum extracted in any one year over the whole run was equal to the BE volume.

The difference in system behaviour compared to the revised base case is illustrated in Figure 8-30. Higher urban demands mean that total storage at the end of the BE run is 21,900 ML less than the revised base case, an average reduction of 580 ML/yr. The average annual flow in Moorabool River downstream of Batesford (Figure 8-31) reduces 15% from 31,700 ML/yr to 26,200 ML/yr. The average annual supplied demand increases from 25,500 ML to 34,900 ML.

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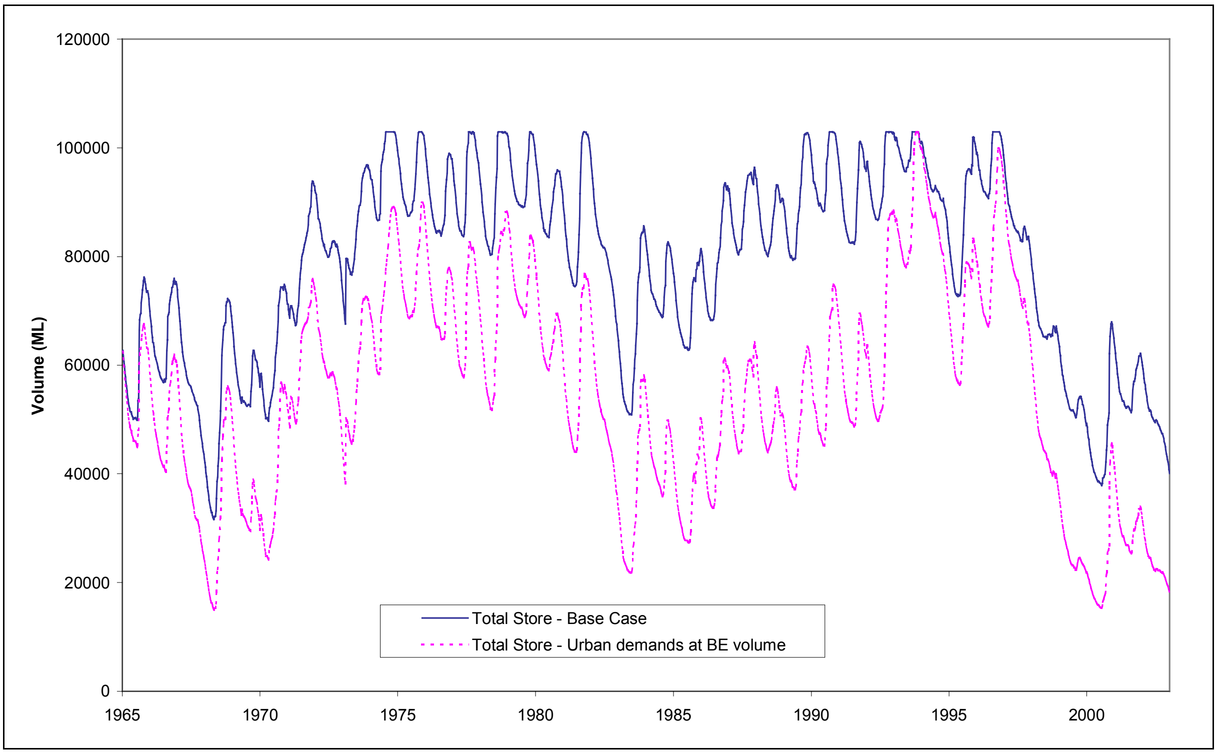
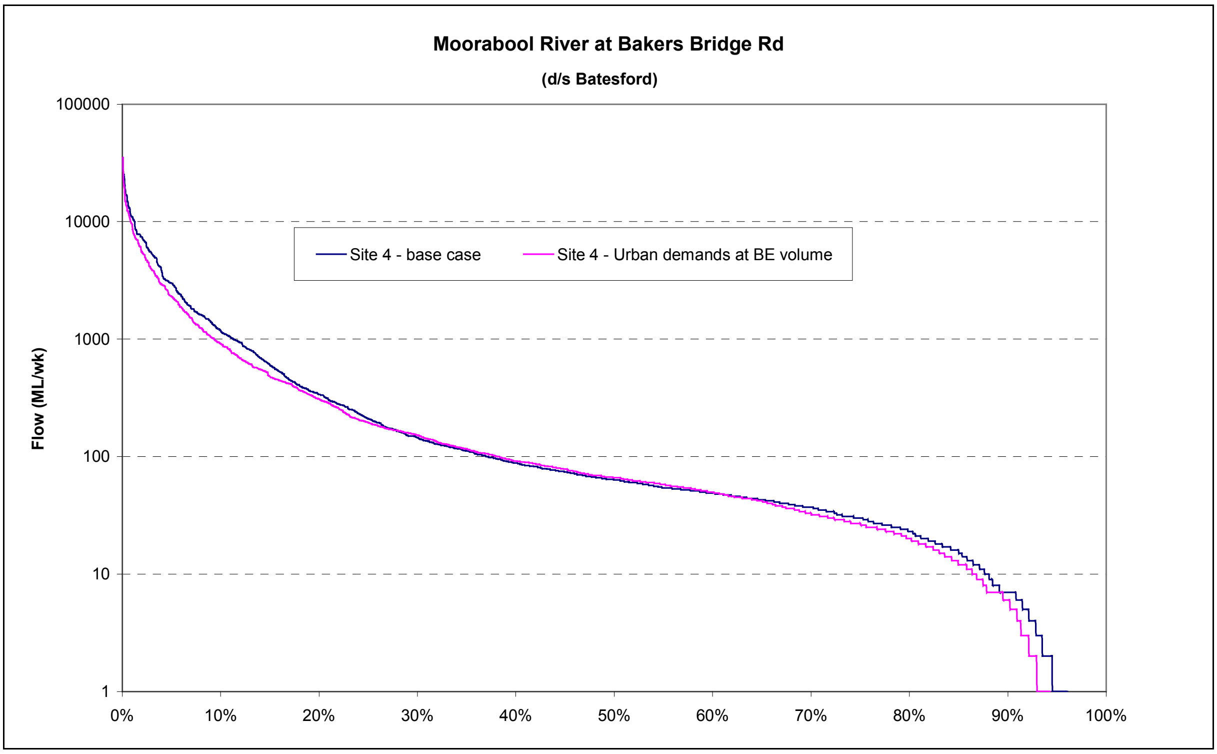
■ Figure 8-30: Storage Behaviour with Urban Demands at BE volume



■ Figure 8-31: System Outflow with Urban demands at BE Volume



9. Assess current and natural flows at key locations

9.1 Overview

To assist with the determination of environmental flows, the base case REALM model was used to determine current and natural flows at the compliance points shown in Table 9-1. Flows were also estimated under the climate change scenario discussed in Section 5.

Natural flows were estimated without any storages, diversions, groundwater diversions or catchment farm dams. Current flows were those at the current level of water use (not at licensed volume).

- **Table 9-1: Compliance Points**

Compliance Point	Description	Extraction Point in REALM Model (ARC NAME/S)
Site 1	East Moorabool River at Egerton-Bungettap Road	Below Bostock Reservoir (BOSTOCK TO CONF)
Site 2	West Moorabool River at Hunts Bridge (Elaine-Egerton Road)	Below Lal Lal Reservoir (LAL LAL TO CONF)
Site 3	Moorabool River at Sharps Crossing, Sharps Rd She Oaks (downstream of She Oaks Weir)	Below She Oaks Weir (SHE OAKS SPILLS + SHE OAKS PASS FLOW)
Site 4	Moorabool River at Bakers Bridge Rd	Downstream of Batesford (D/S BATESFORD)

9.2 Disaggregation of Weekly to Daily Flows

For the adequate assessment of environmental passing flows, daily streamflow time series are required, however the REALM model operates on a weekly time step. Model outputs were therefore adjusted by summing to a monthly timestep and then disaggregating to daily using the modified method of fragments.

The method of fragments is a technique which disaggregates monthly flows by the pattern of gauged daily streamflows observed under current or natural conditions. This pattern is selected from daily flow data which sums to a similar monthly total from the same part of the year as the monthly flow being disaggregated. The modified technique includes a condition placed on the data to achieve continuity of the flow hydrograph. Continuity is critical for successful environmental flow determination. This technique has previously been applied to estimate current and natural flows in the Thomson River Catchment and has been reviewed and approved by the Department of Sustainability and Environment (DSE).

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9.2.1 Selection of Stations to use for Daily Pattern

Gauges available in the Moorabool catchment are shown in Table 9-2. A number are unsuitable for use as their period of record is too short, or they are poorly rated at high flows.

- **Table 9-2: Moorabool Basin Flow Gauges**

Station	River	Description	Start	Comments
232214	Black Ck	U/S_of_Bungal_Dam	1990	Period of record to short to use
232223	Frawley Ck	U/S_Wilson_Reservoir	1995	Period of record to short to use
232225	Mahars Ck	U/S_Wilson_Reservoir	1995	Period of record to short to use
232224	Slater Ck	U/S_Wilson_Reservoir	1995	Period of record to short to use
232215	Woollen Ck	U/S_of_Bungal_Dam	1990	Period of record to short to use
	West Moorabool R	U/s Moorabool Res	1969	Poorly rated at high flows
	Devils Creek	U/s Moorabool Res	1969	Poorly rated at high flows
232213	Lal Lal Ck	U/S_of_Bungal_Dam	1977	Influenced by CHW extractions
232204	Moorabool R	Morrisons	1973	Influenced by u/s storages
232202	Moorabool R	Batesford	1908	Influenced by u/s storages
232210	West Moorabool R	Lal_Lal	1978	Influenced by u/s storages
232211	West Moorabool R	Mount_Doran	1972	Influenced by u/s storages

Data used for disaggregation of flows at current level of development should be selected to maximise the length of the series available, but should have a flow regime approximately equivalent to the current situation. For this study, data recorded prior to the construction of Lal Lal Reservoir was excluded from the disaggregation process.

Ideally, weekly natural flow data should be disaggregated using information recorded in unregulated, relatively undisturbed catchments. This was not possible in the Moorabool catchment at there has been very little unregulated flow data recorded. There are however a number of long term gauges in the catchment that exist prior to the construction of White Swan and Lal Lal Reservoirs. Flow measured at 232213 (Lal Lal Creek) is influenced by CHW harvesting at Wilsons and Beales Reservoirs and at the flood gates, as well as by extractions of private diverters. It is not however subject to as much upstream catchment modification as other long term gauges in the catchment and so was used to disaggregate natural flows at Sites 1 & 2.

Weekly flows at each compliance point were disaggregated as shown in Table 9-3.

■ **Table 9-3: Flow Data used for Disaggregation**

Flow pattern used for disaggregation from weekly to daily		
Site	**Current Level of Development Flows**	**Natural Flows**
Site 1	Flow at 232204 after Lal Lal Reservoir was constructed (1975 to date)	Flow at 232213 (1977 to date)
Site 2	Flow at 232211 after Lal Lal Reservoir was constructed (1975 to date)	Flow at 232213 (1977 to date)
Site 3	Flow at 232204 after Lal Lal Reservoir was constructed (1975 to date)	Flow at 232202 prior to construction of White Swan and Lal Lal reservoirs (1908 to 1921*)
Site 4	Flow at 232202 after Lal Lal Reservoir was constructed (1975 to date)	Flow at 232202 prior to construction of White Swan and Lal Lal reservoirs (1908 to 1921*)

* Data missing 1922 to 1959

9.3 Determination of security of supply

Security of supply is reported to indicate the reliability of a system. It is a measure of both the amount of water available, the level of usage in the catchment, and the reliability of supply.

Security of supply for urban demands is usually reported as the percentage of years in which restrictions occur. The base case results for Ballarat are shown in Table 9-4. As discussed in Section 2.3.3, results could not be shown for Barwon Water as restriction triggers were not defined in the model.

■ **Table 9-4: Base Case Restriction Frequency for Ballarat**

Restriction Level	Frequency (No of years out of 38 restrictions occurred)	Security (% of years without restrictions)
1	3	92%
2	1	
3	0	
4	0	

Security of supply for private diverters can be reported either as the percentage of the unrestricted demand supplied, or the percentage of the restricted demand supplied. Both values are included in Table 9-5. As can be seen from the table, private diverter demands are heavily restricted in the model.

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■ **Table 9-5: Base Case Private Diverter Demands**

	Average Annual Unrestricted Demand (ML)	Average Annual Restricted Demand (ML)	Average Annual Supplied Demand (ML)
Irr u/s Mbool Res	192	90	87
Irr between Mbool and Lal Lal Res	73	31	31
Irr u/s Wilsons Res	32	15	15
Irr Tribs u/s Lal Lal Res	657	325	325
Irr She Oaks to Spillers	11	3	3
Irr Spillers Weir	0	0	0
Irr Spillers to Caprons	23	9	9
Irr Caprons to Mattheys	9	3	3
Irr Caprons Weir	17	6	6
Irr Mattheys Weir	181	90	41
Irr Hills Weir	7	2	2
Irr Mitchell Weir	0	0	0
Irr Mitchells to Joaquins	69	28	26
Irr Joaquins Weir	17	6	6
Irr Joaquins to Batesford	87	43	40
Irr d/s Batesford	174	89	80
Lal Lal Ck Offstream Winterfill	54	41	41
Offstrm winterfill Capron to Mattheys	135	103	102
Whiskey Ck Winterfill	6	3	3
D&S u/s She Oaks	24	15	15
D&S etc She-Spillers	98	68	67
D&S etc Spill-Caprons	40	28	28
D&S etc d/s Batesford	200	151	151
D&S Lal Lal Res Tribs	63	46	45
D&S Btwn Mbool and Lal Lal	2	2	2
Industrial Mattheys Weir	58	44	43
TOTAL	2228	1242	1170
Security	94% of restricted demand supplied, 53% unrestricted demand supplied		

10. Determine environmental flow requirements at key locations

10.1 Reach 1: Bostock Reservoir downstream to the confluence with the west Moorabool River

The East Moorabool River downstream of Bostock Reservoir flows through the East Moorabool gorge before reaching a narrow floodplain downstream of Egerton Bungeeltap Road. Further downstream towards Egerton Bungeeltap Road, where no flow was observed, the floodplain widens and ecological condition of the riparian and instream vegetation worsens.

10.1.1 Site description

The site surveyed within this reach was immediately upstream of the narrow floodplain at Egerton Bungeltap Road. Here the river runs through a straight channel, which is bordered by a steep hillslope to the left and an eroded steep bench to the right. The channel is controlled by bedrock in the deeper pools and separated by vegetation in the shallow areas (Figure 10-1). The substrate consisted of cobbles, pebbles and sands. Stock access is particularly evident on the right bank and has probably exacerbated bank erosion.

Riparian vegetation is scattered along the edge of the river and not more than one tree wide, consisting of Woolly Tea-tree, Blackwood and bottlebrush (*Callistemon sp.*). A stand of eucalypts was present on the top of the left hillslope. Blackberries were present along the right bank at transect five. Exotic pasture grasses have replaced native species on the bench.

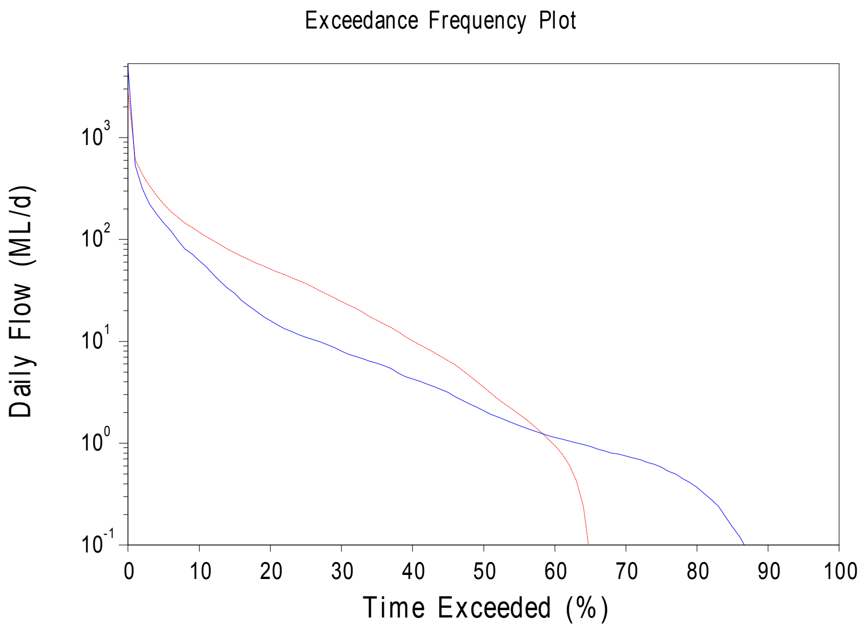
Instream vegetation was dominated by Cumbungi in the shallow areas, which often impeded flow. The pools contained Watermilfoil (*Myriophyllum sp.*), Ribbonweed (*Vallisneria sp.*) and a small amount of rush (*Juncus sp*) (Figure 10-2).

■ **Figure 10-1: East Moorabool River at Egerton Bungeeltap Road, Transect 1, looking downstream (March 2003).**

■ **Figure 10-2 East Moorabool River at Egerton Bungeeltap Road, Transect 2, looking downstream (March 2003).**

10.1.2 Hydrology

The flow duration curve shows that zero flows are naturally common within this reach (Figure 10-3). Currently, the flow is low and more constant. This has lead to the establishment of instream vegetation species common to more stable waters that can potentially choke the channel and impede flow.



■ **Figure 10-3 East Moorabool River daily flow duration for all months. Dashed red line – natural, solid blue line – current.**

10.1.3 Environmental values

A significant knowledge gap exists for the current biological condition of the East Moorabool River. One fish survey, undertaken by Tunbridge (1988), indicates that Short-finned Eel is the only native species present. Other native species that could be potentially present within this reach and found further downstream near the confluence of the east and west branches at Morrisons include River Blackfish, Southern Pygmy Perch and Australian Smelt. However, at present, conditions would be poor habitat for these fish species as there are few pools and those that exist would have low dissolved oxygen concentrations and high temperatures. Therefore if these species were found here, their abundance would be low. The exotic species present within this reach are Redfin (*Perca fluviatilis*) and Brown Trout.

A Waterwatch site is located downstream of the bridge on Bungeeltap Road, however no macroinvertebrate monitoring is undertaken (Michelle Anderson, Barwon Water *pers. comm.*).

The East Moorabool Gorge, immediately downstream of Bostock Reservoir is known to contain significant areas of remnant grasslands (CCMA, 2000b). However the details of these species and their dependence upon water is unknown.

10.1.4 Water quality

Water quality data was obtained from Barwon Water for the Bostock Reservoir outlet. A summary of water quality data at this site and comparison to the draft SEPP objectives is provided in Table 2-12.

Total phosphorus concentrations have exceeded the SEPP objective of ≤ 0.04 mg/L six of the seven years monitored since 1996. Electrical conductivity complied with four of the six years monitored, a 75^{th} percentile maximum of 617 µS/cm in 2000. pH complied with all draft SEPP objectives and turbidity ranged from a low 75% percentile of 5.7 NTU to a maximum of 17.3 NTU in 2002.

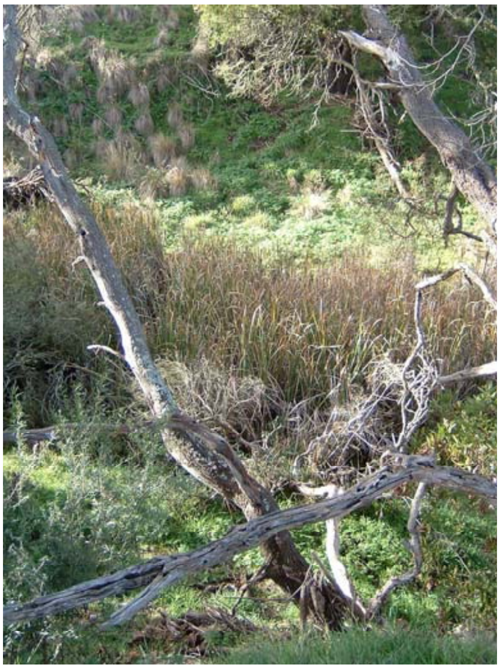
During the site visit, high turbidity was observed in the deeper pools and where the river widened downstream of Egerton Bungeeltap Road. White scum was also visible on the surface indicating low flushing flow.

10.1.5 Issues

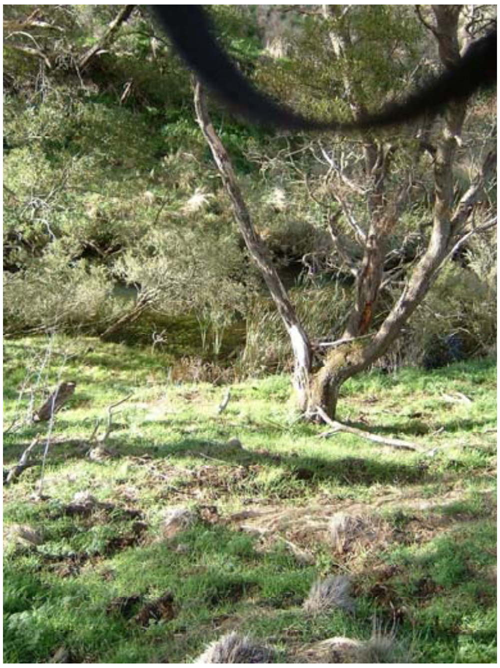
The natural flow regime has been significantly altered within this reach due to the impoundment of water at Bostock Reservoir. Compared to natural, there has been a decrease in cease to flow events (from 35% to 15%), median flows (3.57 to 2.09 ML/d) and an extended low flow period. The absence of these natural mechanisms has created conditions more favourable to instream vegetation species, such as Cumbungi, which are common to slow flowing shallow waters (Figure 10-4). Low median flows decrease the amount of habitat available to native fauna leading to an increase in predation and competition.

Isolation of native migratory fish species, with the probable exception of Short-finned Eels, occurs within this reach due to the presence of barriers upstream (Bostock) and downstream (She Oaks Weir).

In addition, extensive clearing of the riparian zone combined with stock access has resulted in the dominance of exotic terrestrial species such as pasture grasses (Figure 10-5).



▪ **Figure 10-4 East Moorabool River at Egerton Bungeeltap Road, Transect 2 cross section.**



▪ **Figure 10-5 East Moorabool River at Egerton Bungeeltap Road, Transect 3 cross section.**

10.1.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 1 (Table 10-1).

Table 10-1 Ecological objectives for Reach 1.

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Restore self-sustaining population of Mountain Galaxias	F1a	Habitat – resting/rearing	Low flows provide adequate habitat all year (depth)	All year	Low
	F1b	Habitat – resting/rearing	High flows maintain the pools in channel form	Winter	High
	F1c	Breeding/Recruitment	Possibly move upstream to spawn in the headwaters which is triggered by a rise in water level.	Winter/Spring	Freshes
Maintain self-sustaining population of Australian Smelt	F2a	Habitat	Low flows provide adequate habitat all year (depth)	All year	Low
	F2b	Movement	Restricted habitat (upstream movement in Barwon recorded by Tunbridge).	Spring/Summer Winter/Spring	Freshes High
Restore self-sustaining population of River Blackfish	F3a	Habitat	Low flows provide adequate habitat all year (depth)	All year	Low
	F3c	Movement	No apparent migration. Movement is generally limited to a home range 25 to 30 m, no spawning migration	Spring/Summer	High
Restore self-sustaining population of Southern Pygmy Perch	F4a	Habitat	Low flows provide adequate habitat all year (depth)	All year	Low
Maintain self-sustaining population of Short-finned Eel	F5a	Habitat – resting/rearing	Low flows provide adequate habitat all year (depth)	All year	Low
	F5b	Movement	Upstream migration as elvers	Spring/Summer	High flows
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain a diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1	Disturbance	Reset macroinvertebrate community by alteration of habitat	Winter/Spring Summer	Freshes Cease to flow
	M2	Habitat maintenance	Restore riffle habitat by removing accumulated sediment	Winter/Spring	Freshes
	M3	Habitat availability	Maintain riffle habitat	Winter	Low

Vegetation	No.	Process	Rationale	Timing of flow component	Relevant flow component
Maintain in-stream macrophyte species diversity	V1a	Colonisation	Most species flower in the low flow season when they are less prone to damage	Spring	Low
	V1b	Disturbance	Maintain instream species diversity	Summer	Cease to flow
Limit encroachment of emergent in-stream vegetation and species common to non-flowing waterbodies such as Cumbungi	V2	Habitat maintenance	In-stream vegetation in this reach is dominated by cumbungi which choke the channel and prevent flow downstream.	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg tea-tree).	V3	Wetting	Establishment and growth of riparian species	Winter	High
Habitat/Processes	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1	Transport of sediment	Flush sediment to maintain pool habitat	Any time	Freshes/High
Maintain physical processes	H2	Organic matter transport	Flush organic matter through system that has accumulated in pools and transfer carbon energy downstream	Winter/Spring	High
Maintain woody debris/snag habitat	H3	Submergence	Maintain habitat for fish and macroinvertebrates	Anytime	Low
Water quality	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Rehabilitate dissolved oxygen in pools and during periods of low flow	W1	Habitat maintenance/mixing	No evidence of issues from water quality data. However downstream of bridge on Bungeeltap Road, river widens, flow is slow and accumulated scum was visible on the surface	Summer Winter	Freshes
Rehabilitate total phosphorus concentrations	W2	Habitat maintenance	Six of the seven years since 1996, total phosphorus has exceeded SEPP objectives	Summer	Freshes
Rehabilitate electrical conductivity	W3	Habitat maintenance	Electrical conductivity can be quite high at times and may be the result of groundwater inflow.	Summer	Freshes

10.1.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 1 is shown in Table 10-2.

Summer cease to flow

Naturally, this reach was characterised by a long summer cease to flow period as the headwaters dried (Figure 10-6). Cease to flow periods create disturbance that helps to maintain instream macrophyte and macroinvertebrate species diversity. The alteration in habitat structure brought about by cease to flows alters the macroinvertebrate species composition by eliminating some species (ie. grazers) and allowing other species to recolonise (Lake, 2003). The recommendation for a flow of 0 ML/d should occur at a maximum of twice per year in order to replicate the natural frequency and ensure that water quality within isolated pools does not deteriorate such that dissolved oxygen levels are lethal (Figure 10-7). A duration of 30 days is recommended to ensure that species within this reach are adequately disturbed and displaced but an increase in nutrient concentration and high temperatures does not precipitate algal blooms.

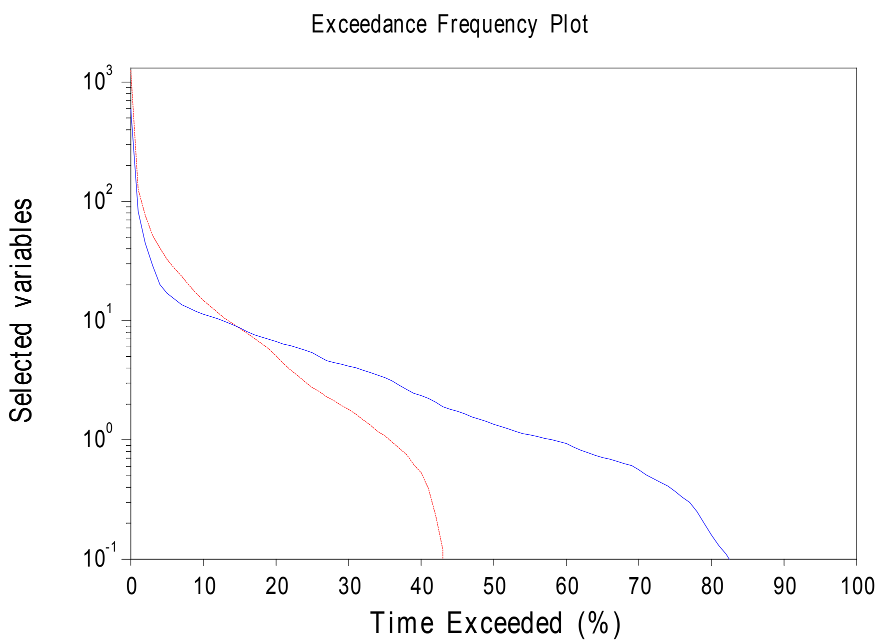
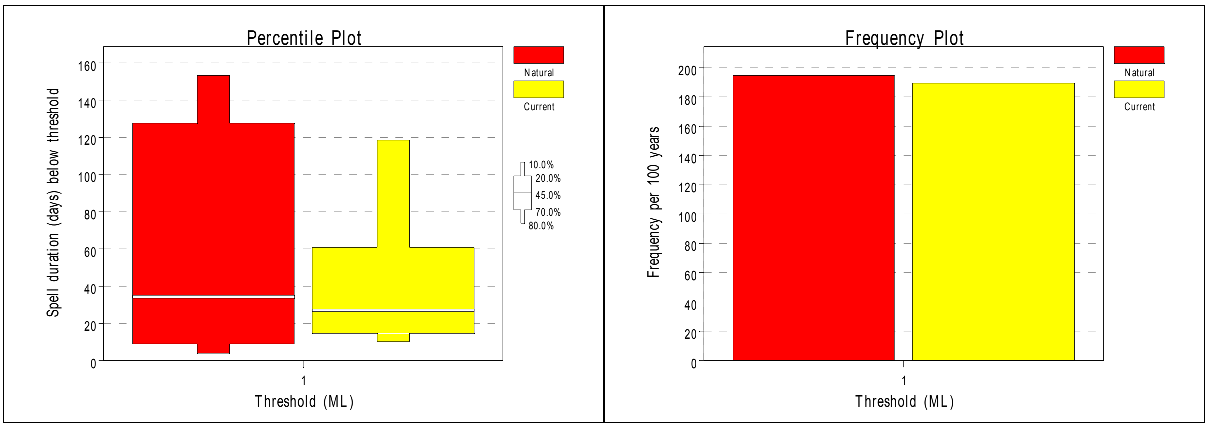


Figure 10-6 East Moorabool River summer flow duration. Dashed red line – natural, solid blue line – current.



■ **Figure 10-7 Duration (left) and frequency (right) of East Moorabool River summer spells below 1 ML/d under natural and current conditions in Reach 1.**

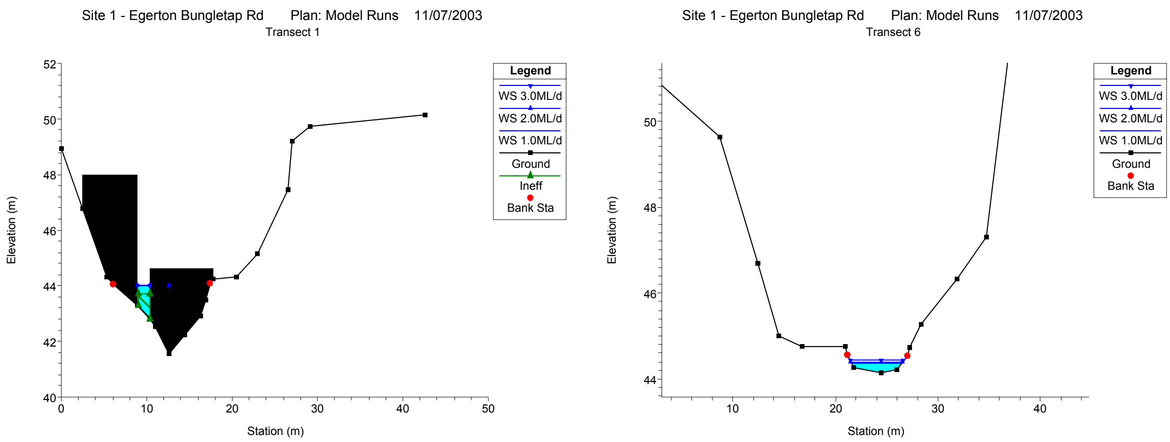
Summer low flow

No summer low flow recommendation has been made for this reach. Given the site features of deep pools separated by shallow riffles and macrophytes, a summer low flow would not have been expected. Analysis also reveals low flow percentiles of 70, 80 and 90 correspond to cease to flow periods. Summer low flow periods therefore did not occur naturally and cease to flow periods would have naturally been interrupted by summer freshes and high flow periods (Figure 10-6).

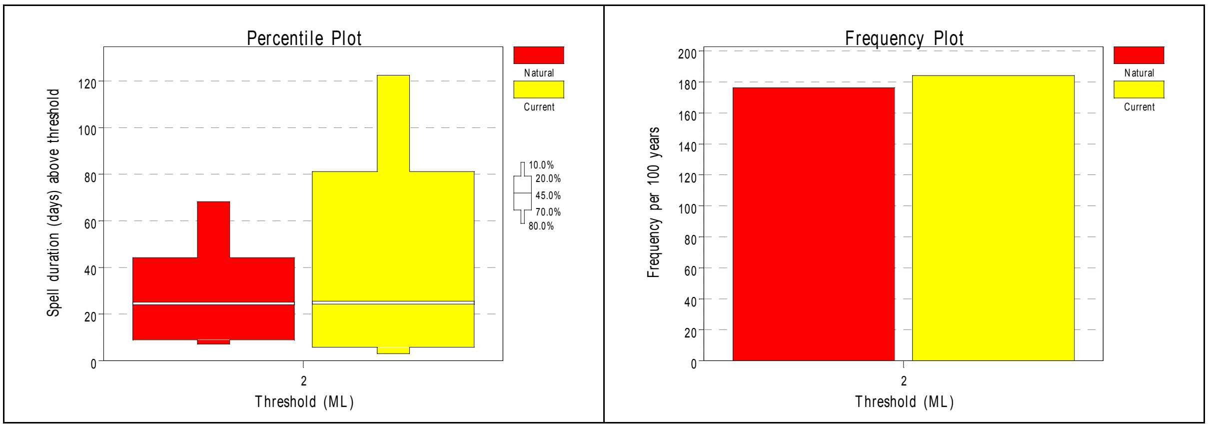
Summer – fresh

The recommended summer fresh flow of 2 ML/d is above the summer median flow of 1ML/d. This is to ensure adequate depth and velocity is achieved in the smaller cross sections in order to provide greater connectivity to the pools for the rehabilitation of water quality. An increase from 1 to 2 ML/d in the riffle at Transect 6, doubles the velocity from 0.01 m/s to 0.2 m/s and increases the depth from 22 cm to 26 cm (Figure 10-8).

This flow should occur at a minimum of twice per year in order to replicate the natural frequency and to allow the flushing and mixing effect to be cumulative (Figure 10-9). It should last for 10 days to ensure significant hydrological inputs are delivered to the pools.



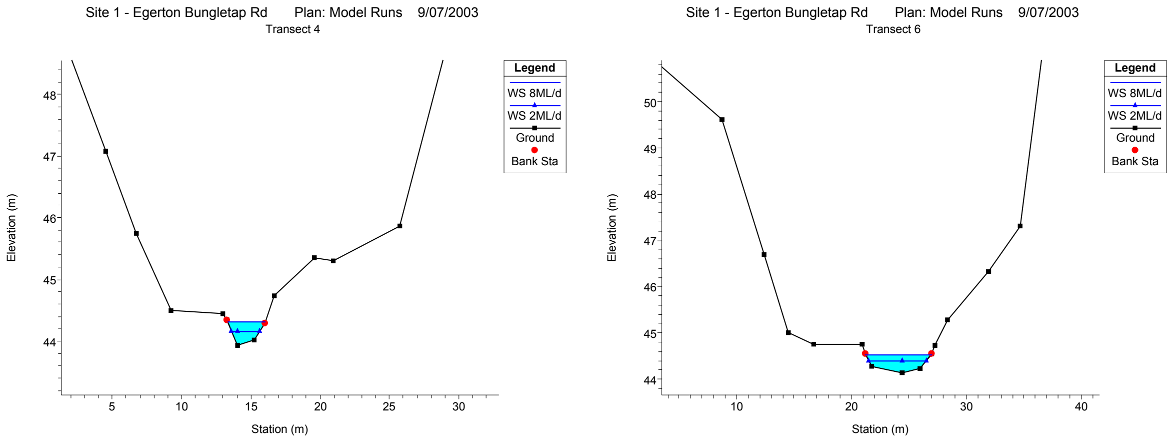
■ **Figure 10-8 Stage height at Transect 1 (left) and Transect 6 (right) for trialed summer fresh flows of 1, 2 and 3 ML/d at Reach 1.**



■ **Figure 10-9 Duration (left) and frequency (right) of East Moorabool River summer spells above 2 ML/d under natural and current conditions in Reach 1.**

Winter – low flow

The recommended winter minimum flow of 8 ML/d is the 70% flow for the winter period June to November. It provides increased velocity and depth in the riffle habitat for movement of fish species without inundating the benches (Figure 10-10). Flows lower than 2 ML/d would provide significantly less velocity in the riffle habitat (0.05 to 0.02 m/s) and reduced channel wetting (5.75 to 5.04 m top width).



- **Figure 10-10 Stage height at Transect 4 (left) and Transect 6 (right) for trialed winter low flows of 2 and 8 ML/d at Reach 1.**

Winter – fresh

The recommended winter fresh flow of 37 ML/d will ensure the majority of benches are inundated in order to entrain organic matter and assist in the reduction of cover of terrestrial exotic grasses to a more natural vegetation mosaic. In addition, it will provide a biological cue for Mountain Galaxias to spawn. Mountain Galaxias have not been found within this reach, however are located on the West Moorabool. For this species to be reinstated and sustainable populations maintained within this reach, the appropriate flow cues for recruitment must be provided.

Naturally, median winter flows are about 29 ML/d or greater. However flows of this magnitude do not perform the function of inundating the banks, particularly at Transects 5 and 6 (Figure 10-11). The recommended flow of 37 ML/d should occur at a minimum of twice a year because often one event is not considered effective alone as a biological cue. Naturally this flow would occur at approximately 45% of the time for 20 days (Figure 10-12). However, a duration of 10 days is recommended to maintain the natural duration of 70% of the natural events and allow for the recolonisation of native species that favour frequent flooding.

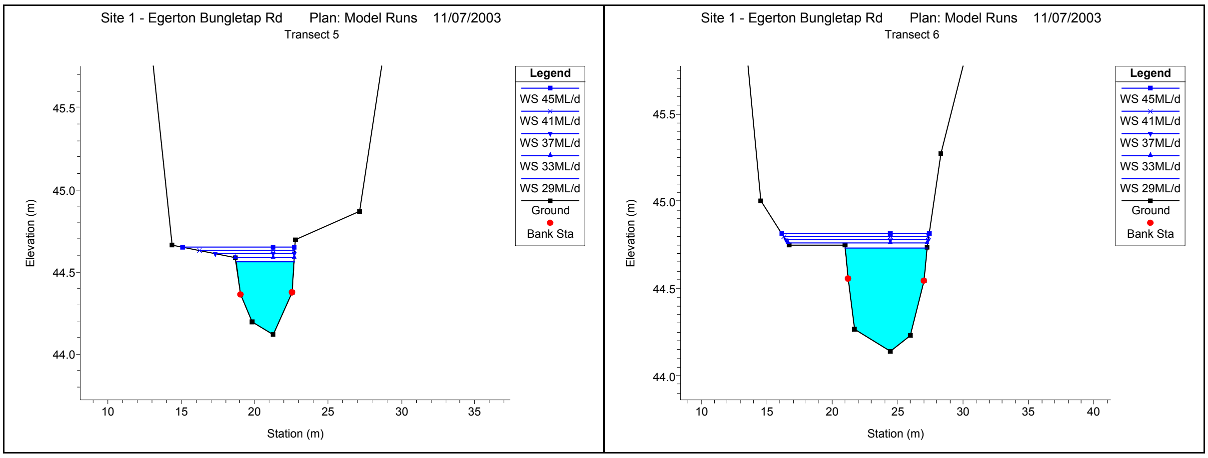


Figure 10-11 Stage height at Transect 5 (left) and Transect 6 (right) for trialed winter fresh flows of 45, 41, 37, 33, and 29 ML/d.

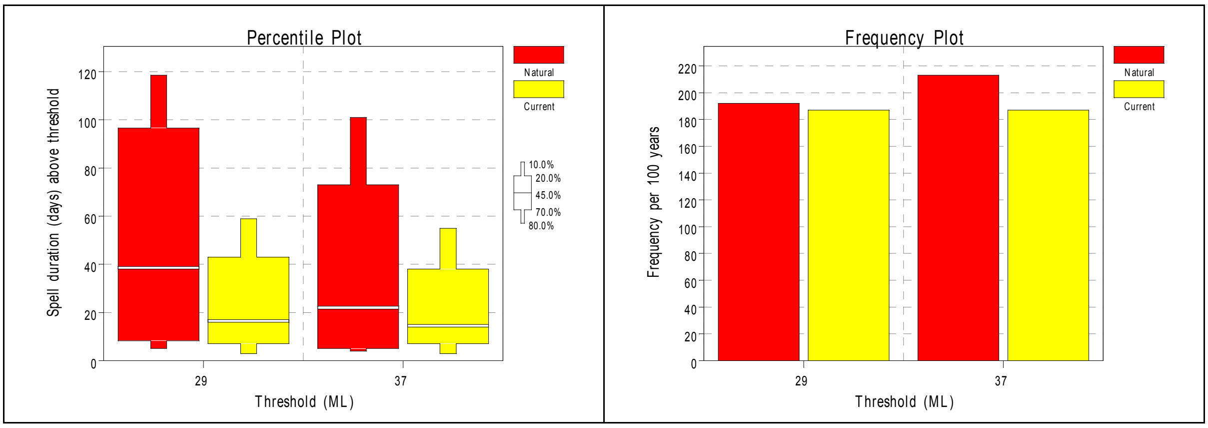
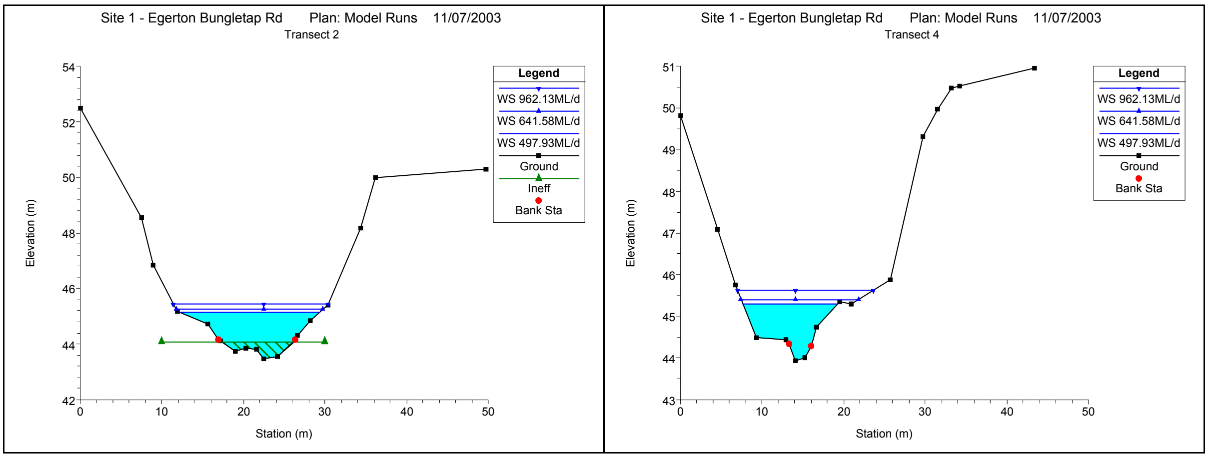


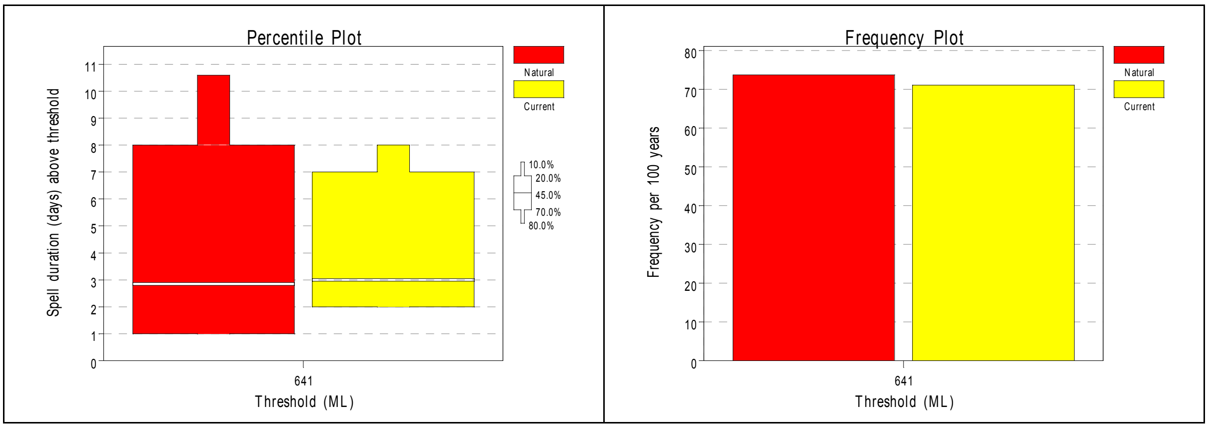
Figure 10-12 Duration (left) and frequency (right) of winter spells above 29 and 37 ML/d under natural and current conditions in Reach 1.

Winter – high flow

Winter high flows are recommended to flatten the Cumbungi and allow organic matter to move through the channel providing energy and a food source to organisms downstream. As the channel has a broad bench, increased habitat area and thorough inundation of the channel will be achieved at flows greater than 641 ML/d. This flow also corresponds to the annual return high flow. A reduction in flow to say, 498 ML/d will not provide adequate depth along the margins, which is particularly evident at Transects 2 and 4 (Figure 10-13). The recommended duration of 1 to 3 days is 45 to 75% of the natural events and is considered a suitable period for which to scour or redistribute sediment that has built up over low flow periods (Figure 10-14).



■ **Figure 10-13 Stage height at Transect 2 (left) and Transect 4 (right) for trialed winter high flows of 962, 641, and 498 ML/d.**



■ **Figure 10-14 Duration (left) and frequency (right) of winter spells above 641 ML/d under natural and current conditions in Reach 1.**

Table 10-2 Flow recommendations for Reach 1.

River	East Moorabool River			Reach	East Moorabool River – Bostock Reservoir to the confluence with the West Moorabool River
Flow					**Rationale**
Season	**Flow component**	**Magnitude**	**Frequency**	**Duration**	**Objective**
Summer Dec - May	Cease to flow	0 ML/d	Maximum twice annually	30 days	M1, V1b
	Low flow	NR			
	Fresh	> 2 ML/d	Minimum twice annually	10 days	F2b, F3c, F5b, H1, H2, W1, W2, W3
Winter Jun - Nov	Low flow	8 ML/d	Annual	Jun - Nov	F1a, F2a, F3a, F4a, F5a
	Fresh	> 37 ML/d	Minimum twice annually	10 days	F1b, M1, M3, V1a, V2, H3
		> 641 ML/d	Once a year	1 - 3 days	F2b, M2, V3, H1, H2

NR – No flow recommendation made

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10.2 Reach 2: West Moorabool River between Moorabool and Lal Lal Reservoirs

10.2.1 Reach description

The upper reach of the West Moorabool River between Moorabool and Lal Lal Reservoirs is characterised by a contracted channel that meanders through pastureland (Figure 10-15, Figure 10-16).

Here, the riparian vegetation is dominated by willows and pasture grasses. The instream vegetation was similarly in poor condition – due in part to grazing, stock access and low flow. However, aquatic macrophytes such as Ribbonweed and rush were present at Yendon Egerton Road. Oil was also visible on the water surface at this site.

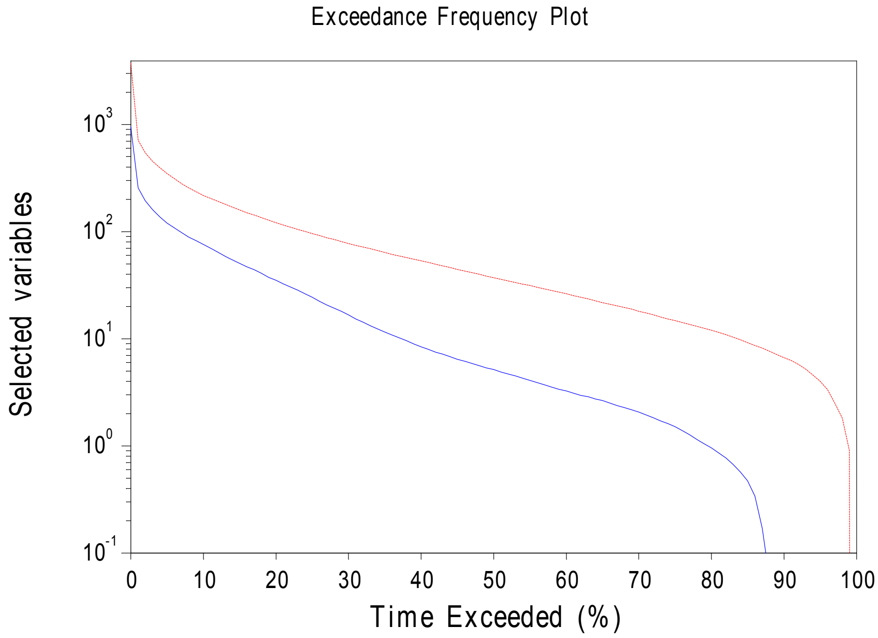
No surveying was undertaken within this reach as the channel is narrow and contracted with few habitat features, meaning that little change would have been observed with modelled flows. As such, an additional site was surveyed downstream of Lal Lal Reservoir at Elaine-Egerton Road. The hydraulic model at this site was used to model the flows upstream of Lal Lal Reservoir and determine the effects and therefore suitability of flow recommendations for upstream of Lal Lal Reservoir. This was only conducted for summer and winter low flows.

- **Figure 10-15 West Moorabool at Butterfactory Road (March 2003).**

- **Figure 10-16 West Moorabool at Yendon Egerton Road looking downstream (March 2003).**

10.2.2 Hydrology

The flow duration curve shows that cease to flow periods are an infrequent occurrence within this reach (Figure 10-17). Currently, there has been an increase in cease to flow events and decrease in overall flow due to the impoundment of water at Moorabool Reservoir. It should be noted that natural flows are calculated with the impact of farm dam and groundwater extraction taken out.



▪ **Figure 10-17 West Moorabool River between Moorabool and Lal Lal Reservoirs daily flow duration of all months. Dashed red line – natural, solid blue line – current.**

10.2.3 Environmental values

Limited fish survey data is available for this reach, but indicates that exotic species including Redfin, Brown Trout and Tench (*Tinca tinca*) dominate. Only one native fish species, Mountain Galaxias has been recorded in this reach and occurs as far downstream as She Oaks. Fish species within this reach are isolated due to the presence of barrier upstream (Moorabool Reservoir) and downstream (Lal Lal Reservoir).

One ISC site is present within this reach. However no aquatic life (ie. SIGNAL and AUSRIVAS) scores are available.

A total of 11 Victorian threatened water dependent bird species have been recorded within the Moorabool River catchment downstream of Moorabool Reservoir and Bostock Reservoir (NRE, 1999b) (Table 2-19). This list includes the critically endangered Little Egret and Intermediate Egret and the endangered Great Egret. Five species are listed under the *FFG Act 1998*. The Great Egret is also declared internationally significant by the Japan and Australia Migratory Bird (JAMBA) and China and Australian Migratory Bird (CAMBA) Agreements.

10.2.4 Water quality

Water quality monitoring within this reach is conducted at Lal Lal (VWQMN site 232210). A summary of water quality data at this site and comparison to the draft SEPP objectives (EPA, 2001) and the ANZECC water quality guidelines (ANZECC, 2000) is provided in Table 2-13.

Total nitrogen concentrations have exceeded all draft SEPP objectives since 1992 and two algal blooms have occurred in the Moorabool Reservoir during 1980 and 1991. Dissolved oxygen complied for the four years in which percentiles could be calculated (1992-3, 2001-2). Turbidity and total phosphorus complied with the draft SEPP objectives four out of the eight and three out of the nine years for which monitoring was undertaken. pH has met the draft SEPP objective during six of the ten years since 1992 for which monitoring was undertaken.

10.2.5 Issues

The natural flow regime in this reach has been significantly altered due to the impoundment of water at Moorabool Reservoir. Compared to natural, there has been an increase in cease to flow events and decrease in median flows (18 to 2 ML/d). The absence of these natural mechanisms has created conditions more favourable to exotic species such as Brown Trout and Redfin. Populations of these species are likely to impact on populations of native aquatic fauna either indirectly through alteration of in-stream habitat or directly through competition for food and shelter and predation on small-bodied species in early life history stages (eg. Brown Trout).

Extensive clearing of the riparian zone in the upper catchment, combined with stock access has resulted in the dominance of exotic species such as willows and pasture grasses. Encroachment of the stream channel by these grasses reduces habitat availability, complexity and diversity and represents a potential risk to aquatic biota. Low flows also favour the presence of filamentous algae.

10.2.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 2 (Table 10-3).

▪ Table 10-3 Ecological objectives for Reach 2.

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Maintain self-sustaining population of Mountain Galaxias	F1a	Habitat – resting/rearing	Low flows provide adequate habitat all year (depth)	All year	Low
	F1b	Habitat – resting/rearing	High flows maintain the pools in channel form	Winter	High
	F2a	Breeding/Recruitment	Possibly move upstream to spawn in the headwaters which is triggered by a rise in water level.	Winter/Spring	High flows
	F2b	Breeding/Recruitment	Possibly move upstream to spawn in the headwaters which is triggered by a rise in water level.	Winter/Spring	Freshes
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain a diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1	Disturbance	Creation of a new habitat for a variety species introduced by recolonisation.	Winter/Spring Summer	Freshes Cease to flow
	M2	Habitat maintenance	Restore riffle habitat by removing accumulated sediment	Winter/Spring	Freshes
	M3	Habitat availability	Maintain riffle habitat	Spring/Summe r	Low
Vegetation	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain in-stream macrophyte species diversity	V1	Colonisation	Most species flower in the low flow season when they are less prone to damage.	Spring	Low
Limit encroachment of in-stream vegetation and species common to non-flowing waterbodies such as Elodea and pasture grasses.	V2	Habitat maintenance	In-stream vegetation can be dominated by species common to non-flowing water bodies. Fast running waters are not favourable habitat for free-floating species or those with floating leaves	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg. Silver Wattle and Blackwood).	V4	Wetting	Establishment and growth of riparian species	Winter	High

Habitat/Processes	No.	Process	Rationale	Timing of flow component	Relevant flow component
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1	Transport of sediment	Flush sediment from behind weir and maintain pool habitat	Any time	Freshes/High
Maintain physical processes	H2	Organic matter transport	Flush organic matter through system that has accumulated in pools and perhaps behind weirs	Winter/Spring	High
Maintain woody debris/snag habitat	H3	Submergence	Maintain and habitat for fish and macroinvertebrates	Anytime	Low
Water quality	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Rehabilitate dissolved oxygen in pools and weir-pools during periods of low flow	W1	Habitat maintenance/mixing	Dissolved oxygen is not monitored but could be low at times due to low flows.	Spring	Freshes
Rehabilitate total nitrogen concentrations	W2	Habitat maintenance	Total nitrogen concentrations have exceeded the SEPP objective since 1992.	Summer	Low
Rehabilitate electrical conductivity	W3a	Habitat maintenance	Electrical conductivity can be quite high and may be the result of groundwater inflow.	Summer	Low

10.2.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 2 is shown in Table 10-4.

Summer – cease to flow

A cease to flow event is recommended to create disturbance that helps to maintain instream macrophyte and macroinvertebrate species diversity. Currently, cease to flow events occur more frequently and for a longer duration than what naturally occurred due to extractions (Figure 10-18). It is recommended that the frequency of cease to flow events should decrease to a maximum of two per year so as to replicate the natural frequency and prevent the encroachment of exotic pasture grasses in the channel. A duration of eight days is recommended for the effect to be cumulative.

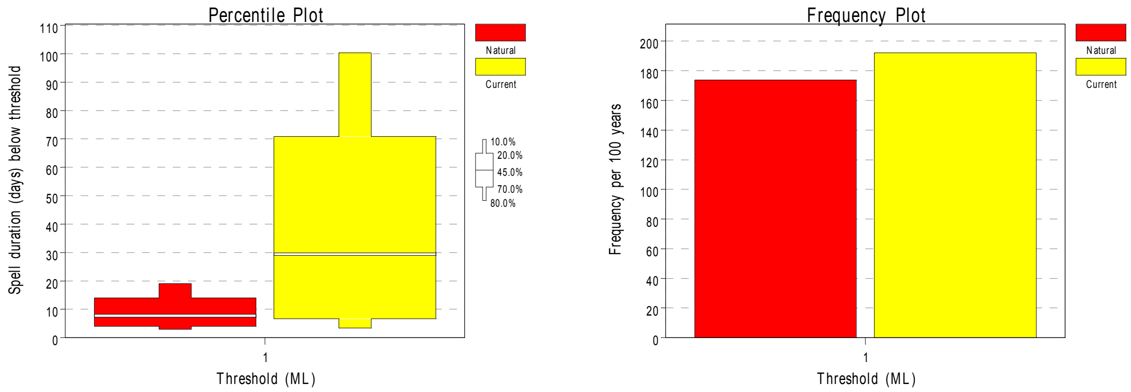


Figure 10-18 Duration (left) and frequency (right) of summer spells below 1 ML/d under natural and current conditions in Reach 2.

Summer – low

A low flow of 4 ML/d is recommended for Reach 2. This recommendation is based on 70th percentile exceedance flow for daily summer flows upstream of Lal Lal Reservoir. As no hydraulic model was developed for this reach upstream of Lal Lal Reservoir, the hydrology from this reach was entered into a hydraulic model downstream of Lal Lal Reservoir. This was used to determine the suitability of flow recommendations for this reach.

A flow of 4 ML/d downstream of Lal Lal Reservoir will wet the bottom of the channel and therefore maintain minimum habitat conditions for aquatic biota. HEC-RAS outputs indicate that a flow of this magnitude would provide a depth of 1.04 m in the deepest pool at Transect 6 and 7 cm in the riffle habitat at Transect 7 (Figure 10-19; Figure 10-20). These depths will enable adequate fish passage between the high and low flow habitats, yet leave the benches exposed for entrainment and weathering of organic matter. This would be an adequate flow recommendation for upstream of Lal Lal Reservoir.

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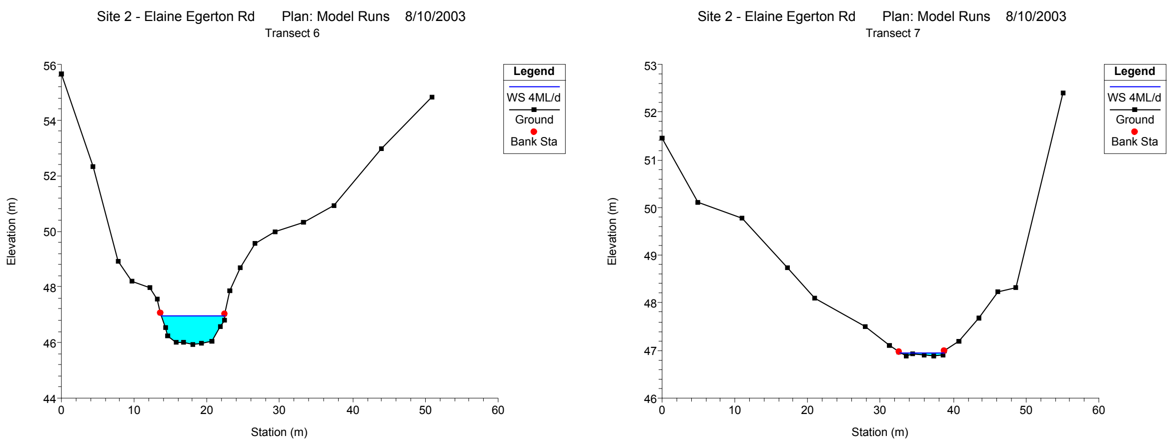
■ **Figure 10-19 Site surveyed downstream of Lal Lal Reservoir – Transect 7, riffle habitat.**

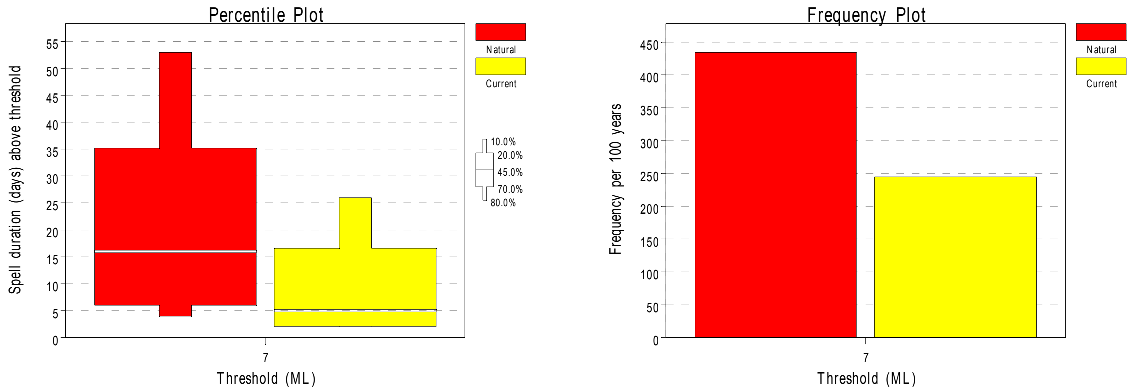


■ **Figure 10-20 Stage height at Transect 6 (left) and Transect 7 (right) for the summer low flow threshold of 4 ML/d.**

Summer – fresh

The recommended summer fresh flow of 7 ML/d will limit the further encroachment of exotic pasture grasses present in the contracted channel as well as improving water quality by flushing and turning over the pools. By increasing the flow from a summer low, depth will also be increased. This will enhance connectivity between pools and provide a great variety of habitats within the degraded channel.

Under natural conditions, flows that exceeded the recommended threshold for summer freshes would have lasted for an average of 16 days and occurred nearly five times a year during the low flow period (Figure 10-21). Under current conditions, flows exceeding the threshold occurred less often, about twice a year and tended to be shorter in duration. This change would have had significant impacts on water quality and channel form. It is therefore recommended that summer freshes be provided at least four times a year and for a minimum duration of seven days. The ecological benefits provided by freshes only require a relatively short duration and seven days is considered adequate to provide wetting and improve water quality. However the benefits are also relatively short lived so more than one fresh is required over the summer low flow period. A frequency of four per year will mimic natural conditions and if interspersed across the low flow period help maintain habitat quality.



▪ **Figure 10-21 Duration (left) and frequency (right) of summer spells above 7 ML/d under natural and current conditions.**

Winter – low

The recommended winter low for Reach 2 is 22 ML/d. As with the summer low flow, this recommendation is based on the 70th percentile exceedance flow for daily winter flows upstream of Lal Lal Reservoir. Again, as no hydraulic model was developed for this reach, the hydrology from this reach was entered into a hydraulic model downstream of Lal Lal Reservoir to determine the suitability for the recommendations upstream.

The recommended flow of 22 ML/d will provide minimum habitat conditions for the winter period by maintaining connection between the shallow and deeper pools. This is evidenced by an increase in wetted area and depth of 11 cm at Transect 1 and 13 cm at Transect 2, compared to summer low flows (Figure 10-22).

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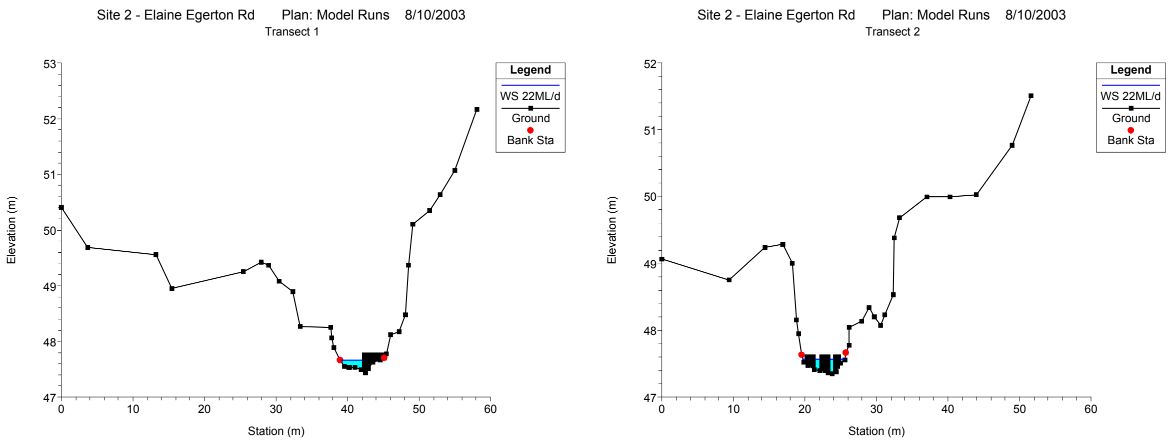
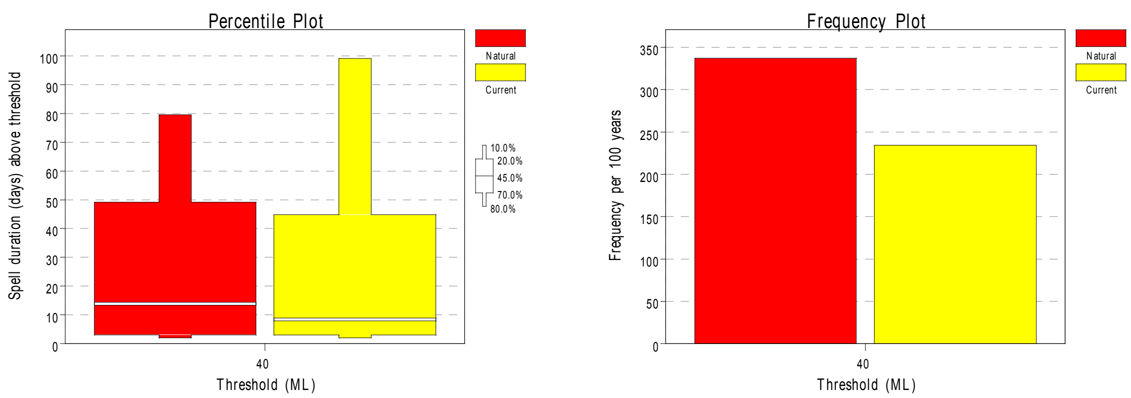


▪ **Figure 10-22 Stage height at Transect 1 (left) and Transect 2 (right) for recommended winter low flow threshold of 22 ML/d.**

Winter – fresh

This reach is characterised by high level eroded benches as a result of stock access and willow growth. A winter fresh flow of 40 ML/d will inundate the margins of these benches and assist in the reduction of cover of terrestrial exotic grasses favoured by low hydrological stability. When the flow expands into the riparian zone, organic matter will also be entrained and carried downstream where it will provide food and energy. In addition, it will provide a biological cue for Mountain Galaxias to spawn.

Compared to natural conditions, flows of this magnitude occurred more frequently and for a similarly long duration (Figure 10-23). It is recommended that winter freshes be allowed to occur at a minimum of three times per year for a minimum of ten days duration to provide an adequate degree of disturbance to terrestrial vegetation.

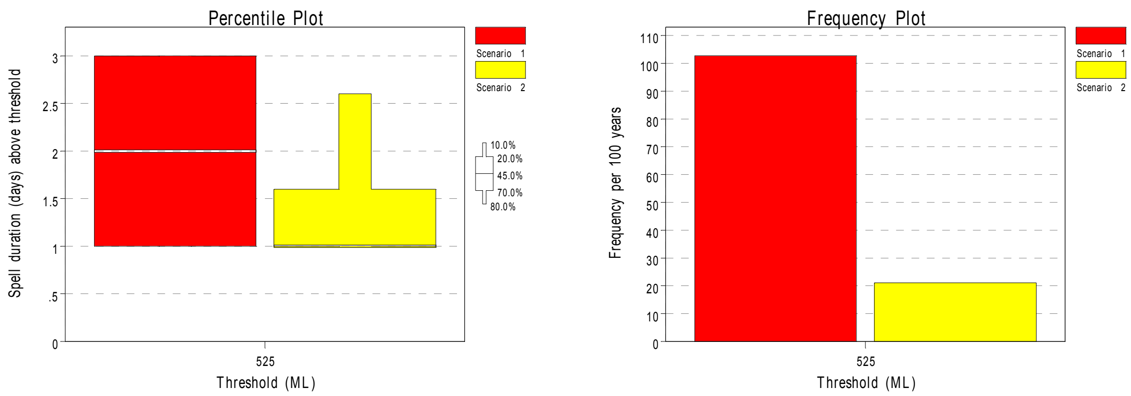


▪ **Figure 10-23 Duration (left) and frequency (right) of winter spells above 40 ML/d under natural and current conditions in Reach 2.**

Winter – high

A winter high flow of 525 ML/d is recommended for Reach 2. It is envisaged that this flow would almost fill the entire channel, inundating all benches, wetting and disturbing riparian vegetation and transporting sediment downstream.

Currently, flows of this magnitude occur for a much short duration (less than 1 day) and frequency (less than 20 in 100 years) (Figure 10-24). Naturally this flow corresponds to the annual return flow. This flow is recommended to occur annually for a minimum duration of 1 –2 days. This is considered a suitable period for which to scour or redistribute sediment that has built up over low flow periods.



▪ **Figure 10-24 Duration (left) and frequency (right) of winter spells above 525 ML/d under natural and current conditions in Reach 2.**

▪ **Table 10-4 Flow recommendations for Reach 2.**

River	West Moorabool River			Reach	West Moorabool River – Moorabool to Lal Lal Reservoirs
Flow					**Rationale**
Season	**Flow component**	**Magnitude**	**Frequency**	**Duration**	**Objective**
Summer Dec - May	Cease to flow	0 ML/d	Maximum twice annually	8 days	F1a, M1, V1b
	Low flow	4 ML/d	Annual	Dec - May	W1
	Fresh	> 7 ML/d	Minimum four per year	7 days	H1, H2, W1, W2, W3
Winter Jun - Nov	Low flow	22 ML/d	Annual	Jun - Nov	F1a, M1
	Fresh	> 40 ML/d	Minimum three per year	10 days	F2b, M1, M3, V1a, V2, H3
	High flow	525 ML/d	Once a year	1 – 2 days	F2a M2, V3, H1, H2

10.3 Reach 3: West Moorabool River below Lal Lal Reservoir to Sharp Road, She Oaks

This reach is located in the middle of the Moorabool River catchment and includes the west branch of the Moorabool River downstream of Lal Lal Reservoir to Sharp Road downstream of She Oaks Weir.

This reach contains some of the most valuable instream and riparian habitats in the catchment - partly due to the fact that the Brisbane Ranges National Park and Steiglitz Historical Park border the river to the east upstream of She Oaks. Downstream of Lal Lal Reservoir at Elaine Egerton Road vegetation such as River Red Gum, Silver Wattle and Woolly Tea-tree are present (Figure 10-25, Figure 10-26). Immediately downstream of the confluence in the vicinity of Morrisons, the presence of River Red Gum declines and impact of farming and willow removal is evident (Figure 10-27).

The channel in this reach varied from constricted and choked by Cumbungi in the vicinity of Morrisons to very wide and shallow downstream at Steiglitz Road. A variety of hydraulic habitats was also present throughout the reach and included large and small pools separated by natural riffles. Just below the confluence, the substrate consisted of cobbles, whereas further downstream bedrock and fine sand was dominant (Figure 10-28). However widening and deepening may be accelerated due to sustained high flows from Lal Lal Reservoir to She Oaks.

- **Figure 10-25 West Moorabool River below Lal Lal Reservoir, Hunts Bridge Transect 5 cross section (May 2003).**

- **Figure 10-26 West Moorabool River below Lal Lal Reservoir, Hunts Bridge Transect 5 upstream (May 2003).**

■ **Figure 10-27 Moorabool River at Morrisons gauging station looking upstream (March 2003).**

■ **Figure 10-28 Moorabool River at Morrisons gauging stations looking downstream (March 2003).**

10.3.1 Site description

One site within this reach was surveyed. It was located immediately downstream of She Oaks Weir at Sharp Road. Here, a long deep pool separated when the river bifurcated downstream of the bridge at Transects 2 and 3. A large bar between the channels was vegetated with pasture grasses and Woolly Tea-tree. Flow was diverted around the bar and a large fallen tree to the right, leaving the smaller channel to the left with no flow. This channel during the site visit was still quite wet and contained a large amount of woody debris and leaf litter. Riffles were present immediately upstream and downstream of the bifurcation at Transects 2 and 4.

Riparian vegetation at the site consisted of River Red Gum over dense scrub consisting of Woolly Tea-tree, Silver Wattle and bottlebrush (Figure 10-29). Instream species were sparse and consisted of rush and Common Reed (*Phragmites australis*). Blackberries densely lined the left bank for approximately 100 m between Transects 3 and 4.

The left bank at this site was flat where walking and car access to the adjoining park was evident. At Transect four the basalt bank became steeply graded and levelled off again at Transect 7 where a large pool and swimming hole was present. Farming was evident over the top of the hill.

The right bank was only assessable by crossing the river. It was densely vegetated with eucalypts and tea-tree. A high flow channel here was unable to be surveyed.

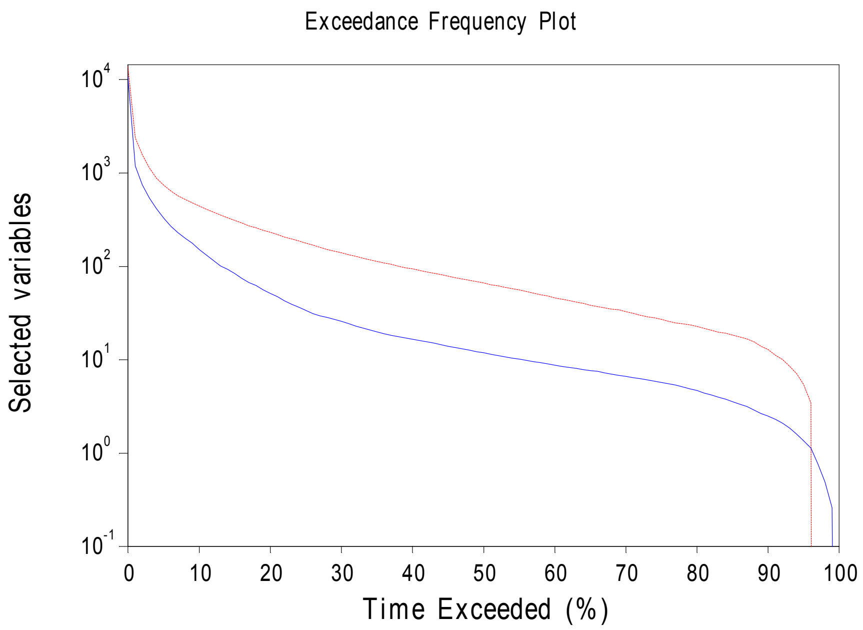
The substrate at the site consisted of bedrock in the pools, and cobbles and pebbles in the riffles (Figure 10-30). Transect 3 contained a deep gravel depression within the vegetated bar. Woody debris had accumulated just upstream and within the bar.

- **Figure 10-29 Moorabool River Sharp Road downstream of She Oaks Weir, Transect 1 cross section.**

- **Figure 10-30 Moorabool River Sharp Road downstream of She Oaks Weir, Transect 6 looking upstream.**

10.3.2 Hydrology

Naturally flow in this reach would be variable. However constant flows, lower than what naturally occurs, are present due to this reach being used as a conduit for delivering water to She Oaks Weir and subsequently Geelong (Figure 10-31).



▪ **Figure 10-31 West Moorabool River Lal Lal Reservoir to below She Oaks at Sharps Road. Dashed red line – natural, solid blue line – current.**

10.3.3 Environmental values

Four native fish species have been recorded from the Moorabool River downstream of Lal Lal Reservoir to She Oaks Weir (Table 10-5). Of these, River Blackfish and Australian Smelt have a wide distribution in the Moorabool River that extends from the junction with the Barwon River to the junction with Coolebarghurk Creek (running up past Meredith) (NRE, 2003a).

Short-finned Eel are the only migratory species recorded upstream of She Oaks weir. The decrease in species richness and particular lack of migratory species upstream of She Oaks is most likely due to the presence of She Oaks Weir.

A number of other native fish species including Australian Grayling, Common Galaxias and Spotted Galaxias have been recorded further downstream in the vicinity of Batesford. Their distribution as far upstream of She Oaks is probable, but doubtful, considering a number of weirs downstream of She Oaks. Environmental flow recommendations have been provided for with these species in mind.

▪ **Table 10-5 Fish species recorded in the West Moorabool River below Lal Lal Reservoir to She Oaks Weir (NRE, 2003a; Zampatti and Grgat, 2000).**

Scientific name	Common name	Victorian conservation status	Migratory	Last observed
Gadopsis marmoratus	River Blackfish	Common	N	1998
Anguilla australis	Short-finned Eel	Common	Y	1998
Retropinna semoni	Australian Smelt	Common	N	1998
Nannoperca australis	Southern Pygmy Perch	Common	N	1998

The Environment Protection Authority (EPA) sampled the Moorabool River for macroinvertebrates at Sharp Road, She Oaks on four occasions. Two habitats (edge/pool, kick/riffle) were sampled from the EPA site in the autumn and spring of 1998 and 2000. The results of the combined data from the two seasons were compared against the draft SEPP macroinvertebrate objectives for regions classed as cleared hills and coastal plains (EPA, 2001). The indicators met all the respective EPA objectives and well exceeded the number of families and key families typically found in streams of this region. This indicates that in general, at this site, the macroinvertebrate community diversity is high and is not limited by habitat availability or water quality. Given the variety of hydraulic and substrate habitats within this reach, fast and slow flowing species such as net spinning caddis (Family: Hydropsychidae) and damselflies (Family: Coenagrionidae) would be present.

10.3.4 Water quality

Water quality within this reach is monitored at Morrisons (VWQMN site 232204). A summary of water quality data at this site and comparison to the draft SEPP objectives (EPA, 2001) and the ANZECC water quality guidelines (ANZECC, 2000) is provided in Table 2-14.

Total nitrogen has exceeded the draft SEPP objective for the last eleven years. However during the last four of these, 75^{th} percentile concentrations have stabilised to within 0.01 to 0.09 mg/L. On the other hand, total phosphorus and turbidity have complied. Trend analyses conducted by Barton (2000) show that turbidity concentrations have generally decreased at Morrisons since 1980.

Electrical conductivity exceeded the SEPP guideline of ≤ 500 µS/cm ten out of the last eleven years and reached a record 75 % of 1450 in 2002. Dissolved oxygen was well above the ANZECC guideline of ≥ 6 mg/L.

10.3.5 Issues

Prolonged periods of low flow, reduced median flow and lack of flow variability have been identified as the primary issues impacting environmental values present within this reach. This is primarily the result of impoundment of water at Lal Lal Reservoir and the need to transfer water to She Oaks for Geelong's water supply. Flow variability is crucial in maintaining populations of native fish species and improving habitat diversity. Species such as Australian Grayling and Common Galaxias require flushing flows for spawning cues and upstream migration from the sea. These cues are essential in maintaining native fish populations.

She Oaks Weir forms a major barrier preventing fish movement further upstream into this reach (Figure 10-32). It is probable, but doubtful, that other native fish species currently found further downstream such as Australian Grayling and Tupong would migrate upstream to She Oaks weir due to the presence of a number a small weirs between She Oaks and Batesford. If this migration was possible, habitat for native fish species is favourable due to the presence of deep pools and a variety of hydraulic habitats in the vicinity of Sharps Road.

In the vicinity of Morrisons and downstream of Lal Lal Reservoir at Elaine-Egerton Road stock access was evident and has perhaps accelerated bank erosion. Riparian management including willow poisoning and removal is currently undertaken near the confluence at Morrisons. Willows invade stream channels creating localised hydraulic problems and smother and destroy native vegetation.

■ **Figure 10-32 She Oaks Weir (March 2003).**

10.3.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 3 (Table 10-6).

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■ **Table 10-6 Ecological objectives for Reach 3.**

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Restore self-sustaining population of Australian Grayling	F1a	Habitat	Provide adequate habitat all year.	All year	Low
	F1b	Recruitment	Spawning possibly occurs when water levels rise (possibly mature adults migrate back upstream from sea to spawn). Spawn in same portion of river they inhabit	Spring/Summer	Freshes
	F1c	Movement	Upstream migration from sea at end of first year	Spring/Summer	High flows
Maintain self-sustaining population of Short-finned Eel	F2a	Habitat	Provide adequate habitat all year	All year	Low
	F2b	Movement	Upstream migration as elvers	Spring/Summer	High flows
Restore self-sustaining population of Common Galaxias	F3a	Habitat	Provide adequate habitat all year in pools	All year	Low
	F3b	Recruitment Movement	Juveniles migrate upstream from sea.	Spring/Summer	High
Restore self-sustaining population of Spotted Galaxias	F4a	Habitat	Provide adequate habitat all year in pools	All year	Low
	F4b	Recruitment	Juveniles migrate upstream from sea	Spring/Summer	High/Freshes
	F4c	Movement	Post-spawning move back upstream	Spring/Summer	High
Restore self-sustaining population of Short-headed Lamprey	F5a	Habitat	Provide adequate habitat all year in pools	All year	Low
	F5b	Recruitment	Downstream migration to sea (related to marked increases in freshwater discharge)	Autumn/Spring	Freshes/High flow
	F5c	Movement	Upstream spawning migration (reduced river flow and increased water temperature).	Spring/Summer	High
Restore self-sustaining population of Tupong	F6a	Habitat	Provide adequate habitat all year.	All year	Low
	F6b	Recruitment	Downstream spawning migration	Autumn/Winter	High
	F6c	Movement	Gradual upstream migration by juveniles	Winter	High
Maintain self-sustaining population of River Blackfish	F7a	Habitat	Provide adequate habitat all year in pools	All year	Low

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
	F7b	Movement	No apparent migration. Movement is generally limited to a home range 25 to 30 m, no spawning migration	Spring	High
Maintain self-sustaining population of Southern Pygmy Perch	F8	Habitat	Provide adequate habitat all year	All year	Low
Maintain self-sustaining population of Australian Smelt	F9a	Habitat	Provide adequate habitat all year	All year	Low
	F9b	Movement	Upstream movement through lower barrage in Barwon River (Koehn and O'Connor 1990)	Summer	Fresh
	F9c	Recruitment	Larvae washed to sea - In lower Barwon River, larvae not collected after high flows suggesting possibility that larvae are washed to sea (Koehn and O'Connor 1990). Diadromous populations have not been substantiated.	Winter	High
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1a	Disturbance	Reset macroinvertebrate community – colonisation by new species	Summer	Cease to flow
	M1b	Habitat maintenance	Restore riffles	Winter/Spring	Freshes
	M1c	Habitat availability	Maintain riffles	Spring/Summer	Low
Vegetation	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain in-stream macrophyte species diversity	V2a	Colonisation	Colonisation	Spring	Low
	V2b	Disturbance	Maintain instream species diversity	Summer	Low/cease to flow
Limit encroachment of in-stream vegetation and species common to non-flowing waterbodies such as Elodea and Azolla	V3	Disturbance	In-stream vegetation in the lower Moorabool can be dominated by species common to non-flowing water bodies	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg. Silver Wattle and Blackwood).	V4	Wetting	Establishment and growth of riparian species	Winter	High

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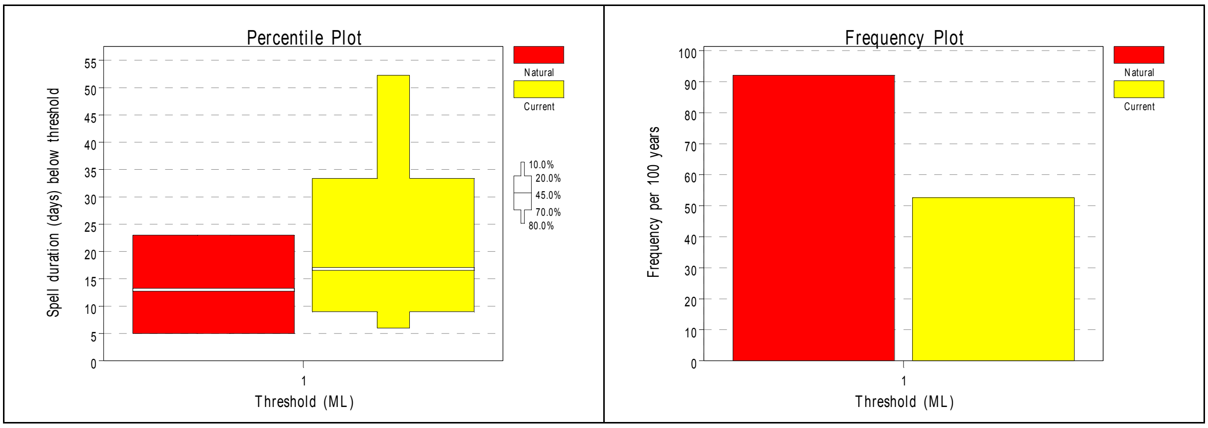
Habitat/Processes	No.	Process	Rationale	Timing of flow component	Relevant flow component
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1a	Transport of sediment	Flush sediment and maintain pool habitat	All year	High
Maintain physical processes	H1b	Organic matter transport	Flush organic matter through system that has accumulated in pools and perhaps behind weirs	Spring	High
Maintain woody debris/snag habitat	H2	Submergence	Bugs and fish (River Blackfish lay eggs on woody debris)	Anytime	Low
Water quality	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Rehabilitate dissolved oxygen in pools and weir-pools during periods of low flow	W1a	Mixing	No evidence of issues but could be low at times due to low flows.	Spring	Freshes
	W1b	Habitat maintenance	No evidence of issues but could be low at times due to low flows.	Summer	Low
Rehabilitate total nitrogen concentrations	W2	Habitat maintenance	Total nitrogen concentrations have exceeded the SEPP objective since 1992.	Summer	Low
Rehabilitate electrical conductivity	W3a	Habitat maintenance	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Summer	Low
	W3b	Mixing	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Spring	Freshes

10.3.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 3 is shown in Table 10-7.

Summer – Cease to flow

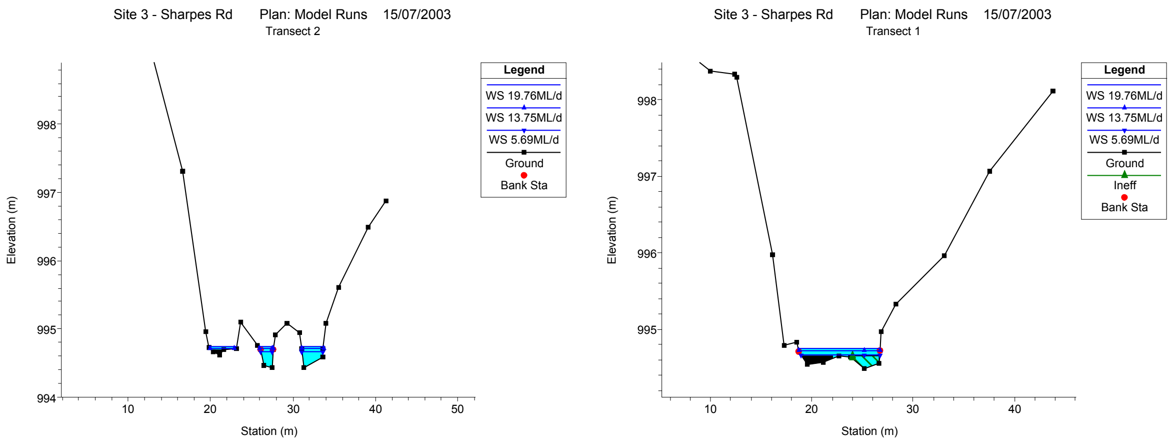
Cease to flow events are recommended to create disturbance that maintains the macroinvertebrate species diversity already present within this reach. Disturbance creates patches and a range of habitats that enable colonisation by a range of predatory and grazing macroinvertebrate species (Lake, 2003). The recommendation for a flow of 0 ML/d occurring once a year replicates the natural frequency and is deemed sufficient for resetting macroinvertebrate communities. A duration of ten days is long enough for biota in the riffles to be affected by water loss yet not too long so as to reduce habitat quality in the pools (Figure 10-33).



■ **Figure 10-33 Duration (left) and frequency (right) of summer spells below 1 ML/d under natural and current conditions in Reach 3.**

Summer – low flow

A low flow of 20 ML/d is recommended for Reach 3. Flows of this magnitude will maintain minimum habitat conditions for aquatic biota by inundating the bottom of the channel yet leave benches exposed for entrainment and weathering of organic matter (Figure 10-34). The HEC-RAS model indicates a flow of this magnitude would provide a maximum depth of 1.6 m in the pools at Transect 7 and 26 cm in the shallower areas. A maximum depth of 26 cm is considered enough to allow longitudinal fish movement and connectivity that will slow the deterioration of water quality in pools. Any flow magnitude less than 20 ML/d will not provide adequate flow area and velocity to allow fish movement between pools following cease to flow events.

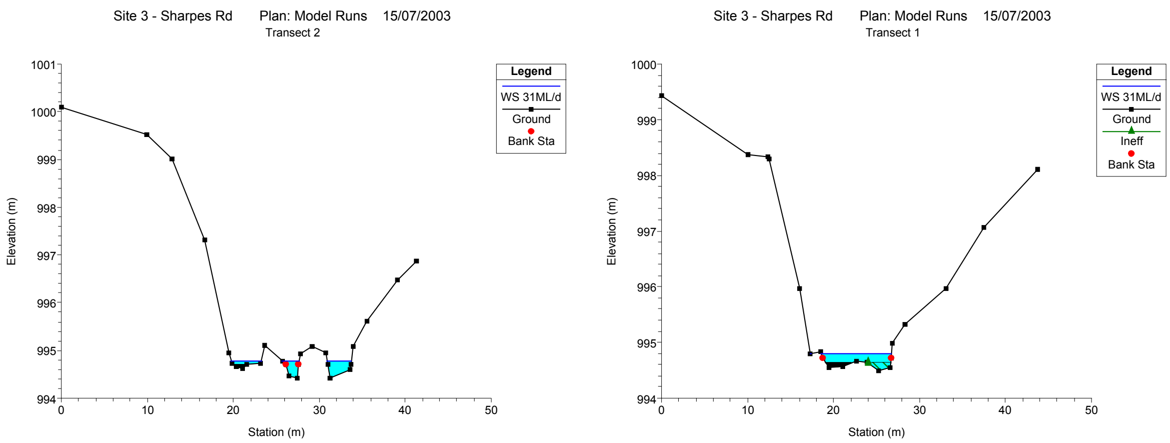


■ **Figure 10-34 Stage height at Transect 2 (left) and Transect 1 (right) for trialed summer low flows of 20, 14 and 6 ML/d at Reach 3.**

Summer – fresh

The recommended summer fresh flow of 31 ML/d is a critical cue for Australian Grayling to spawn during summer to early autumn and the upstream migration of Spotted Galaxias that are found downstream of She Oaks in the vicinity of Batesford. In addition, it will increase the depth in the channels inundated during low flow by a minimum of 3 cm and provide flow in the channels that were only wetted during low flows (Figure 10-35). This will enhance connectivity between pools, allowing fish movement in the deeper channels and refuge in the shallower channels as well as improving water quality by flushing and turning over pools.

A frequency of once per year may not be biological significant and more than one, preferably three freshes, are recommended to ensure a biological effect (Figure 10-36). Although only a short duration is required to scour excess silt from within riffles and flush nutrients from deep pools, a duration of ten days is recommended to ensure fish respond to the cue and have the opportunity to move.



▪ **Figure 10-35 Stage height at Transect 2 (left) and Transect 1 (right) for recommended summer fresh threshold of 31 ML/d at Reach 3.**

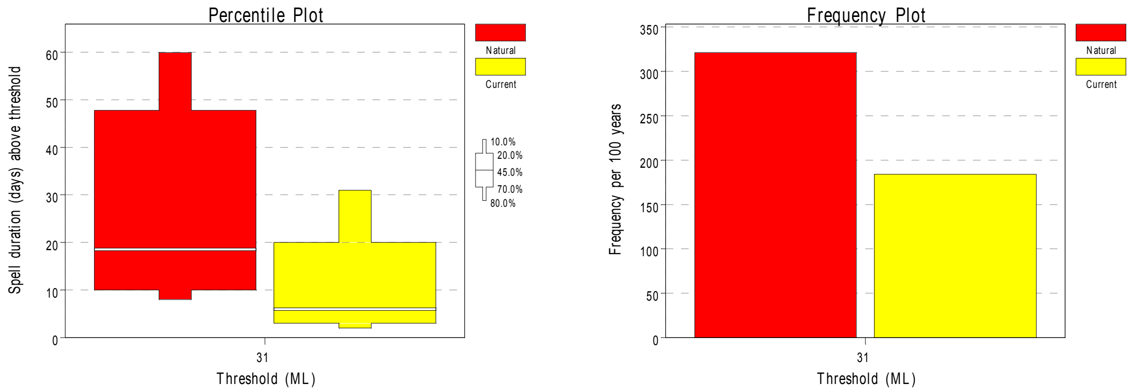


Figure 10-36 Duration (left) and frequency (right) of summer spells above 31 ML/d under natural and current conditions in Reach 3.

Winter – low

A winter low flow of 83 ML/d is recommended to provide a range of hydraulic habitats for native fish and macroninvertebrates. At this flow, high and low flow habitats will be connected as water depth will be maintained in the pools and all channels inundated either side of the vegetated bar at Transects 2 and 3 (Figure 10-37, Figure 10-38). This will provide excellent habitat for native fish particularly where large woody debris is inundated and the maintenance of riffle habitat for macroinvertebrates. Maximum water depth in the shallower channel areas is 37 cm and adequate for the movement of native fish species in this reach. Flows of this magnitude will also inundate most emergent and marginal aquatic vegetation zones established around the edge of the wetted channel and will suppress encroaching terrestrial vegetation that is sensitive to inundation.

Flows lower than 83 ML/d will not inundate all of the channel at most transects, therefore limiting the amount of habitat available to instream fauna.

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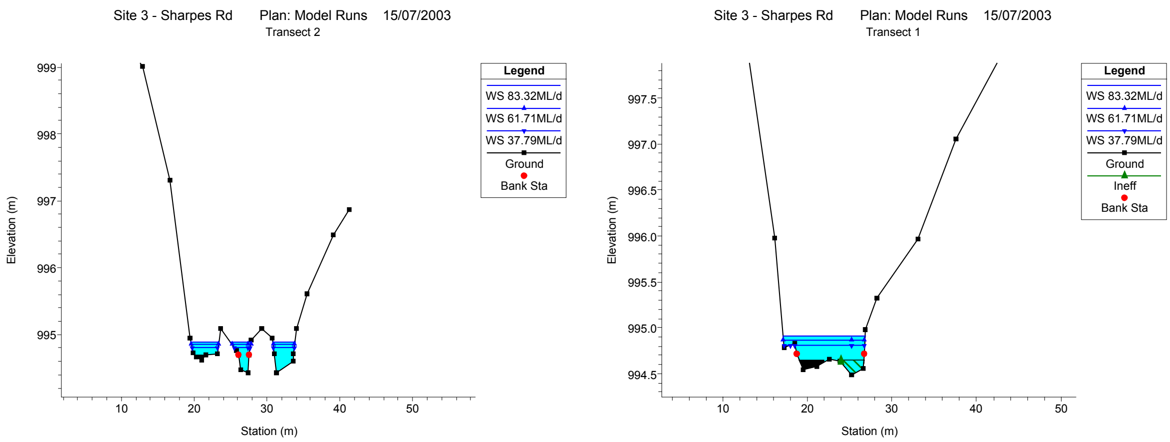
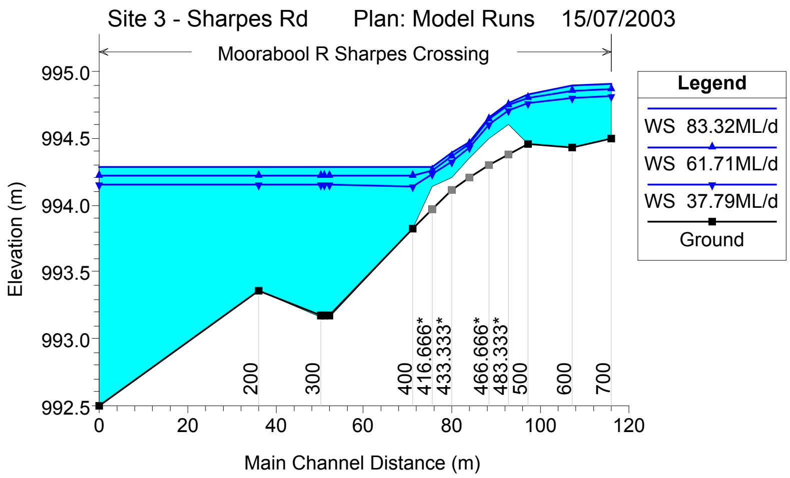


▪ **Figure 10-37 Stage height at Transect 2 (left) and Transect 1 (right) for trialed winter low flows of 38, 62 and 83 ML/d at Reach 3.**

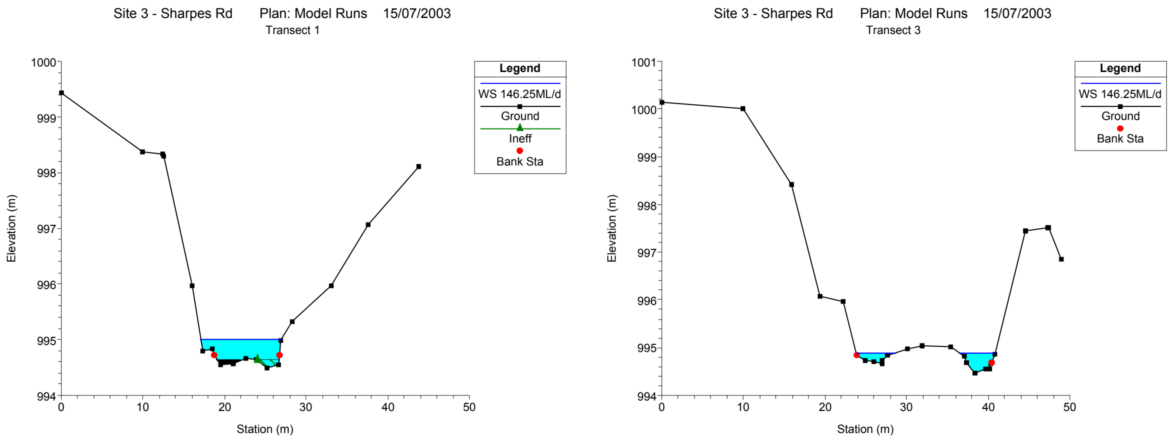


▪ **Figure 10-38 Longitudinal profile for recommended winter low threshold of 83 ML/d at Reach 3.**

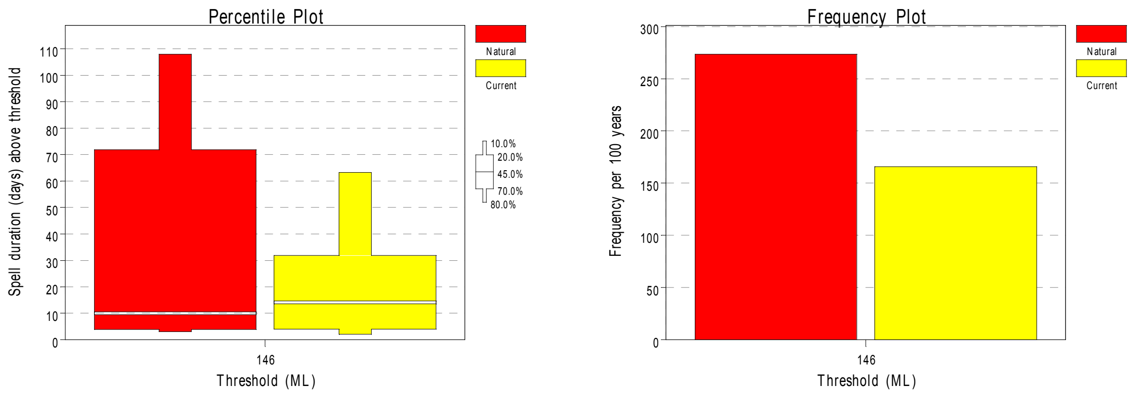
Winter – fresh

This reach is characterised by low level benches and a vegetated bar at Transect 2 and 3. A winter fresh flow of 146 ML/d will inundate the margins of these benches and assist in the reduction of cover of terrestrial exotic grasses favoured by low hydrological stability to native floodplain species such as rush (Figure 10-39). In addition, this flow will flush the litter present in the high flow left channel downstream, providing organic matter and therefore energy to sites further downstream.

The winter fresh should occur at a maximum of twice per year in order for the effects to be cumulative. A duration of five days is recommended on the basis that this is adequate timing for inundation of terrestrial exotic grasses and movement of organic litter downstream (Figure 10-40).



- **Figure 10-39 Stage height at Transect 1 (left) and Transect 3 (right) for recommended winter fresh threshold of 146 ML/d at Reach 3.**



- **Figure 10-40 Duration (left) and frequency (right) of winter spells above 146 ML/d under natural and current conditions in Reach 3.**

Winter – high

Higher flows in winter are required to maintain the geomorphic processes of re-shaping the channel elements (scouring pools etc) and maintenance (ie. wetting) of riparian communities such as tea-tree. A flow of 3115 ML/d will ensure all channels are thoroughly inundated, and provide a cue for the downstream spawning migration of Tupong and gradual upstream migration by juveniles (Figure 10-41). A flow of this magnitude will not inundate the high flow channel at Transect 4 and is not required to achieve the desired ecological objectives.

The winter high flow of 3115 ML/d also corresponds to the annual return high flow (Figure 10-42). A higher frequency will not provide any extra biological benefits. A flow of this magnitude will achieve

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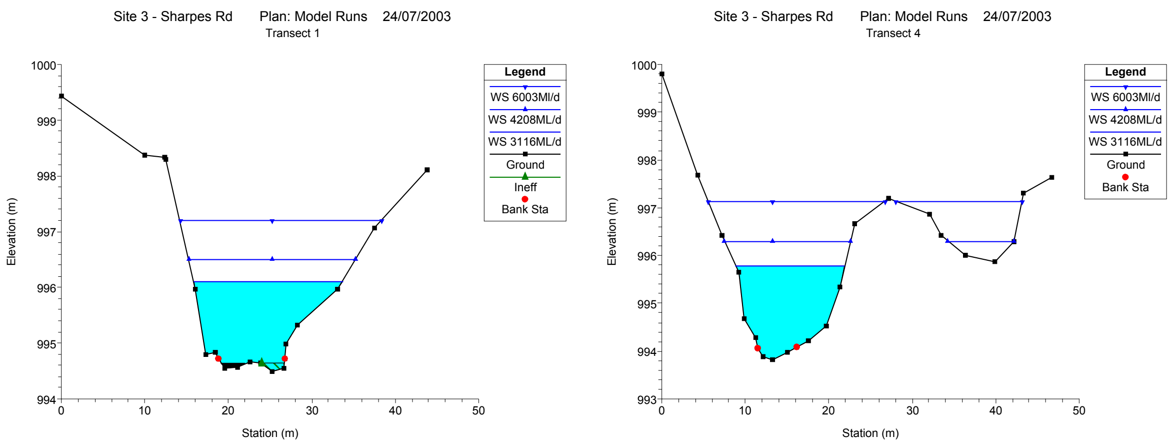
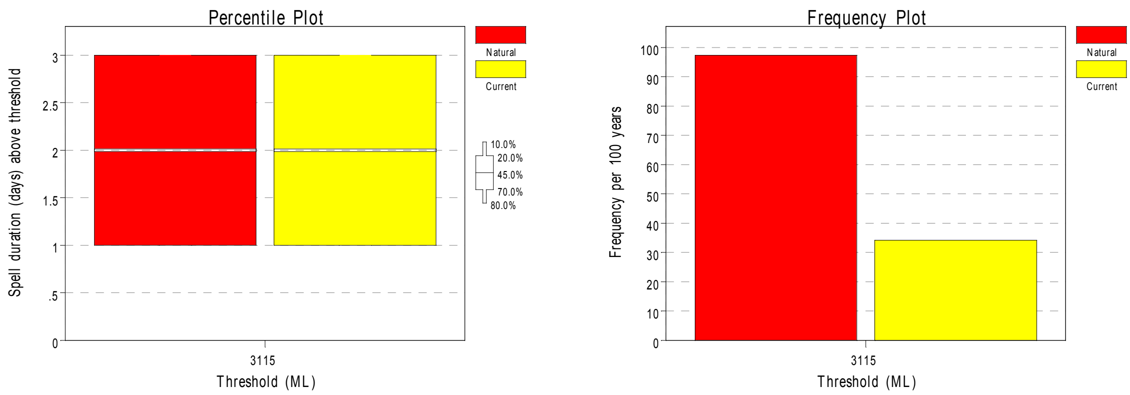
the desired ecological effects in one day and is 70% of the natural exceedance flow events. The recommended duration of one to two days is adequate time for sediment to be transported and Tupong to move downstream.

Overbank flows have not been recommended for this reach as there are no significant wetlands identified in the area and little floodplain value.



■ **Figure 10-41 Stage height at Transect 2 (left) and Transect 4 (right) for trialed winter high flows of 3115, 4209 and 6003 ML/d at Reach 3.**



■ **Figure 10-42 Duration (left) and frequency (right) of winter spells above 3115 ML/d under natural and current conditions in Reach 3.**

Table 10-7 Flow recommendations for Reach 3.

River	Moorabool River			Reach	East Moorabool River below Lal Lal Reservoir to Sharp Road, She Oaks
Flow					Rationale
Season	Flow component	Magnitude	Frequency	Duration	Objective
Summer Dec - May	Cease to flow	0 ML/d	Annual	10 days	M1a, V2b
	Low flow	20 ML/d	Annual	Dec - May	F1a, F2a, F2a, F3a, F4a, F5a, F6a, F8, F9a, V2b, H2, W1a, W1b, W2, W3a
	Fresh	> 31 ML/d	Three a year	10 days	F1b, F4b, F5c, F9b, H1a, H1b
Winter Jun - Nov	Low flow	83 ML/d	Annual	Jun - Nov	F1a, F2a, F3a, F4a, F5a, F6a, F8, F9a, V2a, H2
	Fresh	> 146 ML/d	Two a year	5 days	M1b, V3, W1a, W1b, W3b
	High flow	> 3000* ML/d	One a year	1 - 2 days	F1c, F2b, F3b, F4c, F5b, F6a, F6c, F7b, F9c, V3, V4, H1a, H1b

* This value has been rounded to 3000 ML/d instead of 3115 ML/d for ease of reporting

10.4 Reach 4: Moorabool River below Sharp Road, She Oaks to the confluence with the Barwon River.

This reach is located downstream of Sharp Road, She Oaks Weir, to the confluence with the Barwon River at Fyansford (Figure 10-43).

The in-stream and riparian vegetation communities varied throughout the reach and ranged from poor to fair condition at the more populated lower end to excellent condition at the top end of the reach at the southern end of Steiglitz Historical Park.

Figure 10-43 Looking upstream from the confluence of the Barwon River (left) and Moorabool River (right) (March 2003).

10.4.1 Site description

One survey site was located immediately downstream of Bakers Bridge Road. At this site, the river was a deeply incised u-shaped channel with a series of alternating deep pools and shallow glides (Figure 10-44, Figure 10-45). The channel is mostly controlled by bedrock in the deeper pools with interstitial fines and organic matter. In the shallower glides, the substrate consisted of cobbles, sand and fine organic matter.

Riparian vegetation consisted of very sparse mature River Red Gums along with occasional Blackwood on the bank face. Stock access was evident where pasture grasses were dominant or in some cases no grass, but bare earth.

In-stream vegetation consisting of floating green Azolla was present in most pools, along with emergent species such as rush, Cumbungi, Common Reed, Water Ribbons (*Triglochin procerum*) and submerged species such as Ribbonweed, Elodea, Watermilfoil and spike rush (*Eleocharis spp*). A light loading of large woody debris was also present.

- **Figure 10-44 Moorabool River Bakers Bridge Road at Transect 1 cross section (May 2003).**

- **Figure 10-45 Moorabool River Bakers Bridge Road at Transect 5 cross section (May 2003)**

10.4.2 Hydrology

Figure 10-46 shows the impact from diverted flows at She Oaks Weir and large extractions by licensed diverters from a number of small weirs within this reach. Compared to natural, current cease to flow and median flows have decreased (from 68 ML/d to 10 ML/d) such as there is a loss in flow variability. Flows are now low and more constant.

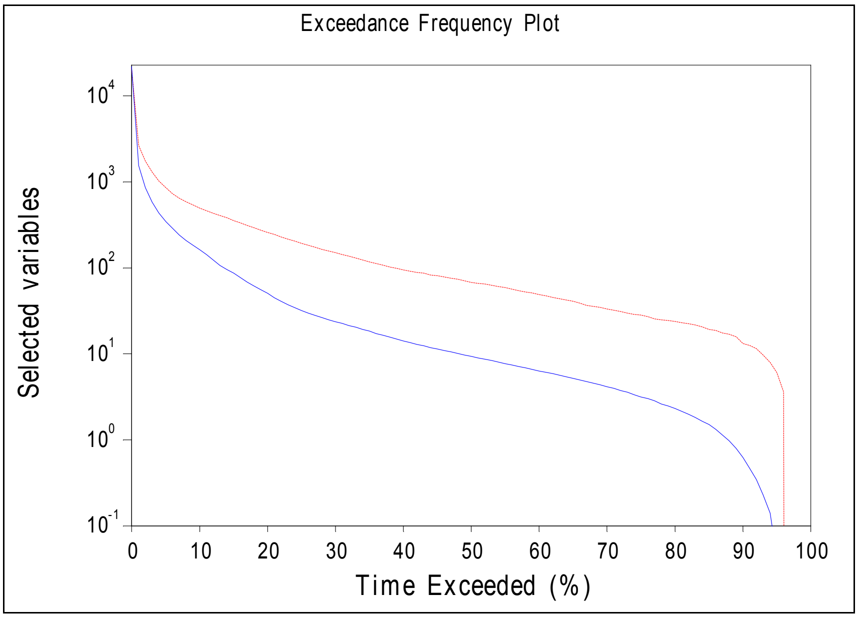


Figure 10-46 Moorabool River below She Oaks at Sharp Road to below Batesford. Dashed red line – natural, solid blue line – current.

10.4.3 Environmental values

Eight species of native fish have been previously recorded from the Moorabool River downstream of She Oaks Weir (Table 10-8). Surveys indicate that these species, except for the Short-finned Eel are restricted in distribution to the lower reaches downstream of Batesford.

One species, the Australian Grayling, is listed as vulnerable in Victoria, listed under the Victorian *FFG Act 1988*, listed as threatened under the Commonwealth *EPBC Act 1999* and listed on the 2002 IUCN Red List of Threatened Species.

Table 10-8 Fish species recorded in the Moorabool River below She Oaks weir (NRE, 2003a; Zampatti and Grgat, 2000).

Scientific name	Common name	Victorian conservation status	Migratory	Last observed
Gadopsis marmoratus	River Blackfish	Common	N	1998
Galaxias maculatus	Common Galaxias	Common	Y	1998
Galaxias truttaceus	Spotted Galaxias	Common	Y	1998
Anguilla australis	Short-finned Eel	Common	Y	1998
Mordacia mordax	Short-headed Lamprey	Common	Y	1998
Prototrocetes maraena	Australian Grayling	Vulnerable	Y	1998
Nannoperca australis	Southern Pygmy Perch	Common	N	1998
Pseudaphritis urvillii	Tupong	Common	Y	1998

A total of 11 Victorian threatened water dependent bird species have been recorded within the Moorabool River catchment downstream of Moorabool Reservoir and Bostock Reservoir (NRE, 1999b) (Table 2-19). This list includes the critically endangered Little Egret and Intermediate Egret and the endangered Great Egret. Five species are listed under the *FFG Act 1998*. The Great Egret is also declared internationally significant by the Japan and Australia Migratory Bird (JAMBA) and China and Australian Migratory Bird (CAMBA) Agreements.

10.4.4 Water quality

Water quality monitoring is undertaken on the Moorabool River at Batesford (VWQMN site 232202). A summary of water quality data at this site and comparison to the draft SEPP objectives (EPA, 2001) and the ANZECC water quality guidelines (ANZECC, 2000) is provided in Table 2-15.

The draft SEPP objective for total nitrogen and electrical conductivity has been exceeded on nine occasions for which it was measured during the past eleven years. Total phosphorus concentrations were also high and did not comply with the draft SEPP objective of ≤ 0.04 mg/L for seven of the nine years statistics were able to be produced. Dissolved oxygen can be potentially low due to extended periods of low flow and has the potential to be lethal to native fish. However, the dissolved oxygen has met the ANZECC (2000) guideline since 1992. Turbidity was quite variable and did not comply with the draft SEPP objective of ≤ 10 NTU during 1992-93, 1996 and 2000. pH complied with all draft SEPP objectives.

10.4.5 Issues

Prolonged periods of low flow, reduced median flow and lack of flow variability have been identified as the primary issues impacting environmental values present within this reach. This is the result of diversions at She Oaks, large extractions by licensed diverters and a number of small weirs impeding flow. Flow variability is crucial in maintaining populations of native fish species and improving habitat diversity.

However, it is likely that the prolonged low flow is this reach is the crucial factor for sustaining the high value fish communities and good riparian and instream conditions (such as habitat for River Blackfish and populations of Australian Grayling). In addition, increased flow may provide greater movement to native species such as River Blackfish but will also provide greater passage through the catchment to exotic species such as Carp. Australian Grayling are found within this reach and as such the flows should be managed for this vulnerable species.

Downstream of She Oaks, a number of weirs have been constructed over the past 50 years (Figure 10-47). The weirs create pools upstream allowing licensed diverters to extract water. Behind the weirs, organic matter and silt accumulate smothering aquatic vegetation and reducing habitat availability. Higher and more regular flushing flows should alleviate this problem over time.

▪ **Figure 10-47 Looking downstream at weir from bridge on the Midland Highway (March 2003).**

10.4.6 Ecological objectives

Based on the information obtained from the background review and the field inspection, ecological objectives have been developed for Reach 4 (Table 10-9).

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- **Table 10-9 Ecological objectives for Reach 4.**

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
Maintain self-sustaining population of Australian Grayling	F1a	Habitat	Provide adequate habitat all year.	All year	Low
	F1b	Recruitment	Spawning possibly occurs when water levels rise (possibly mature adults migrate back upstream from sea to spawn). Spawn in same portion of river they inhabit	Spring/Summer	Freshes
	F1c	Movement	Upstream migration from sea at end of first year	Spring/Summer	High flows
Maintain self-sustaining population of Short-finned Eel	F2a	Habitat	Provide adequate habitat all year	All year	Low
	F2b	Movement	Upstream migration as elvers (also to overcome weirs)	Spring/Summer	High flows
Maintain self-sustaining population of Common Galaxias	F3a	Habitat	Provide adequate habitat all year	All year	Low
	F3b	Recruitment/Movement	Juveniles migrate upstream from sea.	Spring/Summer	High
Maintain self-sustaining population of Spotted Galaxias	F4a	Habitat	Provide adequate habitat all year	All year	Low
	F4b	Recruitment	Juveniles migrate upstream from sea	Spring/Summer	High/Freshes
	F4c	Movement	Post-spawning move back upstream	Spring/Summer	High
Maintain self-sustaining population of Short-headed Lamprey	F5a	Habitat	Provide adequate habitat all year	All year	Low
	F5b	Recruitment	Downstream migration to sea (related to marked increases in freshwater discharge)	Autumn/Spring	Freshes/High flow
	F5c	Breeding	Upstream spawning migration (reduced river flow and increased water temperature).	Spring/Summer	High
Maintain self-sustaining population of Tupong	F6a	Habitat	Provide adequate habitat all year.	All year	Low
	F6b	Recruitment	Downstream spawning migration	Autumn/Winter	High
	F6c	Movement	Gradual upstream migration by juveniles	Winter	High
Maintain self-sustaining population of River Blackfish	F7a	Habitat	Provide adequate habitat all year	All year	Low
	F7b	Movement	No apparent migration. Movement is generally	Spring/Summer	High

Fish	No.	Process	Rationale	Timing of flow component	Relevant flow component
			limited to a home range 25 to 30 m, no spawning migration		
Maintain self-sustaining population of Southern Pygmy Perch	F8	Habitat	Provide adequate habitat all year	All year	Low
Macroinvertebrates	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain diverse macroinvertebrate community consisting of both slow water (Coenagrionidae) and fast water (Hydropsychidae) species.	M1a	Disturbance	Reset macroinvertebrate community – colonisation by new species	Summer	Freshes
	M1b	Habitat maintenance	Restore riffles	Winter/Spring	Freshes
	M1c	Habitat availability	Maintain riffles	Spring/Summer	Low
Vegetation	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Maintain in-stream macrophyte species diversity	V2a	Colonisation	Colonisation	Spring	Low
	V2b	Disturbance	Maintain instream species diversity	Summer	Low
Limit encroachment of in-stream vegetation and species common to non-flowing waterbodies such as Elodea and Azolla.	V3	Disturbance	In-stream vegetation in the lower Moorabool can be dominated by species common to non-flowing water bodies (weir pools create stagnant flow).	Winter/Spring	Freshes/High
Maintenance of riparian vegetation communities (eg. Silver Wattle and Blackwood).	V4	Wetting	Establishment and growth of riparian species	Winter	High
Maintain floodplain communities	V5	Inundation	Establishment and growth of floodplain species	Spring	High
Habitat/Processes	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Re-shape in-channel forms to maintain physical habitat diversity and complexity	H1	Transport of sediment	Flush sediment from behind weirs and maintain pool habitat	Winter	High
Maintain physical processes	H2	Organic matter transport	Flush organic matter through system that has accumulated in pools and perhaps behind weirs	Spring	High
Maintain woody debris/snag habitat	H3	Submergence	Bugs and fish (River Blackfish)	Anytime	Low

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Water quality	No.	Process	Rationale	Timing of flow component	Relevant flow component
Rehabilitate dissolved oxygen in pools and weir-pools during periods of low flow	W1a	Mixing	No evidence of issues but could be low at times due to low flows.	Spring	Freshes
	W1b	Habitat maintenance	No evidence of issues but could be low at times due to low flows.	Summer	Low
Rehabilitate total nitrogen concentrations	W2	Habitat maintenance	Total nitrogen concentrations have exceeded the SEPP objective since 1992.	Summer	Low
Rehabilitate electrical conductivity	W3a	Habitat maintenance	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Summer	Low
	W3b	Mixing	Electrical conductivity have exceeded the SEPP objective 10 out of the last 11 years.	Spring	Freshes
Floodplains	**No.**	**Process**	**Rationale**	**Timing of flow component**	**Relevant flow component**
Restore floodplain communities	FLa	Wetting	River Red Gum regeneration	Spring	High
Restore floodplain processes (connectivity)	FLb	Inundation	Floodplain areas have been identified in the lower reaches, in the vicinity of Lethbridge.	Spring	High

10.4.7 Flow recommendations

Flow recommendations have been provided for the flow components described below. A summary of the recommendations for Reach 4 is shown in Table 10-10.

Summer –cease to flow

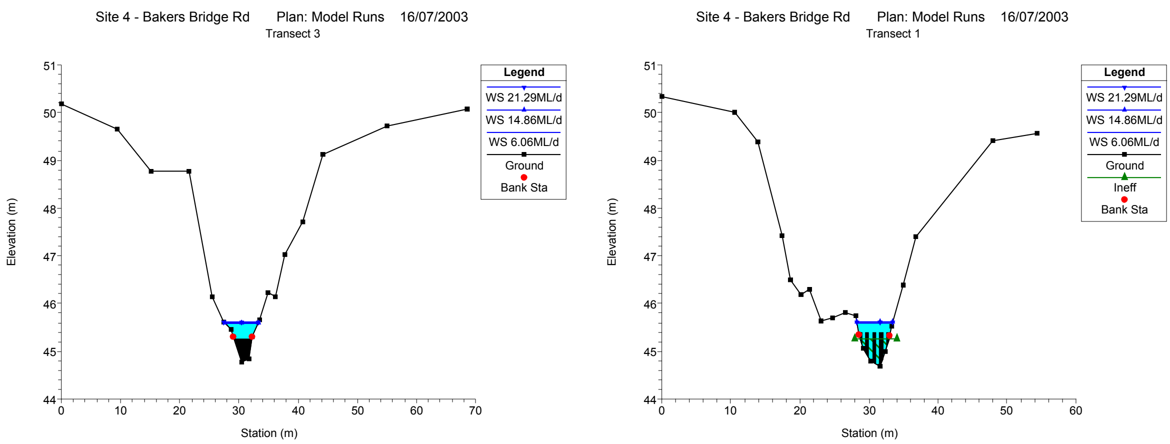
No cease to flow recommendation has been made for this reach because natural cease to flow periods were infrequent and short-lived (Figure 10-46). Cease to flow periods are unlikely to provide any real benefits and may pose a significant risk to remaining environmental values.

Summer – low

A low flow of 21 ML/d is recommended for Reach 4. A flow of this magnitude maintains minimum habitat conditions for aquatic biota by inundating the bottom of the channel and allowing adequate flow for fish movement between the shallow glides and deeper pools. HEC-RAS outputs of 6, 15 and 21 ML/d revealed little difference in depth at each of the sites, probably as a result of channel confinement (Figure 10-48, Figure 10-49). The depth at the shallowest point within the site at Transect 3 was 32 cm for 6 ML/d compared to 35 cm for 21 ML/d. Both of these depths will provide longitudinal connectivity throughout the reach.

However, these outputs also indicate that flows less than 21 ML/d will not provide adequate velocity in the glides. Velocity at each of the cross sections, for each of the modelled flows, showed a maximum three-fold increase between 6 ML/d and 21 ML/d. This is particularly important at Transect 3 where the minimum velocity was 0.06 cm/s and maximum 0.18 cm/s. A larger velocity is preferable to ensure flow through vegetation in the shallower areas and rehabilitation of dissolved oxygen in the pools.

■ **Figure 10-48 Bakers Bridge Transect 1 looking downstream (May 2003).**



■ **Figure 10-49 Stage height at Transect 3 (left) and Transect 1 (right) for trailed summer low flows of 6, 15 and 21 ML/d.**

Summer – fresh

Freshes during the summer months, December to May, are important flow components for this reach. The recommended summer fresh flow of 32 ML/d is a critical cue for Australian Grayling, which require a rise in water level from May to July when larvae are washed to sea and another regular rise

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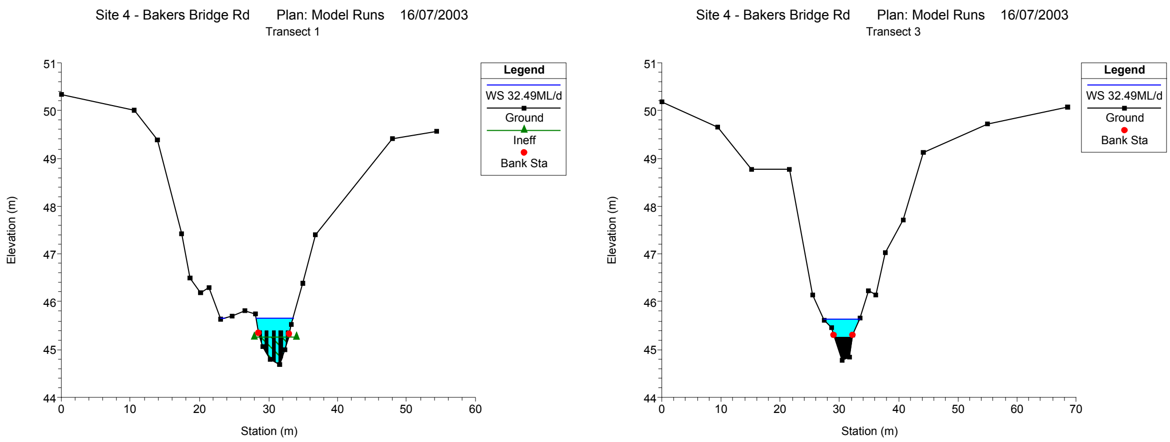
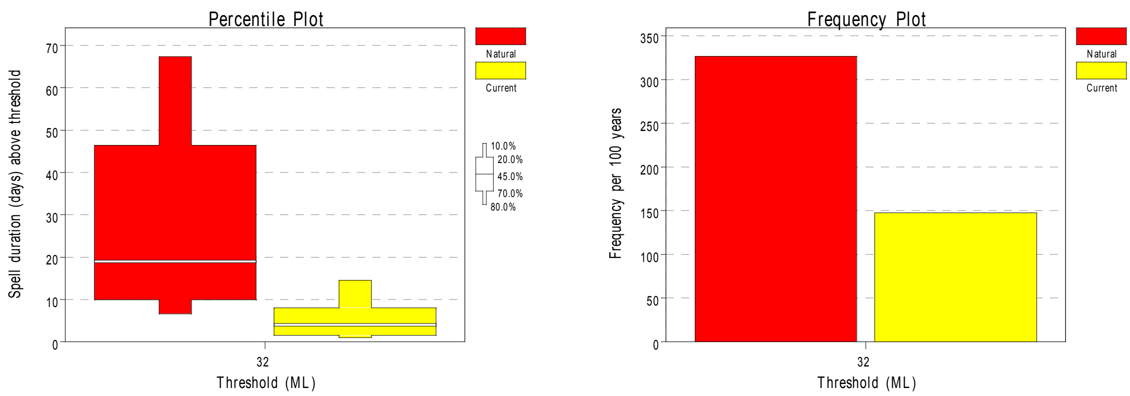
from February to April as a spawning trigger. In addition, these flows will provide greater wetted habitat area in the channels and increase depth in the glides by 3 cm (Figure 10-50). This will enhance connectivity between the shallower glides and deeper pools.

Summer freshes of 32 ML/d would occur naturally about three times per year. Currently they occur less than twice a year (Figure 10-51). A fresh occurring once per year may not be biologically significant and more than one fresh, preferably three are required to ensure that the cue has its effect. A duration of ten days is recommended to ensure Australian Grayling receive the cue for movement and actually have time to move, as well as disperse low flow favoured vegetation species such as Azolla and provide flushing and mixing within the deeper pools. The natural flow duration of ten days is the 70% exceedance flow of natural events.



■ **Figure 10-50 Stage height at Transect 1 (left) and Transect 3 (right) for recommended summer fresh threshold of 32 ML/d at Reach 4.**

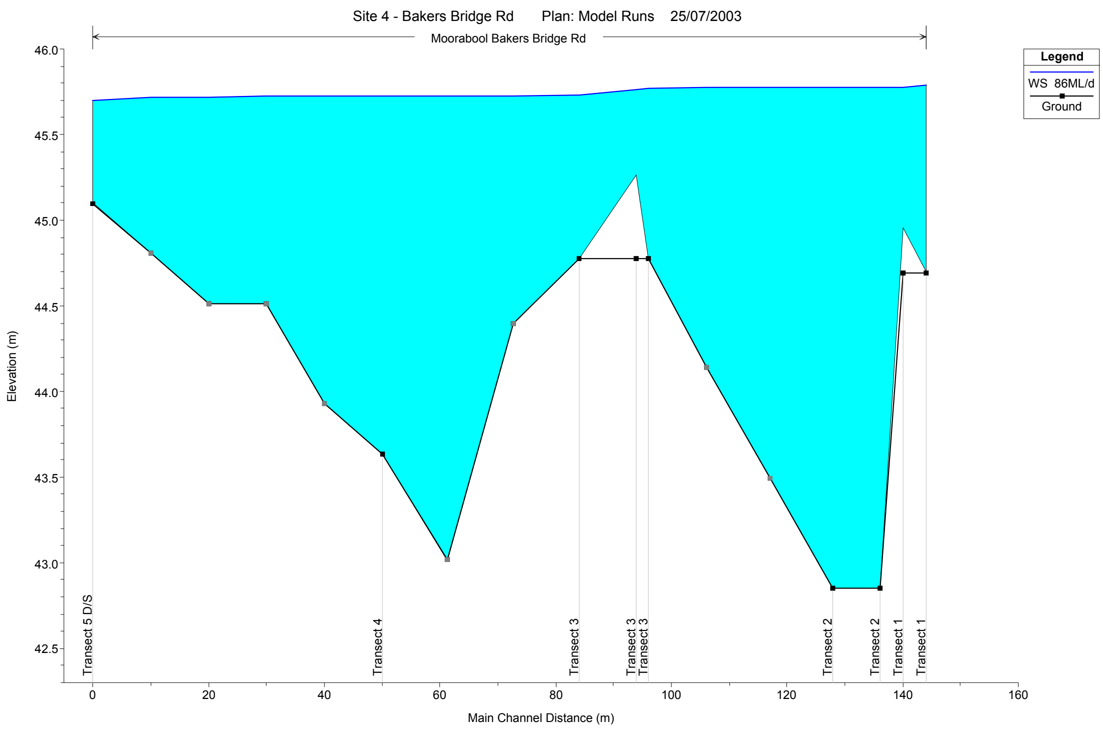


■ **Figure 10-51 Duration (left) and frequency (right) of summer spells above 32 ML/d under natural and current conditions in Reach 4.**

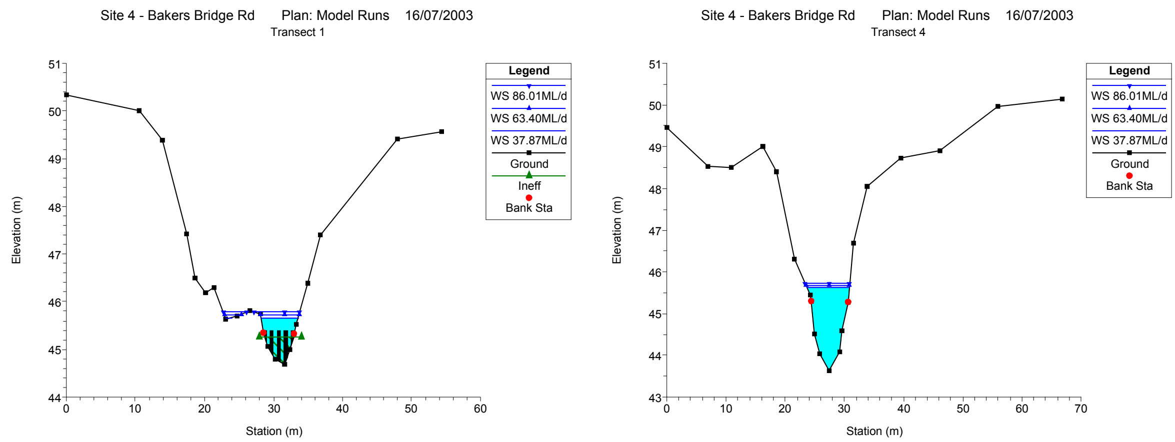
Winter – low

The winter low flow of 86 ML/d is recommended to provide a sustained link between the glide and pools habitats throughout the reach (Figure 10-52). As such, an increase in the wetted area of the channel and a range of hydraulic habitats will be provided. At Transect 1 for example, the left bank channel will be wetted therefore providing a refuge for native fish (Figure 10-53, Figure 10-54). In addition, sustained flow will suppress encroaching terrestrial vegetation that has been able to colonise the shallow glides during summer flows.

Flows lower than 86 ML/d will not provide a link between all habitats in the reach and in particular wet the high flow channel at Transect 1 (Figure 10-53).



■ **Figure 10-52 Longitudinal profile for recommended winter low threshold of 86 ML/d at Reach 4.**

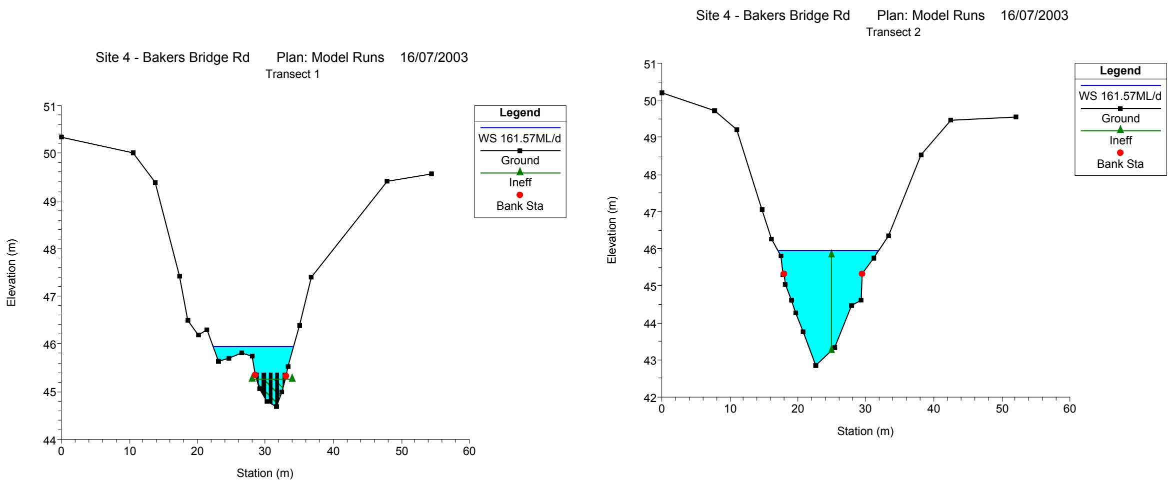


▪ **Figure 10-53 Stage height at Transect 1 (left) and Transect 4 (right) for modelled winter low flows of 86, 6. and 38 ML/d at Reach 4.**

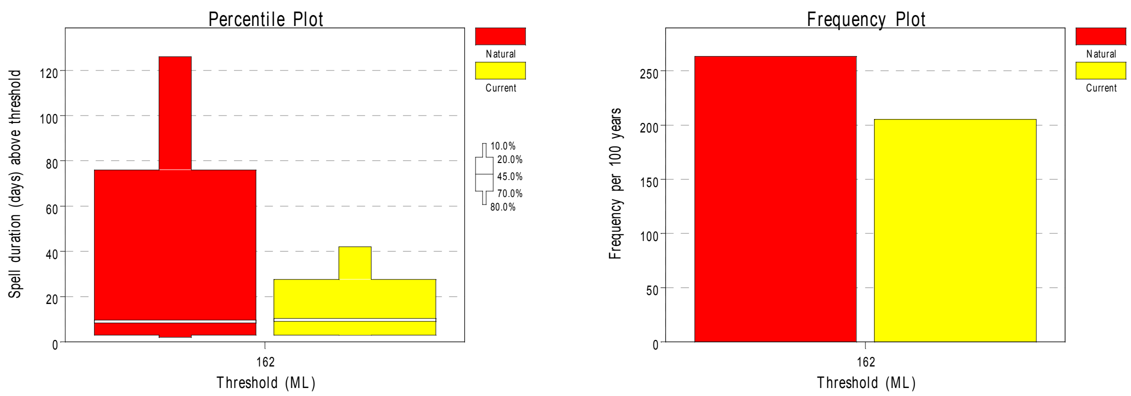
▪ **Figure 10-54 Bakers Bridge Road at Transect 1 looking downstream (May 2003).**

Winter – fresh

The recommended winter fresh flow of 162 ML/d is critical in assisting the downstream migration of Short-headed Lamprey to sea and providing further movement to other species such as River Blackfish. In addition, it will inundate the higher benches and link the high and low flow channel and Transect 1 (Figure 10-55). This will ensure organic material present on the benches is swept into the river, providing an important source of carbon substrate and energy downstream. It is recommended that a winter fresh should occur three times per year during this period in order to provide adequate opportunity for fish movement over weirs and more closely replicate the natural conditions (Figure 10-56). The duration is recommended to be a minimum of ten days in order to provide a sufficient timing for fish movement during each event.



■ **Figure 10-55 Stage height at Transect 1 (left) and Transect 2 (right) for winter fresh flow threshold of 162 ML/d at Reach 4.**



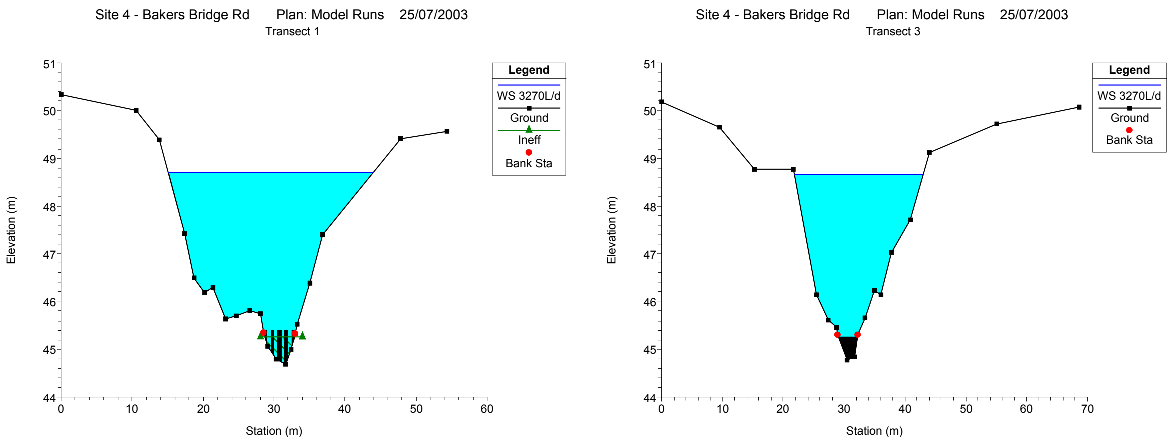
■ **Figure 10-56 Duration (left) and frequency (right) of winter spells above 162 ML/d under natural and current conditions in Reach 4.**

Winter – high

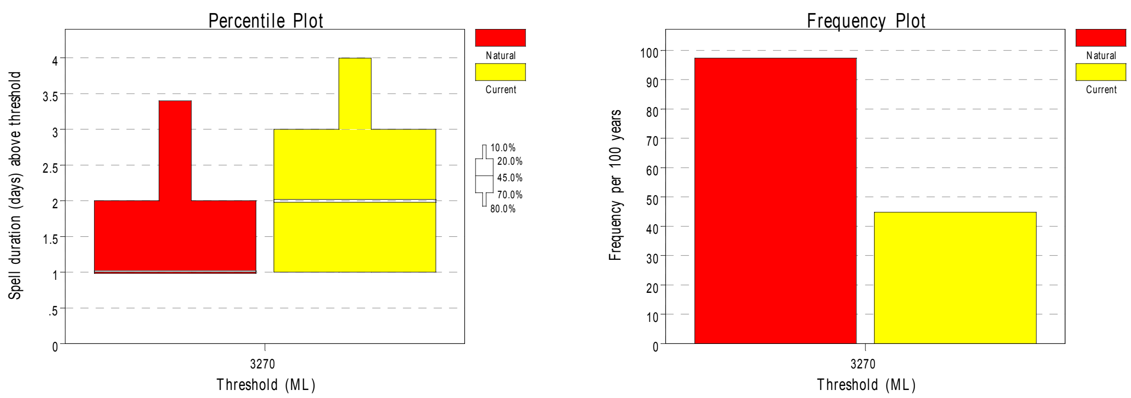
Winter high flows are recommended to provide geomorphic disturbance and inundation of River Red Gums and floodplains identified further downstream in the vicinity of Lethbridge. In addition, juvenile Australian Grayling also require high flows for adult movement between October to December and larvae which are washed to sea between May and July.

A flow of 3270 ML/d will almost fill the channel, inundating all benches and riparian communities as well as transporting sediment downstream (Figure 10-57). A flow of this magnitude will also remove sediment and organic matter accumulated behind the weirs and provide increased inputs to the Barwon River and associated lakes.

Under natural conditions flows of this magnitude occurred once a year, however under current conditions this frequency occurred once every two years (Figure 10-58). An annual event is recommended, as a frequency greater than this for a magnitude of this size is not required ecologically and would in fact create excessive disturbance to aquatic biota. The recommended duration of one to two days is adequate time for sediment to be transported and Australian Grayling to move downstream.



▪ **Figure 10-57 Stage height at Transect 1 (left) and Transect 3 (right) for winter high flow threshold of 3270 ML/d at Reach 4.**



▪ **Figure 10-58 Duration (left) and frequency (right) of winter spells above 3270 ML/d under current and natural conditions in Reach 4.**

▪ **Table 10-10 Flow recommendations for Reach 4.**

River	Moorabool River			Reach	Moorabool River below Sharp Road, She Oaks to confluence with the Barwon River
Flow					Rationale
Season	Flow component	Magnitude	Frequency	Duration	Objective
Summer Dec - May	Cease to flow	NR			
	Low flow	21 ML/d	Annual	Dec - May	F1a, F2a, F4a, F5a, F6a, F7a, F8, M1c, V2a, V2b, H3, W2, W3a
	Fresh	> 32 ML/d	Minimum 3 per year	10 days	F1b, F3a, F3b, F4b, M1a, W1a, W3b
Winter Jun - Nov	Low flow	86 ML/d	Annual	Jun - Nov	F2a, F3a, F4a, F5a, F6a, F7a, F8, H3
	Fresh	> 162 ML/d	Minimum 3 per year	10 days	F1b, F4b, M1b, W1a
	High flow	> 3000* ML/d	One year	1 – 2 days	F1c, F2b, F4b, F4c, F5b, F5c, F6b, F6c, F7b, V3, V4, V5, H1, H2, Fla, Flb

NR – No flow recommendation provided

* This value has been rounded to 3000 ML/d instead of 3270 ML/d for ease of reporting

10.5 Ramp rates

The rate at which flows rise and fall are known as ramp rates. These rates are environmentally significant particularly for short duration spells such as freshes and bank-full flows. If rates of rise are too fast they may exceed the ability of biota to adapt, thereby causing stress. Rapid falls in flow can increase the risk of bank failure leading to increased erosion and sediment loads.

Median ramp rates were calculated from daily flow data recorded at flow gauges downstream of all storages on the Moorabool River. Due to the large scatter in the data a single intermediary ramp rate is for all reaches. Median ramp rates are recommended because they provide the most conservative estimate of maximum rates of rise and fall in the Moorabool River.

The ramp rate recommendations are provided as a factor of the previous days flow. For example a recommended rate of rise of 1.6 stipulates that flow on a given day should not exceed 1.6 times the previous day's flow.

The recommended ramp rates should be applied to any change in flow, including changes from high to low flow seasons, freshes and high flows. The recommended ramp rates are:

- Rise – 1.3
- Fall – 0.8

11. Criteria to Assess Options

11.1 Development of criteria for use in the MCA of options

SKM conducted an internal workshop to develop criteria against which to assess the relative performance of the identified options. The general process that was followed in developing the criteria is outlined below.

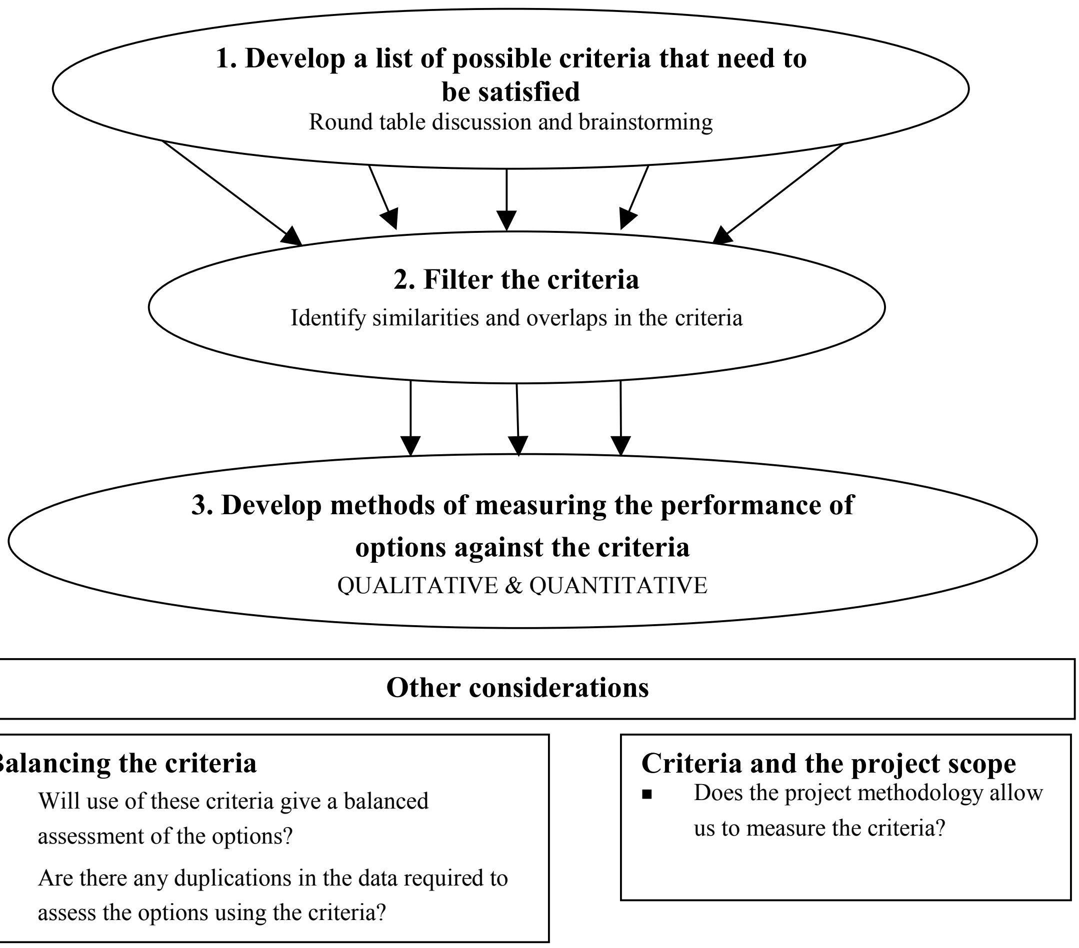


Figure 11-1 Development of Assessment Criteria

Knowledge of the criteria enabled the project team to effectively focus the technical investigations so that they answered the key questions, thus enabling the most feasible and attractive options to be identified. The recommended criteria were reviewed and accepted by the Technical Reference Group. The criteria were subsequently tested and verified by the Community and Stakeholder Reference Group.

Table 11-1: Development of criteria for the assessment of options

CRITERIA "To what extent does the option help to…"	PRIMARY MEASURE Indicator of performance against the criterion.	METHOD OF MEASUREMENT Method of evaluation against the indicator. Quantitative/Qualitative	PRINCIPAL CONSIDERATION Economic	Social	Environmental
Protect and improve the riverine environment ■ By enhancing the environmental value of the riverine environment in the Moorabool Basin	■ ecological biodiversity (number of species) ■ distribution and abundance of populations of threatened significant species ■ Ecological water quality - EC (lower catchment) - TN and TP in upper catchment - Ph - Turbidity ■ Water quality within a range that is suitable for treatment for supply - Faecal coliforms	■ Expert judgement to evaluation impact of option [1]. } Expert opinion[2]	✓	✓	✓
■ By improving the volume, variability and timing of flow to better match natural patterns throughout the basin.	■ Stream flow volumes ■ Flow variability	■ REALM ■ Gauge readings		✓	✓
Maintain security of supply for users ■ By providing access to water users under varying system conditions	■ Licensed water allocations ■ Stream flow	■ NRE, BW, CHW and CMA records ■ REALM		✓	✓
Minimise financial cost ■ By optimising the infrastructure, operation and maintenance costs[3]	■ Net present value of infrastructure costs	■ Design of option ■ Schedule of option over design life ■ Quantity surveyor	✓		
	■ Marginal average annual operation and maintenance costs	■ Cost of water purchasing ■ Physical maintenance costs ■ Estimate of operating costs			
Add value to the region ■ By optimising the economic outcome	■ Change in per acre agricultural value ■ Change in land value due to urban development or change in land-use.	■ Employment statistics ■ Landuse data	✓		
■ By improving social assets	■ Number of social assets ■ Duration of use			✓	
Ensure long-term viability ■ By using the basin's water resources in a sustainable manner.	■ Water use versus the sustainable yield of groundwater and surface water resources	■ REALM ■ Allocated values/ sustainable yield		✓	✓

1. The collection of ecological data is beyond the scope of this project. The existing baseline ecological condition to be determined through Index of Stream Condition and AUSRIVAS, over time as the ecology of the basin responds to the option, new information from future Index of Stream Condition surveys and AUSRIVAS may be used to assess the ecological outcome.
2. The collection of water quality data is beyond the scope of this project. Standard testing of water quality parameters at specified gauging stations.
3. A follow on consideration to this criteria are the financial impacts that the option may have on the Water Authorities' operating structure

11.2 Additional Criteria

At the meeting held with the Community and Stakeholder Reference Group and the Technical Reference Group on the 27th August 2003 an additional criterion was added to the five listed above. This criterion sought to ensure that any preferred option would result in no adverse impact on neighbouring catchments. Such an impact could involve the improvement or worsening of the environment, security of supply, cost, regional value and long-term viability of adjacent catchments. For example, the option of taking water from Upper Werribee River and transferring it into the East Moorabool River would most likely reduce the environmental values in the Werribee catchment. As another example, transferring STP discharges that currently flow into the Leigh River back to the Moorabool catchment is likely to have security of supply impacts in the Leigh catchment.

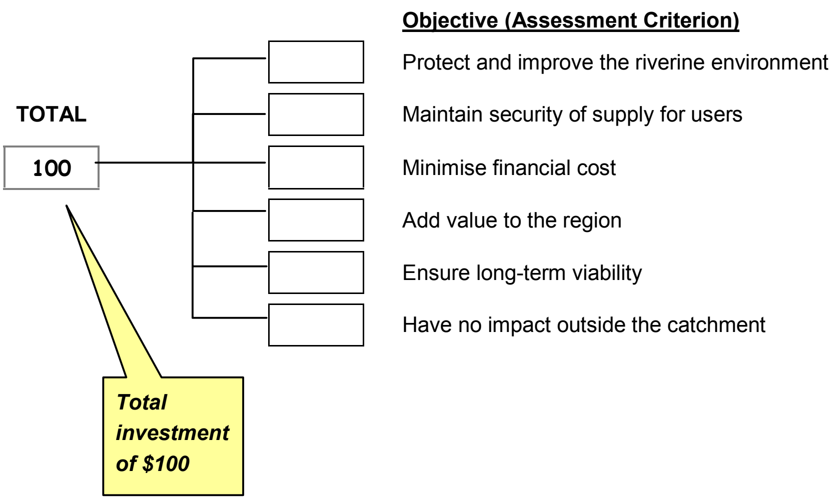
11.3 Prioritisation of Criteria

Typically, in assessing the relative performance or merits of options some criteria are more important than others to decision makers. The relative importance of the criteria will also vary within and between stakeholder groups. It is, however, important to convey and apply these priorities (or weightings) in evaluating options and identifying a preferred option(s). (Failure to examine the relative weightings of the various criteria effectively applies an equal weighting to each criterion which is rarely representative of the true decision environment.)

Members of the Community and Stakeholder Reference Group and the Technical Reference Group were therefore provided with a questionnaire with a request that they convey their (or their organisation's) weighting to each of the 6 criteria as shown below. Respondents were requested to convey their relative weightings by considering how they would assign a potential investment of $100 to achieve the outcomes described by the objectives or criteria.

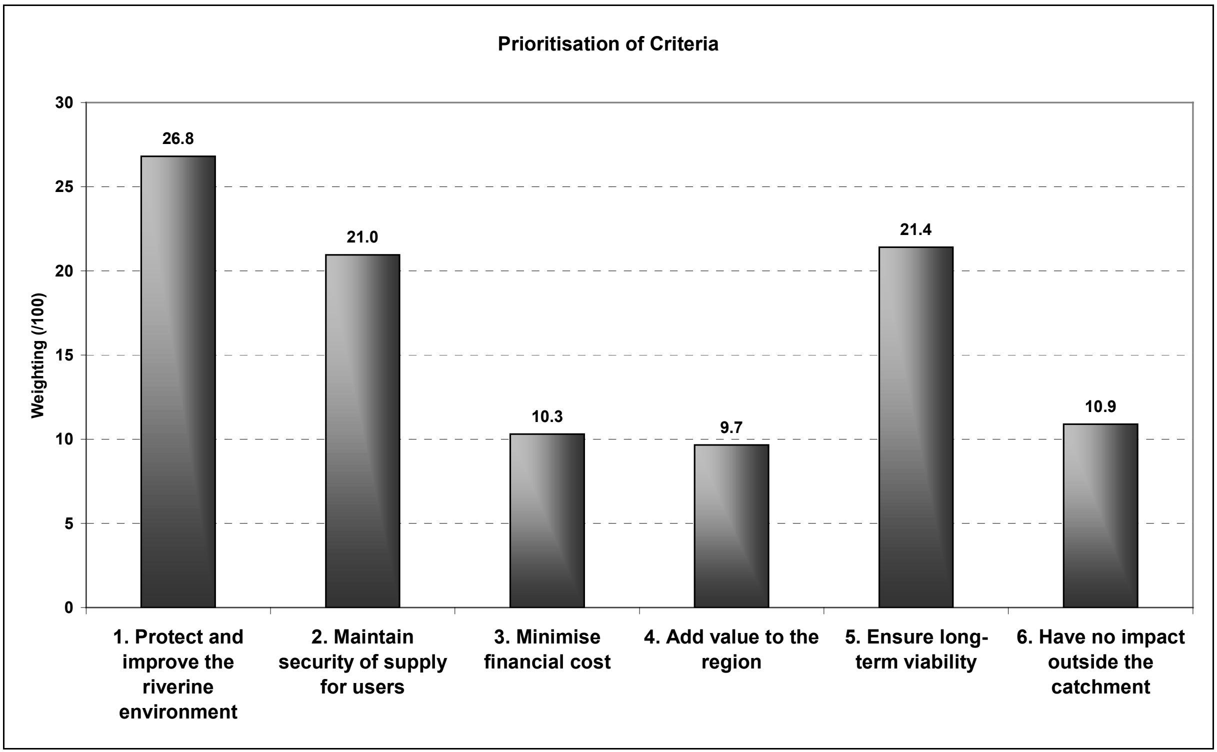
- **Figure 11-2: Questionnaire to determine prioritisation of criteria**

Your Preference Diagram to Complete

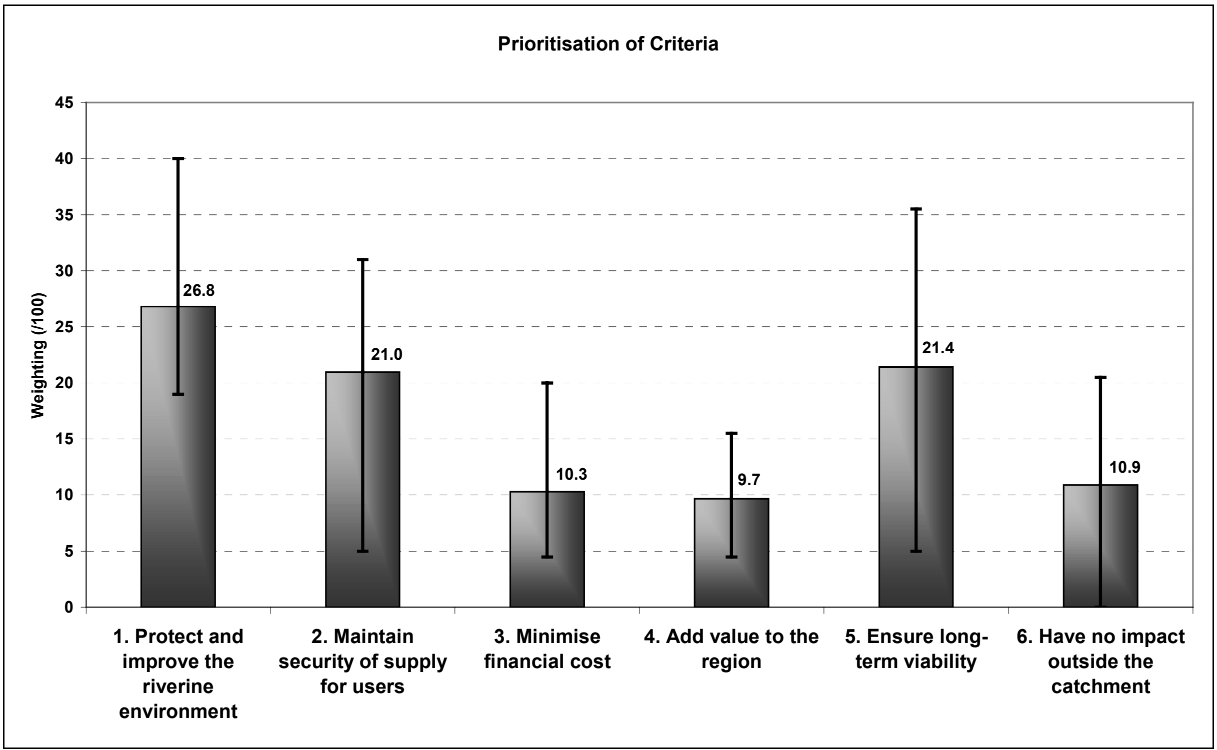


Forty-five (45) questionnaires were distributed to stakeholders with 20 responses (44%) received. On the basis of the responses received, SKM calculated the average weighting for each criterion as shown in Figure 11-3. The spread of responses between the 10th and the 90th percentile are shown in Figure 11-4.

- **Figure 11-3: Weighted Criteria**



■ **Figure 11-4: Spread of responses**



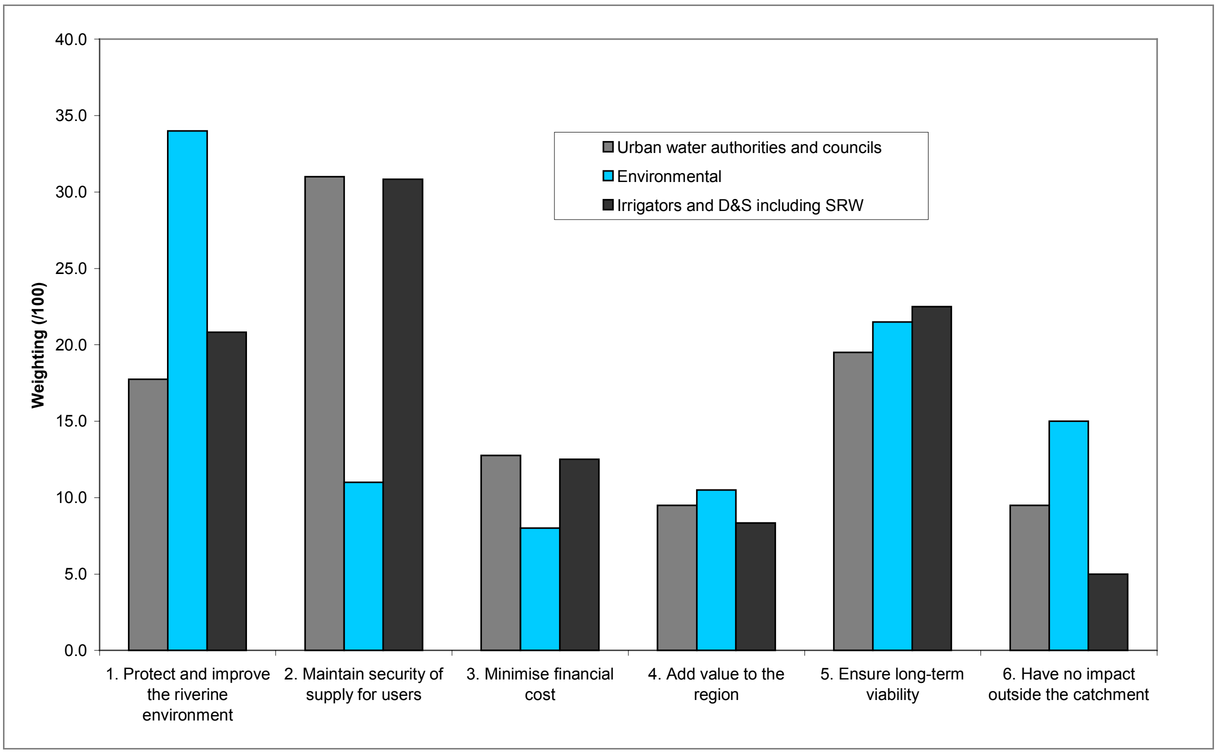
11.3.1 Prioritisation by Interest Group

The respondees were divided into three interest groups:

1) Urban water authorities and councils (4 respondees)
2) Environmental (10 respondees)
3) Irrigators and D&S including SRW (6 respondees)

As can be seen in Figure 11-5, in general the groups' weightings were similar for criteria 3 to 6, but there were differing responses for criteria 1 and 2. Environmental interest groups and irrigators saw the criteria to protect and improve the riverine environment as much more important than did the urban water authorities and councils. In contrast the irrigators, urban water authorities and councils considered maintaining the security of supply as much more important than did the environmental interest groups.

▪ **Figure 11-5: Criteria Prioritisation by Interest Group**



This fundamental difference of opinion in regard to the first two criteria is not unexpected, but should be recognised as a potential stumbling block in getting stakeholder agreement on actions. It is recommended that as part of any future work some further discussion is undertaken with stakeholders on the relative importance of these criteria in an attempt to reduce the disparity in weightings.

It should also be noted that the current combined criteria weighting is skewed towards irrigator preferences due to the greater number of respondees from that group.

12. Identify options for improving streamflow

A list of suggested options to improve environmental flows is included in this report for discussion. Once finalised these options will be assessed in terms of security of supply, as well as environmental, social and financial impacts.

12.1 Review of Previous Studies

A review of previous studies and investigations was conducted to identify flow augmentation options that had been considered in the past. As stated earlier, the surface waters of the basin are already heavily relied upon and harvested and there is little potential for further development. However, several options have been developed in the recent past including increasing the storage capacity within the basin, water reclamation, water savings and water trading.

In the draft stages of *the 'Water Resources Development Plan – Barwon, Moorabool & Gellibrand Region*' Barwon water proposed an additional 10,000 ML water storage on East Moorabool River upstream of the West Moorabool confluence. The proposed storage would provide an incremental yield of 2000ML/a. However, this proposal was mentioned but not pursued further in the final Water Resources Development Plan released in March 2003.

There are no water reclamation or wastewater disposal practices in the catchment (SKM, 2002a). All effluent from wastewater treatment plants serving towns supplied by the Moorabool Basin is discharged outside of the basin and therefore is not returned to the river. No proposal seeking to redirect the effluent was found.

Water savings may also present a flow augmentation option. Barwon Water plans to enhance their system operation by implementing a closed system to increase water savings by channel lining and covering storages (Barwon Water, 2002).

There is also potential for water trading in the Moorabool River Catchment on a temporary basis (SKM, 2002a).

12.2 Brainstorming Workshop

To come up with this list of options, a brainstorming workshop was held. It drew upon the collective knowledge of members of the project team, the Technical Reference Group and Community and Stakeholder Reference Group. The guiding principle of this workshop was to come up with options to enhance environmental flows while minimising the impact on the existing security of supply.

Options were suggested, discussed and rated using the following system:

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Rating A = option to be discussed and modelled (evaluated quantitatively)
B = option to be discussed (evaluated qualitatively)
C = option not considered viable (but will be mentioned in report)

Options discussed are shown in Table 12-1.

Table 12-1: Options to Enhance Environmental Flows

Option	Rating
Option 1: Enhance flows passed downstream	
At Moorabool Reservoir	A
By increasing summer passing flow	
By including flushes	
By improving storage inflow	
At Lal Lal Reservoir	
By changing timing of releases	
At Bostock Reservoir	
by increasing summer passing flow	
by including flushes	
At She Oaks Weir	
By increasing summer passing flow	
by including flushes	
Option 2: Connect Barwon Water to the Upper Werribee system and buy/trade back some of their share of Lal Lal	A
Water could be traded from the Werribee system if lower Werribee irrigators use some recycled water from the Werribee WWTP. CHW advised that Western Water's share of Merrimu will not be available for use if Melton goes onto the Melbourne Water supply system. The unallocated share of Merrimu is currently earmarked for urban use.	
Option 3: Find an augmentation option for Ballarat and get back part of Moorabool or Lal Lal Reservoir	
Bores (west of Ballarat?)	A
Hepburn Lagoon	C
Newlyns Reservoir	C
Connect Moorabool Reservoir to Korweinguboora	C
Storages currently dormant (Creswick, Blackwood, Clunes, etc)	B
Option 4: Encourage trading of regulated water upstream, and keep the savings for the environment downstream of Lal Lal	B
This could save the current losses between Lal Lal and She Oaks	
Option 5: Storage augmentation	
Probably not viable but should be discussed.	C

Option	Rating
Option 6: Conversion to offstream winterfill Summer flows could be enhanced by converting some groundwater users to offstream winterfill. Converting onstream winterfill irrigators to offstream winterfill ensures all summer flow is passed and also enhances fish passage.	B
Option 7: Supply some diverters in the Lower Moorabool from the Barwon Water system (eg. She Oaks pipeline) Barwon Water said this is not viable since the She Oaks pipeline is already fully committed.	C
Option 8: Buy back licences/sleepers While buying back sleeper will not reduce current use it will prevent future use and/or trading that may occur. Selling current licences may be attractive to some current users depending on price.	A
Option 9: Encourage on-farm savings and high value use In general most of the catchment is already under high value use. On farm savings are already being implemented and there may be scope for further savings, but it is felt that in general these would remain on the farm.	B
Option 10: A single large winterfill offstream storage for the region (downstream of Lal Lal) Not viable	C
Option 11: Change reservoir operating rules to reduce evaporation Not viable	C
Option 12: Encourage conjunctive use This could be a good option for urbans and irrigators outside the Bungaree WSPA. SKM felt that a potential groundwater source exists at Bannockburn.	B
Option 13: Augment Barwon Waters resources in the Barwon catchment and trade it with Moorabool water in one of their storages Not viable. Barwon Water explained that there is no further resource available in this catchment.	C
Option 14: Give CHW more Leigh River so they use less Moorabool River water CCMA explained that this water is fully committed to irrigators, and is being supplemented by discharges from the Ballarat Sth WWTP.	B
Option 15: Savings in the distribution system/bulk water supply system (possibly high losses in the channel system) Pipelining of BW channels may yield some savings. It was explained that CHW channels are more likely to gain than lose water.	B
Option 16: Metering of users to encourage compliance to their licensed volume	

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Option	Rating
This is already happening in the catchment and is affecting behaviour	B
Option 17: Aquifer storage and recovery SKM staff explained this is not viable in this region.	C
Option 18: Significant industrial use in the lower catchment. Encourage reduction in the volume used, or the use of recycled water Barwon Water already looking into the possibility of this.	B
Option 19: Use of recycled water for pasture irrigation Little pasture in the catchment	C
Option 20: Transfer Ballarat Sth recycled water into Moorabool Basin CHW suggested that this might be an option. As noted above it would impact on current irrigators. This water would have to be discharged below Lal Lal unless Ballarat/Geelong could be persuaded to accept it as part of their potable supply.	A
Option 21: Find an alternative water source to top up Lake Wendouree Top up using stormwater, recycled water, groundwater, etc. This would reduce Ballarat total demand by 300-400 ML/yr.	A
Option 22: Pumping of Groundwater into the upper stream Groundwater discharge currently believed to occur in West Moorabool River just above Lal Lal Reservoir. Proposal to pump this water into the stream further up. CHW bore on Devils Ck suggested.	B
Option 23: Farm Dams to Pass Summer Flows It may be that this would have little impact on yield but substantial impact on summer flows	A
Option 24: Demand Management CHW and BW are already looking at this issue.	B

12.3 Additional Options

A number of additional options arose from the meeting held with the Community and Stakeholder Reference Group and the technical Reference Group on the 27th August 2003. These included the following table.

Table 12-2: Additional Options

Option	Rating
Option 25: Encourage conjunctive use Use of rainwater tanks, wastewater reuse, etc in new developments.	A
Option 26: Potable Water substitution for Ballarat	A
Option 27: Reallocation from savings due to demand management across all consumptive users other than the environment	A
Option 28: Environmental Water Allocation 500ML to be set aside in Moorabool Res for the environment (capacity share).	A

12.4 Shortlisting Options

At the meeting on the 27th of August, the options were shortlisted to 10 "A" options for detailed assessment. 13 "B" options were also listed to be discussed in less detail. A number of options were listed as "B" since previous investigations had already been carried out on these.

Table 12-3: A Options

No	Description / Comments / Method
25	Encourage conjunctive use
27	Reallocation from savings due to demand management across all consumptive users other than the environment
1	Enhance flows passed downstream from major storages
2	Connect Barwon Water to the Upper Werribee system and buy/trade back some of their share of Lal Lal
3a	Find an augmentation option for Ballarat and get back part of Moorabool or Lal Lal Reservoir: - Bores (west of Ballarat)
8	Buy back licences/sleepers
20	Transfer Ballarat Sth recycled water into Moorabool Basin
23	Farm dams to pass summer flows
26	Potable Water substitution for Ballarat
28	Environmental Water Allocation

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Table 12-4: B Options

No	Description	Investigations part done
19	Use of recycled water to replace irrigation water	
3	Find an augmentation option for Ballarat and get back part of Moorabool or Lal Lal Reservoir: e) Storages currently dormant (Creswick, Blackwood, Clunes, etc)	
4	Encourage trading of regulated water upstream, and keep the savings for the environment downstream of Lal Lal	
6	Conversion to offstream winterfill	
9	Encourage on-farm savings and high value use	
12	Give CHW more Leigh River so they use less Moorabool River water	
14	Savings in the distribution system/bulk water supply system (possibly high losses in the channel system)	
15	Metering of users to encourage compliance to their licensed volume	
16	Significant industrial use in the lower catchment. Encourage reduction in the volume used, or the use of recycled water	*
18	Pumping of Groundwater into the upper stream	
22	Find an alternative water source to top up Lake Wendouree	
24	Transfer Ballarat Nth recycled water into Moorabool Basin	*
21	Desalination Plant	

STAGE B - Assessment of options

13. Assessment of A Options

13.1 Option Assessment Methodology

13.1.1 Options Assessed and Assessment Criteria

As previously mentioned, the A options assessed in this report are:

- Option 25: Encourage conjunctive use
- Option 27: Reallocation from savings due to demand management across all consumptive users other than the environment
- Option 1: Enhance flows passed downstream from major storages
- Option 2: Connect Barwon Water to the Upper Werribee system and buy/trade back some of their share of Lal Lal
- Option 3a: Find an augmentation option for Ballarat and get back part of Moorabool or Lal Lal Reservoir: - Bores (west of Ballarat)
- Option 8: Buy back licences/sleepers
- Option 20: Transfer Ballarat Sth recycled water into Moorabool Basin
- Option 23: Farm dams to pass summer flows
- Option 26: Potable Water substitution for Ballarat
- Option 28: Environmental Water Allocation

Each of these options was assessed in terms of security of supply, financial costs and benefits, environmental costs and benefits, and socio-economic costs and benefits.

The results of this assessment was then used to come up with a score between 0 and 1 for each of the six criteria:

1) Protect and improve the riverine environment – scoring was based on the results of the environmental impacts assessment
2) Maintain security of supply for users - scoring was based on the results of the security of supply assessment
3) Minimise financial cost – scoring was based on the assessment of net present value (NPV) costs
4) Add value to the region – scoring was based on the results of the socio-economic impacts assessment
5) Ensure long-term viability - scoring was based on the results of the socio-economic impacts assessment with a focus on the amount of water saved by the option

6) Minimise impact outside the catchment – scoring was based on the results of all assessments specifically considering areas outside the catchment.

13.1.2 Option Scoring Method

All options were assigned a score between 0 and 1 (with a score of 1 being highly favourable) for each of the six criteria. Provided below is a description of how the model results were translated into criteria scores.

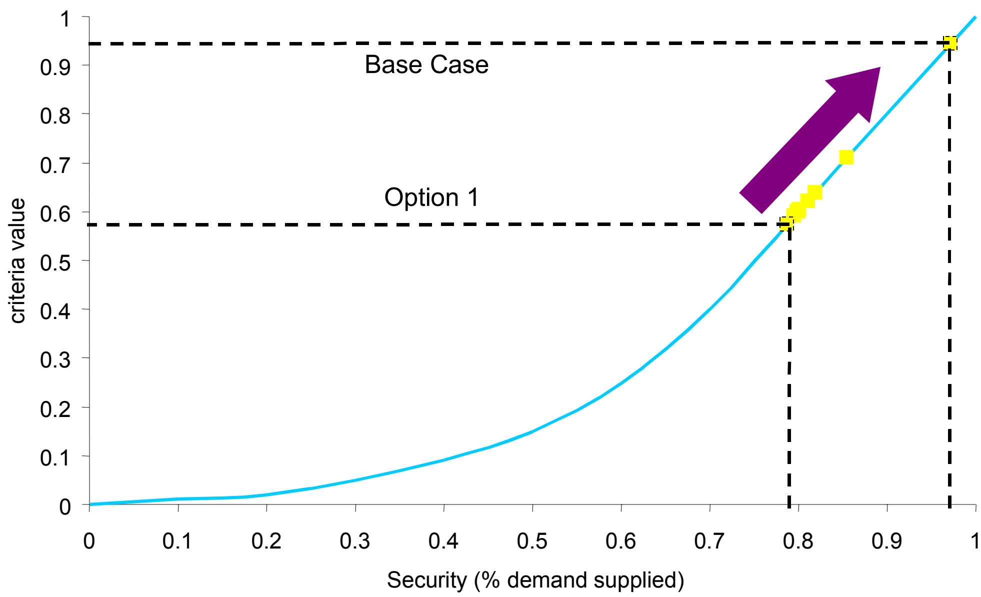
Basis of Scoring – Protect and improve the riverine environment

The environmental flow assessment needed to consider flow performance at 4 different locations over different parts of the year (summer and winter) and over different flow ranges (baseflow, flushes, high and low flows). A detailed description of how this assessment was undertaken is included in Appendix H.

Basis of Scoring – Maintain security of supply for users

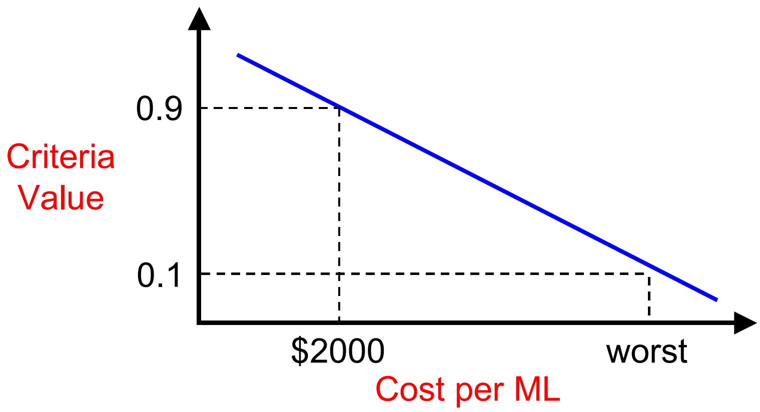
Ratings against this criterion were made based on the modelling results of the security of supply. When security of supply was evaluated for all the options the results fell roughly between 80% and 100%. However, when the impact of these figures on water users is considered, it seems reasonable that the relationship between security of supply and criterion score should not be one to one. For example, if an irrigator was only able to get 70% of the water currently supplied this may be low enough to make his business non-viable. On this basis, the relationship shown below was used to determine criterion scoring.

- **Figure 13-1: Security of Supply vs Criteria Value**



Basis of Scoring – Minimise financial cost

Net Present Value (NPV) was calculated from capital and ongoing costs using 8% discount rate over 30 years. Options were scored by examining NPV cost in $ per ML . The reference points chosen for the scoring system were the highest cost option, which was given a score of 0.1, and the estimated market value of water ($2000/ML), which was given a score of 0.9 as shown in the figure below.



The calculation of the financial costs and benefits were based on preliminary assessment methods and so should be considered in light of the qualifications given in Appendix G.

For each option it has been assumed that the storage outlet structures are capable of releasing the environmental flows as required, and so requires no further capital outlay. This capacity should be checked if further work is undertaken. A check should also be made on the possibility of erosion effects downstream of valves when large flushes are released.

Basis of Scoring – Add value to the region

This criterion is based on the socio-economic impact of the options, and consisted of two predefined sub-criteria:

- Optimising the economic outcome, as measured by change in economic values associated with land use and production.
- Improving the duration and number of social assets (as described in Section 2.7.4)

Given that the change in economic values associated with the options is largely based on the security of supply, and so overlapped with criterion 2 (maintain security of supply), it was decided that the assessment of this option should be focused on the ability of the options to improve social assets.

The potential for the option to improve the duration and number of social assets to the region was assessed by assuming that the positive benefits to social assets of environmental flows, relating to recreation and aesthetic values, outweighed the potential negative impacts on other social assets such as winery tourist attractions. In selecting an appropriate relative ranking for the options it was also assumed that the negative community perceptions of recycled water would make it a less attractive option compared to the current situation. In addition, it was assumed that acquiring irrigation licences to meet environmental demands is less favourable than the *social* benefits of using water for environmental purposes, and so also rated below the current situation. These assumptions were communicated at a local stakeholder meeting and were unchallenged by the stakeholders.

Basis of Scoring - Ensure long-term viability

The option was based on amount of water saved by the option, and so indicated the ability of the option to meet both the use and non-use demands of the water resource both now and into the future.

Basis of Scoring - Minimise impact outside of the catchment

Options were scored against this criteria based on the assessment of impacts specifically considering those impacts on areas outside of the catchment.

13.1.3 Option Ranking Method

Option ranking within a multi-criteria analysis can be performed by several methods, as outlined in Figure 13-2.

For this assessment, the results for each criteria were combined using two methods, the first and more straightforward method was the ‘Aggregate’ method where a relative weighting was applied to the score for each criteria (using the preferences discussed in Section 11.3), and the results then summed to obtain a relative ranking for each of the options. The second method was to calculate the dominance factor for each option, based on how the option ranked compared to the other options for each criteria. Options that rank highly on multiple criteria get a higher dominance factor. The two scoring methods enabled the calculation of two alternative rankings of the options. These rankings were averaged to get the final set of rankings for the options.

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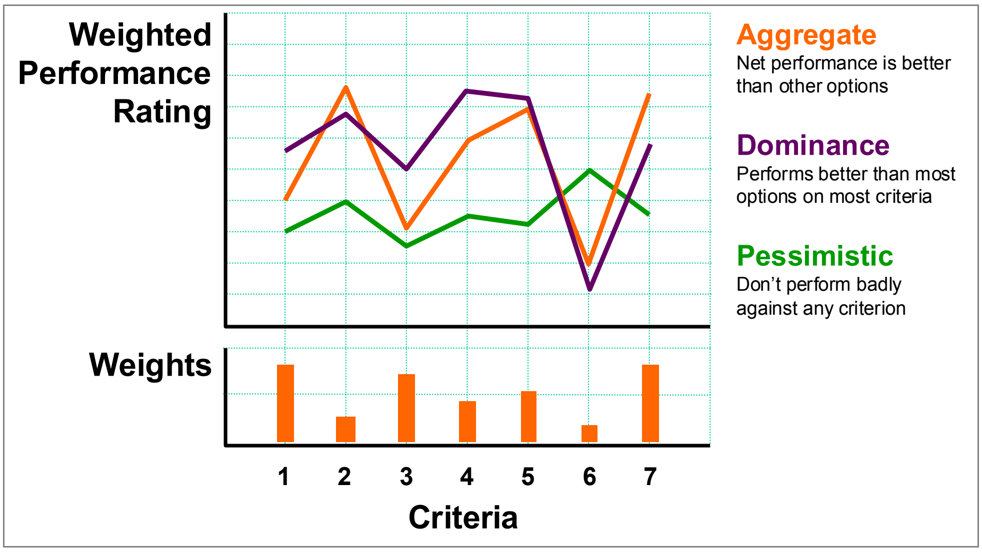
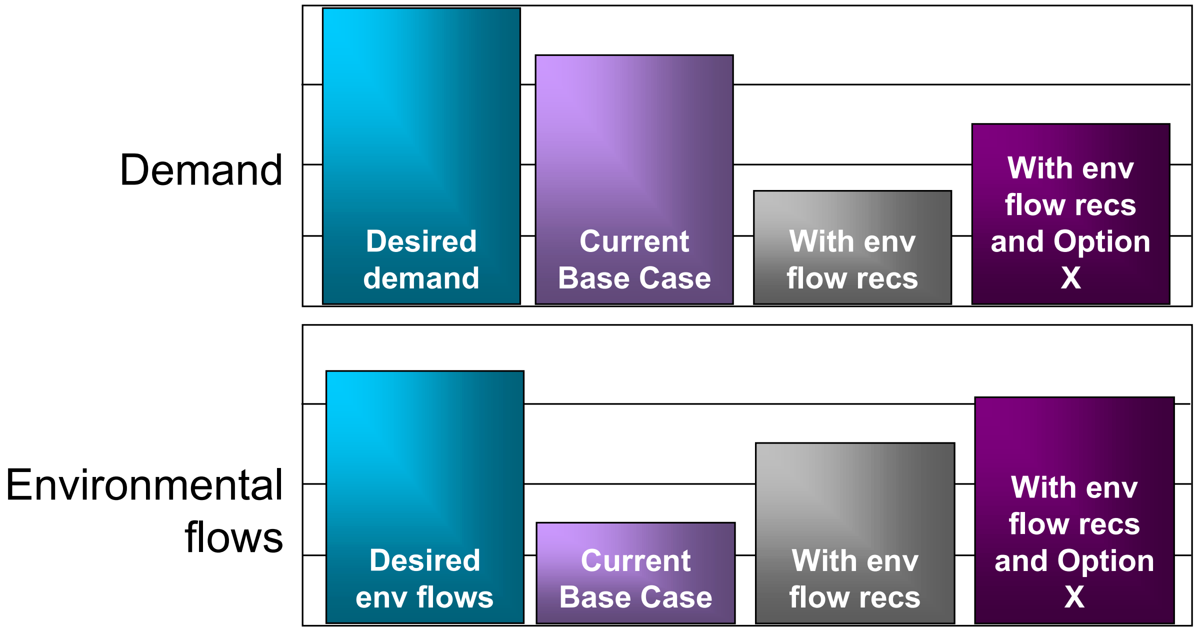
- **Figure 13-2: Alternative methods of evaluating the overall performance or merit of options**



13.2 Option 1: Enhance flows passed downstream from major storages

This option is effectively the implementation of the environmental flow recommendations without any other adjustment to the system. As such it forms an "ideal" environmental flows case to which all other options can be compared. This is shown diagrammatically in Figure 13-3.

- **Figure 13-3: Comparison of Options**



13.2.1 Environmental Impacts

This option improves the flow in the system by implementing a number of measures such as increasing summer passing flows, including flushes, improving storage inflows and changing the timing of releases from Moorabool Reservoir, Lal Lal Reservoir, Bostock Reservoir and at She Oaks Weir. This option is better than the base case but does not fully meet the flow recommendation. There are no outside catchment impacts.

Score between 0 and 1 = 0.814.

13.2.2 Impact on Security of Supply

The application of the environmental flow requirements reduces the amount of urban demand that can be supplied by 25% and reduces the proportion of rural demand that can be supplied by 17% when compared to current supply levels (i.e. the base case).

- **Table 13-1: Security of Supply Comparison – Option 1**

Scenario	Urban	Rural
Base Case (current level of development) Percentage of Restricted demand supplied	100	94.3
Option 1 Percentage of base case demand supplied	74.6	82.8

13.2.3 Cost of Infrastructure

Negligible unless outlet structures require alteration.

13.2.4 Socio Economic Impact

Assumptions - From a social assets perspective, it was assumed that the positive benefits of environmental flows to social assets relating to recreation and aesthetic values outweigh the potential negative impacts on other social assets such as winery tourist attractions.

Positive Impacts – The environmental flows are likely to have positive impact on lookouts, swimming holes, kayaking, fishing and camping (particularly in lower catchment as corresponds to higher flow, whereas in upper reaches no flow periods will be more frequent) i.e. recreation and aesthetic values. Some increase in tourism potential could be expected, however the current situation appears to be mainly local public uses. Downstream rapids and Lal Lal falls should have enhanced values due to the changed flow regime.

Negative Impacts - Reduced supplied demands for irrigation and urban - will negatively affect wineries and winery tourism. Also parks, reserves and public swimming pools may not receive water due to demand restriction. There may be reduced aesthetic values of picnic facilities around reservoirs, as reservoir storage will be more sporadic. Gem and gold fossicking in upper reaches may be negatively affected by increased periods of no flow.

No change - No change is expected for historic bridges, community centres, wildlife park and state parks.

Score between 0 and 1 = 0.8.

13.2.5 Assessment Against Criteria

For Option 1, the criteria values were as follows:

Table 13-2: Criteria Scoring for Option 1

Criteria	Score
1. Protect and improve the riverine environment	0.814
2. Maintain security of supply for users	0.57
3. Minimise financial cost	0.95
4. Add value to the region	0.80
5. Ensure long-term viability	0.10
6. Have no impact outside the catchment	0.73
Weighted sum	0.61
Dominance factor	0.06
Rank based on weighted sum	8
Rank based on dominance factor	11
Average ranking	9.5

13.3 Option 25: Encourage conjunctive use

The idea behind this option was to reduce urban demand by the use of rainwater tanks, wastewater reuse, etc. This was represented by estimating a reduction in demand for urban centres. A 15% reduction in BW demand and a 10% reduction in CHW demand was assumed. The model was run with environmental flow recommendations in place.

13.3.1 Environmental Impact

This option involves encouraging conjunctive use, such as the use of rainwater tanks and wastewater reuse in new developments in the Ballarat region. Without this option water for new developments would be supplied to from the Moorabool system. This option is better than the base case but does not fully meet the flow recommendation.

The out of catchment impacts are likely to be relatively small as a result of these measures only being undertaken for new developments. The use of rainwater tanks would result in less local catchment runoff and therefore potentially less runoff entering the local waterways. The implementation of wastewater reuse systems would lead to reduced flows in local waterways where this water is currently discharged. For example, reduced discharges from the Ballarat North Wastewater Treatment Plant into Yarrowee River (which becomes Leigh River) would potentially impact on flows as this discharge accounts for a considerable volume of the flow in this river. The ecosystem components which currently depend on these flows would be impacted.

Score between 0 and 1 = 0.815.

13.3.2 Impact on Security of Supply

As can be seen from the table that a reduction in urban demands gives a 3% increase in security of supply but does not improve the security of supply to rural users.

- **Table 13-3: Security of Supply Comparison – Option 25**

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 25	77.6	82.7

13.3.3 Cost of Infrastructure

Rainwater Tanks

This assessment considers the use of rainwater tanks to reduce urban water consumption, and is based on information obtained from the report, "Strategy Directions Report – Planning for the future of our water resources", prepared by Melbourne Water. The option provides for the installation of a 4.5kL rainwater tank and pump to provide water for toilet flushing and garden watering. The capital cost of the installation is estimated at $2000. Ongoing operating costs are assumed to be negligible and so were not considered in this preliminary financial assessment.

Assuming that a 4.5 kL rainwater tank and pump for toilet flushing and garden watering results in a 35% reduction for 10% of households in Ballarat, and the infrastructure has a 15 year lifespan, this option saves a total of 250 ML/yr at a cost of $29,000 per ML saved.

Wastewater Reuse

This option looks at the use of water recycling to reduce water consumption, and is based on information obtained from the report, "New Water for Victoria – Victoria's Water Recycling Action Plan", prepared by DNRE. The above report indicates that the supply of recycled water to urban development varies significantly depending on scale of scheme, distance from treatment plant and whether special finishing treatment is needed. Reticulation of urban areas using infrastructure shared with high volume users costs about $600-$700/ML based on the estimated cost of the Sandhurst estate if undertaken in conjunction with Eastern Irrigation Scheme.

Stand alone projects involving dedicated trunk distribution are prohibitively expensive. For example, at Rouse Hill in Sydney, the cost of adding an additional wastewater reuse network to the existing distribution system is estimated to cost over $30,000 per ML (including capital and operation and maintenance costs).

13.3.4 Socio Economic Impact

As per Option 1. Score between 0 and 1 = 0.8.

13.3.5 Assessment Against Criteria

For Option 25, the criteria values were as follows:

- **Table 13-4: Criteria Scoring for Option 25**

Criteria	Score
1. Protect and improve the riverine environment	0.815
2. Maintain security of supply for users	0.60
3. Minimise financial cost	0.13
4. Add value to the region	0.80
5. Ensure long-term viability	0.70
6. Have no impact outside the catchment	0.60
Weighted sum	0.65
Dominance factor	0.10
Rank based on weighted sum	7
Rank based on dominance factor	2
Average ranking	4.5

SKM

13.4 Option 27: Reallocation from savings due to demand management across all consumptive users other than the environment

For this option the water recovered was shared between the environment and water users. It was assumed half the amount saved by option 25 goes to supply environmental flows.

13.4.1 Environmental Impact

The flow impacts of this option are the same as Option 25 except that only half the volume of water provided to the environment in Option 25 is provided in this option.

This option is better than the base case but does not fully meet the "Env flow recs". This option is slightly less desirable than other options as a result of the lower compliance to the recommendations for winter low flows in Reaches 2, 3 and 4, and winter freshes and floods in Reach 3. There are no outside catchment impacts.

Score between 0 and 1 = 0.805.

13.4.2 Impact on Security of Supply

As can be seen from the table, the security of supply increased by just under 4% for urban demands and just under 1% for rural demands. This is roughly a 1% improvement over the case where all water saved was used by the environment (Option 25).

- **Table 13-5: Security of Supply Comparison – Option 27**

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 25	77.6	82.7
Option 27	78.5	83.6

13.4.3 Cost of Infrastructure

As per option 25.

13.4.4 Socio Economic Impact

As per Option 1. Score between 0 and 1 = 0.8

13.4.5 Assessment Against Criteria

For Option 27, the criteria values were as follows:

▪ Table 13-6: Criteria Scoring for Option 27

Criteria	Score
1. Protect and improve the riverine environment	0.805
2. Maintain security of supply for users	0.62
3. Minimise financial cost	0.95
4. Add value to the region	0.80
5. Ensure long-term viability	0.65
6. Have no impact outside the catchment	0.73
Weighted sum	0.74
Dominance factor	0.09
Rank based on weighted sum	2
Rank based on dominance factor	4
Average ranking	3

13.5 Option 2: Connect Barwon Water to the Upper Werribee system and buy/trade back some of their share of Lal Lal

For this option an assumption needed to be made about how much water could be bought and/or traded. Assuming a 30ML/wk pipe resulted in an average transfer 833 ML/yr and a maximum transfer 1440 ML/yr.

13.5.1 Environmental Impact

This option would create less demand on the Moorabool system and return some flow to the Moorabool system.

This option is the closest to the Environmental Water Requirements, and is slightly more desirable with respect to flows than other options. This is as a result of the higher compliance to the recommendations for summer freshes, summer cease to flow and winter freshes in Reach 1, winter floods in Reach 2, summer low flow and summer freshes in Reach3 and winter freshes in Reach 4.

Possible impacts within the catchment (other than flow related issues) may include potential implications associated with the placement and construction of the pipeline to deliver the water (in and out of catchment), however this is likely to be minimal if the design and construction of the pipeline addresses environmental issues. There may also be potential issues associated with the translocation of water from the Werribee system into the upper Moorabool catchment. Translocation issues include the transport of biological organisms into an area unnatural to these organisms. This may result in the competition, predation or infection of species naturally occurring within the catchment as a result of more dominant species, competitors and parasites/diseases being introduced.

Out of catchment impacts would involve extracting water from the Werribee River system. This demand however will only be approximately 4.5% of mean annual flow in the Werribee River and water for this option would only be taken in periods of high flow. The Werribee River is already a flow stressed river and the removal of further water may significantly limit the potential for this option to be implemented.

Score between 0 and 1 = 0.806.

13.5.2 Impact on Security of Supply

As can be seen from the table below this option increased the security of supply to urban users by just under 3%, but did not increase the security of supply to rural users.

The potential impact on Werribee system security was not evaluated but should be considered if this option is pursued further.

- **Table 13-7: Security of Supply Comparison – Option 2**

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 2	77.4	82.5

13.5.3 Cost of Infrastructure and Entitlements

Cost of Pipeline

This option provides for a pumping station and pipeline to transfer water from the Werribee River upstream of Ballan to the Bostock Reservoir. The capacity of the pumps and pipeline will be 4.3ML/d, and will operate about 50% of the year. The pipeline will consist of 3km of 200mm dia. pipe, with an operating head of 50m.

Cost of Water Purchase

To supply this water licences must be purchased. Either permanent or temporary water could be purchased. The spilt between permanent and temporary water was optimised using run results:

Permanent trade (Werribee system) $1500-2000 per ML
Temporary trade (Werribee system) $500+ per ML
Optimised split assuming a price of $2,000 for permanent transfers and $500 for temporary transfers = 965 ML permanent water, the rest temporary water as needed.

Total cost = $4620 per ML

13.5.4 Socio Economic Impact

Positive Impacts – As per Option 1.

Negative Impacts - As per Option 1. Likely to also result in some form of social/economic impact to the Upper Werribee system (not included within this criteria as impact is outside of catchment).

No change – As per Option 1.

Score between 0 and 1 = 0.8.

13.5.5 Assessment Against Criteria

For Option 2, the criteria values were as follows:

- **Table 13-8: Criteria Scoring for Option 2**

Criteria	Score
1. Protect and improve the riverine environment	0.816
2. Maintain security of supply for users	0.60
3. Minimise financial cost	0.83
4. Add value to the region	0.80
5. Ensure long-term viability	0.60
6. Have no impact outside the catchment	0.57
Weighted sum	0.70
Dominance factor	0.09
Rank based on weighted sum	4
Rank based on dominance factor	5
Average ranking	4.5

13.6 Option 3a: Find an augmentation option for Ballarat and get back part of Moorabool or Lal Lal Reservoir: - Bores (west of Ballarat)

Groundwater investigations indicate that there is a good supply source in the Cardigan area, with water at 800-1600 EC (refer Appendix I).

A calculation was undertaken to determine the degree to which this source could be shandied with the surface water and still ensure Ballarats water was of an acceptable EC and the system yield was not exceeded.

CHW target EC:		800 EC		*from 2002 Water Quality Report*
Current source EC:	Lal Lal	645 EC		*from 2002 Water Quality Report*
	White Swan	274 EC		*from 2002 Water Quality Report*
Current proportion of use:	Lal Lal	40.6 ML/wk	(17%)	*from base case BAS4.log*
	White Swan	204.0 ML/wk	(83%)	*from base case BAS4.log*
Total		244.6 ML/wk		*from base case BAS4.log*
Est current supply EC:		336 EC		*calculated*
EC of bores:		1200 EC		*from Appendix I*
Yield of bores:		2000 ML/yr		*from Appendix I*
Current demand:		12,700 ML/yr		*from base case BAS4.log*

Test using different percentages of bore water:

- **Table 13-9: Test shandying options**

Proportion of demand supplied by bore	Volume of demand supplied by bore	Salinity of supply
2%	254 ML/yr	353 EC
4%	508 ML/yr	370 EC
6%	762 ML/yr	388 EC
8%	1016 ML/yr	405 EC
10%	1270 ML/yr	422 EC
12%	1524 ML/yr	439 EC
14%	1778 ML/yr	457 EC
16%	2032 ML/yr	474 EC

On the bases of the above results it was assumed that 10% of Ballarat supply provided by bores.

SKM

13.6.1 Environmental Impact

There will be a reduction in demand on the Moorabool system as a result of this option. It is assumed that this reduction in demand is 10%.

This option is better than the base case but does not meet the flow recommendations. Out of catchment issues potentially include impacts on groundwater dependant ecosystems as water would be sourced from bores west of Ballarat.

Score between 0 and 1 = 0.816.

13.6.2 Impact on Security of Supply

Using the Cardigan bore increases the urban security of supply by 1.5%, and slightly increases the rural security of supply.

- **Table 13-10: Security of Supply Comparison – Option 3a**

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 3a	76.1	82.9

13.6.3 Cost of Infrastructure

This option provides for the supply of bore water from 6 bores west of Ballarat to the existing water supply system near Lake Wendouree. It provides for the pumps and 9.5km of 250mm dia. pipeline to a new water storage at Ballarat. The cost estimate includes the drilling investigations, bore development, bore hole pumps, and connecting pipework. The supply system is based on providing 4.3ML/d.

Total cost is $3,000 per ML.

13.6.4 Socio Economic Impact

As per Option 1. Score between 0 and 1 = 0.8.

13.6.5 Assessment Against Criteria

For Option 3a, the criteria values were as follows:

Table 13-11: Criteria Scoring for Option 3a

Criteria	Score
1. Protect and improve the riverine environment	0.816
2. Maintain security of supply for users	0.59
3. Minimise financial cost	0.87
4. Add value to the region	0.80
5. Ensure long-term viability	0.60
6. Have no impact outside the catchment	0.80
Weighted sum	0.72
Dominance factor	0.10
Rank based on weighted sum	3
Rank based on dominance factor	3
Average ranking	3

SKM

13.7 Option 8: Buy back licences/sleepers

There would be no impact on system performance if sleeper licences were purchased. It was it was felt however that this option would have little impact, even if current licences were purchased. To test this, it was assumed that current PDs usage was halved (excluding D&S).

13.7.1 Environmental Impact

Buying back sleeper licences will not reduce the current use but will prevent future use and/or trading that may occur. It is assumed that sleeper licences comprise a very small percentage of the overall demand.

This option is better than the base case but does not meet the flow recommendation. There are no outside catchment impacts.

Score between 0 and 1 = 0.814.

13.7.2 Impact on Security of Supply

As shown in the table this option increases rural supply security by 2.4%, and slightly increases urban security.

- **Table 13-12: Security of Supply Comparison – Option 8**

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 8	74.8	85.2

13.7.3 Cost of Infrastructure

It is difficult to know what the price of permanent water would be in the Moorabool. As an indicator the price of water in the neighbouring Werribee system has been used. Werribee permanent trade price is around $2000 per ML (SRW pers. comm.).

13.7.4 Socio Economic Impact

Positive impacts - As per Option 1.

Negative Impacts - As per Option 1, but may affect wineries and would negatively affect future winery development as water licences become more scarce on the market and so would be expected to increase in price. Agricultural returns as a result of this option expected to drop sharply (irrigation significantly more profitable than dryland farming), which in turn would affect local communities and may indirectly lead to a decline in maintenance and value of some social assets. There would be some buffering of the impacts however given that an increase in water prices may lead to more efficient uses of water within the catchment.

The impacts will partly depend on how licences are acquired, however the licence acquisition would still remove production values from the catchment (so would not 'add value' as per the criteria), and whilst environmental improvements are positive these may relatively more time to take effect.

Purchasing irrigation licences in the volume specified is likely to involve unwilling sellers and so the negative social impacts are expected to be less favourable than the social benefits of using water for environmental purposes. As such this option has been rated below the base case against the socio-economic criteria..

Score between 0 and 1 = 0.1.

13.7.5 Assessment Against Criteria

For Option 8, the criteria values were as follows:

- **Table 13-13: Criteria Scoring for Option 8**

Criteria	Score
1. Protect and improve the riverine environment	0.814
2. Maintain security of supply for users	0.60
3. Minimise financial cost	0.90
4. Add value to the region	0.10
5. Ensure long-term viability	0.30
6. Have no impact outside the catchment	0.90
Weighted sum	0.61
Dominance factor	0.08
Rank based on weighted sum	9
Rank based on dominance factor	7
Average ranking	8

13.8 Option 20: Transfer Ballarat Sth recycled water into Moorabool Basin

For this option it was assumed that a pipeline would run from the ballarat South STP to just downstream of She Oaks Weir. It was assumed that enough could be transferred to supply all private diverter demands downstream of this point. CHW figures on STP discharge show that ample volumes of water are available.

13.8.1 Environmental Impact

This option would result in wastewater being discharged to the Moorabool system (which would come in below She Oaks). Currently water is discharged from the Ballarat South treatment plant into Yarrowee River which in turn becomes Leigh River. The proportion of water to be discharged to the Moorabool system would not be the total amount currently discharged to the Leigh River system and would likely be a small proportion of the mean annual flow in the Moorabool system.

This option is better than the base case but does not meet the flow recommendation.

Potential water quality issues (especially nutrients) associated with discharging recycled water to the Moorabool system are likely to be minor. Although discharges from the Ballarat South Wastewater Treatment Plant currently act to elevate nutrient levels in Yarrowee River (WSL, 2002), the proportion of water likely to be discharged to the Moorabool system will be smaller, in effect allowing for dilution of this water. High nutrient levels can lead to an increase in primary production resulting in depletion of dissolved oxygen and other associated water quality problems (WSL, 2002). Any discharge of wastewater to the Moorabool system will need agreement with the EPA and a discharge licence specifying the water quality guidelines to be met.

There may also be potential implications associated with the placement and construction of the pipeline to deliver the water (in and out of catchment) however this is likely to be minimal if the design and construction of the pipeline addresses environmental issues. The pipeline will be run from Ballarat and enter the Moorabool River downstream of She Oaks.

Other out of catchment impacts include reduced flows in the Leigh River. Flows in the Yarrowee/Leigh River will be reduced as the water is currently discharged to this river and the water discharged is currently viewed as having an environmental benefit in the Leigh River, as it is a significant proportion of the current flow in the system.

Score between 0 and 1 = 0.812.

13.8.2 Impact on Security of Supply

As can be seen from the table, this option has a significant effect on the security of supply of rural users.

Table 13-14: Security of Supply Comparison – Option 20

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 20	75.1	95.9

13.8.3 Cost of Infrastructure

This option provides for a pumping station and pipeline to take treated effluent from the Ballarat South STP to the Moorabool River down stream of She Oaks Weir. The capacity of pumps and pipeline will be 5.7ML/d based on the magnitude of PD demands downstream of She Oaks Weir, and will operate about 80% of the year. The pipeline will consist of a 250mm dia. pipe 48km long with a pump head of 200m.

Total cost is $24,000 per ML of water saved.

13.8.4 Socio Economic Impact

Positive impacts - As per Option 1, but increased value for wineries as all irrigation demands are able to be supplied downstream of Lal Lal, and decreased social benefits due to concerns regarding water quality.

Negative Impacts - As per Option 1, but no negative impacts for wineries. Reduced (or perceived reduction in) water quality for consumptive use. Five domestic and stock irrigators will require alternative supply.

No change – as per Option 1.

Score between 0 and 1 = 0.3.

13.8.5 Assessment Against Criteria

For Option 20, the criteria values were as follows:

SKM

Table 13-15: Criteria Scoring for Option 20

Criteria	Score
1. Protect and improve the riverine environment	0.812
2. Maintain security of supply for users	0.71
3. Minimise financial cost	0.28
4. Add value to the region	0.30
5. Ensure long-term viability	0.20
6. Have no impact outside the catchment	0.47
Weighted sum	0.52
Dominance factor	0.07
Rank based on weighted sum	11
Rank based on dominance factor	10
Average ranking	10.5

13.9 Option 23: Farm dams to pass summer flows

For this option it was assumed that all inflows between November and April were passed by farm dams larger than 5ML in capacity.

13.9.1 Environmental Impact

Farm dams are distributed throughout the catchment. Those dams located higher in the catchment would potentially yield greater flows however it is unlikely that yield will be greatly impacted as a result of this option.

This option is better than the base case but does not meet the flow recommendation. There are no outside catchment impacts.

Score between 0 and 1 = 0.815.

13.9.2 Impact on Security of Supply

This option results in a 3.6% increase in urban demand security and a 2.8% increase in rural demand security. The impact on security of supply to farm dam users was not evaluated.

- **Table 13-16: Security of Supply Comparison – Option 23**

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 23	78.2	85.6

13.9.3 Cost of Infrastructure

The financial assessment of this option considers the infrastructure required to allow summer stream flows to bypass farm dams. The concept and estimated cost is based on figures provided by DSE from calculations carried out in 2001. The concept adopted for this report includes a weir constructed in the waterway above the fulls supply level with a suitably sized offtake to allow bypassing of base summer flows. The weir overflows into the dam only when the capacity of the bypass pipe/channel is exceeded. The study identified a number of other options, each with their own advantages/disadvantages. This option has been applied only to farm dams with a storage capacity of 5ML and above.

Cost is estimated to be approximately $15,000 per dam equating to $9,200 per ML of water saved.

13.9.4 Socio Economic Impact

As per Option 1. Score between 0 and 1 = 0.8.

13.9.5 Assessment Against Criteria

For Option 23, the criteria values were as follows:

Table 13-17: Criteria Scoring for Option 23

Criteria	Score
1. Protect and improve the riverine environment	0.815
2. Maintain security of supply for users	0.64
3. Minimise financial cost	0.70
4. Add value to the region	0.80
5. Ensure long-term viability	0.70
6. Have no impact outside the catchment	0.90
Weighted sum	0.75
Dominance factor	0.12
Rank based on weighted sum	1
Rank based on dominance factor	1
Average ranking	1

13.10 Option 26: Potable Water substitution for Ballarat

Some water consumed in Ballarat is for non-potable uses (eg industry). This option assumes that 10% of Ballarat's demand could be supplied from non-potable sources.

13.10.1 Environmental Impact

The flow outputs from this option will be the same as that for option 3a; it is assumed that the Ballarat demand will be reduced by 10%. Instead of using water sourced from the Moorabool system to supply Ballarat, greywater reuse and wastewater reuse options would be implemented.

This option is better than the base case but does not meet the flow recommendation.

Out of catchment impacts include potentially lower flows in local waterways as a result of lower discharges to these systems. The implementation of greywater reuse and wastewater reuse systems could potentially lead to reduced local flows as a result of the change from wastewater discharge to wastewater reuse.

Score between 0 and 1 = 0.816.

13.10.2 Impact on Security of Supply

This option increases urban supply security by 1.5% but has little effect on rural demand security.

- **Table 13-18: Security of Supply Comparison – Option 26**

Scenario	Percentage of Base Case Demand Supplied	
	Urban	Rural
Option 1	74.6	82.8
Option 26	76.1	82.9

13.10.3 Cost of Infrastructure

This option looks at the cost of substituting potable water with treated water. The information for this option was obtained from the report "Water Resources Development Plan", prepared by Barwon Water. The report indicates that potable water substitution would cost $1100 per ML per year of operation to recover the capital and O&M costs of a very simple scheme to transfer treated effluent from Black Rock STP into the existing water supply system. The capital cost includes the cost of design and construction of the treatment plant up-grade and pipeline to the existing water supply storage.

Total cost is $10,050 per ML of water saved (note: net present value rather than annualised cost as per Barwon Water report).

13.10.4 Socio Economic Impact

Recycled water for use as potable water will require considerable community consultation due to negative perceptions. For the assessment of this option against socio-economic criteria it was assumed that these negative perceptions are outweighed by the social benefits of environmental flows combined with the ability to better supply irrigation demands.

In assessing this option in comparison to similar options, it was assumed that the negative perceptions regarding recycled water for use as potable water are not outweighed by the social benefits of environmental flows alone, and so options involving environmental flows by recycling wastewater for potable supplies are less favoured than the current situation.

Other impacts as per Option 1.

Score between 0 and 1 = 0.1.

13.10.5 Assessment Against Criteria

For Option 26, the criteria values were as follows:

- **Table 13-19: Criteria Scoring for Option 26**

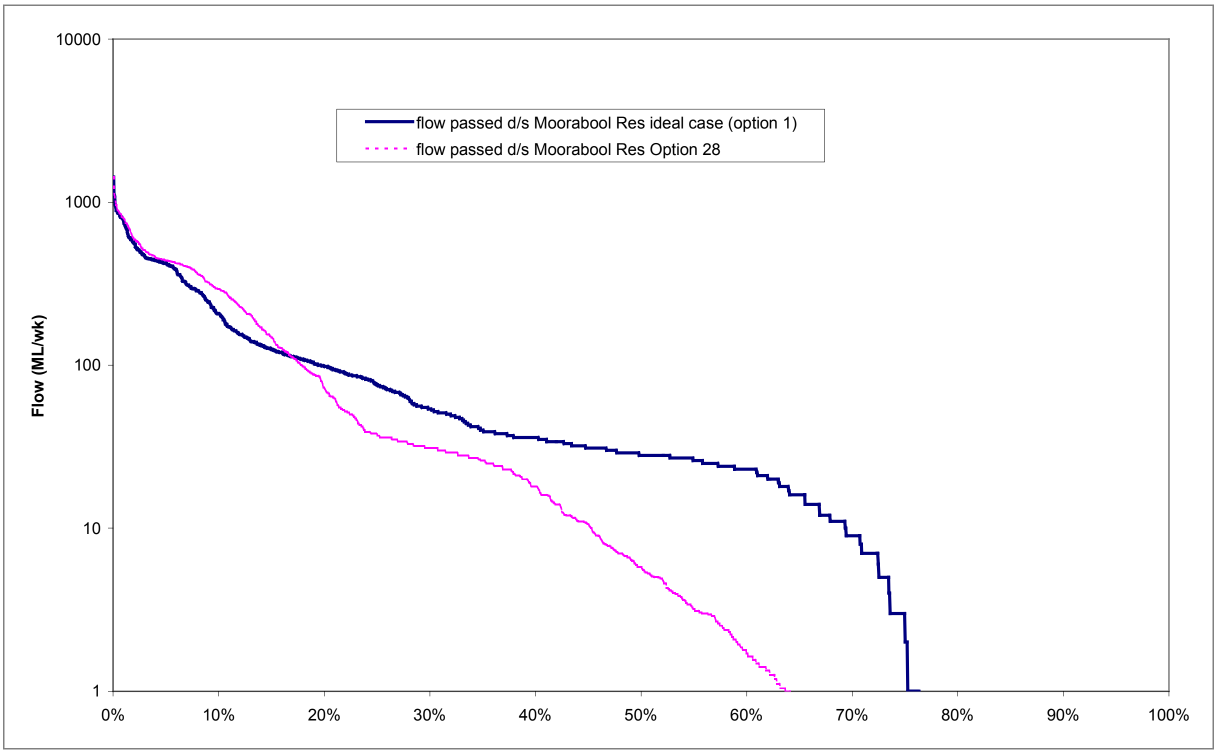
Criteria	Score
1. Protect and improve the riverine environment	0.816
2. Maintain security of supply for users	0.59
3. Minimise financial cost	0.10
4. Add value to the region	0.10
5. Ensure long-term viability	0.65
6. Have no impact outside the catchment	0.70
Weighted sum	0.58
Dominance factor	0.08
Rank based on weighted sum	10
Rank based on dominance factor	6
Average ranking	8

13.11 Option 28: Environmental Water Allocation

This option assumed that 500ML of the capacity of Moorabool Reservoir (7.4%) belonged to the environment and the rest to CHW (92.6%). The equivalent percentage of inflows was assigned to each capacity share.

The REALM model was unstable under this setup and so storage behaviour and flow downstream of Moorabool Reservoir under this option was modelled in a spreadsheet. As shown by the figure below, the environmental storage frequently emptied and so little water was available to pass environmental flows.

- **Figure 13-4: Flow d/s Moorabool Reservoir – Option 28**



13.11.1 Environmental Impact

Under this option 500ML would be set aside in Moorabool Reservoir for the environment.

A REALM run was not carried out for this option and as a result no flow assessment was carried out. It is assumed that this option is only slightly better than the base case, because of the relatively small volume of water to be set aside.

There are no outside catchment impacts.

Score between 0 and 1 = 0.740.

SKM

13.11.2 Impact on Security of Supply

Assumed the same as for the base case.

13.11.3 Cost of Infrastructure

Negligible.

13.11.4 Socio Economic Impact

Positive Impacts - As per Option 1, but overall decrease in positive outcomes as environmental demands unable to be met, and so less benefit associated with social assets based on recreational and aesthetic values.

Negative Impacts – no significant impact on existing demands.

No change – as per Option 1

Less benefit associated with environment eg. recreational, aesthetic values, due to less environmental flow.

Score between 0 and 1 = 0.6.

13.11.5 Assessment Against Criteria

For Option 28, the criteria values were as follows:

- **Table 13-20: Criteria Scoring for Option 28**

Criteria	Score
1. Protect and improve the riverine environment	0.740
2. Maintain security of supply for users	0.94
3. Minimise financial cost	0.95
4. Add value to the region	0.60
5. Ensure long-term viability	0.10
6. Have no impact outside the catchment	0.90
Weighted sum	0.67
Dominance factor	0.08
Rank based on weighted sum	5
Rank based on dominance factor	8
Average ranking	6.5

Subsequent to the assessment of this option is was requested that it be re-run with the 500ML in set aside in Moorabool Reservoir for the environment be represented as a dead storage. As this additional run is outside the scope of this project it is recommended that it be undertaken as part of future work.

13.12 Summary of A Option Assessment

The scores and rankings for all the options as well as the base case are shown in the table below. It is interesting to note that a number of options (1, 8, 20, 36) are ranked lower than the base case. From this it can be concluded that the disbenefits of these options outweigh the benefits.

- **Table 13-21: Summary of A Option Assessment**

Criteria	Options										
	1	25	27	2	3a	8	20	23	26	28	Base
1. Protect and improve the riverine environment	0.814	0.815	0.805	0.816	0.816	0.814	0.812	0.815	0.816	0.740	0.711
2. Maintain security of supply for users	0.57	0.60	0.62	0.60	0.59	0.60	0.71	0.64	0.59	0.94	0.94
3. Minimise financial cost	0.95	0.13	0.95	0.83	0.87	0.90	0.28	0.70	0.10	0.95	0.95
4. Add value to the region	0.80	0.80	0.80	0.80	0.80	0.10	0.30	0.80	0.10	0.60	0.50
5. Ensure long-term viability	0.10	0.70	0.65	0.60	0.60	0.30	0.20	0.70	0.65	0.10	0.10
6. Have no impact outside the catchment	0.73	0.60	0.73	0.57	0.80	0.90	0.47	0.90	0.70	0.90	0.90
Results											
Weighted sum of performance ratings	0.61	0.65	0.74	0.70	0.72	0.61	0.52	0.75	0.58	0.67	0.65
Ranking Weighted sum	8	7	2	4	3	9	11	1	10	5	6
Dominance Factor (Weighted)	0.056	0.1	0.093	0.092	0.096	0.079	0.068	0.122	0.08	0.078	0.072
Ranking Dominance factor	11	2	4	5	3	7	10	1	6	8	9
Average Ranking	9.5	4.5	3	4.5	3	8	10.5	1	8	6.5	7.5

As can be seen from the table, Option 23 has the highest ranking. Options 27 and 3a follow. Though seemingly expensive, Option 23 ranks well because other options have an even higher cost. Therefore cost is not very effective in excluding options.

In general it can be said that imposing the environmental flow requirements reduces security of supply by around 25%. Implementing most of the options is able to marginally restore security, however the best results are obtained from options 23 and 28. Option 28 however performs poorly in terms of environmental flows and so has a poor ranking.

Any options that score poorly on the three highest weighted criteria (1, 2 and 5) are effectively "knocked out" of the race. For those that are left, it can be seen from the summary table that in terms of the two of the three highest weighted criteria, criteria 1 and criteria 2, there is little difference between the results. While there may be some performance improvements from investigating options in combination (as discussed in Section 15) it is important to appreciate that the rankings of the best performing options are being driven by the more subjective criteria 4 and 6.

In summary:

- Implementing the environmental flow requirements reduces security of supply, mostly for sources supplied from Lal Lal Reservoir and downstream
- Implementing options makes small improvements to performance but are not able to restore the current (base case) security, or supply full environmental flows
- All options very similar in terms of environmental benefit
- There is real potential to achieve environmental flow benefits in the upper catchment
- Positive recreation and aesthetic values with most options, negative impacts on wineries in the lower catchment for some options
- All options are of relatively high cost (well above the cost of permanent water)
- Result is driven by scoring of the subjective criteria

If further investigation into these options is undertaken it is recommended that more work be done in consultation with the community to refine the weighting and scoring of the more subjective criteria. It is also recommended that a realistic upper limiting cost be established to eliminate expensive options.

Subsequent to the completion of this option assessment it was found that the winter fresh in Reach 1 was specified incorrectly. While this should not effect the comparison between options as the flow is the same in all cases, it is recommended that this be corrected as part of any future work.

14. B Options

The project scope did not allow for assessment of B options. Therefore these options are listed here for completeness, but should be considered for investigation as part of future work.

- Option 19: Use of recycled water to replace irrigation water
- Option 3: Find an augmentation option for Ballarat and get back part of Moorabool or Lal Lal Reservoir: e) Storages currently dormant (Creswick, Blackwood, Clunes, etc)
- Option 4: Encourage trading of regulated water upstream, and keep the savings for the environment downstream of Lal Lal
- Option 6: Conversion to offstream winterfill
- Option 9: Encourage on-farm savings and high value use
- Option 12: Give CHW more Leigh River so they use less Moorabool River water
- Option 14: Savings in the distribution system/bulk water supply system (possibly high losses in the channel system)
- Option 15: Metering of users to encourage compliance to their licensed volume
- Option 16: Significant industrial use in the lower catchment. Encourage reduction in the volume used, or the use of recycled water
- Option 18: Pumping of Groundwater into the upper stream
- Option 22: Find an alternative water source to top up Lake Wendouree
- Option 24: Transfer Ballarat Nth recycled water into Moorabool Basin
- Option 21: Desalination Plant

14.1 Options Analysed by Central Highlands Water and Barwon Water

At the August Steering Committee Meeting it was noted that CHW and BW had previously carried out work on some options.

14.1.1 Central Highlands Water

The tender evaluation process is currently occurring for the Ballarat North Waste Water treatment project. The issue of reuse in Ballarat (for Lake Wendouree or other uses) has not progressed. Treatment of the water to a quality suitable for the Lake would add considerably to the cost. The council has not shown significant interest in this project (Pat Russell, CHW, pers. comm).

14.1.2 Barwon Water

The Water Resources Development Plan (Barwon Water, 2002) has set a target of 15% reduction in consumption for all customers - residential, industrial and commercial. There are a suite of actions that will be rolled out over time to achieve this. The actions below are what are currently occurring:

Potable Water Substitution

Northern Geelong Sewerage Management Study - This feasibility study currently underway is looking in part at the potential for a recycled water plant in Northern Geelong which would provide recycled water to a number of Barwon Water's major industrial customers.

Dual water reticulation scheme, Torquay - Barwon Water is working with Surf Coast Shire and a developer on establishing a dual water reticulation development in North Torquay.

Reduction in industrial and commercial water demand

Barwon Water has developed water management action plans with City of Greater Geelong, Surfcoast Shire, Colac-Otway Shire and Golden Plains Shire. Retrofitting of water appliances at City of Greater Geelong has already commenced and will result in an estimated 17% reduction in consumption.

Draft water management action plans have also been prepared for a major industry and large secondary school customer. This program will in turn be rolled out for other industrial and commercial customers.

The recycled water plant described in the first point will also have a major effect on reducing industrial demand.

15. Future Work

A range of future work could be undertaken to improve or advance work undertaken as part of this project.

15.1 Farm Dam Impacts

Farm dams demand factor

Subsequent to the release of the Stage A report, work done as part if the Sustainable Diversion Limits Study (SKM, 2003b) indicated a demand factor of 0.84 for irrigation dams and 0.5 for D&S dams in Victoria. It is recommended that the use of these reduced factors be considered as part of any future work in this catchment.

Farm dam volume versus surface area relationship

Subsequent to the release of the Stage A report, a new volume versus surface area relationship was developed as part of the sustainable diversion limits study (SKM, 2003c). The new relationship predicts volumes that are higher than those derived using Equation 1 above. It is recommended that use of this revised relationship be considered as part of any future work in this catchment.

Ground truthing of GIS farm dam layer

Further ground truthing of the larger dams in the GIS layer is recommended.

15.2 REALM Modelling

Update level of groundwater usage

Subsequent to this analysis, metered 2002/03 groundwater usage figures became available for Bungaree. Usage was around 3750 ML in that year. It is recommended that as part of any future work a check should be made on the implications and persistence of this higher usage figure.

Investigate private rights

The volume of private rights in the Moorabool could in the order of 12,000 ML. Anecdotal evidence suggests however that current usage is well below this volume. Private right usage is not explicitly represented in the REALM model but is indirectly included in the derivation of inflows and losses. To fully understand all uses in the catchment there would be benefit in seeking a greater understanding of the magnitude of private rights, their current usage and their likely future usage as part of future work.

Barwon Water demand

Subsequent to the usage figures in this report being adopted for the base case and scenario modelling, BW staff advised that in future usage in the catchment is likely to increase to 8-10,000 ML/yr. The ratio of usage from the East and West Moorabool is also likely to change, with greater use of Lal Lal water in the future. It is recommended that any changes to Moorabool usage by BW be reassessed before any future work is undertaken.

15.3 Environmental Flows

Once environmental flows are implemented, the development of an environmental monitoring program is recommended. The results of this program could then be evaluated and an adaptive management plan put in place to modify the flow recommendations as new information becomes available.

15.4 Groundwater Surface Water Interactions

It is recommended that the following work should be undertaken to better define the components of the groundwater cycle:

1) Evaluate the effects of time delays in groundwater and surface water responses so that a time consistent water balance can be produced.
2) Future groundwater monitoring to incorporate installation of monitoring bores adjacent existing river gauging locations. This will enable the collection of time series groundwater and surface water data at locations strategic to the evaluation of groundwater surface water interaction.
3) Future installation of monitoring bores adjacent to the river in areas of intensive groundwater extraction to ultimately enable baseflow to be managed through the setting of target groundwater levels. It should be noted however, that the setting of minimum water levels could lead to a significantly greater level of groundwater management than currently exists.
4) Rigorous reviews of available literature to better define the hydraulic conductivity of the aquifers in the catchment, their areal extent and flow gradients in order to assess the feasibility of aquifer outflow.
5) Refine the understanding of the change in storage in the basalt aquifer by use of GAM analyses to determine the relative impacts of climate versus groundwater extraction.
6) Identification of the extent and quantity of domestic and stock usage.
7) Evaluation of evapotranspiration rates across the study area, in particular assessment of where shallow water tables would allow evapotranspiration to occur.
8) Further investigation of recharge rates in the study area through, for example the sampling and analysing of isotopes and hydrograph analyses.

9) Ongoing re-visiting of the groundwater components as the results of these assessments are completed. A water balance provides an important tool in evaluating of the impacts of any management strategies implemented.

15.5 Option Assessment

Assessment of B options

Undertake investigations of B options not included in the scope of this project.

Re-run Option 28

Subsequent to the assessment of this option, is was requested that it be re-run with the 500ML in set aside in Moorabool Reservoir for the environment be represented as a dead storage. It is recommended that it be undertaken as part of future work.

Investigate capacity of storage outlets to release flush flows

It may well be the case that the existing infrastructure as storages is physically unable to release the recommended flush flows.

Investigate possible erosion impacts of releasing flush flows

The possible erosion impacts of flush flows should be considered before implementation.

Reconcile weightings for criteria 1 and 2

The difference of opinion between interest groups in regard to the first two criteria is not unexpected, but should be recognised as a potential stumbling block in getting stakeholder agreement on actions. It is recommended that as part of any future work some further discussion is undertaken with stakeholders on the relative importance of these criteria in an attempt to reduce the disparity in weightings.

Scenario modelling using combined options

The aim of this task would be to attempt to achieve security and environmental flow targets by combining options. This was discussed with Stakeholders at the October 2003 meeting and the following targets were suggested:

Environmental Flows	95% achieved at upper catchment sites 60% achieved at lower catchment sites
Demand Security	90% of current demand supplied (Target A) Current security minus 5% (Target B)

Refinement of weightings and scoring for subjective criteria 4 and 6

As the results for the highest ranking options is similar for the easily quantified criteria such as security, the final ranking is being driven by the weight and scoring given to more subjective criteria. If further investigation into these options is undertaken it is recommended that more work be done in consultation with the community to refine the weighting and scoring of the more subjective criteria.

Establishment of an upper limiting cost

The costings for each of the options assessed were consistently high. It is recommended that a realistic upper limiting cost be established to eliminate expensive options.

Correct Winter Fresh for Reach 1

Subsequent to the completion of the option assessment it was found that the winter fresh in Reach 1 was specified incorrectly. While this should not effect the comparison between options as the flow is the same in all cases, it is recommended that this be corrected as part of any future work.

16. References

Allen, G.R., S.H. Midgley and M. Allen, 2002. *Field Guide to the Freshwater Fishes of Australia.* CSIRO, Perth.

ANZECC, 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Managment Council of Australia and New Zealand, Canberra.

Barton, A., 2000. *A Study of Water Quality and Streamflows in the Moorabool River, Victoria, Australia.* PhD Thesis, Deakin University.

Barwon Moorabool Corangamite Waterway Management Consultative Action Team, 1995. *Framework for Waterway Management: Barwon, Moorabool and Corangamite Basins*.

Barwon Water, 2002. *Water Resources Development Plan - Barwon, Moorabool and Gellibrand Region.* Draft Report.

Bennett, P., 1994. *Environmental values associated with the Moorabool River*. Office of Water Reform. Department of Natural Resources and Environment. Draft, Melbourne.

Boulton, A.J. and M.A. Brock, 1999. *Australian Freshwater Ecology. Processes and Management.* Gleneagles Publishing, Adelaide.

Braaten, R. & Gates, G., Groundwater – surface water interaction in inland New South Wales: a scoping study, Department of Land and Water Conservation, unpublished report

Bureau of Meteorology, 2000, Climatic atlas of Australia – rainfall: Bureau Meteorol. Australia.

CCMA, 2000a. *Corangamite Regional Nutrient Management Plan - a framework to reduce the incidence of blue-green algal blooms in regional waters.* Corangamite Catchment Management Authority, Colac.

CCMA, 2000b. *Draft Waterway Health Strategy*. Corangamite Catchment Management Authority, Colac.

CCMA, 2002. *Corangamite Regional Catchment Strategy Community Draft 2002-2007: RCS Stategy Overview*. Corangamite Catchment Management Authority, Colac.

Chessman, B. C. (1999). Predicting the macroinvertebrate faunas of rivers by multiple regression of biological and environmental differences. *Freshwater Biology*, **41:** 747-757

CHRWA, 2002. *Central Highlands Region Water Authority. Annual Report 2000-2001*, Ballarat.

CHW, 2003. *Protecting Water Quality in the Moorabool Shire. A Draft Water Catchment Protection Policy.* Central Highlands Water, Barwon Water, Southern Rural Water, Western Water.

City of Ballarat, 2002. *Municipal Strategic Statement - Draft*.

City of Greater Geelong, 2003. *Title to be supplied*. On line: www.geelongcity.vic.gov.au/greater/indprofile.html, www.geelongcity.vic.gov.au/greater/stats.html

Cottingham, P., G. Bennison, R. dunn, J. Lidston and D. Robinson, 1995. *Algal Bloom and Nutrient Status of Victorian Inland Waters.* Government of Victoria.

Craigie, N., S. Briszga and P. Condina, 2002. *Stream Assessment in the Corangamite Waterway Management District*. Final draft. Corgangamite Catchment Management Authority, Colac.

Dahlhaus, P., Heislers, D. & Dyson, P., 2002, Groundwater Flow Systems, Corangamite Catchment Management Authority

Dahlhaus, P., 2003, Process for the initial selection of target areas for salinity management - Background report for the development of the Corangamite Salinity Action Plan

DEWR, 2002. *Smoothed Small Area Labour Markets*. Department of Employment and Workplace Relations.

Doeg, T.J. and J.D. Koehn, 1994. Effects of draining the desilting a small weir on downstream fish and macroinvertebrates. *Regulated River: Research and Management*, 9: 263-77.

Douglas Partners, 1996, Report on the Ballarat Groundwater Resource Investigation, unpublished report prepared for DNRE.

DSE, 2003. *Victorian Water Resources Data Warehouse*. Department of Sustainability and Environment. On line: http://www.vicwaterdata.net/

DSE (2002): New Water for Victoria – Victoria's Water Recycling Action Plan

EPA, 2000. *The health of streams in the Goulburn and Broken Catchments*. Environment Protection Authroity Publication 678

EPA, 2001. *Draft State Environmental Protection Policy (Waters of Victoria).* Environment Protection Authority Victoria, Melbourne.

Fletcher, T., 1998. *The cumulative effects of recent land and water use on the West Moorabool River, Victoria, Australia.* Ph.D Thesis, University of Melbourne, Melbourne.

Frazier, S., 2002. *A Directory of Wetlands of International Importance*. Wetlands International and Ramsar Convention Bureau. On line: http:/www.ramsar.org

Genrke, P.C. and J.H. Harris, 2001. Regional-scale effects of flow regulation on lowland riverine fish communities in New South Wales, Australia. *Regulated River: Research and Management*, 17: 369-91.

Gutteridge, Haskins & Davey, 1987. *Farm Dam Catchments Study - A Report to the Department of Water Resources Victoria*

Good, M. & McMurray, D. ,1997. *The Management of Farm Dams and their Environmental Impact in the Mount Lofty Ranges* in ANCLOD Seminar on "Dams and the Environment" (updated). Water Resources Group, South Australian department of Environmental and Natural Resources.

HydroTechnology, 1995. PRIDE Documentation. Prepared for Goulburn-Murray Water

Jeanes, J.A., 1996. Flora of Victoria. In N.G. Walsh and T.J. Entwiste (eds.), *Dicotyledons: Winteraceae to Myrtaceae,* 3. Reed International Books, Victoria: 942-1044.

Koehn, J.D. and W.G. O'Connor, 1990. *Biological Information for the Management of Freshwater Fish in Victoria.* Arthur Rylah Institute for Environmental Research, Melbourne.

Lake, P.S., 2003. Ecological effects of perturbation by drought in flowing waters. *Freshwater Biology* **48:** 1-12

Land and Water Australia, 2002. *Australians and Natural Resource Management 2002 - National Land and Water Resources Audit*.

Larson, H.K. and D.F. Hoese, 1996. Family Gobiidae, subfamilies Gobiidae and Gobiinellinae. In R.M. McDowall (ed.) *Freshwater fishes of south eastern Australia.* A.H. and A.W. Reed Pty. Ltd., Chatswood: 220-8.

McDowall, R.M., 1976. Fishes of the Family Prototroctidae (Salmoniformes). *Australian Journal of Marine and Freshwater Research*, **27**: 641-59.

McDowall, R.M., 1996a. Family Prototroctidae: Southern graylings. In R.M. McDowall (ed.) *Freshwater fishes of south eastern Australia.* A.H. and A.W. Reed Pty. Ltd., Chatswood: 92-5.

McDowall, R.M., 1996b. Family Retropinnidae: Southern smelts. In R.M. McDowall (ed.) *Freshwater Fishes of south-eastern Australia*. Reed Books, Chatswood: 96-8.

McDowall, R.M. and W. Fulton, 1996c. Family Galaxiidae: Galaxiids. In R.M. McDowall (ed.) *Freshwater fishes of south-eastern Australia.* A.H. and A.W. Reed Pty. Ltd., Chatswood: 52-77.

Melbourne Water (2001): Strategy Directions Report – Planning for the future of our water resources

Nathan, R. J. & McMahon, T. A.,1990. "Evaluation of automatic techniques for baseflow and recession analyses." Water Resources Research 26(7): 1465-1473.

Nicholls, N., 2001, *Twentieth Century Australian Climate Change*. Bureau of Meteorology.

Nolan ITU, 1998. Basal Bore Monitoring Assessment – Bungaree Groundwater Management Area, unpublished report no. 1092-03 prepared for Southern Rural Water, April 1998.

NRE, 1999a. *Atlas of Vicotorian Wildlife: Reedy Lake*. Department of Natural Resources and Environment. Database.

NRE, 1999b. *Atlas of Victorian Wildlife: Moorabool River*. Department of Natural Resources and Environment, Victoria. Database.

NRE, 2002a. *The FLOWS method. A method for determining environmental flow requirements in Victoria.* Catchment and Water Division, Department of Natural Resources and Environment, Melbourne.

NRE, 2002b. *Healthy Rivers, Health Communities and Regional Growth: Victorian River Health Strategy*. Department of Natural Resources and Environment, Melbourne.

NRE, 2003a. *Victorian Fish Database*. Department of Natural Resources and Environment, Victoria.

NRE, 2003b. *Victorian Flora Information System.* Department of Natural Resources and Environment. Victoria. Database.

OCFE, 1988. *Victoria's Inland Waters: State of the Environment Report.* Office of the Commissioner for the Environment, Melbourne.

Parks Victoria, 2000. *Reedy Lake, Geelong - Water Level Management Plan*. PPK Environment and Infrastructure Pty. Ltd., Melbourne.

Parks Victoria, 2002. *Draft Strategic Management Plan of the Port Philip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site*. Department of Natural Resources and Environment, Melbourne.

Porter, J.W., and Ladson, A.R., 1993. *An Application of Fixed-Area Rainfall Reduction Factors*. In Engineering for Hydrology and Water Resources Conference Newcastle 1993. The Institution of Engineers, Barton, pp. 273-279.

Raadik, T.A. and W.M. Koster, 2000. *Pre- and Post-fishway Construction Assessment - Barwon and Moorabool Rivers, and Otway Streams - Supplementary Data Report*. Arthur Rylah Institute of Freshwater Ecology.

Rigby, J.W., 1994, The Security for the Ballarat Region from the Ballarat-Lal Lal Water Supply System. Appendix A: Ballarat and Lal Lal Streamflow Data.

SKM, 1998, Permissible Annual Volume project – The Bungaree WSPA, unpublished report prepared for the Department of Natural Resources and Environment

SKM, 2000a. Development of a weekly REALM Model of Moorabool River. Report prepared for SRW.

SKM, 2000b. *National Land and Water Resources Audit. Theme 1 - Water Availability, Surface Water, Analysis and Reporting Requirements, Version 2*. Sinclair Knight Merz, Melbourne.

SKM, 2000c. Farm Dam Impacts study Stage 1 - TEDI Modelling - Impact of Farm Dams in Five Catchments

SKM, 2001a, Projections of Groundwater Extraction Rates and Implications for Future Demand and Competition for Surface Water, unpublished report prepared for the Murray Darling Basin Commission

SKM, 2001b, Survey of baseflow in unregulated catchments in the Murray Darling Basin, unpublished report for Murray Darling Basin Commission.

SKM, 2002a. *Investigation of the Status of the Water Resources South West Victoria. Water for Growth Committee of the South West Region*. Sinclair Knight Merz, Melbourne.

SKM, 2002b. *Sustainable Diversions Limit Project - GIS Viewer of Data Sets*. CD prepared for the Department of Natural Resources and Environment.

SKM, 2002c, *Development of a Weekly REALM Model of Moorabool River: Final Report.*

SKM, 2003a. *The Impact of Farm Dams - TEDI Modelling.*

SKM, 2003b: Estimating Available Water in Catchments Using Sustainable Diversion Limits - Farm Dam Demand Factors

SKM, 2003c: Estimating Available Water in Catchments Using Sustainable Diversion Limits - Farm Dam Surface Area and Volume Relationship

SRW, 1997. *Streamflow Management Plan for the Moorabool River: Background Paper*. Southern Rural Water.

Taylor, D. and Gentle, L. V., 2002. Evolution of deep-lead palaeodrainages and gold exploration at Ballarat, Australian Journal of Earth Sciences, v. 49, pgs. 869-878

Tunbridge, B.R., 1988. *Environmental flows and fish populations of waters in the South-Western Region of Victoria.* ARI Technical Report Series No. 65. Arthur Rylah Institute for Environmental Research, Heidelberg.

URS, 2002, Bungaree Technical Assessment, unpublished report prepared for Southern Rural Water

Whetton, P.H., Suppiah, R., McInnes, K.L., Hennessy, K.J. and Jones, R.N., 2002, Climate change in Victoria: High resolution regional assessment of climate change impacts. Department of Natural Resources and Environment.

WSL Consultants (2002). *Biological assessment of the impact of wastewater discharge from Ballarat North, Creswick and Ballarat South Wastewater Treatment Plants in the Central Highlands Region on the ecology of their receiving waterways.* Draft Report to Central Highlands Water. WSL Consultants Pty Ltd

Zampatti, B.P. and L.M. Grgat, 2000. *An Assessment of Environmental Flow Requirements for the Moorabool River: A Component of the Moorabool River Streamflow Management Plan*. Arthur Rylah Institute for Freshwater Ecology., Heidelberg.

Appendix A Stakeholder consultation list

Name	Position	Organisation	Date of initial contact
Alan May	Environment	Moorabool Shire	5 Feb 2003
Alicia Tewierik	Development	Golden Plains Shire	6 Feb 2003
Naomi Burridge	Community and Recreation	Golden Plains Shire	6 Feb 2003
Andrew Bishop	Environmental/ Development	Golden Plains Shire	7 Feb 2003
Nicole Hunter	Community Activities	Department of Primary Industries	5 Feb 2003
Lyneve Whiting	Regional Development	Department of Primary Industries	5 Feb 2003
Ewen McColl	Planner	Ballarat City Council	5 Feb 2003
Digby Jessop	Recreation & Community Support	Ballarat City Council	5 Feb 2003
Craig Marshall	Social Planner	Ballarat City Council	6 Feb 2003
Paul Northerly	Senior Water Planner	Barwon Water	6 Feb 2003
Rachael Bryant	Marketing Manager	Central Highlands Water	5 Feb 2003
Chris Worrell	Manager	Parks Victoria	7 Feb 2003
Greg Campbell	Landholder	Moorabool River Rescue Group	7 Feb 2003
Tim Fletcher		CRC Catchment Hydrology	7 Feb 2003
Erica Nathan	Landholder	Lal Lal Landcare group	10 Feb 2003
Elspeth Swan		East Moorabool Landcare Group	6 Feb 2003
Tevor Prescott		Geelong Field Naturalists	5 Feb 2003
Joan Lindros		Geelong Environment Council	5 Feb 2003
John Gregurke		Ballarat Field Naturalists	5 Feb 2003
Pat Toohey		Landholder	18 Feb 2003
Isabelle Gabas	Environment Officer	Southern Rural Water	5 Feb 2003

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B.1 Hydrogeology

B.1.1 Topography & Drainage

The Moorabool catchment forms a southward-opening valley flanked by a number of ridgelines (to the east and the north) which form the surface water divide and hills along the southern and western margins. Local hills occur in the valley. The Moorabool River drains the catchment via two arms, the West and East Branches upstream of Morrisons upon which a number of large water storages and reservoirs are established, including the Moorabool, Bostock, Korweinguboora and Lal Lal Reservoirs. The river carves through a number of outcropping ridgelines, often forming steeply incised valleys. Downstream of Lethbridge the river meanders over a gentler gradient towards Geelong where it meets the Barwon River. A number of tributaries discharge to the Moorabool along its course.

B.1.2 Geology

The geology of the catchment is composed of lava flows of the Newer Volcanics group, overlying Tertiary sediments or Ordovician bedrock.

Ordovician bedrock

The Ordovician bedrock is composed of a thick sequence of slates, siltstones and greywacke. The Ordovician rocks form prominent outcrops throughout the catchment forming a sequence of highlands from the Creswick and Wombat State Forests in the north to the Lal Lal and Bungal State Forests and Brisbane Ranges and Steiglitz parks down catchment. The units were deposited under deep marine conditions to form interbedded turbiditic sediments that have been tightly folded with predominantly north-south axes. They have a variable deeply weathered profile and are covered by an uneven thickness of weathered rock and soil.

Granitic intrusions occasionally occur throughout the catchment metamorphosing the bedrock units to hornfels, which are more resistant to weathering. The hornfels forms higher ridgelines that flank the valley to the east and north.

Deep Leads

Clays, sands and gravels formed via the erosion of the weathered bedrock units were deposited along the incised depressions formed in the Ordovician bedrock or earlier deposited Tertiary sediments during the Pliocene period (circa 5 Ma). These sediments are known as the Tertiary "deep leads" and occur to a small extent in the parish of Bungaree and Warrenheip at the upper end of the Moorabool catchment. Taylor & Gentle (2002) found these channel deposits to be in the order of tens of metres wide and on average 5 metres thick. They are a valuable groundwater resource due to their coarse nature and extent elsewhere throughout the region, however due to uncertainty regarding their extent and location within the Moorabool catchment they are not a major groundwater resource. URS (2002) used bore fences to delineate three deep leads systems in the upper part of the Moorabool catchment. An un-named deep lead occurs north of the surface water divide and is understood to flow to the north beyond the catchment. The remaining two, the Morrison and Pootilla deep leads, are considered to flow south through the valley. Dahlhaus et al. (2002) also indicates a number of deep leads having formed in the ancient valleys of the Moorabool River and its tributaries, flow south and south east in the upper part of the catchment above Morrisons.

Newer Volcanics basalt

The lava plains of the Western District have been extruded via a number of lava flows originating from numerous small vents throughout the catchment and form the surface geology for much of the area. Up to four phases of volcanic activity have infilled the valleys formed by elevated Ordovician rocks. Sediments may be found between successive lava flows indicating a period of quiescence between subsequent eruptions. The Newer Volcanics lava flows in the catchment range in thickness from a few metres to over 100 metres where they infill pre-existing drainage channels.

Quaternary alluvial sediments

The unconfined Quaternary aquifer systems vary in thickness, mode of formation and materials throughout the catchment. These range from stream alluvium, colluvium, swamp and lake deposits, lunettes, recent marine sediments and coastal dunes. Its extent is limited to narrow drainage lines located between flows of the Quaternary volcanics.

B.2 Hydrogeology of the catchment

B.2.1 Bedrock Aquifer

The bedrock aquifer is unconfined and semi-confined and comprises fractured and jointed Ordovician units and Devonian granitic intrusions. Groundwater moves slowly through these fractured rocks in both local and intermediate flow systems (Dahlhaus et al., 2002). Hydraulic parameters are highly variable in both fresh and weathered profiles. The hydraulic gradient is moderate, although it can be steep where the system is localised. Recharge occurs catchment wide and varies with the depth of weathering and confining units. Groundwater salinity generally varies between 1,000 and 8,000 mg/L TDS. It is used to a limited extent for stock and domestic purposes.

B.2.2 Deep Leads

The Deep Leads are understood to form high volume regional systems with an expected moderate groundwater salinity and salt store (Dahlhaus et al., 2002). A number of deep leads are inferred along ancient river valleys of the Moorabool River and its tributaries Taylor and Gentle (2002). Originating in the far north west corner of the catchment, the Pootilla deep lead system extends west toward Pootilla and heads south toward Lal Lal and Gordon. Another deep lead system trends north east south west extending toward the eastern boundary of the catchment, while the Morrisons deep lead appears to follow the West branch of the Moorabool terminating at Morrisons. These channel deposits are believed to be up to 30 km in length and typically are in the order of tens of metres wide and around 5 metres thick.

The systems are confined and receive recharge via leakage from the overlying Newer Volcanics basalt and Quaternary sediments. Their hydraulic parameters are poorly understood and highly variable due to the wide range of sediment size (clay to gravel).

B.2.3 Basalt aquifer system

The principal aquifer of interest in the catchment is located within the fractured basalts of the Newer Volcanics.

The multitude of lava flows that developed from sequential eruptions has produced a complex system of interconnected aquifer units. Some flows are highly fractured, forming high yielding aquifers, while other flows are more massive and dense. The dense flow may be of sufficient thickness to act as an aquitard that separates an upper unconfined aquifer unit from a deeper confined one. Hydraulic parameters for the aquifer are highly variable.

The lava and scoria cones act as main recharge sources for the fractured basalt aquifer system. Recharge to the aquifer is catchment wide and occurs principally via infiltration of precipitation. In areas of thin soil cover, such as around the volcanic vents, infiltration is favoured. Where a deep soil profile has developed as the result of weathering, such as on the basalt plains, infiltration is greatly restricted. Groundwater moves through these fractured rocks at highly variable rates. Well fractured rock and scoria can be highly transmissive to groundwater flow, while soil and weathered rock hinders flow (URS, 2002). Groundwater flow is typically horizontal and radially outward from the elevated recharge sources.

Groundwater is expected to discharge at the margins of the lava flows into streams, lakes, springs and swamps. Where these margins meet with Ordovician outcrops, the groundwater is likely to enter the fracture system of these rocks. Bore data indicates a downward vertical hydraulic gradient where some discharge is also likely to occur vertically to the deeper portions of the basalt aquifer and underlying Tertiary and Ordovician sediments via leakage. It is suggested that recharge to the Pootilla deep lead occurs south of the Bungaree WSPA (URS, 2002).

Dahlhaus et al. suggests there is strong connection between the surface water bodies and the groundwater system in the basalt plains aquifer system in the middle to lower part of the catchment where watertables are naturally shallow. Saline groundwater discharges in lakes, streams, swamps and over broad depressions in the landscape. Saline discharge occurs along drainage lines around Ross Creek, Haddon and Elaine (Dahlhaus et al., 2002).

In the middle to lower part of the catchment where the unit forms wider volcanic plains it is understood to be a major contributor to salinity. Groundwater salinity generally deteriorates down catchment and ranges between 1,000 and 10,000 mg/L TDS. This resource is a major asset for irrigation of summer crops in the upper part of the catchment where the groundwater quality is best. Bore yields are typically 0.5 to 5 L/s.

In previous determinations of the permissible annual volume (PAV) of the basalt aquifer (SKM, 1998) recharge was assigned an infiltration of 5% of rainfall in recharge areas (proximal to vents) and 1.5% of rainfall across the basalt plains.

The aquifer parameters used by SKM in their 1998 estimation of the PAV for Bungaree noted the hydraulic conductivity as 5 m/day, storage co-efficient of 5.00E-02.

B.2.4 Quaternary alluvial deposits

The extent of the unconfined Quaternary aquifer systems is limited to narrow drainage lines located between flows of the Quaternary volcanics. Recharge occurs via infiltration from precipitation.

Groundwater moves at varying rates through these unconsolidated sediments in localised flow systems that develop at shallow depths below the natural surface (Dahlhaus et al., 2002).

The hydraulic gradient varies with the landscape; very low in rivers and swamps, and moderately steep in colluvium and lunettes. Where water tables are shallow there is a strong connection between groundwater and surface water systems.

Use of the alluvial aquifer for stock and domestic purposes is limited by its thickness. Groundwater salinity generally ranges between 3,000 and 10,000 mg/L TDS.

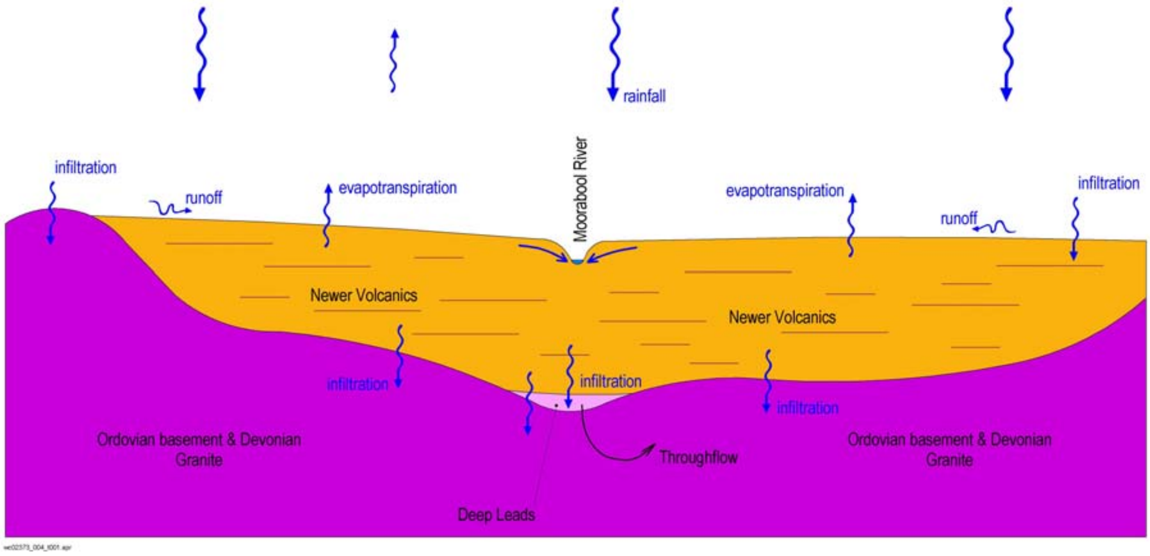
B.3 Hydrogeological Conceptualisation of Moorabool River reaches

B.3.1 Upper Catchment

The upper part of the catchment is characterised by moderately undulating hills and ridgelines formed by outcropping basement material and the Newer Volcanics basalt. The Moorabool River incises the basalt and underlying bedrock. The higher gradient flow of the river has resulted in little or no deposition of alluvial material.

The hydrogeological conceptualisation of the upper part of the Moorabool catchment is presented below in Figure 16-1. The deep leads units are represented here as remnants of ancient riverbeds now buried by the Newer Volcanics lava flows. In a water balance context the schematic is annotated to show how groundwater flows throughout the system.

- **Figure 16-1 – Hydrogeological Conceptualisation of the Upper Moorabool Catchment**

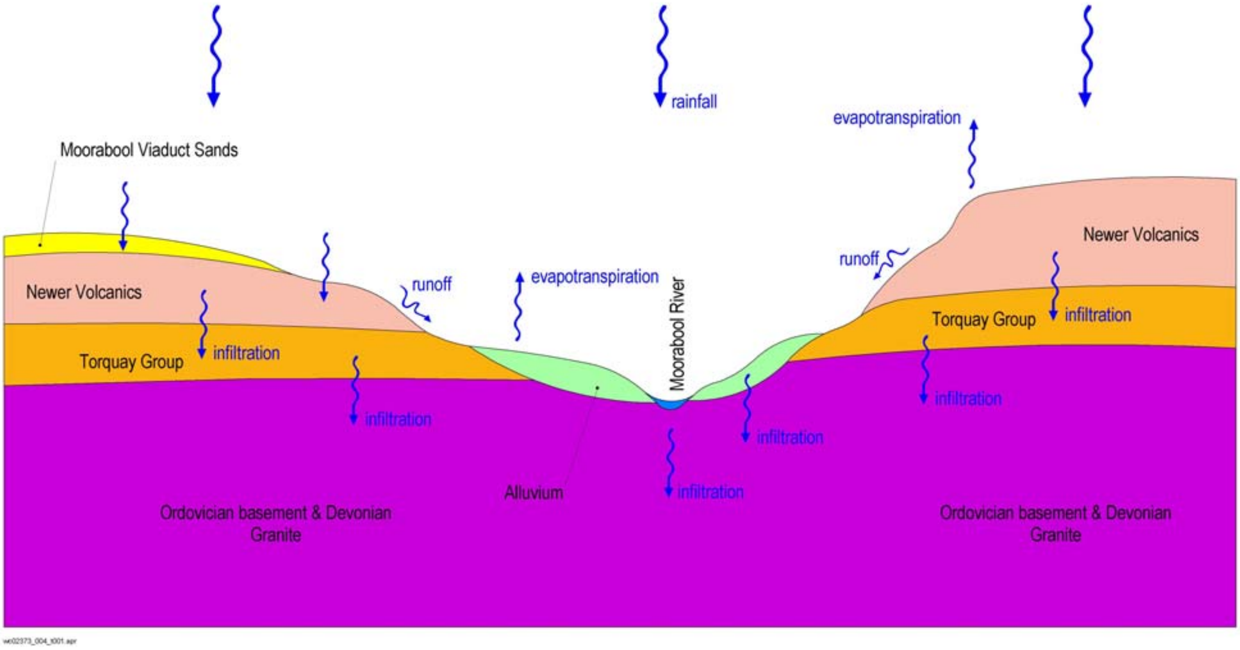


B.3.2 Lower Catchment

Down catchment the river valley opens up and the topography more gentle. The river incises the bedrock aquifer through a thicker sequence of Tertiary sediments over which the Newer Volcanics basalt was extruded. This sequence known as the Torquay Group comprises clay, limestone and basalt units. Alluvial sediments are more extensive along the river reaches downstream of Maude deposited along low level river terraces. Deposits of the Moorabool Viaduct sands occasionally overlie the basalt.

The hydrogeological conceptualisation of the upper part of the Moorabool catchment is presented below in Figure 16-2.

▪ **Figure 16-2 – Hydrogeological Conceptualisation Lower Catchment**



B.4 Data

B.4.1 Groundwater bore data

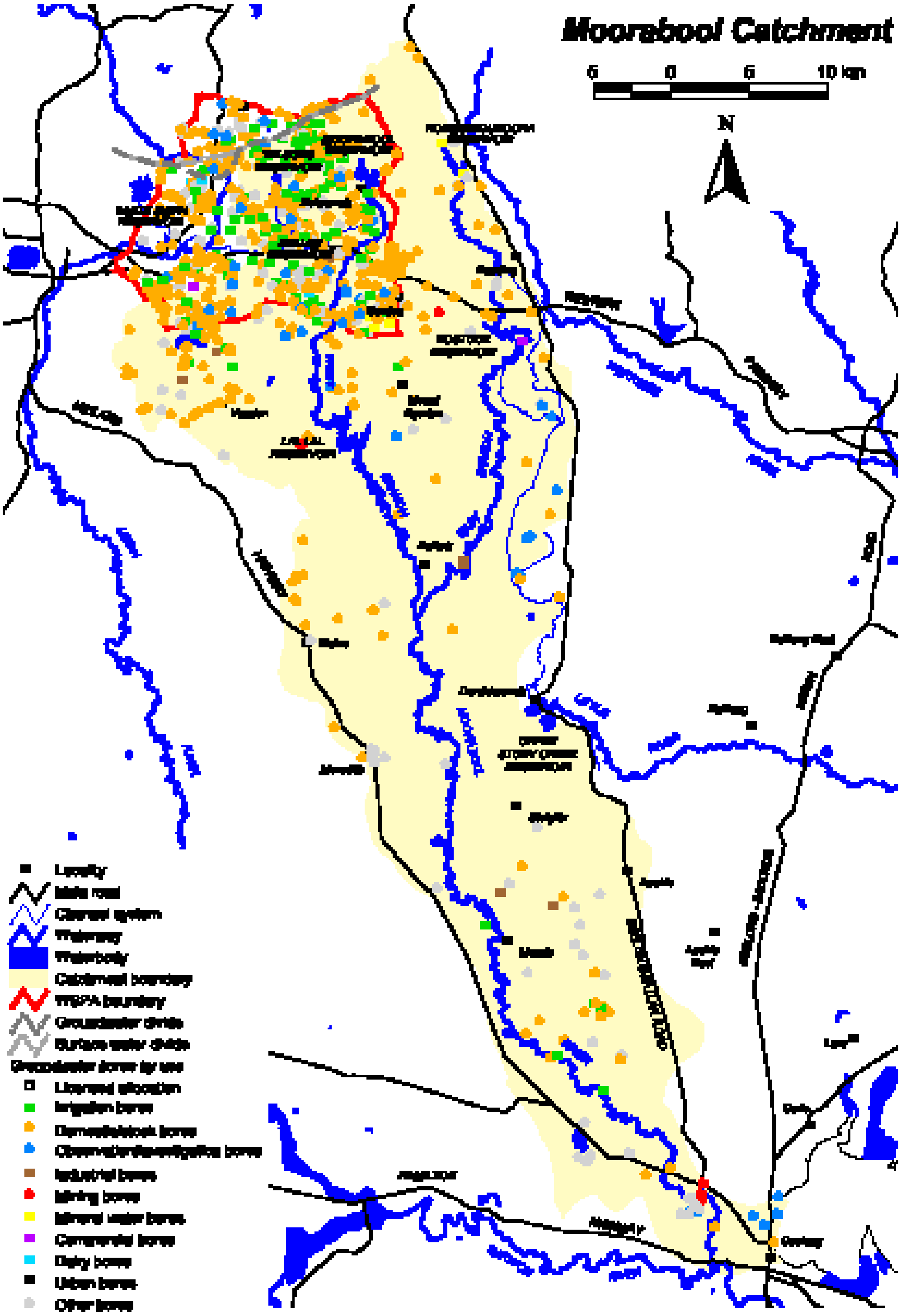
There are 1065 bores registered for groundwater purposes within the Moorabool River catchment. Their distribution according to bore use type and allocations is shown in Figure 16-3. Bores located within the Bungaree Water Supply Protection Area (WSPA) located in north west corner of the catchment are also included in the figure as they are relevant to the later discussion of impact of groundwater use on streamflow.

Almost half of these are being utilised for domestic and stock purposes. 15% are used for irrigation purposes, largely within the Bungaree WSPA. The spatial distribution of bores along the upper east branch of the Moorabool and downstream of the Lal Lal Reservoir is poor. Only 15% of bores have been drilled for investigation or observation purposes whereby very limited time series waterlevel data is available and few if any of this data is located adjacent to the River. The scarcity of near stream groundwater data is the major limitation in being able to evaluate groundwater surface water interaction.

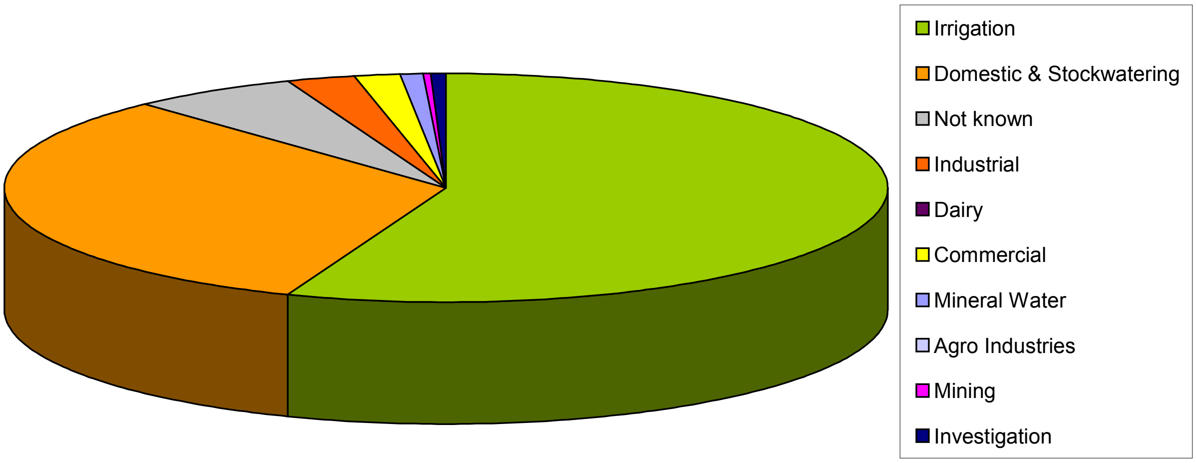
Total licensed allocation within the Moorabool catchment (and including the Bungaree WSPA) is in the order of 6,600 ML/yr (corrected to exclude triple counting of licences registered for multiple purposes). These allocations are registered for irrigation, industrial, mining, dairy and commercial purposes. Approximately 5,000 ML/yr of this total is registered within the

Bungaree WSPA. The distribution of these bores by groundwater use and allocation licence is shown in Figure 16-3. The breakdown of allocation type by volume is shown in Figure 16-4.

■ **Figure 16-3 – Distribution of Groundwater Users in the Moorabool catchment**



- **Figure 16-4 – Groundwater Users by Volume**



B.4.2 Streamflow Data

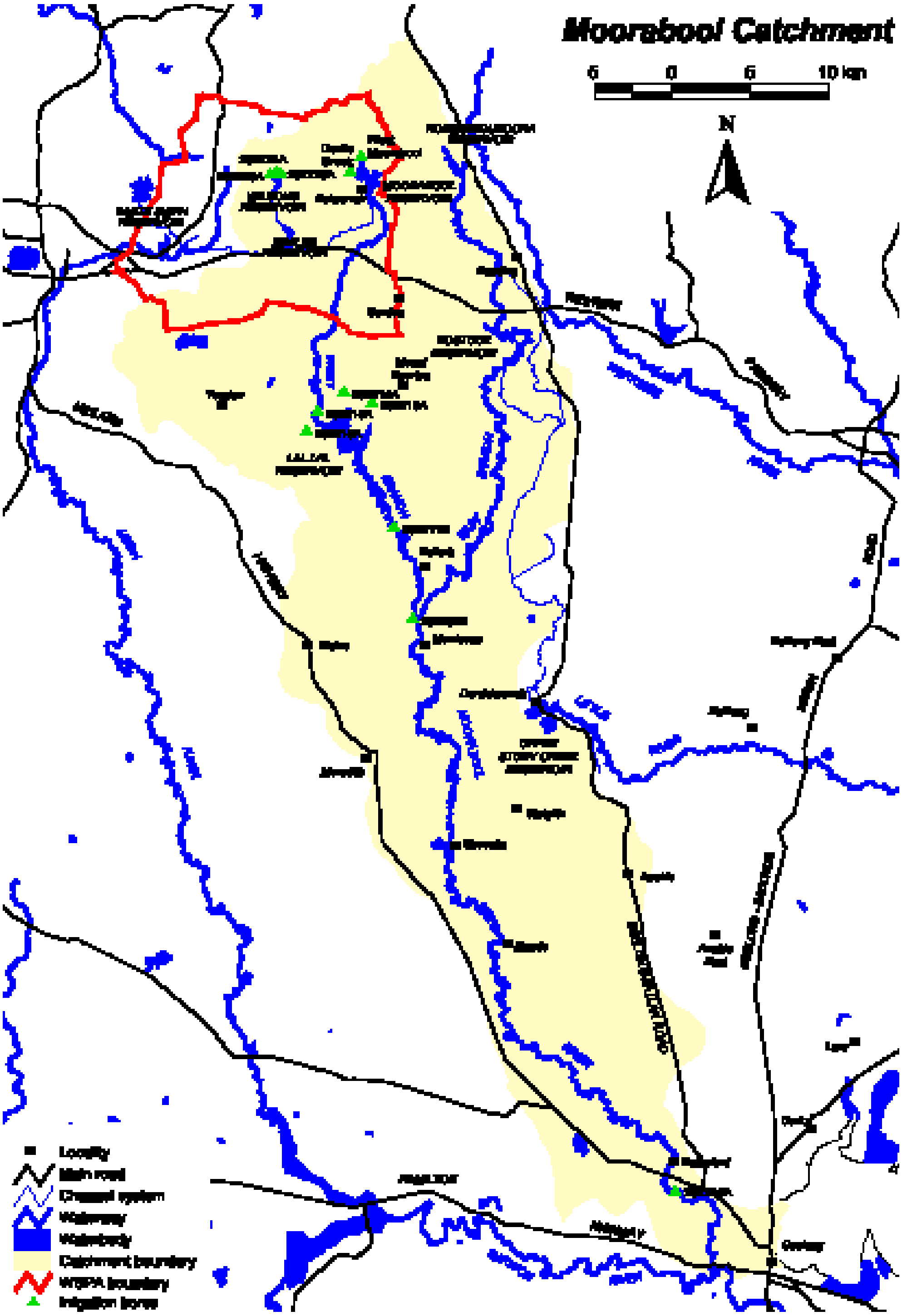
Data was sourced from both Thiess, Central Highlands Water and previous SKM project archives. Data acquired is shown in Table 16-1. The locations of the Gauging Stations throughout the catchment are shown in Figure 16-5.

▪ Table 16-1 Gauging Station Data Availability

Location	Description	Streamflow	EC	Survey	Elevation
Inflow to West Moorabool River between Moorabool Reservoir and Lal Lal Reservoir	REALM Inflow Series (WMOORBL INFLOW)	Y			
Inflow between Lal Lal, Bostock and Morrisons gauge	REALM Inflow Series (INFLOW UPSTREAM 204)	Y			
Batesford	Thiess Gauge 232202	Y		Y	
Morrisons	Thiess Gauge 232204	Y		Y	
Lal Lal	Thiess Gauge 232210	Y	Y	Y	Y
Black Ck U/S Bungal Dam	Thiess Gauge: 232214	Y		Y	
Frawley Ck U/S Wilsons Reservoir	Thiess Gauge: 232223	Y	Y	Y	Y
Mahars Ck U/S Wilsons Reservoir	Thiess Gauge: 232225	Y		Y	
Slater Ck U/S Wilsons Reservoir	Thiess Gauge: 232224	Y		Y	
Woollen Ck U/S Bungal Dam	Thiess Gauge: 232215	Y		Y	
Devil Creek	Central Highlands Water Gauge	Y			
West Moorabool River	Central Highlands Water Gauge	Y			

SKM

■ **Figure 16-5 – Location of Gauging Stations within the Moorabool Catchment**



B.5 Groundwater Issues

The potential impacts of groundwater use on flows in the Moorabool River have been assessed upstream of the Lal Lal Reservoir. For the most part groundwater extraction is concentrated about the north western corner of the catchment where due to increased demand on the resource the Bungaree Water Supply Protection Area (WSPA) was declared in April 2001. The Bungaree WSPA straddles the north western boundary of the Moorabool catchment with approximately one third of its area located outside the catchment.

The total allocation for groundwater extraction within the Bungaree WSPA (corrected to exclude duplicates) is approximately 5,000 ML, 82% of which is from metered bores. These allocations currently exceed the permissible annual volume (PAV), established at 4,400 ML/year. However in 2001/2002, 70% of license holders used less than 60% of their allocation, pumping approximately 1,583 ML in total (URS, 2002). Usage in 2002/03 was in the order of 3,750 ML.

Due to the lack of long term historical data in the area, only limited assessment can be made of the impact groundwater extraction has had on groundwater levels within the WSPA. Analysis of allocation volumes by Douglas & Partners (1996) indicated that the aquifer is under considerable stress as current allocations are in excess of recharge.

Measurable reduction in inflows to Moorabool Reservoir has also occurred in the Devil Creek sub-catchment in the north-eastern part of the Moorabool catchment. Possible causes of these reductions include groundwater extractions, onstream storages and farm dams. This task looks to quantify the potential impact groundwater usage in the Devil Creek sub-catchment is having on baseflow.

Surface water resources are also over committed within the catchment and downstream the Moorabool River has run dry since approximately 1993/1994. Anecdotal evidence suggests that this decline in flows coincide with increased groundwater usage and increased storage in farm dams.

B.6 Groundwater Surface Water Interaction

B.6.1 Definition

Total streamflow includes components of surface runoff, inflow from unsaturated soil (interflow) and baseflow from groundwater. The streamflow components are differentiated according to the path that water takes before it enters the channel. Surface runoff (also known as overland or quickflow) is that portion of the streamflow that reaches the stream after falling as rain and then travelling over the ground surface. Surface runoff travels rapidly to the river channel and therefore it generally represents a significant portion of the flood peak. Some of the water that infiltrates the ground surface may move laterally through shallow soils until it reaches the river channel. This water, called interflow or subsurface flow, moves more slowly than the surface runoff and generally reaches the channel at a later time. Interflow may however represent a significant portion of the total streamflow in those basins that have large regions of permeable soils and subsoils. The final component of the streamflow is water that percolates into the water table and then is held as aquifer storage before being discharged into the channel. Known as baseflow, the groundwater discharge component becomes the dominant streamflow component in dry weather after surface runoff and interflow have ceased. The baseflow component generally does not respond rapidly to rainfall and often represents a relatively stable and constant streamflow component.

B.6.2 Baseflow

Baseflow itself comprises a number of components, namely groundwater discharge, unsaturated zone flow, bank storage, delayed surface water (delayed by for example surface water bodies), delayed groundwater flow (delayed by for example perched systems). Methodologies to quantify these baseflow components individually have not yet been sufficiently developed. The component pertinent to this study is that affected by groundwater pumping; namely the groundwater discharge component. However as groundwater discharge cannot be easily separated from the other components this assessment may only serve to quantify the magnitude of the sum total of the five baseflow components. The methodologies applied in the estimation of total baseflow are described below in Section B.6.3.

Groundwater discharge or baseflow provides an important contribution to streamflow in Moorabool River and a significant proportion of its summer flow is derived from groundwater. The rate of groundwater discharge to the Moorabool River fluctuates according to groundwater levels that in turn respond to rainfall and pumping. Pumping from bores draws on water stored in the aquifer thereby lowering groundwater heads and groundwater discharge to streams and springs such as the Moorabool River can be reduced as a consequence. It has been noted that the flow in the Moorabool River is reduced and in some instances it has ceased flowing altogether. An important impact of any groundwater extraction is therefore its effect on the groundwater baseflow to Moorabool River. The principal objective of this part of the study is to assess the significance of the baseflow component of Moorabool River and impacts from groundwater users.

This study has involved the processing of measured and synthesised streamflow in the Moorabool River to obtain an estimate of the baseflow component. The baseflow estimate has then been used in conjunction with cross-sectional hydrological assessments along the Moorabool River to formulate predictions of streamflow changes in the creek arising from groundwater use upstream of the Lal Lal Reservoir.

Dahlhaus et al. suggests there is strong connection between the surface water bodies and the groundwater system in the basalt plains aquifer system in middle to lower part of the catchment. Saline groundwater discharges in lakes, streams, swamps and over broad depressions in the landscape.

B.6.3 Methodology for Assessment

Broadscale Mapping

The relative river and groundwater levels were compared throughout the catchment to identify those reaches that appear to have some hydraulic connections.

Digital Elevation Model data for the Moorabool catchment was used along with the 1:25,000 scale hydrological elevation data to plot both the RWLs and river elevations creating relative surfaces. From this plot groundwater flow toward and away from the river was broadly defined and hence where reaches are apparently gaining and losing. Those reaches where a high potential of groundwater surface water interaction is identified were then validated via more detailed analysis.

Using gauging station survey data obtained from Thiess Services, a series of cross-sections were used to approximate bank slope and depth of river incision throughout the catchment. Despite the limited near stream groundwater level data, this information provides an indication of the interval over which it is possible for groundwater to discharge to the river.

Baseflow Analysis

Streamflows in the Moorabool River catchment are affected by the upper catchment storages of Moorabool Reservoir, Lal Lal Reservoir, Korweinguboora Reservoir and Bostock Reservoir. A baseflow separation analysis, which estimates the proportion of total streamflow, which is sourced from baseflow, can only reliably be performed on unregulated streamflows. There are only a few gauges on unregulated tributaries in the catchment.

The analyses depend upon the availability of concurrent, continuous streamflow data at upstream and downstream locations, the influence of in-stream diversions, travel time between the gauges and the accuracy of the streamflow gauges themselves. Due to these factors the table below applies a quality indicator where 1 represents the highest level of confidence and 4 the lowest. Data for baseflow index determination was sourced from daily streamflow records and weekly inflow estimates. Data quality has been assessed for the input data, with details given in Table 16-2.

SKM

- **Table 16-2 Locations of baseflow index estimation**

Location	Description	Data Frequency	Data Quality
Inflow to West Moorabool River between Moorabool Reservoir and Lal Lal Reservoir	REALM Inflow Series (WMOORBL INFLOW)	Weekly	4.
Inflow between Lal Lal, Bostock and Morrisons gauge	REALM Inflow Series (INFLOW UPSTREAM 204)	Weekly	3.
Black Ck U/S Bungal Dam	Thiess Gauge: 232214	Daily	2.
Frawley Ck U/S Wilsons Reservoir	Thiess Gauge: 232223	Daily	1.
Mahars Ck U/S Wilsons Reservoir	Thiess Gauge: 232225	Daily	1.
Slater Ck U/S Wilsons Reservoir	Thiess Gauge: 232224	Daily	1.
Woollen Ck U/S Bungal Dam	Thiess Gauge: 232215	Daily	2.
Devil Creek	Central Highlands Water Gauge	Daily	2.
West Moorabool River	Central Highlands Water Gauge	Daily	1.

Data Quality:

1. High level of confidence in flows.
2. May be effected by catchment activity (farm dams, onstream storages, etc)
3. Calculated by reach balance
4. Calculated by reach balance - may be effected by catchment activity

Note: Gauging Stations 232223, 232224 and 232225 are all located within the Bungaree WSPA.

Base flow indices were determined for unregulated inflows of the Moorabool catchment using the digital filter separation technique. The two parameters to the digital filter separation technique specified by the user are a filter parameter and the number of times (passes) that the filter algorithm is applied to the streamflow data.

Traditionally this technique is applied to daily streamflow series to establish a baseflow series, with the combination of daily streamflow and separated baseflow used to estimate the seasonal baseflow index. There are limited streamflow gauges of the unregulated tributaries of the Moorabool catchment, hence a technique was established for the separation of baseflow from weekly REALM inflow series to allow for a ‘complete catchment’ picture of baseflow indices. The stream flow series for which the baseflow component was estimated are listed in Table 16-2 giving the frequency of data analysed.

Thiess maintains 5 daily streamflow gauges of unregulated streams of the Moorabool catchment, listed in Table 16-3. A filter parameter of 0.925 with three filter passes has been established as the ideal generalised filter parameters for separation of baseflow from a daily streamflow series (Nathan & McMahon, 1990), yet no such recognised parameter set exists for weekly streamflow records such as the REALM inflow series. The daily streamflow gauges of Table 16-3 were aggregated to weekly, with filter parameters tuned to replicate the baseflow indices achieved by separation of the daily series using the above default parameters. The results of this are given in Table 16-4.

- **Table 16-3 Daily unregulated streamflow gauges of the Moorabool catchment**

Station Number	Station Name	Year Record Commences	Year Record Concludes
232214	Black Ck U/S Bungal Dam	1990	To date
232223	Frawley Ck U/S Wilsons Reservoir	1995	To date
232225	Mahars Ck U/S Wilsons Reservoir	1995	To date
232224	Slater Ck U/S Wilsons Reservoir	1995	To date
232215	Woollen Ck U/S Bungal Dam	1990	To date

- **Table 16-4 Results of tuning weekly filter parameters at established sites.**

Gauge	Daily BFI	Weekly Filter Param	Weekly # Passes	Weekly BFI
232214	0.3539	0.6094	3	0.3536
232215	0.3557	0.6140	3	0.3554
232223	0.4703	0.6215	3	0.4555
232224	0.5183	0.6195	3	0.5193
232225	0.6012	0.6092	3	0.6221
Avg:		0.6147		

The results of Table 16-4 show very little variability in the filter parameters of weekly streamflow data to reproduce the baseflow results of daily data. A filter parameter of 0.6147 is accordingly applied to weekly flow series in the absence of better daily streamflow information.

Assessment of the Groundwater Cycle

These baseflow analyses indicate the proportion of streamflow that is baseflow. The outputs were incorporated into an assessment of the components of the groundwater cycle of the Bungaree WSPA to evaluate the relationship between groundwater and surface water and the subsequent impact increased usage (to allocated volumes) might have on the Moorabool River. Further to the discussion of the five components of baseflow in Section B.6.2 the results are taken as an indication of the sum total of all five baseflow components.

The results of this evaluation were then extrapolated to the Devils Creek sub-catchment and used to draw conclusions about downstream reaches to determine whether the results are broadly consistent with the hydrogeological setting in the catchment.

B.7 Results

B.7.1 Broadscale Mapping

Groundwater level data proximal to the Moorabool River is very limited. The waterlevels are also highly variable making it impossible to derive a meaningful relationship between the relative heights of the potentiometric surface and the river stage height.

Very few of the groundwater bores with waterlevel data are surveyed. The Digital Elevation Model of the Moorabool catchment was therefore used to align the available standing water level data to a uniform datum and create a potentiometric surface. Combined with the hydrological survey data of the surface water bodies the relative levels of groundwater and surface water were projected across the catchment. From this plot the directions of groundwater flow were visible in a very broad scale sense providing an indication of where groundwater appeared to flow toward and away from reaches of the Moorabool River and its tributaries.

Cross-sectional data surveyed across gauging station relative to an arbitrary datum was obtained from Thiess Services for the gauging stations shown in the following table. Data reduced to the Australian Height Datum were obtained for only two of the stations as shown.

- **Table 16-5 Gauging Station Data Availability**

Location	Description	Gauge Elevation (AHD)
Moorabool @ Batesford	Thiess Gauge 232202	
Moorabool @ Morrisons	Thiess Gauge 232204	
Moorabool @ Doran	Thiess Gauge 232211	
Moorabool @ Lal Lal	Thiess Gauge 232210	Y
Lal Lal @ Bungal Dam	Thiess Gauge: 232213	
Black Ck U/S Bungal Dam	Thiess Gauge: 232214	
Woollen Ck U/S Bungal Dam	Thiess Gauge: 232215	
Frawley Ck U/S Wilsons Reservoir	Thiess Gauge: 232223	Y
Slater Ck U/S Wilsons Reservoir	Thiess Gauge: 232224	

Plots of these cross-sections are presented in B.12.

Although these plots primarily show the cross-sectional view of the concrete bund or V-notch weir, they also provide an indication of the bank slope, depth of river bed and the degree to which the river incises the topography at various points along the catchment.

An examination of the available nearby groundwater level and hydrograph data is summarised as follows:

Gauge 232202 – Moorabool at Batesford

Cross sectional data indicates riverbank gradient of 0.2.

There was no waterlevel data proximal to gauge section. In both upstream and downstream directions groundwater level data indicated depths of 6 metres below natural surface.

Gauge 232204 – Moorabool at Morrisons

Cross-sectional data indicates a steeply incised bank gradient of 0.6.

There was no waterlevel data proximal to gauge section. Closest bores showed waterlevels exceeding 26 metres below natural surface level.

Gauge 232211 – Moorabool at Doran

Cross sectional data indicates riverbank gradient of 0.3.

There was no waterlevel data proximal to gauge section. Closest bores showed waterlevels exceeding 21 metres below natural surface level.

Gauge 232210 – Moorabool at Lal Lal, Gauge 232214 – Black Creek at Bungal Dam and Gauge 232215 – Woollen Creek at Bungal Dam

Cross sectional data indicates riverbank gradients of 0.2, 0.35 and 0.3, respectively.

A limited amount of groundwater level data is located in the vicinity of these three gauging stations. While some bores show waterlevels ranging between 8 to 15 metres below natural surface level, the hydrograph data available from nearby Bore 119336 shows waterlevels fluctuate between 0.5 and 2 metres below natural surface level. This hydrograph indicates that in the vicinity of the reach immediately upstream of the Lal Lal Reservoir the groundwater may be above the base of the river bed potentially discharging to the stream, and for the river to be therefore gaining (influent).

Gauge 232223 – Frawley Creek at Wilsons Reservoir and Gauge 232224 – Slater Creek at Wilsons Reservoir

Cross sectional data indicates riverbank gradients of 0.15 for both gauges.

There was no waterlevel data proximal to these gauge sections. The closest bores indicate that groundwater levels range between 3 and 7 metres below natural surface level. However, given the moderate degree to which the river incises the topography in this upper part of the catchment, some degree of discharge to the river would be expected.

B.7.2 Results of Baseflow Separation Analyses

A summary of the baseflow analysis results is presented in Table 16-6. These results show that baseflow accounts for approximately 50 to 60 % of the total streamflow in the upper catchment (upstream of Moorabool Reservoir), and 30 to 40 % in the middle catchment (between Moorabool and Lal Lal Reservoirs). In deriving a unit baseflow representative of the respective catchments an average baseflow contribution is calculated across a unit area. An areal figure has been used for each catchment as it may be accurately defined. The alternative of applying a unit baseflow per unit length of stream was not adopted due to significant inaccuracies in accounting for all lengths of contributing streams anastomosed throughout the catchment.

The areal based average baseflow contribution in the upper catchment was therefore found to be 130 ML/year/km^2 (130 mm/year) and in the middle catchment 21 ML/year/km^2 (21 mm/year).

▪ Table 16-6 – Summary of Baseflow Analyses results

Location Description	Middle Catchment				Upper Catchment				
	Wmoorbl – Moorbl to Lal Lal	Lal Lal, Bostock to Morrisons	Black Creek at Bungal Dam	Woollen Creek at Bungal Dam	Bungaree Frawley	Bungaree Slater Ck	Bungaree Mahars Ck	Devils Ck	West Moorabool
Station Number	REALM	232204	232214	232215	232223	232224	232225	CHW	CHW
Data Reliability	4	3	2	2	1	1	1	2	1
TOTAL FLOW Average Annual (ML/yr)	6420	5400	760	456	480	273	243	1862	2169
BASEFLOW Average Annual (ML/yr)	2632	1557	270	170	227	143	147	1092	1269
BFI Approx. % of Total Flow	41%	29%	36%	35%	43%	50%	58%	59%	58%
Catchment Area (km^2)	n/a	320	13	6	1.5	1.1	1.1	9	12
UNIT AREA BASEFLOW Baseflow per km^2 (ML)	n/a	5	21	28	151	130	134	121	106

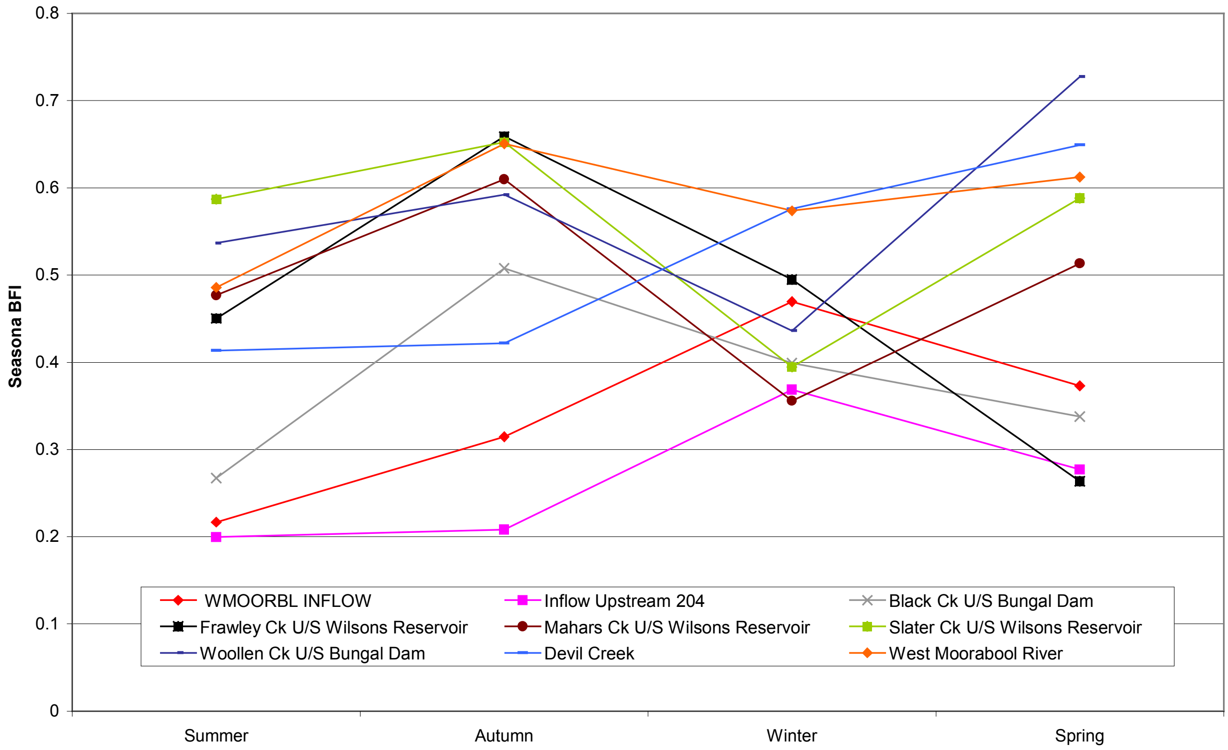
Data Quality:
1. High level of confidence in flows.
2. May be affected by catchment activity (farm dams, onstream storages, etc)
3. Calculated by reach balance
4. Calculated by reach balance - may be affected by catchment activity

CHW – Central Highlands Water

The seasonal baseflow indices are presented below in Figure 16-6.

This plot demonstrates that while peak baseflow volumes would be expected in late Summer and early Autumn, for some of the gauges analysed baseflow volumes at the end of the Winter and Spring months are higher. The graph is evidence that either gauge data is suspect or a significant degree of regulation (e.g. on stream storages) has affected the results.

As expected, the unregulated sub-catchments of Slaters Creek, Frawley Creek and Mahars Creek show higher Summer/Autumn baseflow volumes, as does the West Moorabool sub-catchment. These results correlate with the high level of confidence assumed for these four gauges. In contrast the Winter Spring baseflow volumes derived from the analyses of the Devils Creek catchment are markedly higher than Summer Spring volumes suggesting that the onstream storages have significantly affected the data.



▪ **Figure 16-6 – Seasonal Baseflow Indices**

B.7.3 Assessment of the Groundwater Cycle

Definition of the study area

The north west perimeter of the Moorabool catchment boundary or surface water divide runs to the east of Pootilla and Leigh Creek, outside of which surface flows are directed south west toward Ballarat as part of the Leigh Creek catchment. However, basement contours (URS, 2002) together with the delineation of the Pootilla deep leads (Taylor & Gentle 2002) indicate that the groundwater divide is located to the north west of the surface water divide. As such the groundwater flows and usage in this area outside of the Moorabool catchment is factored into a quantitative assessment of the groundwater cycle used to provide an indication of impacts on streamflow. Furthermore, a portion of the Bungaree WSPA (having a total area of 20 km^2) is also located to the north of both the surface water and groundwater divide. Calculations used in the assessment of groundwater cycle components have been factored down to exclude this portion (comprising approximately 10 % of the Bungaree WSPA). The study area therefore consists of that area within the Bungaree WSPA boundary and below the groundwater divide (approximately 180km^2). The delineation of the catchment boundary, Bungaree WSPA and groundwater divide are shown in Figure 16-3.

Components of the Groundwater Cycle

In order to assess the effect groundwater usage will have on streamflows in the Moorabool River an understanding of the groundwater cycle components is required. That is, the inputs and outputs to the groundwater system that should balance in a sustainable environment.

The permissible annual volume (PAV) for the Bungaree WSPA is 4,400 ML/year. The purpose of defining PAVs however was to provide a guide for prioritisation of WSPAs throughout the State for further investigations. The methodology applied cannot be used to calculate the actual sustainability of the aquifer system. The factored down PAV for the study area is therefore approximated as 4,000 ML/year.

In order to obtain a more complete understanding of the factors affecting baseflow contribution to surface water flows, the components of the groundwater cycle are hereby evaluated. This assessment of the groundwater cycle is considered a crude means of evaluating the different groundwater processes operating within the catchment. It was established using time inconsistent parameters (that is, annual data was used where it was available, it was not available for a common year) and is not representative of a particular year (average, dry, wet). The assessment has been undertaken to demonstrate the relative orders of magnitude of the respective components and draw out the relationship between groundwater use and baseflow.

Essentially the groundwater cycle operates as follows:

Inputs = Outputs – change in Storage

where inputs include recharge and outputs include groundwater extractions, vertical leakage, aquifer throughflow, evapotranspiration and baseflow.

Recharge

Average rainfall throughout the study area is shown on the Bureau of Meteorology rainfall map of Victoria rainfall stations and is in the order of 900 mm/year or approximately 162,000 ML/year in the study area.

In the upper part of the catchment, the recharge areas incorporating volcanic vents will permit greater amounts of infiltration relative to the plains. Values of infiltration were adopted from figures detailed by Douglas Partners (1996) as 5% of rainfall in the uplands (approximately 20.8 km^2) and 1.5% of rainfall on the plains (approximately 187 km^2). Using these figures the overall rainfall recharge for the Bungaree WSPA is given as 4,436 ML/year. This approximates to 4,000 ML/year for the study area. Hydrograph fluctuation data visited by URS (2002) concluded that recharge rates of up to 100 mm/year (11 % of rainfall) were possible. Recharge rates of this magnitude are likely to occur to a limited extent (for example, scoria cones comprising approximately 1 % of the total area). To account for these higher rates occurring within the study area, and for additional recharge that occurs under irrigation areas the recharge component of the groundwater cycle is therefore rounded up to 4,200 ML/year (on average a recharge of 23 mm/year).

Aquifer Inflow

Aquifer inflow accounts for groundwater that flows laterally in to and out of the aquifer system. Given the northern boundary of the study area is defined by the groundwater divide, aquifer inflow is assumed to be nil.

Evapotranspiration and Quickflow

The evapotranspiration component is the most difficult to quantify. Given the depth to the water table throughout the study area averages 10 metres below natural surface level, it can be argued that evapotranspiration is negligible except in the vicinity of the Moorabool and its tributaries. Quickflow (or overland flow) is that portion of the streamflow that reaches the stream after falling as rain and then travelling over the ground surface. Surface runoff travels rapidly to the river channel and therefore it generally represents a significant portion of the flood peak. In the assessment of the groundwater cycle these two components have not been defined.

Groundwater Extractions

Allocated extractions total 4,500 ML although metered usage throughout the WSPA indicates extraction totals 1,583 ML as reported by Southern Rural Water for the metered usage 2001/2002. Usage in 2002/03 was approximately 3,750 ML. Approximately 5 % of irrigation licences appear to occur north of the groundwater divide (outside the study area) whereby this figure is factored down to 1500 ML/yr (approximately 8 mm/year). Domestic and stock usage need also be accounted for in the assessment of the groundwater cycle as approximately 260 bores registered for these purposes are distributed throughout the study area. Most of this use is likely to be for domestic purposes. Assuming an average usage of up to 1 ML per bore, an allowance of 200 ML (approximately 1 mm/year) for domestic and stockwatering extractions has been factored in.

Baseflow

As defined earlier in Section B.6.2 baseflow comprises a number of components, namely groundwater discharge, unsaturated zone flow, bank storage, delayed surface water, delayed groundwater flow. The groundwater discharge component may account for as little as 50 % of total baseflow or as much as 99 % of the total baseflow volume deduced. As this component, which is that affected by groundwater pumping, cannot be separated from the sum total of baseflow a degree of error is assumed in the volume used.

The results of baseflow analyses undertaken on the three gauging stations located within the Bungaree WSPA (Stations 232223, 232224, 232225, Devils Creek and West Moorabool) estimate that the average annual baseflow per square kilometre is in the order of 130 ML/yr (approximately 130 mm/year). This figure is an order of magnitude higher than those estimated for the middle and lower sections of the Moorabool catchment. Applying this rate over the Bungaree study area yields a total baseflow contribution in the order of 23,400 ML/year. This estimate is also an order of magnitude higher than the other components of the groundwater cycle. As explained above the actual groundwater discharge component of this figure will comprise only a portion of this volume. It should therefore be considered only an upper limit of the possible volume of groundwater discharge contributing to baseflow within the study area. In fact the qualitative nature of the inference regarding attenuated streamflow response in the baseflow analysis lends itself to consideration of a baseflow range rather than an absolute figure.

The main input component of the groundwater cycle, rainfall recharge is estimated at 23 mm/year. Outputs such as groundwater extraction are in the order of 8 mm/year. Consideration of these major input and output components suggest that the groundwater discharge component of baseflow in the study area may possibly range from around 10 mm/year to 130 mm/year (1800 to 23,400 ML/year). Using a range for the baseflow estimate is a more realistic consideration of the component given other factors such as the effect of on-stream storages on river reaches analysed in the Upper Moorabool can also significantly vary the final figure.

Aquifer Outflow

Aquifer outflow has been calculated using Darcy's Law Q = K *i* A (m/day).

The hydraulic conductivity of the basalt aquifer has been evaluated on the basis of literature review and available pumping test data as 5 m/day. The hydraulic gradient has been approximated from gradients evidenced in the basement contours and topographic surface as 0.003. The area has been derived from the approximate cross-sectional area of the basalt at the down gradient end of the study area. The lateral extent of the basalt in this area is significantly constrained by the outcropping Lal Lal Granite and estimated at 4 kilometres wide. The area also assumes an average thickness of 20 metres. Aquifer throughflow is therefore estimated at 400 ML/year.

Vertical Leakage

The vertical leakage from the basalt aquifer to the underlying bedrock aquifer has been calculated, along with that possible via the deep leads units where they occur within the study area.

Deep Leads

There is the potential for groundwater to flow down catchment via the deep leads units. The hydraulic conductivity of the basalt aquifer has been evaluated on the basis of literature review as averaging 10 m/day. The hydraulic gradient has been approximated from gradients evidenced in the basement contours and topographic surface as 0.005. The area has been derived from the approximate cross-sectional area of the deep leads units as described in Taylor and Gentle (2002). These units are known to average 5 metres in thickness and be up to tens of metres wide. For these calculations a width of 50 metres has been used. The volumes derived (4.5 ML/yr) are so low they are not likely to impact significantly on overall water availability.

Basalt Aquifer

The hydraulic conductivity of the underlying basement aquifer has been evaluated as being 0.005 m/day. As there is no nested data incorporating bores screening the bedrock aquifer within the study area the hydraulic gradient has been approximated from waterlevel data in nested bores constructed within the basalt as 0.0005. The study area comprising 180 square kilometres defines the cross-sectional area over which leakage occurs. Vertical leakage from the basalt aquifer is therefore estimated at 145 ML/year.

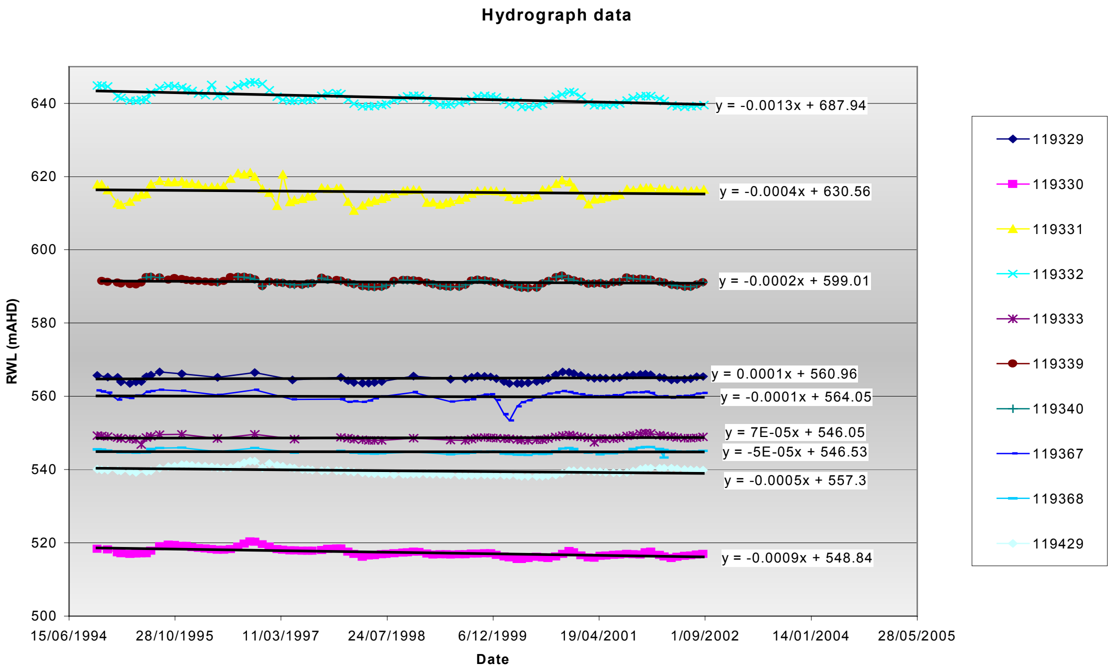
Change in Storage

The change in storage has been calculated from hydrograph data available from 9 bores located within the study area and screening the basalt aquifer. Regular monitoring has occurred since 1994 within the study area. The hydrographs are presented in Figure 16-7. The average decline in the hydrographs is 0.05 m/year.

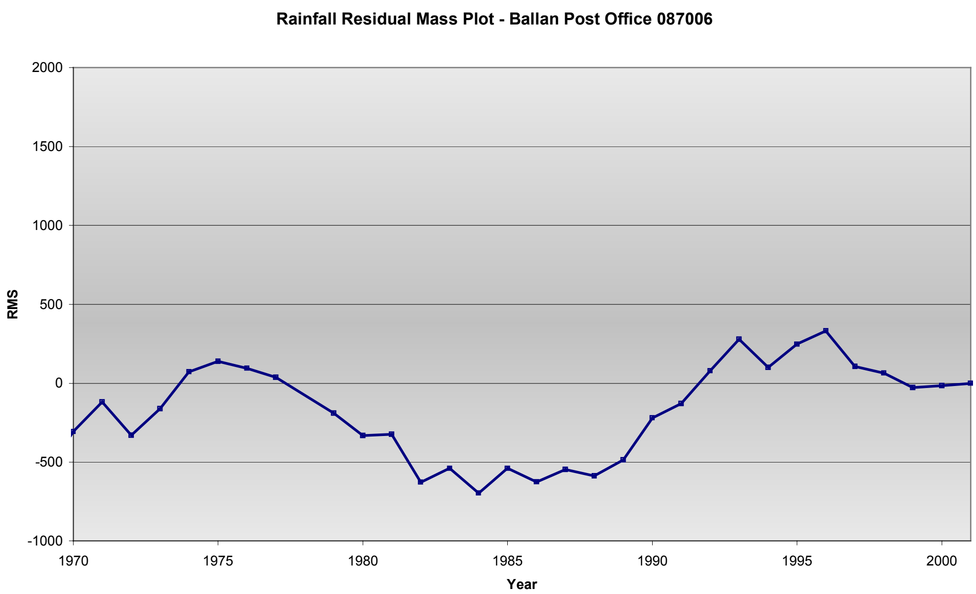
There is insufficient data to conclude whether the declines in groundwater levels within the WSPA are the result of declining rainfall or increased groundwater usage or both. A rainfall residual mass plot of rainfall recorded for the same period at the nearby Ballan Post Office (Station 087006) was developed (see Figure 16-8 – Residual Mass Curve (Station 087006) 1970 to 2001). This plot indicates that while wet years were recorded in the years leading up to 1993 and again between 1994 (when monitoring began) and 1996, since this time dry years (having less than average rainfall) have been recorded.

Assuming a specific yield for the basalt aquifer of 5%, the change in storage over the study area is estimated at 500 ML. However, given the greater part of the hydrograph record is characterised by dry years (refer rainfall residual mass plot Figure 16-8) the change in storage cannot be wholly attributed to extraction. Change in storage due to groundwater extraction is therefore taken as 50 % of the total, and is approximated as 250 ML (approximately 1.4 mm/year).

■ Figure 16-7 – Hydrographs of bores screening the basalt aquifer

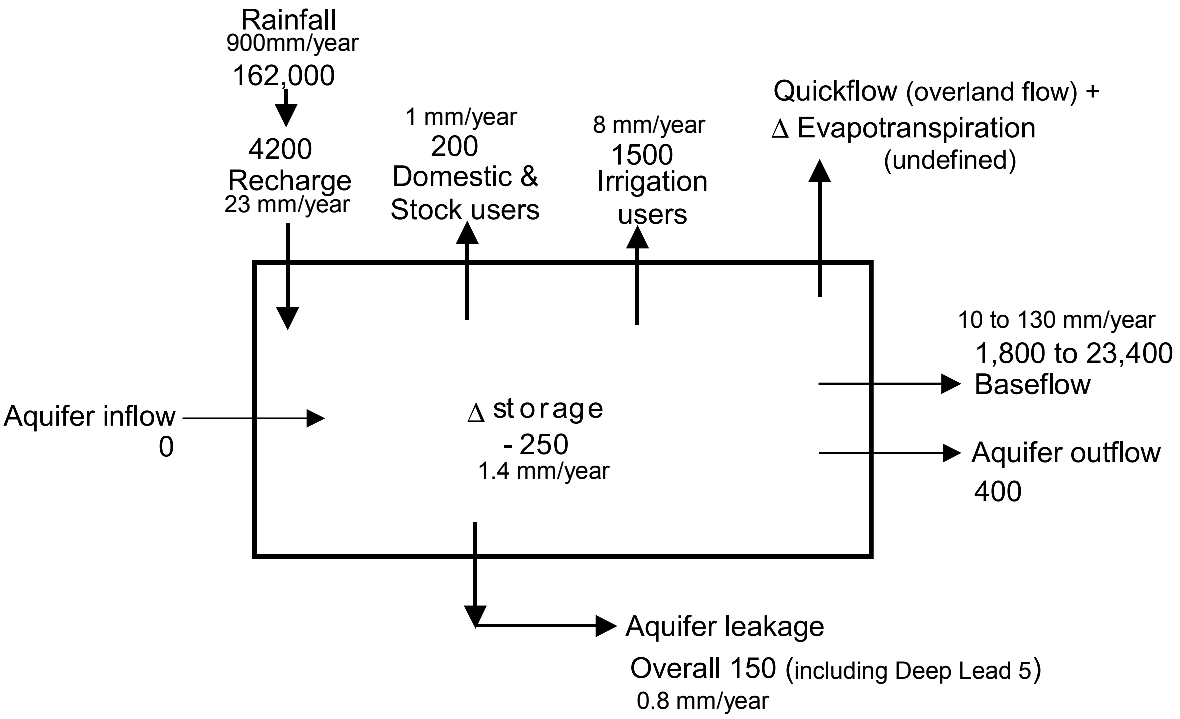


■ Figure 16-8 – Residual Mass Curve (Station 087006) 1970 to 2001



The groundwater cycle of the study area is presented in *Figure 16-9*.

- **Figure 16-9 – Components of the Groundwater Cycle**



Note:
All units in ML/year (and mm /year where indicated)
These calculations ignore time delays inherent in several components of the groundwater cycle

B.8 Discussion of Results

Qualitative assessment undertaken by comparing the Digital Elevation Model layer with the hydrological survey data layer indicated groundwater flow toward the river along most reaches of the Moorabool River. However, the distribution of flow directions plotted via this method was very inconsistent and appeared to be significantly influenced by topography. It was therefore considered an unreliable method for determining influent and effluent reaches of the river, even in a broad sense. The spread of waterlevel data downstream of Lal Lal Reservoir was particularly poor and not sufficiently close to the river. Overall the results were not considered meaningful.

The cross-sectional survey data of gauging stations obtained throughout the catchment provided a good representation of the configuration of the stream measurement points. However, only a small number of the cross-sections extended above the gauge to provide an indication of the bank gradient. It was hoped that nearby time series waterlevel data might be available in order to observe the relative levels of groundwater and surface water over time and assess the potential for hydraulic connection between the two. The distribution of waterlevel data, especially time series data, is very poor and highly variable.

The absence of sufficient time series groundwater level and survey data proximal to the Moorabool River precluded the use of broad scale mapping methods to a definitive quantification of the volumes of baseflow contributing to the given reaches of the Moorabool River. Installation of monitoring bores adjacent to the river in areas of intensive groundwater extraction would be required to ultimately enable baseflow to be better understood and managed through the setting of target groundwater levels. If levels next to rivers are monitored and maintained above a given minimum then the baseflow corresponding with the minimum levels can be protected.

The baseflow analyses results performed on gauging stations upstream of the Lal Lal Reservoir however indicated a strong relationship between groundwater and surface water. While the relative magnitude of the baseflow volumes appears questionable, the seasonal trends in baseflow for most of the gauges analysed indicated a reasonable degree of confidence in the results. The baseflow analysis results indicated that the baseflow contribution in the upper catchment (upstream of Moorabool Reservoir) is in the order of 50 to 60 %. This range is typical for unregulated Victorian streams (SKM, 2001). The baseflow analyses results are lower in the middle portion of the catchment where baseflow accounts for 30 to 40 % of the total flow in the Moorabool River.

Incorporating these results in an assessment of the groundwater cycle of the upper portion of the catchment provides the relative orders of magnitude of the different groundwater processes operating within the catchment and show evidence of a strong relationship between groundwater and surface water. The component of groundwater discharge contributing to baseflow ranging from 10 to 130 mm/year accounts for approximately 1 to 14 % of rainfall falling across the study area. This range in the groundwater discharge component supports the notion that recharge across the study area may be higher than currently estimated rates of rainfall recharge; 1.5% on the Plains and 5 % in the recharge areas (averaging 23 mm/year across the study area). As previously mentioned URS (2002) concluded using hydrograph fluctuation data that recharge rates of up to 100 mm/year (11 % of rainfall) were possible.

A reasonable degree of confidence is assumed in the estimation of the rainfall, groundwater extraction, aquifer inflow and change in storage components. Of these components only groundwater extraction is likely to change (increased groundwater usage) subsequently affecting the other components.

Referring to the assessment of the groundwater cycle components, the short term effect (months) of low rainfall and/or groundwater extraction is a decline in the groundwater level (as evidenced in hydrograph data) causing a change in storage (250 ML). A subsequent decline in evapotranspiration, baseflow, aquifer throughflow and aquifer leakage is then anticipated.

Although a moderate degree of uncertainty is assumed in the estimation of the aquifer throughflow and leakage components, they remain at least two orders of magnitude lower than baseflow and evapotranspiration. Furthermore, due to the distance and rate at which groundwater may travel, any impacts on aquifer throughflow (vertical and horizontal) are likely to occur in the long term. This assessment of the groundwater cycle concludes therefore that the key components affected by increased groundwater pumping in the medium term (years) will be evapotranspiration and baseflow.

Given that the water table is generally at depth throughout the catchment it further demonstrates that conceptually the impacts on evapotranspiration from small changes in water table depth are not significant. It follows that the baseflow component is that which would be most affected by increased groundwater extraction. In the medium term the drop in groundwater level will lower the hydraulic gradient to the river thereby reducing the baseflow component.

The basis for interpreting a high degree of interaction is simply that the other components of the groundwater cycle are small, and hence if groundwater usage varies, only baseflow can vary significantly.

The relationship between groundwater extraction and groundwater discharge is evaluated in relative terms. The assessment of the components of the groundwater cycle indicates that groundwater extraction in the study area (equivalent to 9 mm/year in 2000/01) is comparable to the lower estimate of the groundwater component of baseflow (ranging between 10 and 130 mm/year). In determining the relationship between these two significant components of the groundwater cycle it is considered that should a one to one relationship exist (the most extreme scenario) for every megalitre of groundwater pumped, one megalitre will be lost from the groundwater contribution to baseflow. However, as the proportion of groundwater discharge that makes up baseflow is uncertain so too is the relationship between these two components.

Allowing a degree of error in the subjective assessment of the groundwater discharge component of baseflow it is possible that the relationship may vary between one to one (i.e. 100 % effect; for each megalitre extracted, groundwater discharge will decrease by 1 ML) and one to four (i.e. 25 % effect; for each megalitre extracted, groundwater discharge will decrease by 0.25 ML).

Dahlhaus 2003 (pers. comm.) suggests it is logical that the vast majority of the baseflow is contributed by [groundwater] discharge from the volcanic aquifers, as these are the most transmissive and extensive aquifer in the catchment. Groundwater extraction from the volcanic aquifers, especially for summer crop irrigation, would reduce the fresh discharge component from the volcanics and contribute to the rising trend in salinity of the Moorabool River. Salinity trends (EC) support this relationship. Dahlhaus advised that his analysis of streamflow salinity indicates that EC trends in the Moorabool are rising. The gauging station just above the Lal Lal Reservoir shows a significant rising trend in the salinity of the Moorabool River, which accounting for the influence of flow and seasons suggests a rise in the salinity of the stream baseflow component. The groundwater baseflow component is a significant proportion of the stream flows, especially during summer when the evapotranspiration is high and the precipitation is low.

Should groundwater usage increase to the allocated volume (in the order of 4,500 ML/year) within the study area, the reduction in aquifer storage and decline in groundwater level may be so significant that the hydraulic gradient to the Moorabool River is reversed and it becomes a losing stream.

The assessment of the groundwater cycle in the Bungaree study area may be sensibly extrapolated to the sub-catchment of Devils Creek as a sub-set of the study area. Although this sub-catchment comprises just 4% or the study area, it contains 15% of the total groundwater allocations. The degree to which the baseflow component is affected by increased extraction is therefore likely to be greater and more immediate.

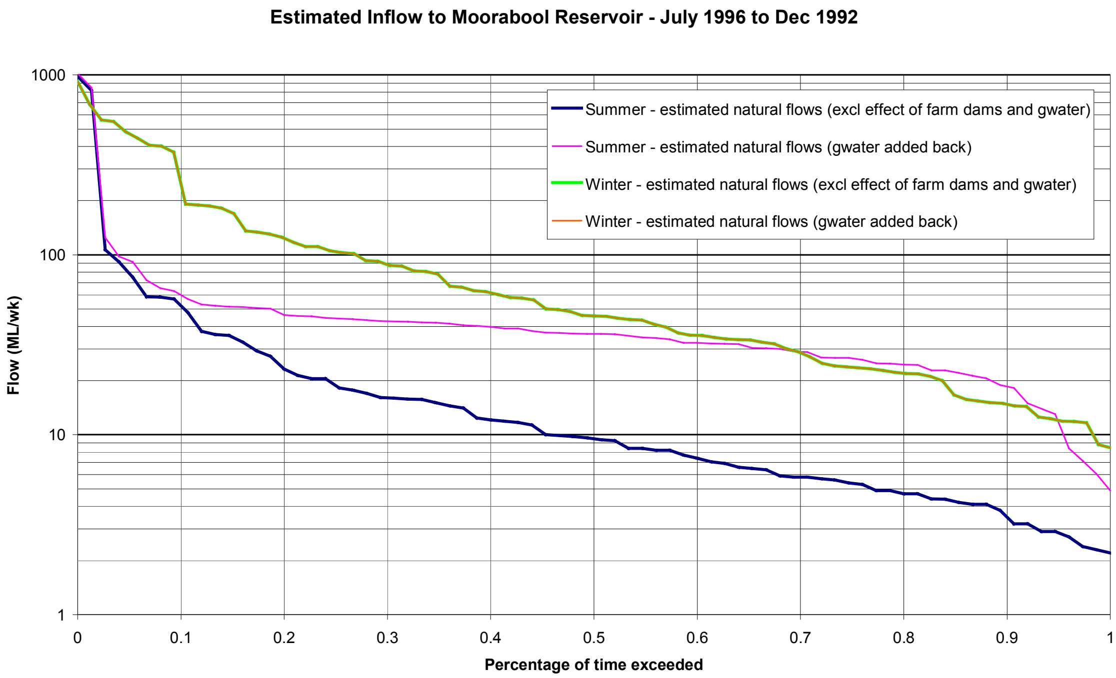
The baseflow contributions determined in the middle catchment, upstream of Lal Lal are slightly lower, in the order of 30 to 40 %. Allocations along this river reach are negligible and therefore usage impacts on the baseflow volumes to the Moorabool are considered to be negligible at this time. Increased usage in the future may begin to impact the baseflow component as they do in the upper catchment.

No baseflow analyses were performed on data downstream of Morrisons due to insufficient quality of streamflow data. The distribution of groundwater and survey data was also not sufficient to provide any meaningful evaluation of the relationship between groundwater and surface water in the lower catchment. Groundwater usage in this part of the catchment is negligible and will not affect baseflow to the Moorabool River where it occurs.

Modelling of potential losses to baseflow adopted the mid-point between the two estimations of the effect of groundwater extraction on baseflow discussed above. The effect of groundwater extraction on streamflows was subsequently calculated by assuming that 60% of the water extracted would have become stream baseflow. The historic change in groundwater usage was also accounted for. This was incorporated using a pattern of irrigation demands for potatoes based on crop water requirements over the period 1965-2002. This time series was adjusted such that usage in the 2001/2002 year was equivalent to the groundwater usage data in each of the sub-catchment modelled in the Upper Moorabool. A time trend was then applied based on the historic number of licences over the 1965-2002 period (e.g. bore usage in 1965 was 17 % of bore usage in 2002).

The natural flows into Moorabool Reservoir were calculated by taking gauged flows, and removing the effects of farm dams, urban demands, and groundwater extraction. The methodology for this calculation is presented in B.13. Figure 16-10 shows the change in the flow duration curve for flows above Moorabool Reservoir between summer and winter, and also shows the effect of groundwater pumping.

- **Figure 16-10 – Calculated seasonal effect of Groundwater on Flows above Moorabool Reservoir**



As expected, winter flows are much higher than summer flows, with median summer flows of approximately 9.5 ML/week currently, and median winter flows of around 45 ML/week.

The flow duration curves for winter are unaffected by groundwater extraction, so the two lines are identical. Whereas the effect of groundwater extraction on summer flows is substantial. While there is little effect on high summer flows (>50 ML/week), groundwater extraction appears to reduce median summer flows from around 35 ML/week to around 9.5 ML/week. The 80 percentile low flows are being reduced from around 25 ML/week, to less than 5 ML/week indicating that significant impact of groundwater extraction on streamflows above Moorabool Reservoir.

Using this rate of influence and the assumption that impact of groundwater extraction on flow occurs at the time of pumping, historical flow in the Upper Moorabool River is not affected by groundwater extraction during winter. However during summer, flows are influenced by groundwater extraction up to 95% of the time. This is when rainfall is at its lowest and streamflow is largely baseflow driven.

B.9 Conclusions

The key conclusions from this evaluation of groundwater surface water interaction are summarised as follows:

- There is a strong relationship between surface water and groundwater determined in baseflow analyses in the upper and middle catchment,
- The assessment of the groundwater cycle components indicates only approximate estimates of magnitude. It is designed to indicate the relative significance of the individual components, not accurate absolute values,
- Assessment of the groundwater cycle suggests that the key components affected by increased extraction are evapotranspiration and baseflow,
- The degree to which increased extraction in the Bungaree WSPA is likely to affect baseflow volumes is considered to range between 1:1 (100 % impact) and 1:4 (25 % impact),
- Modelling of losses to baseflow considered the mid-point between these two estimates, that is 60% influence. Using this rate historical flow in the Upper Moorabool appears to be influenced by groundwater extraction up to 95 % of the time when rainfall is at its lowest and streamflow is largely baseflow driven,
- Groundwater pumping is likely to result in
  - short term change in storage,
  - medium term reduction of evapotranspiration and baseflow, and
  - long term reduction in aquifer throughflow, hence down catchment impacts.
- High intensity groundwater usage in the Devils Creek sub- catchment will result in greater baseflow losses,
- Lower BFIs immediately upstream of the Lal Lal Reservoir combined with current groundwater allocations being negligible suggest that currently groundwater usage impacts on baseflow losses are not significant. Increased usage in the future may begin to impact the baseflow component as they do in the upper catchment,

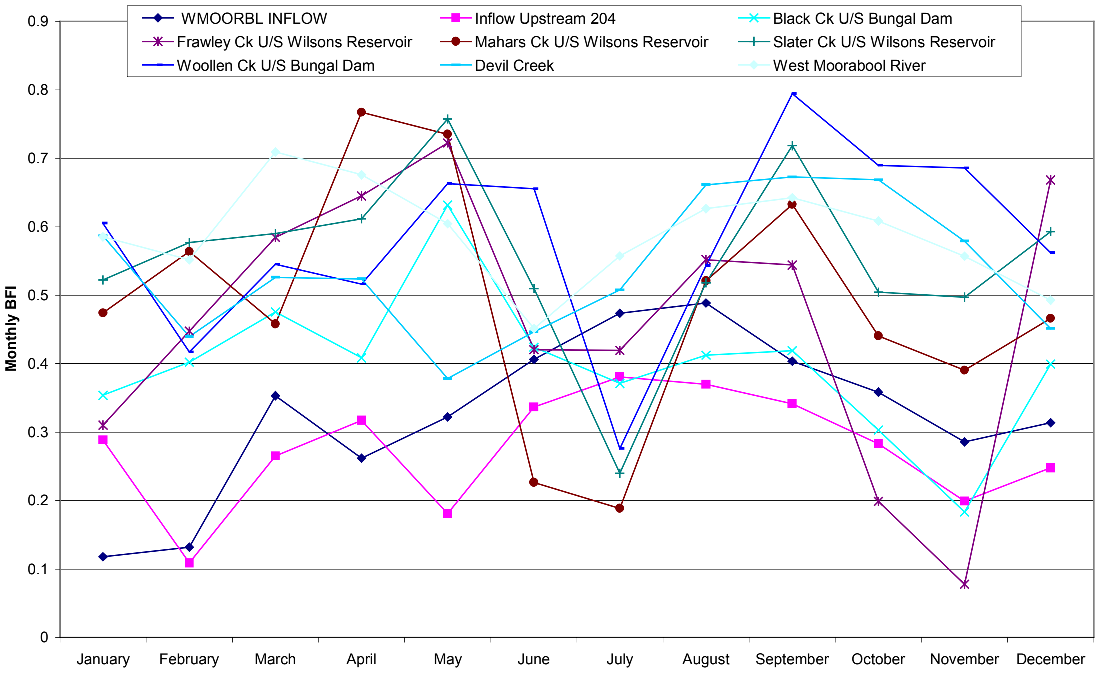
- There is insufficient data to conclude groundwater related impacts account for losses between Lal Lal and Batesford.

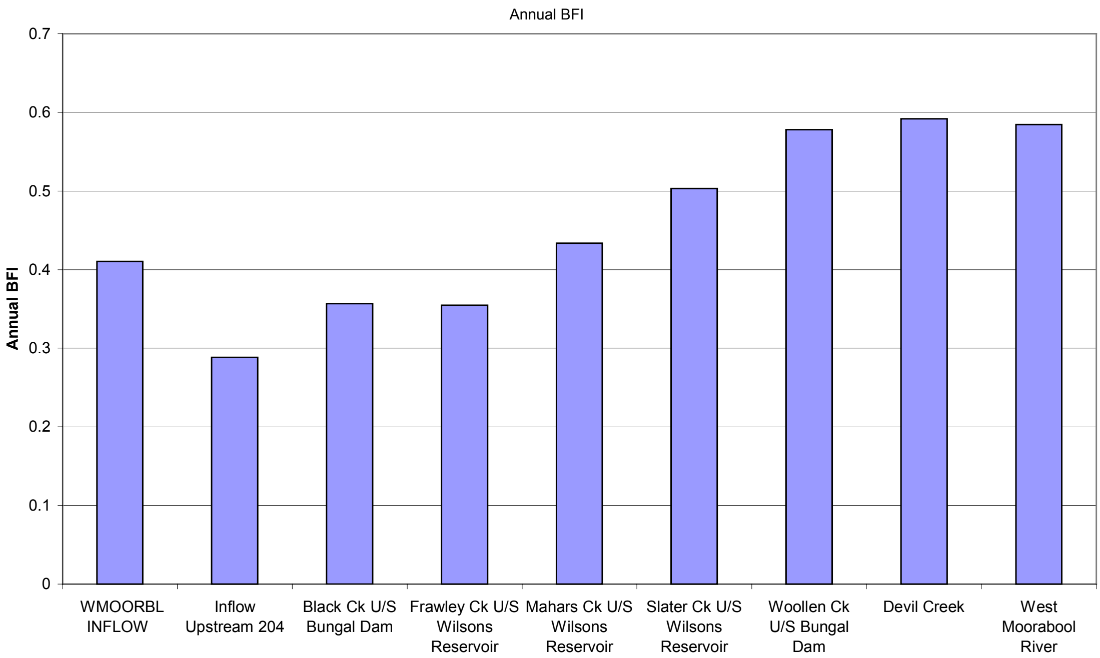
B.10 Recommendations

The following work should be undertaken to better define the components of the groundwater cycle:

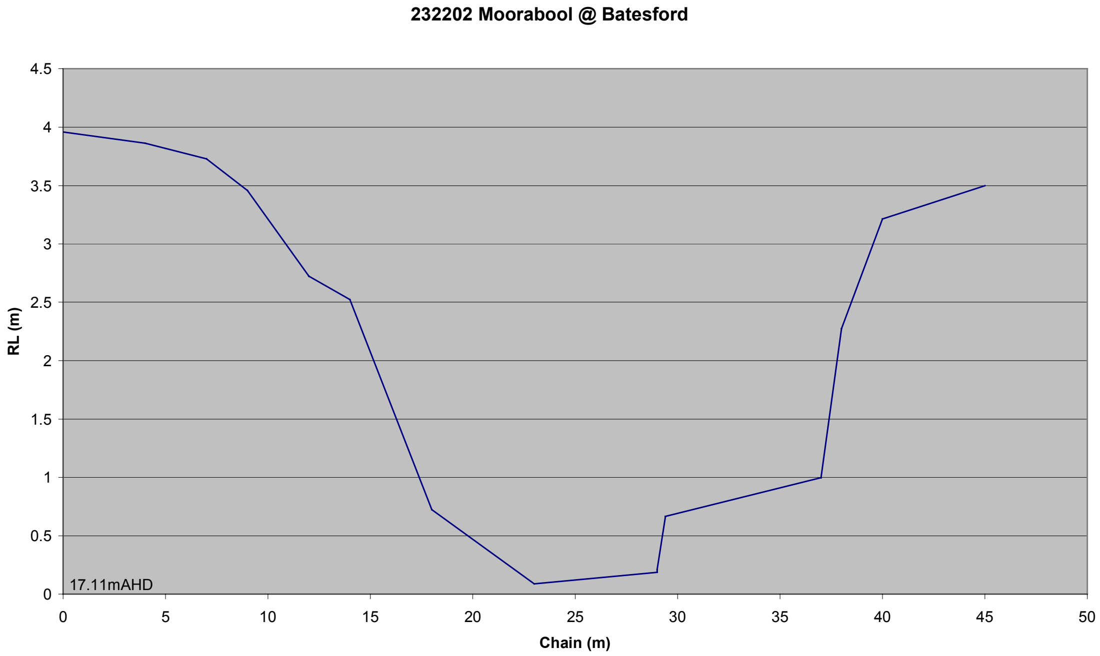
10) Evaluate the effects of time delays in groundwater and surface water responses so that a time consistent water balance can be produced.
11) Future groundwater monitoring to incorporate installation of monitoring bores adjacent existing river gauging locations. This will enable the collection of time series groundwater and surface water data at locations strategic to the evaluation of groundwater surface water interaction.
12) Future installation of monitoring bores adjacent to the river in areas of intensive groundwater extraction to ultimately enable baseflow to be managed through the setting of target groundwater levels. It should be noted however, that the setting of minimum water levels could lead to a significantly greater level of groundwater management than currently exists.
13) Rigorous reviews of available literature to better define the hydraulic conductivity of the aquifers in the catchment, their areal extent and flow gradients in order to assess the feasibility of aquifer outflow.
14) Refine the understanding of the change in storage in the basalt aquifer by use of GAM analyses to determine the relative impacts of climate versus groundwater extraction.
15) Identification of the extent and quantity of domestic and stock usage.
16) Evaluation of evapotranspiration rates across the study area, in particular assessment of where shallow water tables would allow evapotranspiration to occur.
17) Further investigation of recharge rates in the study area through, for example the sampling and analysing of isotopes and hydrograph analyses.
18) Ongoing re-visiting of the groundwater components as the results of these assessments are completed. A water balance provides an important tool in evaluating of the impacts of any management strategies implemented.

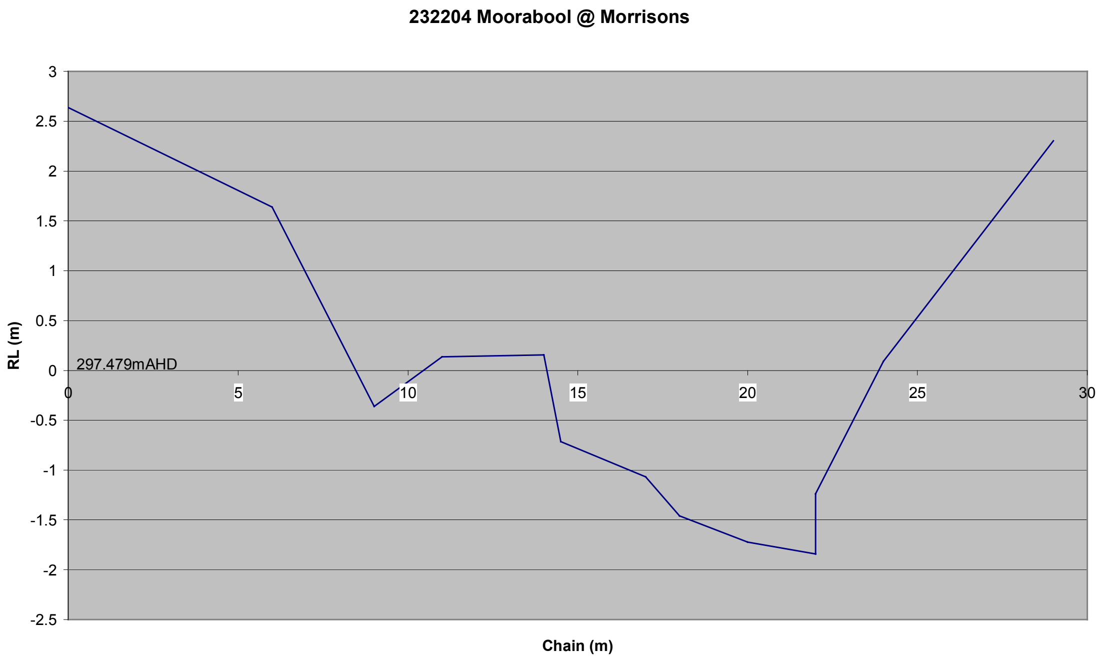
B.11 Baseflow Analysis Results



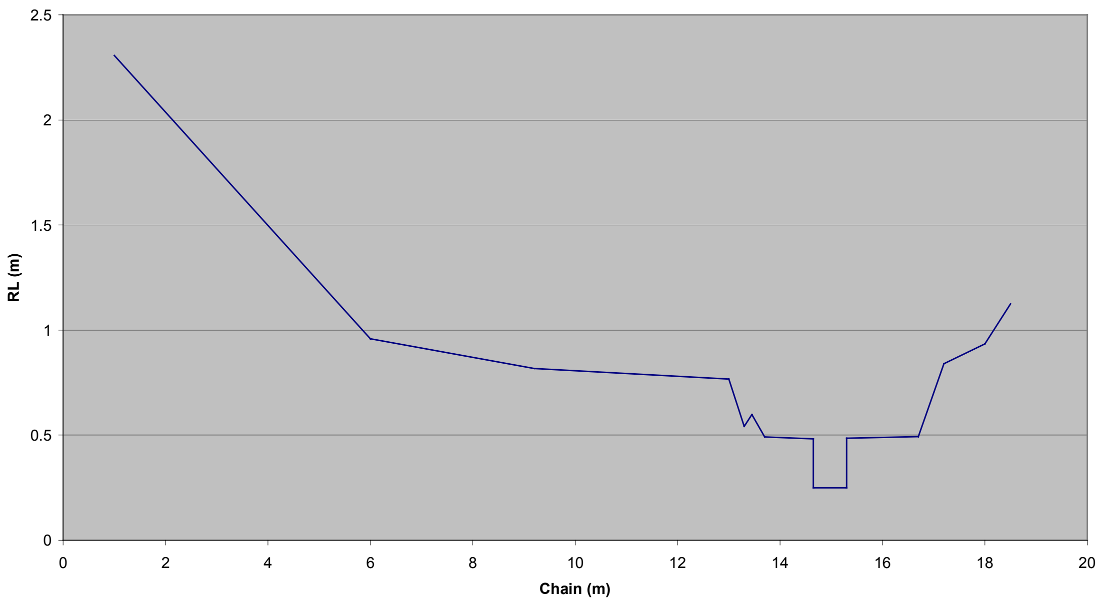


B.12 Gauging Station Cross-sections

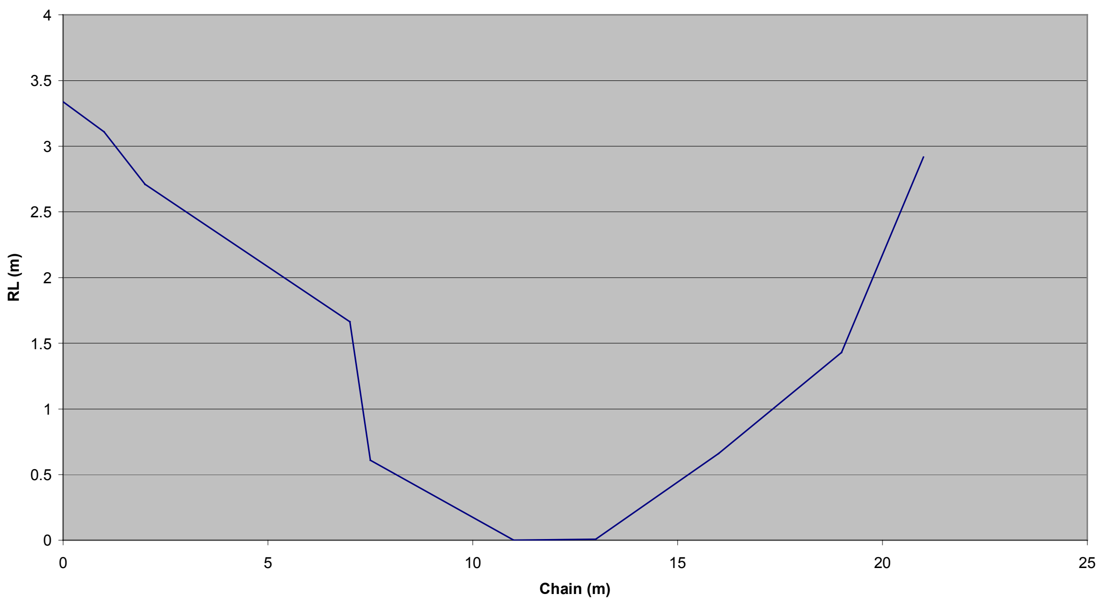




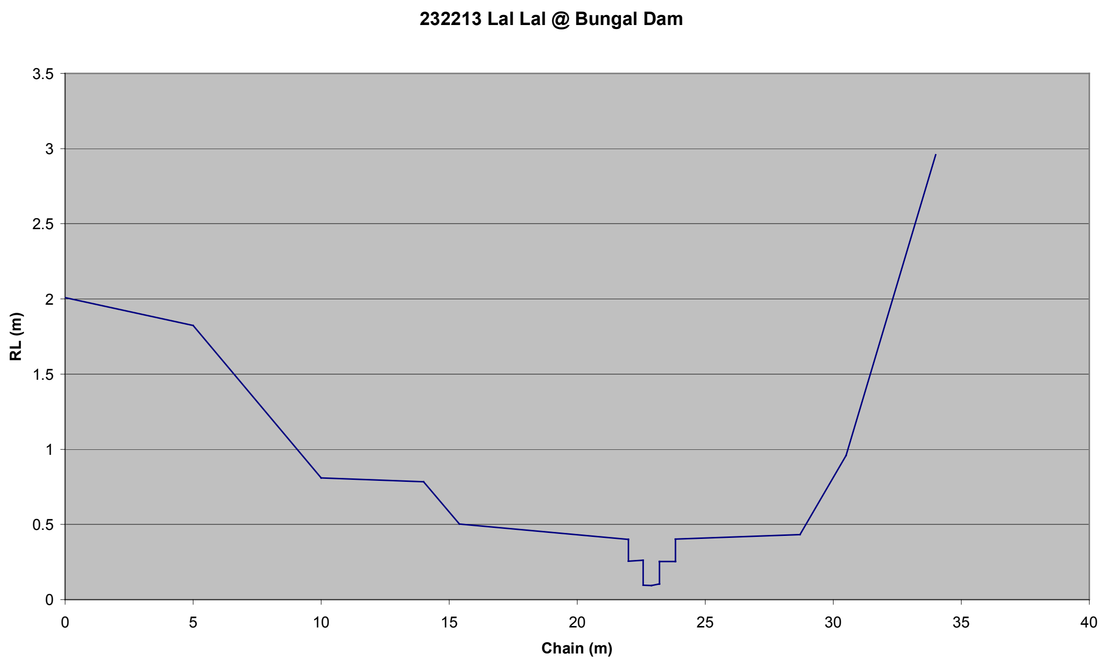
232210 Moorabool @ Lal Lal

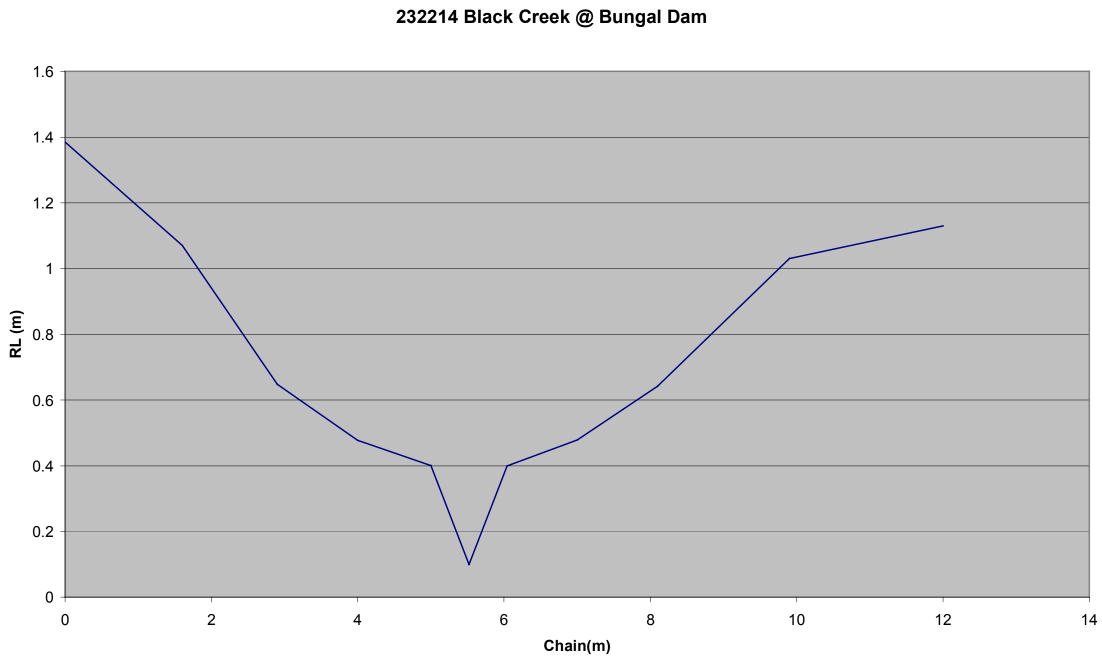


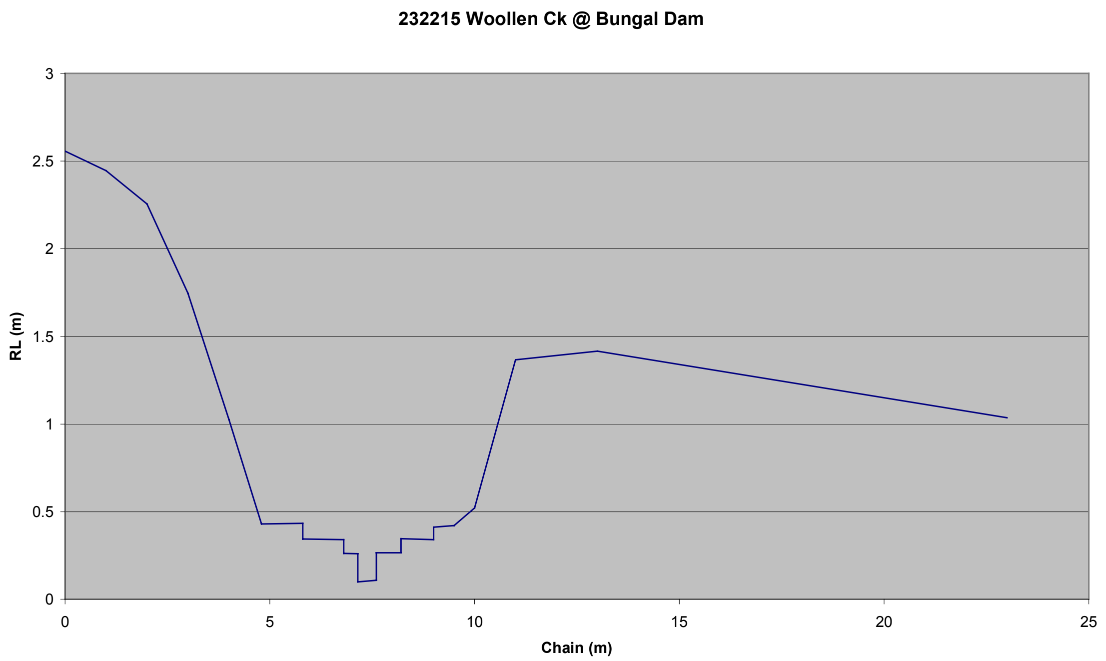
232211 Moorabool @ Doran

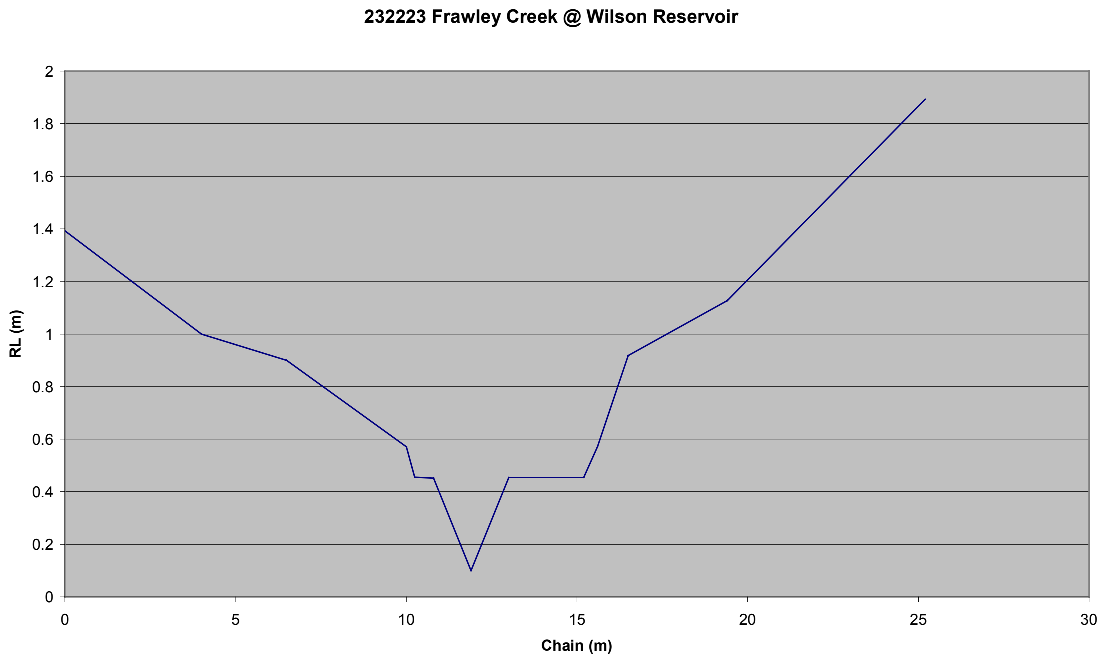


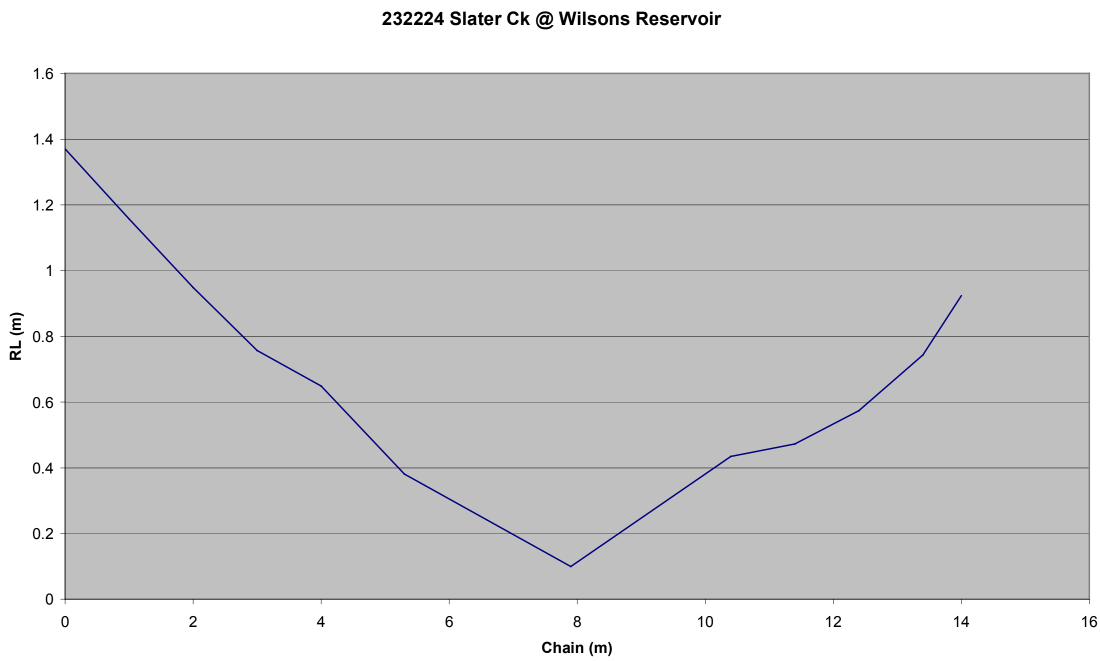
SKM


232213 Lal Lal @ Bungal Dam
RL (m)
Chain (m)
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40


232214 Black Creek @ Bungal Dam
RL (m)
Chain(m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
14


232215 Woollen Ck @ Bungal Dam
RL (m)
Chain (m)
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25


232223 Frawley Creek @ Wilson Reservoir
RL (m)
Chain (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5
10
15
20
25
30



B.13 Calculation of Impact of Groundwater Extraction on Moorabool Flows

The natural flows into Moorabool Reservoir have been calculated by taking gauged flows, and removing the effects of farm dams, urban demands, and groundwater extraction.

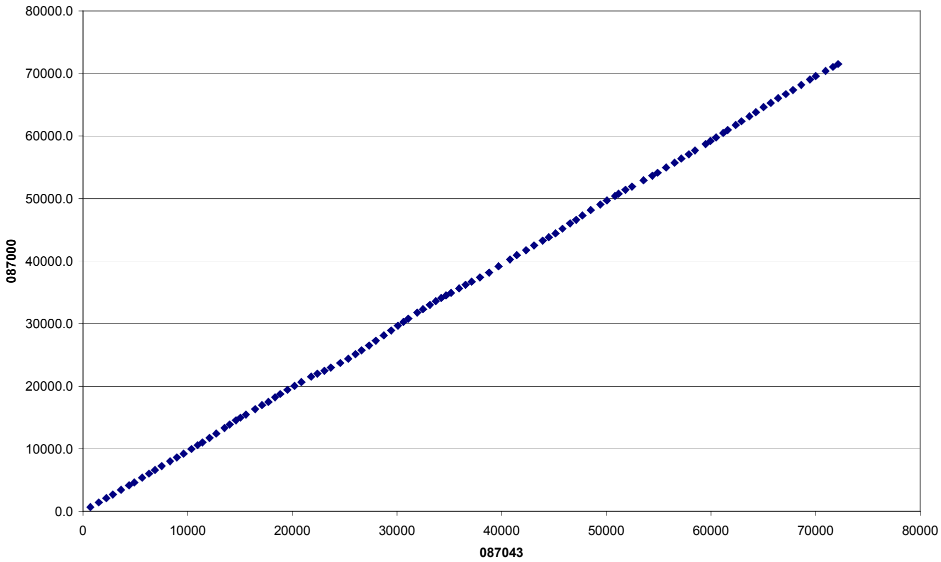
The Tool for Estimating Dam Impacts (TEDI) has been used to determine the effect of farm dams on streamflow. The number of farm dams has increased over the model period, and this increase was estimated using a combination of recent aerial photography, and historic dam numbers given in a 1987 report by GHD.

The effect of groundwater extraction on streamflows was calculated by assuming that 60% of the water extracted would have become stream baseflow. The historic change in groundwater usage was also accounted for. This was incorporated using a pattern of irrigation demands for potatoes based on crop water requirements over the period 1965-2002. This time series was adjusted such that usage in the 2001/2002 year was equivalent to the groundwater usage data in each of the sub-catchment modelled in the Upper Moorabool. A time trend was then applied based on the historic number of licences over the 1965-2002 period (e.g. bores usage in 1965 was 17 % of bore usage in 2002).

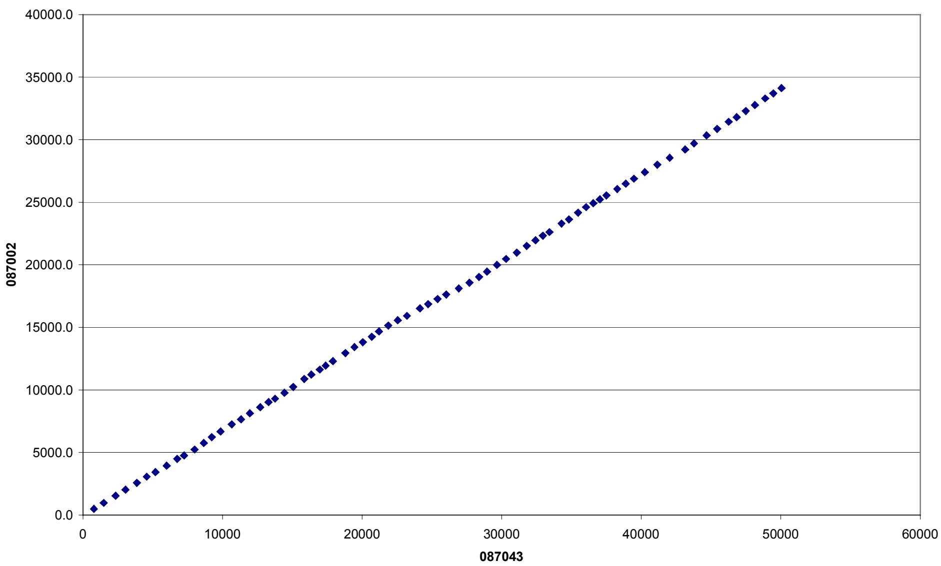
The graph discussed in Section B.8 shows the change in the flow duration curve for flows above Moorabool Reservoir between summer and winter, and also shows the effect of groundwater.

Appendix C Double Mass Curves

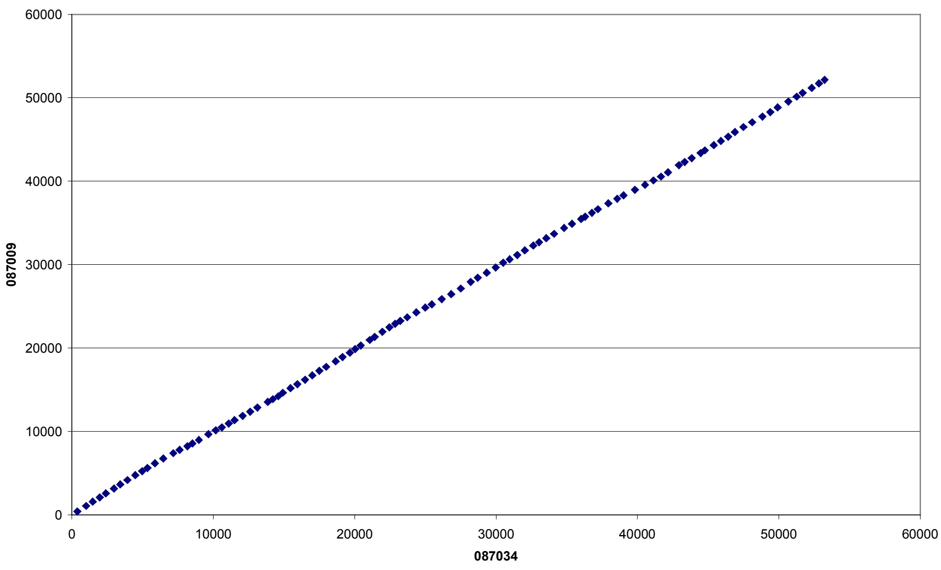
All plots of cumulative annual rainfall are corrected for trends and range in length according to the period of available data.



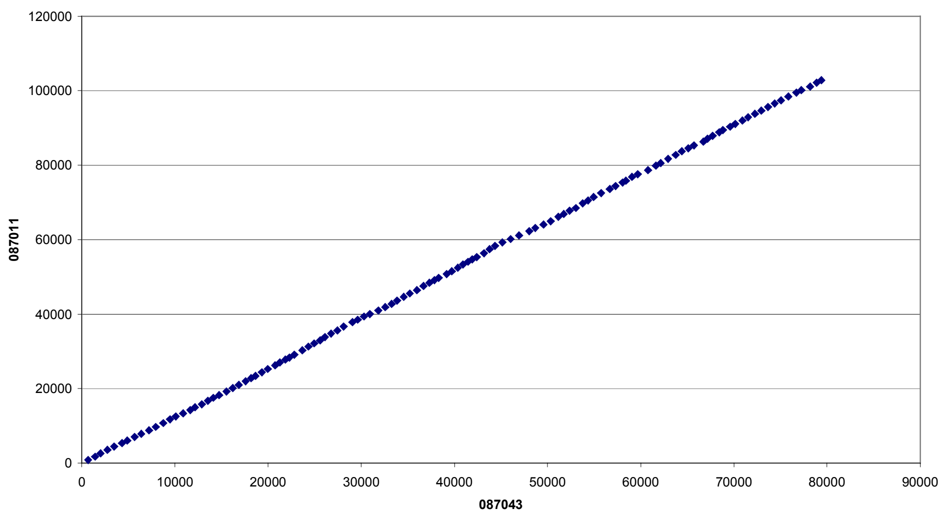
- **Figure 16-11- 087000 Cumulative Annual Rainfall**



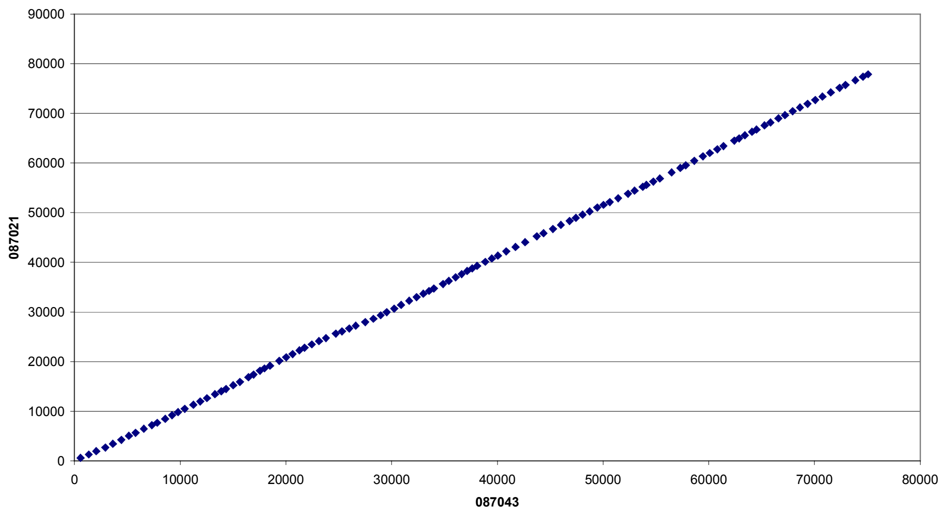
- **Figure 16-12 - 087002 Cumulative Annual Rainfall**



- **Figure 16-13 - 087009 Cumulative Annual Rainfall**



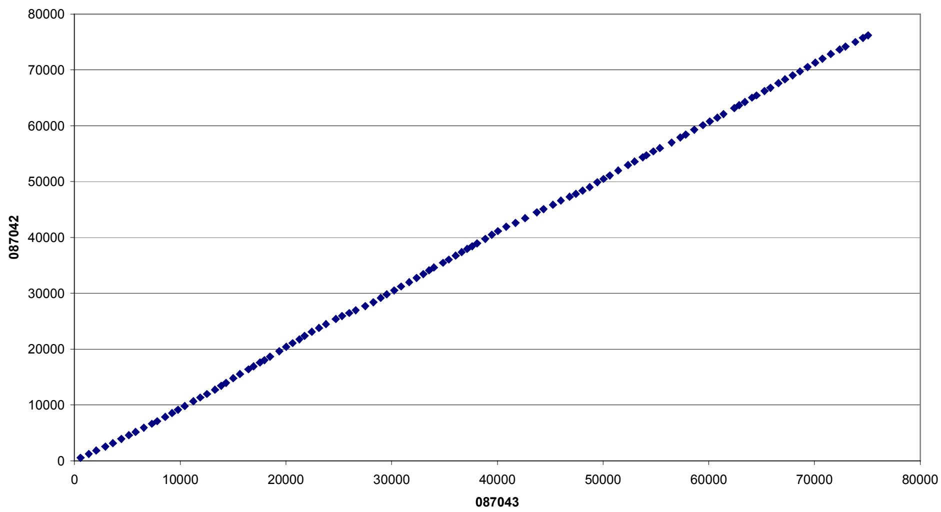
- **Figure 16-14 - 087011 Cumulative Annual Rainfall**



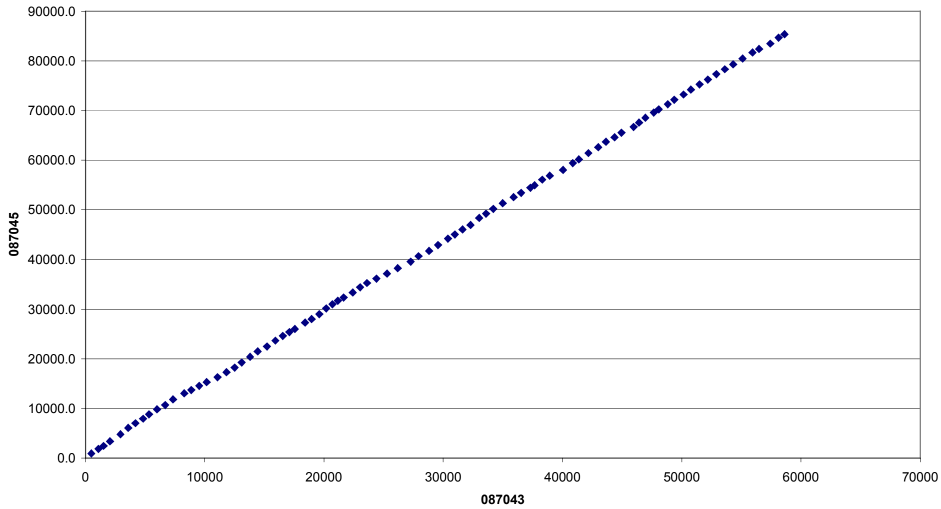
▪ **Figure 16-15 - 087021 Cumulative Annual Rainfall**

087034

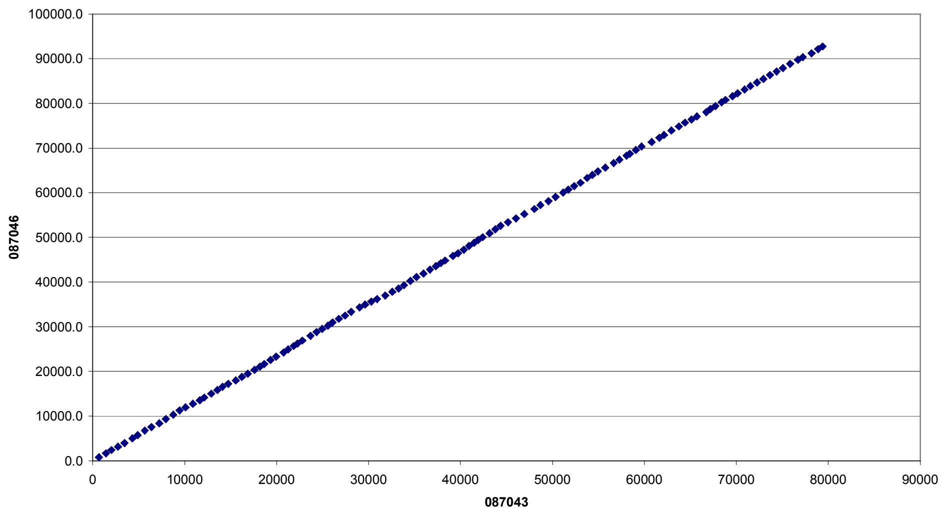
The plot of cumulative annual rainfall for station 087034 is not required as this station represents a stationary rainfall record.



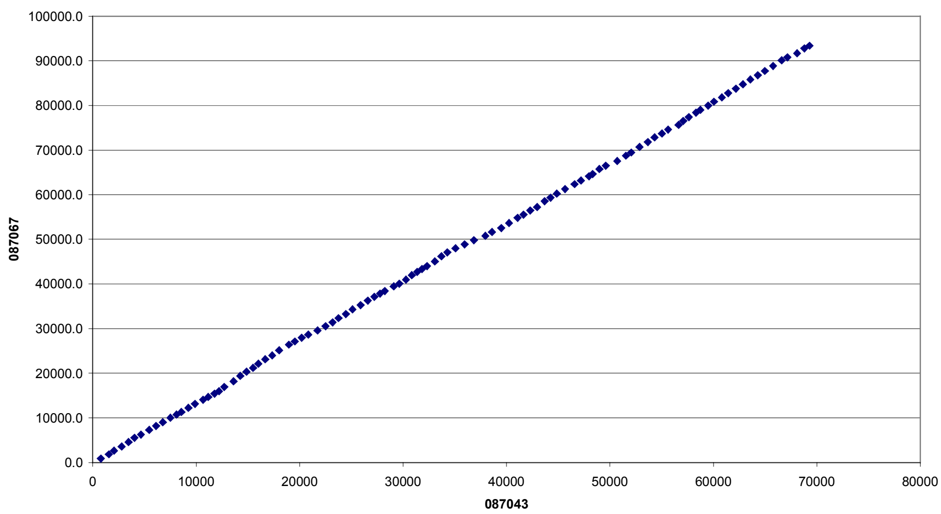
■ **Figure 16-16 - 087042 Cumulative Annual Rainfall**



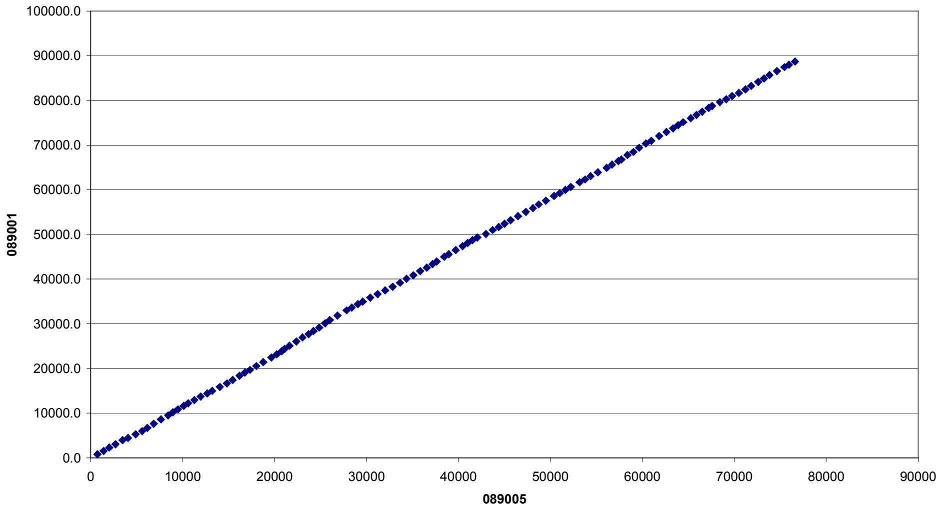
■ **Figure 16-17 - 087045 Cumulative Annual Rainfall**



- **Figure 16-18 - 087046 Cumulative Annual Rainfall**



- **Figure 16-19- 087067 Cumulative Annual Rainfall**

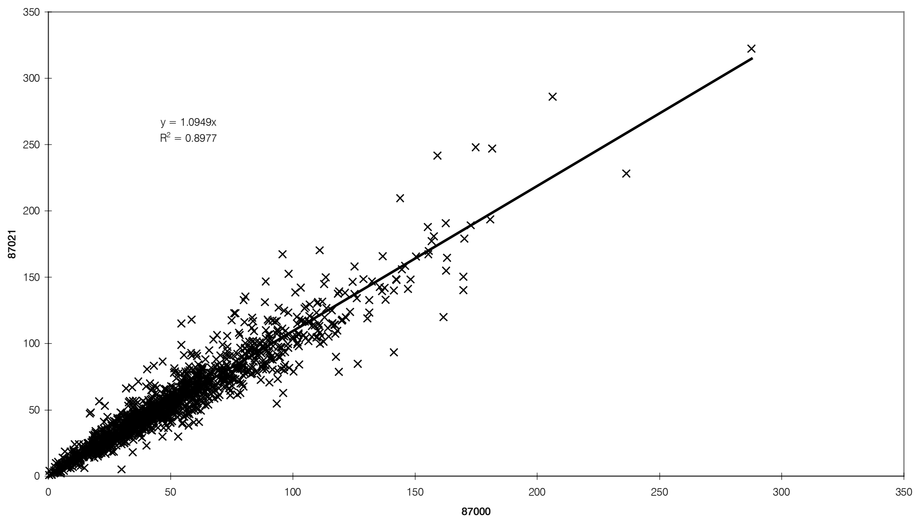


- **Figure 16-20 - 089001 Cumulative Annual Rainfall**

Appendix D Infilling of Climate Data

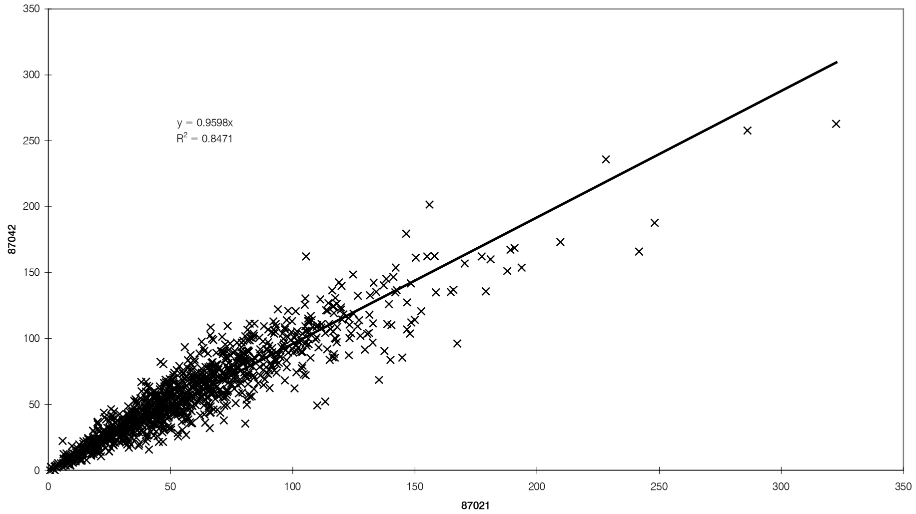
D.1 Rainfall

Rainfall Station	Regressed Against	Equation
087021	087000	y = 1.0949x R^2 = 0.8977
087042	087021	y = 0.9598x R^2 = 0.8471
087046	087011	y = 0.8600x R^2 = 0.8331
089009	087011	y = 0.8210x R2 = 0.8448

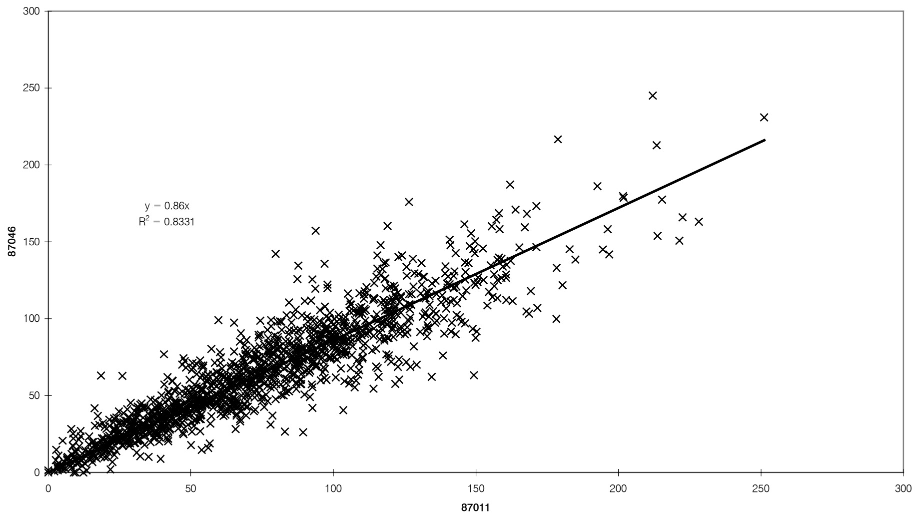


- **Figure 16-21- Rainfall Regression for Site 087021**

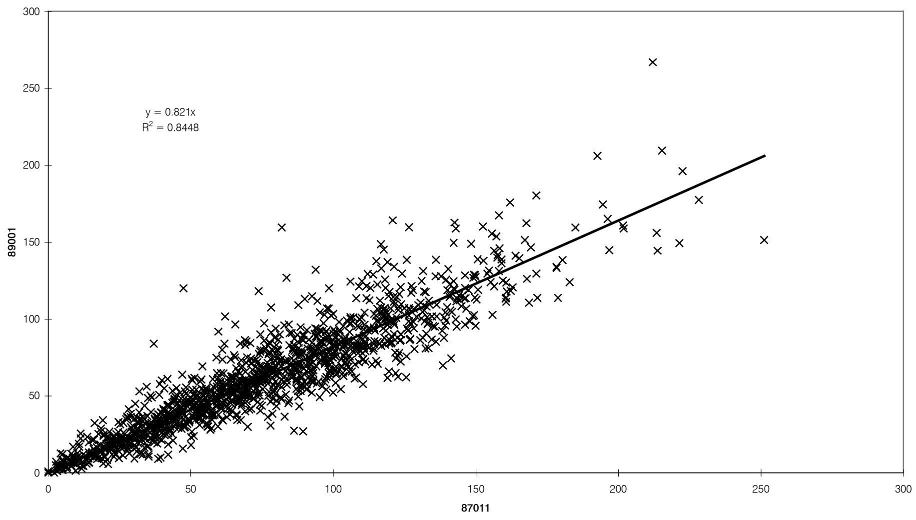
SKM



■ **Figure 16-22 - Rainfall Regression for Site 087042**



■ **Figure 16-23 - Rainfall Regression for Site 087046**

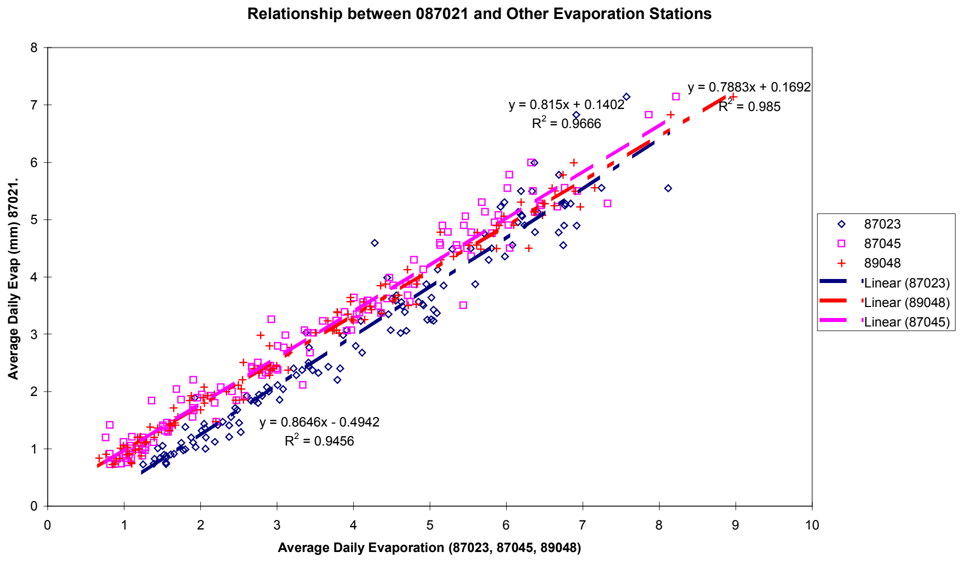


▪ **Figure 16-24 - Rainfall Regression for Site 089001**

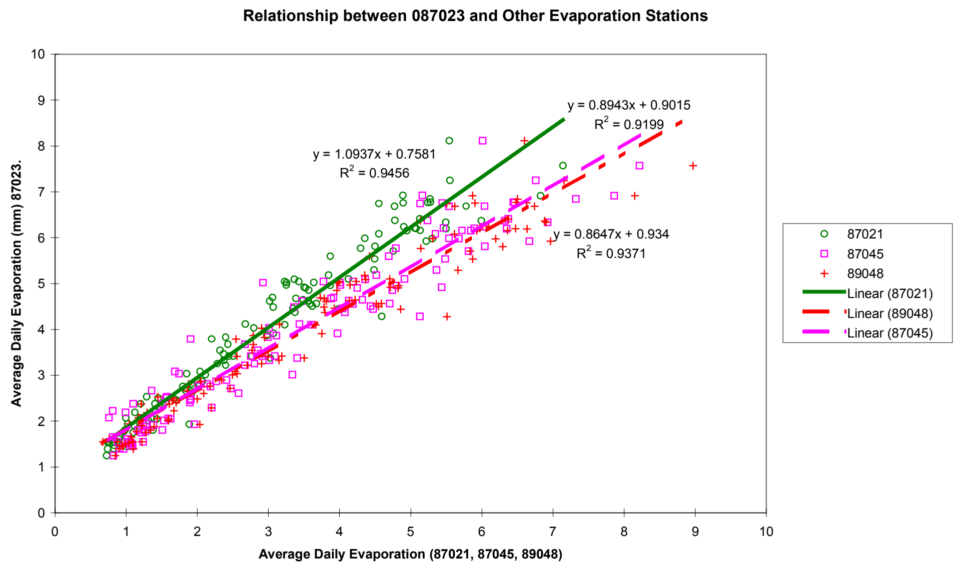
D.2 Evaporation

Regression equations were used preferentially in order of greatest to lowest correlation coefficient.

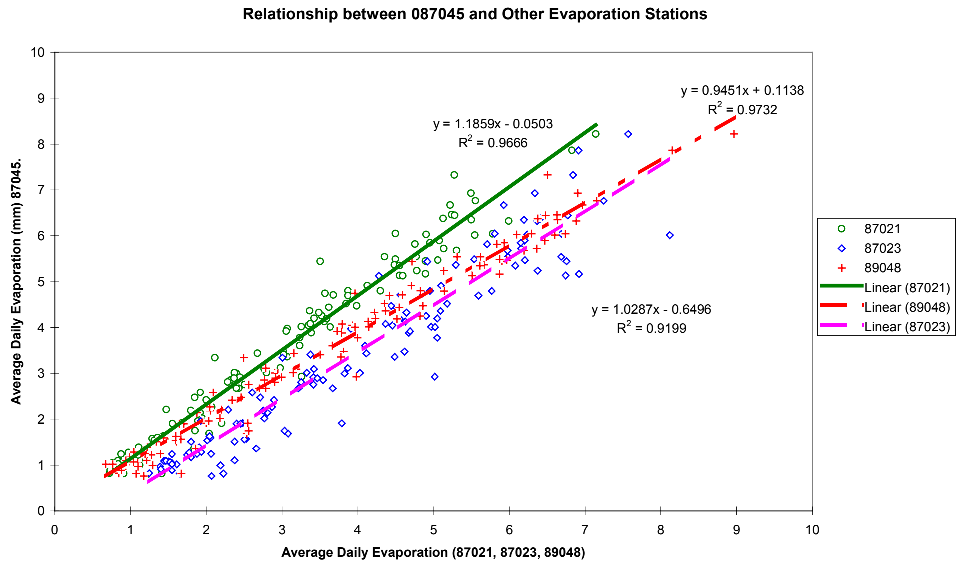
Evaporation station	Regressed against	Equation	
087021	087023	Y = 0.8646x – 0.4942	R^2 = 0.9456
	087045	Y = 0.8150x + 0.1402	R^2 = 0.9666
	089048	Y = 0.7883x + 0.1692	R^2 = 0.9850
087023	087021	Y = 1.0937x + 0.7581	R^2 = 0.9456
	087045	Y = 0.8943x + 0.9015	R^2 = 0.9199
	089048	Y = 0.8647x + 0.9340	R^2 = 0.9371
087045	087021	Y = 1.1859x – 0.0503	R^2 = 0.9666
	087023	Y = 1.0287x – 0.6496	R^2 = 0.9199
	089048	Y = 0.9451x + 0.1138	R^2 = 0.9732
089048	087021	Y = 1.2496x – 0.1583	R^2 = 0.9850
	087023	Y = 1.0836x – 0.7887	R^2 = 0.9371
	087045	Y = 1.0297x – 0.0220	R^2 = 0.9732



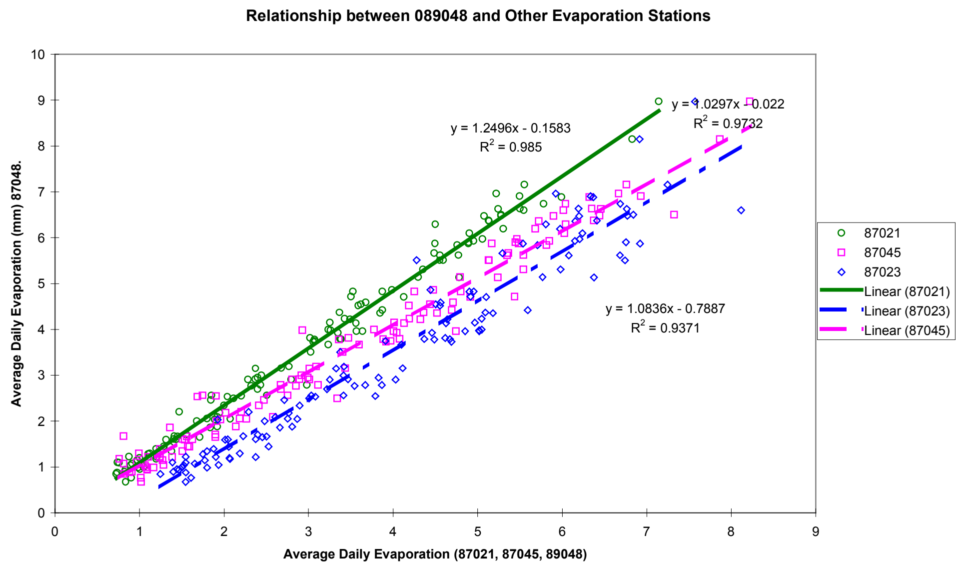
■ **Figure 16-25 - Evaporation Regression for Site 087021 using Monthly Averages**



■ **Figure 16-26 - Evaporation Regression for Site 087023 using Monthly Averages**



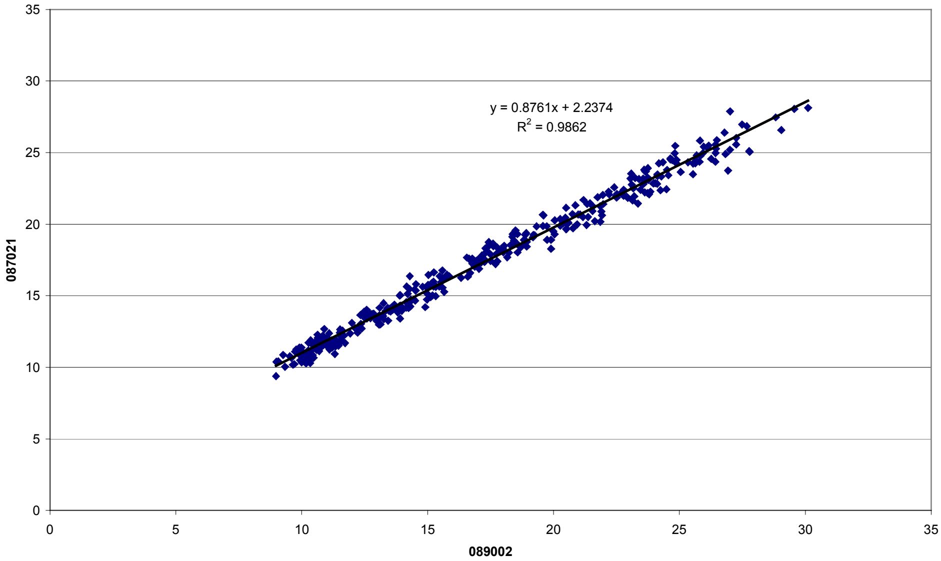
■ **Figure 16-27 - Evaporation Regression for Site 087045 using Monthly Averages**



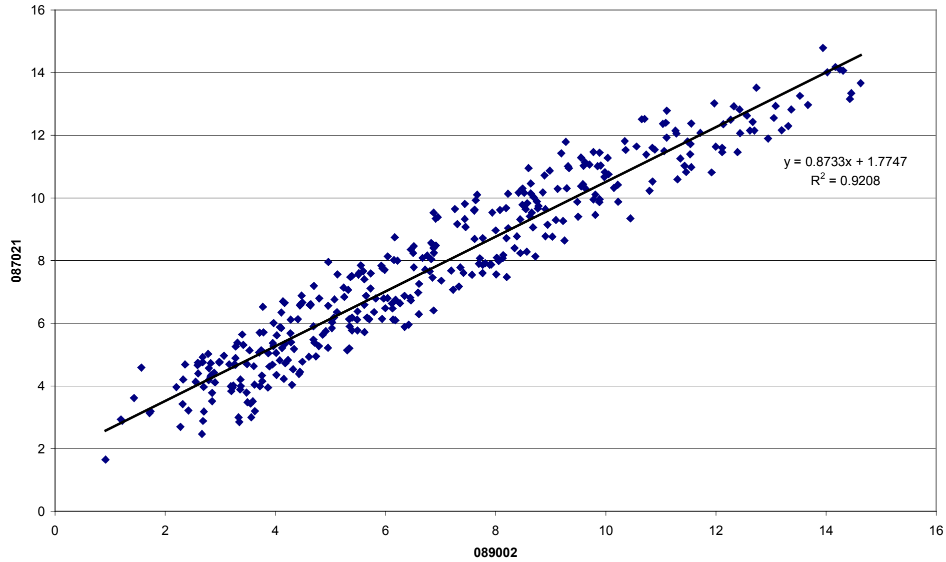
■ **Figure 16-28 - Evaporation Regression for Site 089048 using Monthly Averages**

D.3 Temperature

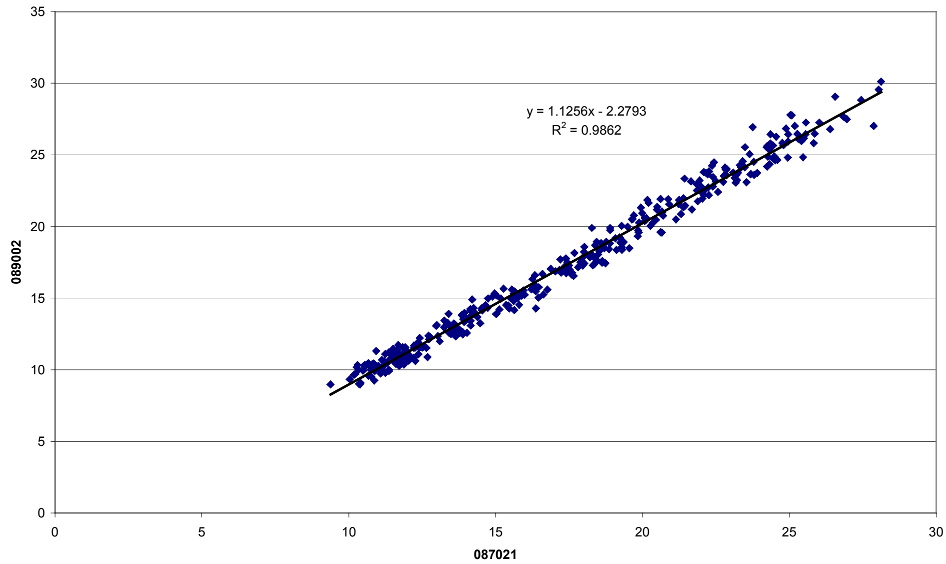
Temperature Site	Regressed Against	Equation
087021	089002	Maximum: y = 0.8761x + 2.2374 R^2 = 0.9862 Minimum: y = 0.8733 + 1.7747 R^2 = 0.9208
089002	087021	Maximum: y = 1.1256x – 2.2793 R^2 = 0.9862 Minimum: y = 1.0544x – 1.3224 R^2 = 0.9208



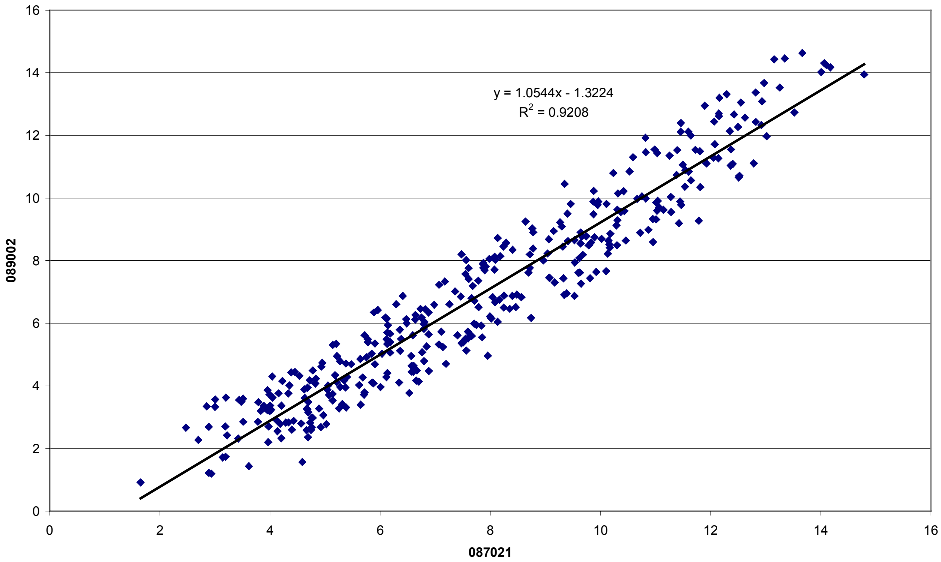
■ **Figure 16-29 – Maximum Temperature Regression for 087021 using Monthly Averages**



■ **Figure 16-30 - Minimum Temperature Regression for 087021 using Monthly Averages**



■ **Figure 16-31– Maximum Temperature Regression for 089002 using Monthly Averages**



■ **Figure 16-32 - Minimum Temperature Regression for 089002 using Monthly Averages**

Appendix E Irrigation Demand Modelling

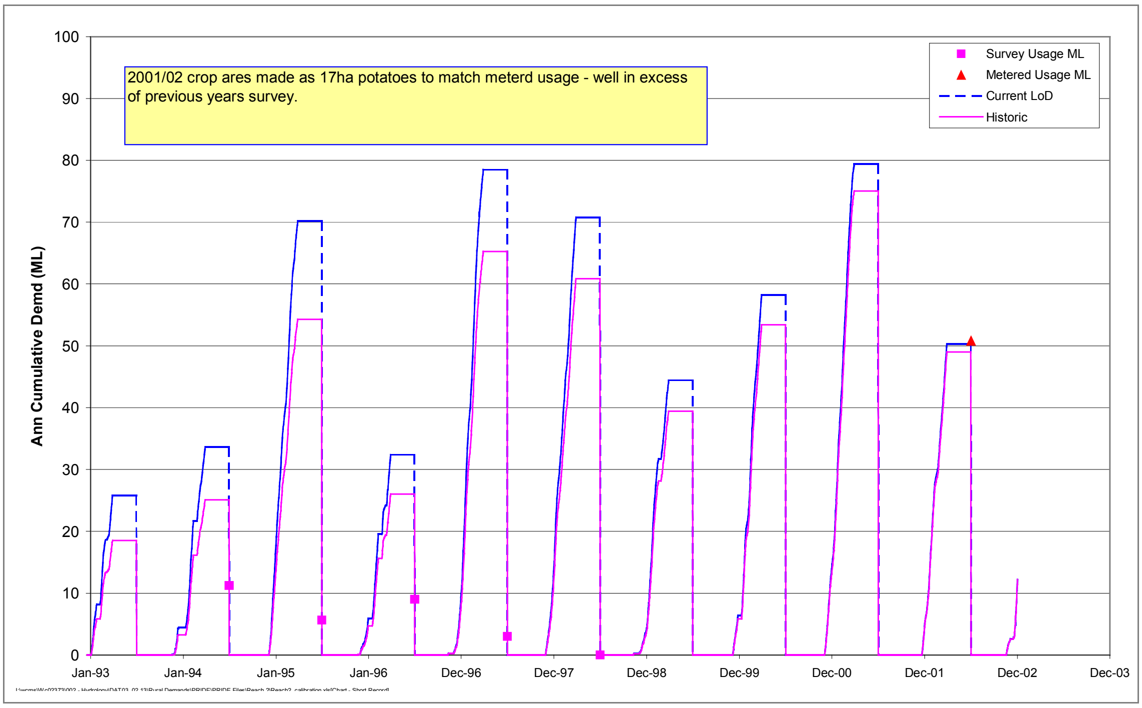
Demand reach		Comments	Climate Data used	Soil Factor
2	mainstream btwn lal lal and mbool	historic assumed equal to trend in potato water usage	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
3	tribs above lal lal	historic assumed equal to trend in potato water usage	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
4	tribs btwn lal lal and mbool	historic assumed equal to trend in potato water usage	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
5	above mbool	historic assumed equal to trend in potato water usage	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
5b	above wilsons	historic assumed equal to trend in potato water usage	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
5c	trib of pincotts	lic vol = 2 therefore too small to model		
6	She Oaks to spillers weir	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
6w	Out of Spillers Weir	Assume not used based on survey data		
7	spillers to caprons	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
7w	Out of Caprons Weir	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
8	caprons to Mattheys	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
8w	Out of Mattheys Weir	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
9w	Mattheys to Maddens	CURRENT = ZERO		
10	Maddens to Buchters	CURRENT = ZERO		

Demand reach		Comments	Climate Data used	Soil Factor
10w	Out of Buchters Weir	CURRENT = ZERO		
11	Buchters to Hills	CURRENT = ZERO		
11w	Out of Hills Weir	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
12w	Hills to Mitchells	CURRENT = ZERO		
13	Mitchells to Joaquin	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
13w	Out of Joaquins Weir	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
14	Joaquin to Batesford	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	
15	below batesford	assume historic = current for REALM calibration	Evap = 087045 Rain = 0.536 * 087011 +0.454*087045	

*Note crop areas shown for the 2001/02 year are not recorded but were determined as part of the calibration process.

Reach 2

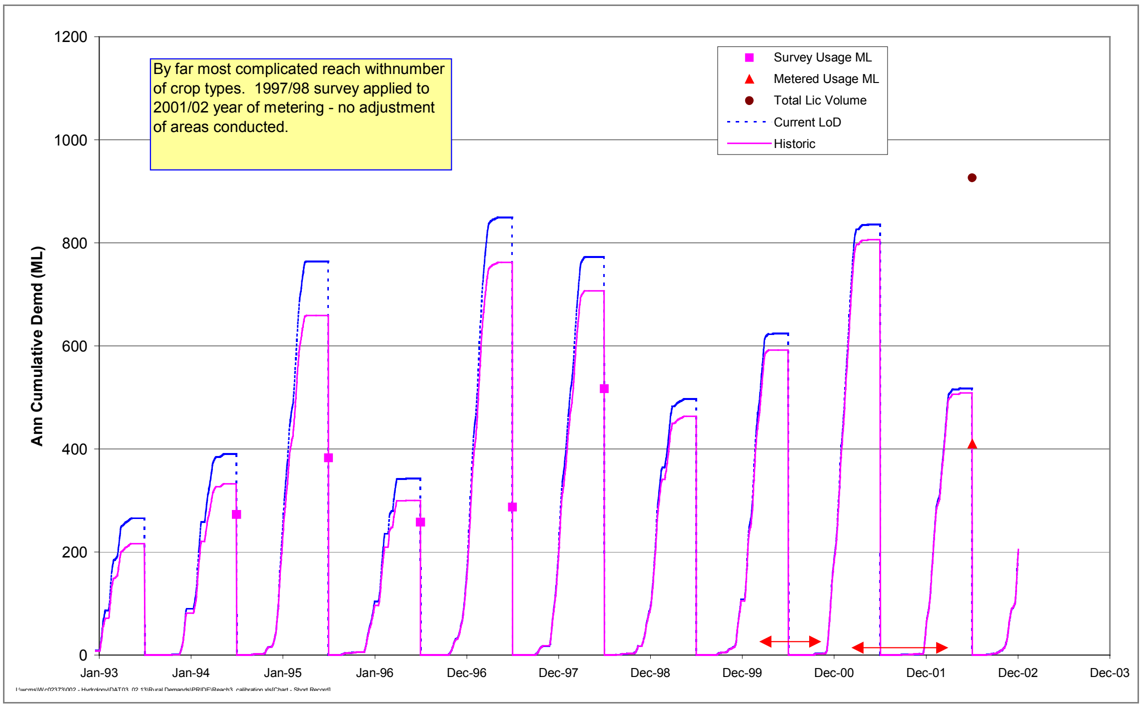
Year	Potato	Summer Crop	Metered consumption (survey consumption)
93/94	5.2	3.2	(11.2)
94/95	5.6	0.0	(5.6)
95/96	6.0	0.0	(9)
96/97	1.0	0.0	(3)
97/98	1.0	0.0	(0)
98/99			
99/00			
00/01			
01/02	17.0	0.0	50.8



Reach 3

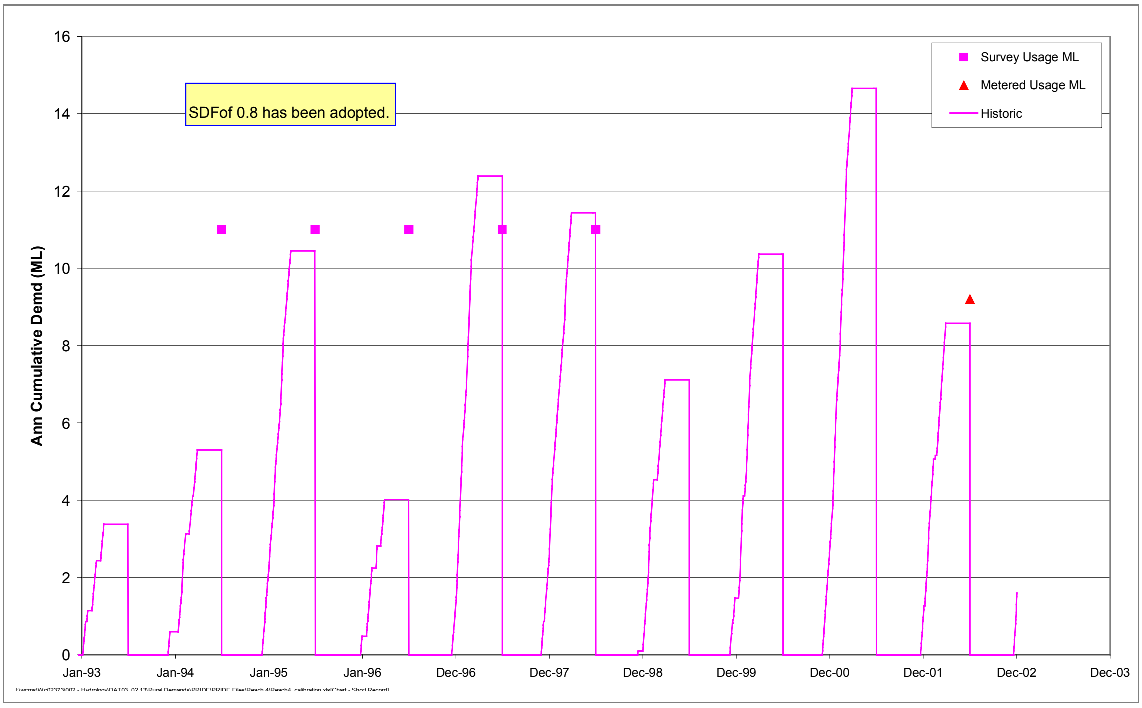
Year	Potato	Summer Crop	Lucerne	Rape	Perennial Pasture	Metered consumption (survey consumption)
93/94						(272)
94/95						(383)
95/96						(258)
96/97						(287)
97/98						(517)
98/99						
99/00						
00/01						
01/02	112.6	15.1	19.0	10.0	26.0	409.6 (2 missing)

SKM



Reach 4

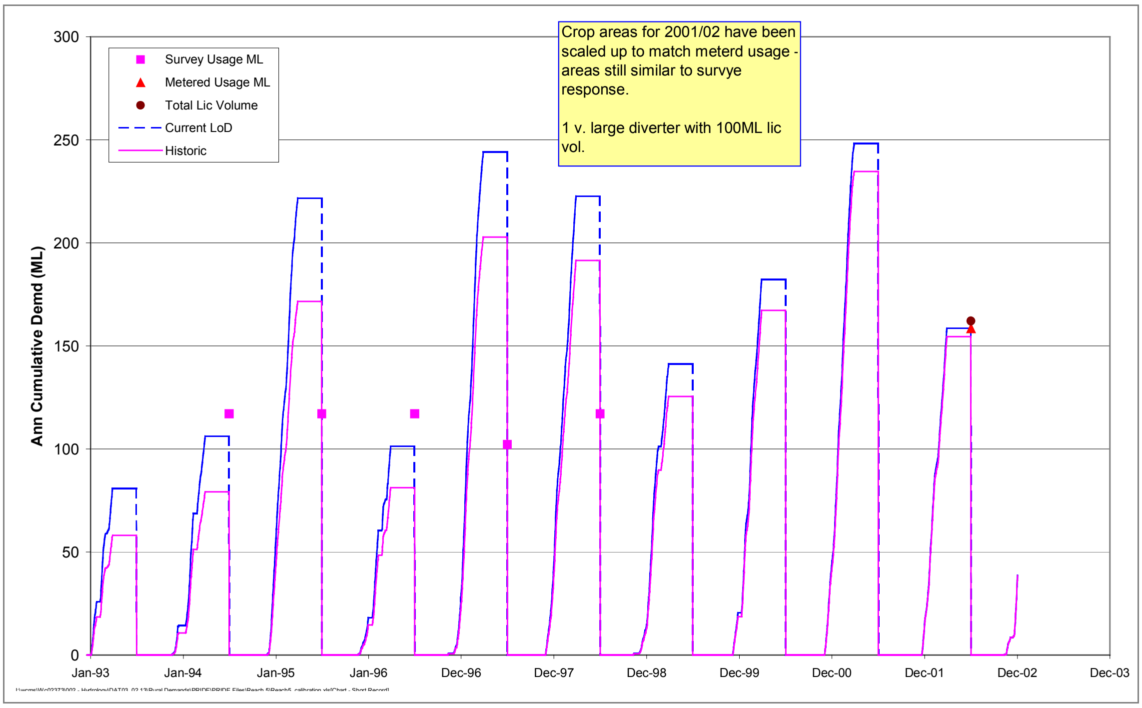
Year	Potato	Metered consumption (survey consumption)
93/94		(11.2)
94/95		(11.2)
95/96		(11.2)
96/97		(11.2)
97/98		(11.2)
98/99		
99/00		
00/01		
01/02	4.0	9.2



Reach 5a

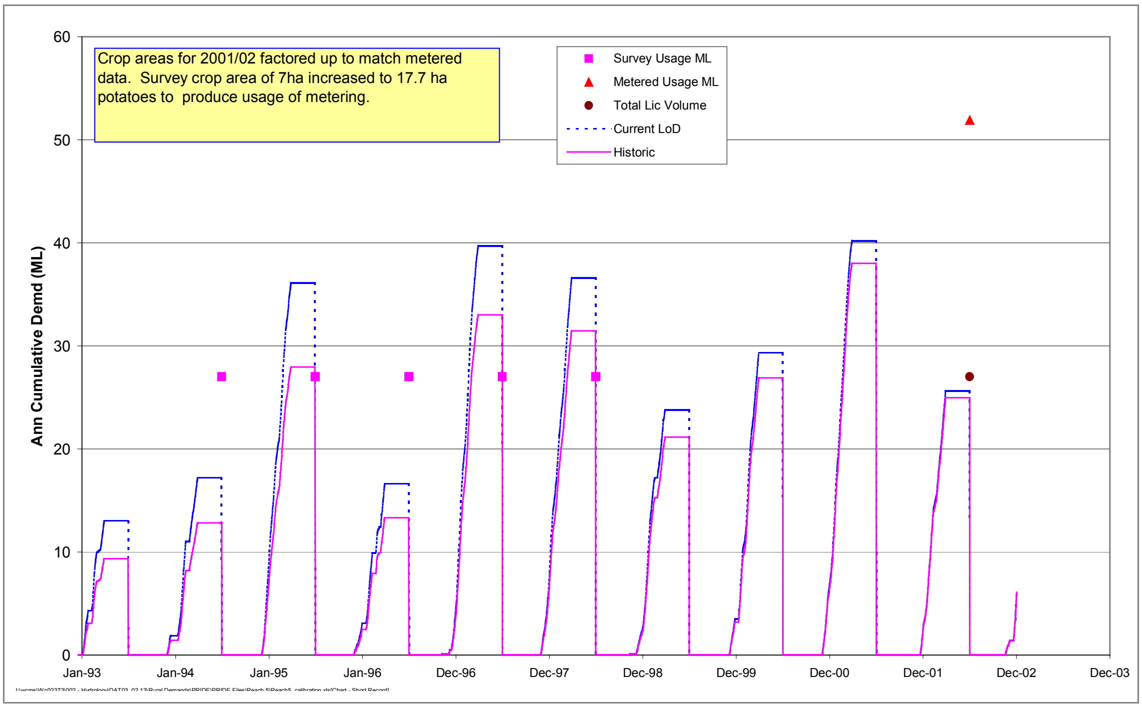
Year	Potato	Metered consumption (survey consumption)
93/94		(117)
94/95	38.6	(117)
95/96	38.6	(117)
96/97	33.6	(102)
97/98	38.6	(117)
98/99		
99/00		
00/01		
01/02	53.3	158.4

SKM



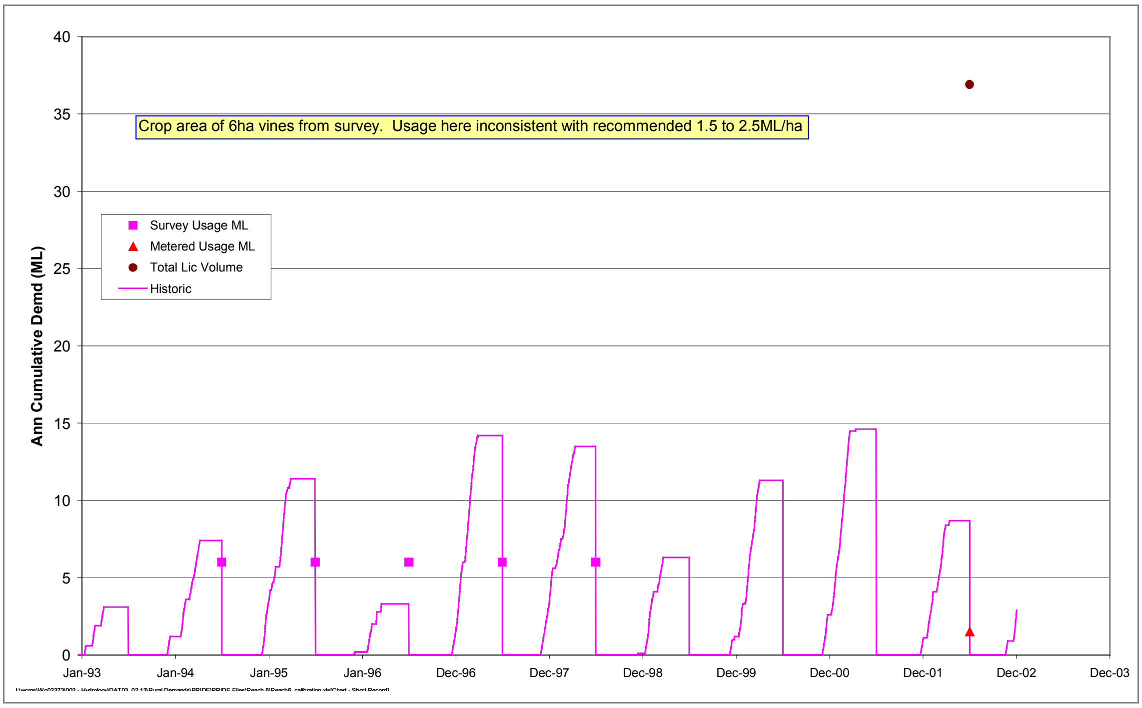
Reach 5b

Year	Potato	Metered consumption (survey consumption)
93/94	7.0	(27)
94/95	7.0	(27)
95/96	7.0	(27)
96/97	7.0	(27)
97/98	7.0	(27)
98/99		
99/00		
00/01		
01/02	17.7	51.9



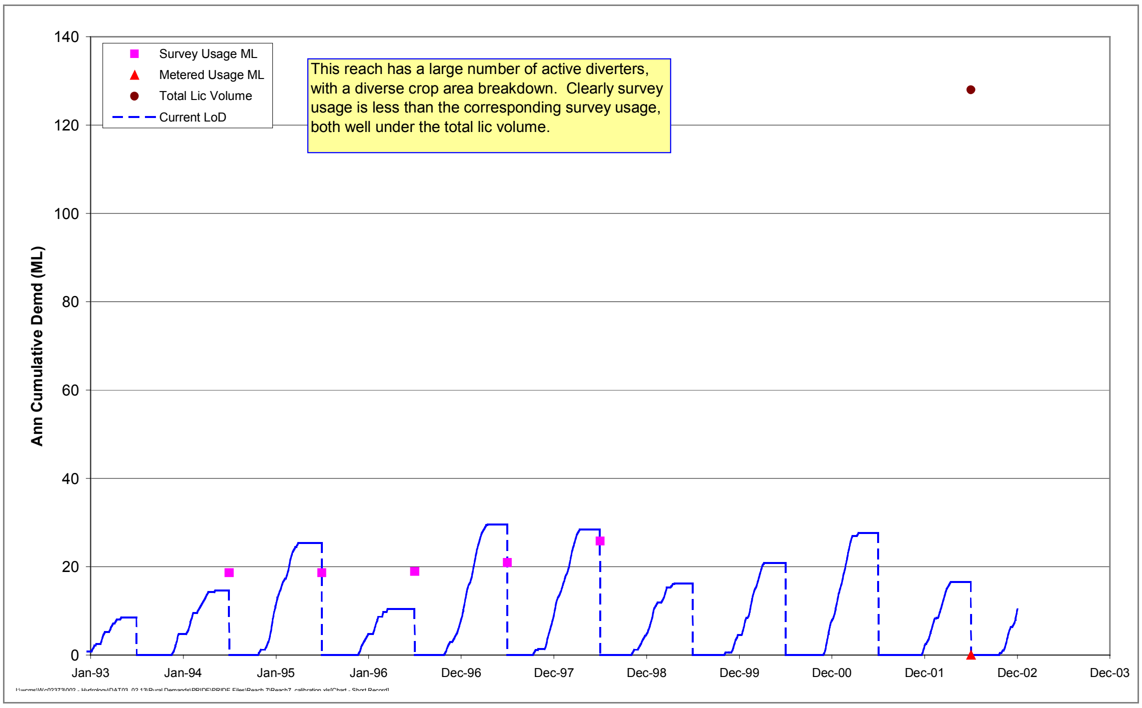
Reach 6

Year	Wine Grapes	Metered consumption (survey consumption)
93/94	6.0	(6)
94/95	6.0	(6)
95/96	6.0	(6)
96/97	6.0	(6)
97/98	6.0	(6)
98/99		
99/00		
00/01		
01/02	6.0	1.5



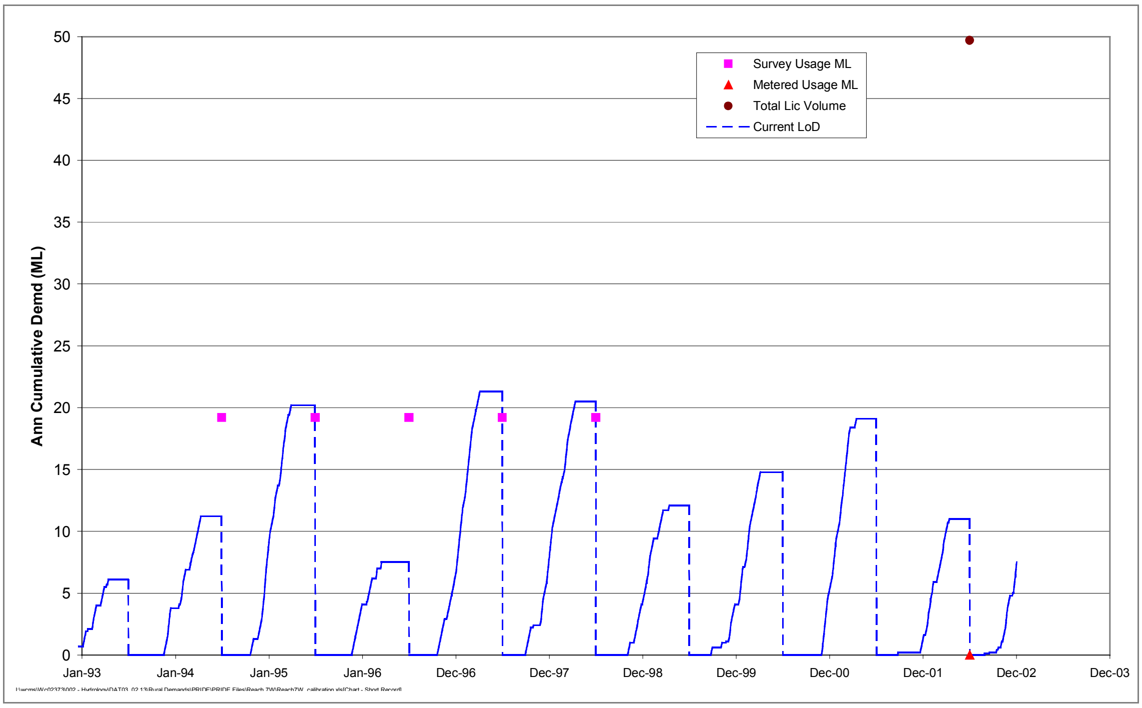
Reach 7

Year	Lucerne	Wine Grapes	Orchard	Metered consumption (survey consumption)
93/94	13.8	3.6	1.0	(18.6)
94/95	13.8	3.6	1.0	(18.6)
95/96	15.6	3.6	1.0	(18.9)
96/97	15.6	3.6	1.0	(20.9)
97/98	17.4	3.6	1.0	(25.77)
98/99				
99/00				
00/01				
01/02	17.4	3.6	1.0	0



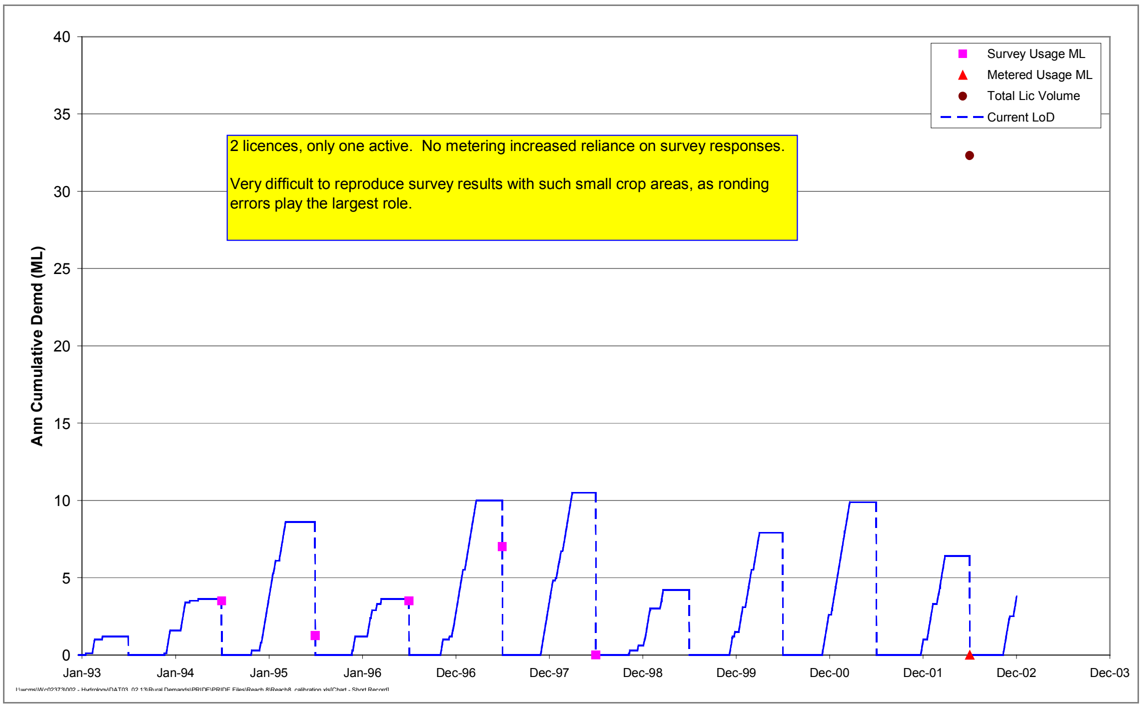
Reach 7w

Year	Perennial Pasture	Metered consumption (survey consumption)
93/94	4.2	(19.2)
94/95	4.2	(19.2)
95/96	4.2	(19.2)
96/97	4.2	(19.2)
97/98	4.2	(19.2)
98/99		
99/00		
00/01		
01/02	4.2	0



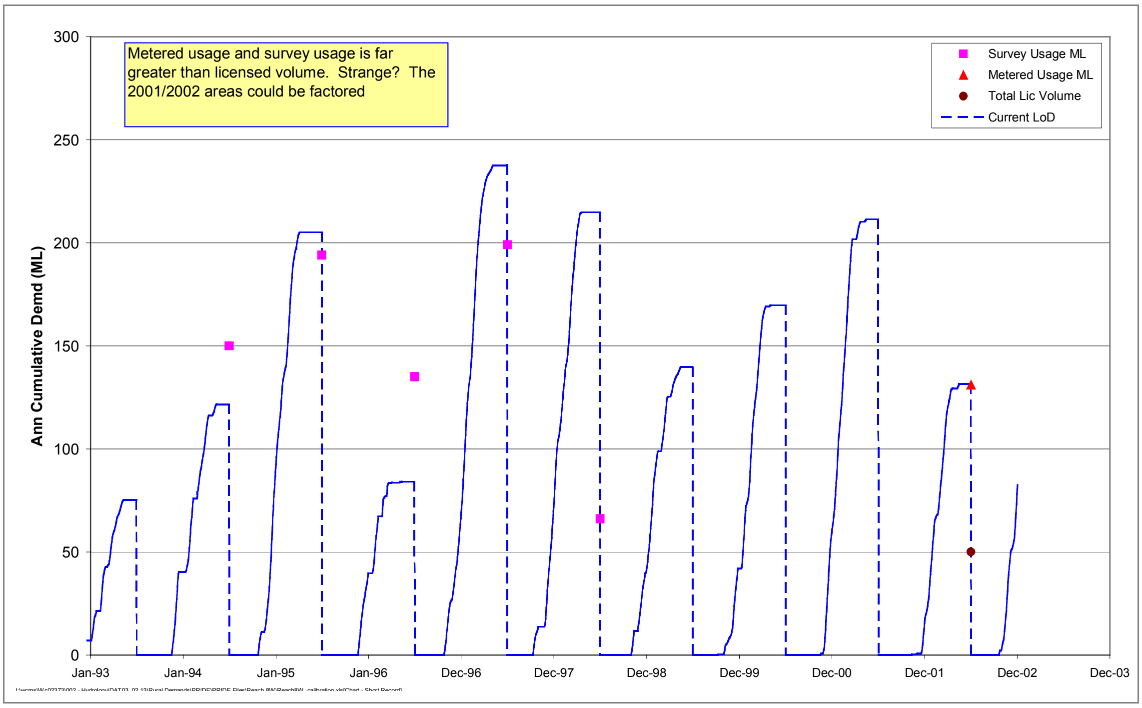
Reach 8

Year	Lucerne	Metered consumption (survey consumption)
93/94	3.0	(3.5)
94/95	3.0	(1.25)
95/96	3.0	(3.5)
96/97	3.0	(7)
97/98	0	(0)
98/99		
99/00		
00/01		
01/02	0	0



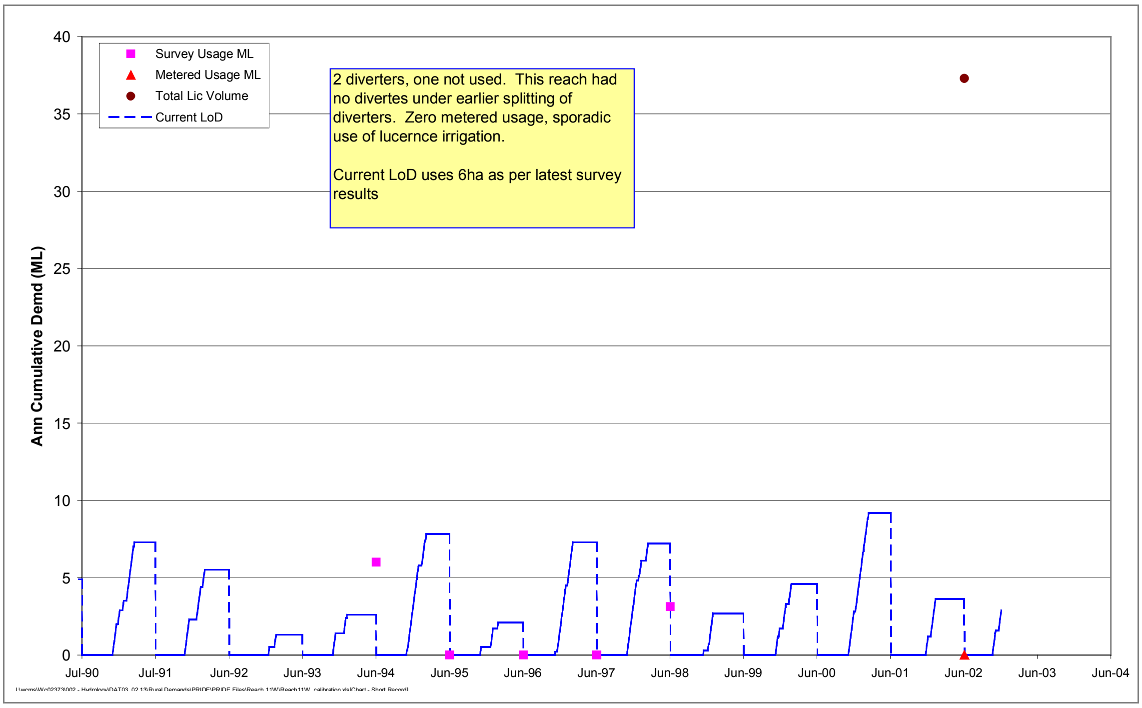
Reach 8w

Year	Summer Crop	Lucerne	Metered consumption (survey consumption)
93/94	0	27.8	(150)
94/95	4.4	35.9	(194)
95/96	0	25.0	(135)
96/97	0	36.8	(199)
97/98	0	12.2	(66)
98/99			
99/00			
00/01			
01/02	0	45.7	131



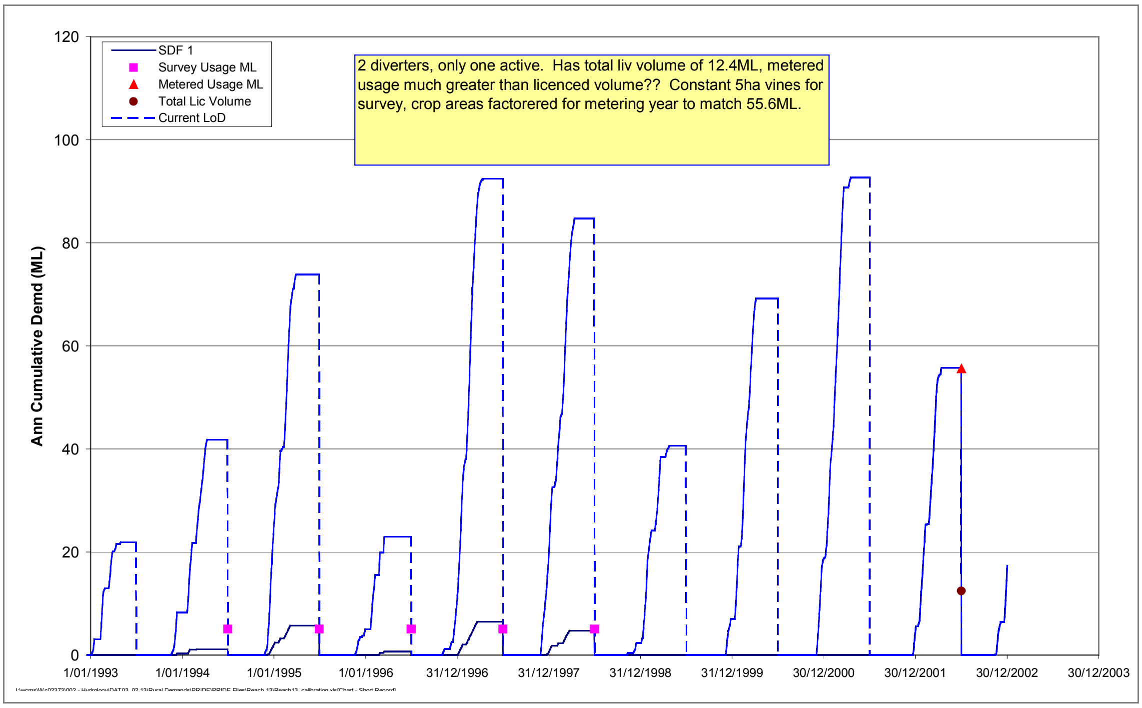
Reach 11w

Year	Summer Crop	Metered consumption (survey consumption)
93/94	4.0	(6)
94/95	0	(0)
95/96	0	(0)
96/97	0	(0)
97/98	6.0	(3.12)
98/99		
99/00		
00/01		
01/02	0	0



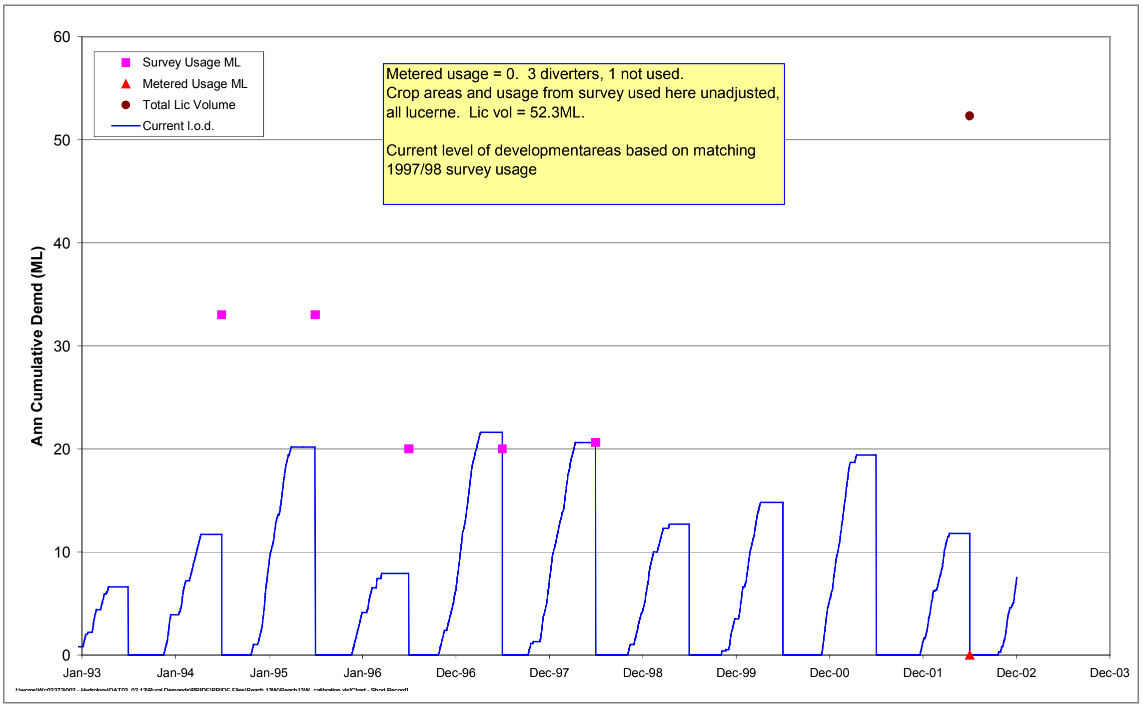
Reach 13

Year	Wine Grapes	Metered consumption (survey consumption)
93/94	2.5	(5)
94/95	2.5	(5)
95/96	2.5	(5)
96/97	2.5	(5)
97/98	2.5	(5)
98/99		
99/00		
00/01		
01/02	36.2	55.6



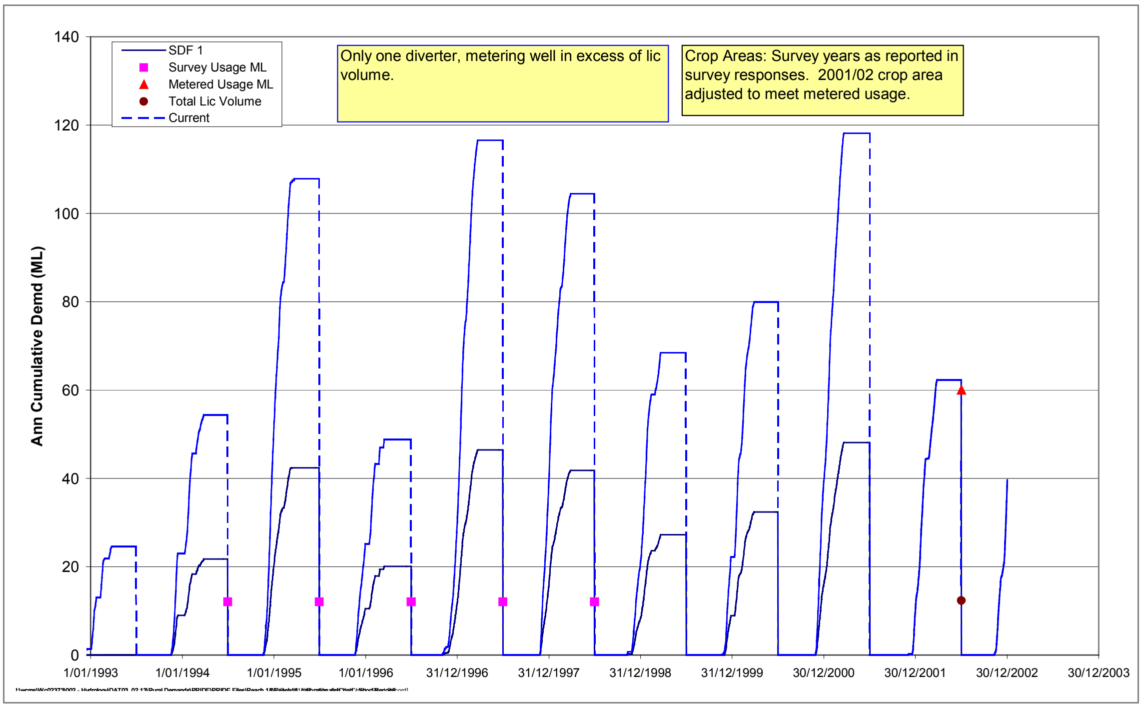
Reach 13w

Year	Lucerne	Metered consumption (survey consumption)
93/94	17.6	(33)
94/95	17.6	(33)
95/96	12.0	(20)
96/97	12.0	(20)
97/98	19.0	(20.6)
98/99		
99/00		
00/01		
01/02	0	0



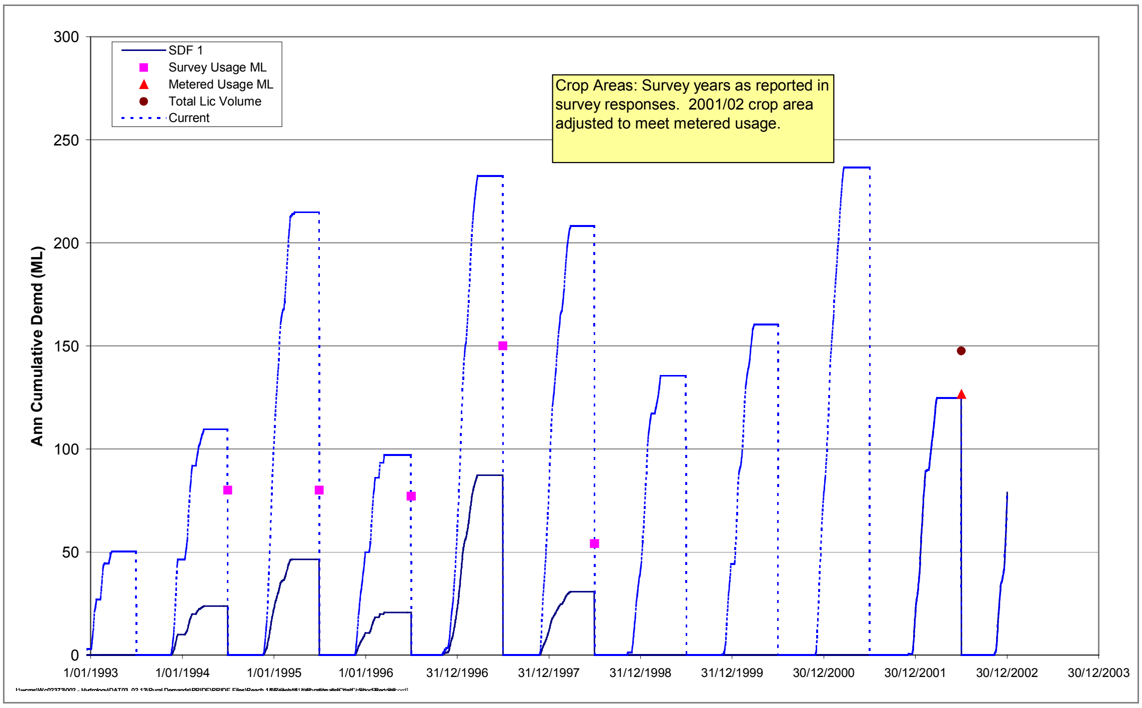
Reach 14

Year	Summer Crop	Metered consumption (survey consumption)
93/94	12.0	(12)
94/95	12.0	(12)
95/96	12.0	(12)
96/97	12.0	(12)
97/98	12.0	(12)
98/99		
99/00		
00/01		
01/02	30.0	60



Reach 15

Year	Summer Crop	Metered consumption (survey consumption)
93/94	12.9	(80)
94/95	12.9	(80)
95/96	12.4	(77)
96/97	22.4	(150)
97/98	8.7	(54)
98/99		
99/00		
00/01		
01/02	60.0	126.5


Ann Cumulative Demd (ML)
SDF 1
Survey Usage ML
Metered Usage ML
Total Lic Volume
Current
Crop Areas: Survey years as reported in survey responses. 2001/02 crop area adjusted to meet metered usage.
300
250
200
150
100
50
0
1/01/1993
1/01/1994
1/01/1995
1/01/1996
31/12/1996
31/12/1997
31/12/1998
31/12/1999
30/12/2000
30/12/2001
30/12/2002
30/12/2003

Appendix F REALM Modelling

System listing revised base case

```
      HHHHH     HHHHHHHH    HHHHHH    H         HHHHHHHHHH
      H   H     H            H    H   H         H    H   H
      HHHHHHHH  HHHHHH     HHHHHHHH   HHH       HHH  H   H
      HHH    H  HHH        HHH    H   HHH       HHH  H   H
      HHH    H  HHH        HHH    H   HHH       HHH  H   H
      HHH    H  HHHHHHHH   HHH    H   HHHHHHHH  HHH  H   H

             ****************************
             *   SYSTEM FILE LISTING    *
             ****************************

 File: base04.SYS

 UID: Realm4.4 UID: 007GAD, Date: 26 Mar 1993, User: DWRVIC

 Simulation label:
     Moorabool System Model - 2003 Level of Development
     BE passing flow rule at Bostock changed to exclude transfers
     from Koorweinguboora (KAA 7/10/03)


 Date: 14:47:50 12/08/03


-------------------------------
|  NODE INFORMATION            |
-------------------------------

-----------------------------------------------------------------------------------------------------
 No          Name              Type          X         Y        Z        Size     Aux Input        No
-----------------------------------------------------------------------------------------------------
   1 KORWEINGUBOORA       Reservoir        99.73   103.74     0.00     1.00 KBOORA INFLOW         1
   2 BOSTOCK              Reservoir        83.28    74.46     0.00     1.00                       2
   3 Node   4             Strm junction    91.49   123.75     0.00     0.50                       3
   4 Node   5             Strm junction    76.67   123.75     0.00     0.50                       4
   5 Node   6             Strm junction    98.63   116.11     0.00     0.50                       5
   6 Node   7             Strm junction   119.54   116.11     0.00     0.50                       6
   7 Node   8             Strm junction   109.65    67.02     0.00     1.00                       7
   8 STONY CREEK          Reservoir       109.42    22.84     0.00     1.00 STONY CREEK INFLOW    8
     Comment: Combined Upper Stony Ck Res storages
   9 Node  10             Strm junction   132.57    49.40     0.00     0.50                       9
  10 Node  11             Strm junction   133.17    30.27     0.00     0.50                      10
  11 GLONG FROM STONY     Demand          109.18     4.04     0.00     1.00                      11
     Comment: Geelong demand supplied from the Stony  Creek reservoirs
  12 MOORABOOL            Reservoir        50.81   104.15     0.00     1.00                      12
  13 LAL LAL BARWON       Reservoir        59.31    68.81     0.00     0.70                      13
     Comment: Barwon Water's capacity share of Lal Lal reservoir
  14 LAL LAL CHW          Reservoir        45.37    68.51     0.00     0.70                      14
     Comment: Central Highlands Water's capacity share of Lal Lal reservoir
  15 NODE 100             Strm junction    51.96    44.94     0.00     0.70                      15
  16 Node  17             Strm junction   137.96    81.29     0.00     0.50                      16
  17 Node  19             Strm junction   119.80   101.54     0.00     0.50                      17
  18 Node  20             Strm junction   119.80    85.57     0.00     0.50                      18
  19 Node  21             Strm junction   138.06    60.28     0.00     0.50                      19
  20 MOORBL INFLOW        Strm junction    50.65   115.14     0.00     0.50 MOORBL INFLOW        20
     Comment: Inflows to Moorabool Reservoir
  21 IRR U/S MBOOL RES    Demand           55.73   112.11     0.00     0.50                      21
     Comment: Direct licenses upstream of            Moorabool Reservoir
  22 WMOORBL INFLOW       Strm junction    51.29    93.17     0.00     0.50                      22
     Comment: West Moorabool River inflows between    Moorabool and Lal Lal reservoirs
  23 IRR BTWN MBOOL & LAL Demand           67.82    88.81     0.00     0.50                      23
     Comment: Private Diverters from West Moorabool R btw Moorabool and LaL Lal reservoirs
  24 Node  27             Strm junction    51.51    79.56     0.00     0.50                      24
  25 WILSONS RES          Reservoir        40.52   109.99     0.00     0.70                      25
  26 TRIB INFLOWS         Strm junction    38.62    93.14     0.00     0.50                      26
     Comment: Total tributary inflows to Lal Lal      reservoir
  27 WHITE SWAN           Reservoir         6.54   103.27     0.00     1.00                      27
  28 IRR U/S WILSONS      Demand           37.82   115.08     0.00     0.50                      28
     Comment: diverters upstream of Wilson           Reservoir
  29 BALLARAT             Demand            6.54    74.12     0.00     1.00                      29
     Comment: Represents 80% of the total Ballarat    demand-supply from either Ws or Lal Lal
  30 LL OFFSTRM WINTERFIL Demand           32.43    89.61     0.00     0.50                      30
     Comment: Offstream Winterfill Diverters on tribs  upstream of Lal Lal reservoir
  31 IRR TRIBS U/S LALLAL Demand           35.92    81.97     0.00     0.50                      31
     Comment: ONSTREAM DIVERTERS U/S LAL LAL
  32 Node  39             Strm junction    12.31    61.78     0.00     0.50                      32
  33 Node  40             Strm junction    12.63    44.15     0.00     0.50                      33
  34 Node  41             Strm terminator  39.42    60.00     0.00     0.50                      34
  35 Node  42             Strm terminator  64.86    61.68     0.00     0.50                      35
  36 BALLARAT FROM LL     Demand           29.22    57.74     0.00     0.70                      36
     Comment: Represents 20% of Ballarat total demand which can be supplied from Lal Lal only
  37 BALLAN               Demand           21.97    62.84     0.00     0.70                      37
     Comment: Includes demands for Gordon, Mt Egerton, Bungaree, Wallace, and Ballan
  38 D&S U/S SHE OAKS     Demand           58.47    41.60     0.00     0.50                      38
  39 MEREDITH OFFTAKE     Strm junction    52.11    41.41     0.00     0.70                      39
  40 SHE OAKS WEIR        Reservoir        52.24    36.96     0.00     0.70                      40
  41 Node 109             Strm junction    52.08    33.18     0.00     0.70                      41
  42 MEREDITH PS          Demand           40.21    40.04     0.00     1.00                      42
  43 SHE OAKS PS          Demand           59.70    37.88     0.00     1.00                      43
  44 DIRECT SHE-SPILLERS  Demand           40.17    33.77     0.00     0.50                      44
  45 Node  63             Strm terminator  83.57     5.00     0.00     1.00                      45
  46 RAIN BW              Strm junction    66.88    73.77     0.00     0.50 BEALES RAIN          46
  47 RAIN CHW             Strm junction    40.94    75.16     0.00     0.50 BEALES RAIN          47
  48 D&S ETC SHE-SPILLERS Demand           40.01    35.92     0.00     0.50                      48
  49 BOLWARRA WEIR        Reservoir        94.21    90.39     0.00     0.70                      49
  50 Node  65             Strm junction    31.68    67.96     0.00     0.70                      50
  51 Node  66             Strm junction   119.01    49.13     0.00     0.50                      51
  52 Node  67             Strm junction   119.27    29.00     0.00     0.50                      52
  53 Node  70             Strm junction    52.27    65.19     0.00     0.50                      53
  54 Node  74             Strm junction   123.77     3.66     0.00     0.50                      54
  55 Node  75             Strm junction   122.98    20.32     0.00     0.50                      55
  56 TERM                 Strm terminator  59.86    79.80     0.00     0.50                      56
  57 Node  71             Strm junction    25.60   129.61     0.00     1.00                      57
  58 Node  72             Strm junction    39.09   131.08     0.00     1.00                      58
  59 EXCESS RAIN          Strm terminator  51.71    73.14     0.00     0.50                      59
  60 Node  77             Strm junction    51.44    85.48     0.00     0.50                      60
  61 LOSS FN W MBOOL      Strm terminator  53.82    89.09     0.00     0.50                      61
  62 ONSTRM DAMS U/S MOOR Reservoir        50.49   110.93     0.00     0.50                      62
  63 WHISKEY CK AT PIPE   Strm junction    44.30   101.41     0.00     0.50                      63
  64 Node  86             Strm junction    46.08    96.83     0.00     0.50                      64
  65 WHISKEY CK WINTERFIL Demand           44.17    95.00     0.00     0.50                      65
  66 BEALES RES           Reservoir        40.52   105.29     0.00     0.70                      66
  67 ONSTREAM U/S WILSONS Reservoir        40.37   114.49     0.00     0.50                      67
  68 Node  87             Strm junction    40.68   100.78     0.00     0.50                      68
  69 FLOODGATES           Strm junction    31.95   100.68     0.00     0.50                      69
  70 Node  88             Strm junction    33.70   103.52     0.00     0.50 UNREG TRIBS          70
  71 LAL LAL ONSTRM       Reservoir        42.27    86.87     0.00     0.50                      71
  72 Node  90             Strm junction    22.11    98.13     0.00     0.50                      72
  73 Node  91             Strm junction    24.01   101.95     0.00     0.50 GILES CREEK INFLOW   73
  74 KIRKS RES            Reservoir        22.58    91.18     0.00     0.70                      74
  75 GONG GONG RES        Reservoir        21.15    83.34     0.00     0.70                      75
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76	Node 94	Strm junction	27.03	87.26	0.00	0.50		76
77	Node 95	Strm terminator	19.41	96.08	0.00	1.00		77
78	Node 96	Strm junction	11.47	94.71	0.00	0.50		78
79	Node 97	Strm junction	17.50	102.35	0.00	0.50	CLARKES CREEK INFLOW	79
80	Node 98	Strm junction	15.60	98.62	0.00	0.50		80
81	Node 99	Strm terminator	36.72	97.28	0.00	1.00		81
82	Node 101	Strm junction	48.11	83.74	0.00	0.50		82
83	Node 102	Strm junction	52.43	55.33	0.00	1.00		83
84	Node 103	Strm junction	52.43	51.22	0.00	1.00		84
85	Node 104	Strm terminator	46.08	49.06	0.00	1.00		85
86	Node 107	Strm junction	67.64	55.14	0.00	1.00		86
87	SPILLERS WEIR	Reservoir	52.04	29.95	0.00	0.50		87
88	CAPRONS WEIR	Reservoir	51.60	23.81	0.00	0.50		88
89	MATTHEYS WEIR	Reservoir	51.21	18.05	0.00	0.50		89
90	MADDENS WEIR	Reservoir	51.28	14.67	0.00	0.50		90
91	BUCHTERS WEIR	Reservoir	51.28	7.49	0.00	0.50		91
92	HILLS WEIR	Reservoir	57.11	5.00	0.00	0.50		92
93	MITCHELLS WEIR	Reservoir	61.34	5.14	0.00	0.50		93
94	JOAQUINS WEIR	Reservoir	68.86	4.61	0.00	0.50		94
95	Node 110	Strm junction	52.01	26.58	0.00	0.50		95
96	Node 111	Strm junction	51.28	20.94	0.00	0.50		96
97	Node 112	Strm junction	51.07	11.01	0.00	0.50		97
98	Node 113	Strm junction	53.61	4.87	0.00	0.50		98
99	Node 114	Strm junction	65.05	4.74	0.00	0.50		99
100	Node 115	Strm junction	72.35	4.74	0.00	0.50		100
101	BATESFORD	Strm junction	76.06	4.87	0.00	1.00		101
102	Node 117	Strm junction	79.86	5.00	0.00	0.50		102
103	DIRECT SPILLERS WEIR	Demand	55.22	29.16	0.00	0.50		103
104	D&S ETC SPILL-CAPRON	Demand	48.76	27.73	0.00	0.50		104
105	DIRECT SPILL-CAPRON	Demand	48.87	26.42	0.00	0.50		105
106	OFFSTRM CAPRON-MATT	Demand	48.87	22.24	0.00	0.50		106
107	DIRECT CAPRON-MATT	Demand	48.97	21.07	0.00	0.50		107
108	DIRECT CAPRONS WEIR	Demand	54.48	23.94	0.00	0.50		108
109	DIRECT MATTHEYS WEIR	Demand	54.26	18.19	0.00	0.50		109
110	DIRECT HILLS WEIR	Demand	57.12	7.49	0.00	0.50		110
111	DIRECT MITCHELLS W	Demand	61.35	7.36	0.00	0.50		111
112	DIRECT MITCH-JOAQ	Demand	65.06	7.62	0.00	0.50		112
113	DIRECT JOAQUINS WEIR	Demand	68.55	7.36	0.00	0.50		113
114	DIRECT JOAQ-BATESFRD	Demand	72.47	7.49	0.00	0.50		114
115	D&S ETC D/S BATESFRD	Demand	78.71	8.01	0.00	0.50		115
116	DIRECT D/S BATESFORD	Demand	80.51	8.40	0.00	0.50		116
117	D&S LL TRIBS	Demand	33.75	87.22	0.00	0.50		117
118	D&S BTWN MBOOL & LAL	Demand	66.21	85.14	0.00	0.50		118
119	IND MATTHEYS WEIR	Demand	46.37	18.14	0.00	0.50		119
120	Node 131	Strm terminator	75.58	8.64	0.00	0.50		120
121	Node 132	Strm junction	73.04	18.05	0.00	1.00		121
122	Node 133	Strm junction	76.69	17.95	0.00	1.00		122
123	Node 127	Strm junction	83.20	79.62	0.00	0.50	BOSTOCK INFLOW	123
124	Node 129	Strm junction	49.18	54.38	0.00	1.00	INFLOW UPSTREAM 204	124
125	Node 134	Strm junction	48.55	44.85	0.00	1.00	204 TO SHE OAKS INF	125
126	Node 135	Strm junction	54.03	94.54	0.00	1.00	WMOORBL INFLOW	126
127	Node 137	Strm junction	39.22	96.24	0.00	1.00	LL TRIB INFLOW	127
128	Node 139	Strm junction	44.40	103.95	0.00	1.00	WHISKEY CK U/S PIPE	128
129	Node 142	Strm junction	40.81	117.79	0.00	1.00	WILSONS RES INFLOW	129
130	Node 143	Strm junction	58.18	20.28	0.00	1.00	INF SHE-BATES	130
131	Node 145	Strm junction	36.25	108.32	0.00	1.00	BEALES RES INFLOW	131
132	Node 156	Strm junction	23.48	82.26	0.00	1.00	FELLMONGERS CK	132
133	Node 158	Strm junction	24.97	92.57	0.00	1.00	LEIGH CREEK INFLOW	133
134	PINCOTTS	Strm junction	27.72	99.05	0.00	1.00		134
135	Node 157	Strm junction	29.16	42.62	0.00	1.00		135
136	Node 159	Strm junction	32.55	38.04	0.00	1.00		136
137	Node 160	Strm junction	52.16	40.19	0.00	0.50		137
138	Node 161	Strm junction	18.22	47.09	0.00	1.00		138
139	Node 162	Strm junction	7.92	64.76	0.00	1.00		139
140	Node 163	Strm terminator	49.38	119.54	0.00	1.00		140
141	Node 164	Strm terminator	32.59	106.31	0.00	1.00		141
142	Node 165	Strm terminator	57.16	99.55	0.00	1.00		142
143	Node 166	Strm terminator	40.25	98.67	0.00	1.00		143
144	Node 167	Strm terminator	43.83	108.96	0.00	1.00		144
145	Node 168	Strm terminator	37.99	120.14	0.00	1.00		145
146	Node 169	Strm terminator	34.10	109.76	0.00	1.00		146
147	Node 170	Strm terminator	19.81	103.76	0.00	1.00		147
148	Node 171	Strm terminator	23.46	88.09	0.00	1.00		148
149	Node 172	Strm terminator	78.44	83.15	0.00	1.00		149
150	Node 173	Strm terminator	59.54	16.63	0.00	1.00		150

Reservoir data:

No	Name	Min Cap	Max Cap	No Above	No Below	Spill Type
1	KORWEINGUBOORA	0	2091	5	5	Downstream
2	BOSTOCK	0	7455	1	1	Downstream
8	STONY CREEK	0	9324	1	1	External
12	MOORABOOL	0	6738	5	5	Downstream
13	LAL LAL BARWON	0	59550	1	1	Downstream
14	LAL LAL CHW	0	59550	1	1	Downstream
25	WILSONS RES	0	1010	5	5	Downstream
27	WHITE SWAN	0	14107	5	5	No spill
40	SHE OAKS WEIR	0	150	20	20	Downstream
49	BOLWARRA WEIR	0	122	5	5	Downstream
62	ONSTRM DAMS U/S MOOR	0	162	1	1	Downstream
66	BEALES RES	0	415	5	5	Downstream
67	ONSTREAM U/S WILSONS	0	27	1	1	Downstream
71	LAL LAL ONSTRM	0	925	1	1	Downstream
74	KIRKS RES	0	400	5	5	Downstream
75	GONG GONG RES	0	1902	5	5	Downstream
87	SPILLERS WEIR	0	25	1	1	Downstream
88	CAPRONS WEIR	0	37	1	1	Downstream
89	MATTHEYS WEIR	0	36	1	1	Downstream
90	MADDENS WEIR	0	14	1	1	Downstream
91	BUCHTERS WEIR	0	23	1	1	Downstream
92	HILLS WEIR	0	21	1	1	Downstream
93	MITCHELLS WEIR	0	16	1	1	Downstream
94	JOAQUINS WEIR	0	40	1	1	Downstream

Reservoir evaps: (if A=B=0 evaps not calculated!)

No	Name	NET EVAP = (A	+ B	* EVAPORATION)	- RAINFALL
1	KORWEINGUBOORA	0.000	0.700	MOORABOOL EVAP	MOORABOOL RAIN
2	BOSTOCK	0.000	0.700	MOORABOOL EVAP	MOORABOOL RAIN
8	STONY CREEK	0.000	0.700	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
12	MOORABOOL	0.000	1.000	MOORABOOL EVAP	MOORABOOL RAIN
25	WILSONS RES	0.000	0.800	MOORABOOL EVAP	BEALES RAIN
27	WHITE SWAN	0.000	0.700	WSWAN EVAP	BEALES RAIN
62	ONSTRM DAMS U/S MOOR	0.000	1.000	MOORABOOL EVAP	MOORABOOL RAIN
66	BEALES RES	0.000	0.800	MOORABOOL EVAP	BEALES RAIN
67	ONSTREAM U/S WILSONS	0.000	1.000	MOORABOOL EVAP	BEALES RAIN
71	LAL LAL ONSTRM	0.000	1.000	MOORABOOL EVAP	MOORABOOL RAIN
74	KIRKS RES	0.000	0.800	WSWAN EVAP	BEALES RAIN
75	GONG GONG RES	0.000	0.800	WSWAN EVAP	BEALES RAIN
87	SPILLERS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
88	CAPRONS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
89	MATTHEYS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
90	MADDENS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
91	BUCHTERS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
92	HILLS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
93	MITCHELLS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN
94	JOAQUINS WEIR	0.000	1.000	DURDIDWARRAH EVAP	DURDIDWARRAH RAIN

Surface area/volume relationships

No	Name	pt1	pt2	pt3	pt4	pt5	pt6	pt7	pt8	pt9	pt10

No	Name											
1	KORWEINGUBOORA	Vol	11	53	132	256	442	710	1052	1490	2091	0
		Area	0	0	11	14	23	30	38	50	61	0
2	BOSTOCK	Vol	10	190	560	1155	1918	2927	4170	5680	6524	7455
		Area	0	1	20	27	37	47	63	74	80	85
8	STONY CREEK	Vol	0	140	605	1135	2010	3074	4353	5841	7504	9324
		Area	0	5	13	24	73	121	139	154	174	189
12	MOORABOOL	Vol	0	1220	2150	3600	4275	4650	5050	5487	6400	6738
		Area	0	41	74	99	119	125	133	141	150	154
25	WILSONS RES	Vol	0	200	400	600	800	1010	0	0	0	0
		Area	0	14	19	29	32	33	0	0	0	0
27	WHITE SWAN	Vol	0	700	1520	2593	4186	6163	7860	10156	12488	14324
		Area	0	18	33	51	65	84	98	113	125	133
62	ONSTRM DAMS U/S MOOR	Vol	0	162	0	0	0	0	0	0	0	0
		Area	0	5	0	0	0	0	0	0	0	0
66	BEALES RES	Vol	0	80	160	240	320	415	0	0	0	0
		Area	0	8	13	21	28	33	0	0	0	0
67	ONSTREAM U/S WILSONS	Vol	0	27	0	0	0	0	0	0	0	0
		Area	0	2	0	0	0	0	0	0	0	0
71	LAL LAL ONSTRM	Vol	0	925	0	0	0	0	0	0	0	0
		Area	0	17	0	0	0	0	0	0	0	0
74	KIRKS RES	Vol	0	80	160	240	320	400	0	0	0	0
		Area	0	8	16	24	32	40	0	0	0	0
75	GONG GONG RES	Vol	0	400	800	1200	1600	1902	0	0	0	0
		Area	0	38	78	118	158	188	0	0	0	0
87	SPILLERS WEIR	Vol	0	25	0	0	0	0	0	0	0	0
		Area	0	1	0	0	0	0	0	0	0	0
88	CAPRONS WEIR	Vol	0	37	0	0	0	0	0	0	0	0
		Area	0	2	0	0	0	0	0	0	0	0
89	MATTHEYS WEIR	Vol	0	36	0	0	0	0	0	0	0	0
		Area	0	2	0	0	0	0	0	0	0	0
90	MADDENS WEIR	Vol	0	14	0	0	0	0	0	0	0	0
		Area	0	1	0	0	0	0	0	0	0	0
91	BUCHTERS WEIR	Vol	0	23	0	0	0	0	0	0	0	0
		Area	0	1	0	0	0	0	0	0	0	0
92	HILLS WEIR	Vol	0	21	0	0	0	0	0	0	0	0
		Area	0	1	0	0	0	0	0	0	0	0
93	MITCHELLS WEIR	Vol	0	16	0	0	0	0	0	0	0	0
		Area	0	1	0	0	0	0	0	0	0	0
94	JOAQUINS WEIR	Vol	0	40	0	0	0	0	0	0	0	0
		Area	0	2	0	0	0	0	0	0	0	0

Levels/volume relationships

No	Name		pt1	pt2	pt3	pt4	pt5	pt6	pt7	pt8	pt9	pt10	pt11	pt12	pt13	pt14	pt15
1	KORWEINGUBOORA	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	BOSTOCK	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	STONY CREEK	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	MOORABOOL	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	LAL LAL BARWON	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	LAL LAL CHW	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	WILSONS RES	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	WHITE SWAN	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	SHE OAKS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	BOLWARRA WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	ONSTRM DAMS U/S MOOR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	BEALES RES	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	ONSTREAM U/S WILSONS	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	LAL LAL ONSTRM	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	KIRKS RES	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	GONG GONG RES	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	SPILLERS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	CAPRONS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	MATTHEYS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	MADDENS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	BUCHTERS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	HILLS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	MITCHELLS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	JOAQUINS WEIR	Vol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lvl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

demand data:

No	Name	No Bypass	S/F Priority		Monthly Factors Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
11	GLONG FROM STONY	1	31	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
21	IRR U/S MBOOL RES	1	23	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
23	IRR BTWN MBOOL & LAL	1	21	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
28	IRR U/S WILSONS	1	22	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
29	BALLARAT	1	35	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
30	LL OFFSTRM WINTERFIL	1	10	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
31	IRR TRIBS U/S LALLAL	1	19	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
36	BALLARAT FROM LL	1	34	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
37	BALLAN	1	33	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
38	D&S U/S SHE OAKS	1	24	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
42	MEREDITH PS	1	30	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
43	SHE OAKS PS	1	32	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
44	DIRECT SHE-SPILLERS	5	20	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
48	D&S ETC SHE-SPILLERS	1	25	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
65	WHISKEY CK WINTERFIL	1	9	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
103	DIRECT SPILLERS WEIR	5	8	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
104	D&S ETC SPILL-CAPRON	1	26	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
105	DIRECT SPILL-CAPRON	5	18	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
106	OFFSTRM CAPRON-MATT	1	17	min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
				max	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

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   107 DIRECT CAPRON-MATT    5   16   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   108 DIRECT CAPRONS WEIR   5    7   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   109 DIRECT MATTHEYS WEIR  5    6   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   110 DIRECT HILLS WEIR     5    4   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   111 DIRECT MITCHELLS W    5    3   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   112 DIRECT MITCH-JOAQ     5   13   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   113 DIRECT JOAQUINS WEIR  5    2   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   114 DIRECT JOAQ-BATESFRD  5   12   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   115 D&S ETC D/S BATESFRD  1   27   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   116 DIRECT D/S BATESFORD  5   11   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   117 D&S LL TRIBS          1   28   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   118 D&S BTWN MBOOL & LAL  1   29   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
   119 IND MATTHEYS WEIR     1    1   min   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
                                      max   0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000


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|  ARC INFORMATION            |
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 No          Name            Type        From        To        Cost       Offset        Loss     Ann Vol   Shr Gp Shr%     No
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   1 KBOORA SPILLS         River          1        49           0           1        0fix                     0     0%        1
   2 KBOORA RELEASE        River          1        49           0           0        0fix                     0     0%        2
   3 KBOORA PASS RULE      Pipe           3         4           0           0        0fix                     0     0%        3
   4 BOSTOCK PASS RULE     Pipe           3         4           0          -1        0fix                     0     0%        4
   5 BALLAN CHANNEL        Pipe          49         7           0           0        0fix                     0     0%        5
   6 BOSTOCK CH COUNTER    Pipe           5         6           0           1        0fix                     0     0%        6
   7 STONY COUNTER         Pipe           5         6           0           2        0fix                     0     0%        7
     Comment: Sums the annual flows in the supply    aqueduct to Geelong from Stony Ck res
   8 BOLWARRA TO BOSTOCK   River         49         2           0           0        0fix                     0     0%        8
   9 BOSTOCK CHANNEL       Pipe           2         7           0           0        0fix                     0     0%        9
     Comment: Assume dead storage 5% cap.=373ML.     BE=6000ML/year; not exceeding 27 ML/day
  10 BALLAN CHANNEL2       Pipe           7         8           0           0        0fix                     0     0%       10
     Comment: Capacity=35 ML/day
  11 Arc  14               Pipe           9        10           0           0        0fix                     0     0%       11
  12 STONY TO GEELONG      Pipe           8        11           0           0        0fix                     0     0%       12
     Comment: BE = 9000ML/YR; not exceeding 22ML/day
  13 BOST PASS RULE        Pipe          17        18           0           0        0fix                     0     0%       13
  14 LL SURFACE AREA       Pipe          17        18           0           1        0fix                     0     0%       14
     Comment: Surface Area of Lal Lal reservoir
  15 Arc  22               Pipe          17        18           0          -1        0fix                     0     0%       15
  16 BOSTOCK SPILLS        River          2        86           0           1        0fix                     0     0%       16
  17 LL PASS FLOW 20       Pipe          16        19           0           0        0fix                     0     0%       17
     Comment: Passing flow = 20 ML/day or natural
  18 LL PASS FLOW 5        Pipe          16        19           0           1        0fix                     0     0%       18
     Comment: Paasing flow equals 5ML/day or natural
  19 ONE YEAR INFLOW       Pipe          16        19           0          -1        0fix                     0     0%       19
     Comment: Total 12 month inflow at end of         financial year
  20 BOSTOCK PASS FLOW     River          2        86   -53000000           0        0fix                     0     0%       20
     Comment: BE passing flow
  21 TO IRR U/S MBOOL RES  Pipe          62        21   -90000000           0        0fix                     0     0%       21
  22 TRIBS US MOORBL       River         20        62           0           0        0fix                     0     0%       22
     Comment: Total inflows to Moorabool Reservoir
  23 MOORABOOL SPILLS      River         12        22           0           1        0fix                     0     0%       23
     Comment: Spills from Moorabool Reservoir
  24 MOORABOOL PASS FLOW   River         12        22   -53000000           0        0fix                     0     0%       24
     Comment: If flow 3ML/day then = inflow else      = 3ML/day
  25 TO IRR MBOOL TO LAL   Pipe          60        23   -90000000           0        0fix                     0     0%       25
  26 WMOORBL FLOWS         River         60        24           0           0        0fix                     0     0%       26
  27 MOORABOOL PIPELINE    Pipe          12        63           0           0        0fix                     0     0%       27
     Comment:                                         Pipeline capacity = 15ML/day
  28 TO IRR U/S WILSONS    Pipe          67        28   -90000000           0        0fix                     0     0%       28
  29 WILSONS ONSTRM SPILL  River         67        25           0           1        0fix                     0     0%       29
  30 WIL TO BEALES SPILL   River         25        66           0           1        0fix                     0     0%       30
  31 WSWAN OP TRIGGER      Pipe          78        29           0           1        0fix                     0     0%       31
     Comment: Based on operating storage triggers for Wswan.  Capacity = 50ML/day
  32 WF3 DIVERSIONS        Pipe          26        30           0           0        0fix                     0     0%       32
  33 SD2 DIVERSIONS        Pipe          71        31   -90000000           0        0fix                     0     0%       33
  34 LL TRIB FLOWS         River         26        71           0           0        0fix                     0     0%       34
  35 CHW INFLOW            River         24        14           0           0        0fix                     0     0%       35
     Comment: Represents 2/3 of the total inflow to   Lal Lal reservoir
  36 BARWON INFLOW         River         24        13           0           0        0fix                     0     0%       36
     Comment: Represents 1/3 of the total inflows to  Lal Lal reservoir
  37 CHW ONE YR SUM        Pipe          32        33           0           0        0fix                     0     0%       37
     Comment: Total releases for previous YEAR
  38 SUM CHW RELEASE       Pipe          32        33           0           1        0fix                     0     0%       38
     Comment: Sum of releases to CHW over a 3 year    period
  39 EVAP CHW              River         14        34   -53000000           0        0fix                     0     0%       39
     Comment: Evaporation from CHW share of Lal Lal   Shared in proportion to the vol in stor.
  40 EVAP BARWON           River         13        35   -53000000           0        0fix                     0     0%       40
     Comment: Evaporation from Barwon's share of LL   Shared in proportion to vol. in stor.
  41 Arc  57               Pipe          32        33           0          -1        0fix                     0     0%       41
  42 CHW PASS FLOW         River         14        83   -53000000           1        0fix                     0     0%       42
     Comment: Represents 2/3 of the total passing flow requirement from Lal Lal res.dead=1800
  43 BARWON PASS FLOW      River         13        83   -53000000           1        0fix                     0     0%       43
     Comment: Represents 1/3 of the total passing flow requirement for Lal Lal reservoir
  44 LL TO BALLRT ONE      Pipe          50        36           0           0        0fix                     0     0%       44
  45 LL TO BALLRT TWO      Pipe          50        29           0           0        0fix                     0     0%       45
  46 LL TO BALLAN          Pipe          50        37           0           0        0fix                     0     0%       46
     Comment: Ballan pipeline supplied from Lal Lal
  47 SD3 DIVERSIONS        Pipe          39        38           0           0        0fix                     0     0%       47
  48 204 TO MEREDITH       River         15        39           0           0        0fix                     0     0%       48
     Comment: River reach between 232204 and the      Meredith offtake
  49 MEREDITH DIVERSION    Pipe          39        42           0           0        0fix                     0     0%       49
  50 MEREDITH TO SHE OAKS  River         39       137           0           0        0fix                     0     0%       50
  51 SHE OAKS SPILLS       River         40        41           0           0        0fix                     0     0%       51
  52 SD5 DIVERSIONS        Pipe          41        44           0           0        0fix                     0     0%       52
  53 U/S SPILLERS          River         41        87           0           0        0fix                     0     0%       53
  54 BARWON RAIN           Pipe          46        13           0           0        0fix                     0     0%       54
     Comment: Rainfall on Barwon's share of Lal Lal   Shared in proportion to the vol in store
  55 CHW RAIN              Pipe          47        14           0           0        0fix                     0     0%       55
     Comment: Rainfall on CHW share of Lal Lal        Shared in proportion to the vol is store
  56 WF4 DIVERIONS         Pipe          41        48           0           0        0fix                     0     0%       56
  57 BOLWARRA COUNTER      Pipe           5         6           0           0        0fix                     0     0%       57
  58 TWO YEAR INFLOWS      Pipe          16        19           0          -2        0fix                     0     0%       58
     Comment: Cumulative inflows over 2 years
  59 LL RELEASE TO CHW     Pipe          14        50           0           0        0fix                     0     0%       59
     Comment:                                         Current pump capacity 50ML/day DEAD=1800
  60 LL BARWON RELEASE     River         13        83   -53000000           0        0fix                     0     0%       60
     Comment: Assume max release=70ML/d based on max. max. pump cap=65ML/d@SheOaks. 7% losses
  61 BARWON THREE YR REL   Pipe          51        52           0           0        0fix                     0     0%       61
     Comment: Total release for the previous 3 years
  62 BARWON ONE YR SUM     Pipe          51        52           0           1        0fix                     0     0%       62
  63 SHE OAKS PUMPS        Pipe          40        43           0           0        0fix                     0     0%       63
  64 CHW SPILLS            River         14        53   -53000000          -1        0fix                     0     0%       64
  65 BARWON SPILLS         River         13        53   -53000000          -1        0fix                     0     0%       65
  66 CHW HARVEST SPILLS    River         53        14           0           0        0fix                     0     0%       66
     Comment: Internal spills from Barwon capacity    share to CHW share
  67 BARWON HARVEST SPILL  River         53        13           0           0        0fix                     0     0%       67
     Comment: Internal spills from CHW's capacity     share to Barwon's share
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68	LAL LAL SPILLS	River	53	83	-55000000	0	0fix	0	0%	68
69	SHE OAKS ONE YR REL	Pipe	55	54	0	0	0fix	0	0%	69
	Comment: Sum of She Oaks diversions over the previous year									
70	SUM SHE OAKS DIV	Pipe	55	54	0	-1	0fix	0	0%	70
	Comment: Sum of She Oaks diversions over 3 consecutive years									
71	Arc 91	Pipe	24	56	50000000	0	0fix	0	0%	71
72	Arc 92	Pipe	57	58	0	0	0fix	0	0%	72
73	EXCESS RAIN2	Pipe	47	59	0	0	0fix	0	0%	73
74	EXCESS RAIN1	Pipe	46	59	0	0	0fix	0	0%	74
75	TO W.MBOOL DEMANDS	River	22	60	0	0	0fix	0	0%	75
76	WEST MBOOL R LOSS	Pipe	60	61	-50000000	0	0fix	0	0%	76
77	MBOOL ONSTRM SUMMER	River	62	12	-53000000	1	0fix	0	0%	77
78	MBOOL ONSTRM SPILL	River	62	12	0	0	0fix	0	0%	78
79	MBOOL ONSTRM BYPASS	River	20	12	-53000000	-1	0fix	0	0%	79
80	WHISKEY CK	River	63	64	1000000	0	0fix	0	0%	80
	Comment: +VE COST TO ENCOURAGE FLOW DOWN PIPE									
81	WHISKEY CK BELOW DIV	River	64	22	0	0	0fix	0	0%	81
82	TO WHISKEY CK WINTER	Pipe	64	65	0	0	0fix	0	0%	82
83	WIL TO BEALES RELEAS	Pipe	25	66	0	0	0fix	0	0%	83
84	WILSON ONSTRM SUMM	River	67	25	-53000000	0	0fix	0	0%	84
85	BEALES RELEASE	Pipe	66	68	0	0	0fix	0	0%	85
86	PIPE WHISK TO BEALES	Pipe	63	68	0	0	0fix	0	0%	86
87	BEALES SPILL	River	66	81	0	0	0fix	0	0%	87
88	CHL BEALES TO GATES	Pipe	68	69	0	0	0fix	0	0%	88
89	FLOODGATE SPILLS	River	70	81	100000	0	0fix	0	0%	89
	Comment: +VE COST TO ENCOURAGE FLOW DOWN CHL									
90	TRIBS TO CHANNEL	Pipe	70	69	0	0	0fix	0	0%	90
91	LAL LAL ONSTRM SPILL	River	71	82	0	1	0fix	0	0%	91
92	LL ONSTRM SUMM	River	71	82	-53000000	0	0fix	0	0%	92
93	LL ONSTRM BYPASS	River	26	82	-53000000	0	0fix	0	0%	93
94	CHL GATES TO PINCOTT	Pipe	69	134	0	0	0fix	0	0%	94
95	CHL PINCOTT TO GILES	Pipe	134	72	0	0	0fix	0	0%	95
96	GILES CK SPILL	River	73	74	100000	1	0fix	0	0%	96
	Comment: +VE COST TO ENCOURAGE FLOW DOWN CHL									
97	GILES TO CHL	Pipe	73	72	0	0	0fix	0	0%	97
98	PINCOTTS RELEASE	Pipe	134	76	0	0	0fix	0	0%	98
99	PINCOTTS TO GONG	Pipe	76	75	0	0	0fix	0	0%	99
100	PINCOTTS TO KIRKS	Pipe	76	74	0	0	0fix	0	0%	100
101	KIRKS SPILL	River	74	77	0	0	0fix	0	0%	101
102	GONG GONG SPILL	River	75	77	0	0	0fix	0	0%	102
103	KIRKS TO DEMAND	Pipe	74	78	0	0	0fix	0	0%	103
	Comment: Apply BE max div capacity 15 ML/d									
104	GONG GONG TO DEMAND	Pipe	75	78	0	0	0fix	0	0%	104
	Comment: Apply BE max div capacity 30 ML/d									
105	WHITE SWAN TO DEMD	Pipe	27	78	0	0	0fix	0	0%	105
	Comment: apply BE max div capacity 100 ML/d									
106	CHL GILES TO CLARKES	Pipe	72	80	0	0	0fix	0	0%	106
107	CLARKES TO CHL	Pipe	79	80	0	0	0fix	0	0%	107
108	CLARKES SPILL	River	79	77	100000	0	0fix	0	0%	108
	Comment: +VE COST TO ENCOURAGE FLOW DOWN CHL									
109	CHL CLARKES TO WSWAN	Pipe	80	27	0	0	0fix	0	0%	109
110	FIELD+BEALES SPILL	River	81	26	0	0	0fix	0	0%	110
111	232213 TO LAL LAL	River	82	24	0	0	0fix	0	0%	111
112	LAL LAL TO CONF	River	83	84	0	0	0fix	0	0%	112
113	CONF TO 204	River	84	15	0	0	0fix	0	0%	113
114	LOSS UPSTREAM 204	Pipe	84	85	-53000000	0	0fix	0	0%	114
115	BOSTOCK TO CONF	River	86	84	0	0	0fix	0	0%	115
116	D/S SPILLERS	River	41	95	0	-1	0fix	0	0%	116
117	U/S CAPRONS	River	95	88	0	0	0fix	0	0%	117
118	D/S CAPRONS	River	95	96	0	-1	0fix	0	0%	118
119	U/S MATTHEYS	River	96	89	0	0	0fix	0	0%	119
120	U/S MADDENS	River	96	97	0	-2	0fix	0	0%	120
121	U/S BUCHTERS	River	97	91	0	0	0fix	0	0%	121
122	D/S BUCHTERS	River	97	98	0	0	0fix	0	0%	122
123	U/S HILLS	River	98	92	0	0	0fix	0	0%	123
124	U/S MITCHELLS	River	98	99	0	-2	0fix	0	0%	124
125	U/S JOAQUINS	River	99	94	0	0	0fix	0	0%	125
126	D/S JOAQUINS	River	99	100	0	-1	0fix	0	0%	126
127	U/S BATESFORD	River	100	101	0	0	0fix	0	0%	127
128	D/S BATESFORD	River	101	102	0	0	0fix	0	0%	128
129	U/S BARWON RIVER	River	102	45	0	0	0fix	0	0%	129
130	TO DIRECT SPILLERS W	Pipe	87	103	0	0	0fix	0	0%	130
131	Arc 141	Pipe	95	104	0	0	0fix	0	0%	131
132	Arc 142	Pipe	95	105	0	0	0fix	0	0%	132
133	Arc 143	Pipe	88	108	0	0	0fix	0	0%	133
134	Arc 144	Pipe	96	106	0	0	0fix	0	0%	134
135	Arc 145	Pipe	96	107	0	0	0fix	0	0%	135
136	Arc 146	Pipe	89	109	0	0	0fix	0	0%	136
137	Arc 151	Pipe	92	110	0	0	0fix	0	0%	137
138	Arc 152	Pipe	93	111	0	0	0fix	0	0%	138
139	Arc 153	Pipe	99	112	0	0	0fix	0	0%	139
140	Arc 154	Pipe	94	113	0	0	0fix	0	0%	140
141	Arc 155	Pipe	100	114	0	0	0fix	0	0%	141
142	Arc 156	Pipe	102	115	0	0	0fix	0	0%	142
143	Arc 157	Pipe	102	116	0	0	0fix	0	0%	143
144	SPILLERS SPILL	River	87	95	0	1	0fix	0	0%	144
145	CAPRONS SPILL	River	88	96	0	1	0fix	0	0%	145
146	MATTHEYS SPILL	River	89	90	0	1	0fix	0	0%	146
147	MADDENS SPILL	River	90	97	0	1	0fix	0	0%	147
148	BUCHTERS SPILL	River	91	98	0	1	0fix	0	0%	148
149	HILLS SPILL	River	92	93	0	1	0fix	0	0%	149
150	MITCHELLS SPILL	River	93	99	0	1	0fix	0	0%	150
151	JOAQUINS SPILL	River	94	100	0	1	0fix	0	0%	151
152	Arc 166	Pipe	26	117	0	0	0fix	0	0%	152
153	Arc 167	Pipe	60	118	0	0	0fix	0	0%	153
154	Arc 168	Pipe	89	119	0	0	0fix	0	0%	154
155	LOSS U/S BATESFORD	Pipe	101	120	-53000000	0	0fix	0	0%	155
156	DUMMY DURD RAIN	Pipe	121	122	0	0	0fix	0	0%	156
157	DUMMY DURD EVAP	Pipe	121	122	0	1	0fix	0	0%	157
158	LOCAL BOST INFLOW	River	123	2	0	0	0fix	0	0%	158
159	TO FARM DAMS BOSTOCK	Pipe	123	149	-90000000	0	0fix	0	0%	159
160	Arc 164	River	124	84	0	0	0fix	0	0%	160
161	TO FARM DAMS US 204	Pipe	124	85	-90000000	0	0fix	0	0%	161
162	LOCAL U/S 204	River	125	39	0	0	0fix	0	0%	162
163	TO FARM DAMS 204 TO	Pipe	125	85	-90000000	0	0fix	0	0%	163
164	TO FARMDAMS U/S MBOO	Pipe	20	140	-99000000	1	0fix	0	0%	164
165	TO FARM DAM UNREG TR	Pipe	70	141	-90000000	1	0fix	0	0%	165
166	Arc 173	River	126	22	0	0	0fix	0	0%	166
167	TO FARM DAMS WMOORBL	Pipe	126	142	-90000000	1	0fix	0	0%	167
168	Arc 175	River	127	26	0	0	0fix	0	0%	168
169	TO GWATER LL TRIB	Pipe	127	143	-90000000	0	0fix	0	0%	169
170	Arc 177	River	128	63	0	0	0fix	0	0%	170
171	TO FARM DAMS WHISKEY	Pipe	128	144	-90000000	1	0fix	0	0%	171
172	Arc 179	River	129	67	0	0	0fix	0	0%	172
173	TO GWATER U/S WILSON	Pipe	129	145	-90000000	0	0fix	0	0%	173
174	0.5 INF SHE-BATES	River	130	95	0	0	0fix	0	0%	174
175	Arc 182	River	130	97	0	0	0fix	0	0%	175
176	TO FARM DAMS SHE-BAT	Pipe	130	150	-90000000	0	0fix	0	0%	176
177	Arc 184	River	131	66	0	0	0fix	0	0%	177
178	TO FARM DAMS BEALES	Pipe	131	146	-90000000	1	0fix	0	0%	178
179	TO MBOOL GWATER	Pipe	20	140	-99000000	0	0fix	0	0%	179
180	TO GWATER UNREG TRIB	Pipe	70	141	-90000000	0	0fix	0	0%	180
181	TO GWATER WMOORBL	Pipe	126	142	-90000000	0	0fix	0	0%	181
182	TO FARM DAMS LL TRIB	Pipe	127	143	-90000000	1	0fix	0	0%	182
183	TO GWATER WHISKEY CK	Pipe	128	144	-90000000	0	0fix	0	0%	183
184	TO FARM DAMS U/S WIL	Pipe	129	145	-90000000	1	0fix	0	0%	184
185	TO GWATER U/S BEALES	Pipe	131	146	-90000000	0	0fix	0	0%	185
186	TO GWATER GILES CK	Pipe	73	147	-90000000	0	0fix	0	0%	186
187	TO GWATER CLARKES CK	Pipe	79	147	-90000000	0	0fix	0	0%	187
188	Arc 195	River	132	75	0	0	0fix	0	0%	188
189	TO GWATER FELLMONGER	Pipe	132	148	-90000000	0	0fix	0	0%	189
190	Arc 197	River	133	74	0	0	0fix	0	0%	190
191	TO GWATER LEIGH CK	Pipe	133	148	-90000000	0	0fix	0	0%	191
192	KBOORA PASS FLOW	River	1	2	-53000000	-1	0fix	0	0%	192
193	SUM MEREDITH INFLOWS	Pipe	135	136	0	0	0fix	0	0%	193
194	MEREDITH FLOW DEFN	Pipe	135	136	0	1	0fix	0	0%	194
195	SHEOAKS PASS FLOW	River	137	41	-53000000	1	0fix	0	0%	195
196	U/S SHE OAKS	River	137	40	0	0	0fix	0	0%	196

197	SRW RESTRICTION	Pipe	33	138	0	0	0fix	0	0%	197
198	WSWAN PROPORTION	Pipe	32	139	0	0	0fix	0	0%	198
199	WHITE SWAN EXTRA	Pipe	78	29	10000	0	0fix	0	0%	199

Maximum Flows

No	Name	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	KBOORA SPILLS	0	0	0	0	0	0	0	0	0	0	0	0
2	KBOORA RELEASE	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
3	KBOORA PASS RULE	4	4	4	3	3	1	1	1	1	3	3	4
4	BOSTOCK PASS RULE	8	8	8	8	8	8	8	8	6	6	6	8
5	BALLAN CHANNEL	245	245	245	245	245	245	245	245	245	245	245	245
8	BOLWARRA TO BOSTOCK	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
9	BOSTOCK CHANNEL	189	189	189	189	189	189	189	189	189	189	189	189
10	BALLAN CHANNEL2	245	245	245	245	245	245	245	245	245	245	245	245
11	Arc 14	0	0	0	0	0	0	0	0	0	0	0	0
13	BOST PASS RULE	8	8	8	8	8	8	8	6	6	6	6	8
15	Arc 22	0	0	0	0	0	0	0	0	0	0	0	0
16	BOSTOCK SPILLS	999999999	999999999	999999999	999999999	999999999	999999999	999999999	999999999	999999999	999999999	999999999	999999999
21	TO IRR U/S MBOOL RES	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
22	TRIBS US MOORBL	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
23	MOORABOOL SPILLS	0	0	0	0	0	0	0	0	0	0	0	0
25	TO IRR MBOOL TO LAL	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
26	WMOORBL FLOWS	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
27	MOORABOOL PIPELINE	105	105	105	105	105	105	105	105	105	105	105	105
28	TO IRR U/S WILSONS	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
29	WILSONS ONSTRM SPILL	0	0	0	0	0	0	0	0	0	0	0	0
30	WIL TO BEALES SPILL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
32	WF3 DIVERSIONS	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
33	SD2 DIVERSIONS	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
34	LL TRIB FLOWS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
41	Arc 57	0	0	0	0	0	0	0	0	0	0	0	0
44	LL TO BALLRT ONE	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
45	LL TO BALLRT TWO	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
46	LL TO BALLAN	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
47	SD3 DIVERSIONS	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
48	204 TO MEREDITH	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999
50	MEREDITH TO SHE OAKS	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999
51	SHE OAKS SPILLS	0	0	0	0	0	0	0	0	0	0	0	0
52	SD5 DIVERSIONS	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
56	WF4 DIVERIONS	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
63	SHE OAKS PUMPS	455	455	455	455	455	455	455	455	455	455	455	455
71	Arc 91	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
72	Arc 92	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
73	EXCESS RAIN2	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
74	EXCESS RAIN1	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999	999999
75	TO W.MBOOL DEMANDS	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999	9999999
78	MBOOL ONSTRM SPILL	0	0	0	0	0	0	0	0	0	0	0	0
80	WHISKEY CK	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
81	WHISKEY CK BELOW DIV	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
82	TO WHISKEY CK WINTER	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
83	WIL TO BEALES RELEAS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
85	BEALES RELEASE	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
86	PIPE WHISK TO BEALES	105	105	105	105	105	105	105	105	105	105	105	105
87	BEALES SPILL	0	0	0	0	0	0	0	0	0	0	0	0
88	CHL BEALES TO GATES	980	980	980	980	980	980	980	980	980	980	980	980
89	FLOODGATE SPILLS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
90	TRIBS TO CHANNEL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
91	LAL LAL ONSTRM SPILL	0	0	0	0	0	0	0	0	0	0	0	0
94	CHL GATES TO PINCOTT	980	980	980	980	980	980	980	980	980	980	980	980
95	CHL PINCOTT TO GILES	980	980	980	980	980	980	980	980	980	980	980	980
96	GILES CK SPILL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
97	GILES TO CHL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
98	PINCOTTS RELEASE	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
99	PINCOTTS TO GONG	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
100	PINCOTTS TO KIRKS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
101	KIRKS SPILL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
102	GONG GONG SPILL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
103	KIRKS TO DEMAND	105	105	105	105	105	105	105	105	105	105	105	105
104	GONG GONG TO DEMAND	210	210	210	210	210	210	210	210	210	210	210	210
105	WHITE SWAN TO DEMD	700	700	700	700	700	700	700	700	700	700	700	700
106	CHL GILES TO CLARKES	980	980	980	980	980	980	980	980	980	980	980	980
107	CLARKES TO CHL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
108	CLARKES SPILL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
109	CHL CLARKES TO WSWAN	980	980	980	980	980	980	980	980	980	980	980	980
110	FIELD+BEALES SPILL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
111	232213 TO LAL LAL	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
112	LAL LAL TO CONF	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
113	CONF TO 204	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
115	BOSTOCK TO CONF	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
116	D/S SPILLERS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
118	D/S CAPRONS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
120	U/S MADDENS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
122	D/S BUCHTERS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
124	U/S MITCHELLS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
126	D/S JOAQUINS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
127	U/S BATESFORD	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
128	D/S BATESFORD	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
129	U/S BARWON RIVER	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
130	TO DIRECT SPILLERS W	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
131	Arc 141	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
132	Arc 142	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
133	Arc 143	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
134	Arc 144	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
135	Arc 145	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
136	Arc 146	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
137	Arc 151	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
138	Arc 152	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
139	Arc 153	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
140	Arc 154	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
141	Arc 155	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
142	Arc 156	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
143	Arc 157	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
144	SPILLERS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
145	CAPRONS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
146	MATTHEYS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
147	MADDENS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
148	BUCHTERS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
149	HILLS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
150	MITCHELLS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
151	JOAQUINS SPILL	0	0	0	0	0	0	0	0	0	0	0	0
152	Arc 166	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
153	Arc 167	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
154	Arc 168	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
158	LOCAL BOST INFLOW	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
160	Arc 164	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
162	LOCAL U/S 204	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
166	Arc 173	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
168	Arc 175	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
170	Arc 177	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
172	Arc 179	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
175	Arc 182	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
177	Arc 184	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
188	Arc 195	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
190	Arc 197	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
196	U/S SHE OAKS	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999
199	WHITE SWAN EXTRA	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999	99999999

Functional Capacities

No	Name		pt1	pt2	pt3	pt4	pt5	pt6	pt7	pt8	pt9	pt10	pt11	pt12
6	BOSTOCK CH COUNTER	V	-99999	0	99999	0	0	0	0	0	0	0	0	0
	Fn Name:	C	0	0	99999	0	0	0	0	0	0	0	0	0

```
 Equation used: IF(('1-27),('2+'3),'2,('2+'3))
 ' 1 = SEASON                    Type: TIME
 ' 2 = BOSTOCK CHANNEL           Type: FLOW(#  9)
 ' 3 = BOSTOCK CH COUNTER        Type: -CAP(#  6)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 7 STONY COUNTER                V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: IF(('1-27),('2+'3),'2,('2+'3))
 ' 1 = SEASON                    Type: TIME
 ' 2 = STONY TO GEELONG          Type: FLOW(# 12)
 ' 3 = STONY COUNTER             Type: -CAP(#  7)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

12 STONY TO GEELONG             V   -99999       0     154   99999       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0     154     154       0       0       0       0       0       0       0       0
 Equation used: if((9000-'1),0,0,(9000-'1))
 ' 1 = STONY COUNTER             Type: CAPC(#  7)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

14 LL SURFACE AREA              V   -99999       0    3600    7660   12470   15610   23300   32930   38480   47670   59549  999999
  Fn Name:                      C        0       0  680000  950000 1370000 1630000 2110000 2590000 2830000 3180000 3740000 3740000
 Equation used: '1+'2
 ' 1 = LAL LAL CHW               Type: STOR
 ' 2 = LAL LAL BARWON            Type: STOR
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

17 LL PASS FLOW 20              V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: if((('1+'2)-140),('1+'2),140,140)
 ' 1 = LL TRIB FLOWS             Type: FLOW(# 34)
 ' 2 = WMOORBL FLOWS             Type: FLOW(# 26)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

18 LL PASS FLOW 5               V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: if((('1+'2)-35),('1+'2),35,35)
 ' 1 = LL TRIB FLOWS             Type: FLOW(# 34)
 ' 2 = WMOORBL FLOWS             Type: FLOW(# 26)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

19 ONE YEAR INFLOW              V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: IF(('1-27),('2+'3+'4),('2+'3),('2+'3+'4))
 ' 1 = SEASON                    Type: TIME
 ' 2 = LL TRIB FLOWS             Type: FLOW(# 34)
 ' 3 = WMOORBL FLOWS             Type: FLOW(# 26)
 ' 4 = ONE YEAR INFLOW           Type: -CAP(# 19)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

20 BOSTOCK PASS FLOW            V ********       0********       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0********       0       0       0       0       0       0       0       0       0
 Equation used: MIN('1,('3+'4+(MAX(('2-'5),0))))
 ' 1 = BOST PASS RULE            Type: CAPC(# 13)
 ' 2 = BOLWARRA TO BOSTOCK       Type: -FLO(#  8)
 ' 3 = LOCAL BOST INFLOW         Type: -FLO(#158)
 ' 4 = KBOORA PASS FLOW          Type: -FLO(#192)
 ' 5 = KBOORA RELEASE            Type: -FLO(#  2)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

24 MOORABOOL PASS FLOW          V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: IF(('1+'3+'4-21),('1+'3+'4),('1+'3+'4),21)
 ' 1 = MBOOL ONSTRM BYPASS       Type: FLOW(# 79)
 ' 2 = MOORABOOL                 Type: STOR
 ' 3 = MBOOL ONSTRM SPILL        Type: FLOW(# 78)
 ' 4 = MBOOL ONSTRM SUMMER       Type: FLOW(# 77)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

31 WSWAN OP TRIGGER             V   -99999       0     350   99999       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0     350     350       0       0       0       0       0       0       0       0
 Equation used: '1/100*'2
 ' 1 = WSWAN PROPORTION          Type: CAPC(#198)
 ' 2 = BALLARAT                  Type: UNRS
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

35 CHW INFLOW                   V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: (2/3)*('2+'3)
 ' 1 = LAL LAL CHW               Type: STOR
 ' 2 = LL TRIB FLOWS             Type: FLOW(# 34)
 ' 3 = WMOORBL FLOWS             Type: FLOW(# 26)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

36 BARWON INFLOW                V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: (1/3)*('2+'3)
 ' 1 = LAL LAL BARWON            Type: STOR
 ' 2 = LL TRIB FLOWS             Type: FLOW(# 34)
 ' 3 = WMOORBL FLOWS             Type: FLOW(# 26)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

37 CHW ONE YR SUM               V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: '1+'2
 ' 1 = LL RELEASE TO CHW         Type: {051(# 59)
 ' 2 = LL RELEASE TO CHW         Type: FLOW(# 59)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

38 SUM CHW RELEASE              V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: '1+'2+'3
 ' 1 = LL RELEASE TO CHW         Type: {103(# 59)
 ' 2 = LL RELEASE TO CHW         Type: FLOW(# 59)
 ' 3 = CHW ONE YR SUM            Type: @104(# 37)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

39 EVAP CHW                     V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: (('4/1000*'1)*0.7/1000)*('3/('2+'3))
 ' 1 = LL SURFACE AREA           Type: CAPC(# 14)
 ' 2 = LAL LAL BARWON            Type: STOR
 ' 3 = LAL LAL CHW               Type: STOR
 ' 4 = MOORABOOL EVAP            Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

40 EVAP BARWON                  V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: (('4/1000*'1)*0.7/1000)*('2/('2+'3))
 ' 1 = LL SURFACE AREA           Type: CAPC(# 14)
 ' 2 = LAL LAL BARWON            Type: STOR
 ' 3 = LAL LAL CHW               Type: STOR
 ' 4 = MOORABOOL EVAP            Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

42 CHW PASS FLOW                V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: IF((1800-'4-'5),(if(('1-43000),(2/3*'3),(2/3*'2),(2/3*'2))),0,0)
 ' 1 = TWO YEAR INFLOWS          Type: CAPC(# 58)
 ' 2 = LL PASS FLOW 20           Type: CAPC(# 17)
 ' 3 = LL PASS FLOW 5            Type: CAPC(# 18)
 ' 4 = LAL LAL CHW               Type: STOR
 ' 5 = LAL LAL BARWON            Type: STOR
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

43 BARWON PASS FLOW             V   -99999       0   99999       0       0       0       0       0       0       0       0       0
  Fn Name:                      C        0       0   99999       0       0       0       0       0       0       0       0       0
 Equation used: IF((1800-'4-'5),(If(('1-43000),(1/3*'3),(1/3*'2),(1/3*'2))),0,0)
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  ' 1 = TWO YEAR INFLOWS          Type: CAPC(# 58)
  ' 2 = LL PASS FLOW 20           Type: CAPC(# 17)
  ' 3 = LL PASS FLOW 5            Type: CAPC(# 18)
  ' 4 = LAL LAL CHW               Type: STOR
  ' 5 = LAL LAL BARWON            Type: STOR
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 49 MEREDITH DIVERSION          V ********      099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0      099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF(('1-3.5),'1,'1,(IF(('1-70),'2,'2,25)))
  ' 1 = SUM MEREDITH INFLOWS      Type: CAPC(#193)
  ' 2 = MEREDITH FLOW DEFN        Type: CAPC(#194)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 53 U/S SPILLERS                V ********      099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0      099999999       0       0       0       0       0       0       0       0       0
  Equation used: if('1,99999999,99999999,0)
  ' 1 = SUMMER TRIGGER            Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 54 BARWON RAIN                 V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: (('4/1000*'1)/1000)*('2/('2+'3))
  ' 1 = LL SURFACE AREA           Type: CAPC(# 14)
  ' 2 = LAL LAL BARWON            Type: STOR
  ' 3 = LAL LAL CHW               Type: STOR
  ' 4 = BEALES RAIN               Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 55 CHW RAIN                    V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: (('4/1000*'1)/1000)*('3/('2+'3))
  ' 1 = LL SURFACE AREA           Type: CAPC(# 14)
  ' 2 = LAL LAL BARWON            Type: STOR
  ' 3 = LAL LAL CHW               Type: STOR
  ' 4 = BEALES RAIN               Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 57 BOLWARRA COUNTER            V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: IF(('1-27),('2+'3),'2,('2+'3))
  ' 1 = SEASON                    Type: TIME
  ' 2 = BALLAN CHANNEL            Type: FLOW(#  5)
  ' 3 = BOLWARRA COUNTER          Type: -CAP(# 57)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 58 TWO YEAR INFLOWS            V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2+'3+'4
  ' 1 = LL TRIB FLOWS             Type: {103(# 34)
  ' 2 = WMOORBL FLOWS             Type: {103(# 26)
  ' 3 = LL TRIB FLOWS             Type: FLOW(# 34)
  ' 4 = WMOORBL FLOWS             Type: FLOW(# 26)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 59 LL RELEASE TO CHW           V   -99999       0     35099999999       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0     350     350       0       0       0       0       0       0       0       0
  Equation used: IF((1800-'3-'4),99999999,0,0)
  ' 1 = SUM CHW RELEASE           Type: CAPC(# 38)
  ' 2 = SUM CHW RELEASE           Type: -CAP(# 38)
  ' 3 = LAL LAL CHW               Type: STOR
  ' 4 = LAL LAL BARWON            Type: STOR
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 60 LL BARWON RELEASE           V   -99999       0     490   99999       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0     490     490       0       0       0       0       0       0       0       0
  Equation used: IF((1800-'2-'3),(('4+'5)*1.15),0,0)
  ' 1 = BARWON THREE YR REL       Type: CAPC(# 61)
  ' 2 = LAL LAL BARWON            Type: STOR
  ' 3 = LAL LAL CHW               Type: STOR
  ' 4 = SHE OAKS PS               Type: DEMD
  ' 5 = MEREDITH PS               Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 61 BARWON THREE YR REL         V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2+'3
  ' 1 = LL BARWON RELEASE         Type: {103(# 60)
  ' 2 = LL BARWON RELEASE         Type: FLOW(# 60)
  ' 3 = BARWON ONE YR SUM         Type: @104(# 62)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 62 BARWON ONE YR SUM           V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2
  ' 1 = LL BARWON RELEASE         Type: {051(# 60)
  ' 2 = LL BARWON RELEASE         Type: FLOW(# 60)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 64 CHW SPILLS                  V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2+'3-'4-'5-39700
  ' 1 = LAL LAL CHW               Type: STOR
  ' 2 = CHW RAIN                  Type: FLOW(# 55)
  ' 3 = CHW INFLOW                Type: FLOW(# 35)
  ' 4 = EVAP CHW                  Type: FLOW(# 39)
  ' 5 = CHW PASS FLOW             Type: FLOW(# 42)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 65 BARWON SPILLS               V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2+'3-'4-'5-'6-19850
  ' 1 = LAL LAL BARWON            Type: STOR
  ' 2 = BARWON INFLOW             Type: FLOW(# 36)
  ' 3 = BARWON RAIN               Type: FLOW(# 54)
  ' 4 = EVAP BARWON               Type: FLOW(# 40)
  ' 5 = BARWON PASS FLOW          Type: FLOW(# 43)
  ' 6 = LL BARWON RELEASE         Type: FLOW(# 60)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 66 CHW HARVEST SPILLS          V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: 39700-('1+'2+'3-'4-'5)
  ' 1 = LAL LAL CHW               Type: STOR
  ' 2 = CHW INFLOW                Type: FLOW(# 35)
  ' 3 = CHW RAIN                  Type: FLOW(# 55)
  ' 4 = EVAP CHW                  Type: FLOW(# 39)
  ' 5 = CHW PASS FLOW             Type: FLOW(# 42)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 67 BARWON HARVEST SPILL        V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: 19850-('1+'2+'3-'4-'5-'6)
  ' 1 = LAL LAL BARWON            Type: STOR
  ' 2 = BARWON INFLOW             Type: FLOW(# 36)
  ' 3 = BARWON RAIN               Type: FLOW(# 54)
  ' 4 = EVAP BARWON               Type: FLOW(# 40)
  ' 5 = BARWON PASS FLOW          Type: FLOW(# 43)
  ' 6 = LL BARWON RELEASE         Type: FLOW(# 60)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 68 LAL LAL SPILLS              V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2+'3+'4+'7+'8-'9-'10-'13-'14-'15-59550
  ' 1 = LAL LAL CHW               Type: STOR
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 ' 2 = LAL LAL BARWON          Type: STOR
 ' 3 = CHW INFLOW              Type: FLOW(# 35)
 ' 4 = BARWON INFLOW           Type: FLOW(# 36)
 ' 5 = CHW HARVEST SPILLS      Type: FLOW(# 66)
 ' 6 = BARWON HARVEST SPILL    Type: FLOW(# 67)
 ' 7 = CHW RAIN                Type: FLOW(# 55)
 ' 8 = BARWON RAIN             Type: FLOW(# 54)
 ' 9 = EVAP CHW                Type: FLOW(# 39)
 '10 = EVAP BARWON             Type: FLOW(# 40)
 '11 = CHW SPILLS              Type: FLOW(# 64)
 '12 = BARWON SPILLS           Type: FLOW(# 65)
 '13 = CHW PASS FLOW           Type: FLOW(# 42)
 '14 = BARWON PASS FLOW        Type: FLOW(# 43)
 '15 = LL BARWON RELEASE       Type: FLOW(# 60)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 69 SHE OAKS ONE YR REL         V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2
 ' 1 = SHE OAKS PUMPS          Type: {051(# 63)
 ' 2 = SHE OAKS PUMPS          Type: FLOW(# 63)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 70 SUM SHE OAKS DIV            V   -99999       0   99999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0   99999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2+'3
 ' 1 = SHE OAKS PUMPS          Type: {103(# 63)
 ' 2 = SHE OAKS PUMPS          Type: FLOW(# 63)
 ' 3 = SHE OAKS ONE YR REL     Type: @104(# 69)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 76 WEST MBOOL R LOSS           V  -999999       0  999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       0  999999       0       0       0       0       0       0       0       0       0
  Equation used: IF(('1+'2+'3-40),(0.45*('1+'2+'3)),0,0)
 ' 1 = MOORABOOL PASS FLOW     Type: FLOW(# 24)
 ' 2 = MOORABOOL SPILLS        Type: FLOW(# 23)
 ' 3 = WHISKEY CK BELOW DIV    Type: FLOW(# 81)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 77 MBOOL ONSTRM SUMMER         V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,0,0,'2)
 ' 1 = SUMMER TRIGGER          Type: STRM
 ' 2 = MOORBL INFLOW           Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 79 MBOOL ONSTRM BYPASS         V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: (42/50)*'1
 ' 1 = MOORBL INFLOW           Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 84 WILSON ONSTRM SUMM          V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,0,0,'2)
 ' 1 = SUMMER TRIGGER          Type: STRM
 ' 2 = Arc 197                 Type: FLOW(#190)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 92 LL ONSTRM SUMM              V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,'2,0,0)
 ' 1 = SUMMER TRIGGER          Type: STRM
 ' 2 = LL TRIB FLOWS           Type: FLOW(# 34)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 93 LL ONSTRM BYPASS            V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: 0.5*('1+'2)
 ' 1 = Arc 175                 Type: FLOW(#168)
 ' 2 = FIELD+BEALES SPILL      Type: FLOW(#110)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

114 LOSS UPSTREAM 204           V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF(('1+'2-600),(0.15*('1+'2)),0,0)
 ' 1 = LAL LAL TO CONF         Type: FLOW(#112)
 ' 2 = BOSTOCK TO CONF         Type: FLOW(#115)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

117 U/S CAPRONS                 V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,99999999,99999999,0)
 ' 1 = SUMMER TRIGGER          Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

119 U/S MATTHEYS                V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,99999999,99999999,0)
 ' 1 = SUMMER TRIGGER          Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

121 U/S BUCHTERS                V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,99999999,99999999,0)
 ' 1 = SUMMER TRIGGER          Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

123 U/S HILLS                   V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,99999999,99999999,0)
 ' 1 = SUMMER TRIGGER          Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

125 U/S JOAQUINS                V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF('1,99999999,99999999,0)
 ' 1 = SUMMER TRIGGER          Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

155 LOSS U/S BATESFORD          V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: ((('1-'2)/'3)*'4)*'5
 ' 1 = DUMMY DURD EVAP         Type: RC04(#157)
 ' 2 = DUMMY DURD RAIN         Type: RC04(#156)
 ' 3 = 193                     Type: NUMB
 ' 4 = U/S BATESFORD           Type: FLOW(#127)
 ' 5 = LOSS U/S 202 TRIGGER    Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

156 DUMMY DURD RAIN             V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: '1
 ' 1 = DURDIDWARRAH RAIN       Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

157 DUMMY DURD EVAP             V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: '1
 ' 1 = DURDIDWARRAH EVAP       Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

159 TO FARM DAMS BOSTOCK        V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                     C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: MIN('1,'2)
 ' 1 = BOSTOCK INFLOW          Type: STRM
 ' 2 = FARM DAMS U/S BOSTOC    Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2
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161 TO FARM DAMS US 204          V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = FARM DAMS U/S 204         Type: DEMD
  ' 2 = INFLOW UPSTREAM 204       Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

163 TO FARM DAMS 204 TO          V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = FARM DAMS 204 TO SHE      Type: DEMD
  ' 2 = 204 TO SHE OAKS INF       Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

164 TO FARMDAMS U/S MBOO         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN(('1-'2),'3)
  ' 1 = MOORBL INFLOW             Type: STRM
  ' 2 = TO MBOOL GWATER           Type: CAPC(#179)
  ' 3 = FARM DAMS U/S MOORBL      Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

165 TO FARM DAM UNREG TR         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN(('1-'2),'3)
  ' 1 = UNREG TRIBS               Type: STRM
  ' 2 = TO GWATER UNREG TRIB      Type: CAPC(#180)
  ' 3 = FARM DAMS UNREG TRIB      Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

167 TO FARM DAMS WMOORBL         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN(('1-'2),'3)
  ' 1 = WMOORBL INFLOW            Type: STRM
  ' 2 = TO GWATER WMOORBL         Type: CAPC(#181)
  ' 3 = FARM DAMS WMOORBL         Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

169 TO GWATER LL TRIB            V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = GWATER LL TRIB            Type: DEMD
  ' 2 = LL TRIB INFLOW            Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

171 TO FARM DAMS WHISKEY         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN(('1-'2),'3)
  ' 1 = WHISKEY CK U/S PIPE       Type: STRM
  ' 2 = TO GWATER WHISKEY CK      Type: CAPC(#183)
  ' 3 = FARM DAMS WHISKEY CK      Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

173 TO GWATER U/S WILSON         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = GWATER U/S WILSONS        Type: DEMD
  ' 2 = WILSONS RES INFLOW        Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

174 0.5 INF SHE-BATES            V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: 0.5*('1-'2)
  ' 1 = INF SHE-BATES             Type: STRM
  ' 2 = TO FARM DAMS SHE-BAT      Type: CAPC(#176)
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

176 TO FARM DAMS SHE-BAT         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = FARM DAMS SHE-BATES       Type: DEMD
  ' 2 = INF SHE-BATES             Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

178 TO FARM DAMS BEALES          V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN(('1-'2),'3)
  ' 1 = BEALES RES INFLOW         Type: STRM
  ' 2 = TO GWATER U/S BEALES      Type: CAPC(#185)
  ' 3 = FARM DAMS US BEALES       Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

179 TO MBOOL GWATER              V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = GWATER U/S MOORBL         Type: DEMD
  ' 2 = MOORBL INFLOW             Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

180 TO GWATER UNREG TRIB         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = UNREG TRIBS               Type: STRM
  ' 2 = GWATER UNREG TRIBS        Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

181 TO GWATER WMOORBL            V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = GWATER WMOORBL            Type: DEMD
  ' 2 = WMOORBL INFLOW            Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

182 TO FARM DAMS LL TRIB         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN(('1-'2),'3)
  ' 1 = LL TRIB INFLOW            Type: STRM
  ' 2 = TO GWATER LL TRIB         Type: CAPC(#169)
  ' 3 = FARM DAMS LL TRIB         Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

183 TO GWATER WHISKEY CK         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = GWATER WHISKEY CK         Type: DEMD
  ' 2 = WHISKEY CK U/S PIPE       Type: STRM
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

184 TO FARM DAMS U/S WIL         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN(('1-'2),'3)
  ' 1 = WILSONS RES INFLOW        Type: STRM
  ' 2 = TO GWATER U/S WILSON      Type: CAPC(#173)
  ' 3 = FARM DAMS U/S WILSON      Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

185 TO GWATER U/S BEALES         V ********      099999999      0      0      0      0      0      0      0      0      0
   Fn Name:                      C       0       099999999      0      0      0      0      0      0      0      0      0
  Equation used: MIN('1,'2)
  ' 1 = BEALES RES INFLOW         Type: STRM
  ' 2 = GWATER U/S BEALES         Type: DEMD
Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

186 TO GWATER GILES CK           V ********      099999999      0      0      0      0      0      0      0      0      0
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   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: MIN('1,'2)
  ' 1 = GILES CREEK INFLOW        Type: STRM
  ' 2 = GWATER GILES CREEK        Type: DEMD
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 187 TO GWATER CLARKES CK     V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: MIN('1,'2)
  ' 1 = CLARKES CREEK INFLOW      Type: STRM
  ' 2 = GWATER CLARKES CREEK      Type: DEMD
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 189 TO GWATER FELLMONGER     V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: MIN('1,'2)
  ' 1 = FELLMONGERS CK            Type: STRM
  ' 2 = GWATER FELLMONGERS        Type: DEMD
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 191 TO GWATER LEIGH CK       V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: MIN('1,'2)
  ' 1 = LEIGH CREEK INFLOW        Type: STRM
  ' 2 = GWATER LEIGH CREEK        Type: DEMD
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 192 KBOORA PASS FLOW         V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: MIN('1,'2)
  ' 1 = KBOORA PASS RULE          Type: CAPC(#  3)
  ' 2 = KBOORA INFLOW             Type: STRM
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 193 SUM MEREDITH INFLOWS     V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: '1+'2
  ' 1 = 204 TO MEREDITH           Type: FLOW(# 48)
  ' 2 = LOCAL U/S 204             Type: FLOW(#162)
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 194 MEREDITH FLOW DEFN       V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: (0.34*7)+((0.33*7)*'1)
  ' 1 = SUM MEREDITH INFLOWS      Type: CAPC(#193)
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 195 SHEOAKS PASS FLOW        V ********       099999999       0       0       0       0       0       0       0       0       0
   Fn Name:                   C        0       099999999       0       0       0       0       0       0       0       0       0
  Equation used: IF(('1+'2-280),('1+'2),('1+'2),280)
  ' 1 = INFLOW UPSTREAM 204       Type: STRM
  ' 2 = 204 TO SHE OAKS INF       Type: STRM
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 197 SRW RESTRICTION          V ********       0       0      14      15      28      29      42      43      56      5799999999
   Fn Name:                   C        0       0       4       4       3       3       2       2       1       1       0       0
  Equation used: '1
  ' 1 = D/S BATESFORD             Type: FLOW(#128)
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2

 198 WSWAN PROPORTION         V ********       0    5470    5471    6545    6546    8218    821999999999       0       0       0
   Fn Name:                   C        0       0       0       0       0      50      50      80      80       0       0       0
  Equation used: '1+'2+'3+'4+'5+'6
  ' 1 = MOORABOOL                 Type: STOR
  ' 2 = WILSONS RES               Type: STOR
  ' 3 = WHITE SWAN                Type: STOR
  ' 4 = BEALES RES                Type: STOR
  ' 5 = KIRKS RES                 Type: STOR
  ' 6 = GONG GONG RES             Type: STOR
 Capacity set option (0-off 1-prev 2-recalc) Jan=2   Feb=2   Mar=2   Apl=2   May=2   Jun=2   Jul=2   Aug=2   Sep=2   Oct=2   Nov=2   Dec=2


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|  TARGET INFORMATION         |
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 Number of target sets:  1

------------------------------------------------------------------------------------------------------------------------
 Target set 1 ( Jan Feb Mar Apl May Jun Jul Aug Sep Oct Nov Dec)
 Name                    Draw Pri                                    Targets
------------------------------------------------------------------------------------------------------------------------
KORWEINGUBOORA           1         0         0         0         0      2091
BOSTOCK                  2         0      3727      7455      7455      7455
STONY CREEK              3         0      9324      9324      9324      9324
MOORABOOL                3         0       200       200       200      6738
LAL LAL BARWON           4         0     19850     19850     19850     59550
LAL LAL CHW              7         0     14325     14325     14325     59550
WILSONS RES              1         0         0         0         0      1010
WHITE SWAN               6         0      3527      7054     10580     14107
SHE OAKS WEIR            5         0       150       150       150       150
BOLWARRA WEIR            6         0       122       122       122       122
ONSTRM DAMS U/S MOOR    11         0       162       162       162       162
BEALES RES               2         0         0         0         0       415
ONSTREAM U/S WILSONS    13         0        27        27        27        27
LAL LAL ONSTRM          14         0       925       925       925       925
KIRKS RES                4         0       400       400       400       400
GONG GONG RES            5         0      1902      1902      1902      1902
SPILLERS WEIR           17         0        25        25        25        25
CAPRONS WEIR            18         0        37        37        37        37
MATTHEYS WEIR           19         0        36        36        36        36
MADDENS WEIR            20         0        14        14        14        14
BUCHTERS WEIR           21         0        23        23        23        23
HILLS WEIR              22         0        21        21        21        21
MITCHELLS WEIR          23         0        16        16        16        16
JOAQUINS WEIR           24         0        40        40        40        40

 totals                            0     54853     62108     65634    164140



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|  RESTRICTION INFORMATION    |
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 Number of restriction groups:  3

 NB. Each restriction group is treated separately
     with its own rule curve definitions;
     for irrigation demand groups by its allocations functions.

----------------------------------------------------------------------
Restriction Group:  1     Type: Urban/industrial demand centers
----------------------------------------------------------------------

      Reservoirs/                Demands
     arcs in Group              in Group
      ----------                --------
     MOORABOOL                BALLARAT
     LAL LAL CHW              BALLARAT FROM LL
     WILSONS RES              BALLAN
     WHITE SWAN
     BEALES RES
     KIRKS RES
     GONG GONG RES
```

Restriction Level	Relative Position	% of Restrictable Demand Restricted	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			Storage as % of Average Annual Demand											
0	0.0	0.0	-29008.00	-27585.00	-26396.00	-25331.00	-24436.00	-24085.00	-24302.00	-25428.00	-27459.00	-29200.00	-30259.00	-30097.00
1	33.0	50.0	-23964.94	-23011.53	-22214.90	-21501.35	-20901.70	-20666.53	-20811.92	-21566.34	-22927.11	-24093.58	-24803.11	-24694.57
2	67.0	80.0	-18769.06	-18299.47	-17907.10	-17555.65	-17260.30	-17144.47	-17216.08	-17587.66	-18257.89	-18832.42	-19181.89	-19128.43
3	100.0	95.0	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00	-13726.00
Base levels (% AAD)			-208.00	-208.00	-208.00	-208.00	-208.00	-208.00	-208.00	-208.00	-208.00	-208.00	-208.00	-208.00

NB. Negative values will be interpreted as absolute values

Restriction Group: 2 Type: Urban/industrial demand centers

Reservoirs/ arcs in Group	Demands in Group
KORWEINGUBOORA	GLONG FROM STONY
BOSTOCK	MEREDITH PS
STONY CREEK	SHE OAKS PS
LAL LAL BARWON	

Restriction Level	Relative Position	% of Restrictable Demand Restricted	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			Storage as % of Average Annual Demand											
0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Base levels (% AAD)			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB. Negative values will be interpreted as absolute values

Restriction Group: 3 Type: Urban/industrial demand centers

Reservoirs/ arcs in Group	Demands in Group
SRW RESTRICTION	IRR BTWN MBOOL & LAL
	DIRECT SHE-SPILLERS
	DIRECT SPILLERS WEIR
	DIRECT SPILL-CAPRON
	DIRECT CAPRON-MATT
	DIRECT CAPRONS WEIR
	DIRECT MATTHEYS WEIR
	DIRECT HILLS WEIR
	DIRECT MITCHELLS W
	DIRECT MITCH-JOAQ
	DIRECT JOAQUINS WEIR
	DIRECT JOAQ-BATESFRD
	DIRECT D/S BATESFORD
	IND MATTHEYS WEIR

Restriction Level	Relative Position	% of Restrictable Demand Restricted	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			Storage as % of Average Annual Demand											
0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	33.0	25.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	67.0	50.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	100.0	75.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Base levels (% AAD)			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB. Negative values will be interpreted as absolute values

| MULTI SYSTEM INFORMATION |

Reservoirs

KORWEINGUBOORA	1
BOSTOCK	1
STONY CREEK	1
MOORABOOL	2
LAL LAL BARWON	3
LAL LAL CHW	2
WILSONS RES	2
WHITE SWAN	2
SHE OAKS WEIR	3
BOLWARRA WEIR	1
ONSTRM DAMS U/S	4
BEALES RES	2
ONSTREAM U/S WI	4
LAL LAL ONSTRM	4
KIRKS RES	2
GONG GONG RES	2
SPILLERS WEIR	4
CAPRONS WEIR	4
MATTHEYS WEIR	4
MADDENS WEIR	4
BUCHTERS WEIR	4
HILLS WEIR	4
MITCHELLS WEIR	4
JOAQUINS WEIR	4

Appendix G Cost Estimate Qualifications

The following qualifications are provided to clarify the pipeline and other asset creation cost estimates.

1) The objective was to prepare order of cost estimates based on a preliminary concepts and estimating rates for use in the comparison of options only. These estimates are not intended for capital investment or financial planning and should not be used the basis for any financial or legal commitments by any authority.
2) Before any options are adopted as "preferred" it is recommended that more detailed investigations be completed to provide more certainty to assumptions and cost estimates for those options..
3) No site investigations were undertaken to assess construction conditions, physical obstructions or environmental constraints that could cause significant relocation of assets and cost variations.
4) Pipeline alignments and long sections were scaled distances from 1:25,000 or 1:100,000 Vicmap plans.
5) Cost estimating rates were based on typical rates for construction of buried pipelines in open going, at normal depth without significant quantities of rock or dewatering of groundwater. Refer unit rates in table below. These are typically 20% higher than minimum rates that may be used if site conditions were known to be straightforward. This is not really a contingency but a realistic allowance for variation in assumed conditions.

Pipe Diameter (mm)	Cost ($/m)
150	72
200	77
225	96
250	108
300	132
375	185
450	223
525	315
600	360
750	450
900	540
1100	660

6) All inclusive rates were used without consideration of pipe fittings, structures, special crossings of water courses, services etc. More detailed estimates would be prepared to account for these if the project progresses.
7) The estimates allowed for simple electrical control systems only suited for regular inspection by operators. No provision was made for SCADA, remote monitoring and control or telemetry.
8) The cost estimates are based on the items shown in the schedules prepared and do not allow for other works.
9) Nominal allowances were made for provision of power supply from the existing network. The power supply companies were not consulted at this stage.
10) The rates do not include for fees and costs associated with the obtaining of planning, environmental and other approvals.
11) There is no provision for land purchase or acquisition of easements.
12) There is no provision for communications community consultation.
13) The estimates, and apportionment of costs within the estimate, assume implementation by detailed design, tender and construction by contractors under AS 2124 or equivalent. This assumes that design and construct (D&C), design build operate (DBO), build own operate and transfer (BOOT) implementation do not save significant costs but do offer alternative risk profiles and project finance options that may be more suitable.
14) The cost estimates allow for project management, project development and construction supervision costs at 25% of “contract” costs, comprising:

Component	Provision as %age of “Contract” Cost
Project Management/ Stakeholder consultation	2%
Functional Design	1%
Survey and geotechnical	1%
Concept Design	2%
Environmental and Planning Assessments	1%
Detailed Design	6%
Tender Process	1%
Contract Supervision	2%
Site Supervision	4%
Total “On-cost”	20%

15) The 25% contingency sum is applied to all project cost elements as a provision for unforeseen circumstances.

Appendix H Environmental Impact Assessment

H.1 Method

A flow series was generated for the expected flows under each option within the Moorabool catchment. This modelled data set was based on actual flow data collected between 1965 and 2002 inclusive. The flow series was derived using rules based on the environmental flow recommendations presented in Section 10. Where daily natural flow was less than the recommended daily flow the "or natural" rule was applied and the natural flow used. This flow series has been called "Env flow recs" in that flow series and will be referred to as Environmental Water Requirements (EWRs) for the calculations and comparison of options.

For the comparison of options within the Moorabool catchment an eight-step process was undertaken in order to rank the options with respect to their environmental impact. These steps are as follows:

1) The percentage of time that each option met the Environmental Water Requirements was calculated for each flow component within each reach (eg. Table 16.9 to Table 16.12);
2) These values were then multiplied by a weighting based on the relative ecological importance of each flow component to the system (eg. Table 16.13 to Table 16.16);
3) All scores were adjusted to take into account whether the flows occurring under the various options deliver too little or too much water. Option values were subtracted from the Environmental Water Requirements if too much water was delivered compared to the Environmental Water Requirements. While the Environmental Water Requirements was subtracted from the option value if too little water was delivered. This resulted in the difference between the Environmental Water Requirements and the options being determined relative to zero, the closer to zero, the closer the option was to meeting the Environmental Water Requirements (eg. Table 16.17 to Table 16.20);
4) These scores were summed to produce a single overall score for each reach (eg. Table 16.17 to Table 16.20);
5) All flow component scores were then adjusted so that 100 represented the Environmental Water Requirements and all options were relative to this (ie. the closer to 100 the closer the option was to meeting the Environmental Water Requirements) (eg. Table 16.17 to Table 16.20);
6) The adjusted scores for each reach were then multiplied by a weighting relative to the importance of environmental flows at these locations within the system (Table 16.21);
7) These scores were then added to produce a single overall score for each option (eg. Table 16.21).

8) This overall score was adjusted so that Environmental Water Requirements was equal to 1 and all options were relative to this. This was done to enable the option values to conform to the criteria used for the assessment of options in the MCA process. The options were then ranked in order of most desirable to least desirable with respect to environmental benefits (Table 16.22).

Assumptions of the model include:

- Bostock summer cease to flow/freshes are not spread according to the environmental flow recommendations (ie. no 30 day cease to flow period). The recommendation for the cease to flow is a maximum of 2 annually and for freshes it is a minimum of 2 annually. In the model the cease to flow and freshes have been run as exactly 2 which does not allow for a maximum cease to flow of 30 days.
- Bostock winter high flow has been entered in the model as 64 ML/day instead of the environmental flow recommendations of 641 ML/day.
- A range has been used to calculate the compliance with the EWRs for summer and winter low flows and winter freshes. This was done by taking a range from the low flow (summer or winter) value to the fresh (summer or winter) value, and taking a range from the winter fresh value to the winter flood value.

- **Table 16.7 Weighting given to flow components.**

Flow component	Weighting (%)	Rationale
Summer low flow	30	Critical as it underpins the survival of aquatic organisms
Winter low flow	30	Critical as it underpins the survival of aquatic organisms
Winter fresh	20	Required for breeding, migration and recruitment of aquatic organisms
Summer fresh	10	Important stress alleviator
Summer cease to flow	5	Can have disbenefits so need to be careful where/when implemented
Winter high flow	5	Habitat factor but less affected from management of structures

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Table 16.8 Weighting given to reaches.

Reach	Weighting (%)	Rationale
Reach 1 – Bostock	25	Areas of good habitat but spatially separated
Reach 2 – Lal Lal	15	Significantly degraded (often factors other than flow impacting)
Reach 3 – She Oaks	30	High environmental values
Reach 4 – Batesford	30	High environmental values

In addition to the flows assessment, any negative impacts within catchment but non flow related, were included in the overall scoring. Any negative impact was given a score of 0.001 and this value was subtracted from the final overall score for each option. A relatively low score was chosen for these impacts as all the impacts are considered to be relatively minor.

Outside of catchment impacts were assessed qualitatively based on the limited descriptive information that was available at the time and were included in the ranking method above.

H.2 Worked calculations

Table 16.9 to Table 16.12 present the percentage time when the flow matches the environmental flow recommendation or the natural flow for each flow component within each reach. Highlights are where Option 27 is worse than all other options and Option 2a is better than all other options.

Table 16.9 Reach 1 Bostock – percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	13.6%	na	0.1%	0.3%	0.1%	0.1%	0.1%	0.0%	0.3%	0.4%
summer fresh	49.2%	5.4%	9.3%	10.0%	9.3%	9.3%	9.3%	9.5%	10.0%	8.5%
summer cease	37.2%	94.6%	90.6%	89.7%	90.6%	90.6%	90.6%	90.5%	89.7%	91.1%
winter low	5.2%	53.5%	28.4%	26.3%	28.4%	28.4%	28.4%	27.7%	26.3%	28.3%
winter fresh	6.7%	8.4%	11.1%	11.4%	11.1%	11.2%	11.1%	11.3%	11.4%	10.8%
winter flood	22.7%	0.0%	0.224	24.2%	22.4%	22.3%	22.4%	22.9%	24.2%	22.9%

Table 16.10 Reach 2 Lal Lal – percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	11.0%	57.3%	47.6%	48.2%	48.2%	47.5%	47.6%	45.0%	47.5%	47.6%
summer fresh	14.0%	12.0%	19.9%	20.2%	20.2%	20.0%	19.9%	23.9%	20.1%	19.9%
summer cease	25.7%	7.7%	4.8%	4.0%	3.9%	4.5%	4.7%	3.3%	4.1%	4.8%
winter low	6.9%	56.3%	26.2%	26.5%	26.4%	26.2%	26.3%	26.3%	25.9%	26.3%
winter fresh	32.5%	18.3%	38.8%	39.4%	39.4%	38.7%	38.8%	38.6%	39.3%	38.9%
winter flood	10.7%	1.6%	10.1%	10.1%	10.2%	10.2%	10.0%	10.2%	10.1%	9.9%

Table 16.11 Reach 3 She Oaks – percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	7.2%	54.7%	29.3%	33.0%	30.4%	29.5%	29.9%	29.5%	31.2%	33.6%
summer fresh	13.7%	16.8%	30.1%	29.1%	30.7%	29.9%	29.5%	39.7%	27.9%	26.3%
summer cease	4.1%	7.7%	0.2%	0.1%	0.1%	0.2%	0.2%	0.0%	0.1%	0.1%
winter low	3.4%	61.3%	31.6%	31.1%	32.1%	31.7%	31.4%	33.5%	27.2%	30.7%
winter fresh	18.3%	7.5%	24.2%	25.3%	24.2%	24.2%	24.4%	24.4%	25.9%	24.6%
winter flood	4.8%	1.1%	3.3%	3.5%	3.3%	3.3%	3.3%	3.5%	3.7%	3.3%

Table 16.12 Reach 4 Batesford – percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	3.64%	57.29%	16.60%	16.30%	17.00%	16.40%	16.50%	21.76%	16.09%	15.89%
summer fresh	9.21%	16.90%	12.85%	13.26%	13.06%	13.06%	13.46%	16.30%	12.85%	12.75%
summer cease	9.41%	na	1.62%	1.42%	1.42%	1.62%	1.62%	1.32%	1.42%	1.42%
winter low	2.23%	50.20%	21.05%	22.17%	21.66%	21.15%	21.56%	21.96%	18.52%	21.76%
winter fresh	20.75%	19.64%	32.49%	32.89%	32.59%	32.69%	32.89%	34.01%	33.40%	31.98%
winter flood	7.09%	1.21%	6.48%	6.48%	6.48%	6.48%	6.48%	6.58%	6.28%	6.58%

Table 16.13 to Table 16.16 present the percentage time when the flow matches the environmental flow recommendation or the natural flow for each flow component within each reach multiplied by a weighting for each flow component. A sum of all flow components for each option is also given.

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▪ Table 16.13 Reach 1 Bostock – weighted percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Weighting (%)	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	30	4.0688	0.0000	0.0304	0.0911	0.0304	0.0304	0.0304	0.0000	0.0911	0.1215
summer fresh	10	4.9190	0.5364	0.9312	1.0020	0.9312	0.9312	0.9312	0.9514	1.0020	0.8502
summer cease	5	1.8623	4.7318	4.5294	4.4838	4.5294	4.5294	4.5294	4.5243	4.4838	4.5547
winter low	30	1.5486	16.0628	8.5324	7.8947	8.5324	8.5324	8.5324	8.3198	7.8947	8.5020
winter fresh	20	1.3360	1.6802	2.2267	2.2874	2.2267	2.2470	2.2267	2.2672	2.2874	2.1660
winter flood	5	1.1336	0.0000	1.1184	1.2095	1.1184	1.1134	1.1184	1.1437	1.2095	1.1437
	sum	**14.8684**	**23.0111**	**17.3684**	**16.9686**	**17.3684**	**17.3836**	**17.3684**	**17.2065**	**16.9686**	**17.3381**

▪ Table 16.14 Reach 2 Lal Lal – weighted percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Weighting (%)	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	30	3.3097	17.1862	14.2713	14.4534	14.4534	14.2409	14.2713	13.5121	14.2409	14.2713
summer fresh	10	1.3968	1.2045	1.9939	2.0243	2.0243	2.0040	1.9939	2.3887	2.0142	1.9939
summer cease	5	1.2854	0.3846	0.2379	0.2024	0.1974	0.2227	0.2328	0.1670	0.2075	0.2379
winter low	30	2.0648	16.8826	7.8644	7.9555	7.9251	7.8644	7.8947	7.8947	7.7733	7.8947
winter fresh	20	6.4980	3.6640	7.7530	7.8745	7.8745	7.7328	7.7530	7.7126	7.8543	7.7733
winter flood	5	0.5364	0.0810	0.5061	0.5061	0.5111	0.5111	0.5010	0.5111	0.5061	0.4960
	sum	**15.0911**	**39.4028**	**32.6265**	**33.0162**	**32.9858**	**32.5759**	**32.6468**	**32.1862**	**32.5962**	**32.6670**

▪ Table 16.15 Reach 3 She Oaks – weighted percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Weighting (%)	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	30	2.1559	16.3968	8.7753	9.8988	9.1093	8.8360	8.9575	8.8360	9.3522	10.0810
summer fresh	10	1.3664	1.6802	3.0061	2.9150	3.0668	2.9858	2.9453	3.9676	2.7935	2.6316
summer cease	5	0.2075	0.3846	0.0101	0.0051	0.0051	0.0101	0.0101	0.0000	0.0051	0.0051
winter low	30	1.0324	18.4008	9.4737	9.3219	9.6255	9.5040	9.4130	10.0506	8.1680	9.2004
winter fresh	20	3.6640	1.4980	4.8381	5.0607	4.8381	4.8381	4.8785	4.8785	5.1822	4.9190
winter flood	5	0.2379	0.0557	0.1670	0.1771	0.1670	0.1670	0.1670	0.1771	0.1872	0.1670
	sum	**8.6640**	**38.4160**	**26.2702**	**27.3785**	**26.8117**	**26.3411**	**26.3715**	**27.9099**	**25.6883**	**27.0040**

Table 16.16 Reach 4 Batesford – weighted percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Weighting (%)	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	30	1.0931	17.1862	4.9798	4.8887	5.1012	4.9190	4.9494	6.5283	4.8279	4.7672
summer fresh	10	0.9211	1.6903	1.2854	1.3259	1.3057	1.3057	1.3462	1.6296	1.2854	1.2753
summer cease	5	0.4706	0.0000	0.0810	0.0709	0.0709	0.0810	0.0810	0.0658	0.0709	0.0709
winter low	30	0.6680	15.0607	6.3158	6.6498	6.4980	6.3462	6.4676	6.5891	5.5567	6.5283
winter fresh	20	4.1498	3.9271	6.4980	6.5789	6.5182	6.5385	6.5789	6.8016	6.6802	6.3968
winter flood	5	0.3543	0.0607	0.3239	0.3239	0.3239	0.3239	0.3239	0.3289	0.3138	0.3289
	sum	**7.6569**	**37.9251**	**19.4838**	**19.8381**	**19.8178**	**19.5142**	**19.7470**	**21.9433**	**18.7348**	**19.3674**

Table 16.17 to Table 16.20 present the adjusted scores for each flow component. These values represent the closeness of each option to the Environmental Water Requirements and takes into consideration whether an option is wetter or drier than the Environmental Water Requirements.

Table 16.17 Reach 1 Bostock – standardised weighted percentage time when flow matches the environmental flow recommendations or natural.

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	-16.0931	0.0000	-12.2065	-12.2976	-12.0850	-12.2672	-12.2368	-10.6579	-12.3583	-12.4190
summer fresh	-0.7692	0.0000	-0.4049	-0.3644	-0.3846	-0.3846	-0.3441	-0.0607	-0.4049	-0.4150
summer cease	0.4706	0.0000	0.0810	0.0709	0.0709	0.0810	0.0810	0.0658	0.0709	0.0709
winter low	-14.3927	0.0000	-8.7449	-8.4109	-8.5628	-8.7146	-8.5931	-8.4717	-9.5040	-8.5324
winter fresh	-0.2227	0.0000	-2.5709	-2.6518	-2.5911	-2.6113	-2.6518	-2.8745	-2.7530	-2.4696
winter flood	0.2935	0.0000	0.2632	0.2632	0.2632	0.2632	0.2632	0.2682	0.2530	0.2682
Sum	**-30.7136**	**0.0000**	**-23.5830**	**-23.3907**	**-23.2895**	**-23.6336**	**-23.4818**	**-21.7308**	**-24.6964**	**-23.4970**
Proportion (standardised to 100)	**69.2864**	**100.0000**	**76.4170**	**76.6093**	**76.7105**	**76.3664**	**76.5182**	**78.2692**	**75.3036**	**76.5030**

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■ **Table 16.18 Reach 2 Lal Lal – standardised weighted percentage time when flow matches the environmental flow recommendations or natural.**

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	4.0688	0.0000	0.0304	0.0911	0.0304	0.0304	0.0304	0.0000	0.0911	0.1215
summer fresh	-4.3826	0.0000	-0.3947	-0.4656	-0.3947	-0.3947	-0.3947	-0.4150	-0.4656	-0.3138
summer cease	-2.8694	0.0000	-0.2024	-0.2480	-0.2024	-0.2024	-0.2024	-0.2075	-0.2480	-0.1771
winter low	-14.5142	0.0000	-7.5304	-8.1680	-7.5304	-7.5304	-7.5304	-7.7429	-8.1680	-7.5607
winter fresh	0.3441	0.0000	-0.5466	-0.6073	-0.5466	-0.5668	-0.5466	-0.5870	-0.6073	-0.4858
winter flood	-1.1336	0.0000	-1.1184	-1.2095	-1.1184	-1.1134	-1.1184	-1.1437	-1.2095	-1.1437
Sum	**-18.4868**	**0.0000**	**-9.7621**	**-10.6073**	**-9.7621**	**-9.7773**	**-9.7621**	**-10.0962**	**-10.6073**	**-9.5597**
Proportion (standardised to 100)	**81.5132**	**100.0000**	**90.2379**	**89.3927**	**90.2379**	**90.2227**	**90.2379**	**89.9038**	**89.3927**	**90.4403**

■ **Table 16.19 Reach 3 She Oaks – standardised weighted percentage time when flow matches the environmental flow recommendations or natural.**

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	-14.2409	0.0000	-7.6215	-6.4980	-7.2874	-7.5607	-7.4393	-7.5607	-7.0445	-6.3158
summer fresh	0.3138	0.0000	-1.3259	-1.2348	-1.3866	-1.3057	-1.2652	-2.2874	-1.1134	-0.9514
summer cease	-0.1771	0.0000	-0.3745	-0.3796	-0.3796	-0.3745	-0.3745	-0.3846	-0.3796	-0.3796
winter low	-17.3684	0.0000	-8.9271	-9.0789	-8.7753	-8.8968	-8.9879	-8.3502	-10.2328	-9.2004
winter fresh	-2.1660	0.0000	-3.3401	-3.5628	-3.3401	-3.3401	-3.3806	-3.3806	-3.6842	-3.4211
winter flood	-0.1822	0.0000	-0.1113	-0.1215	-0.1113	-0.1113	-0.1113	-0.1215	-0.1316	-0.1113
Sum	**-33.8209**	**0.0000**	**-21.7004**	**-20.8755**	**-21.2804**	**-21.5891**	**-21.5587**	**-22.0850**	**-22.5860**	**-20.3796**
Proportion (standardised to 100)	**66.1791**	**100.0000**	**78.2996**	**79.1245**	**78.7196**	**78.4109**	**78.4413**	**77.9150**	**77.4140**	**79.6204**

▪ **Table 16.20 Reach 4 Batesford – standardised weighted percentage time when flow matches the environmental flow recommendations or natural.**

Flow component	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
summer low	-13.8765	0.0000	-2.9150	-2.7328	-2.7328	-2.9453	-2.9150	-3.6741	-2.9453	-2.9150
summer fresh	-0.1923	0.0000	-0.7895	-0.8198	-0.8198	-0.7996	-0.7895	-1.1842	-0.8097	-0.7895
summer cease	-0.9008	0.0000	-0.1468	-0.1822	-0.1872	-0.1619	-0.1518	-0.2176	-0.1771	-0.1468
winter low	-14.8178	0.0000	-9.0182	-8.9271	-8.9575	-9.0182	-8.9879	-8.9879	-9.1093	-8.9879
winter fresh	-2.8340	0.0000	-4.0891	-4.2105	-4.2105	-4.0688	-4.0891	-4.0486	-4.1903	-4.1093
winter flood	-0.4555	0.0000	-0.4251	-0.4251	-0.4302	-0.4302	-0.4200	-0.4302	-0.4251	-0.4150
Sum	**-33.0769**	**0.0000**	**-17.3836**	**-17.2976**	**-17.3381**	**-17.4241**	**-17.3532**	**-18.5425**	**-17.6569**	**-17.3634**
Proportion (standardised to 100)	**66.9231**	**100.0000**	**82.6164**	**82.7024**	**82.6619**	**82.5759**	**82.6468**	**81.4575**	**82.3431**	**82.6366**

Table 16.21 presents the total flow component value for each reach multiplied by a reach weighting. The results for each reach have been summed to provide an overall score for each option.

▪ **Table 16.21 Totalled flow components weighted for each reach.**

Reach	Weighting (%)	Base case	EWR	Ideal Case	op25	op3a	op8a	op20	op23	op27	op2a
Reach 1 Bostock	30	2078.593	3000	2292.51	2298.279	2301.316	2290.992	2295.547	2348.077	2259.109	2295.091
Reach 2 Lal Lal	25	2037.829	2500	2255.946	2234.818	2255.946	2255.567	2255.946	2247.596	2234.818	2261.007
Reach 3 She Oaks	30	1985.374	3000	2348.988	2373.735	2361.589	2352.328	2353.239	2337.449	2322.419	2388.613
Reach 4 Batesford	15	1003.846	1500	1239.246	1240.536	1239.929	1238.639	1239.701	1221.862	1235.147	1239.55
sum	**100**	**7105.6**	**10000**	**8136.7**	**8147.4**	**8158.8**	**8137.5**	**8144.4**	**8155**	**8051.5**	**8184.3**

Table 16.22 presents the options ranked in order of their score.

Table 16.22 Option values (* these options include within catchment impacts separate from the flow assessment).

Option no.	Reach score	Proportion (standardised to 1)	In catchment impacts included
Base case	7105.643	0.711	0.711
op27	8051.493	0.805	0.805
op20	8144.433	0.814	0.812*
Ideal Case	8136.69	0.814	0.814
op8a	8137.525	0.814	0.814
op25	8147.368	0.815	0.815
op23	8154.985	0.815	0.815
op3a	8158.78	0.816	0.816
op2a	8184.261	0.818	0.816*
EWR	10000	1.000	1.000

H.3 Assessment

A summary of the comparison of the options is provided in Table 16.23. Note that option 3 and 26 are considered the same with respect to the within catchment flow assessment and that there was no flow assessment undertaken for Option 28. A comparison of within catchment rankings between options shows that there is very little difference between the scores generated for each option (excluding the base case and the Environmental Water Requirements). Although there is very little difference between options, Option 23 is ranked the most favourable in terms of being the closest to matching the Environmental Water Requirements generated. Option 27 is considered the least favourable. Outside catchment impacts have generally been assessed as minimal given the current extent of our knowledge. The greatest outside catchment impact is likely to be associated with Option 20 as a result of the reduction in flow in Leigh River, which in turn may result in habitat loss and water quality issues.

Table 16.23 Summary of option impacts within and outside catchment and option ranking.

Option no.	Within catchment		Outside catchment	
	Impact	Ranking	Impact	Ranking
Base case (current)	• Currently the base case does not meet flow recommendations. • Water quality guidelines often not met (particularly salinity, nutrients). • Undesirable species favoured (eg. Cumbungi, trout, redfin).	0.711	• No impact	0.9
Option 1 (ideal case)	• This option is better than the base case but does not meet the flow recommendations.	0.814	• No impact	0.9

Option no.	Within catchment Impact	Ranking	Outside catchment Impact	Ranking
Option 25	• This option is better than the base case but does not meet the flow recommendations.	0.815	• Some reduction in local runoff (with use of rainwater tanks) • Reduced flows in waterways where wastewater is currently discharged (where wastewater reuse is adopted)	0.8
Option 27	• This option is better than the base case but does not meet the flow recommendations. Of all the options this is the least desirable as a result of winter low flows in Reaches 2, 3 and 4, and winter freshes and floods in Reach 3 having lower % time matching the EWRs.	0.805	• No impact	0.9
Option 2a	• This option is better than the base case but does not meet the flow recommendations. Of all the options this is the most desirable from a flows perspective as a result of summer freshes, summer cease to flow and winter freshes in Reach 1, winter floods in Reach 2, summer low flow and summer freshes in Reach3 and winter freshes in Reach 4 having higher % time matching the EWRs. There are potential within catchment impacts associated with pipeline construction and translocation of water.	0.816*	• Slight reduction in flows in the Werribee River • Potential habitat/vegetation/soil disturbance with construction of a pipeline • Potential issues associated with translocation of water into the upper Moorabool catchment	0.8
Option 3a	• This option is better than the base case but does not meet the flow recommendations.	0.816	• Potential for impact on groundwater dependant ecosystems	0.8
Option 8	• This option is better than the base case but does not meet the flow recommendations.	0.814	• No impact	0.9
Option 20	• This option is better than the base case but does not meet the flow recommendations. There are potential within catchment impacts associated with pipeline construction and nutrients from wastewater treatment water released.	0.812*	• Large reduction in flows in Leigh River	0.5
Option 23	• This option is better than the base case but does not meet the flow recommendations.	0.815	• No impact	0.9
Option 26	• This option is better than the base case but does not meet the flow	0.816	• Reduced flows in waterways where wastewater is currently discharged (where wastewater	0.7

Option no.	Within catchment		Outside catchment	
	Impact	Ranking	Impact	Ranking
	recommendations.		and greywater reuse is adopted)	
Option 28	• No flow assessment undertaken however considered to be only slightly better than the base case.	0.740	• No impact	0.9

* these options have within catchment impacts in addition to the flows assessment score.

Appendix I Ballarat Water Supply Options for Groundwater Supplement

I.1 Introduction

Ballarat's water supply is principally sourced from surface water harvested across the northern sectors of the Barwon and Moorabool River Drainage Basins. All of the main storages are located to the east of Ballarat with the water transferred to the City, and to the townships further west, by a pipeline network. The storage capacity of the system is generally sufficient to ensure continuity of supply to Central Highlands Water's customers. Rainfall however has been at a historic low for the past four years and surface water resources are reducing in yield and reliability. Water in storage has been reaching critical, minimum levels and adversely affected environmental flows in the Moorabool River.

As a consequence Central Highlands Water initiated investigations into possible alternative, emergency water supplies. One such option was groundwater. For groundwater to become a viable option the quantity of water required is a minimum of 15ML/day delivered to a central storage, or slightly lesser volumes if delivered direct to discrete supply areas.

In 2002 Sinclair Knight Merz was engaged by Central Highlands Water to undertake a desktop study of the potential for accessing suitable groundwater resources in the region to supplement Ballarat's water supply. As part of the assessment of options to enhance environmental flows in the Moorabool River the results of this study are summarised herein.

The assessment provides comment on the following:

- Viability of the source
- Groundwater quality
- Groundwater quantity
- Infrastructure cost to supply to Ballarat

I.2 Water Supply Development Options Discussion

Evaluation of the geological and hydrogeological data from within the study zone has highlighted a number of aquifer systems and specific areas from which significant volumes of groundwater may be sourced and transferred into the CHW supply network.

Principally three main supply options have emerged, namely:

1) extraction of groundwater to the north and east of Ballarat in the vicinity of the surface storages
2) utilisation of groundwater extracted from the mines in Ballarat currently discharged to waste
3) extraction of groundwater to the west of Ballarat

I.2.1 Extraction from Vicinity of the Storages

The groundwater resources contained in principally the volcanics aquifer and to a lesser extent the deep lead systems to the east, northeast and northwest of Ballarat have been shown to contain the lowest salinity groundwaters in the region. They are of high beneficial use with much of the resource falling within Beneficial Use Category A1 (Potable – desirable). These waters would be regarded on quality alone as the optimum source to be added to the water supply system. Most of Central Highlands Water storages also lie in close proximity to these low salinity waters to the east of Ballarat.

The areas of low salinity waters contained in the volcanics and Deep Lead systems however almost entirely fall into the three Groundwater Management Areas (GMAs) of Bungaree, Springhill and Ascot. These GMAs are considered to be fully allocated or over committed whereby the current licensed allocations exceed the Permissible Annual Volume (PAV) for the resource. The PAV is considered as essentially the sustainable yield of the resource. No new allocations are being licensed in these GMA's.

Transferable water entitlements are considered by Southern Rural Water (SRW) in the Bungaree GMA but would be limited (Jo Donovan, SRW pers comm.). Individual groundwater licences are generally small in allocation in the Bungaree GMA and the bore yields are typically less than 1ML/day. To achieve the desired daily flow for the CHW system would necessitate the construction of some 15-20 bores in this area and the purchase of many licences. To reach the required allocation from this GMA would be considered extremely difficult and unlikely to occur as most of the farmers in this region have indicated to SRW that they would be unwilling to enter into a TWE agreement. The allocations committed from this region are fully utilised for potato production and any release of groundwater from this area for non agricultural use would be considered politically sensitive. The political backlash against CHW from the farming community would be extremely high.

Likewise the resources contained in the Springhill and Ascot GMA's are fully committed and heavily utilised for agricultural purposes. Goulburn Murray Water (GMA), the managers of the groundwater resources in these regions, are at present not allowing TWE and as such the likelihood of obtaining sufficient volume in the short term from these areas is considered extremely low. Again if water became available in these regions the political ramifications for CHW would be considered high from the farming community. These GMA's are also at a distance from most of the storages and transfer systems.

Two of Ballarats main storages do however fall outside the GMA boundaries to the east of Ballarat. A review of the geological and hydrogeological setting around both White Swan and Lal Lal Reservoirs has shown the potential for high volume extraction of low salinity groundwater to be low.

White Swan lies just to the west of the Bungaree GMA. It is predominantly constructed on the Palaeozoic basement rocks that have been shown previously to be low yielding and contain poor quality groundwater. On its eastern boundary however a thin sequence of volcanics are present. Government drilling during gold exploration programs early last century showed that the volcanics are approximately 30m in thickness and contain groundwater of salinity in the range of 500-1,000mg/L TDS. The saturated thickness of the volcanics is only small and the likelihood of high bore yields is considered low. It may be possible to construct 2-3 bores in this area to obtain a proportion of the demand requirement. This water could then be directly spilled to the reservoir. The volcanics are in direct connection with those within the Bungaree GMA and obtaining an extraction licence from SRW may be difficult if not impossible.

Lal Lal Reservoir to the south east lies in a complex geological setting. On its southern and western boundaries the Palaeozoic basement rocks, both sediments and granites, appear at surface. To the north and east thin basalts overlie Early Tertiary age Werribee Formation sediments. The volcanics are essentially unsaturated in this area whilst the Werribee Formation contains fine grained, low permeability clays and brown coal that are not conducive for large volume production. The salinity of the groundwater in all formations surrounding the reservoir is also high, typically exceeding 2-3,000mg/L TDS.

Groundwater potential in the vicinity of Lal Lal reservoir is very poor and not worthy of further consideration.

I.2.2 Extraction from Ballarat Mines

The extracted groundwater from the mine of Ballarat Goldfields is of poor quality. It is relatively brackish to saline of some 2,500mg/L TDS and contains elevated levels of iron, manganese and arsenic. Significant treatment or dilution with 'fresh' surface waters would have to occur before this water could be committed to the CHW supply system. Due to the elevated levels of specific parameters, namely arsenic, a stringent chemical testing program would be required to ensure that the final mix delivered to the consumers conforms to the drinking water guidelines. If this water is to be considered as a supply to maintain parklands and playing fields only, the water would still require significant treatment to fulfil these purposes due to its elevated salinity.

The volume discharged from the mines at present averages some 4-5ML/week up to 20ML/week when disposal conditions are suitable. These volumes are not high enough to fulfil the total demand requirements but they may be sufficient to supply discrete supply areas within the network. The supply of this water must be regarded as a short term option only as all mines have a finite lifespan and closure must be expected over time. To entertain this option would require further development options to be brought online by CHW in the future.

Overall due to the relatively small volumes available from this source and the poor quality of the waters this supply option is ranked lowly.

I.2.3 Groundwater Extraction from a Wellfield Located to the West of Ballarat

The Newer Volcanics and Deep Lead aquifer systems to the west of Ballarat have been generally regarded as containing marginal quality groundwater with salinities typically greater than 1,000mg/L TDS. Bore yields recorded to date in this region have been low to moderate with most bores drilled only into the upper flows of the volcanics as 'first' water bores.

Competition for the resource is not as fierce in this area as compared to the zones to the east and north of Ballarat with the majority of the water extracted for stock and/or domestic use. Due to the general paucity of the soils minimal cropping takes place in this region and the area is dominated by dry land farming and small acerage hobby farms. The total allocation extracted from the deep lead systems is also minimal due to low requirement for irrigation purposes and the difficulty in locating these buried deposits. The pathways of the ancient drainage lines have only been loosely defined with only minimal gold exploration drilling and underground mining taking place in this region.

Recent investigations by Government Departments of Victoria, namely the Geological Survey and the Rural Water Corporation in the late 1980's and early 1990's, have shown that the potential to extract large volumes of low salinity groundwater from both the Newer Volcanics and the Deep Leads is high in a broad area stretching from Cardigan through to Ercildoun. Pumping tests conducted on fully constructed bores in the volcanics have shown that yields of 4ML/day are capable from individual bores. Airlift tests conducted on narrow diameter observation wells screened in the Deep Leads have produced yields of up to 1ML/day. The Deep Lead sediments have been shown to contain up to 50-60m of sand and gravel in some bores. Fully constructed, larger diameter wells would undoubtedly have the potential to produce yields in the range of 2-4ML/day similar to those extracted from the Ascot-Clunes Deep Lead to the north of Ballarat.

The recent investigations have also redefined the course of the upper reaches of the Madam Hopkins Deep Lead. Previously thought to run to the north east of Mount Ercildoun and Mount Misery the lead is now postulated to run to the southeast of these mounts through Ercildoun before swinging northwards towards Bung Bong. There are presently no bores constructed along this stretch of the Deep Lead, length of greater than 20km.

The groundwater salinity in both the volcanics and the deep lead sediments in this zone has been shown to be of good quality with the salinity ranging between 500-1,000mg/L TDS. Although not as low as that recorded in the areas to the east and north of Ballarat these resources however are regarded as potable class waters conforming to Beneficial Use Class A2 (Potable-acceptable). The resources in this region are not heavily utilised. This region is not covered by a GMA and groundwater licences and allocations are not restricted or limited.

Like the aquifer systems in the GMA 's surrounding Ballarat the deep leads and the volcanics would be considered to be in direct hydraulic connection. Recharge to the aquifers is principally via direct infiltration of rainfall. To calculate an approximate sustainable yield (PAV) for the identified zone we can assign a percentage of rainfall as recharge into a surface area. If we assume the zone of good quality groundwater exists over a $20km^2$ area and a 2 percent recharge rate of the annual rainfall of some 600mm occurs then the PAV for this region is in the order of 2,800ML. This recharge rate was adopted for the general basaltic plains regions in the neighbouring GMA's. Limited licensed allocation has been committed in this area to date meaning that over 2,000-2,500ML, as a minimum, would be available on an annual basis. Extracting at the desired rate for the Ballarat system of 15ML/day would mean that at least 150 days full supply would be available. If however the recharge rate is considered conservative a small increase in recharge rate, or an increase in the area of good quality water will significantly increase the available volume from this zone.

Taking into account general licensing conditions, such as the guidelines for interference effects on neighbouring users, a wellfield could be constructed in this region at relatively small cost. Bores drilled and constructed in the volcanics would cost in the order of $30K each whilst those in the Deep Leads, if required to spread the load on the system, some $60-70K. A four bore wellfield constructed in the volcanics and equipped with pumps is estimate to cost in the order of $250K. Additional costs such as purchase or lease of land and ancillary infrastructure such as sheds, compound fencing and onsite treatment facilities (if required) would need to added.

The groundwater salinity in the identified zone of 500-1,000mg/L TDS is higher than that currently delivered to CHW's consumers. If deemed unacceptable to directly input this water into the supply system the groundwater would need to be 'shandied' with lower salinity surface water. The nearest storage to the Cardigan of any size White Swan Reservoir, located almost 20km to the east. To deliver the water to the reservoir would require the construction of a transfer system including pipelines and pumping stations. Cost estimates have been produced for this transfer system after adopting a broad scale route from Cardigan via the Western Highway, the Ring Road, Invermay Road and Swan Road to the reservoir. The costings produced take into account the topography, pipe sizes and pumping stages necessary. A broad cost estimate of $12M has been determined for the transfer system for both a single stage and dual pumping scenario with annual pumping costs ranging between $250-$300K.

I.3 Summary

I.3.1 Extraction from Storages

The lowest salinity water closest to the quality provided currently by CHW lies to the east and north of Ballarat near the existing storages. These resources are however fully to over committed, and the likelihood of obtaining sufficient allocation from these regions is extremely low. Politically it is considered that CHW would face strong opposition from the agricultural community in these regions if large volumes of water were to be directed out of these zones for non-agricultural use. This view has been supported by SRW, the managers of the resource in this area. The bore yields in this region are also relatively which would require the construction of a complex, multiple bore wellfield and delivery system.

I.3.2 Extraction from Ballarat Mines

Utilisation of the water extracted at the mine sites in Ballarat is ranked lowly due to the poor quality of the water, the low flows available and the finite lifespan of the option. Further consideration may be given to use this water in the short term for discrete purposes but it is likely that significant treatment of the water would be required.

I.3.3 Extraction from Cardigan area (west of Ballarat)

The groundwater resource to the west of Ballarat is not heavily utilised and competition for the resource is not fierce at present or, anticipated if CHW entertained this option. A minimum of 2,000-2,500ML/annum is estimated to be available in the Cardigan region from the Newer Volcanics/Deep Lead aquifer system. Individual bore yields are high and only 4-5 bores would be required to extract the total daily demand of 15ML/day predicted in emergency periods. The salinity of the groundwater is low, ranging between 500-1,000mg/L TDS falling into Beneficial Use Category A2 (Potable-acceptable). This range may be deemed to high for direct input into the supply system and as such would require shandying with lower salinity surface waters. If this is the case a transfer system would need to be constructed from the Cardigan area to White Swan Reservoir, the nearest major storage some 20km to the east. The cost for the delivery system is high calculated in the order of $12M.

Although the Cardigan option is expensive this option is ranked the highest of the three groundwater options considered on the basis of resource availability and water quality.

The viability of these three options is summarised in the table below.

I.4 Recommendations

Based upon the available information from the study zone and following the evaluation of the potential supply options it is recommended that the construction of a wellfield and transfer system from the Cardigan area be adopted as the principal groundwater supply option for Ballarat in an emergency supply situation.

Before any further testing and investigations be conducted with respect to the Cardigan option it is however recommended that CHW undertake an economic evaluation of the Cardigan option against alternate water supply sources.

If the Cardigan option is economically attractive site availability for the installation of production bores would need to be firstly considered. This task would entail the location of all existing bores in the area and the liaison with private landholders and public authorities with a view to purchase or lease the required land for the permanent installations and site access.

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- **Summary of Viability of Groundwater Options**

Supply Source	Viability	Quantity	Quality	Cost
1.Vicinity of the Storages	POOR Over allocated, over committed resource, requires many licences to be traded under TWE. May be impossible to succeed. Politically sensitive, significant opposition from agricultural community if diverted for non-agricultural use	Low bore yields, require 15-20 bores for 15ML/day	Low salinity, below 500mg/L TDS	Low bore yields, require complex, multi-bore wellfield delivery system Close to storages, low transfer cost
2. From the Mines	POOR Could supply discrete users in short term only	Not sufficient volume to fulfil entire demand on system Finite lifetime of mines limits resource availability	High salinity, over 2,500mg/L TDS limits usage Elevated levels of specific parameters would require treatment	
3. Cardigan Wellfield	GOOD Small competition for resource, Good quantity and quality Expensive to deliver	Minimum 2,000 to 2,500 ML/annum High bore yields, 4-5 bores only required to provide total demand	Good quality water, 500-1,000mg/L Water quality may require dilution before input into system	Distance to nearest storage 20km, requires expensive transfer system in vicinity of $12M