Tarra River Environmental FLOWS Assessment

FLOW RECOMMENDATIONS

- Final
- 20 October 2006

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Executive summary

This report provides the recommended environmental flow recommendations for the Tarra River and is the third and final output for the project. The report assesses the environmental flow requirements for the Tarra River using the FLOWs method (DNRE 2002a) and does not include the social and economic requirements. These will be assessed during the development of a Stream Flow Management Plan (SFMP) at a later date.

The flow recommendations have been provided for each of the reaches based on one site in each reach and outputs from hydraulic modelling, cross section surveys and the Environmental Flows Technical Panel (EFTP) workshop. The recommendations for each flow component have been assessed against the environmental objectives developed for each reach and are aimed at protecting or improving the current flow regime.

Overall, the flow recommendations have good compliance with the current flow regime, however compliance for volume for summer and winter low flows and winter low flows at sites below Yarram are less than the sites above Yarram. The lower compliance at Macks Creek for summer and winter freshes compared to the other tributaries may be due to farm dams, although the modelling found the natural and current flow regimes were the same. The flow recommendations and compliance are summarised in Table E-1.

A number of supporting, non-flow related recommendations have also been proved. These recommendations relate to common problems that are generally catchment wide and include management of willows, stock access to the streams, barriers to fish movement, maintaining suitable freshwater inflows to the estuary and additional groundwater monitoring. The West Gippsland CMA is already addressing a number of these issues.

- **Table E-1 Summary of reach flow recommendations and compliance for Tarra River environmental flow determination.**

Component	Months	Flow Rec	Reach 1	Reach 2	Reach 3	Reach 4a	Reach 4b	Reach 6	Reach 7
			Tarra River	Macks Ck	Greigs Ck	Spring Ck	Bodman Ck	Tarra River	Tarra River
Summer low	Dec - May	Volume	7	3	2.5	0.3	0.4	13	13
Summer fresh	Dec - May	Volume	26	10	4	1	2	54	53
		Frequency	3	4	4	4	3	3	3
		Duration	3	3	5	4	4	6	6
Summer high	Dec - May	Volume	26					150	150
		Frequency	1					1	1
		Duration	12					4	4
Winter low	Jun - Nov	Volume	17	6	5	1	1	32	32
Winter fresh	Jun - Nov	Volume	48	30	20	3	10	143	143
		Frequency	3	2	4	3	3	3	3
		Duration	5	4	4	5	4	5	5
Winter High	Jun - Nov	Volume	200	150	250	50	100	450	
		Frequency	1	1	1	1	1	1	
		Duration	2	2	2	2	2	4	
Winter High 2	Jun-Nov	Volume						1100	
		Frequency						1	
		Duration						2	
Bankfull	Jun - Nov	Volume	1000			500		5000	450
		Frequency	0.2			0.1		0.3	1
		Duration	2			1		2	4
Overbank		Volume				501			1100
		Frequency				1			1
		Duration				1			2

LEGEND							
Mostly complies		Greater than	95	%			of time / years / events
Frequently complies		Between	76	&	95	%	of time / years / events
Often complies		Between	51	&	75	%	of time / years / events
Occassionally complies		Between	26	&	50	%	of time / years / events
Rarely complies		Between	5	&	25	%	of time / years / events
Never complies		Between	0	&	5	%	of time / years / events

SINCLAIR KNIGHT MERZ

1. Introduction

This report is the third and final output for the determination of environmental flow requirements for the Tarra River in Gippsland. This report provides the flow recommendations for each of the reaches investigated during the project. Previous reports – the Site Paper and Issues Paper provided the supporting information required to develop the environmental flow recommendations and should be read in conjunction with this report.

The purpose of this study is to determine environmental flow requirements for the Tarra River and its tributaries including, Bodman Creek, Greig Creek and Macks Creek using the FLOWS method (DNRE 2002a). The FLOWS method involves the collection of information through desktop studies, field assessments, and consultation. The FLOWs method only assesses the environmental requirements of the Tarra River. The social and economic needs, the management of water resources including the security of supply for urban water consumption and irrigators, are not considered as part of this study but will be considered during the development of the Stream Flow Management Plan (SFMP) or similar process.

1.1 Structure of report

The Flow Recommendations report provides details on the methods used for carrying out the HECRAS (Version 3.1.3) modelling, the generation of cross section profiles for each reach and the process followed in the Environmental Flows Technical Panel (EFTP) workshop to determine each flow component for each reach (Section 2). The flow recommendations are described in detail in Section 3. Supporting cross sections are provided as well as the current flow regime's compliance with the flow recommendations (Section 3). Supporting recommendations are provided in Section 4. The agreed environmental objectives and spells duration and frequency plots for each reach are provided in the Appendices A and B.

2. Methods

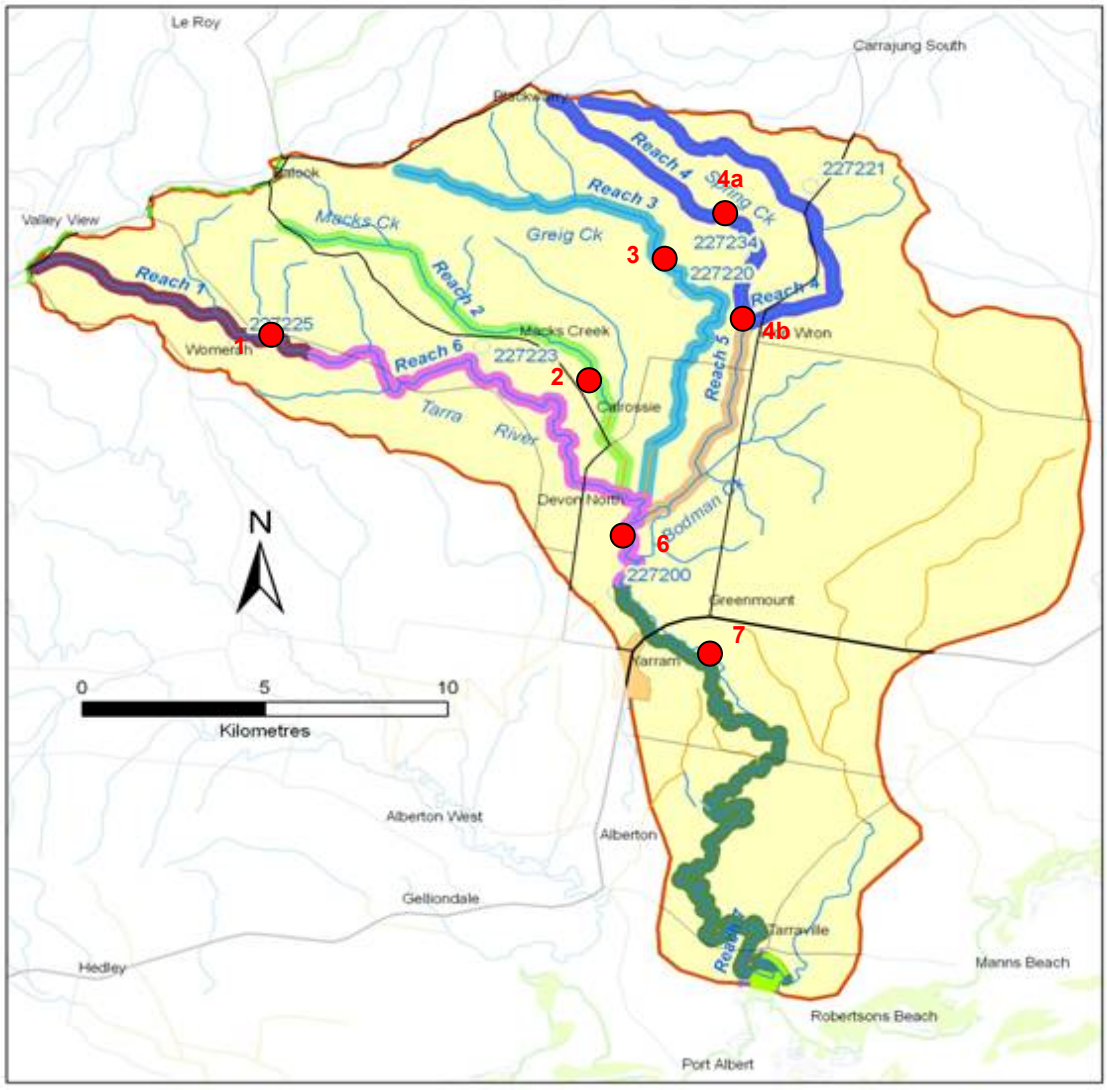
The environmental flows recommendations for the Tarra River have been determined using the FLOWs method (DNRE 2002) which has been described in early reports for this project (SKM 2006a; SKM 2006b). The FLOWs method comprises a number of steps and outcomes including site selection and field assessments, cross section surveys and hydraulic modelling. The data derived during these tasks have been used to generate the flow recommendations for each reach.

2.1 Site selection and field assessments

The Tarra River was divided into seven reaches with one site on each reach selected for detailed field assessment by the Environmental Flows Technical Panel (EFTP) and cross section surveys (Figure 2-1). Reach 5, Bodman Creek from its confluence with Spring Creek to the confluence with the Tarra River, exhibits limited natural attributes as the creek has been channelled in many parts. A number of drains intersect the creek at this site and the river has been known to disappear (Charles Puccio, *pers comm.*) for a number of kilometres upstream of its confluence with the Tarra River. Modelling flows through this reach has been problematic and showed that this section of Bodman Creek contributes little in the way of flow compared to the section of the creek upstream of its confluence with Spring Creek. As a result, during the field assessment the EFTP (in consultation with West Gippsland CMA (WGCMA) determined that there would be no value in having environmental flows determined for this reach. The sites assessed are shown in Table 2-1. Detailed descriptions of each site are provided in SKM (2006a and 2006b).

Table 2-1 Tarra River reaches and field assessment sites.

Reach		Site location
1	Tarra River upstream of the South Gippsland Water offtake	Tarra River at the Picnic Ground on Tarra Valley Road
2	Macks Creek	Macks Creek at the 'Poplars' on McKenzie Road
3	Greig Creek	Greig Creek above the gauge on Greig Creek Road
4a	Spring Creek to the confluence with Bodman Creek	Spring Creek at Beaumont on Spring Creek Road
4b	Bodman Creek to the confluence with Spring Creek	Bodman Creek at Bridge on Hyland Way
5	Bodman Creek from the confluence with Spring Creek to the confluence with the Tarra River	No site selected
6	Tarra River from the South Gippsland Water Offtake to Yarram (South Gippsland Highway)	Tarra River above gauge at Yarram
7	Tarra River from Yarram (South Gippsland Highway) to the estuary	Tarra River at 'Greenmount' on Missens Lane



■ **Figure 2-1: Map of reaches and sites for the Tarra River.**

2.2 Environmental flow objectives

Environmental flow objectives set the direction and target for the environmental water recommendations and are clear statements of what outcomes should be achieved in providing environmental flows. The process of setting environmental objectives involves first identifying the environmental assets, setting environmental objectives against these, and identifying the flow required to meet the environmental objectives. Environmental objectives are developed for those ecological assets that have a clear dependence on some aspect of the flow regime, including:

- Individual species and communities;
- Habitats; and
- Ecological (physical and biological) processes.

Following the FLOWS method the direction of a particular objective is expressed as one of three main targets:

1) maintain – keep the condition of the resource in its current state;
2) rehabilitate – move the condition of the resource to some improved state other than natural (usually less than natural); and
3) restore – move the condition of the resource back to natural conditions.

The *maintain* objective is applicable where the current condition indicates a species, community or process is in a sustainable condition and not subject to current or future threats.

The *rehabilitate* objective is applicable where there has been a decline in the condition of a threatened species or community, or where there are active threatening processes that require management intervention to prevent further degradation. A rehabilitate objective specifies the end point of the rehabilitation, either ecologically healthy, or an improvement over current conditions.

The *restore* objective is applicable where there is scope to improve the condition of a particular species or community to a level that would have occurred without the current levels of impact. The restore objective is not often applied in environmental flows studies because the development within the affected catchment is often too great to support a return to natural or pre-development conditions. However, the restore objective has been used for native fish communities in the Tarra River at the Yarram gauge and at Missens Lane with the aim of restoring diversity and for the geomorphology objective for the Tarra River at the Yarram gauge and at Spring and Bodman Creeks with the aim of restoring instream habitat condition.

The environmental flow objectives for the Tarra River have been endorsed by the Steering Committee and Advisory Committee and are provided in Appendices A.

2.3 Hydraulic modelling

To assist the development of environmental flow recommendations for the selected reaches, the effect of different streamflows on the instream and riparian environment needed to be assessed. A hydraulic model of a typical stretch of the waterway was developed and used to determine the relationship between flow, water depth and velocity. This information was then used to determine the effect of different flow rates on waterway features, such as sandbars, riffles and bank vegetation.

The hydraulic model required the following information:

- The geometry of the stream - surveyed cross sections at regular intervals along each reach;
- Flow data - likely flows in the reach; and
- Boundary conditions - Generally, HECRAS requires a reference point or boundary condition at the downstream end of the model in order to back calculate the change in flow depth upstream. In this case, however, both up and downstream boundary conditions were required because a mixed flow assumption was used. Mixed flow is where subciritical or deep, slow flow and supercritical or shallow, fast flow is evident. The up and downstream reference points or boundary conditions may be a rating table or a water level. In this case, however, normal depth was used. Normal depth is the depth at which steady uniform flow occurs. It is calculated by HECRAS using Manning's equation which requires a user-defined energy slope.

In addition, the following information is required to calibrate the model:

- Surveyed water levels at each cross section (these are used for the up and downstream boundary conditions in calibration); and
- The flow on the day of survey.

Most of the data was available from the field survey and previous modelling (SKM, 2006c). However, there was limited data available to derive the downstream boundary condition for flows other than the calibration flow. The downstream boundary condition was calculated based a number of assumptions (see Section 2.7).

2.4 Cross section surveys

Cross section surveys were undertaken between the 18th and 24th July 2006. The number of cross sections surveyed at each site varied from between 4 and 7 depending on the reach. At the same time a longitudinal section, other salient details of the site and water level were surveyed. The water levels, together with estimates of streamflow on the day from nearby streamflow gauges were used to calibrate each model.

2.5 Deriving flow data

In the past there have been many gauges in operation within the Tarra River catchment, however only three of these are still in operation today:

- Gauge #227251 Tarra River at the South Gippsland Water offtake;
- Gauge #227225 Tarra River at Fischers; and
- Gauge #227200 Tarra River at Yarram.

Gauge #227251 was the only gauge that was telemetered therefore data was able to be collected from this site for the majority of the survey period (from the 18th to the 21st). Data for the 24th was extrapolated from this data. The other two sites required manual data collection and because of processing delays, data was not available from these sites for the dates of survey.

Relationships derived in the Tarra River REALM model (SKM 2006c) were used to transpose recorded flows at #227251 to other sites within the catchment. Table 2-2 lists the gauges which were used for each site. Inflows or losses could be expected between the gauge and site however these were assumed to be minimal and were not accounted for in the analysis.

- **Table 2-2 Tarra River reaches and stream gauges used for each site.**

Site no.	Site location	Flow information used
1	Tarra River at the Picnic Ground on Tarra Valley Road	Gauge #227251(2 km upstream of the site)
2	Macks Creek at the 'Poplars' on McKenzie Road	Gauge #227223 (4.5 km upstream of the site)
3	Greig Creek above the gauge on Greig Creek Road	Gauge #227220 (400 m downstream of the site)
4a	Spring Creek at Beaumont on Spring Creek Road	Gauge #227234 (900 m downstream of site)
4b	Bodman Creek at Bridge on Hyland Way	Gauge #227221 (4.5 km upstream of the site)
5	No site selected	REALM
6	Tarra River above gauge at Yarram	Gauge #227200 (300 m downstream of the site)
7	Tarra River at 'Greenmount' on Missens Lane	Gauge #227200 (5-10 km upstream of the site)

2.6 Calibration

Cross section data and surveyed reach lengths were entered into the hydraulic model HECRAS (Version 3.1.3). As mentioned in Section 2.3, Manning's equation is used by HECRAS to calculate normal depth at the boundary. Manning's equation requires an estimate of Manning's n which is a

measure of roughness. Roughness information was estimated using a combination of site observation and information in the HECRAS manual which relates Manning's n to stream appearance (based on type, vegetation, rocks present etc.). Boundary conditions were adopted based on the surveyed water levels at the upstream and downstream ends of the model.

Cross section locations were chosen by the EFTP which were based on features which may have ecological significance. In some cases, this meant that features which controlled the hydraulic behaviour of the waterway were not surveyed in cross sections. In these cases, cross sectional information was estimated during the calibration process based on site observation, and surveyed longitudinal section levels.

In general, the calibration of each model involved adding hydraulic features to the waterway, and adjusting those features so that the modelled water surface profile matched the surveyed water levels at each cross section. Hydraulic features added to each model included:

- Ineffective areas (representing vegetation, pebbled areas, submerged snags, or parts of the cross section which did not contribute to the downstream flow);
- Obstructions (representing rock weirs / riffles, large fallen trees, sandbars); and
- Levees (to prevent flow being computed for secondary flow paths which only operate in high flow conditions).

Where additional cross sections were required to accurately represent these features, the cross sections were developed based on similar nearby sections, modified as required based on site observation and site photos. Also, longitudinal section data was used to estimate the level and location of features such as riffles and deep pools.

The accuracy of the calibration process relied on the precision of surveyed water levels. In general, water levels were recorded at each bank. Typically, the recorded levels at opposite banks differed by around 30 mm. However in some cases, the levels differed by up to 180 mm, and were occasionally inconsistent with levels in nearby sections (e.g. water level significantly lower than the next section downstream). The most likely reason for this difference is survey error although it is possible that the difference may be due to localised hydraulic conditions in the waterway.

In general, the average recorded water level was adopted however, where water levels between cross sections appeared inconsistent, it was assumed that the highest water level at a cross section was most likely correct (this is because the survey staff often sinks into a muddy bank by as much as 25-30 mm).

2.7 Using the models to develop environmental flow recommendations

Once the models were calibrated, they were used to simulate water levels for a range of different flows. The downstream boundary assumption used in the simulation was normal depth. The slope adopted for the normal depth calculation varied in most cases as, due to the nature of the sites selected it was appropriate to adopt a different slope for low compared to high flows. In general, most of the sites have a flat water surface at the downstream end under the low calibration flow. This suggests that there is a feature downstream which may be controlling water level at low flows. Therefore, at low flows a flat slope was assumed for the normal depth calculation. At high flows it is likely that this feature will be drowned out, therefore it is assumed that the water surface profile will become steeper, approaching the topographic slope for the area.

In the plots used to assess the environmental flow recommendations for each reach, water surface profiles were presented for flows from 1 ML/d to a maximum recorded level at that site. During the EFTP workshop, the models were also run to simulate water level under the following flows:

- The 20th, 50th, 80th percentile flow for all flows, summer and winter flows;
- The mean flow;
- The maximum summer flow;
- Recommended environmental flows, being:
- Site 1: 3 ML/d under the Bulk Entitlement (BE) and 0.5 ML/d under the BE with high restrictions in place;
- Site 2: 2.5 ML/d (Lieschke and Zampatti, 2001);
- Site 3: 2.5 ML/d for River Blackfish (*Gadopsis marmoratu*s) (Lieschke and Zampatti, 2001); and
- Site 6: 10 ML/d for River Blackfish (Lieschke and Zampatti, 2001).

Sites 4a, 4b and 7 have had no previous environmental flow recommendations.

Hydraulic output

A key output from the hydraulic model is a graphical representation of each transect. An example of a hydraulic output is provided in Table2-2. These outputs are from HECRAS which uses default nomenclature in the legend. The table below explains the symbols used in the figures.

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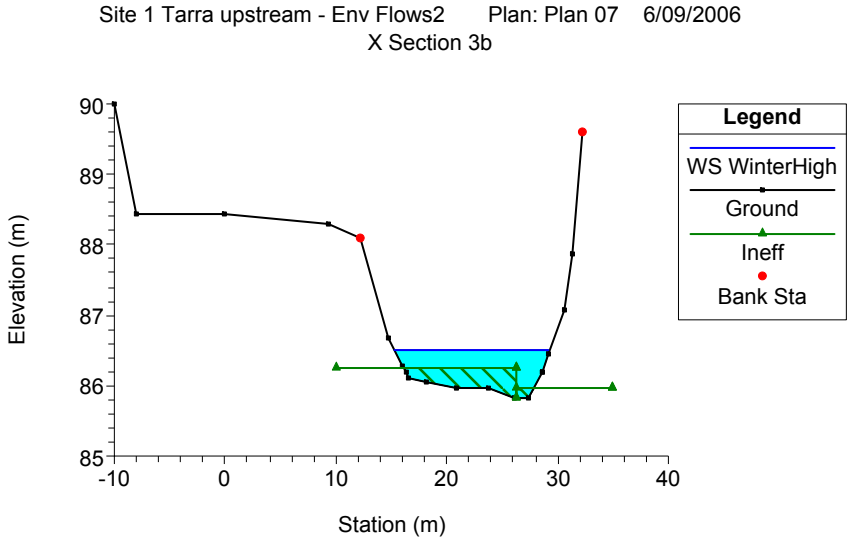
- **Table 2-3 Description of symbols used in outputs from the hydraulic model.**

HECRAS symbol	Description in legend	Further description
	Ground	Black line represents the ground surface. Black squares represent surveyed points (note that these are more frequent in the channel than further out).
	Bank Sta	Bank Station (Bank Sta). Indicative of the channel boundary.
	WS WinterHigh	Blue line is the water surface (WS) under the specified flow. Blue shaded area is the inundated cross sectional area under the specified flow.
	Ineff	Ineffective (Ineff) flow area. Represents area where through flow does not occur. This is most likely due to vegetation but may also occur at the bottom of a deep pool.
	N/A	Obstruction. Represents an object which blocks flow,, for example a rock or build up of mud and debris.

The outputs from the model include the flows (ultimately expressed in ML/d) required to cover the steam bed to a certain depth, or inundate channel features such as benches.



- **Table2-2 Example transect output from the hydraulic model in Reach 1, Tarra River at picnic ground.**

2.8 Hydrology

The hydrological assessment of each reach was provided in SKM (2006b). The assessment involved consideration of a range of hydrological parameters to describe the flow regime, including:

- flow duration curves which show the percentage of time that a flow of a given rate is exceeded;
- time series graphs to examine the sequence of flow events, particularly during very dry or very wet conditions; and
- flow spell analysis to describe the frequency, duration and start month of flow spells (flow events above or below a flow magnitude that serves a specific function).

Spells analysis output

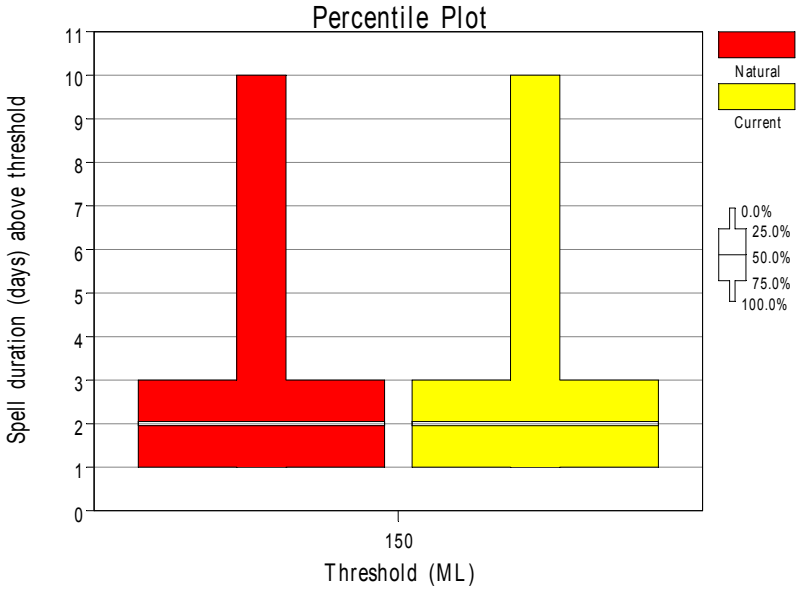
Spells analyses were used to describe and compare the duration, start months and frequency of flow events (spells) that rise above or fall below a stipulated flow threshold under current and natural conditions. These analyses were carried out using modelled daily flow data for either high flow (winter/spring) or low flow (summer/autumn) periods but not the entire year combined. The analysis assumes that flow events were independent of each other if separated by more than seven days.

An example of the spells analysis output is provided in Figure 2-2 using a threshold value of 150 ML/d. The **percentile plot** summarises the duration of flow spells over 150 ML/d. In the plot the median spell duration (50^{th} percentile) is indicated with variation in spell durations described by the box and whiskers plots. Thirty percent of flow spells have a duration that lies within the box (25^{th} and 75^{th} percentiles) while 70 percent of the spells are described by the whiskers (spells within the 10^{th} and 90^{th} percentiles). In the example provided for spells higher than 150 ML/d that occurred during winter/spring under current conditions:

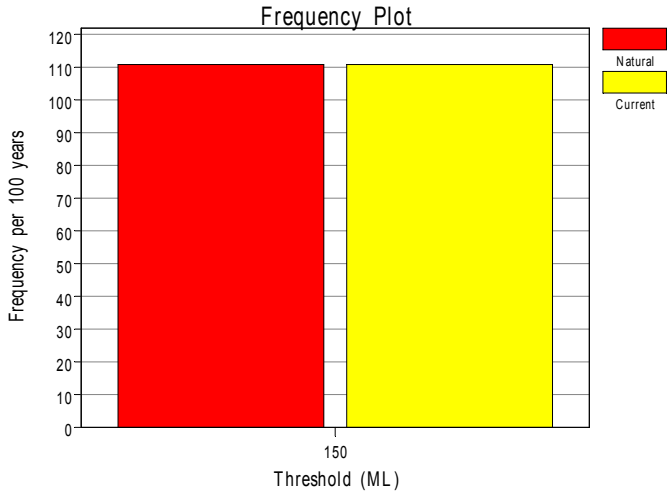
- the median duration of spells above the threshold is 2 days;
- 50% of spells above the threshold lasted between 2 and 3 days; and
- 25% of spells above the threshold lasted between 2 and 10 days.

The upper box and whisker plot have a greater spread than the lower box and whisker. This indicates that the data is skewed, that is to say that spells of a long duration occur relatively less frequently than shorter spells.

The **frequency plot** shows the frequency of spells determined by the median (50^{th} percentile) number of times that spells over 150 ML/d occur in the modelled flow data (Figure 2-3). Flows of this size occur approximately once a year. Spells duration and frequency plots for each recommended flow for each reach are provided in Appendix B.



- **Figure 2-2 Duration of spells 150 ML/d or greater under current and natural conditions for Reach 2 in winter/spring.**



- **Figure 2-3 Frequency of spells 150 ML/d or greater under current and natural conditions for Reach 2 in winter/spring.**

2.9 Development of flow recommendations

Environmental flow recommendations for the Tarra River were determined by the EFTP at a workshop on 1st September 2006. The workshop included representatives from the Department of Sustainability and Environment and the WGCMA.

Prior to the workshop the hydraulic model was set up to include BE restrictions, mean flows, maximum and minimum flows, 20th, 50th and 80th percentile flows and environmental flows recommended by Lieschke and Zampatti (2001) for each of the study reaches.

Each reach was considered in turn and the current ecological condition and flow objectives reviewed along with field notes and photos and HECRAS profiles of each cross section. A number of criteria were also used to ensure minimum ecological requirements were met (Table 2-4). Key environmental features (i.e. benches, riffles) in each reach were examined and the model used to ascertain the impact of a number of flow scenarios along each reach. The flow was then identified that would meet the environmental objective. Summer low flows, summer freshes, winter low flows, winter freshes, winter high flows and bankfull and overbank flows were considered for each reach. Spells analyses were undertaken to determine the appropriate frequency and duration of the recommended flow.

- **Table 2-4 Criteria used for the assessment of flow recommendations for each flow component.**

Flow component	Physical description	Criteria for determining recommendation
Low flow	Minimum flow that provides a continuous flow throughout the channel (maintains permanent pools with an adequate depth of water to provide habitat for aquatic biota)	The EFTP used a depth of 0.1 m at the shallowest cross section for macroinvertebrates and a depth of 0.4 m depth in the shallowest pool for native fish species (i.e. River Blackfish) (Khan *et al*. 2004)
Freshes	Small and short duration peak flow events that exceed baseflow	The EFTP used the inundation of in-channel low flow benches and availability of fish passage in the shallowest cross-section as morphological features. The inundation of benches entrains organic material. The EFTP used an average velocity of 0.4 m/s to scour biofilms (Biggs *et al.*, 1999).
High flows	Persistent increases in the seasonal baseflow that remain within the channel	The EFTP used an increase in habitat area (compared to freshes) and the inundation of in-channel benches and high flow channels as morphological features.
Bankfull flow	Flow that completely fills the channel	Morphologically defined, with some interpretation required as transects may differ in capacity.

2.10 Ramp rates

The rate of rise and fall of the flow regime is referred to as a ramp rate. Ramp rates are environmentally significant for short duration spells such as freshes and bankfull flows as rapid rises and falls in flow can cause stress to aquatic flora and fauna and may lead to bank failure and increased erosion. As the Tarra River is an unregulated stream, the rates of rise and fall should mirror the natural rise and fall of the river.

Ramp rates were calculated from daily modelled natural data for each reach. The differences between flows on individual days were divided into days when flows rose and days when flows fell. The ratio of the change in flow was calculated for each rise or fall. The maximum desirable rate of rise was selected as the 90th percentile value of all recorded rates of rise (representing a fairly high rate that was recorded naturally) and the maximum desirable rate of fall was selected as the 10th percentile value of all recorded rates of fall.

The ramp rate recommendations are provided as a percentage of the previous days' flow. For example a recommended rate of rise of 345% stipulates that flow on a given day should not exceed 345% of the previous day's flow (Table 2-5).

Note: An 'or as naturally occurs' proviso has been added to some flow recommendations to allow for the natural variability in the flow regime. The addition of the proviso to a recommendation means that flows should be allowed to occur at their natural volume, frequency and duration.

- **Table 2-5 Recommended maximum rates of rise and fall (expressed as a percentage of the previous days' flow) for the study reaches.**

Reach		Rate of rise	Rate of fall
1	Tarra River at the Picnic Ground on Tarra Valley Road	201	80
2	Macks Creek at the 'Poplars' on McKenzie Road	244	72
3	Greig Creek above the gauge on Greig Creek Road	265	71
4a	Spring Creek at Beaumont on Spring Creek Road	345	61
4b	Bodman Creek at Bridge on Hyland Way	345	61
5	No site selected	432	51
6	Tarra River above gauge at Yarram	241	71
7	Tarra River at 'Greenmount' on Missens Lane	253	68

3. Environmental flow recommendations

This section outlines the environmental flow recommendations for each reach. A standard format is provided for each reach and includes:

- Summary of the **current condition**. A brief summary of the geomorphology, macroinvertebrates, fish and vegetation condition taken from information presented in the *Issues Paper*;
- **Flow recommendations**. A rationale of the various flow recommendations chosen for each reach. A number of cross section diagrams from HECRAS are presented with the flow recommendations which demonstrate the impact of each flow within the cross section. The HECRAS diagrams use default nomenclature in the legend. The table provided in section 2.7 explains the symbols used in the figures; and
- **Compliance of the current flow regime against the flow recommendations**. An analysis of the current frequency and duration of the recommended flows was undertaken to assess whether the recommendations are achieved under current operational practices. Natural and current flow data were entered into an excel macro which was designed by SKM to calculate the percentage of time flow volume, frequency and duration of flow events are met. Compliance is expressed as a percentage and colour coded according to pre-determined categories for comparative purposes. Representative current flows for each of the environmental flow reaches were derived using the following method:
  - Site 1 Tarra River at picnic ground: REALM modelled flows at the South Gippsland Water offtake;
  - Site 2 Macks Creek: Natural flow time series derived by adding back upstream modelled historic demands to gauged flows at 227223;
  - Site 3 Greig Creek: Natural flow time series derived by adding back upstream modelled historic demands to gauged flows at 227220;
  - Site 4a Spring Creek: Natural flow time series derived by adding back upstream modelled historic demands to gauged flows at 227234;
  - Site 4b Bodman Creek: Natural flow time series derived by adding back upstream modelled historic demands to gauged flows at 227221; and
  - Sites 6 and 7 Tarra River at Yarram gauge and Tarra River at Missens Lane: REALM modelled flows at Yarram gauge.

The current flow time series for sites 2, 3, 4a and 4b were derived by subtracting modelled upstream current level of development demands from natural flow time series.

3.1 Reach 1 Tarra River at Picnic Ground

3.1.1 Current condition

A detailed description of the current condition of Reach 1 was provided in the *Issues Paper*. A summary is provided in Table 3-1 below.

Table 3-1 Current condition of Reach 1: Tarra River at Picnic Ground.

Aspect	Current condition
Hydrology	▪ Generally good. Limited demands upstream of this site. Only a small number of diversions and little difference between current and natural flows.
Geomorphology	▪ No channel issues, some degradation of right bank due to picnic ground and bridge.
Water quality	▪ Generally good. River flows through National Park.
Fish	▪ Barriers to fish passage in downstream reaches and possible predation on small native fish by trout.
Macroinvertebrates	▪ Generally good. River flows through National Park.
Instream and riparian flora	▪ Exotic plants, cleared for recreational uses, no instream vegetation.

3.1.2 Flow recommendations

The environmental flow recommendations for Reach 1 are summarised in Table 3-2. No cease-to-flow recommendation has been made as the flow record shows that cease-to-flows do not naturally occur at this site. There is a Bulk Entitlement flow of 3 ML/day required in this reach which is reduced to 0.5 ML/day under high restrictions.

Table 3-2 Summary of flow recommendations for Reach 1: Tarra River at Picnic Ground.

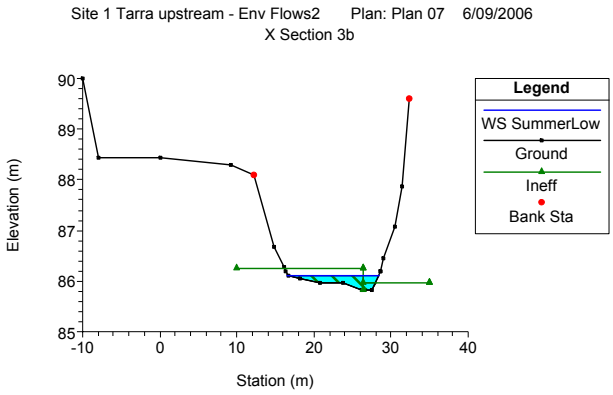
Reach 1 Tarra River at Picnic Ground				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Low flow	7 ML/day or natural		
	Freshes	26 ML/day	3 per year or as natural	3 days or as natural
			1 per year or as natural	12 days or as natural
Winter	Low flow	17 ML/day or natural		
	Freshes	48 ML/day	3 per year or as natural	5 days or as natural
	High	200 ML/day	1 per year or as natural	2-3 days or as natural
	Higher	1000 ML/day	1 in 5 years or as natural	1-2 days or as natural

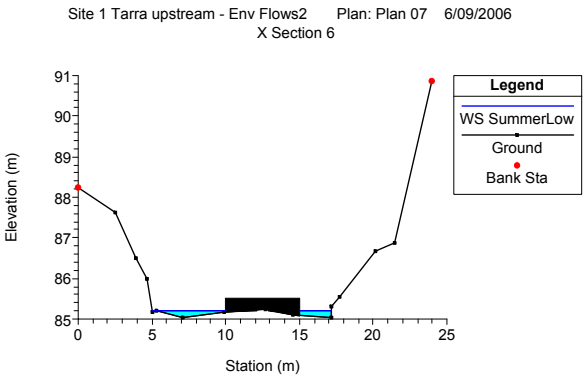
Reach 1 Tarra River at Picnic Ground				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
	Overbank	Overbank flows should be allowed to occur as natural		

Summer low flow

A summer low flow of 7 ML/d or as naturally occurs has been recommended for Reach 1. The criteria for determining the summer low flow was to ensure flows encroached on the gravel bar at cross section 6 (Figure 3-1). Flows at this level will maintain deep pool habitat for fish and adequate water depth over the riffles for macroinvertebrates. A summer low flow will also maintain biofilms on submerged rocks and surface sediments and maintain water quality.

The accumulated mud, grass and debris in the channel was modelled in Figure 3-1 as an obstruction and has been shaded black in cross section 6. The gravel bar at cross section 3b is shown as an ineffective area (green hatching) as it is less dense (more rocky and pebbly) than at cross section 6 (Figure 3-1).

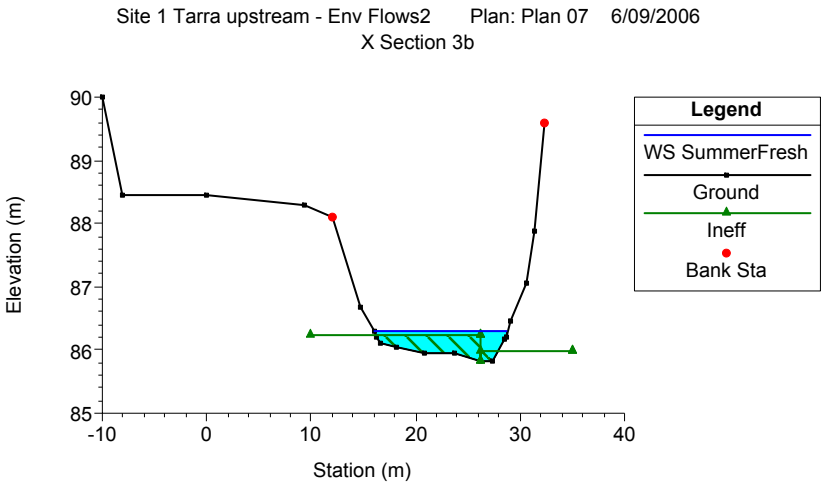




- **Table3-1 Water depth at cross sections 3b (left) and 6 (right), Reach 1 under summer low flow.**

Summer fresh

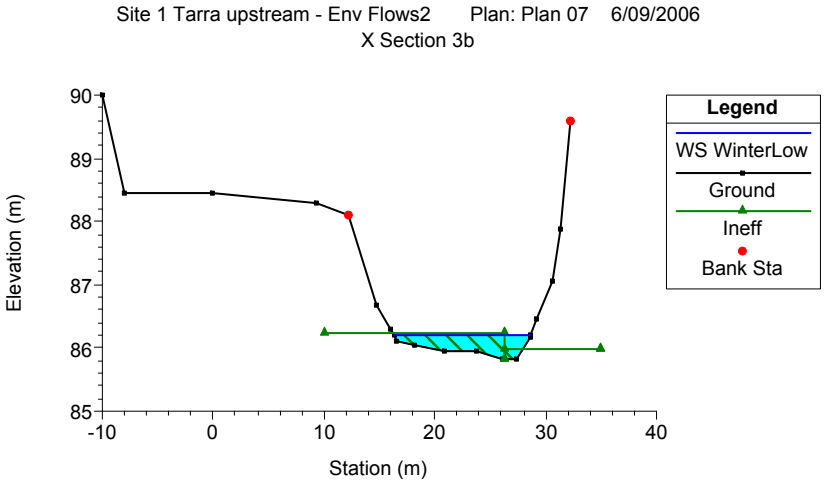
Four summer freshes have been recommended for Reach 1. Three freshes of 26 ML/day are required and need to last for three3 days. One fresh of 26 ML/day should last for 12 days. A summer fresh will mix pools, entrain organic matter and inundate the gravel bar at cross section 3b (Figure 3-2). Benthic and pool habitat area will be increased and maintained during a fresh.



- **Table3-2 Water depth at cross section 3b, Reach 1 under a summer fresh.**

Winter low flow

A winter low flow of 17 ML/day or as naturally occurs has been recommended for Reach 1. A flow of this size is equivalent to the 80th percentile flow during winter. A minimum winter low flow will maintain water over the gravel bar shown in Figure 3-3, maintain riparian vegetation and increase the area for colonisation of desirable emergent sedges and rushes.

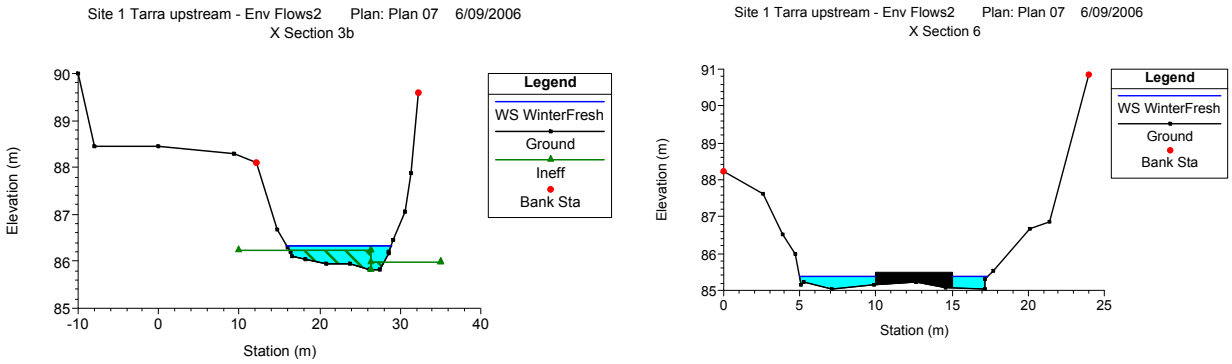


- **Figure 3-3 Water depth at cross section 3b, reach 1 under a winter low flow.**

Winter fresh

Three winter freshes of 48 ML/day have been recommended for this reach. Each fresh should last for five days. The model (Figure 3-4) shows that a fresh of this magnitude provides additional water above the gravel bar in cross section 3b but does not quite inundate the gravel bar at cross section 6.

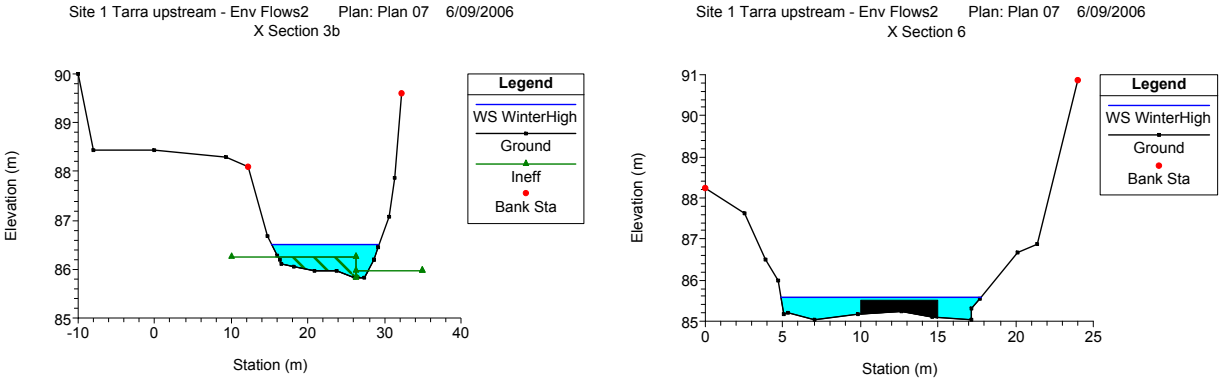
Winter freshes will provide flow for entrainment of organic material, provide channel maintenance, maintain existing riparian vegetation and benthic habitat and creates enough disturbance to turn rocks and provide access for fish and macroinvertebrates to the substrate.



- **Figure 3-4 Water depth at Reach 1, cross sections 3b and 6, under a winter fresh.**

Winter high

A winter high flow of 200 ML/day has been recommended. A flow of this size should occur once a year and last for two to three days (Appendix B). A winter high flow flushes pools and improves water quality, assists in physically maintaining the channel, creates a disturbance that entrains organic material and allows movement of native fish species. A flow of this magnitude inundates the gravel bar and other low gravel benches throughout the reach (Figure 3-5).

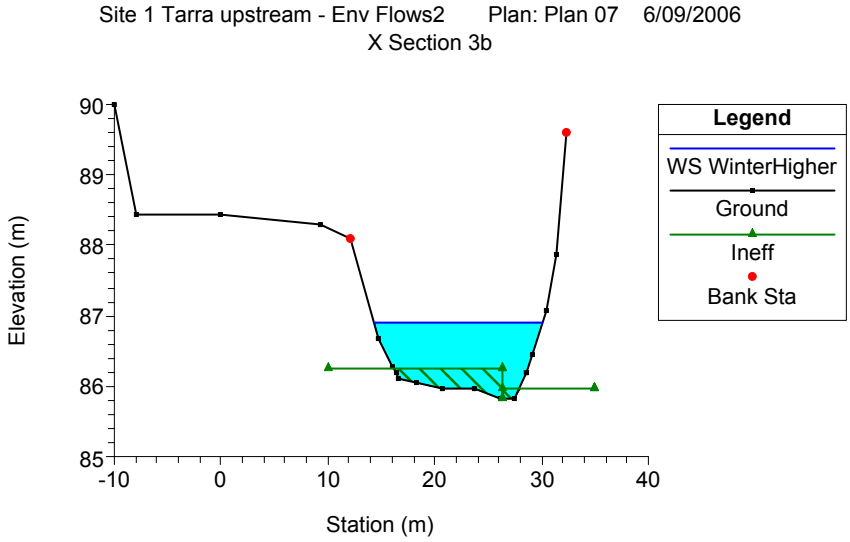


- **Figure 3-5 Water depths at reach 1, cross sections 3b and 6 under a winter high flow.**

Winter higher flow

An additional higher winter flow of 1000 ML/day has been recommended to inundate the higher benches and sections of the bank along the reach. A flow of this magnitude should occur once every five years and last for one to two days (Appendix B).

A flow of 1000 ML/day would provide some control over the encroachment of exotic vegetation species, such as *Iris sp*, observed on the banks along the reach. It is also an important flow for channel forming processes and channel maintenance.



- **Figure 3-6 Water depth at Reach 1, cross section 3b under a higher winter flow.**

3.1.3 Current compliance against flow recommendations

The flow recommendations for Reach 1 were compared with the current flow regime to assess the degree of compliance (Table 3-3). Flows regularly complied with recommended flows for all flow components.

- **Table 3-3 Compliance of flow recommendations against current flow regime for Reach 1 (volume= ML/day).**

Component	Months	Flow Rec		Or Natural	Compliance
Summer low	Dec - May	Volume	7	Yes	*97%*
Summer fresh	Dec - May	Volume	26		*100%*
		Frequency	3	Yes	*100%*
		Duration	3	Yes	*100%*
Summer high	Dec - May	Volume	26		*100%*
		Frequency	1	Yes	*100%*
		Duration	12	Yes	*100%*
Winter low	Jun - Nov	Volume	17	Yes	*100%*
Winter fresh	Jun - Nov	Volume	48		*100%*
		Frequency	3	Yes	*100%*
		Duration	5	Yes	*100%*
Winter high	Jun - Nov	Volume	200		*100%*
		Frequency	1	Yes	*100%*
		Duration	2	Yes	*100%*
Bankfull	Jun - Nov	Volume	1000		*100%*
		Frequency	0.2	Yes	*100%*
		Duration	2	Yes	*100%*

LEGEND							
Mostly complies		Greater than	95	%			of time / years / events
Frequently complies		Between	76	&	95	%	of time / years / events
Often complies		Between	51	&	75	%	of time / years / events
Occassionally complies		Between	26	&	50	%	of time / years / events
Rarely complies		Between	5	&	25	%	of time / years / events
Never complies		Between	0	&	5	%	of time / years / events

3.2 Reach 2 Macks Creek

3.2.1 Current condition

A detailed description of the current condition of Reach 2 was provided in the *Issues Paper*. A summary is provided in Table 3-4 below.

Table 3-4 Current condition of Reach 2: Macks Creek.

Aspect	Current condition
Hydrology	▪ There are no demands upstream of the gauge except for farm dams and there is little difference between current and natural flows.
Geomorphology	▪ Bars were present in-channel associated with willow stumps resulting in formation of shallow backwaters.
Water quality	▪ Cattle access to stream, no shade to stream. Potential for algal blooms.
Fish	▪ Poor habitat, degraded riparian zone, fish barriers.
Macroinvertebrates	▪ Poor instream habitat and food source, lack of shade, cattle access to streams, willow infestations upstream.
Instream and riparian flora	▪ Presence of exotic plants, removal of willows effects both riparian and instream plants, grazing, nutrient enrichment, disturbance and altered flows.

3.2.2 Flow recommendations

The environmental flow recommendations for Reach 2 are summarised in Table 3-5. No cease-to-flow recommendation has been made as the flow record shows that cease-to-flows do not naturally occur at this site. A minimum environmental flow recommendation of 2.5 ML/day has previously been recommended by Lieschke and Zampatti (2001) for this reach.

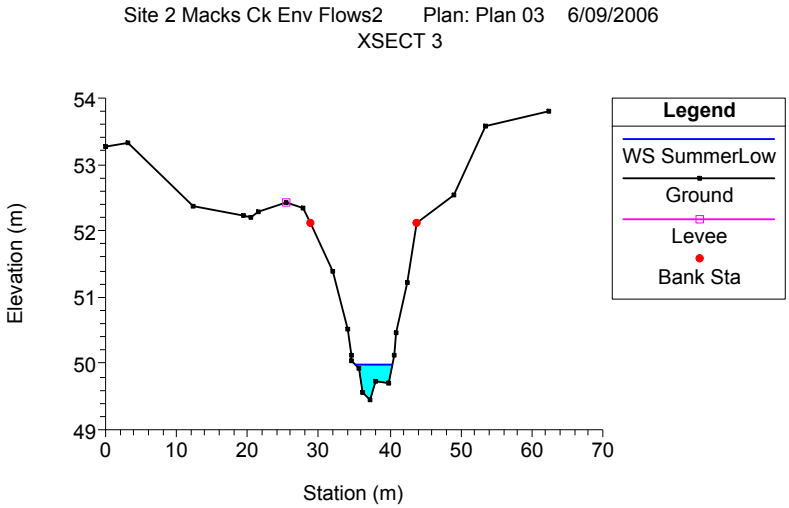
Table 3-5 Summary of flow recommendations for Reach 2: Macks Creek.

Reach 2 Macks Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Low flow	3 ML/day or natural		
	Freshes	10 ML/day	4 per year or as natural	3 days or as natural
Winter	Low flow	6 ML/day or natural		
	Freshes	30 ML/day	2 per year or as natural	4 days or as natural
	High	150 ML/day	1 per year or as natural	2 days or as natural
	Bankfull	2000 ML/day	1 in 10 years or as natural	1 day or as natural
	Overbank	As naturally occurs		

Summer low flow

A summer low flow of 3 ML/day or as naturally occurs has been recommended for this reach (Figure 3-7). This is equivalent to the 80th percentile flow.

A summer low flow in this reach will assist the establishment and maintenance of submerged macrophytes, provide access to pool habitat for fish and macroinvertebrates and minimise increases in water temperature.

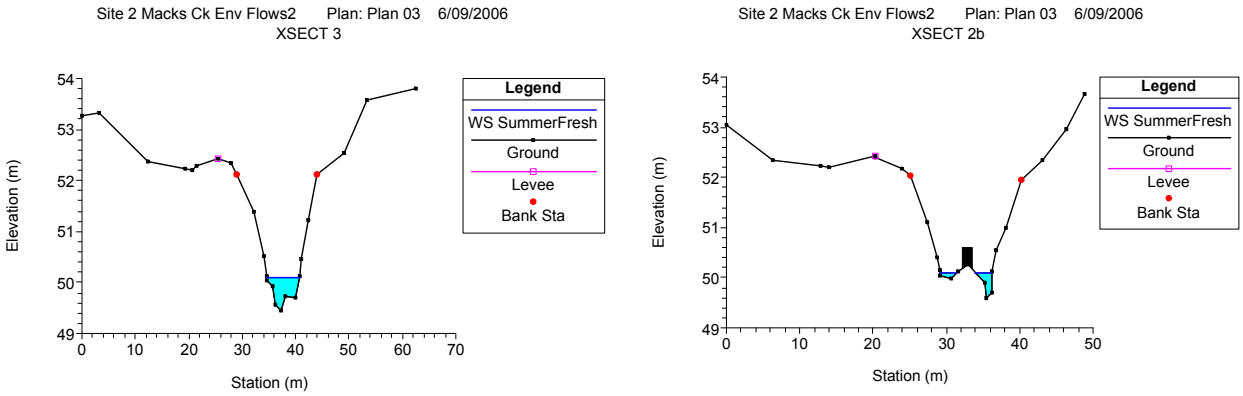


- **Figure 3-7 Water depth at Reach 2, cross section 3 under a summer low flow.**

Summer fresh

Four summer freshes have been recommended for this reach, each of 10 ML/day lasting for three days (Appendix B). This flow is equivalent to the 20th percentile summer flow.

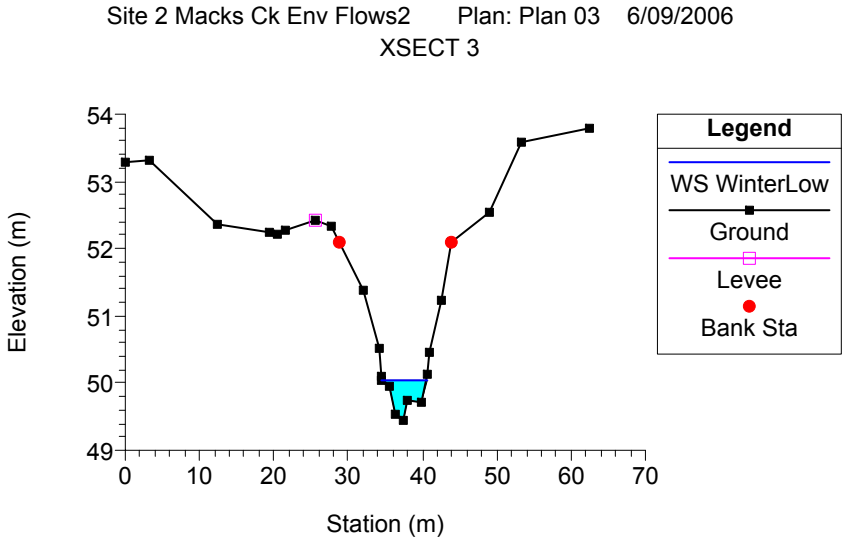
A summer fresh through this reach will inundate backwaters and low benches within the channel. A fresh also provides an increase in available habitat, maintains benthic habitat and improves water quality during summer. Figure 3-8 shows the inundation of backwaters under a summer fresh. The shaded black area represents a willow (*Salix sp.*) stump and associated mud and debris modelled as an obstruction.



- **Figure 3-8 Water depth at cross sections 3 (left) and 2b (right), Reach 2, under a summer fresh.**

Winter low flow

A winter low flow of 6 ML/day or as naturally occurs has recommended for this reach. This is equivalent to the 80th percentile flow during winter. A flow of this size allows the establishment and maintenance of riparian, emergent and submerged vegetation and access for fish to suitable pool habitat. Figure 3-9 shows the area of the channel that would be inundated by a winter low flow.

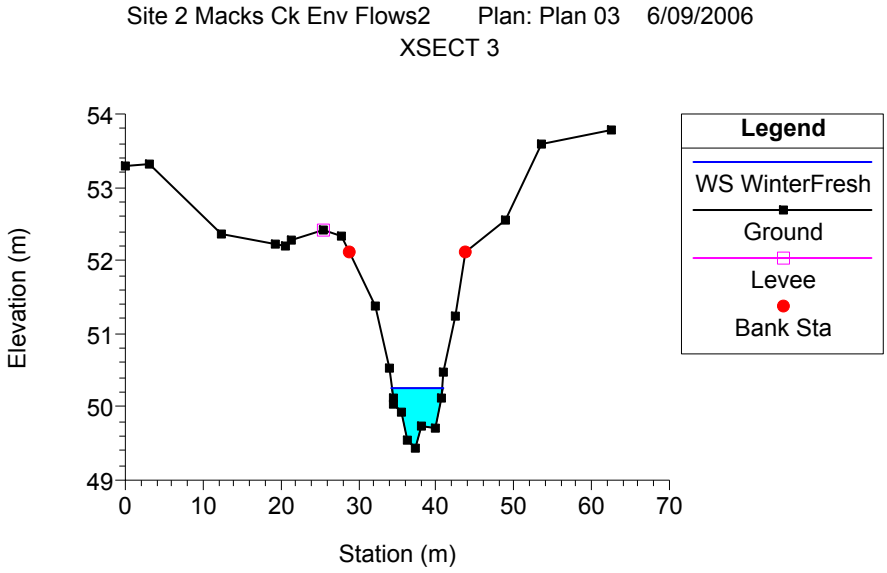


- **Figure 3-9 Water depth at cross section 3, Reach 2 under a winter low flow.**

Winter fresh

Two winter freshes have been recommended at this reach on Macks Creek. Each fresh should be 30 ML/day and last for four days (Appendix B). Freshes of this size will fill the bottom of the channel (Figure 3-10).

Winter freshes assist in maintaining the physical features of the channel and inundate addition areas of the bank which provides additional area for emergent vegetation to colonise. In addition, freshes create a disturbance, turning rock and cobbles which provides access by macroinvertebrates to parts of the substrate previously unavailable.

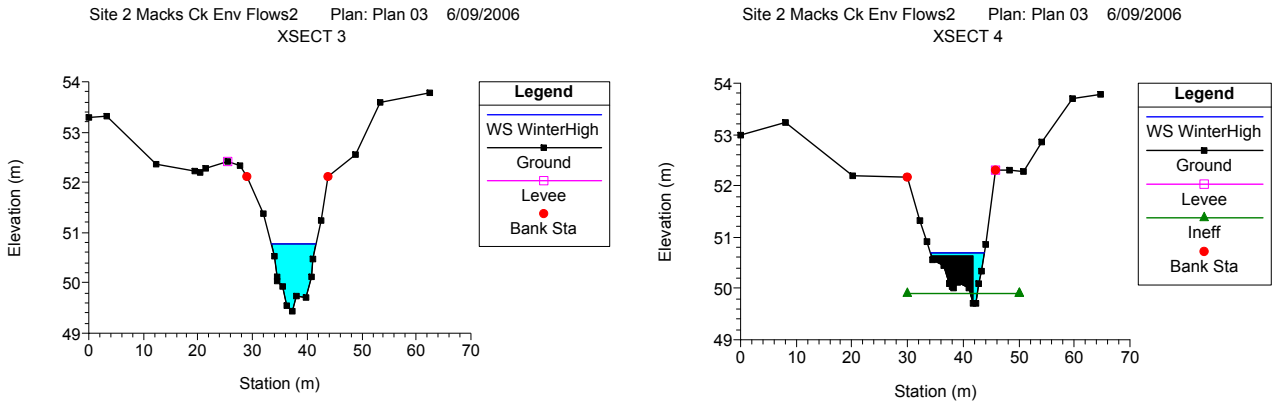


- **Figure 3-10 Water depth a cross section 3, reach 2 under a winter fresh.**

Winter high

A winter high flow of 150 ML/day once a year, lasting two days should be provided as part of the flow regime for this reach (Appendix B). The recommended winter high is essentially a high fresh that covers all the willows and low branches in the channel. This flow will fill backwaters and allow movement of native fish through the reach. As the willow stumps decompose, flows of this size will assist in entraining accumulated sediments, flushing them down stream.

The willow stump, mud and associated debris at cross section 4 were modelled as an obstruction (shaded black) which is inundated under the winter high flow (Figure 3-11).



- **Figure 3-11 Water depth at cross sections 3 and 4, Reach 2 under a winter high flow.**

Bankfull and overbank flows

Bankfull and overbank flows should be maintained within the current flow regime and allowed to occur as natural

3.2.3 Current compliance against flow recommendations

The flow recommendations were assessed against the current flow regime to determine compliance (Table 3-6). Compliance ranged from high to very high for all flow components.

- **Table 3-6 Compliance of flow recommendations to current flow regime for Reach 2 (volume= ML/day).**

Component	Months	Flow Rec		Or Natural	Compliance
Summer low	Dec - May	Volume	3	Yes	*80%*
Summer fresh	Dec - May	Volume	10		*95%*
		Frequency	4	Yes	*100%*
		Duration	3	Yes	*78%*
Winter low	Jun - Nov	Volume	6	Yes	*84%*
Winter fresh	Jun - Nov	Volume	30		*89%*
		Frequency	2	Yes	*85%*
		Duration	4	Yes	*78%*
Winter high	Jun - Nov	Volume	150		*100%*
		Frequency	1	Yes	*100%*
		Duration	2	Yes	*82%*

LEGEND							
Mostly complies		Greater than	95	%			of time / years / events
Frequently complies		Between	76	&	95	%	of time / years / events
Often complies		Between	51	&	75	%	of time / years / events
Occassionally complies		Between	26	&	50	%	of time / years / events
Rarely complies		Between	5	&	25	%	of time / years / events
Never complies		Between	0	&	5	%	of time / years / events

3.3 Reach 3 Greigs Creek

3.3.1 Current condition

A detailed description of the current condition of Reach 3 was provided in the *Issues Paper*. A summary is provided in Table 3-7 below.

Table 3-7 Current condition of Reach 3: Greigs Creek.

Aspect	Current condition
Hydrology	■ There are few demands upstream of the gauge except for farm dams. Current and natural flows are similar.
Geomorphology	■ Shallow pools and short riffles. Cattle access to left bank.
Water quality	■ Stock access to creek. Possible nutrient enrichment.
Fish	■ Moderate habitat available, fish barriers in downstream reaches.
Macroinvertebrates	■ Stock access, moderate instream habitat such as wood and aquatic plants but riffles and pools available.
Instream and riparian flora	■ Habitat reduction, exotic plants, effects of light regime on instream plant growth.

3.3.2 Flow recommendations

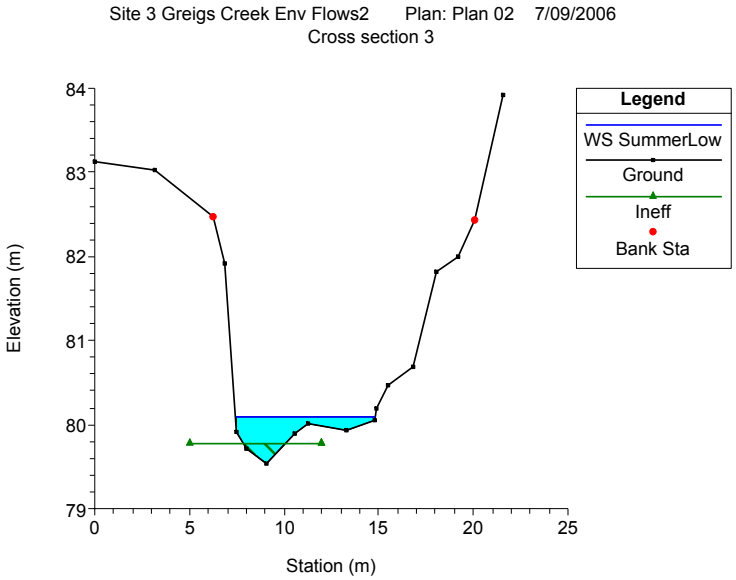
The environmental flow recommendations for Reach 3 are summarised in Table 3-8. No cease-to-flow recommendation has been made as the flow record shows that cease-to-flows do not naturally occur at this site. An environmental flow recommendation of 2.5 ML/day has previously been recommended by Lieschke and Zampatti (2001) to provide sufficient flow for River Blackfish movement through the reach.

Table 3-8 Summary of flow recommendations for Reach 3: Greigs Creek.

Reach 3 Greigs Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Low flow	2.5 ML/day or natural		
	Freshes	4 ML/day	4 per year or as natural	5 days or as natural
Winter	Low flow	5 ML/day or natural		
	Freshes	20 ML/day	4 per year or as natural	4 days or as natural
	High	250 ML/day	1 per year or as natural	2 days or as natural
	Bankfull	High flows need to be protected and should be allowed to occur as natural		
	Overbank			

Summer low flow

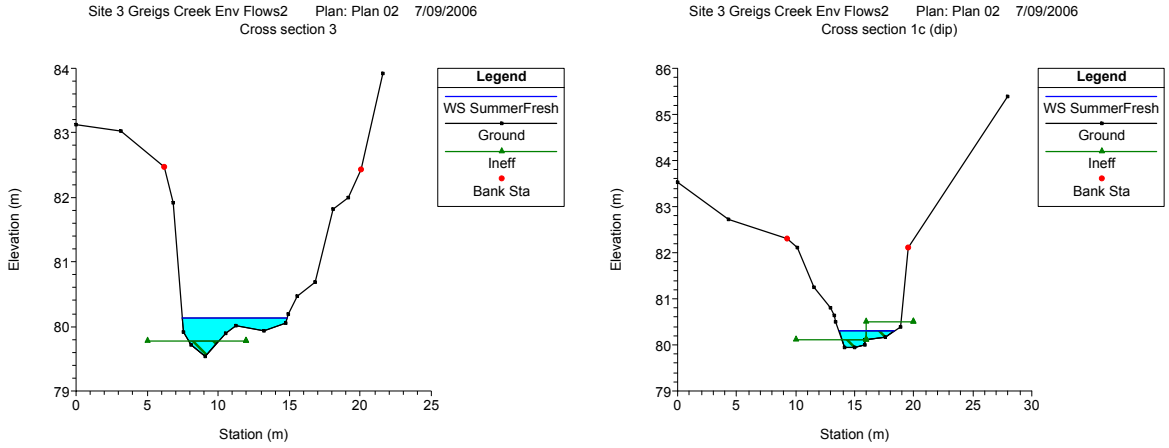
A summer low flow of 2.5 ML/day or as naturally occurs has been recommended for this reach. This is slightly more than the 80th percentile summer flow. A summer low flow maintains flow over the lower benches through the reach (Figure 3-12) providing access to habitat for fish and macroinvertebrates and reducing the impact of increasing water temperatures during summer.



- **Figure 3-12 Water depth at cross section3, Reach 3 under summer low flow.**

Summer fresh

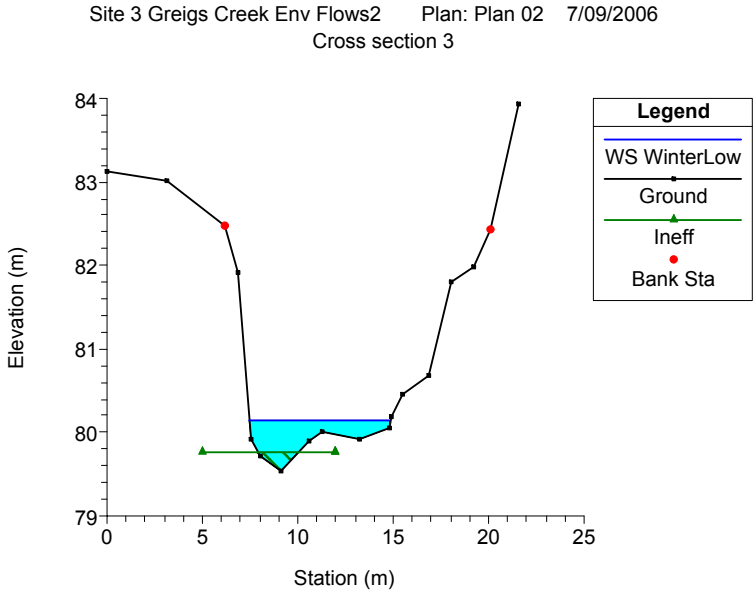
Four summer freshes per year of 4 ML/day have been recommended for this reach. Each fresh needs to last for five days (Appendix B) and is approximately equivalent to the summer 50th percentile flow. Freshes will inundate buttercup (*Ranunculus sp*) growing in the channel as indicated by the cross hatched area in Figure 3-13. Summer freshes are also aimed at providing some disturbance to desilt areas of the channel and flush silt and organic material from the pools and assist in maintaining the thalweg. Summer freshes will also be required to maintain any future revegetation that is carried out at this site.



- **Figure 3-13 Water depth at cross section 3 (left) and cross section 1c (right) at Reach 3 under a summer fresh.**

Winter low flow

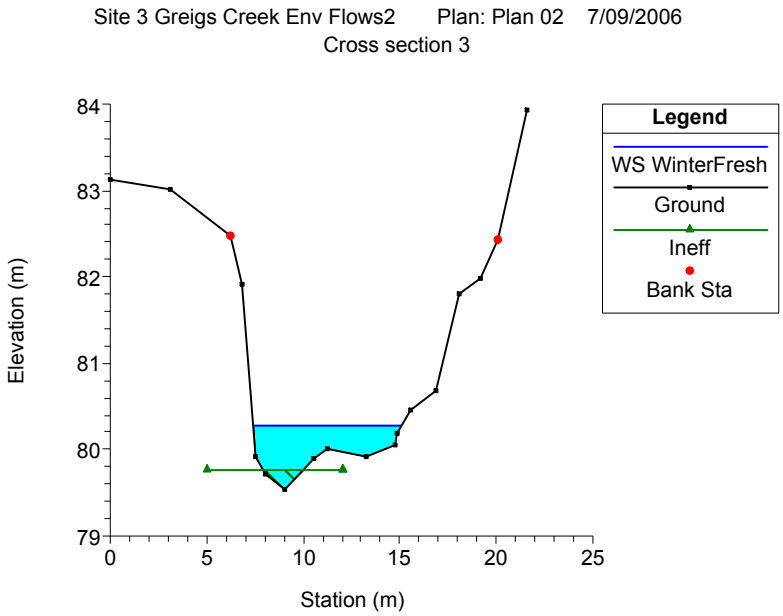
A winter low flow of 5 ML/day or as naturally occurs has been recommended for this reach. A winter low flow will inundate some of the lower benches and sections of the bank providing additional area for establishment of emergent aquatic vegetation and maintain connectivity between pools (Figure 3-14).



- **Figure 3-14 Water depth at cross section 3, Reach 3 under winter low flow.**

Winter fresh

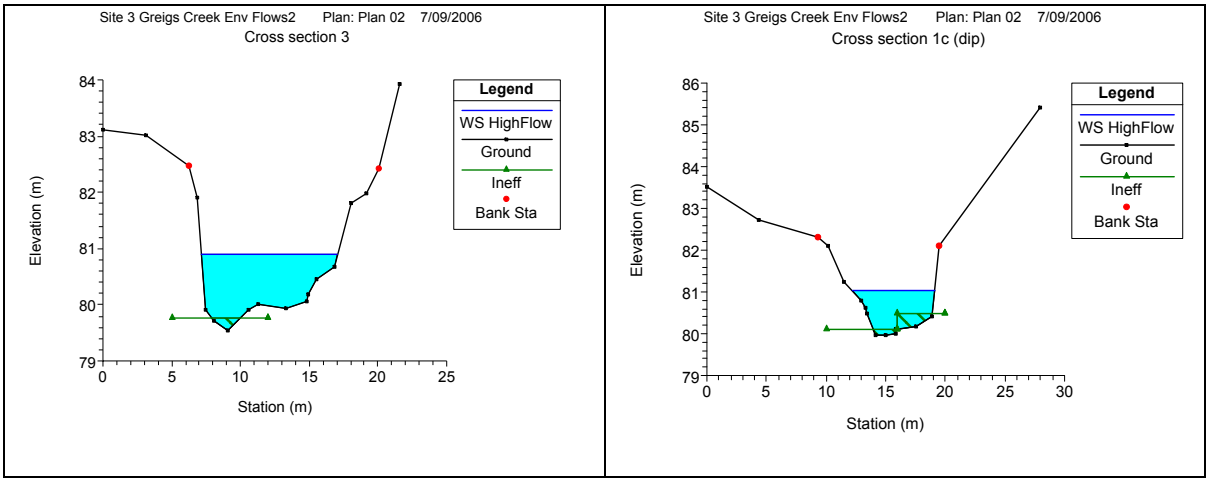
Four winter freshes per year of 20 ML/day have been recommended for this reach. Each fresh is approximately equivalent to the 20th percentile winter flow and should last for four days (Appendix B). The aim of winter freshes is to provide channel maintenance, desilting of pools and to provide water to riparian vegetation on the banks. In addition, a winter fresh will assist in maintaining benthic habitat, disturb rocks and provide access to substrate for fish and macroinvertebrates. A fresh of 20 ML/day will inundate low benches and banks (Figure 3-15).



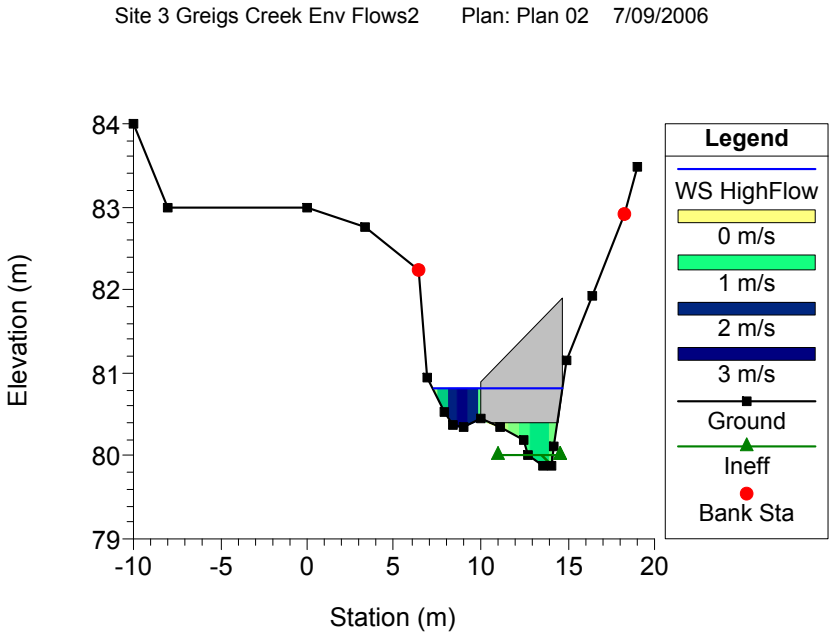
- **Figure 3-15 Water depth at cross section 3, Reach 3 under winter fresh.**

Winter high flow

A winter high flow of 250 ML/day has recommended for this reach. A flow of this magnitude should occur once a year and last for two days (Appendix B). A winter high flow will inundate all benches (Figure 3-16), scour Buttercup from the channel and provide a disturbance to the substrate providing access for macroinvertebrates, entrain organic material and provide movement for native fish. The high velocities created by such a flow have been modelled at cross section 2 and 3 to determine the flow around a large log within the stream and the associated pool (Figure 3-17).



- **Figure 3-16 Water depth at cross section 3 and cross section 1c, Reach 3 under winter high flow.**



- **Figure 3-17 Water depth at log between cross sections 2 and 3, Reach 3 (Log shown as grey shaded area).**

Winter bankfull and overbank flow

These high flows should be allowed to occur as natural.

3.3.3 Current compliance against flow recommendations

The compliance of the flow recommendations against the current flow regime were assessed for Reach 3 (Table 3-9). Winter freshes and winter high flow had very good compliance. The volume of water was available for summer freshes four times during the year however the duration is less than the required 4 days for about 10% of the time. Summer low flows and winter low flows comply about 80% of the time under the current flow regime.

- **Table 3-9 Compliance of current flow regime with flow recommendations for Reach 3 (volume= ML/day).**

Component	Months	Flow Rec		Or Natural	Compliance
Summer low	Dec - May	Volume	2.5	Yes	*78%*
Summer fresh	Dec - May	Volume	4		*97%*
		Frequency	4	Yes	*96%*
		Duration	5	Yes	*91%*
Winter low	Jun - Nov	Volume	5	Yes	*78%*
Winter fresh	Jun - Nov	Volume	20		*100%*
		Frequency	4	Yes	*100%*
		Duration	4	Yes	*100%*
Winter high	Jun - Nov	Volume	250		*100%*
		Frequency	1	Yes	*100%*
		Duration	2	Yes	*100%*

LEGEND							
Mostly complies		Greater than	95	%			of time / years / events
Frequently complies		Between	76	&	95	%	of time / years / events
Often complies		Between	51	&	75	%	of time / years / events
Occassionally complies		Between	26	&	50	%	of time / years / events
Rarely complies		Between	5	&	25	%	of time / years / events
Never complies		Between	0	&	5	%	of time / years / events

3.4 Reach 4a Spring Creek

3.4.1 Current condition

A detailed description of the current condition of Reach 4a (Spring Creek) was provided in the *Issues Paper*. A summary is provided in Table 3-10 below.

Table 3-10 Current condition of Reach 4: Spring Creek.

Aspect	Current condition
Hydrology	▪ Farm dams in Spring Creek catchment. Current flows are lower than natural particularly during summer.
Geomorphology	▪ Pugging and bank erosion due to cattle access and wombat activity, lack of riparian vegetation.
Water quality	▪ Nutrients, stock access, fertiliser runoff, lack of riparian vegetation, sluggish flows.
Fish	▪ Degraded riparian zone, barriers to fish movement, increased periods of cease-to-flow and low flow, poor available instream habitat.
Macroinvertebrates	▪ Very poor instream habitat, poor water quality, no native vegetation.
Instream and riparian flora	▪ Exotic plants, grazing and nutrient enrichment, impacts to water quality from fertiliser runoff.

3.4.2 Flow recommendations

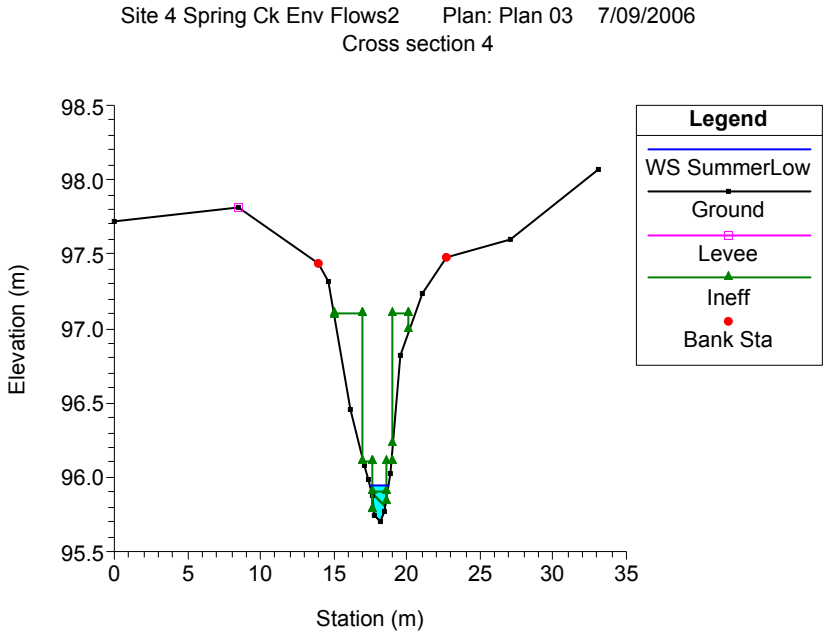
The environmental flow recommendations for Reach 4a are summarised in Table 3-11. Although Spring Creek ceases-to-flow for up to two weeks under current conditions (Appendix B), under natural conditions there is still a very small flow present in the creek during summer, therefore no cease-to-flow recommendation has been made. The flow record shows flows through this reach to be generally low with a current mean flow of 3.30 ML/day and a natural mean flow of 3.36 ML/day.

Table 3-11 Summary of flow recommendations for Reach 4a Spring Creek.

Reach 4a Spring Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Low flow	<1 ML/day or natural		
	Freshes	1 ML/day	4 per year or as natural	4 days or as natural
Winter	Low flow	1 ML/day or natural		
	Freshes	3 ML/day	3 per year or as natural	5 days or as natural
	High	50 ML/day	1 per year or as natural	2 days or as natural
	Bankfull	500 ML/day	1 in 10 years or as natural	1 day or as natural
	Overbank	>500 ML/day	As naturally occurs	As naturally occurs

Summer low flow

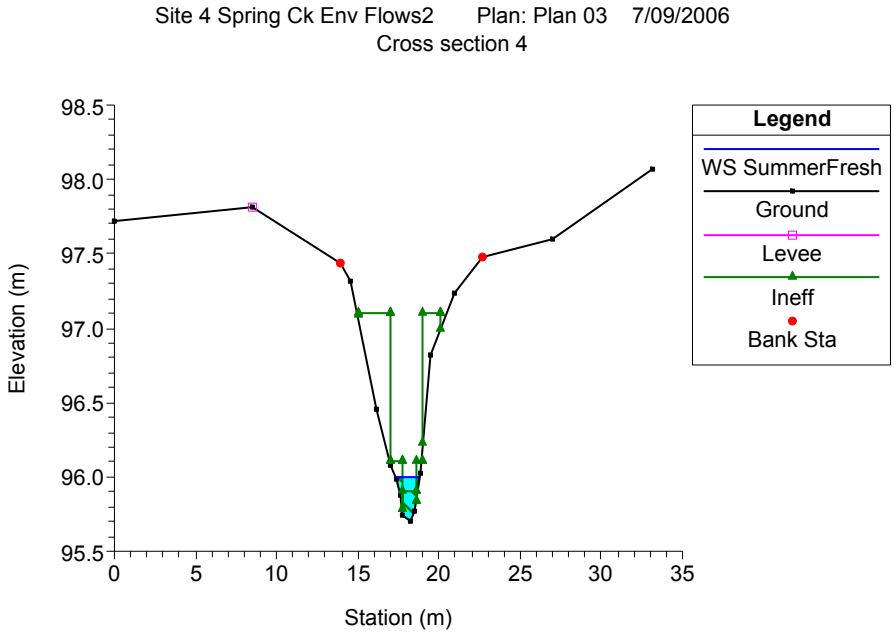
A summer low flow at this site of < 1 ML/day (approximately 0.3 ML/day) or as naturally occurs has been recommended for this reach. Maintaining water in the channel during the summer would allow connectivity between pools and provide some wetted surface for habitat and maintenance of instream and emergent vegetation. A flow of this size fills a small area of the channel and is small enough to prevent trout colonisation within the reach (Figure 3-18).



- **Figure 3-18 Water depth at cross section 4, Reach 4a (Spring Creek), under summer low flow.**

Summer fresh

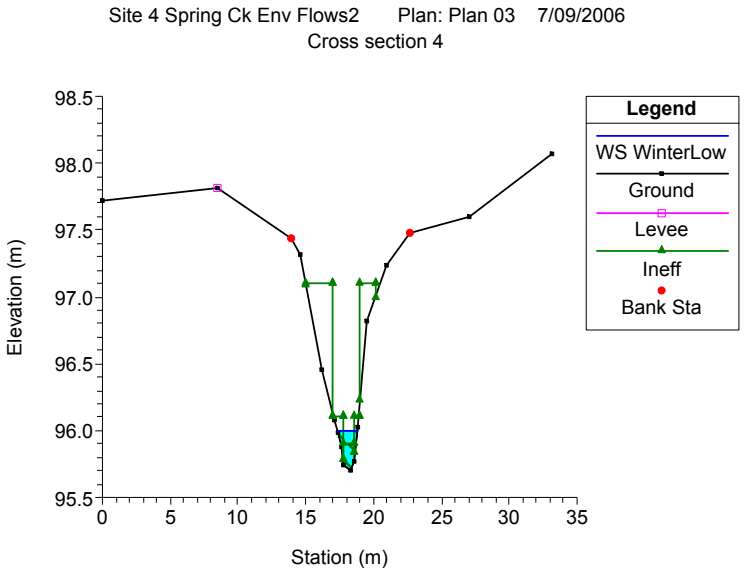
Four summer freshes of 1 ML/day have been recommended for this reach. Each fresh should last for four days (Appendix B). A summer fresh through this reach will freshen water quality in pools, wet bank vegetation and provide water for maintenance of areas of revegetation downstream of the reach. Figure 3-19 shows the area of channel that would be inundated by a 1 ML/day flow.



- **Figure 3-19 Water depth at cross section 4, Reach 4a (Spring Creek), under summer fresh.**

Winter low flow

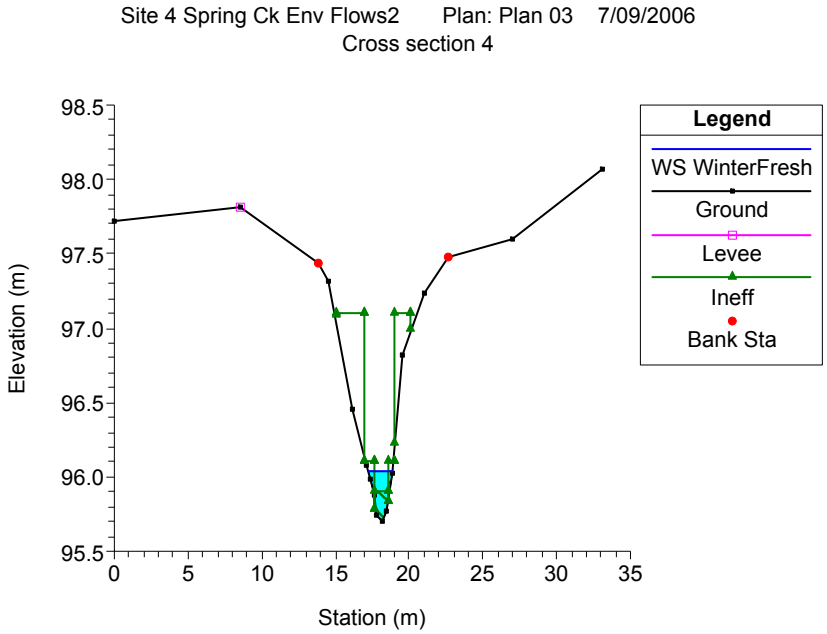
A winter low flow of 1 ML/day or as naturally occurs has been recommended for this reach which would provide water to allow establishment and maintenance of bank and instream vegetation and maintain connectivity between pools. Figure 3-20 shows the area of channel that would be inundated.



- **Figure 3-20 Water depth at cross section 4, Reach 4a (Spring Creek), under winter low flow.**

Winter fresh

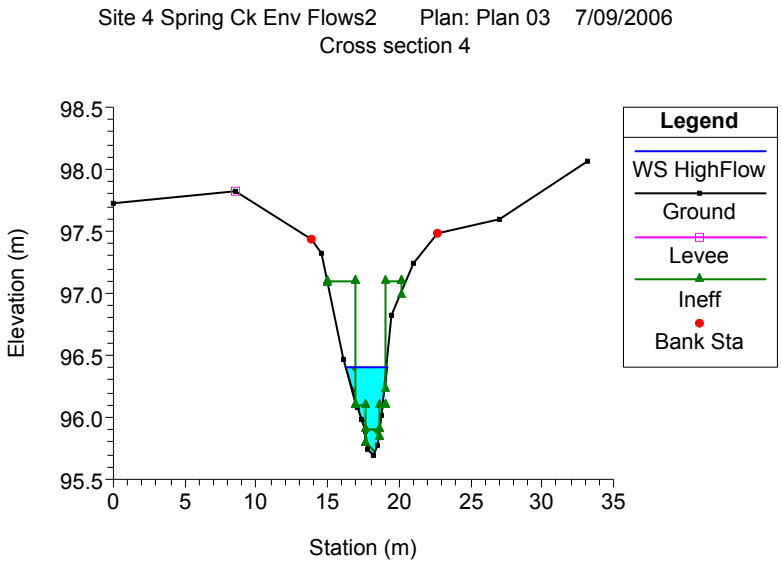
Three winter freshes of 3 ML/day for a duration of five days each have been recommended for this reach. A flow of this size is equivalent to the 20th percentile winter flow and is aimed at providing channel maintenance, inundation of a greater area of channel for use as habitat, improve benthic habitat and create sufficient disturbance to facilitate decomposition of organic matter and freshen water quality. Figure 3-21 shows the area of channel and bank that would be inundated by a winter fresh.



- **Figure 3-21 Water depth at cross section 4, Reach 4a (Spring Creek), under winter fresh.**

Winter high flow

A winter high flow of 50 ML per day once a year has been recommended for this reach. A flow of this size should last for 1 day and modelling shows it is a mid bank flow (Figure 3-22). Winter high flows of this size in this reach will maintain opportunities for movement of native fish, maintain the physical features of the channel and entrain and transport sediments downstream.



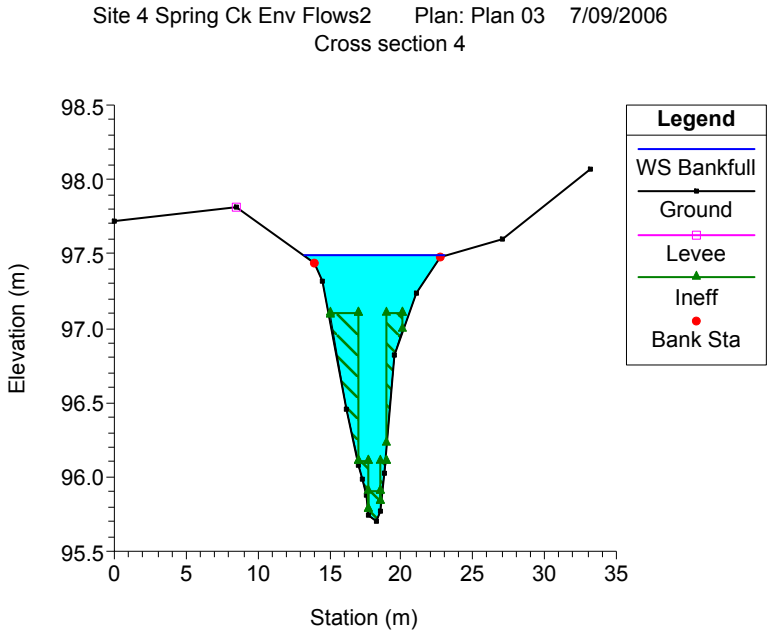
- **Figure 3-22 Water depth at cross section 4, Reach 4a (Spring Creek), under winter high flow.**

Bankfull

Only five bankfull flows have been identified in the flow records. A one in ten year bankfull flow of 500 ML/day lasting for one day would assist with physical channel forming processes and provide recruitment opportunities to riparian vegetation. Figure 3-23 shows the height and area of channel inundated by a bankfull flow.

Overbank flow

Overbank flows should be allowed to occur as natural.



- **Figure 3-23 Water depth at cross section 4, Reach 4a (Spring Creek), under bankfull flow.**

3.4.3 Current compliance and recommendations

The current flow regime for Spring Creek was assessed against the flow recommendations (Table 3-12). Summer low flows and winter low flows often comply (72% of the time in summer and only 60% of the time in winter). Summer freshes with less than the required volume and duration occur under the current flow regime. All other recommendations are complied with greater than 95% of the time.

- **Table 3-12 Current compliance of current flow regime to flow recommendations for Reach 4a (volume= ML/day).**

Component	Months	Flow Rec		Or Natural	Compliance
Summer low	Dec - May	Volume	0.3	Yes	*72%*
Summer fresh	Dec - May	Volume	1		*97%*
		Frequency	4	Yes	*78%*
		Duration	4	Yes	*100%*
Winter low	Jun - Nov	Volume	1	Yes	*60%*
Winter fresh	Jun - Nov	Volume	3		*100%*
		Frequency	3	Yes	*100%*
		Duration	5	Yes	*100%*
Winter high	Jun - Nov	Volume	50		*100%*
		Frequency	1	Yes	*100%*
		Duration	2	Yes	*100%*
Bankfull	Jun - Nov	Volume	500		*100%*
		Frequency	0.1	Yes	*100%*
		Duration	1	Yes	*100%*
Overbank		Volume	501		*100%*
		Frequency	1	Yes	*100%*
		Duration	1	Yes	*100%*

LEGEND							
Mostly complies		Greater than	**95**	%			of time / years / events
Frequently complies		Between	**76**	&	**95**	%	of time / years / events
Often complies		Between	**51**	&	**75**	%	of time / years / events
Occassionally complies		Between	**26**	&	**50**	%	of time / years / events
Rarely complies		Between	**5**	&	**25**	%	of time / years / events
Never complies		Between	**0**	&	**5**	%	of time / years / events

3.5 Reach 4b Bodman Creek

3.5.1 Current condition

A detailed description of the current condition of Reach 4b (Bodman Creek) was provided in the *Issues Paper*. A summary is provided in Table 3-13 below.

Table 3-13 Current condition of Reach 4b: Bodman Creek.

Aspect	Current condition
Hydrology	▪ Farm dams, significant difference between natural and current flows.
Geomorphology	▪ Pugging and bank erosion due to cattle access and wombat activity.
Water quality	▪ Nutrients from stock access, lack of riparian vegetation and shading, high turbidity.
Fish	▪ Degraded riparian zone, possible barriers to fish movement, increased periods of cease-to-flow.
Macroinvertebrates	▪ Very poor instream habitat. Poor water quality.
Instream and riparian flora	▪ Degraded riparian zone but some potential for revegetation and regeneration, exotic plants, grazing and nutrient enrichment.

3.5.2 Flow recommendations

The environmental flow recommendations for Reach 4b are summarised in Table 3-14. Although Bodman Creek ceases-to-flow under current conditions, under natural conditions there is a small flow present in the creek during summer, therefore no cease-to-flow recommendation has been made. The flow record shows flows through this reach to be generally low with a current mean flow of 5.37 ML/day and a natural mean flow of 5.53 ML/day.

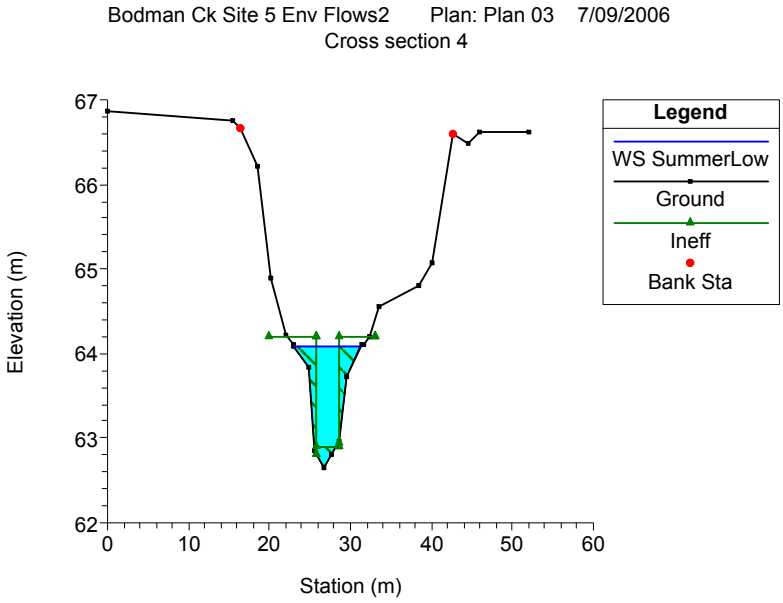
Bodman Creek in this reach has good potential for revegetaion and regeneration of native vegetation in this reach is currently high. The recommended flows provided reflect the vegetation potential of the reach.

Table 3-14 Summary of flow recommendations for Reach 4b Bodman Creek.

Reach 4b Bodman Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Low flow	<1 ML/day or natural		
	Freshes	2 ML/day	3 per year or as natural	4 days or as natural
Winter	Low flow	1 ML/day or natural		
	Freshes	10 ML/day	3 per year or as natural	4 days or as natural
	High	100 ML/day	1 per year or as natural	2 days or as natural
	Bankfull	Does not occur		
	Overbank	Does not occur		

Summer low flow

A summer low flow of < 1 ML/day (approximately 0.4 ML/day) or natural has been recommended for this reach. This is approximately equivalent to the 80th percentile natural summer flow. The low flow will maintain a wetted channel bed and provide connectivity between pools and reduce the impact of increasing water temperatures in summer. The riparian and instream vegetation will also benefit from these flows. A low summer flow would stay within the low flow channel (Figure 3-24).

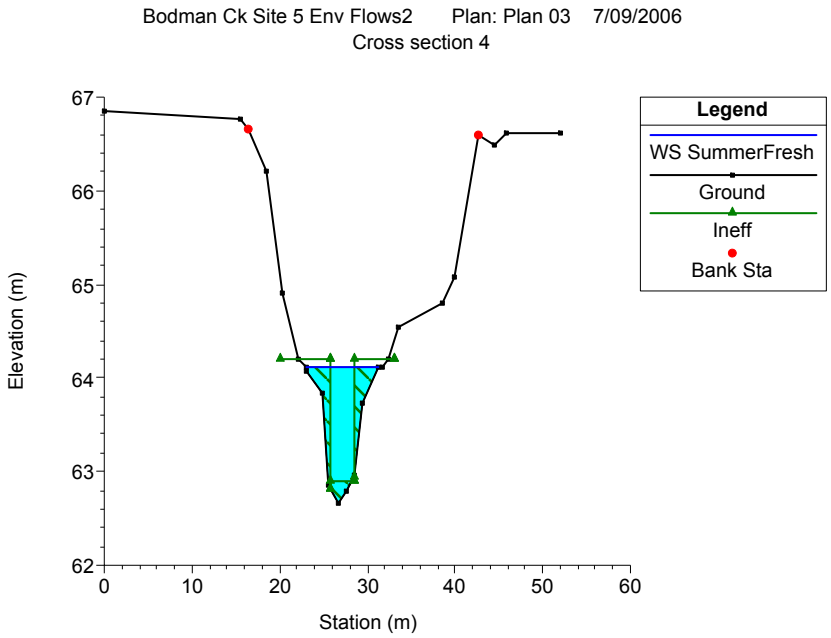


- **Figure 3-24 Water depth at cross section 4, Reach 4b (Bodman Creek), under summer low flow.**

Summer fresh

Three summer freshes per year of 2 ML/day have been recommended for this reach. Each fresh should last for four days (Appendix B). Modelling showed that there was no discernable difference between a 2 ML/day and a 5 ML/day flow within the channel.

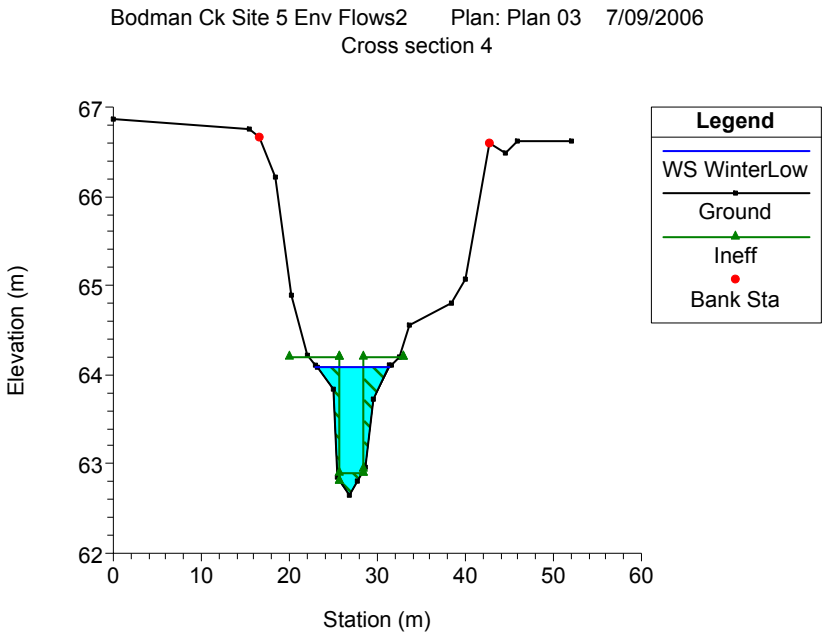
A fresh will provide longitudinal connectivity through the reach and assist in meeting the environmental flow objectives of maintaining and improving existing instream, stream side and riparian vegetation, improving water quality in summer and restoring native fish communities. Figure 3-25 shows the area of channel inundated during a summer fresh.



- **Figure 3-25 Water depth at cross section 4, Reach 4b (Bodman Creek), under summer fresh of 2 ML/day.**

Winter low flow

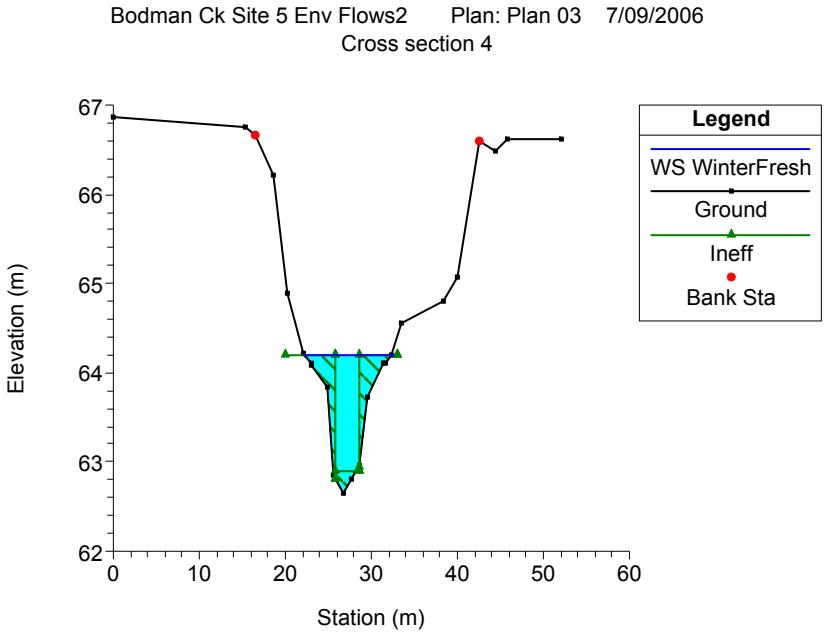
A low winter flow of 1 ML/day or as naturally occurs has been recommended for this reach. A low winter flow will remain within the low flow channel but serve to maintain and improve instream and riparian vegetation (Figure 3-26). A flow of this size is equivalent to the 80th percentile winter flow for this reach.



- **Figure 3-26 Water depth at cross section 4, Reach 4b, under winter low flow.**

Winter fresh

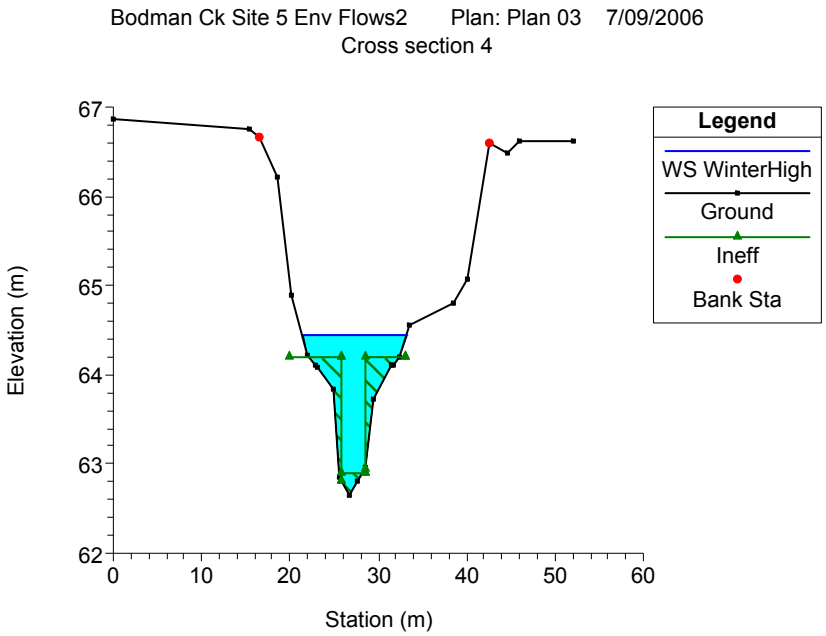
Three winter freshes of 10 ML/day, lasting four days have been recommended for this reach. A 10 ML/day winter fresh is greater than the mean natural winter flow of 7.70 ML/day and will inundate areas of the bank above the low flow channel (Figure 3-27). Winter freshes are aimed at restoring instream habitat condition by maintaining the channel, increasing the area of inundation for colonisation of emergent rushes and sedges, restore diversity to the native fish community and create disturbance within the channel to entrain organic material.



- **Figure 3-27 Water depth at cross section 4, Reach 4b (Spring Creek), under winter fresh.**

Winter high flow

The final flow recommendation for Bodman Creek is for a winter high flow. A high flow of 100 ML/day once a year lasting two days has been recommended. A flow of this magnitude will provide channel maintenance, maintain opportunities for native fish to move through the reach and provide disturbance to transport silt downstream and improve macroinvertebrate habitat and diversity. Figure 3-28 shows the area of channel and banks inundated by a winter high flow.



- **Figure 3-28 Water depth at cross section 4, Reach 4b (Bodman Creek), under winter high flow.**

Bankfull and overbank flows

These do not occur within the flow record therefore no recommendations have been made.

3.5.3 Current compliance against flow recommendations

Table 3-15 shows the compliance of the flow recommendations for Bodman Creek assessed against the current flow regime. The volume of water required for summer low and winter low flows and winter high flows had poor compliance under the current flow regime. Summer and winter freshes generally comply but the number of freshes recommended do not occur under current flows.

Both Spring Creek and Bodman Creek were problematic for modelling due to limited data. This may be reflected in the compliance assessment for both creeks.

- **Table 3-15 Compliance of flow recommendations under the current flow regime for Reach 4b (volume= ML/day).**

Component	Months	Flow Rec		Or Natural	Compliance
Summer low	Dec - May	Volume	0.4	Yes	*65%*
Summer fresh	Dec - May	Volume	2		*92%*
		Frequency	3	Yes	*74%*
		Duration	4	Yes	*100%*
Winter low	Jun - Nov	Volume	1	Yes	*73%*
Winter fresh	Jun - Nov	Volume	10		*87%*
		Frequency	3	Yes	*89%*
		Duration	4	Yes	*100%*
Winter high	Jun - Nov	Volume	100		*55%*
		Frequency	1	Yes	*95%*
		Duration	2	Yes	*100%*

LEGEND							
Mostly complies		Greater than	95	%			of time / years / events
Frequently complies		Between	76	&	95	%	of time / years / events
Often complies		Between	51	&	75	%	of time / years / events
Occassionally complies		Between	26	&	50	%	of time / years / events
Rarely complies		Between	5	&	25	%	of time / years / events
Never complies		Between	0	&	5	%	of time / years / events

3.6 Reach 6 Tarra River at Yarram gauge

3.6.1 Current condition

A detailed description of the current condition of Reach 6 was provided in the *Issues Paper*. A summary is provided in Table 3-16 below.

Table 3-16 Current condition of Reach 6: Tarra River at Yarram gauge.

Aspect	Current condition
Hydrology	▪ Difference between current and natural flows, high demands through this reach and upstream.
Geomorphology	▪ No major issues. Willow removal is already occurring and riparian revegetation is scheduled for this site.
Water quality	▪ Elevated nutrients, lack of shade from riparian vegetation.
Fish	▪ Fish barriers, narrow riparian zone, altered flow regime.
Macroinvertebrates	▪ Poor to moderate instream habitat and food source but heterogeneous streambed.
Instream and riparian flora	▪ Habitat reduction, exotic plants, possible nutrient enrichment, grazing.

3.6.2 Flow recommendations

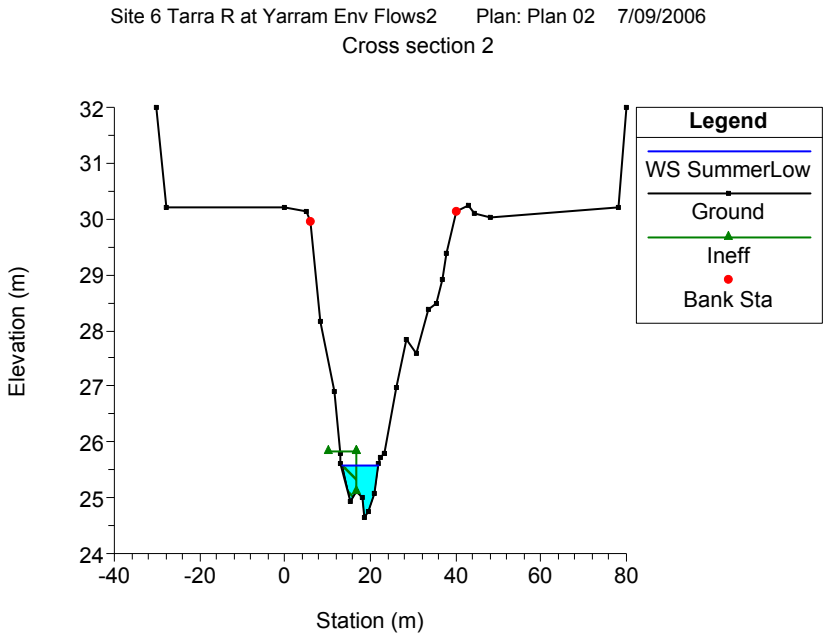
The environmental flow recommendations for Reach 6 are summarised in Table 3-17. An environmental flow recommendation of 10 ML/day has previously been recommended by Lieschke and Zampatti (2001) to provide sufficient flow for River Blackfish movement through the reach.

Table 3-17 Summary of flow recommendations for Reach 6: Tarra River at Yarram gauge.

Reach 6 Tarra River at Yarram gauge.				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Low flow	13 ML/day or natural		
	Freshes	54 ML/day	3 per year or as natural	6 days or as natural
		150 ML/day	1 per year or as natural	4 days or as natural
Winter	Low flow	32 ML/day or natural		
	Freshes	143 ML/day	3 per year or as natural	5 days or as natural
	High	450 ML/day	1 per year or as natural	4 days or as natural
	Higher	1100 ML/day	1 per year or as natural	2 days or as natural
	Bankfull	5000 ML/day	1 in 3 years or as natural	1-2 days or as natural

Summer low flow

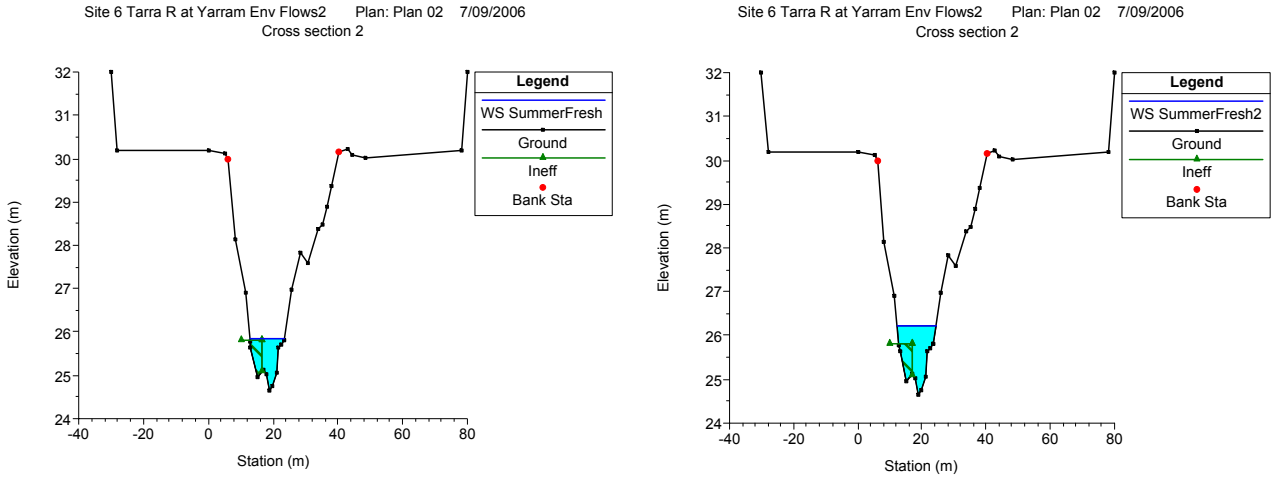
A summer low flow of 13 ML/day or as naturally occurs has been recommended. This is equivalent to the 80th percentile natural summer flow. A summer low flow provides sufficient water within the channel to allow fish access to suitable pool habitat and to maintain instream and bank vegetation. Summer low flows are also important to reduce the impact of increasing water temperatures during summer. Figure 3-29 shows the area of channel inundated by 13 ML/day.



- **Figure 3-29 Water depth at cross section 2, Reach 6, under summer low flow.**

Summer fresh

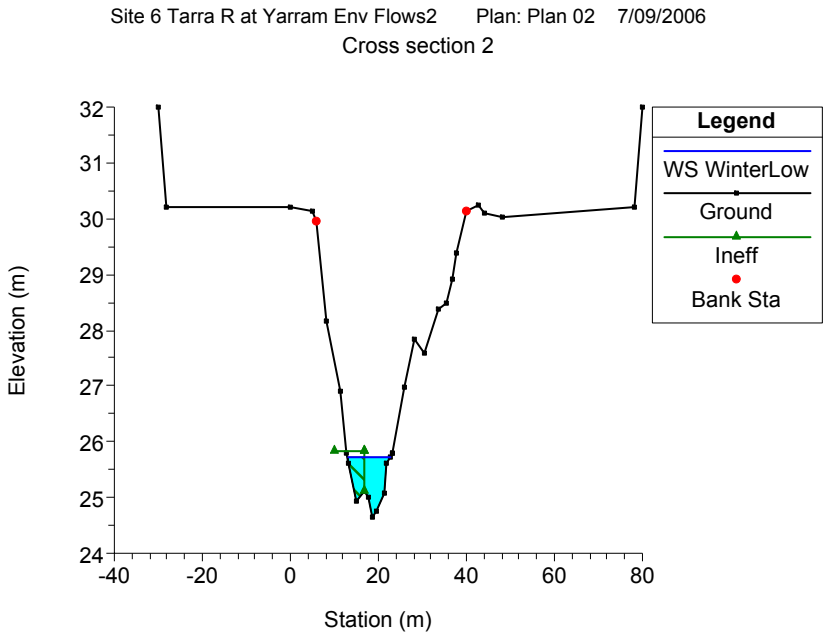
A total of four summer freshes have been recommended for this site. Three freshes of 54 ML/day lasting for six days are required and one fresh of 150 ML/day lasting four days is required. The 150 ML/day fresh is an important flow for trigging release of eggs in Australian Grayling (*Prototroctes maraena*) and transporting the eggs and larvae downstream to the estuary. The smaller freshes will provide channel maintenance, cover benches and maintain benthic habitat. Figure 3-30 shows the area of channel inundated under both flows. The spells and duration plots for each fresh are shown in Appendix B.



- **Figure 3-30 Water depth at cross section 2 under 54 ML/d (left) and 150 ML/d for Reach 6.**

Winter low flow

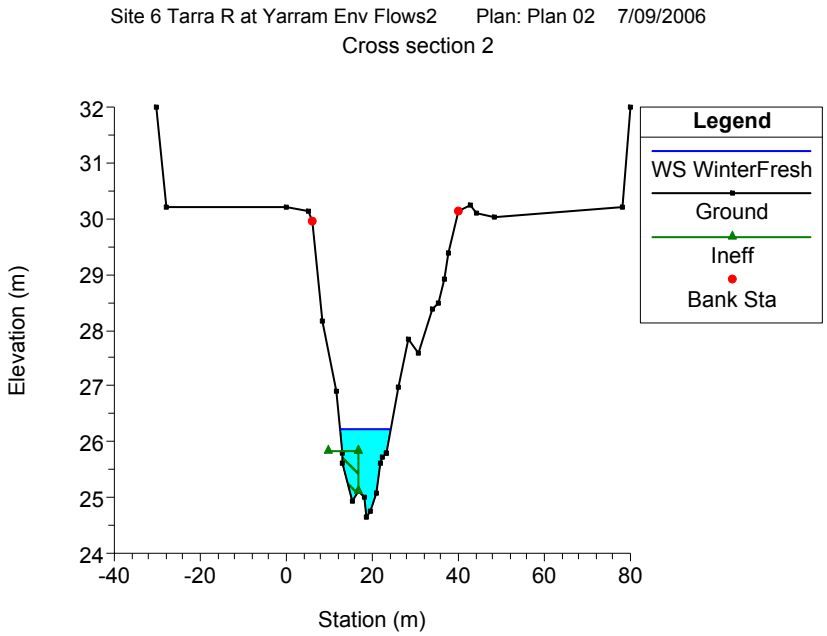
A winter low flow of 32 ML/day or as naturally occurs has been recommended for this reach. This is equivalent to the 80th percentile winter flow. Winter low flows are aimed at maintaining and improving existing instream and riparian vegetation and maintaining longitudinal connectivity within the channel. Figure 3-31 shows the area of channel inundated during a low winter flow.



- **Figure 3-31 Water depth at cross section 2, Reach 6 under winter low flow.**

Winter fresh

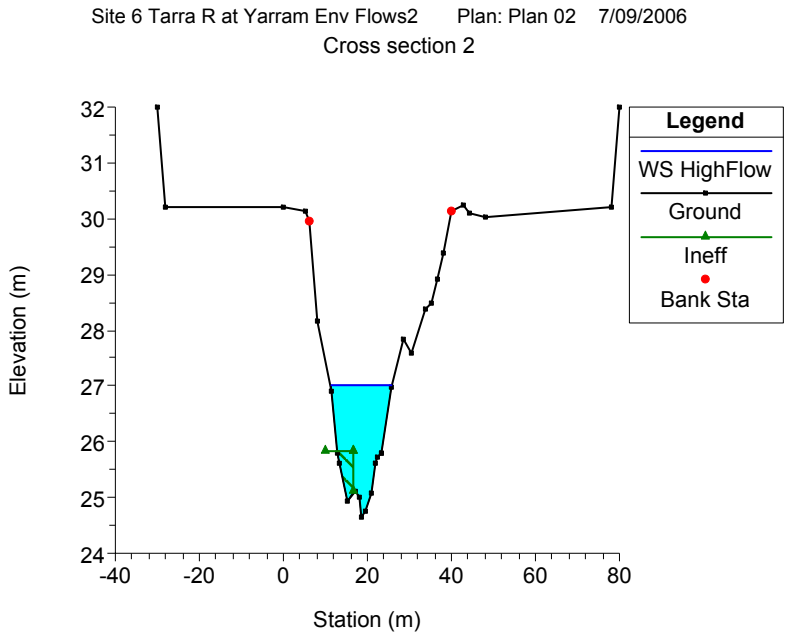
Three freshes a year of 143 ML/day are required during winter in this reach. A fresh should last for five days (Appendix B). Three to four freshes a year naturally occur in this reach. A winter fresh is aimed at meeting the environmental objectives for this reach of restoring instream habitat condition, maintaining the current diversity of native fish communities and maintaining and improving the existing instream and riparian vegetation. Winter freshes will also provide some disturbance which will entrain organic matter and inundate the area of gravel and built up material in the channel (Figure 3-32).



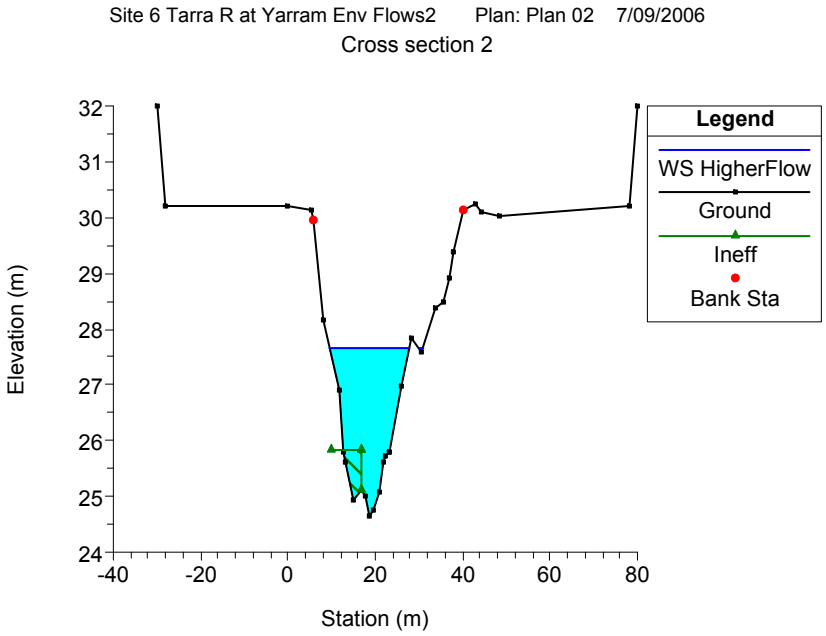
- **Figure 3-32 Water depth at cross section 2, Reach 6 under winter fresh.**

Winter high flow and high flow 2

A winter high flow of 450 ML/day needs to occur once per year in this reach and last for four days. A flow of this size should occur between September and October and has been recommended to allow for native fish movement upstream. This flow is particularly necessary at this time if the recommendation for a higher annual flow of 1100 ML/day lasting two days does not occur during spring. The winter high flows will facilitate transport of sediment downstream and provide channel maintenance. Figure 3-33 shows the area of inundation for a winter high flow (450ML/day) and Figure 3-34 shows the area of inundation for a high flow 2 of 1100 ML/day.



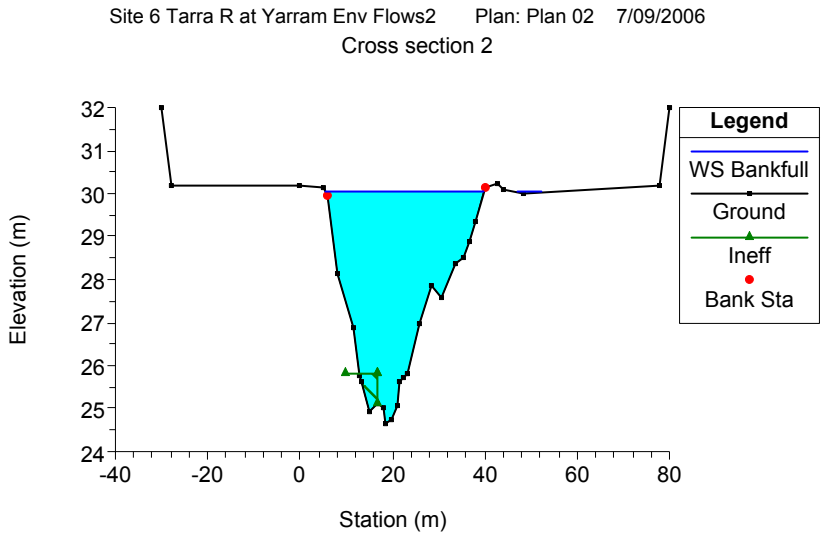
- **Figure 3-33 Water depth at cross section 2, Reach 6 under high flow (450 ML/day).**



- **Figure 3-34 Water depth at cross section 2, Reach 6 under high flow 2 (1100 ML/day).**

Bankfull flow

A bankfull flow of 5000 ML/day once every three years for one to two days is recommended for this reach. A flow of this magnitude is aimed at restoring instream habitat condition by developing the physical form of the channel. Flow would reach the top of the high flow channel and would transport sediments and organic material out of the reach. Figure 3-35 shows the area of inundation under a bankfull flow.



- **Figure 3-35 Water depth at cross section 2, Reach 6 under bankfull flow.**

3.6.3 Current compliance against flow recommendations

The flow recommendations for Reach 6 were assessed against the current flow regime. Compliance for summer freshes and bankfull flows was very good and generally good for summer high, winter low and winter freshes. Compliance for the higher winter volume of 1100 ML/day occur only 58% of the time and 8 % of time did not occur for the required frequency. Volumes for summer low flows and winter high flow (450 ML/day) complied often but were less likely to occur than the other flow components. Compliance rates for this reach are probably related to high water demands through this reach.

- **3-18 Compliance of flow recommendations with current flow regime for Reach 6 (volume= ML/day).**

Component	Months	Flow Rec		Or Natural	Compliance
Summer low	Dec – May	Volume	13	Yes	*67%*
Summer fresh	Dec – May	Volume	54		*100%*
		Frequency	3	Yes	*100%*
		Duration	6	Yes	*100%*
Summer high	Dec – May	Volume	150		*79%*
		Frequency	1	Yes	*97%*
		Duration	4	Yes	*89%*
Winter low	Jun – Nov	Volume	32	Yes	*76%*
Winter fresh	Jun – Nov	Volume	143		*92%*
		Frequency	3	Yes	*90%*
		Duration	5	Yes	*100%*
Winter high	Jun – Nov	Volume	450		*74%*
		Frequency	1	Yes	*97%*
		Duration	4	Yes	*100%*
Winter High 2	Jun – Nov	Volume	1100		*58%*
		Frequency	1	Yes	*92%*
		Duration	2	Yes	*100%*
Bankfull	Jun – Nov	Volume	5000		*100%*
		Frequency	0.3	Yes	*100%*
		Duration	2	Yes	*100%*

LEGEND							
Mostly complies		Greater than	95	%			of time / years / events
Frequently complies		Between	76	&	95	%	of time / years / events
Often complies		Between	51	&	75	%	of time / years / events
Occassionally complies		Between	26	&	50	%	of time / years / events
Rarely complies		Between	5	&	25	%	of time / years / events
Never complies		Between	0	&	5	%	of time / years / events

3.7 Reach 7 Tarra River at Missens Lane

3.7.1 Current condition

A detailed description of the current condition of Reach 7 was provided in the *Issues Paper*. A summary is provided in Table 3-19 below.

Table 3-19 Current condition of Reach 7: Tarra River at Missens Lane.

Aspect	Current condition
Hydrology	■ Difference between current and natural flows, high demands through this reach and upstream.
Geomorphology	■ Willow infestations in channel and cattle access to stream. Some willows have been removed. Old channels visible on adjacent floodplain and are still connected to channel at their lower ends.
Water quality	■ Nutrients, cattle access, degraded riparian zone, algal mats instream.
Fish	■ Increased frequency of cease-to-flow events, good to moderate instream habitat but reduced quality of habitat due to cattle access, willow encroachment and degradation of riparian zone.
Macroinvertebrates	■ Water quality influences, degraded riparian zone, willow infestations in stream.
Instream and riparian flora	■ Exotic plants, grazing, nutrient enrichment, some loss of connectivity.

3.7.2 Flow recommendations

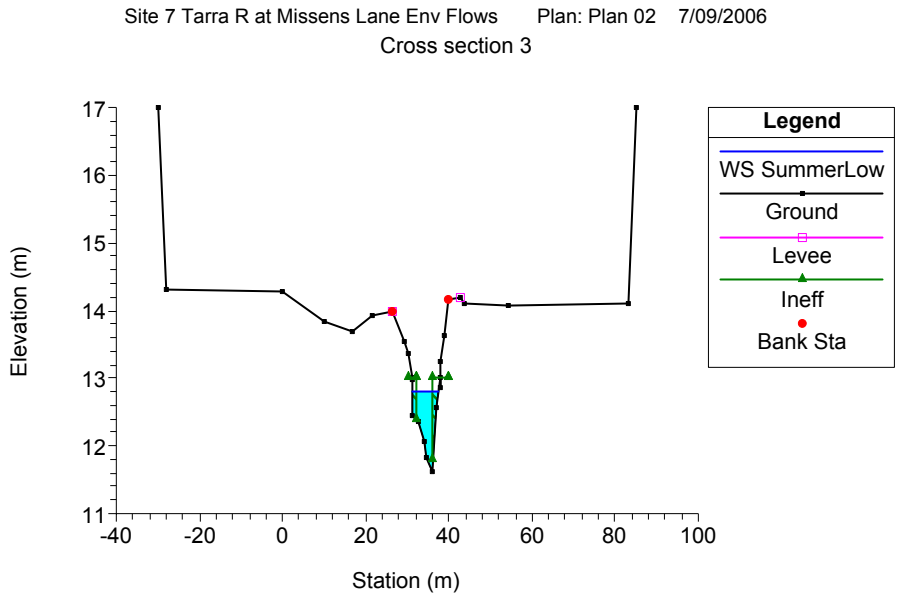
The environmental flow recommendations for Reach 7 are summarised in Table 3-20. The current and natural flows for Tarra River at Missens Lane are based on the same flow data as Reach 6.

Table 3-20 Summary of flow recommendations for Reach 7: Tarra River at Missens Lane.

Reach 7 Tarra River at Missens Lane				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Low flow	13 ML/day or natural		
	Freshes	53 ML/day	3 per year or as natural	6 days or as natural
		150 ML/day	1 per year or as natural	4 days or as natural
Winter	Low flow	32 ML/day or natural		
	Freshes	143 ML/day	3 per year or as natural	5 days or as natural
	High	None recommended		
	Bankfull	450 ML/day	1 per year or as natural	4 days or as natural
	Overbank	1100 ML/day	1 per year or as natural	2 days or as natural

Summer low flow

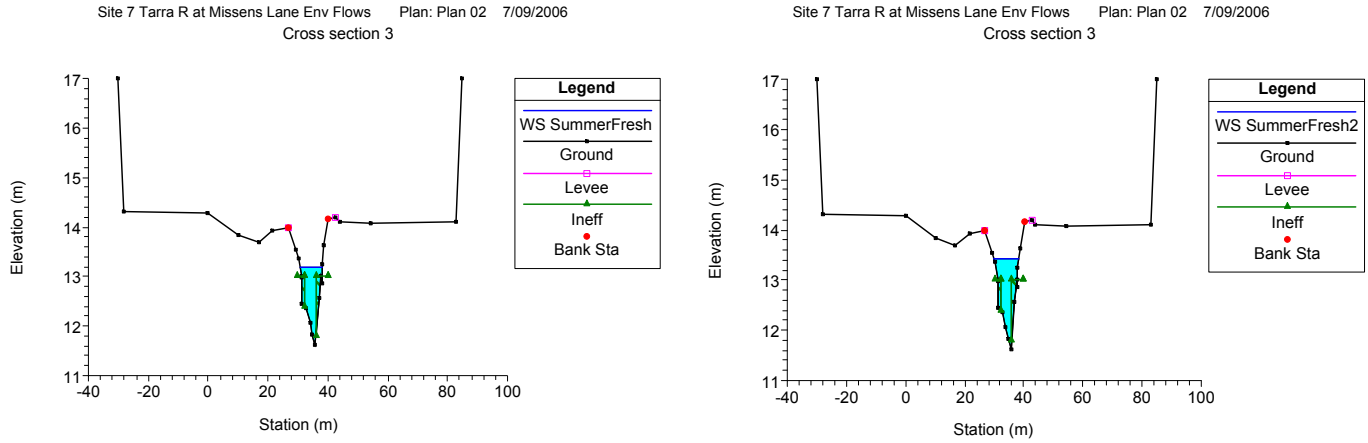
A summer low flow of 13 ML/day or as naturally occurs has been recommended for this reach (Appendix B). This is equivalent to 80th percentile summer flow. This reach is characterised by healthy instream vegetation and the summer low flow objectives are aimed at maintaining and improving the macrophyte community and the riparian vegetation as well as providing accessibility for fish to suitable pool habitat. Figure 3-36 shows the area of the channel covered by a summer low flow.



- **Figure 3-36 Water depth at cross section 3, Reach 7 under summer low flow.**

Summer fresh

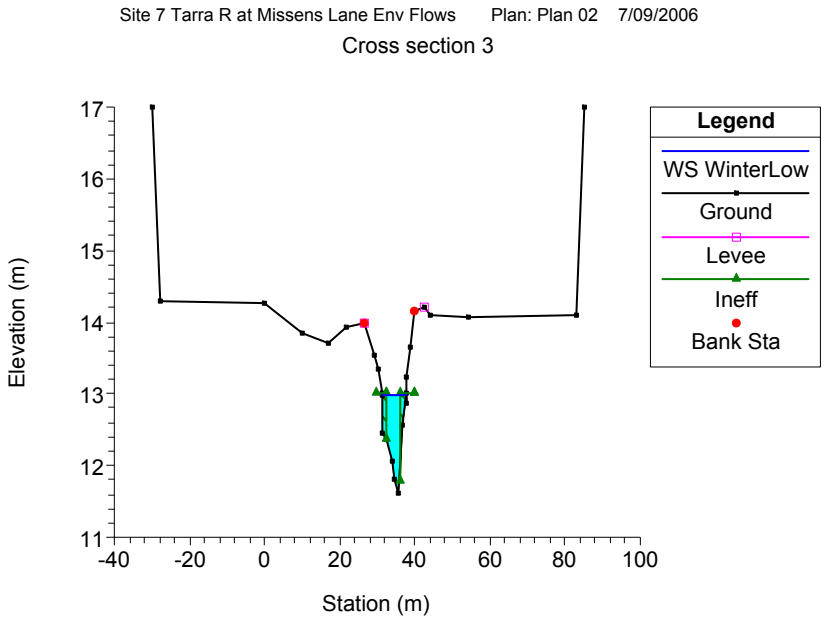
Three summer freshes of 53 ML/day have been recommended for this reach, each lasting for six days (Appendix B). An additional fresh of 150 ML/day lasting four days has also been recommended. The larger fresh is aimed at providing a flow to trigger release of eggs by Australian Grayling and the movement of eggs and larvae downstream to the estuary. Summer freshes also provide channel maintenance, create a disturbance and increase available habitat. The area of channel inundated by both freshes are shown in Figure 3-37.



- **Figure 3-37 Water depth at cross section 3 Reach 7, for 53 ML/d and 150 ML/d.**

Winter low flow

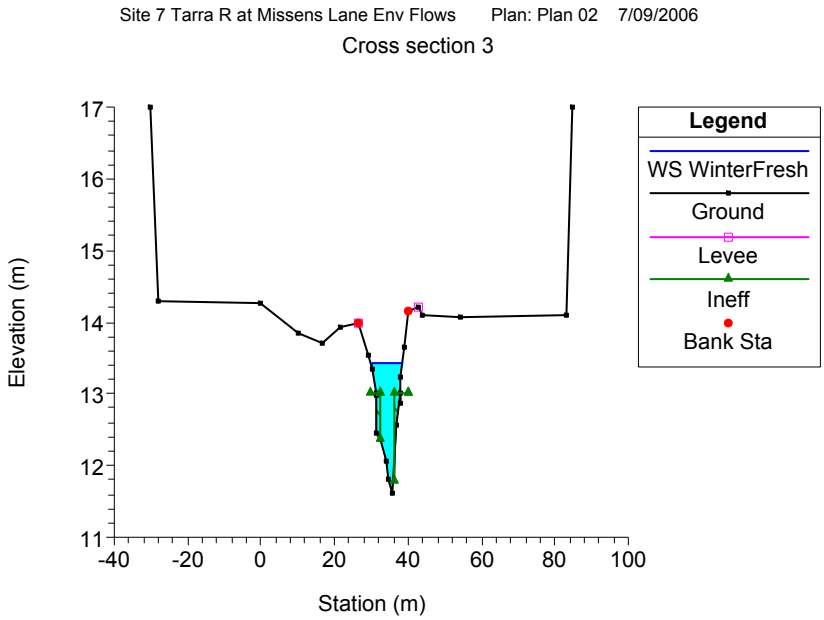
A winter low flow of 32 ML /day or as naturally occurs has been recommended for this reach. The main aim of the winter low flow is to maintain and improve the existing instream macrophytes and to provide additional area for colonisation by desirable rushes and sedges. The area of channel and bank inundated by a winter low flow is shown in Figure 3-38.



- **Figure 3-38 Water depth at cross section 3, Reach 7 under winter low flow.**

Winter fresh

A winter fresh of 143 ML/day, three times a year for five days has been recommended for this reach (Appendix B). This is a mid bank flow and is aimed at rehabilitating instream habitat condition by maintaining the channel, maintaining and improving instream macrophyte communities and riparian vegetation and maintaining benthic habitat for fish and macroinvertebrates. A winter fresh also entrains sediment and organic material which prevents smothering of benthic habitat. Figure 3-39 shows the area of channel inundated by 143 ML/day.



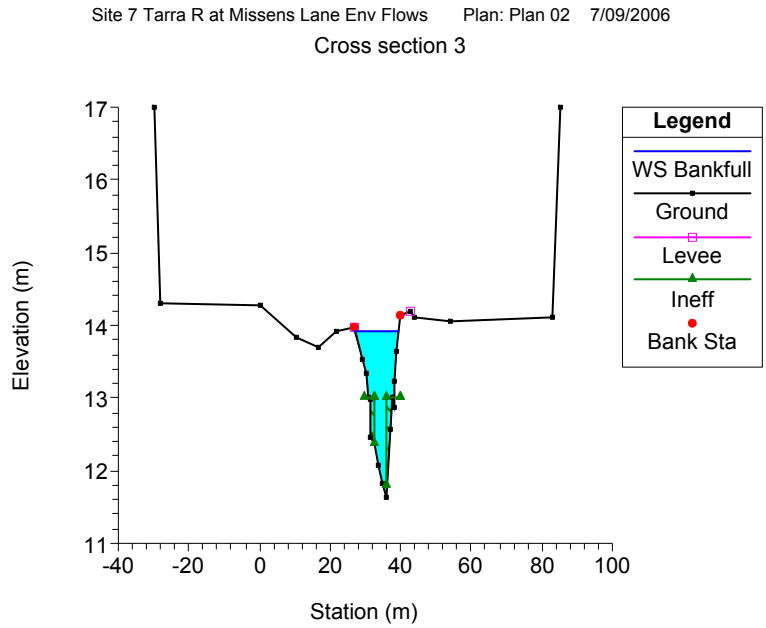
- **Figure 3-39 Water depth at cross section 3, Reach 7 under winter fresh.**

Winter high flow

High flows in winter should be as naturally occurs within the flow regime.

Bankfull

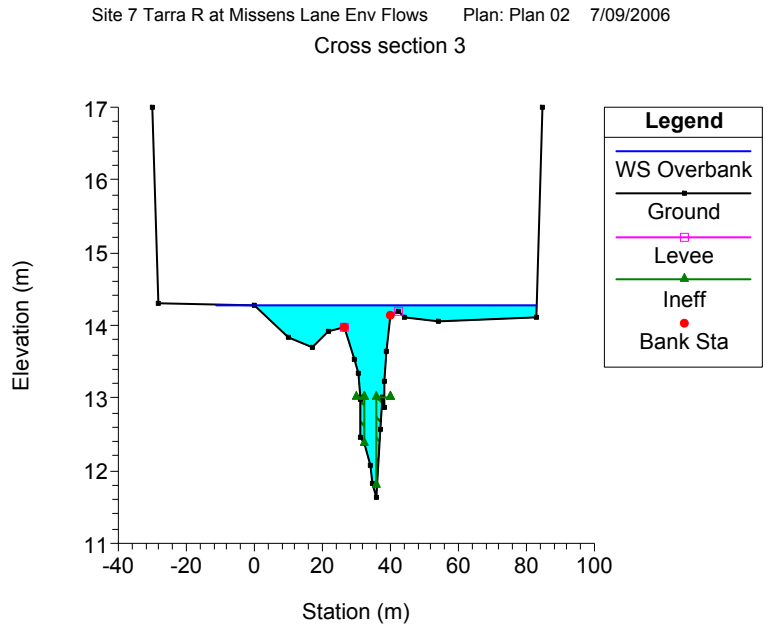
A bankfull flow of 450 ML/day once a year lasting for four days has been recommended for this reach. It is important this flow occurs between September and October to allow for fish movement upstream (in particular Australian Grayling). This flow is also required if a higher flow does not occur during spring. A flow of this size will develop channel form and start to fill the channels connecting the floodplain wetlands. Figure 3-40 shows the area of bank and channel inundated by this flow.



- **Figure 3-40 Water depth at cross section 3, Reach 7 under bankfull flow.**

Overbank

An overbank flow of 1100 ML/day is required once per year lasting for two days in this reach (Appendix B). This flow is important for providing connectivity with the floodplain wetlands located adjacent to the channel. A flow of this size will provide sediment and nutrient exchange between the floodplain and the channel as well as channel maintenance. Figure 3-41 shows the area of the channel and floodplain inundated at 1100 ML/day.



- **Figure 3-41 Water depth at cross section 3, Reach 7 under overbank flow.**

3.7.3 Current compliance against recommendations

The flow recommendations for Reach 7 were assessed against the current flow regime (Table 3-21). In general, compliance for frequency and duration was quite good however volumes required for summer low and overbank flows do not occur about 35% of the time. Volumes for winter low flow and winter freshes occurred 76% of the time under the current flow regime.

- **Table 3-21 Compliance of flow recommendations to current flow regime for Reach 7 (volume= ML/day).**

Component	Months	Flow Rec		Or Natural	Compliance
Summer low	Dec - May	Volume	13	Yes	*67%*
Summer fresh	Dec - May	Volume	53		*95%*
		Frequency	3	Yes	*100%*
		Duration	6	Yes	*100%*
Summer high	Dec - May	Volume	150		*95%*
		Frequency	1	Yes	*100%*
		Duration	4	Yes	*98%*
Winter low	Jun - Nov	Volume	32	Yes	*76%*
Winter fresh	Jun - Nov	Volume	143		*92%*
		Frequency	3	Yes	*93%*
		Duration	5	Yes	*102%*
Bankfull	Jun - Nov	Volume	450		*76%*
		Frequency	1	Yes	*97%*
		Duration	4	Yes	*103%*
Overbank		Volume	1100		*63%*
		Frequency	1	Yes	*92%*
		Duration	2	Yes	*99%*

LEGEND							
Mostly complies		Greater than	95	%			of time / years / events
Frequently complies		Between	76	&	95	%	of time / years / events
Often complies		Between	51	&	75	%	of time / years / events
Occassionally complies		Between	26	&	50	%	of time / years / events
Rarely complies		Between	5	&	25	%	of time / years / events
Never complies		Between	0	&	5	%	of time / years / events

4. Supporting recommendations

The supporting recommendations provided for this study are general to the Tarra River and its tributaries. The Tarra River at the picnic ground was in very good condition, which is to be expected given the river flows out of the National Park at this location, the lack of upstream water demands and little or no cattle grazing. However, the other reaches located within the middle and lower reaches of the catchment have common problems that are generally catchment wide. The key issues are willow infestations and weeds, stock access and associated poor water quality, degraded riparian zones and fish barriers.

The West Gippsland CMA is already addressing a number of these issues. Willows have been removed from 70% of Tarra River and work is on-going. Follow-up revegetation has occurred or is planned at these sites as well as fencing and stock exclusion. Removal of willows benefits the aquatic habitat and the physical process in the channel.

There are a number of areas in the catchment where fish barriers are potentially a problem. These include the weir at the Yarram gauge. An assessment of the potential for fish passage at this weir is recommended. In addition, removal of old weirs at gauges that are no longer used (e.g Greigs Creek) is also recommended. Provision for movement of Australian Grayling in the middle and lower reaches of the Tarra River is important and needs to be encouraged by providing suitable seasonal flows and reducing barriers to movement.

Freshwater inflows to the estuary are recognised as important for maintaining estuarine function. The greatest impact of reduced freshwater inflows to the estuary is a reduction in the production of fish, shellfish and crustaceans which, apart from being ecologically important, are also valued for commercial and recreational fishing (Scheltinga *et al* 2006). Freshwater inflows are required at least once a year to flush the salt wedge out of the lower river channel, to maintain the mangrove and saltmarsh communities adjacent to the channel in the lower reaches of the Tarra River and to provide water to the brackish and freshwater wetlands. These flows will also provide required nutrients and other organic matter to the estuary. However, the flow volumes required and their adequacy for maintaining estuarine function have not been modelled as part of this study.

There is some evidence of declining in baseflow in the study area (SKM, 2005). However, although there is some circumstantial evidence to suggest that these declines are at least partially due to groundwater level decline, the absence of data from key recharge areas meant the study was unable to conclusively determine the relative contributions of climate and groundwater level decline on observed declines in baseflow or predict future impacts. In addition, the REALM model assessed the gauged surface water trend versus estimated natural flows were examined and it was concluded that whilst a downward trend was evident, it was well within the natural variability of

the data, and that there would be difficulty in separating out the impact of offshore extractions from other trends (SKM, 2006c).

The key conclusion from both studies is that there is likely to have been a reduction in the baseflow component of stream flow in the Tarra River and catchments over the last 50 years. The reduction in baseflow is likely to be mainly caused by a reduction in rainfall over this period. Although there is no direct evidence, the circumstantial evidence suggests that the decline in baseflow may also be contributed to a smaller extent by declines in groundwater levels resulting from off-shore gas and oil extraction and local groundwater extraction for irrigation.

To better estimate past, present and future changes to baseflow across the study area resulting from Latrobe Group Aquifer pressure decline on-ground works and monitoring of groundwater levels in the recharge areas, accompanied by installation of stream flow gauges immediately upstream and downstream of the recharge areas is recommended.

5. References

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SKM (2006a) Environmental flow determination for the Tarra River. Site Paper. Report prepared by Sinclair Knight Merz for West Gippsland Catchment Management Authority.

SKM (2006b). Environmental flow determination for the Tarra River. Issues Paper. Report prepared by Sinclair Knight Merz for West Gippsland Catchment Management Authority.

SKM (2006c). Tarra River REALM Development and Estimation of Daily Flows. Report prepared for West Gippsland CMA.

Appendix A Environmental flow objectives for the Tarra River

Table A-5-1: Environmental flow objectives for the Tarra River

Note: The number for each objective in Tables 12-2 to 12-7 refers to the asset, the number of the reach and the objective number. For example, the first objective for a geomorphology asset in Reach 1 is recorded as G1-1.

Reach 1 –Tarra River at picnic ground on Tarra Valley Road						
Asset	**Objective**	**No.**	**Function**	**Flow component**	**Timing**	**Expected response**
Geomorphology	Maintain current hydraulic geometry	G1-1	Channel forming process	Bankfull	Winter	■ Maintain channel form
		G1-2	Channel maintenance	Freshes / high flows	Winter	■ Maintain thalweg / channel complexity
Vegetation	1. Maintain vegetation communities typical of a 1st or 2nd order headwater stream 2. Maintain existing biofilms on submerged surfaces 3. Rehabilitate native riparian vegetation 4. Minimise encroachment of exotic species in stream-side zone	V1-1	Maintain wet biofilms on submerged rocks and interstitial surface sediments	Low flow	Summer	■ Because of heavy shading, the main in-stream vegetation in this reach is biofilms; summer flows will maintain these communities. ■ The riparian zone is heavily colonised by exotic taxa; winter flow flows will maintain and increase native rushes and sedges and winter high-flows will scour undesirable exotic species. ■ Continued weed invasion is expected because of proximity of the site to roads and recreational activities.
		V1-2	Increase area of wetted surfaces for biofilms	Freshes	Summer	
		V1-3	Maintain existing riparian vegetation and increase area for riparian colonisation by desirable rushes and sedges	Low flow and freshes	Winter	
		V1-4	Control encroachment of exotic species	Bankfull	Winter	
Fish	Maintain current diversity of native fish community	F1-1	Access to suitable pool habitat	Low flow	Summer	■ No loss of current diversity ■ No excessive accumulation of biofilm or sediment on benthic surfaces. ■ Movement opportunities provided for various life history stages.
		F1-2	Maintenance of benthic habitat	Freshes	All year	
		F1-3	Maintain opportunities for movement	High flows	Winter & spring	
Water quality	Maintain current water quality	W1-1	Connecting flow sufficient to maintain water quality	Low	Summer	■ Current good water quality would be maintained during summer low flow periods.
		W1-2	Flushing of pools to oxygentate substrate	Low	Summer	
Macroinvertebrates	Maintain current macroinvertebrate diversity	M1-1	Provide suitable habitat	Low	Summer	■ Protects current good diversity and maintains habitat and macroinvertebrate communities.
		M1-2	Disturbance to mix pools and entrained material	Fresh	Summer	
		M1-3	Disturbance to turn rocks and release entrained material	Fresh/high flow	Winter	

Reach 2 – Macks Creek on McKenzie Road at the 'Poplars'.						
Asset	**Objective**	**No.**	**Function**	**Flow component**	**Timing**	**Expected response**
Geomorphology	Rehabilitation of channel after willow removal	G2-1	Channel forming processes	Bankfull	Winter	■ Develop / maintain channel form
		G2-2	Channel maintenance	Freshes / high flows	Winter	■ Maintain thalweg / channel complexity, inundate bars
		G2-3	Connection with floodplain	Overbank flow	Winter	■ Maintain overbank flows at frequency that currently occurs. Develop / maintain channel, sediment exchange with floodplain / floodplain development
Vegetation	Provide a flow regime to help re-establish native in-stream plant communities and a healthy riparian zone by taking advantage of current willow-control measures	V2-1	Establish and maintain in-stream (submerged) rooted macrophytes	Low flow	Summer	■ There is no native in-stream or riparian vegetation at this reach, so flows will be needed to establish desirable native vegetation communities whilst not resulting in excessive erosion. ■ Given the absence of any floodplain vegetation features or wetlands, overbank flows are not warranted at this stage but depending on rehabilitation could be recommended in the future. ■ Continued willow and grazing control, combined with active revegetation, is required also.
		V2-2	Provide colonisable habitat on benches for emergent aquatic vegetation such as rushes and sedges	Freshes	Summer	
		V2-3	Establish and maintain in-stream (submerged) rooted macrophytes	Low flow	Winter	
		V2-4	Provide colonisable habitat on benches for emergent aquatic vegetation such as rushes and sedges, as well as possible riparian trees along stream-side zone	Freshes	Winter	
Fish	Maintain current diversity of native fish community	F2-1	Access to suitable pool habitat	Low flow	Summer	■ No loss of current diversity.
		F2-2	Maintenance of benthic habitat	Freshes	All year	■ No excessive accumulation of biofilm or sediment on benthic surfaces.
		F2-3	Maintain opportunities for movement	High flows	Winter & spring	■ Movement opportunities provided for various life history stages.
Water quality	Improve water quality	W2-1	Improve water quality by mixing	Fresh	Summer	■ Flushing and turn over of pools, improve dissolved oxygen levels in pools. Improves habitat for fish and macroinvertebrates
		W2-2	Minimise increases in temperature	Low flow	Summer	
Macroinvertebrates	Improve macroinvertebrate diversity	M2-1	Create disturbance and facilitate decomposition of organic material	Fresh	All year	■ Provides access to substrate and benthic habitat ■ Prevents sediment accumulation that can smother habitat, assists in maintaining suitable habitat.
		M2-2	Transport of silt/sediment downstream	High flows	Winter	

Reach 3 – Greig Creek at Greig Creek Road.						
Asset	**Objective**	**No.**	**Function**	**Flow component**	**Timing**	**Expected response**
Geomorphology	Maintain current hydraulic geometry	G3-1	Channel forming processes	Bankfull	Winter	■ Maintain channel form
		G3-2	Channel maintenance	Freshes	Winter / Summer	■ Maintain thalweg / channel complexity
		G3-3	Desilting / disturbance	Freshes	Winter / Summer	■ Flush fine sediment and organic material from pools
Vegetation	Maintain and improve remnant in-stream and stream-side vegetation communities and provide a flow regime to facilitate success of any future revegetation activities	V3-1	Establish and maintain in-stream (submerged) rooted macrophytes	Low flow	Summer	■ Almost all this reach has been cleared for pasture and parts of the stream channel are deeply incised: summer and winter low flows and freshes will be required to maintain plants established as part of any future revegetation activities. ■ Improvement in vegetation communities will be possible only with simultaneous grazing control and willow removal; active revegetation may be required also.
		V3-2	Provide colonisable habitat on benches for emergent aquatic vegetation such as rushes and sedges	Freshes	Summer	
		V3-3	Establish and maintain in-stream (submerged) rooted macrophytes	Low flow	Winter	
		V3-4	Provide colonisable habitat on benches for emergent aquatic vegetation such as rushes and sedges, as well as possible riparian trees along stream-side zone where the stream is not too incised	Freshes	Winter	
Fish	Maintain current diversity of native fish community	F3-1	Access to suitable pool habitat	Low flow	Summer	■ No loss of current diversity. ■ No excessive accumulation of biofilm or sediment on benthic surfaces. ■ Movement opportunities provided for various life history stages.
		F3-2	Maintenance of benthic habitat	Freshes	All year	
		F3-3	Maintain opportunities for movement	High flows	Winter & spring	
Water quality	Improve water quality	W3-1	Improve water quality by mixing	Fresh	Summer	■ Flushing and turn over of pools, improve dissolved oxygen levels in pools. Improves habitat for fish and macroinvertebrates
		W3-2	Minimise increases in temperature	Low flow	Summer	
Macroinvertebrates	Improve macroinvertebrate diversity	M3-1	Provide suitable habitat	Low	Summer	■ Maintains and improves diversity and maintains habitat and macroinvertebrate communities.
		M3-2	Disturbance to mix pools and entrained material	Fresh	Summer	
		M3-3	Disturbance to turn rocks and release entrained material	Fresh/high flow	Winter	

Reach 4 – Spring Creek at 'Beaumont' and Bodman Creek at Hylands Way.						
Asset	**Objective**	**No.**	**Function**	**Flow component**	**Timing**	**Expected response**
Geomorphology	Restore instream habitat condition	G4-1	Channel forming processes	Bankfull	Winter	■ Develop channel form
		G4-2	Channel maintenance	Freshes / High flow	Winter / Summer	■ Maintain channel
Vegetation	For Spring Creek: maintain and improve any remnant in-stream and stream-side native vegetation communities and provide a flow regime to facilitate success of any future revegetation activities For Bodman Creek: maintain and improve existing in-stream, stream-side and riparian vegetation	V4-1	Establish and maintain in-stream (submerged) and stream-side (emergent) macrophytes	Low flow	Summer	■ Responses will vary from Spring Creek to Bodman Creek. ■ At Spring Creek, almost all the reach has been cleared for pasture: summer and winter low flows and freshes will be required to maintain plants established as part of any future revegetation activities. Improvement in vegetation communities will be possible only with simultaneous grazing control and willow removal: probably revegetation activities will be required too to colonise the bare riparian zone. ■ At Bodman Creek, the remnant in-stream and stream-side vegetation is in better condition and will benefit from summer and winter low flows and freshes. Bankfull winter flows here will improve the recruitment of young trees into the riparian zone. Grazing control is required to maximise these outcomes.
		V4-2	Provide colonisable habitat on benches for emergent aquatic vegetation such as rushes and sedges	Freshes	Summer	
		V4-3	Establish and maintain in-stream (submerged) and stream-side (emergent) macrophytes	Low flow	Winter	
		V4-4	Provide colonizable habitat on benches for emergent aquatic vegetation such as rushes and sedges, as well as riparian trees along stream-side zone	Freshes	Winter	
		V4-5	Provide recruitment opportunities for riparian vegetation	Bankfull	Winter	
Fish	Restore diversity of native fish community	F4-1	Disturbance to prevent trout colonisation	Cease-to-flow	Summer	■ Trout cannot establish in Spring Creek. ■ Increased diversity of small bodied native fish. ■ No excessive accumulation of biofilm or sediment on benthic surfaces. ■ Movement opportunities provided for various life history stages.
		F4-2	Access to suitable pool habitat	Low flow	Summer	
		F4-3	Improve benthic habitat	Freshes	All year	
		F4-4	Maintain opportunities for movement	High flows	Winter & spring	
Water quality	Improve water quality	W4-1	Improve water quality by mixing	Fresh	Summer	■ Flushing and turn over of pools, improve dissolved oxygen levels in pools. Improves habitat for fish and macroinvertebrates
		W4-2	Minimise increases in temperature	Low flow	Summer	
Macroinvertebrates	Improve macroinvertebrate diversity	M4-1	Create disturbance and facilitate decomposition of organic material	Fresh	All Year	■ Provides access to substrate and benthic habitat ■ Prevents sediment accumulation that can smother habitat, assists in maintaining suitable habitat.
		M4-2	Transport of silt/sediment downstream	High flows	Winter	

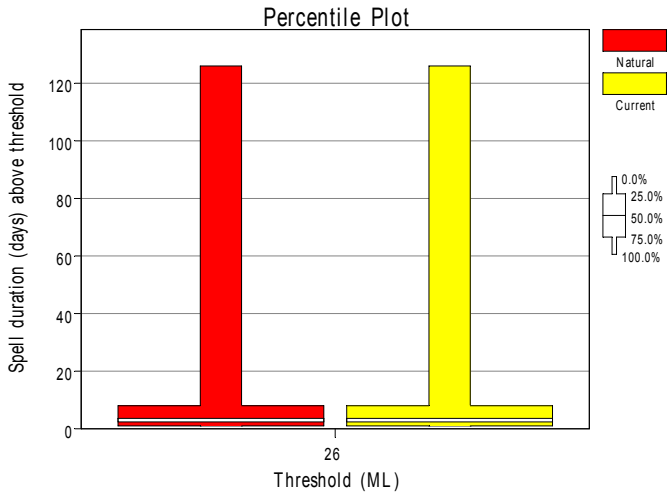
Reach 6 – Tarra River at Yarram Gauge.						
Asset	**Objective**	**No.**	**Function**	**Flow component**	**Timing**	**Expected response**
Geomorphology	Restore instream habitat condition	G6-1	Channel forming processes	Bankfull	Winter	■ Develop channel form
		G6-2	Channel maintenance	Freshes / High flow	Winter / Summer	■ Maintain channel
Vegetation	Maintain and improve existing in-stream, stream-side and riparian vegetation and provide a flow regime to facilitate success of any future revegetation activities	V6-1	Maintain and improve in-stream (submerged) and stream-side (emergent) macrophytes	Low flow	Summer	■ Almost all the reach has been cleared for pasture: summer and winter low flows and freshes will be required to maintain plants established as part of any future revegetation activities. ■ Freshes will be important for covering benches and facilitating more diverse stream-side plant communities. ■ Improvement in vegetation communities will be possible only with simultaneous grazing and weed control and probably also with revegetation activities.
		V6-2	Provide colonisable habitat on benches for emergent aquatic vegetation such as rushes and sedges	Freshes	Summer	
		V6-3	Maintain and improve in-stream (submerged) and stream-side (emergent) macrophytes	Low flow	Winter	
		V6-4	Provide colonizable habitat on benches for emergent aquatic vegetation such as rushes and sedges, as well as riparian trees along stream-side zone	Freshes	Winter	
Fish	Maintain current diversity of native fish community. Restore populations of Australian grayling & Cox's gudgeon	F6-1	Access to suitable pool habitat	Low flow	Summer	■ No loss of current diversity. ■ No excessive accumulation of biofilm or sediment on benthic surfaces. ■ Movement opportunities provided for various life history stages, particularly for Australian grayling larvae to descend to estuaries in Autumn.
		F6-2	Maintenance of benthic habitat	Freshes	All year	
		F6-3	Maintain opportunities for movement	High flows	Autumn, Winter & spring	
Water quality	Improve water quality	W6-1	Improve water quality by mixing	Fresh	Summer	■ Flushing and turn over of pools, improve dissolved oxygen levels in pools. Improves habitat for fish and macroinvertebrates
		W6-2	Minimise increases in temperature	Low flow	Summer	
Macroinvertebrates	Improve macroinvertebrate diversity	M6-1	Create disturbance and facilitate decomposition of organic material	Fresh	All Year	■ Provides access to substrate and benthic habitat ■ Prevents sediment accumulation that can smother habitat, assists in maintaining suitable habitat.
		M6-2	Transport of silt/sediment downstream	High flows	Winter	

Reach 7 – Tarra River at 'Greenmount' on Missens Lane.						
Asset	**Objective**	**No.**	**Function**	**Flow component**	**Timing**	**Expected response**
Geomorphology	Rehabilitate instream habitat condition	G7-1	Maintain connection with floodplain	Overbank flow	Winter	■ Maintain overbank flows at frequency that currently occurs. ■ Develop / maintain channel, sediment exchange with floodplain / connect with Billabong
		G7-2	Channel forming processes	Bankfull discharge	Winter	■ Develop channel form
		G7-3	Channel maintenance	Freshes	Winter / Summer	■ Maintain channel
Vegetation	Maintain and improve existing in-stream, stream-side and riparian vegetation. Inundate floodplain wetlands whilst ensuring they are not infested with willows	V7-1	Maintain and improve in-stream (submerged) and stream-side (emergent) macrophytes	Low flow	Summer	■ This reach was characterised by healthy in-stream macrophyte communities. They can be maintained with the appropriate water regime, but nutrient control may be needed as well to prevent overgrowth with macroalgae. ■ Willow and grazing control will be needed to maximise recovery of stream-side vegetation. ■ Floodplain wetlands are a feature of this site; overbank flows will provide them with an improved water regime. Grazing and nutrient control will be required, as well as willow control to prevent infestation of the rejuvenated wetlands.
		V7-2	Provide colonisable habitat on stream-side zone for emergent aquatic vegetation such as rushes and sedges	Freshes	Summer	
		V7-3	Establish and maintain in-stream (submerged) and stream-side (emergent) macrophytes	Low flow	Winter	
		V7-4	Provide colonisable habitat on benches for emergent aquatic vegetation such as rushes and sedges, as well as riparian trees along stream-side zone	Freshes	Winter	
		V7-5	Maintain connection of floodplain billabongs to river	Overbank flow	Winter	
Fish	Maintain current diversity of native fish community. Restore populations of Australian grayling & Cox's gudgeon	F7-1	Access to suitable pool habitat	Low flow	Summer	■ No loss of current diversity. ■ No excessive accumulation of biofilm or sediment on benthic surfaces. ■ Movement opportunities provided for various life history stages, particularly for Australian grayling larvae to descend to estuaries in Autumn.
		F7-2	Maintenance of benthic habitat	Freshes	All year	
		F7-3	Maintain opportunities for movement	High flows	Autumn, Winter & spring	
Water quality	Improve water quality	W7-1	Improve water quality by mixing	Fresh	Summer	■ Flushing and turn over of pools, improve dissolved oxygen levels in pools. Improves habitat for fish and macroinvertebrates
		W7-2	Minimise increases in temperature	Low flow	Summer	
Macroinvertebrates	Improve macroinvertebrate diversity	M7-1	Create disturbance and facilitate decomposition of organic material	Fresh	All Year	■ Provides access to substrate and benthic habitat ■ Prevents sediment accumulation that can smother habitat, assists in maintaining suitable habitat.
		M7-2	Transport of silt/sediment downstream	High flows	Winter	

Appendix B Spells plots for flow recommendations

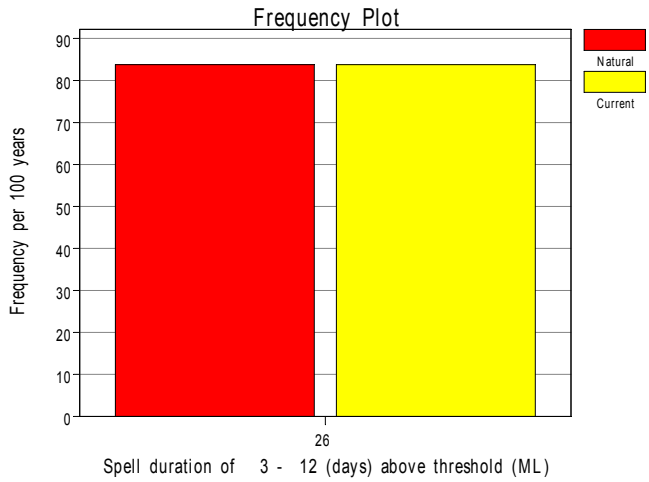
Reach 1 Tarra River at Picnic Ground

Summer Fresh



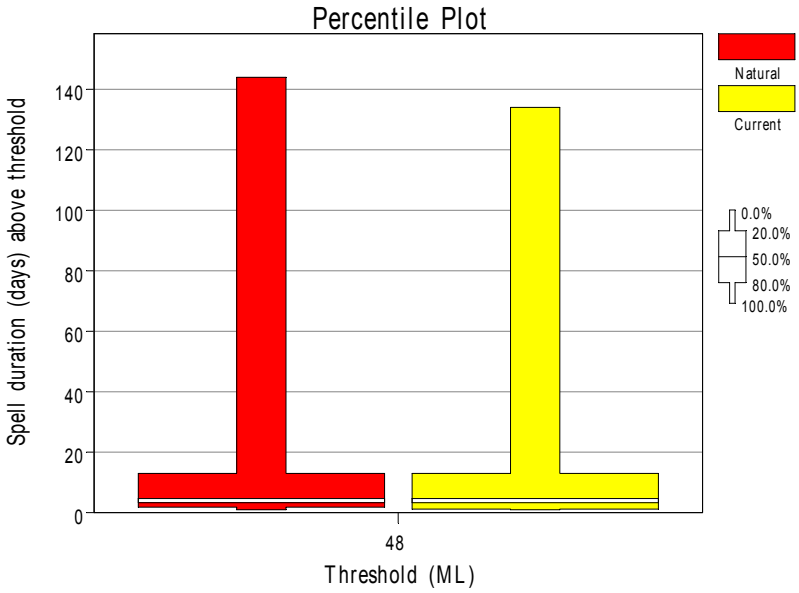
- **Figure B-1 Duration of spells 26 ML/d or greater under current and natural conditions for Reach 1 in summer/autumn.**

- **Figure B-2 Frequency of spells 26 ML/d or greater under current and natural conditions for Reach 1 in summer/autumn.**

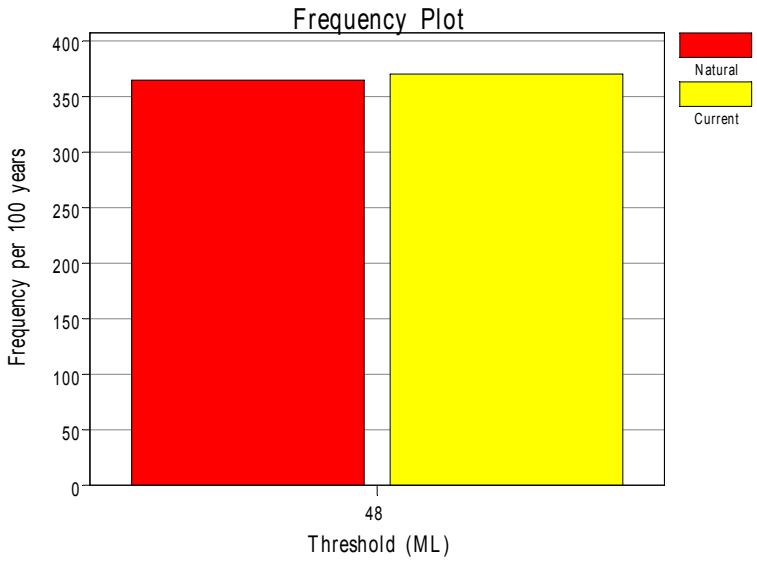


- **Figure B-3 Frequency of spells 26 ML/d or greater and lasting between 3 and 12 days under current and natural conditions for Reach 1 in summer/autumn.**

Winter fresh

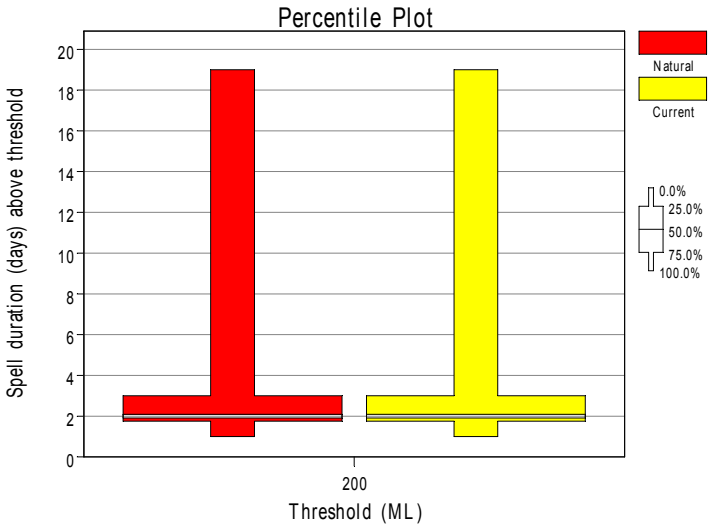


- **Figure B-4 Duration of spells 48 ML/d or greater under current and natural conditions for Reach 1 in winter/spring.**

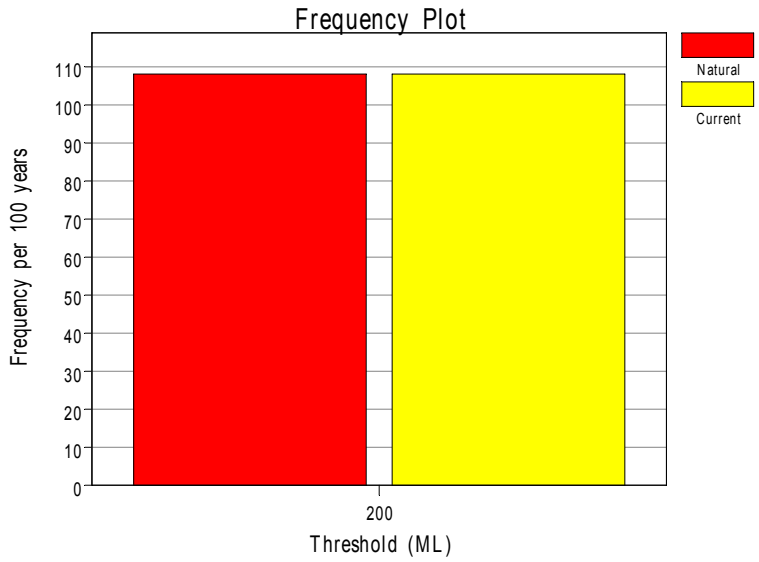


- **Figure B-5 Frequency of spells 48 ML/d or greater under current and natural conditions for Reach 1 in winter/spring.**

Winter high



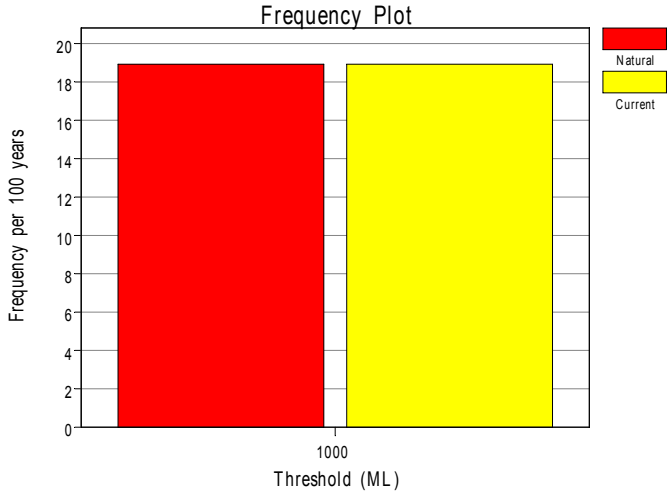
- **Figure B-6 Duration of spells 200 ML/d or greater under current and natural conditions for Reach 1 in winter/spring.**



- **Figure B-7 Frequency of spells 200 ML/d or greater under current and natural conditions for Reach 1 in winter/spring.**

Winter higher flow

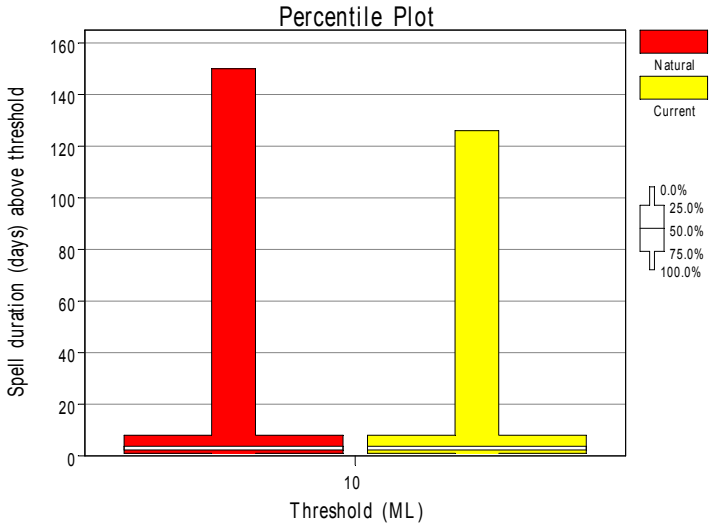
- **Figure B-8 Duration of flows 1000 ML/d or greater under current and natural conditions for Reach 1 in winter/spring.**



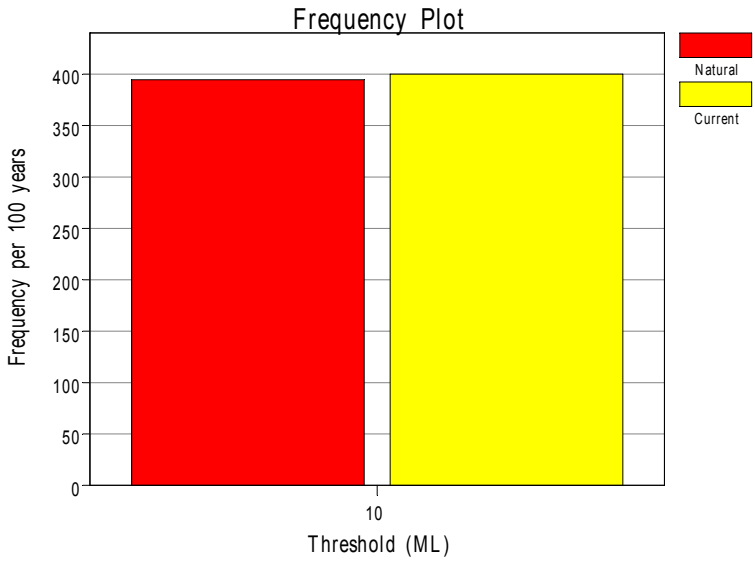
- **Figure B-9 Frequency of flows 1000 ML/d or greater under current and natural conditions for Reach 1 in winter/spring.**

Reach 2 Macks Creek

Summer fresh

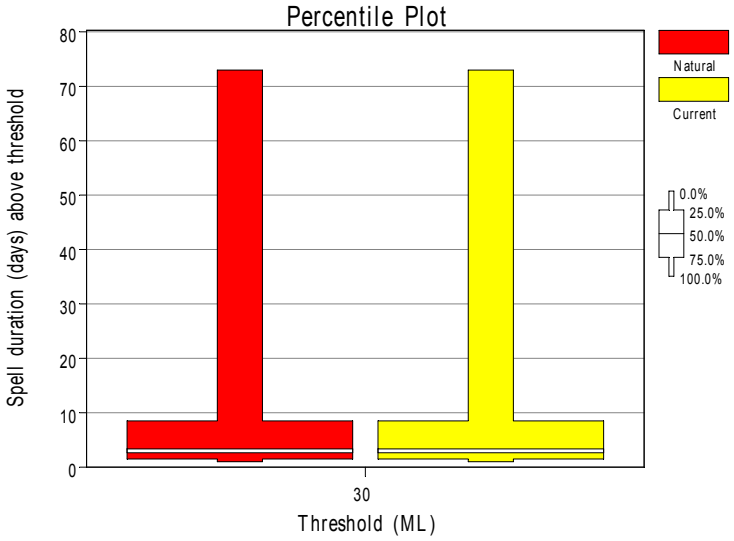


- **Figure B-10 Duration of spells 10 ML/d or greater under current and natural conditions for Reach 2 in summer/autumn.**

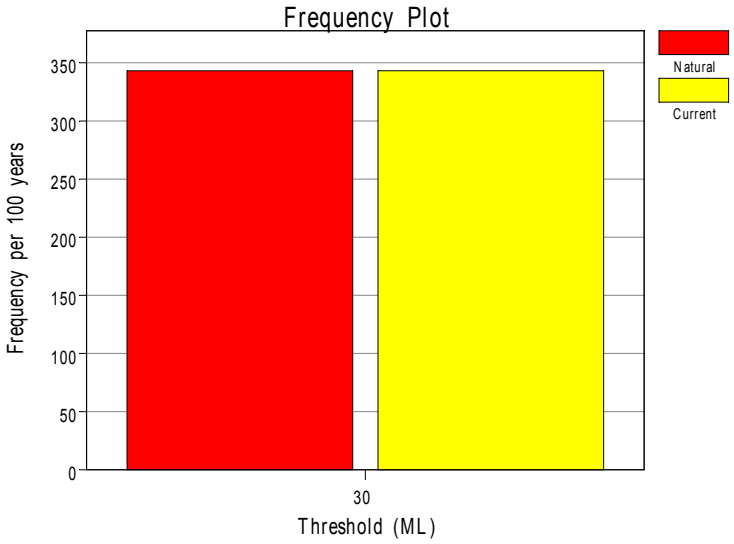


- **Figure B-11 Frequency of spells 10 ML/d or greater under current and natural conditions for Reach 2 in summer/autumn.**

Winter fresh

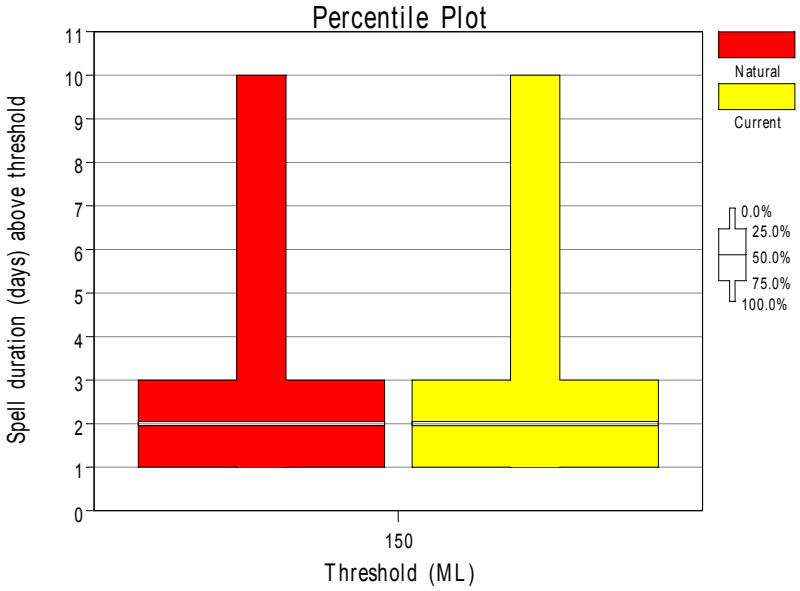


- **Figure B-12 Duration of spells 30 ML/d or greater under current and natural conditions for Reach 2 in winter/spring.**

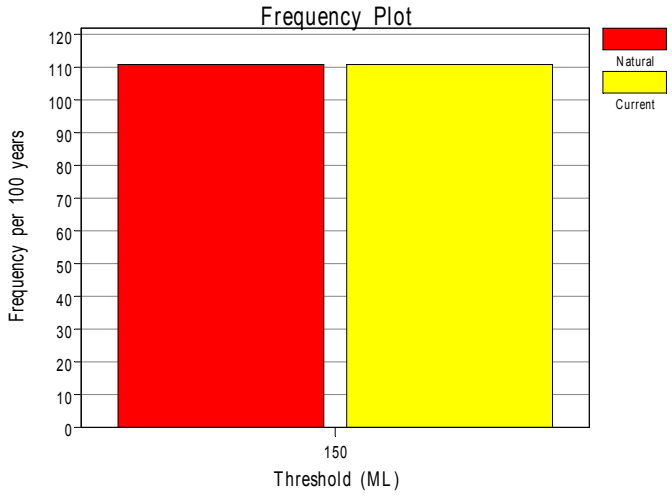


- **Figure B-13 Frequency of spells 30 ML/d or greater under current and natural conditions for Reach 2 in winter/spring.**

Winter high flow



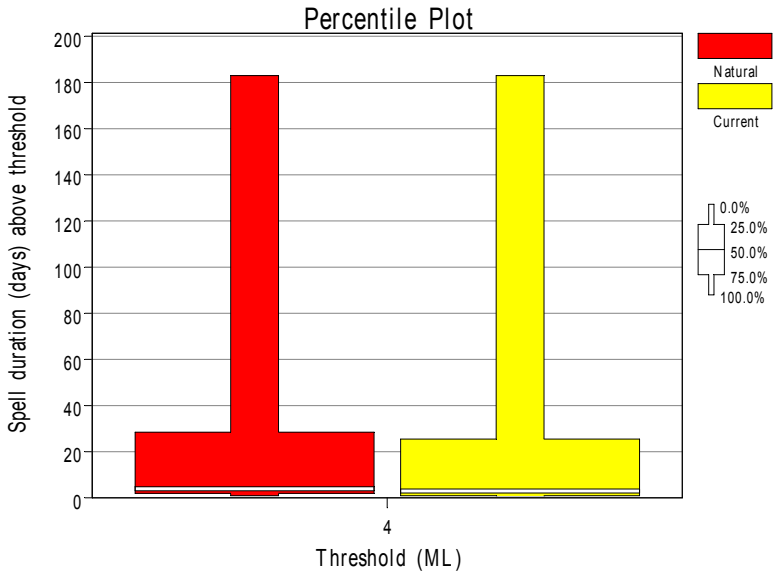
- **Figure B-14 Duration of spells 150 ML/d or greater under current and natural conditions for Reach 2 in winter/spring.**



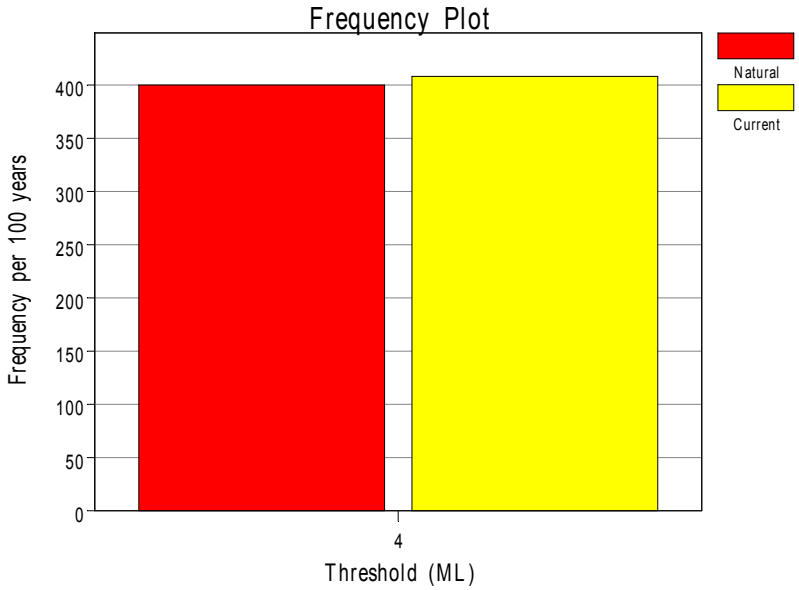
- **Figure B-15 Frequency of spells 150 ML/d or greater under current and natural conditions for Reach 2 in winter/spring.**

Reach 3 Greigs Creek

Summer fresh

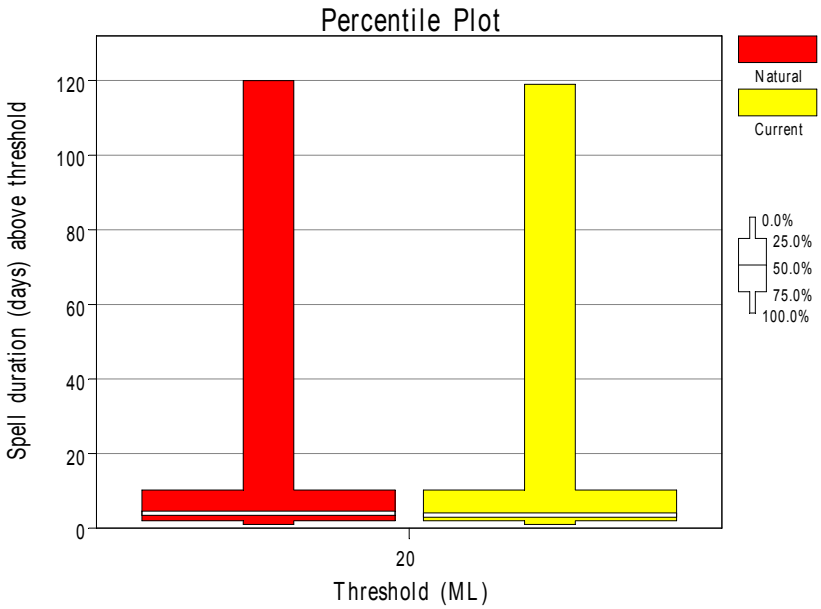


- **Figure B-16 Duration of spells 4 ML/d or greater under natural and current conditions for Reach 3 in summer/autumn.**

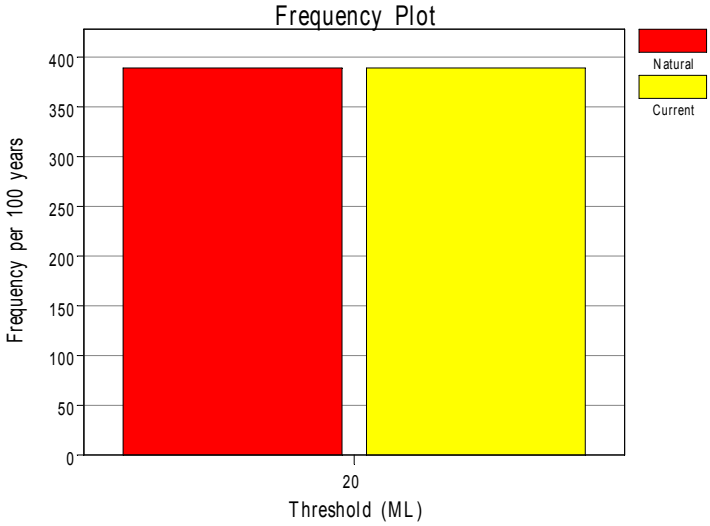


- **Figure B-17 Frequency of spells 4 ML/d or greater under natural and current conditions for Reach 3 in summer/autumn.**

Winter fresh

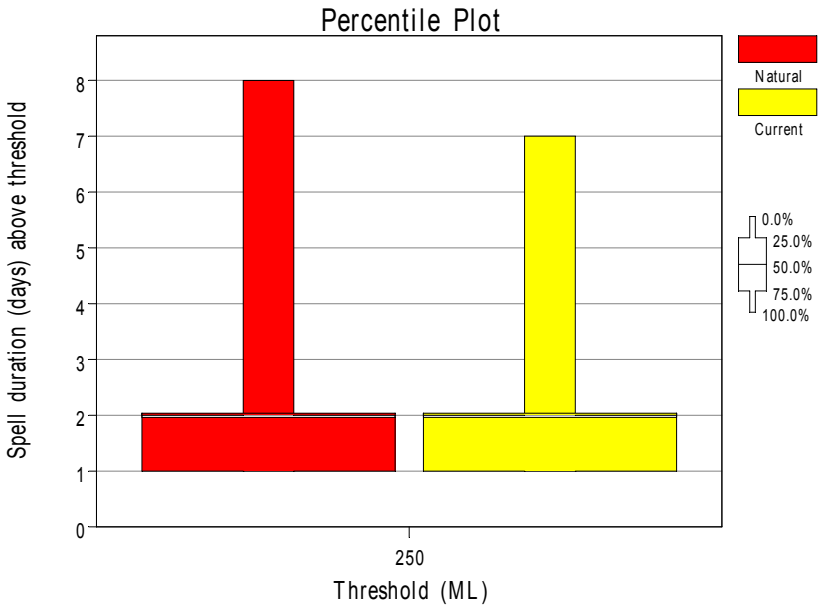


- **Figure B-18 Duration of spells 20 ML/d or greater under natural and current conditions for Reach 3 in winter/spring.**

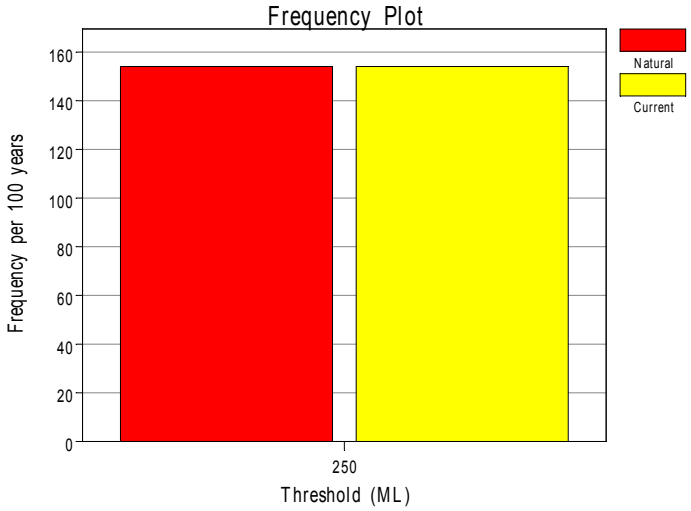


- **Figure B-19 Frequency of spells 20 ML/d or greater under natural and current conditions for Reach 3 in winter/spring.**

Winter high flow



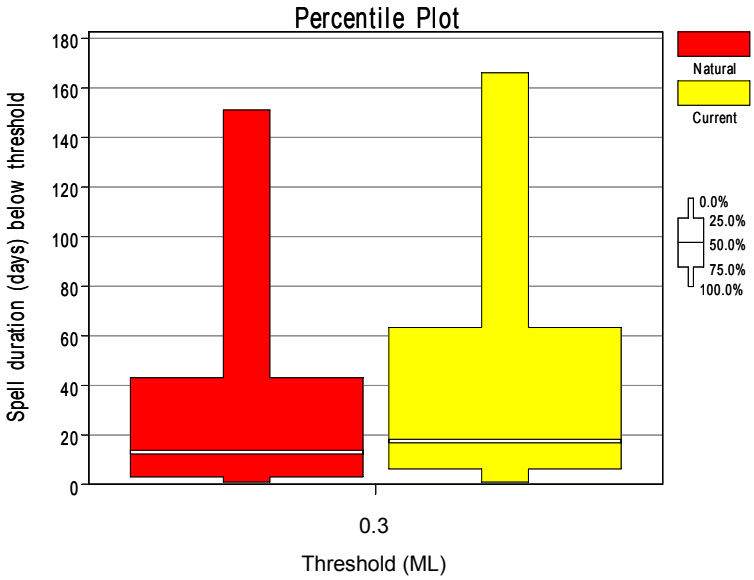
- **Figure B-20 Duration of spells 250 ML/d or greater under natural and current conditions for Reach 3.**



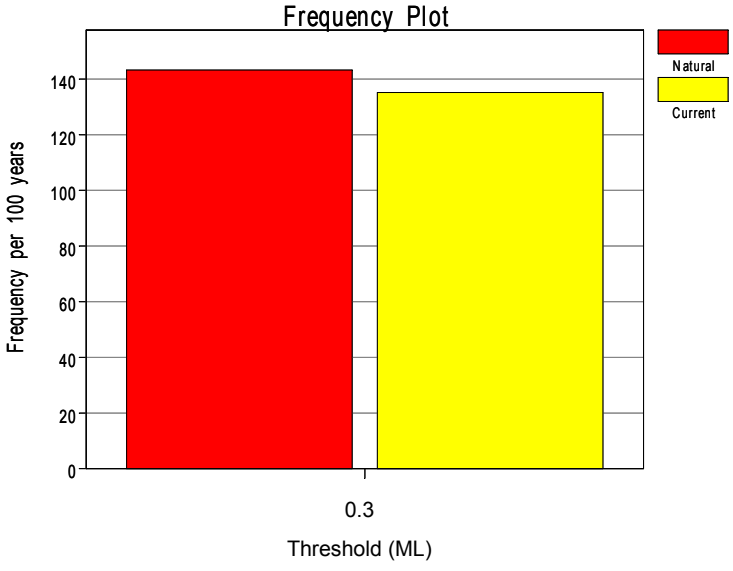
- **Figure B-21 Frequency of spells 250 ML/d or greater under natural and current conditions for Reach 3.**

Reach 4a Spring Creek

Summer low

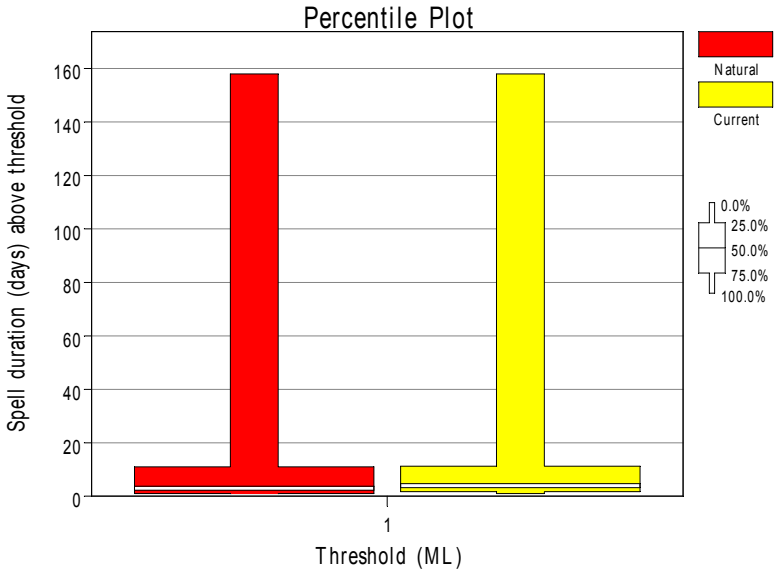


- **Figure B-22 Duration of spells 0.3 ML/d or less under natural and current conditions for Reach 4a in summer/autumn. This plot suggests a cease-to-flow event lasting approximately 2 weeks.**



- **Figure B-23 Frequency of spells 0.3 ML/d or less under natural and current conditions for Reach 4a in summer/autumn.**

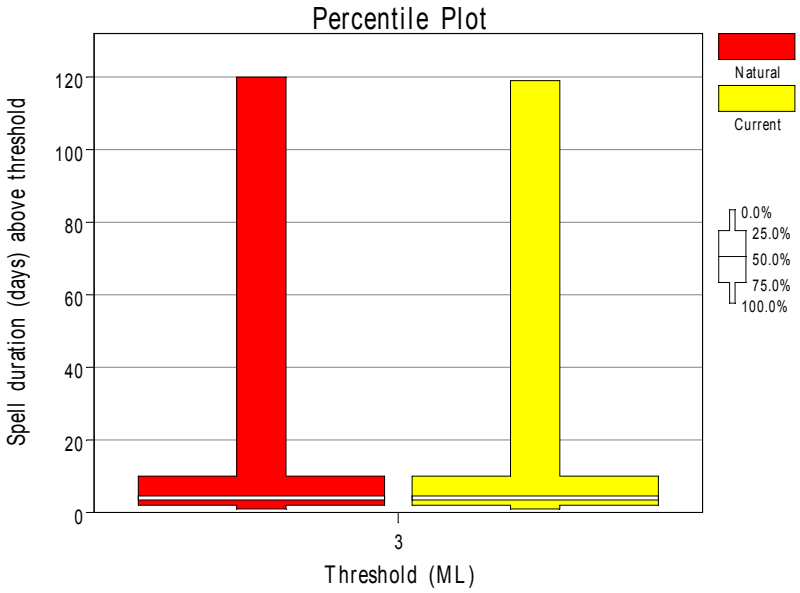
Summer fresh



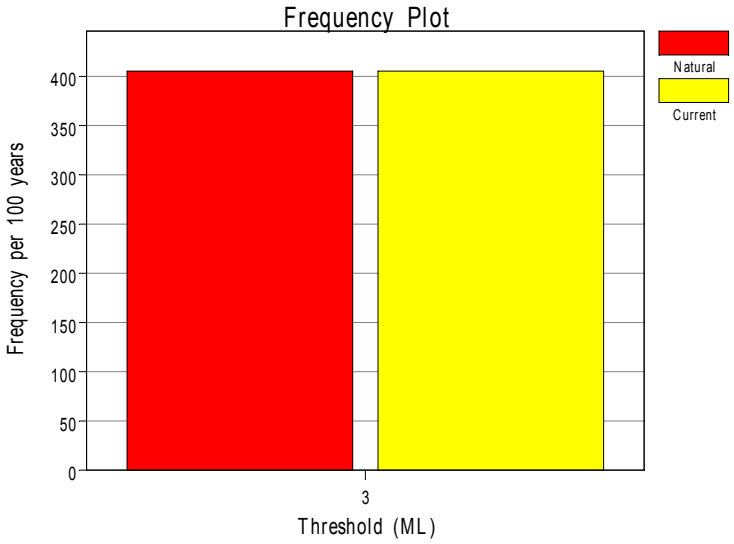
- **Figure B-24 Duration of spells 1 ML/d or greater under natural and current conditions for Reach 4a in summer/autumn.**

- **Figure B-25 Frequency of spells 1 ML/d or greater under natural and current conditions for Reach 4a in summer/autumn.**

Winter fresh

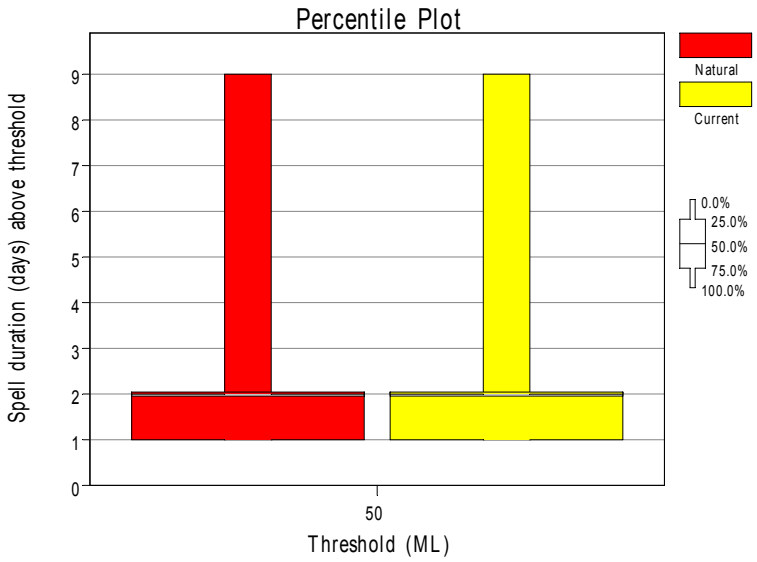


- **Figure B-26 Duration of spells 3 ML/d or greater under natural and current conditions for Reach 4a in winter/spring.**

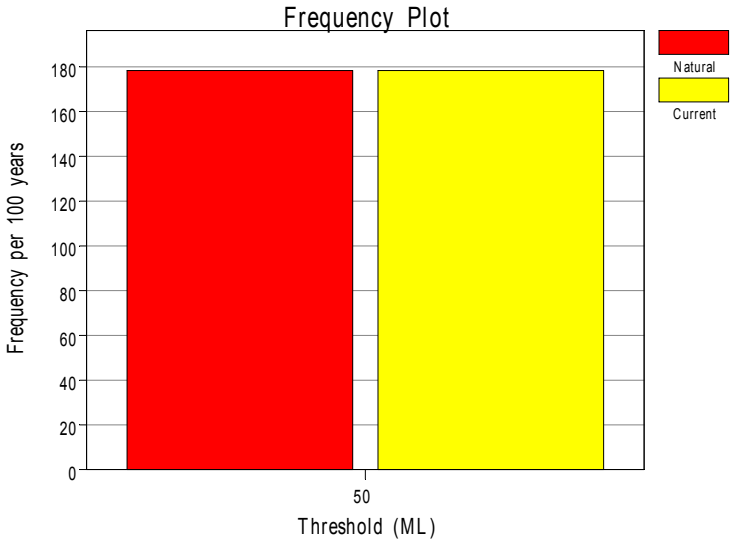


- **Figure B-27 Frequency of spells 3 ML/d or greater under natural and current conditions for Reach 4a in winter/spring. (Note dropped one fresh for the high flow).**

Winter high flow

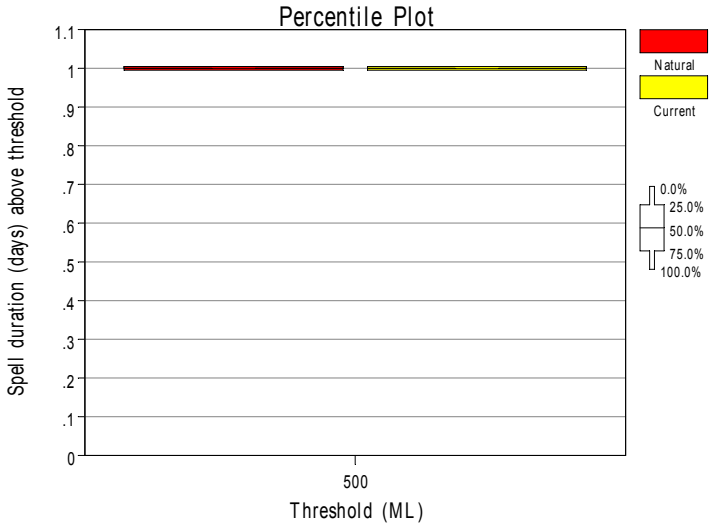


- **Figure B-28 Duration of spells 50 ML/d or greater under natural and current conditions for Reach 4a.**



- **Figure B-29 Frequency of spells 50 ML/d or greater under natural and current conditions for Reach 4a.**

Bankfull flow

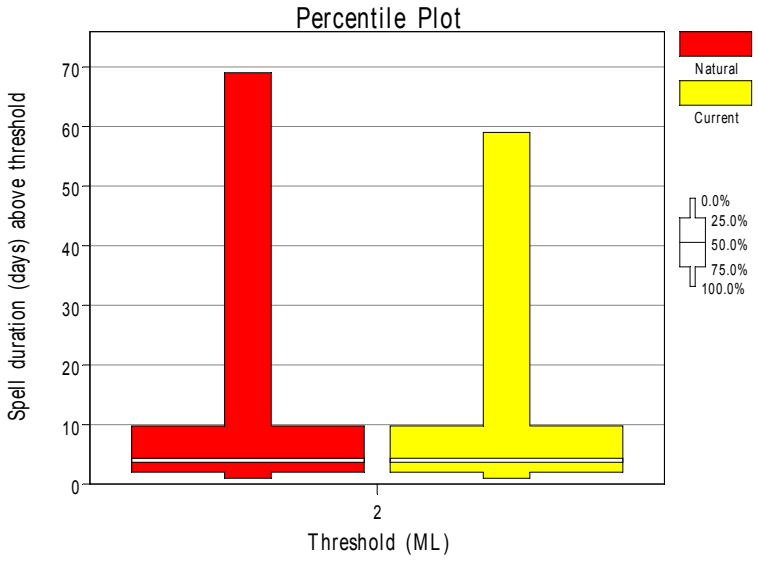


- **Figure B-30 Duration of spells 500 ML/d or greater under natural and current conditions for Reach 4a (Spring Creek).**

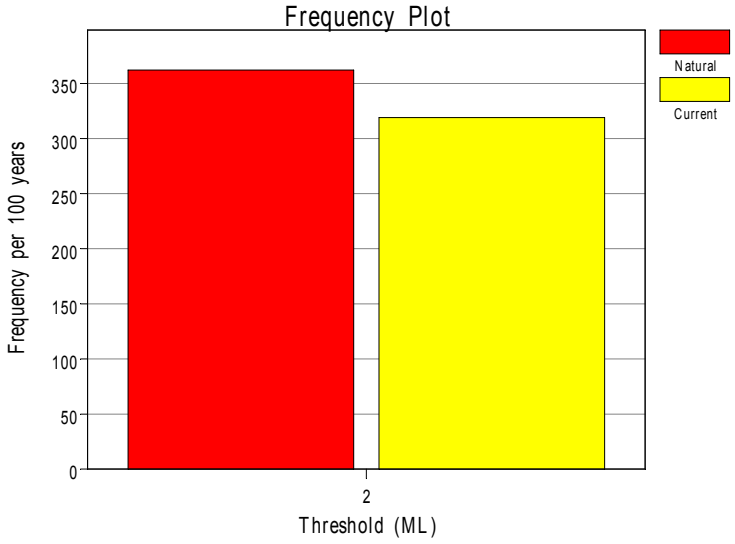
- **Figure B-31 Frequency of spells 500 ML/d or greater under natural and current conditions for Reach 4a (Spring Creek).**

Reach 4b Bodman Creek

Summer fresh

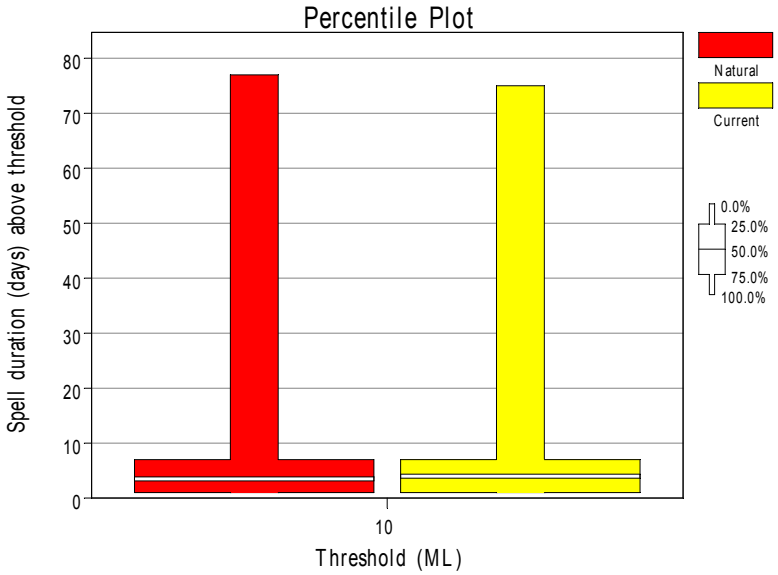


- **Figure B-32 Duration of spells 2 ML/d or greater under natural and current conditions for Reach 4b in summer/autumn.**

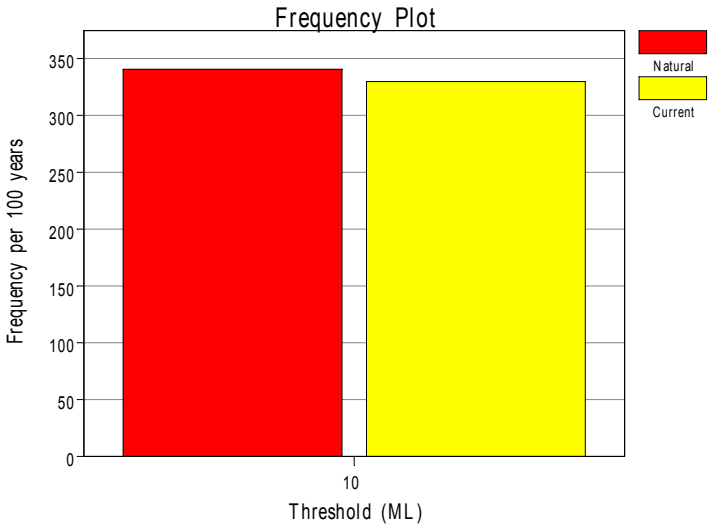


- **Figure B-33 Frequency of spells 2 ML/d or greater under natural and current conditions for Reach 4b in summer/autumn.**

Winter fresh

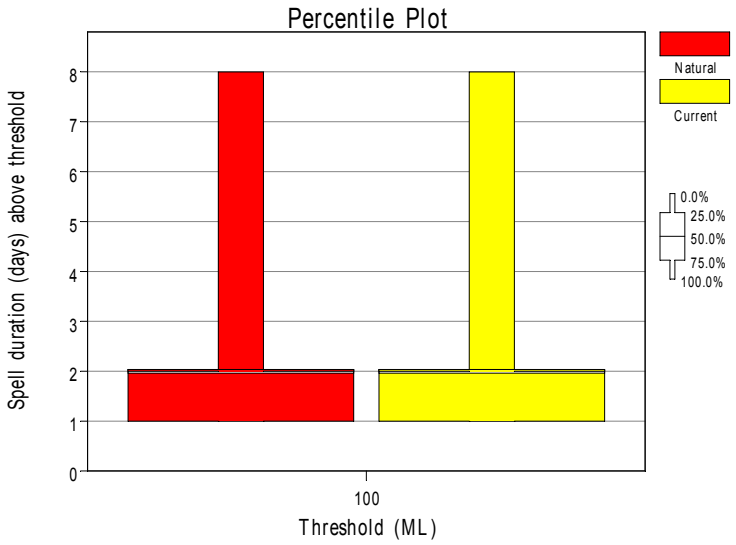


- **Figure B-34 Duration of spells 10 ML/d or greater under natural and current conditions for Reach 4b (Bodman Creek) in winter/spring.**



- **Figure B-35 Frequency of spells 10 ML/d or greater under natural and current conditions for Reach 4b (Bodman Creek) in winter/spring.**

Winter high flow



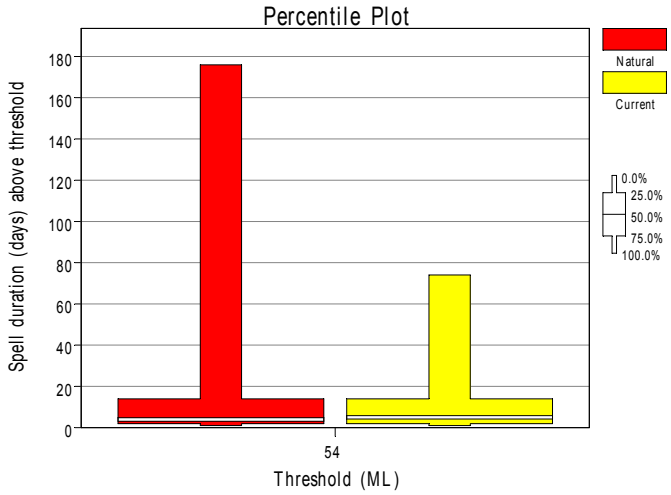
- **Figure B-36 Duration of spells 100 ML/d or greater under natural and current conditions for Reach 4b in winter/spring.**

- **Figure B-37 Frequency of spells 100 ML/d or greater under natural and current conditions for Reach 4b in winter/spring.**

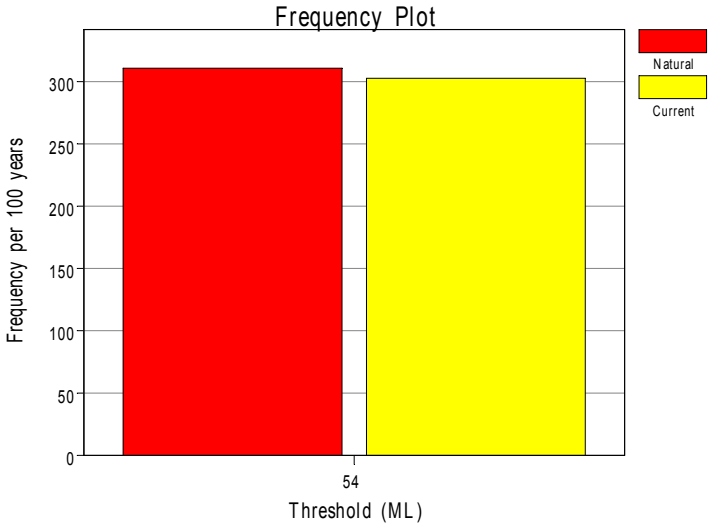
Reach 6 Tarra River at Yarram gauge and Reach 7 Tarra River at Missens Lane

Both sites use the same flow data therefore the spells outputs for Reach 6 and Reach 7 will look the same. Only one set of graphs have been produced.

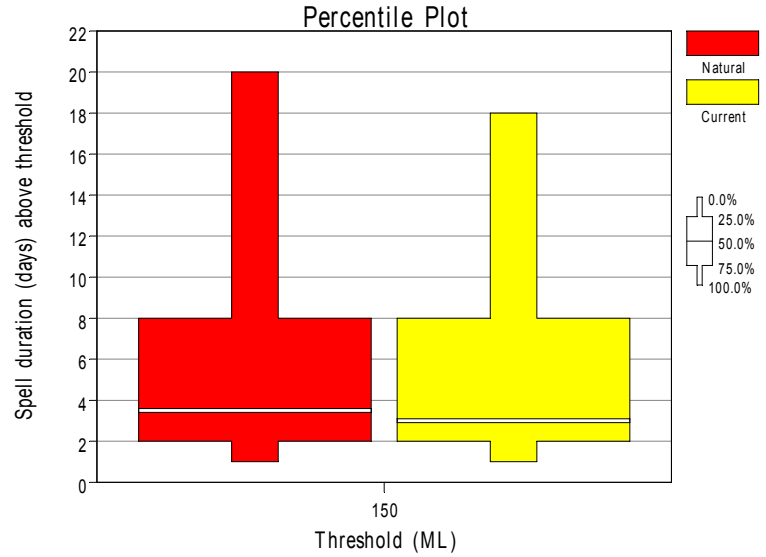
Summer fresh



- **Figure B-38 Duration of spells 54 ML/d or greater under natural and current conditions for Reach 6 in summer/autumn.**



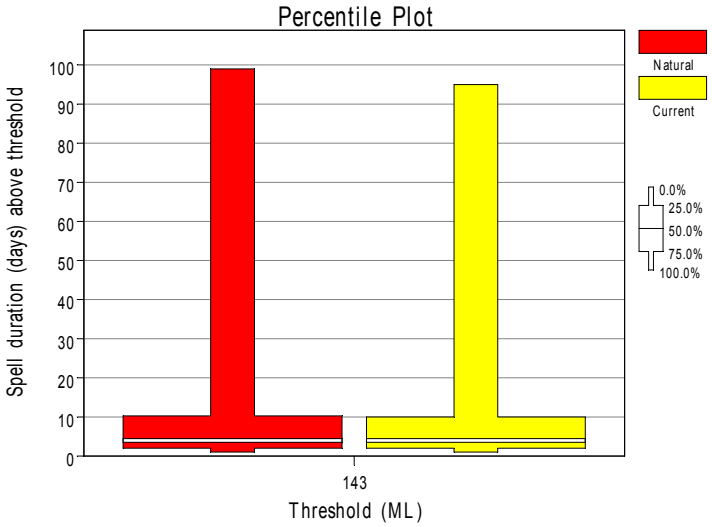
- **Figure B-39 Frequency of spells 54 ML/d or greater under natural and current conditions for Reach 6 in summer/autumn.**



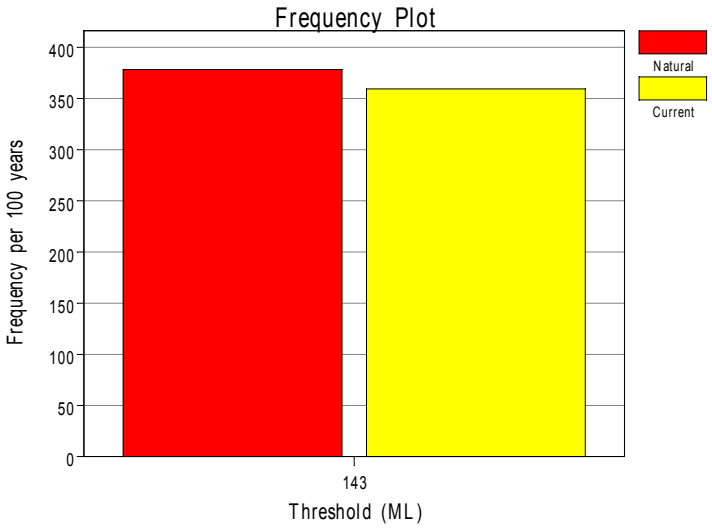
- **Figure B-40 Duration of spells 150 ML/d or greater under natural and current conditions for Reach 6 in summer/autumn.**

- **Figure B-41 Frequency of spells 150 ML/d or greater under natural and current conditions for Reach 6 in summer/autumn.**

Winter fresh

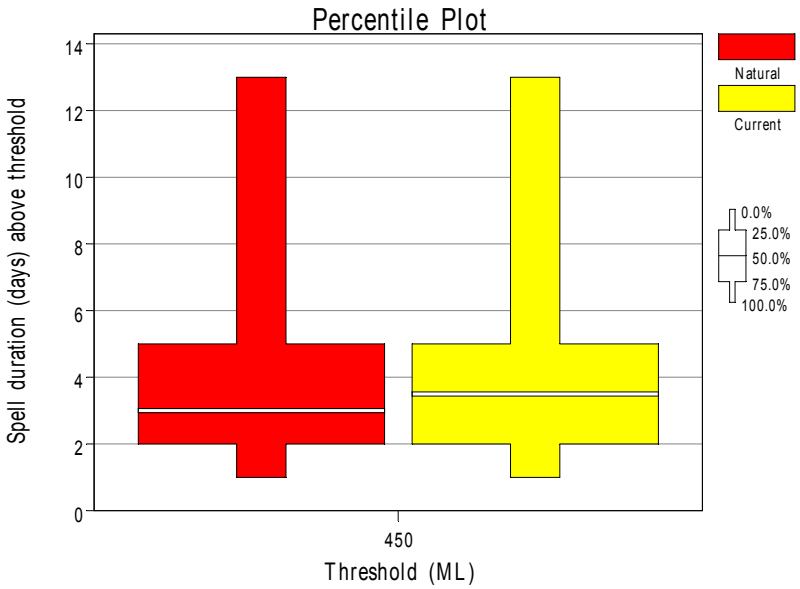


- **Figure B-42 Duration of spells 143 ML/d or greater under natural and current conditions for Reach 6 in winter/spring.**

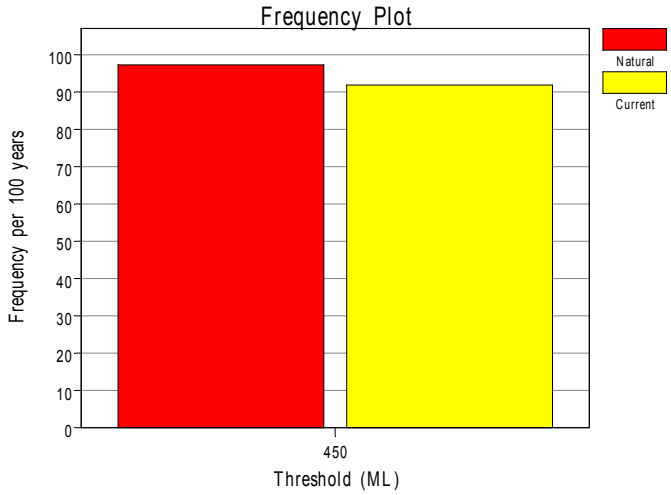


- **FigureB-43 Frequency of spells 143 ML/d or greater under natural and current conditions for Reach 6 in winter/spring.**

Winter high flow

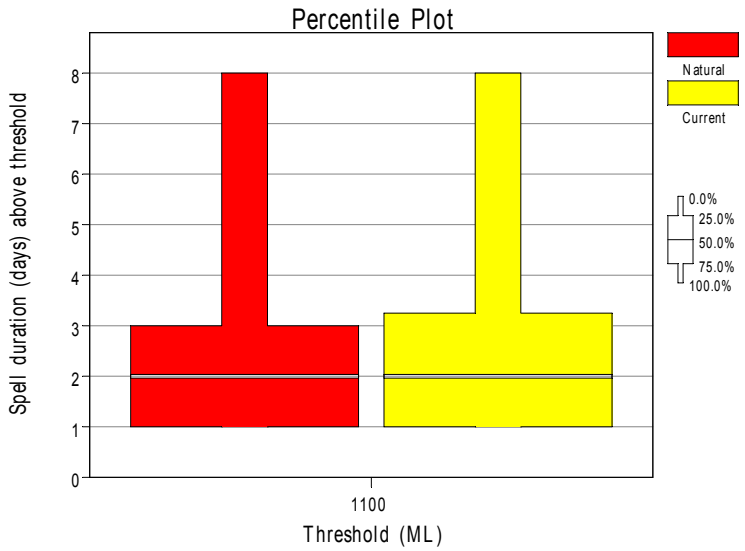


- **Figure B-44 Duration of spells 450 ML/d or greater under natural and current conditions for Reach 6 in spring.**

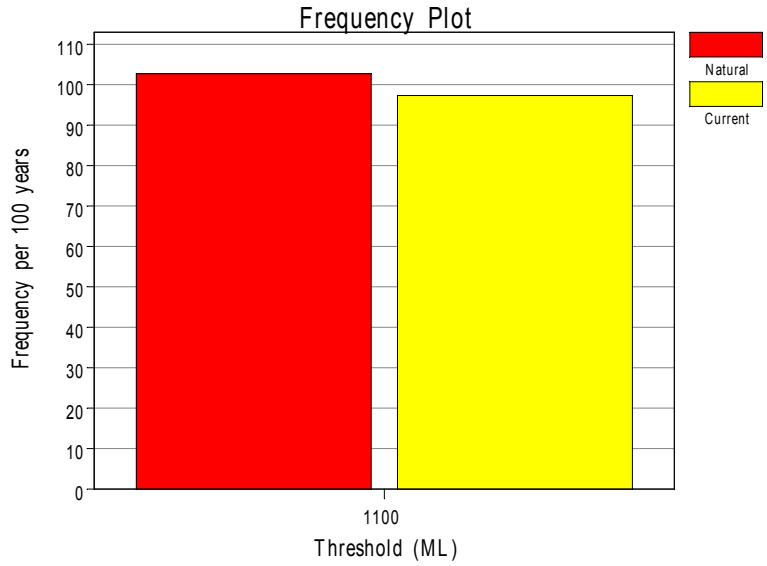


- **Figure B-45 Frequency of spells 450 ML/d or greater under natural and current conditions for Reach 6 in spring.**

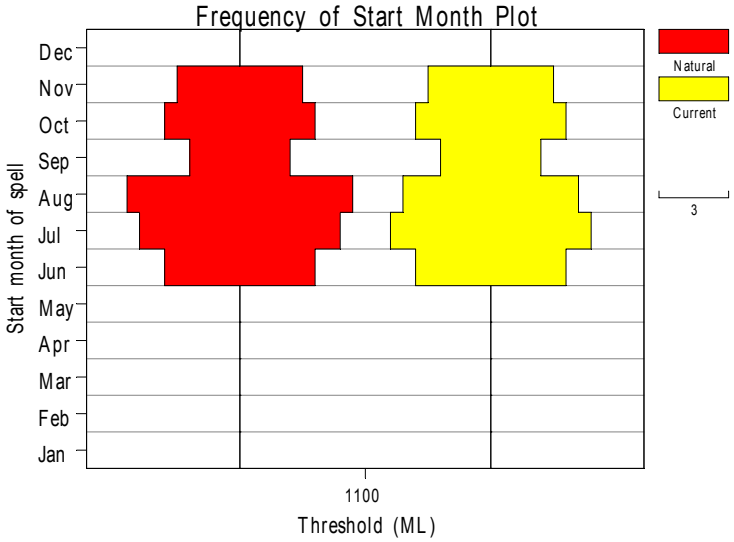
Winter higher flow



- **Figure B-46 Duration of spells 1100 ML/d or greater under natural and current conditions for Reach 6 in winter/spring.**

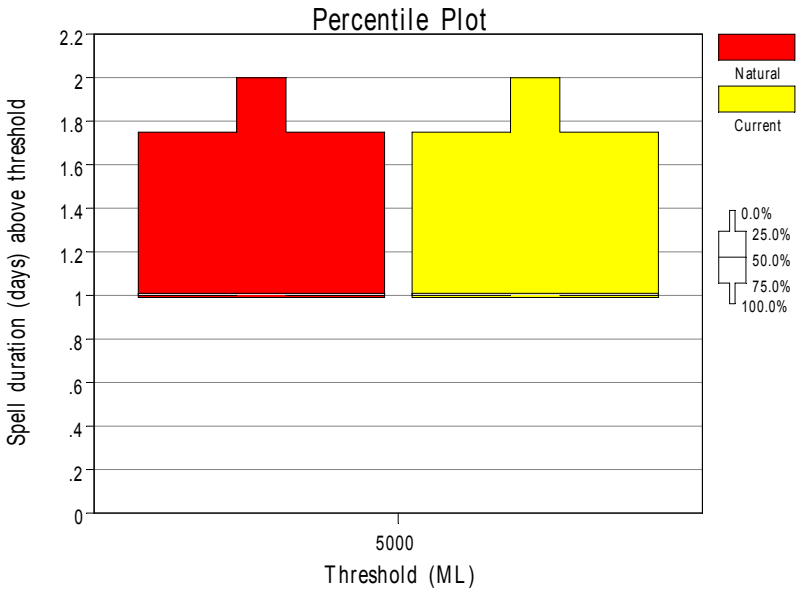


- **Figure B-47 Frequency of spells 1100 ML/d or greater under natural and current conditions for Reach 6 in winter/spring.**

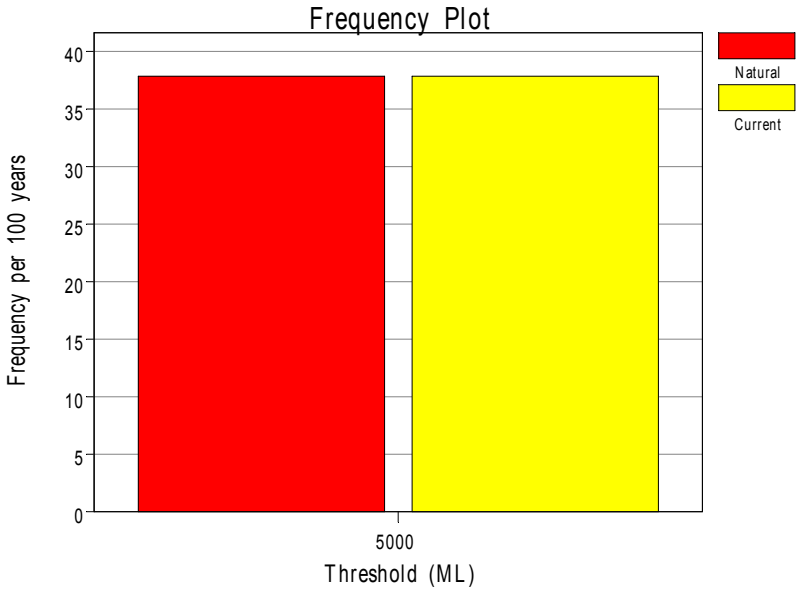


- **Figure B-48 Frequency of start month of spells 1100 ML/d or greater under natural and current conditions for Reach 6 in winter/spring.**

Bankfull flow



- **Figure B-49 Duration of spells 5000 ML/d or greater under natural and current conditions for Reach 6.**



- **Figure B-50 Frequency of spells 5000 ML/d or greater under natural and current conditions for Reach 6.**