Upper Ovens Environmental FLOWS Assessment

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FLOW RECOMMENDATIONS

- Final
- 14 December 2006

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Glossary of terms and abbreviations

AUSRIVAS	Australian River Grade and Assessment System.
Anastomosing	A channel that splits into several channels that rejoin regularly.
Autotrophic	Do not rely on outside sources to supply organic food. Autotrophic systems are dominated by photosynthesising organisms
Biofilm	An organic matrix comprised of microscopic algae, bacteria and microrganisms that grow on stable surfaces (e.g. logs, rocks or large vascular plants) in water bodies.
Catchment	The area of land drained by a river and its tributaries.
Current flow series	Series of streamflows which represent the current level of development.
Compliance point	Gauging station at which flows are measured to ensure compliance with recommendations.
Debouching	Emerge into larger body or area.
Dissolved oxygen (DO)	Concentration of oxygen in the water column. A measure of the amount of oxygen available to aquatic flora and fauna.
DSE	Department of Sustainability and Environment.
EFTP	Environmental Flows Technical Panel.
Environmental flow	River flows (or periods of drying) allocated for the maintenance of aquatic and riparian ecosystem, measured in megalitres per day (ML/d).
Ephemeral stream	A waterway containing water only after unpredictable rain.
Floodplain	Temporarily inundated lateral river flats, usually of lowland rivers.
FSR	Flow Stressed Ranking.
North East CMA	North East Catchment Management Authority
Geomorphology	The study of the physical form of, and processes operating in, rivers. It aims to provide an understanding of the physical processes governing the current state of a river.
G-MW	Goulburn-Murray Water.
Gravel lens	Gravel that is normally deposited on the streambed during high flow events and may either be completely or partially submerged during low flows. Gravel lens are not tightly packed and water may easily flow through interstitial spaces.
Groundwater	Water occurring below the ground surface.
Habitat	The place or environment in which a plant or animal usually lives; the subset of physical and chemical environmental variables that allow an organism to survive and persist.
Heterotrophic	Obtain organic food from the environment. Heterotrophic streams are not dominated by photosynthesising organisms.
Hydrology	The study of the surface and subsurface water. Sometimes used loosely to describe the water regime.
Instream	Of, or occurring within the wetted area of a running water body.
ISC	Index of Stream Condition. Presents an indication of the extent of change in respect of five key 'stream health' indices: hydrology, physical form, streamside zone, water quality and aquatic life.
Lowland waterway	A stream section at low altitude, that is sinuous and often with width to depth ratios greater than 20.

LWD	Large Woody Debris. Branches and trees that have fallen in the river channel. Often referred to as snags.
Macroinvertebrates	Aquatic invertebrates that are large enough to be retained by a 500 µm net or sieve. Includes insects, crustacean, aquatic worms, and aquatic snails.
Macrophytes	The term is used to describe water plants other than microscopic algae; they may be floating or rooted.
Mean	Average. Equally far from two extremes.
Median	The middle value in an ordered sequence of values.
Megalitre (ML)	One million litres (an Olympic size swimming pool is about two megalitres).
Natural flow series	Modelled flow series that reflects what current flows would be without consumptive use. It is not meant to reflect historical flows prior to catchment development.
Nutrients	Natural elements (usually phosphorus and nitrogen) that are essential for plant and animal growth.
Percentile exceedence flows	The flow which is exceeded for the defined percentage of time. E.g. the 80th percentile flow is exceeded 80% of the time and is therefore a low flow. Also commonly used: 20th and 50th percentile where 20th percentile exceedence flow is a relatively high flow and the 50th percentile exceedence flow may also be called the median flow.
pH	Level of acidity in a range from 0-14: low pH (values <7) refers to high acidity and high pH (values >7) refers to low acidity.
Piedmont	The foot of a mountain. Used to describe the gentle slope leading down from the steep mountain to the plains.
Pool	A stream section where there is no discernable flow and usually deep.
Reach	A length of stream that is reasonably uniform with respect to geomorphology, flow and ecology.
Recruitment	The addition of new members into a population through reproduction or immigration.
Regulated catchment/river	A river or creek where the flow of the river is controlled through the operation of large dams or weirs to meet water use demands downstream.
Riffle	A stream section with fast and turbulent flow over a pebble bed with protruding rocks. Characterised by a broken water surface.
Riparian	Vegetation found along the banks of streams and rivers.
Riparian zone	Any land which adjoins, directly influences, or is influenced by a body of water.
Run	A stream section with low to moderate laminar flow with unbroken water surface.
SEPP	State Environment Protection Policy.
SIGNAL	Stream Invertebrate Grade Number Average Level.
SFMP	Stream Flow Management Plan.
Spawning	Production and deposition of eggs; related to fish reproduction.
Spell	Total period of time when flows are either continuously above or continuously below a nominated threshold value
SKM	Sinclair Knight Merz.
Snag	Branches and trees that have fallen in the river channel; also called

	Large Woody Debris (LWD).
Substrate	The base, or material, on the bed of the river.
Taxa	Any defined unit in the classification of living organisms (i.e. species, genus, family).
Thalweg	The long profile of a river valley; term used to describe the line that joins the lowest points along the entire length of the streambed.
Threatened	A generic term used to describe taxa that are rare, vulnerable, endangered or insufficiently known and are subject to a threatening process.
Transect	Line drawn across a stream channel and perpendicular to the direction of flow for standardising measurements of width, depth velocity discharge etc.
Tributary	A river or creek that flows into a larger river.
Turbidity	The cloudy appearance of water due to suspended material (sediment).
Unregulated catchment/river	A river system where no major dams or weir structures have been built to assist in the supply, or extraction of water.
Upland	A stream section at high altitudes with a river channel often less than 10 times the channel depth.
Water-dependent	Aquatic species or those dependent on river water for survival.
Weed	Any plant that has, or has the potential to have, a negative impact on a valuable natural resource and that requires some form of action to reduce that impact.
VRHS	Victorian River Health Strategy.
VWQMN	Victorian Water Quality Monitoring Network.

1. Introduction

This report is the third and final output for the determination of environmental flow requirements for the Upper Ovens River in Northern Victoria. 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.

1.1 Structure of report

The Flow Recommendations report provides details on the methods used for carrying out flows modelling using HECRAS, 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. Supporting recommendations are provided in Section 4.

2. Method

The environmental flows recommendations for the Upper Ovens River have been determined using the FLOWs method (DNRE 2002) which has been described in early reports . 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. A summary of the methods is provided in the following sections.

2.1 Site selection and field assessment

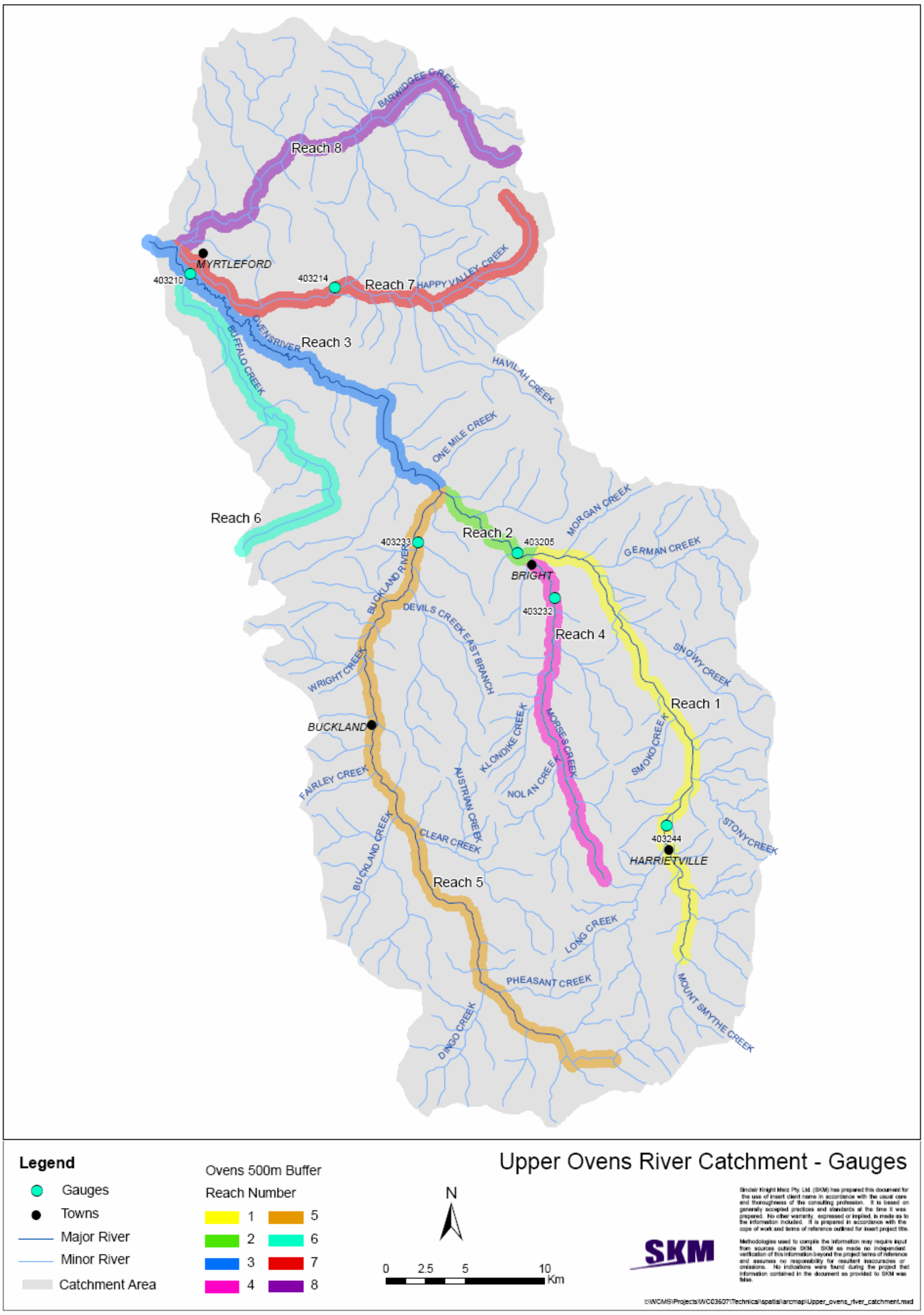
The Upper Ovens River was divided into eight reaches with one site on each reach selected for detailed field assessment by the Environmental Flows Technical Panel (EFTP) (Table 2-1) and cross section surveys (Figure 2-1). The sites assessed are shown in Table 2-2. Detailed descriptions of each site are provided in SKM.

- **Table 2-1: Composition of the Environmental Flows Technical Panel (EFTP).**

EFTP member	Discipline
Dr Bruce Abernethy	Geomorphology
Dr Jane Roberts	Instream and riparian vegetation
Dr Andrew Sharpe	Macroinvertebrates and water quality
Dr Simon Treadwell	Fish and ecological processes
Kristen Sih & Robert Morden	Hydrology

- **Table 2-2: Upper Ovens River reaches and field assessment sites.**

Reach		Site location	Easting/Northing
1	Ovens River upstream of Morses Creek	Ovens River 3 km downstream of Harrietville gauge	506446 / 5920022
2	Ovens River: Morses Creek to Buckland River	Ovens River at Bright gauge	495855 / 5935434
3	Ovens River: Buckland River to Buffalo River	Ovens River at Apex Park Myrtleford	474455 / 5953060
4	Morses Creek catchment	Morses Creek upstream of gauge	498266 / 5932227
5	Buckland River catchment	Buckland River 1.5km upstream of Harris Lane	4891181 / 5934938
6	Buffalo Creek catchment	Buffalo Creek at Clemens Lane	474300 / 5951800
7	Happy Valley Creek catchment	Happy Valley Creek at Carrolls Rd gauge	483863 / 5951923
8	Barwidgee Creek catchment	Barwidgee Creek 1.5km downstream of Kirk's Bridge.	478706 / 5957129



■ **Figure 2-1: Upper Ovens River environmental flows study area.**

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 when providing environmental flows. The process of setting environmental objectives involves first identifying the environmental assets, setting environmental objectives against these assets, 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.

The environmental flow objectives for the Upper Ovens River have been endorsed by the Steering Committee and the local community representatives and are provided in Appendix 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 - the models were run under a mixed flow assumption as both subcritical and supercritical flow was evident. A mixed flow assumption requires both up and downstream boundary conditions. The up and downstream boundary conditions may be a rating table, water level, critical depth or normal depth. In this case, normal depth was used. Normal depth is the depth at which steady uniform flow occurs, where the energy loss due to friction is exactly supplied by the reduction in potential energy which occurs owing to the fall in bed level. 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 were available from the field survey and previous modelling . However, there were limited data 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 3rd and 7th July, 2006. The number of cross sections surveyed at each flow assessment site varied between 4 and 7 depending on the diversity of physical features present. 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

There are a number of gauges in operation within the Ovens River catchment, however a number of these are no longer active or only provide water level data (Table 2-3). Data from the gauges were used to build the REALM model and to derive input for HECRAS modelling. The quality of the data and the calibration of the model are generally good and there is a moderate to very high degree of confidence in the model outputs for each reach.

▪ **Table 2-3: Stream gauges and their location within the Upper Ovens River catchment.**

VWQMN Gauging Station	Location	Comment
403244	Ovens River at Harrietville	
403210	Ovens River at Myrtleford	
403205	Ovens River at Bright	
403233	Buckland River at Harris Lane	
403216	Buffalo Creek at Myrtleford	Records ceased in 1982
403214	Happy Valley Creek at Rosewhite	
403211	Happy Valley Creek at Myrtleford	Records ceased in 1948
403236	Barwidgee Creek at Myrtleford	Records ceased in 1989
403232	Morses Creek at Wandiligong	
403250	Ovens River at Eurobin	Water level only
403253	Buckland River at Twelve Mile	Water level only

2.5.1 Natural and current flows

This flow assessment refers to natural and current flows that have been determined for each reach through a REALM model. Current flows are based on historic climate data and take account of the current level of development demands. Natural flows use historical climate data and assume no level of development demands (i.e. assume no extraction or farm dams). Changes to surface water run-off due to land clearing and increases in impervious area are not incorporated in these models and therefore the natural flow series is an estimate of the flows that may be expected in the catchment with the current land use but no extraction.

2.6 Calibration

Cross section data and surveyed reach lengths were entered into the hydraulic model HECRAS (Version 3.1.3). 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.

The EFTP selected cross section locations based on features that 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).

Some additional cross sections were required to accurately represent site features. These additional cross sections were adapted from similar nearby sections and modified based on site observation and site photos. Longitudinal section data were 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. In some cases, water levels differed between banks. This difference may be due in part to survey error, but may also reflect local hydraulic conditions.

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 flow recommendations

Calibrated models 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.

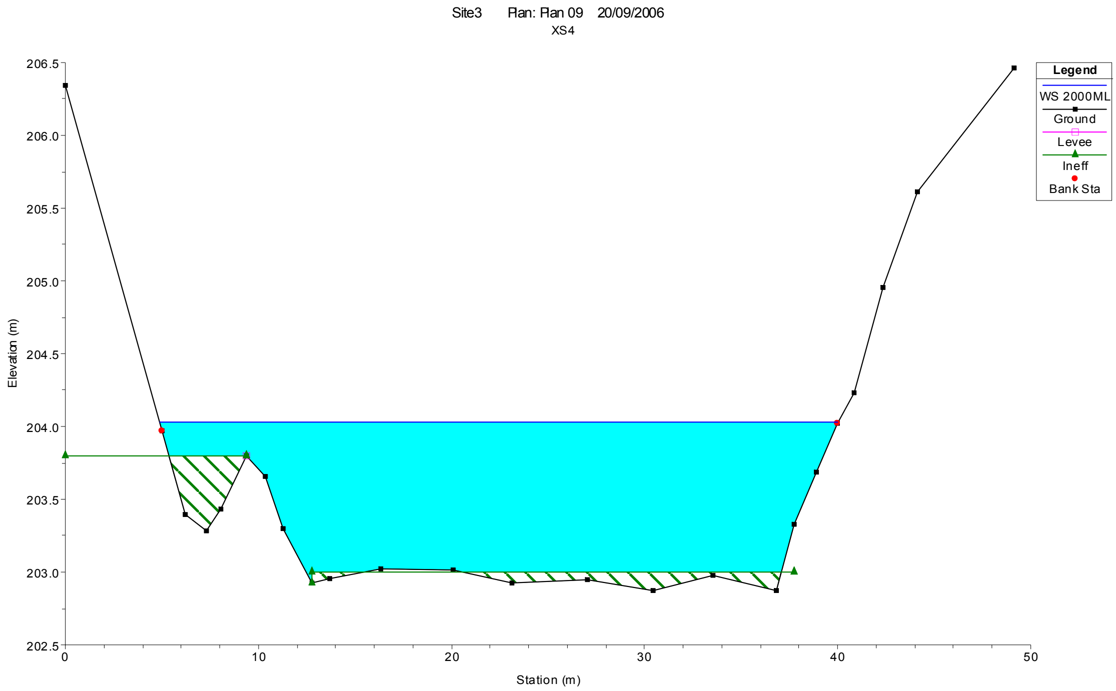
In the plots used to assess the environmental flow recommendations for each reach, water surface profiles were presented for flows from 1 ML/day to a maximum recorded level at that site. During the EFTP workshop, the models were also run to simulate water level under various flows including:

- The 20th, 50th, 80th percentile flow for all flows, summer and winter flows;
- The mean flow;
- The maximum summer flow; and
- Other recommended environmental flows.

2.8 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 Figure 2-2. The black line ("ground" in the legend) represents the ground surface, reflecting the channel shape of the cross section. Small black squares on the ground line show the exact points where survey measurements were taken (note that these are more frequent within the channel than further out). The horizontal blue line within the cross section represents the water surface at a given flow (which is detailed in the legend). The green hatching represents vegetation in the channel that prevents flow in that area.

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.



- **Figure 2-2: Example transect output from the hydraulic model. Reach 3 – Summer high flow of 2000 ML/day.**

2.9 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 given flow magnitude is exceeded;
- Time series graphs to examine the sequence of flow events, particularly during very dry or very wet conditions; and
- Flow spell analyses using GetSpells to describe the frequency, duration and start month of flow spells (flow events above or below a flow magnitude that serves a specific function).

GetSpells output

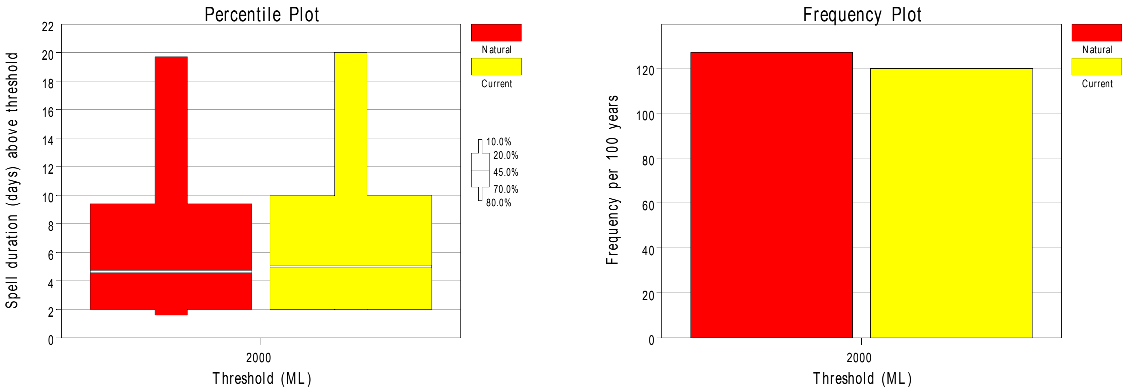
GetSpells (SKM 1999) is a Windows based software program developed by SKM for the Department of Natural Resources and Environment to extract a range of spells characteristics from a given flow series record. For this project GetSpells was used to describe and compare the duration, start months and frequency 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 between 1891 and 2005 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 GetSpells output using a threshold value of 2000 ML/d is provided in Figure 2-3. The **percentile plot** summarises the duration of flow spells over 2000 ML/d. In the plot the median spell duration (50th percentile) is indicated as a horizontal line, and variation in spell durations are described by the box and whiskers plots. Sixty percent of flow spells have a duration that lies within the box (20th and 80th percentiles) while 80 percent of the spells are described by the combination of the box and whiskers (spells within the 10th and 90th percentiles). In the example provided for spells higher than 2000 ML/d that occurred during summer under *natural* conditions:

- The median duration of spells above the threshold (2000 ML/d) is approximately 4 days;
- 20% of spells above the threshold last for up to 9 days; and
- 10% of spells above the threshold last for up to 20 days.

The upper box and whisker plot have a greater spread than the lower box and whisker. This indicates that the data are 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 (50th percentile) number of times that spells over 2000 ML/d occur in the modelled flow data (Figure 2-3). Flows of this size occur approximately 1.2 times per year. GetSpells duration and frequency plots for each recommended flow are given for each flow band for each reach.



- **Figure 2-3: Duration and frequency of spells 2000 ML/d or greater under current and natural conditions for Reach 3 during summer.**

2.10 Developing flow recommendations

Environmental flow recommendations for the Upper Ovens River were determined by the EFTP at a workshop on 6th September 2006. Matthew O'Connell from the North East CMA also attended the workshop. Prior to the workshop the hydraulic model was set up to include, mean flows, maximum and minimum flows, 20th, 50th and 80th percentile flows for each of the study reaches.

Each reach was considered in turn and the current ecological condition and flow objectives were reviewed along with field notes, site photos and HECRAS profiles of each cross section. A number of criteria were 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 objectives as outlined in the *Issues Paper* . Each of the flow components (e.g. summer low flows, summer freshes, winter low flows etc.) identified in the reach objectives (Appendix A) were considered in turn. GetSpells plots were generated to determine the appropriate frequency and duration of the recommended flow.

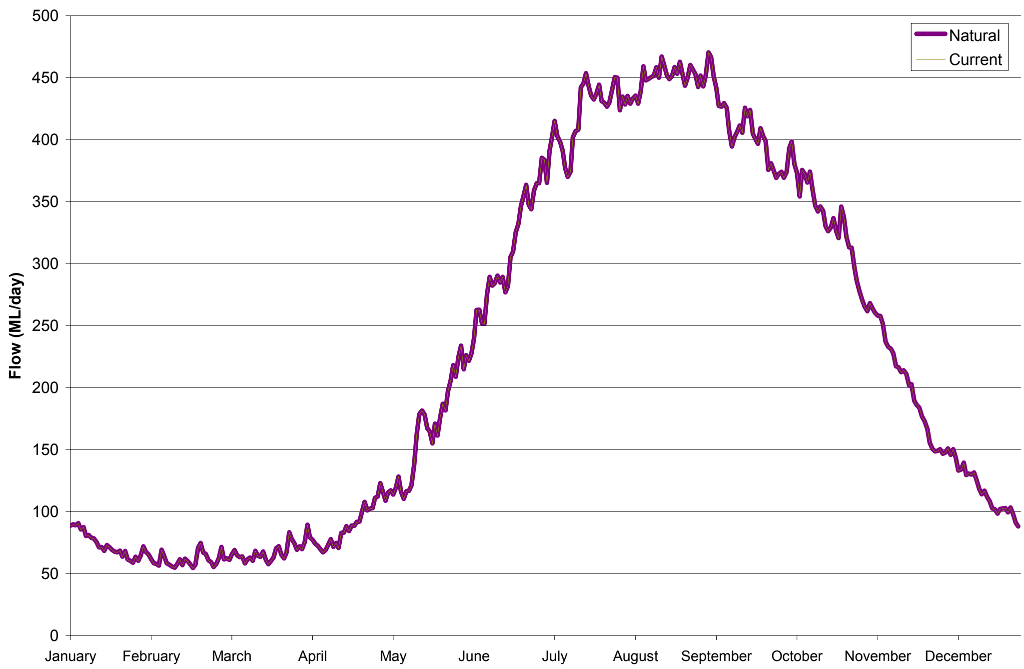
Flow recommendations have been developed separately for each reach. The recommended flow components have been developed for the entire reach and the recommended magnitude for each flow component relates directly to each of the selected study sites. The study assessment sites selected for this project are close to established gauging stations in all reaches except for Buffalo Creek and Barwidgee Creek, which are not gauged. Therefore compliance with the recommended flows can be assessed at established flow gauges in six out of the eight reaches. Compliance in Buffalo Creek and Barwidgee Creek may be modelled, but gauges will need to be established at or near the study sites in these tributaries if more instant and more reliable assessments are required.

- **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)
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
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.

2.11 Seasonal flows

Separate environmental flow recommendations are made for summer and winter periods. Summer relates to the period from December to May inclusive, and winter relates to the period from June to November. These periods reflect the natural seasonal division between low and high average flows in the upper Ovens River catchment as illustrated in Figure 2-4 for Reach 1.



- **Figure 2-4: Average daily natural and current flows for each day of the year in the Ovens River upstream of Morses Creek. Plots are based modelled flows from 1891-2005.**

2.12 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 Ovens River is an unregulated river, the rates of rise and fall should mirror the natural rise and fall of the river. This is particularly important if licensed water extractors are going to suddenly turn pumps on or off when flow in river rises above or falls below certain trigger levels.

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 selection of the 90th and 10th percentiles discounts extreme values from the flow series and provides a pragmatic way of managing the system that will not adversely affect the health of the river.

The ramp rate recommendations have been provided as a percentage of the previous days' flow. For example a recommended rate of rise of 179% stipulates that flow on a given day should not exceed 179% of the previous day's flow. The ramp rates presented in Table 2-5 should be applied when developing operation rules that will allow the recommended flows to occur in each reach.

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

Reach		Rate of rise	Rate of fall
1	Ovens River upstream of Morses Creek	168	87
2	Ovens River: Morses Creek to Buckland River	173	85
3	Ovens River: Buckland River to Buffalo River	172	85
4	Morses Creek catchment	179	84
5	Buckland River catchment	193	84
6	Buffalo Creek catchment	207	80
7	Happy Valley Creek catchment	244	67
8	Barwidgee Creek catchment *	244*	67*
* There was insufficient gauge data for Barwidgee Creek and the simulated data was unreliable for estimating ramp rates, therefore rates of rise and fall for Barwidgee Creek are recommended to be the same as for the neighbouring Happy Valley Creek .			

3. Environmental Flow Recommendations

This section outlines the environmental flow recommendations for each reach. Recommendations are developed independently for each reach, but are part of a continuum where it is assumed that specific flows in upstream reaches will add together and contribute to flows further downstream. The specific flows recommended for each reach target one or more ecological objectives and all are considered necessary. The recommended flows may not occur at the nominated frequency or have the recommended duration in all years due to natural variation. Flows are likely to be larger, more frequent and last longer than these recommendations in wet years and be smaller and less frequent in dry years. However, management actions that prevent recommended flows from occurring are expected to have a detrimental effect on river health in individual reaches where flows are reduced and also in downstream reaches of the upper and lower Ovens River.

Flow recommendations for each reach are presented in a standard format that includes:

- A 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 demonstrates the impact of each flow within the cross section; 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.

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 frequency, duration and volume.

3.1 Reach 1 – Ovens River upstream of Morses Creek

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: Ovens River upstream of Morses Creek.

Asset	Current condition
Hydrology	▪ Little difference between natural and current flow regime. High base flow contribution to streamflow at this site. Limited upstream demands.
Geomorphology	▪ Well connected to floodplain. History of floodplain modifications from gold dredging.
Water quality	▪ Generally excellent with locally elevated nutrients near urban centres.
Fish	▪ Good abundance of small native fish, particularly two-spined blackfish. Excellent to good habitat. Potential predation by trout.
Macroinvertebrates	▪ Good to excellent condition. Excellent habitat. Potential threats from point source pollution.
Instream and riparian flora	▪ Riparian vegetation reduced in extent and diversity. Good instream vegetation at field assessment site. Blackberries and willows present.

3.1.2 Flow recommendations

The environmental flow recommendations for Reach 1 are summarised in Table 3-2. No specific cease-to-flow recommendation has been made as the flow records show cease-to-flow periods do not occur in most years under a natural flow regime. The flow duration curves for the summer and winter natural and current flows for this reach are shown in Figure 3-1.

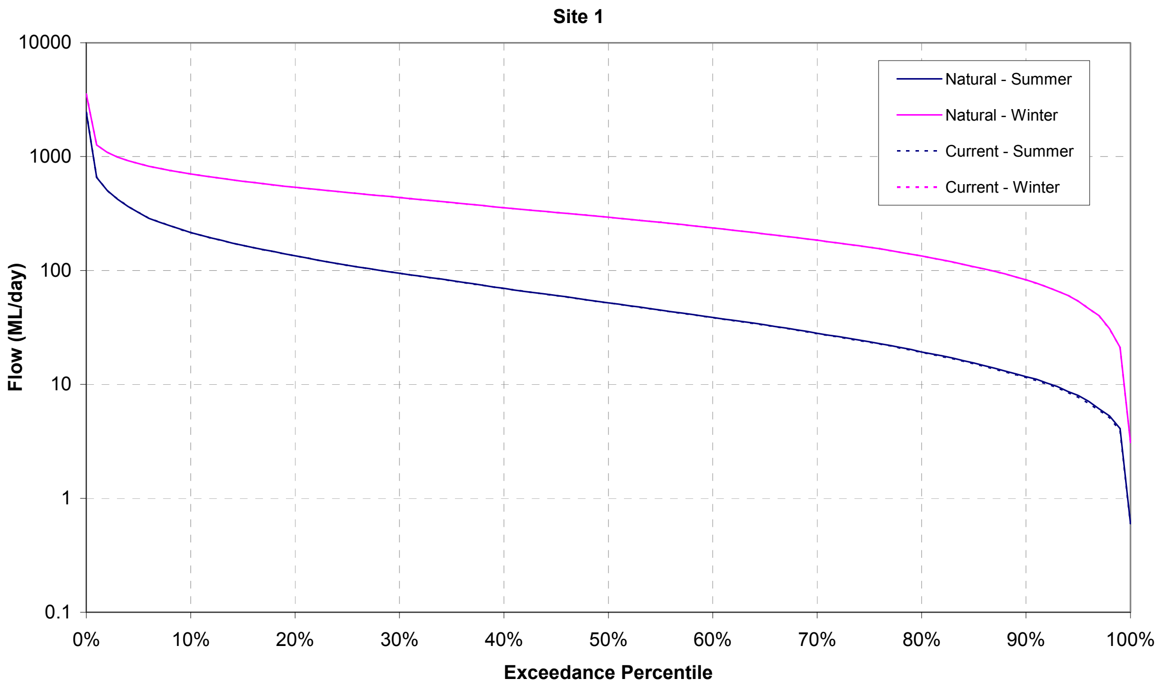
Table 3-2 Summary of flow recommendations for Reach 1: Ovens River upstream of Morses Creek.

Reach 1 Ovens River upstream of Morses Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	19 ML/day or natural		
	Freshes	95 ML/day	2 per year	6 days
	High	250 ML/day	1 per year	3 days
Winter	Low flow	135 ML/day or natural		
	Freshes	294 ML/day	3 per year	10 days
	High 1	1000 ML/day	1 per year	2 days
	High 2 (near bankfull)	1500 ML/day	1 in 4 years	2 days
	Bankfull	As natural		
	Overbank	No specific recommendation		

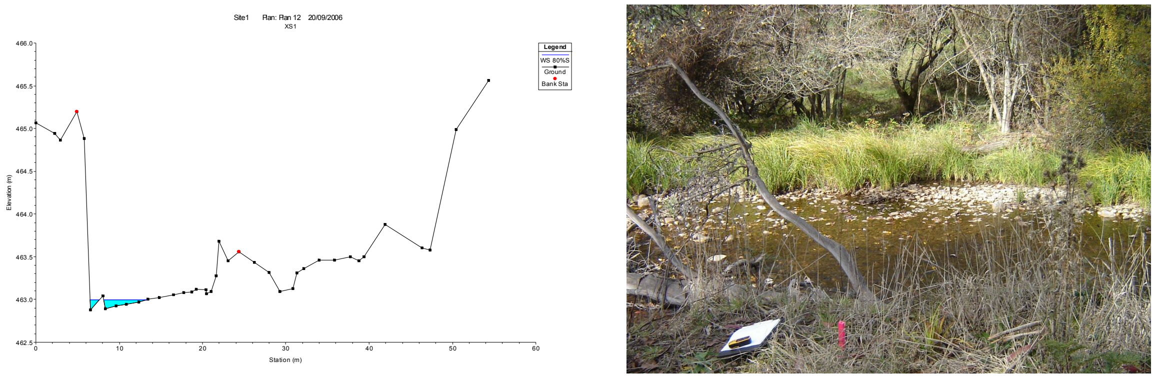
Summer low flow

A summer low flow of 19 ML/day, or as naturally occurs, has been recommended for this site in Reach 1. This flow equates to the 80th percentile flow of the natural daily summer flow for this reach (Figure 3-1). The criteria for determining the summer low flow was to ensure flows wetted half the width of the channel and provided a depth of more than 0.1m in riffle habitats (see cross section 1 in Figure 3-2 and cross section 3 in Figure 3-3). The frequency and duration plots and start months of flows below 19 ML/day are shown in Figure 3-4. Flows events less than 19 ML/day would have naturally occurred approximately three times every two years, and had a median duration of approximately 15 days (Figure 3-4).

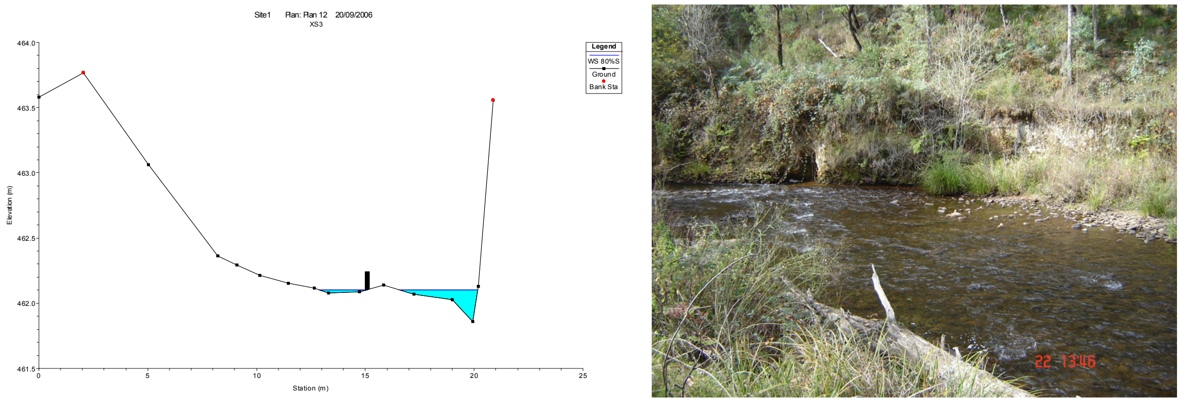
Summer flows of this magnitude within this reach are aimed at maintaining diversity of riparian and instream vegetation, providing longitudinal connectivity between pools and maintaining water quality in pools during summer.



▪ **Figure 3-1: Natural and Current summer and winter percentage exceedance curves for Reach 1.**



- **Figure 3-2 Water depth at cross section 1, at study site, Reach 1, under a summer low flow 19.3 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



- **Figure 3-3 Water depth at cross section 3 at study site, Reach 1, under summer low flow 19.3 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

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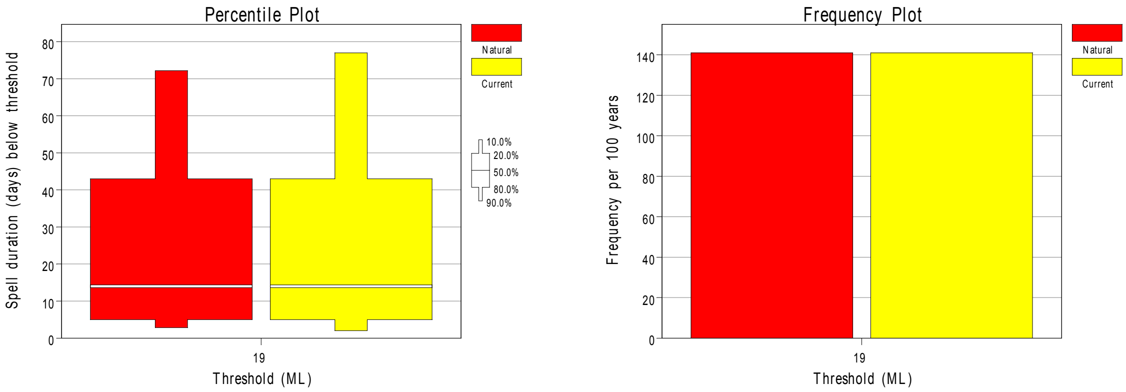
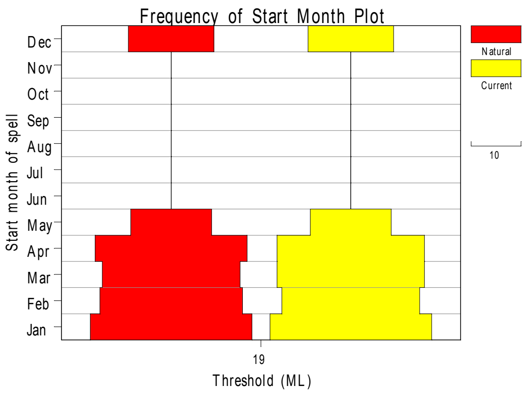
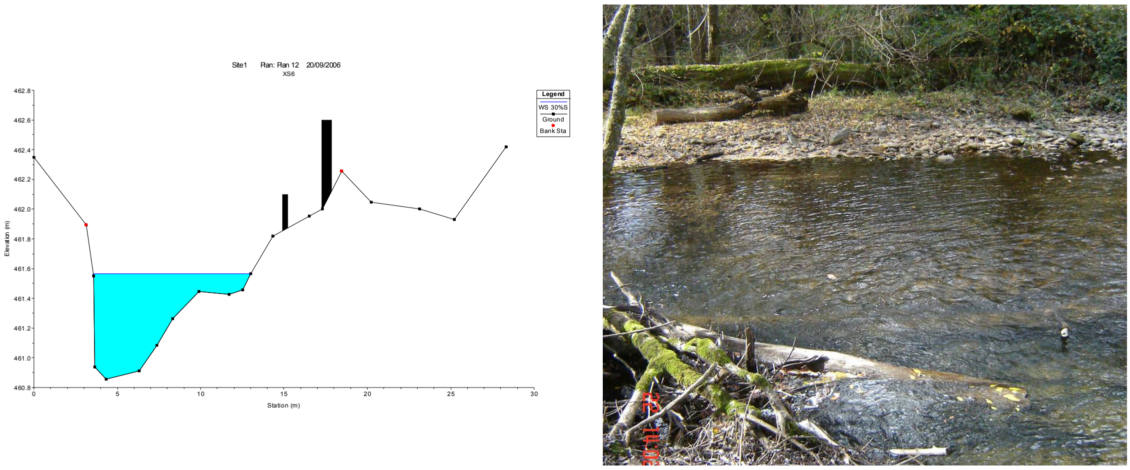




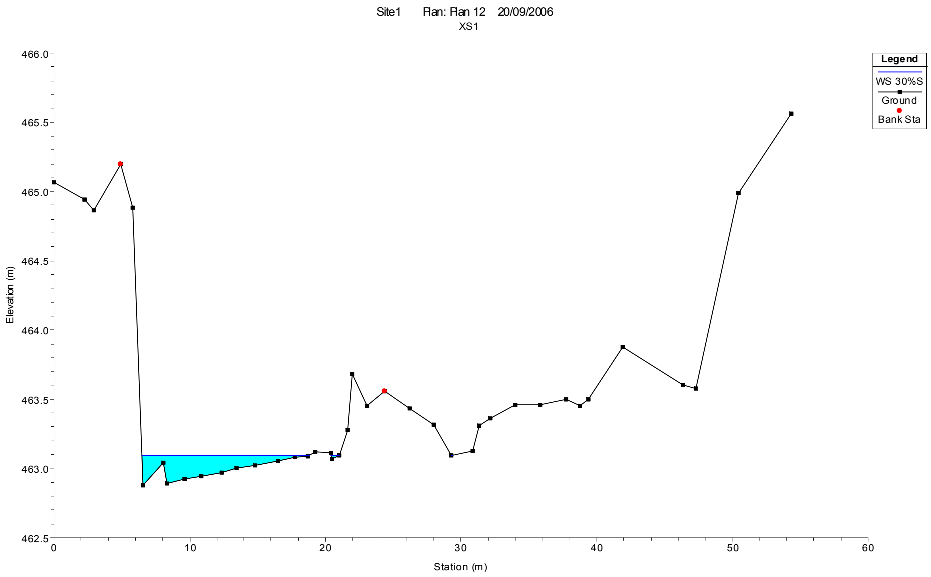
- **Figure 3-4 Duration (top left), frequency (top right) and start month (left) for flows below the summer low flow threshold of 19.3 ML/d at Reach 1.**

Summer fresh

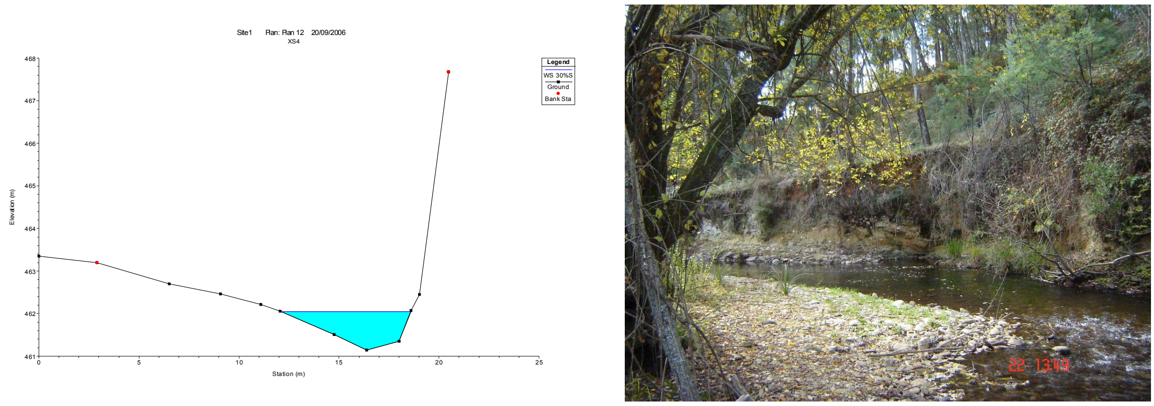
Two summer freshes have been recommended for Reach 1. Each fresh needs to be 95 ML/day and last for six days. A fresh of 95 ML/day represents the 30th percentile flow of the natural summer flow (Figure 3-1). A fresh will inundate approximately one third of the gravel bar at cross section 6 (Figure 3-5). A fresh will fill the full width of the cross-section and wet the root zone of the sedges in cross section 1 and flush the pools in cross section 4 (Figure 3-6 and Figure 3-7).



- **Figure 3-5: Water depth at cross-section 6, at study site, Reach 1, under a summer fresh of 95 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

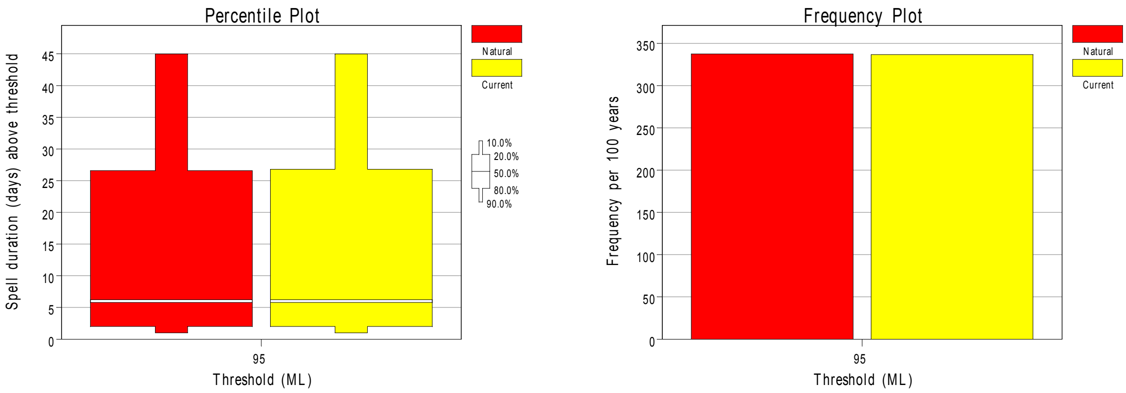


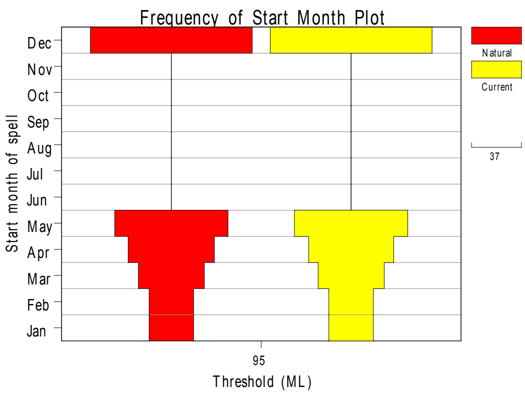
- **Figure 3-6: Water level at cross-section 1, at study site in Reach 1 under a summer fresh of 95 ML/day.**



- **Figure 3-7: Water level at cross-section 4, at study site, Reach 1, under a summer fresh of 95 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

The duration, frequency and start month plots for flows above the 95 ML/day summer fresh recommendation for this site in Reach 1 are shown in Figure 3-8. Summer flows greater than 95 ML/day occur slightly more than three times per year on average and are more common in December and May (Figure 3-8), but a number of these flow events will substantially exceed 95 ML/day and are considered to be summer high flows. There is no difference in the frequency, duration or timing of summer freshes under current flow conditions compared to natural conditions in this reach (Figure 3-8).



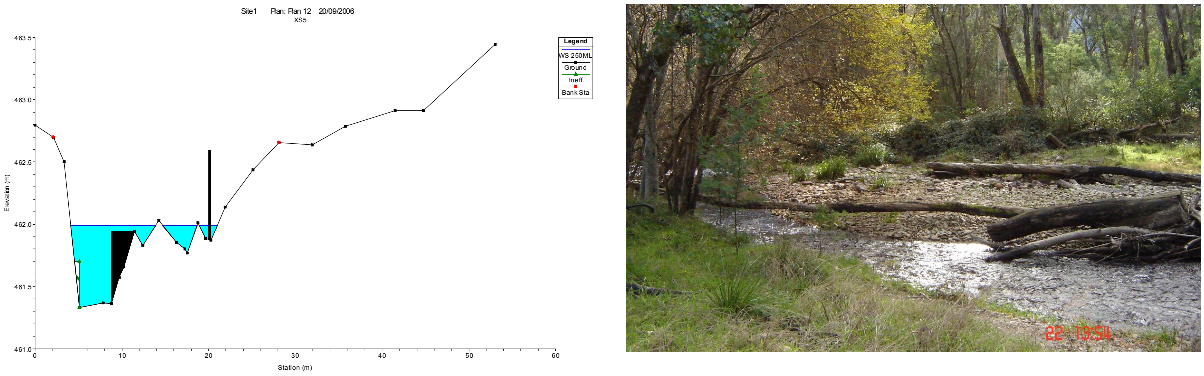


- **Figure 3-8 Duration (top left), frequency (top right) and start month (left) for flows above the summer fresh flow threshold of 95 ML/d at Reach 1.**

Summer freshes provide a disturbance that can prevent nuisance in-channel growth of terrestrial plants and weeds and assist in maintaining water quality by oxygenation and mixing of organic material especially in pools during summer. Improved water quality will benefit the local native fish populations particularly the two-spined black fish.

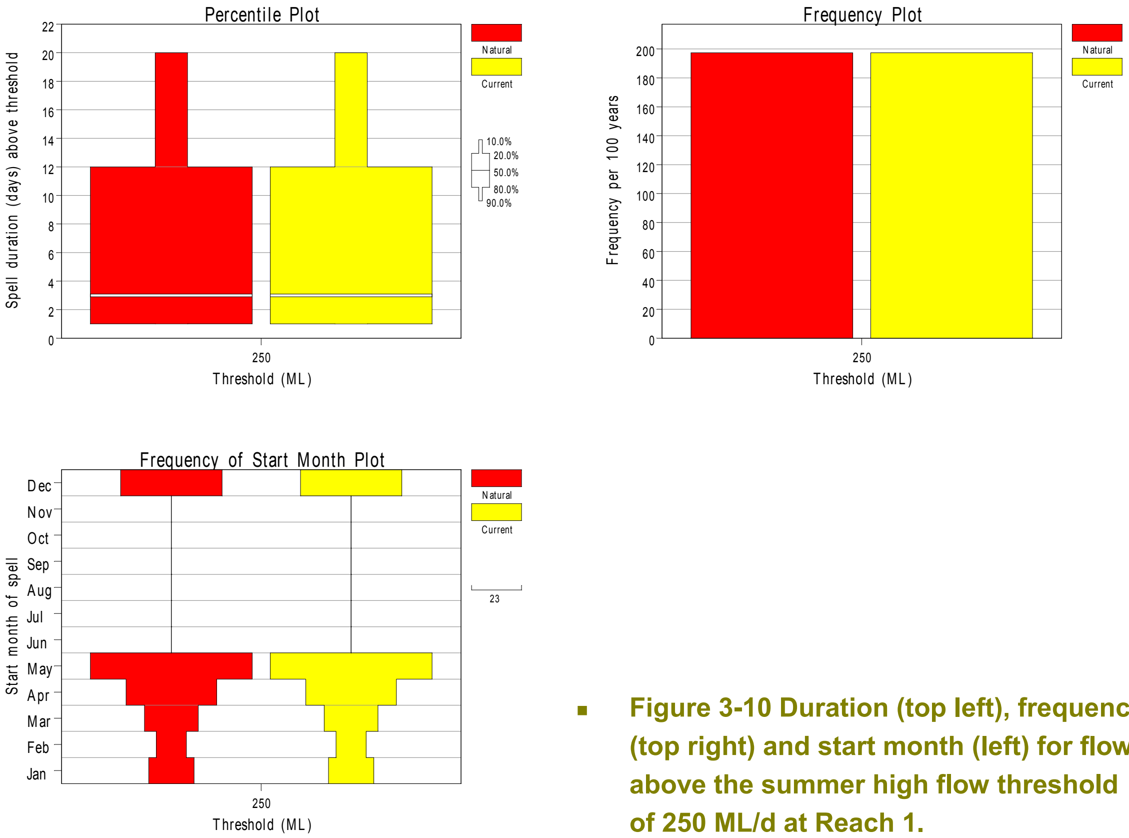
Summer high flow

A summer high flow of 250 ML/day has been recommended for Reach 1. A flow of this magnitude should occur at least once a year and persist for five days. A flow of this size inundates the gravel bar and reduces terrestrial vegetation encroachment at cross section 5 and will disturb cobbles in the stream bed over a wider area (Figure 3-9). Summer high flows are also aimed at maintaining flow variability and preserving seasonal flow patterns.



- **Figure 3-9: Water levels at cross-section 5, at study site, Reach 1, under a summer high flow of 250 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

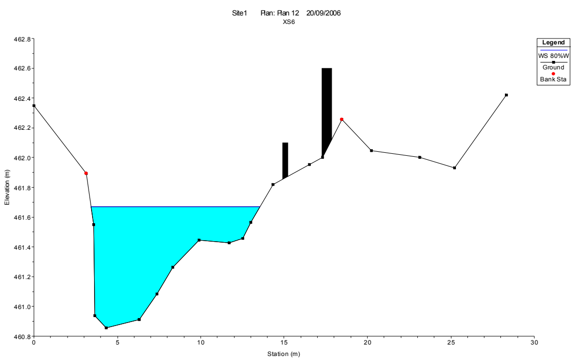
The frequency, duration and start month plots for summer high flows of 250ML/day are shown in Figure 3-10. The duration plot shows that the median duration of flows of this magnitude is usually three days however they can last up to 20 days. The frequency plot indicates that flows of this size can occur up to twice a year, but two summer freshes and one high flow are considered sufficient to meet the ecological objectives for this reach. High flows are most common in December and May and probably reflect late spring or early winter storm events. There is no difference in the duration, frequency and timing of summer high flows under natural and current conditions (Figure 3-10).



- **Figure 3-10 Duration (top left), frequency (top right) and start month (left) for flows above the summer high flow threshold of 250 ML/d at Reach 1.**

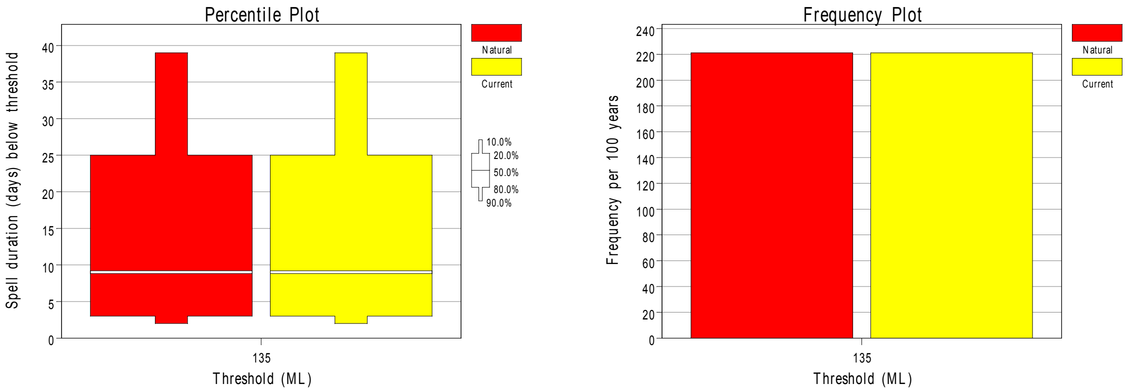
Winter low flow

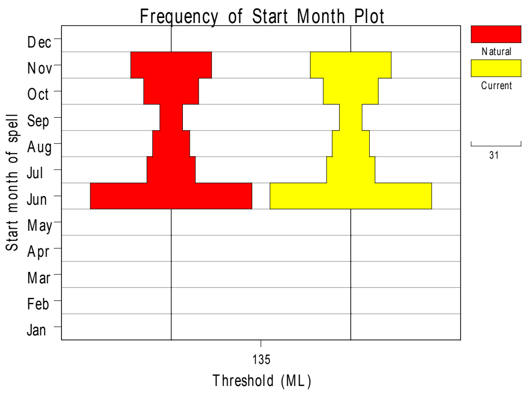
A winter low flow of 135 ML/day or as naturally occurs has been recommended for Reach 1. This flow is equivalent to the 80th percentile winter flow for this reach (Figure 3-1). A flow of this magnitude will inundate the vegetation on the bar at cross section 6 (Figure 3-11). Winter low flows provide seasonal variability, increased opportunity for fish movement through the reach and prevent terrestrial vegetation from colonizing gravel bars and benches, which helps maintain different vegetation zones within the river channel.



- **Figure 3-11: Water level cross-section 6, at study site, Reach 1, under winter low flow of 135 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

The duration, frequency and start of month plots for a flow of 135 ML/day during winter are shown in Figure 3-12. Winter flows exceed 135 ML/day for most of the time under natural and current flow regimes and generally only drop below this level for 8 days, twice a year (Figure 3-12). Lower flows are most common in June and probably reflect years with dry and prolonged autumn periods.

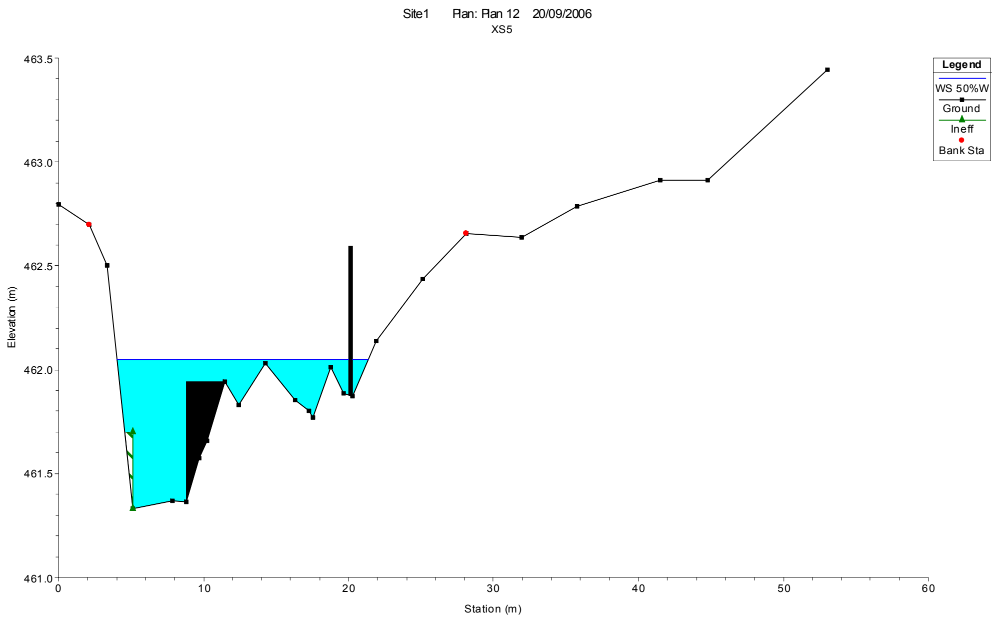




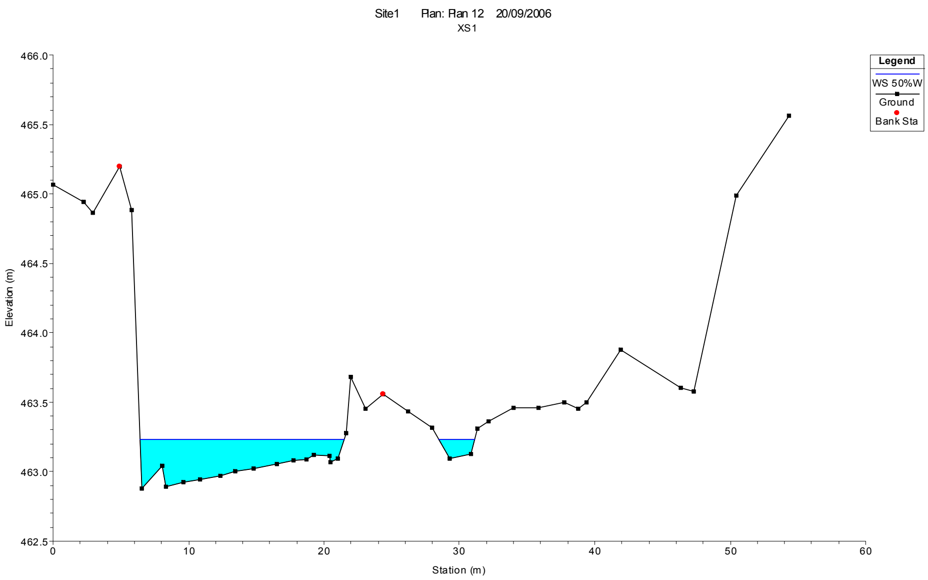
- **Figure 3-12 Duration (top left), frequency (top right) and start month (left) for flows below the winter low flow threshold of 135 ML/d at Reach 1.**

Winter fresh

Three winter freshes of 294 ML/day have been recommended for this Reach. Each fresh should last for up to 10 days and occur at least three times a year to provide sufficient benefit to the ecological values of this reach. A winter fresh will inundate the entire bar at cross section 5, wet the lower and middle banks and start to move some rocks on the streambed, which represents an important type of disturbance (Figure 3-13). A fresh will also fill the side channels and wet the entire bar in the main channel at cross section 1 (Figure 3-14). These responses are important for maintaining the thalweg and channel complexity, preventing the accumulation of excessive vegetation growth on the gravel bars and maintaining natural vegetation zonation. Macroinvertebrates may be temporarily disturbed by these events, but will benefit from the mixing of organic material through the middle to upper layers of the streambed.

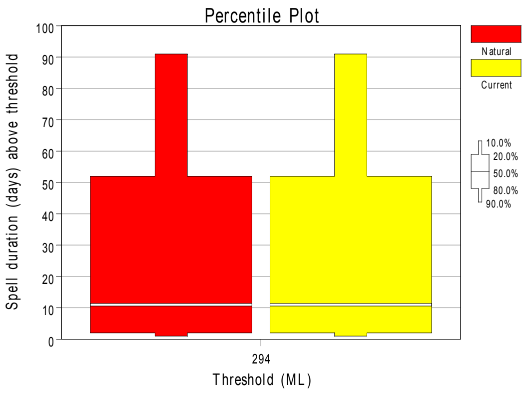


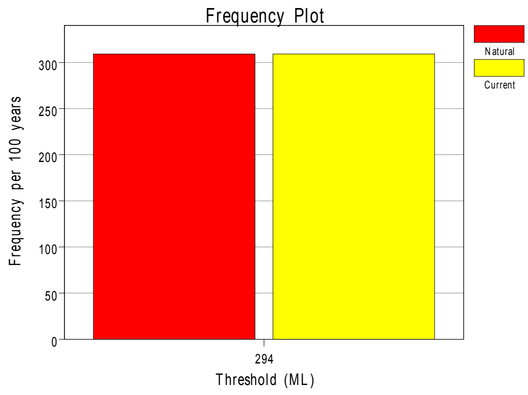
■ **Figure 3-13: Water level at cross-section 5, at the study site, Reach 1, under a winter fresh of 294 ML/day.**

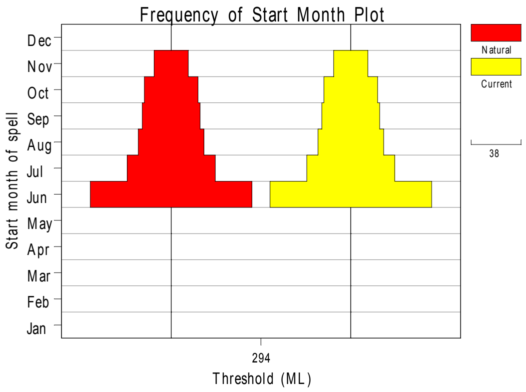


■ **Figure 3-14: Water depth at cross-section 1, at the study site, Reach 1, under a winter fresh of 294 ML/day.**

There is no difference in the frequency or duration of winter freshes between natural and current flow conditions. Flows greater than 294 ML/day occur approximately three times per winter and have a median duration of 10 days (Figure 3-15). Freshes are most likely to occur in June (Figure 3-15).





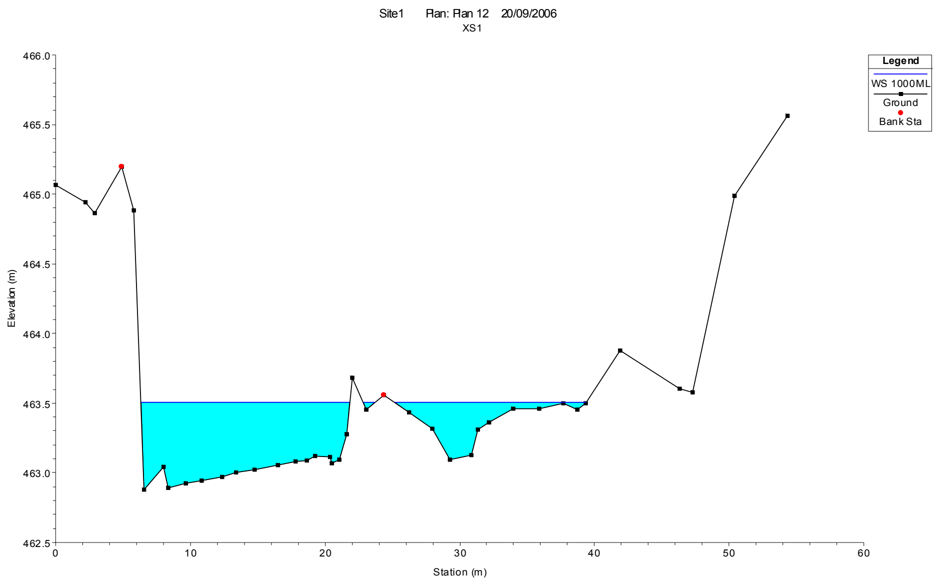


- **Figure 3-15 Duration (top left), frequency (top right) and start month (left) for flows above the winter fresh flow threshold of 294 ML/d at Reach 1.**

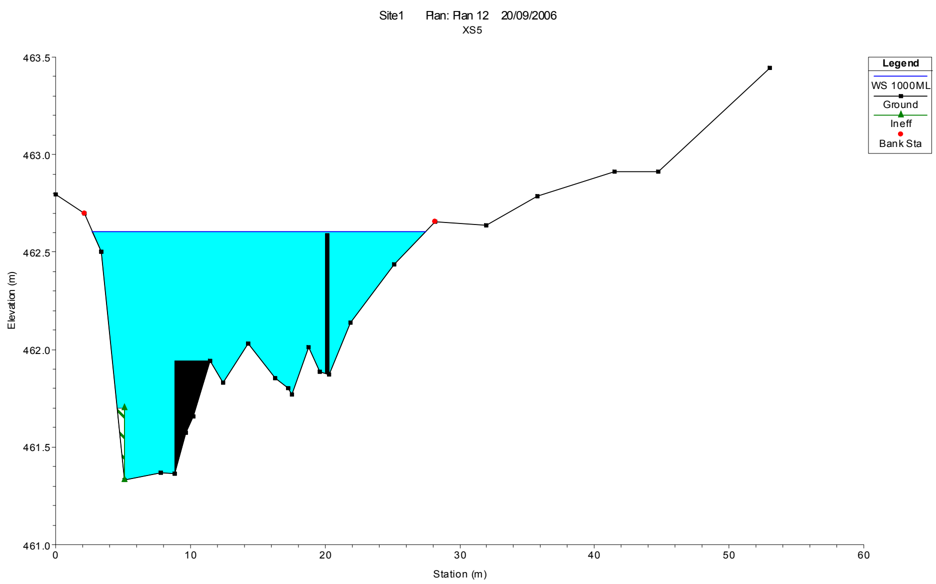
Winter high flow (1)

Two winter high flows have been recommended for Reach 1. The first high flow occurs once each year, has a magnitude of 1000 ML/day and lasts for approximately two days. This high winter flow will cover the bar at cross section 1(Figure 3-16), provide flow through the flood runner at cross section 5 (Figure 3-17) and cover the cobbled bank in cross section 4 (Figure 3-18).

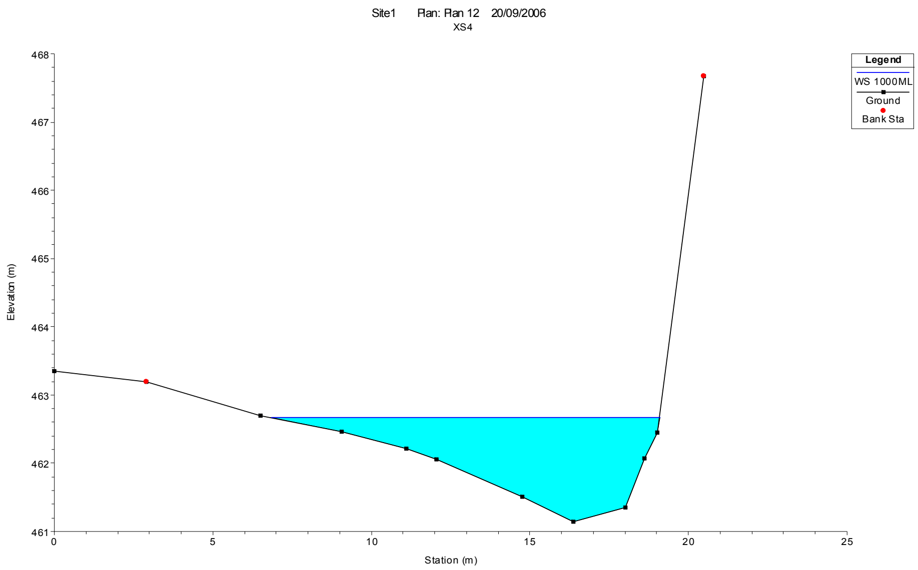
A flow of this size will roll moderate sized rocks in the channel, turn over parts of the substrate, help with channel maintenance and reset ecological processes. High flows provide opportunities for fish movement, access to substrate for benthic macroinvertebrates and maintain biological diversity.



■ **Figure 3-16: Water level at cross-section 1, at study site, Reach 1, for a winter high flow (winter high flow 1) of 1000 ML/day.**



■ **Figure 3-17: Water level at cross-section 5, at study site, Reach 1, for a winter high flow (winter high flow 1) of 1000 ML/day.**



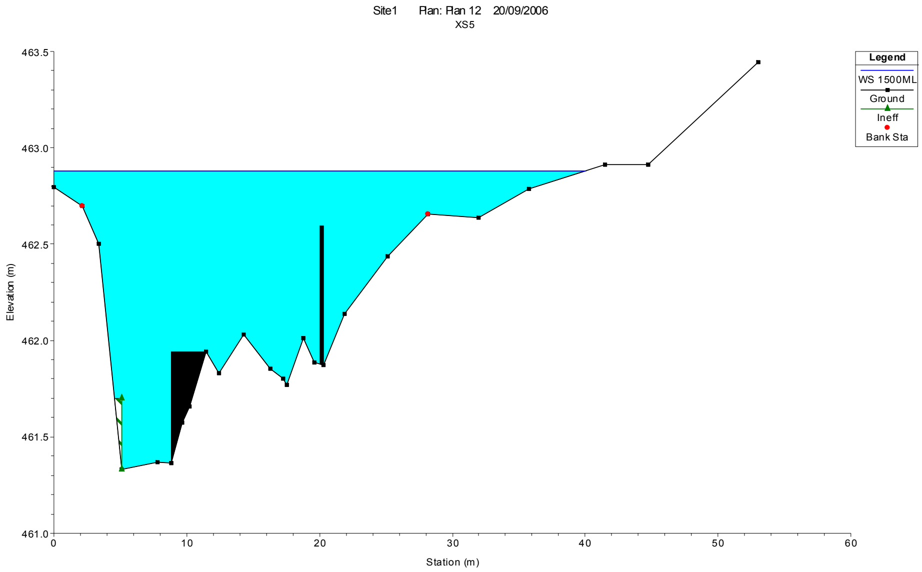
- **Figure 3-18: Water level at cross-section 4, at study site, Reach 1, for a winter high flow (winter high flow 1) of 1000 ML/day.**

There is no difference in the frequency, timing or duration of winter high flows under current conditions compared to natural flow conditions. The plots in Figure 3-19 show the median duration of a 1000 ML/day flow is two days however flows of this size can last up to six days and occur about once a year. A winter high flow is most likely to occur between June and September (Figure 3-19).

- **Figure 3-19 Duration (top left), frequency (top right) and start month (left) for flows above the winter high 1 flow threshold of 1000 ML/d at Reach 1.**

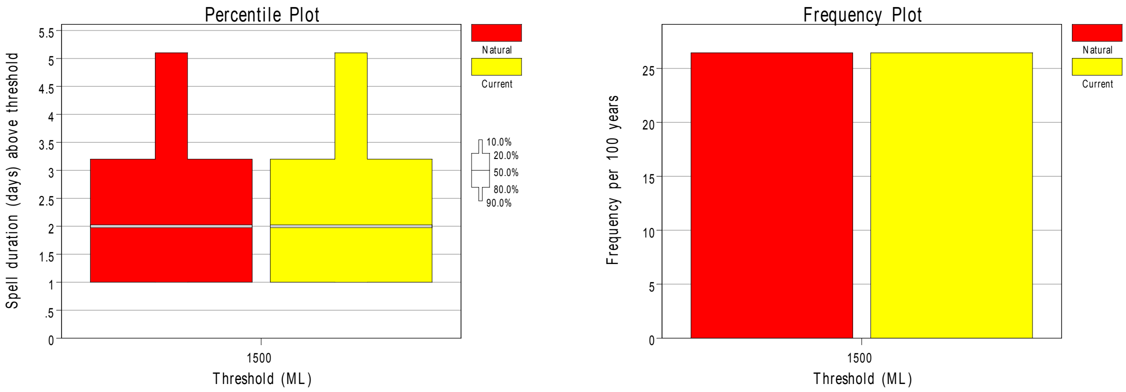
Winter high flow (2)

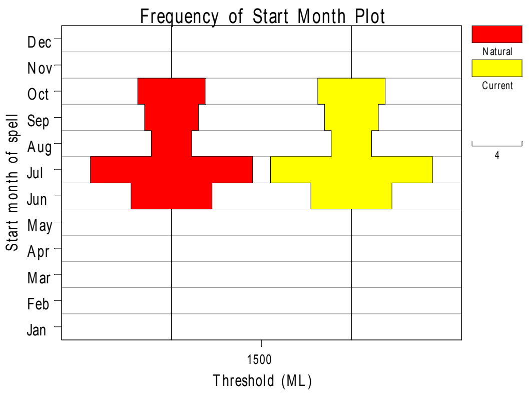
The second high flow recommendation for Reach 1 is for a flow of 1500 ML/day that lasts for two days, once every four years. A 1500 ML/day flow is close to bankfull and will inundate the left bank and low floodplain on the right bank at cross section 5 (Figure 3-20). This flow will help maintain the channel morphology but will not necessarily be bankfull in some places. There is a degree of uncertainty around the exact magnitude of this flow recommendation because the REALM model used in this assessment has been calibrated for low flows. It is not intended that this flow will be actively managed in the upper Ovens River, rather it will occur naturally and should not be harvested.



- **Figure 3-20: Water level at cross-section 5, at study site, Reach 1, under a winter high flow (winter high flow 2) of 1500 ML/day.**

Current water extractions have no effect on flows greater than 1500 ML/day (Figure 3-21). Under current and natural conditions flows of this magnitude occur approximately once every four years (most often in July) and last for a median of two days (Figure 3-21).





- **Figure 3-21 Duration (top left), frequency (top right) and start month (left) for flows above the winter high 2 flow threshold of 1500 ML/d at Reach 1.**

Overbank flows

No specific recommendations have been made for overbank flows in Reach 1. Overbank flows will occur naturally, but modelling suggests that they will be relatively infrequent (i.e. less than once every four years). Any overbank flow that currently occurs should be allowed to continue in order to provide some connectivity to the floodplain.

3.1.3 Comparison of current flows against the recommended flow regime

The flow recommendations for Reach 1 were compared with the natural and current flow regimes to determine the effect of current abstractions and to highlight the potential changes that may be required to deliver the recommended flow regime (Table 3-3). The flow recommendations are not met under the natural flow regime all of the time. This is to be expected and represents natural variability in the system. The comparison of most interest in Table 3-3 is the difference between the flows that are met under the natural and current flow regimes. The recommended environmental flows for Reach 1 are met as often under the current flow regime as the natural flow regime (Table 3-3), which confirms that current water harvesting has relatively little effect on flow in the Ovens River near Harrietville.

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- **Table 3-3 Assessment of the extent to which flow recommendations for Reach 1 are met under the current and natural flow regimes.**

Component	Months	Flow Rec		Current Compliance	Natural Compliance	Ratio of Current to Natural Compliance
Summer low	Dec - May	Volume	19.3	80%	80%	*100%*
Summer fresh	Dec - May	Volume	95	100%	100%	*100%*
		Number	3	70%	71%	*100%*
		Duration	6	47%	47%	*100%*
Summer high	Dec - May	Volume	250	86%	86%	*100%*
		Number	1	86%	86%	*100%*
		Duration	3	57%	57%	*100%*
Winter low	Jun - Nov	Volume	135	80%	80%	*100%*
Winter fresh	Jun - Nov	Volume	294	100%	100%	*100%*
		Number	3	61%	61%	*100%*
		Duration	10	53%	53%	*100%*
Winter high (1)	Jun - Nov	Volume	1000	61%	61%	*100%*
		Number	1	61%	61%	*100%*
		Duration	2	66%	66%	*100%*
Winter high (2)	Jun - Nov	Volume	1500	84%	84%	*100%*
		Number	0.25	84%	84%	*100%*
		Duration	2	60%	60%	*100%*

Legend							
Mostly complies			Greater than	**95**	%		
Frequently complies			Between	**76**	&	**95**	%
Often complies			Between	**51**	&	**75**	%
Occasionally complies			Between	**26**	&	**50**	%
Rarely complies			Between	**5**	&	**25**	%
Never complies			Between	**0**	&	**5**	%

3.2 Reach 2 – Ovens River between Morses Creek and the Buckland River

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: Morses Creek to Buckland River.

Asset	Current condition
Hydrology	▪ Slight reduction in magnitude of low flows under current flow regime compared to natural flow regime. Water extractions can reduce summer flows.
Geomorphology	▪ Stable channel. No active sediment source. Impacts of gold mining.
Water quality	▪ Generally excellent with nutrients locally elevated near urban centres.
Fish	▪ Good abundance of small native fish, particularly two-spined blackfish and mountain galaxias. Good to excellent habitat. Fish barriers at Bright and Porpunkah. Predation by trout.
Macroinvertebrates	▪ Generally excellent. Excellent habitat. Threats include urban impacts and point source pollution.
Instream and riparian flora	▪ Riparian vegetation reduced in extent and diversity. Blackberries, willows and garden weeds present. Instream vegetation good.

3.2.2 Flow recommendations

The environmental flow recommendations for Reach 2 are summarised in Table 3-5. No specific cease-to-flow recommendation has been made as cease-to-flow periods are not expected under natural or current flow conditions in most years. The flow duration curves for the winter and summer current and natural flows are shown in Figure 3-20.

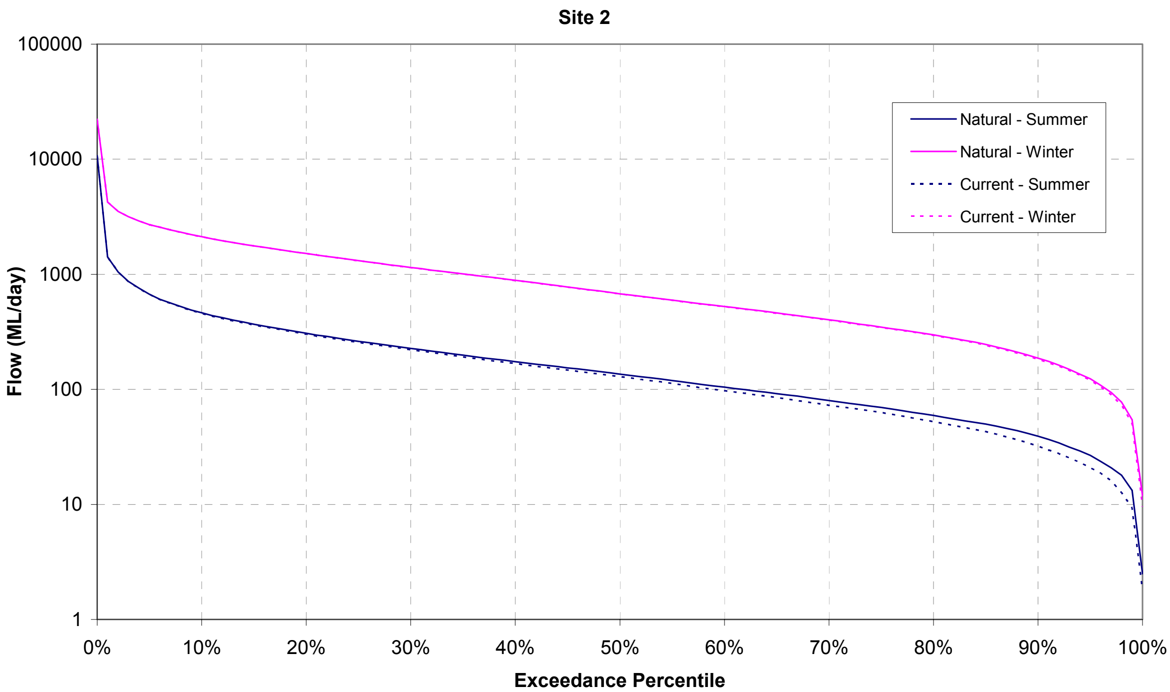
Table 3-5 Summary of flow recommendations for Reach 2: Morses Creek to Buckland River.

Reach 2 Morses Creek to Buckland River				
Season	Component	Magnitude	Frequency	Duration
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	60 ML/day or natural		
	Freshes	230 ML/day	3 per year	10 days
Winter	Low flow	300 ML/day or natural		
	Freshes	677 ML/day	2 per year	15 days
	High	2120 ML/day	2 per year	6 days
	Bankfull	No specific recommendation		
	Overbank	No specific recommendation		

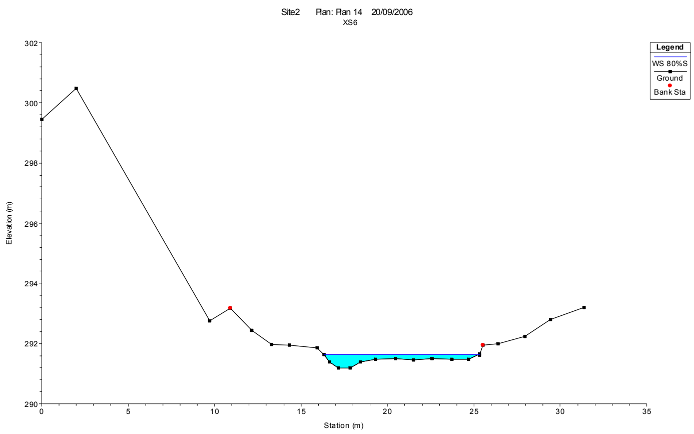
Summer low flow

A summer low flow of 60 ML/day or as naturally occurs has been recommended for Reach 2. This is equivalent to the natural 80th percentile summer flow for this reach (Figure 3-22). The criteria for recommending a summer low flow were to ensure riffles (e.g. cross section 6 in Figure 3-23) remain wet, to maintain moisture in the root zone of riparian plants and to maintain pool depth and longitudinal connectivity for fish movement. Low summer flows also ensure sufficient flow to maintain water quality. Summer low flows would be expected to drop below 60 ML/day approximately 1.45 times per year for a median duration of 15 days under natural conditions, but current water harvesting means that flows less than 60 ML/day occur slightly more often and last for a median of 17 days (Figure 3-24). Flows less than 60 ML/day are most likely to occur between February and April (Figure 3-24).

This summer low flow recommendation is slightly less than the minimum flow (70 ML/day) recommended for this reach in the previous environmental flow assessment (SKM 2001). The minimum flow recommendation in the previous flow assessment was based on the lowest flow observed during that study. The authors of the previous flow study indicated that a lower minimum flow recommendation may be adequate, but they stated that they had no way of determining how much lower the flow could be. The use of a HEC-RAS model in the current study allows this low flow recommendation to be more reliably estimated.



- **Figure 3-22: Natural and Current summer and winter percentage exceedance curves for Reach 2.**



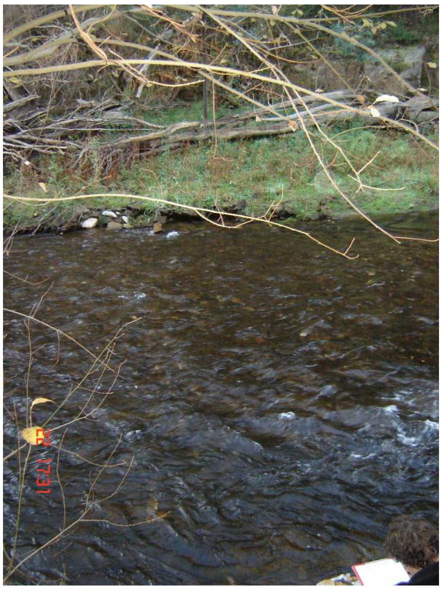
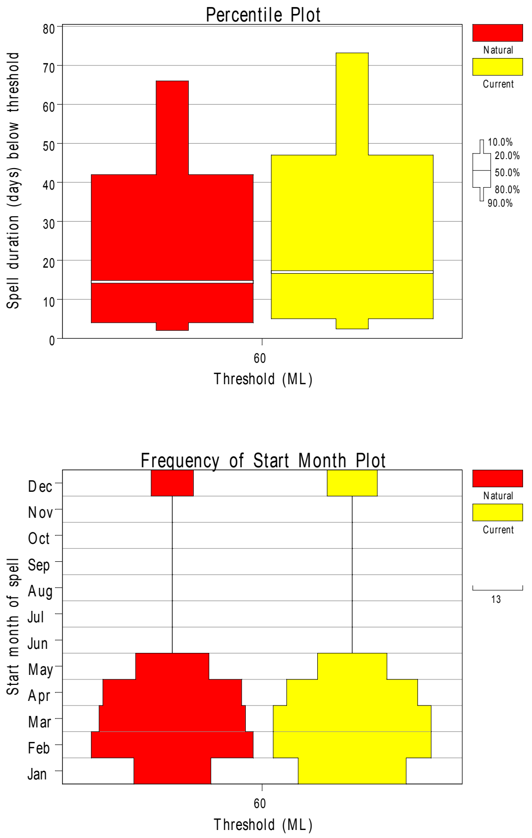


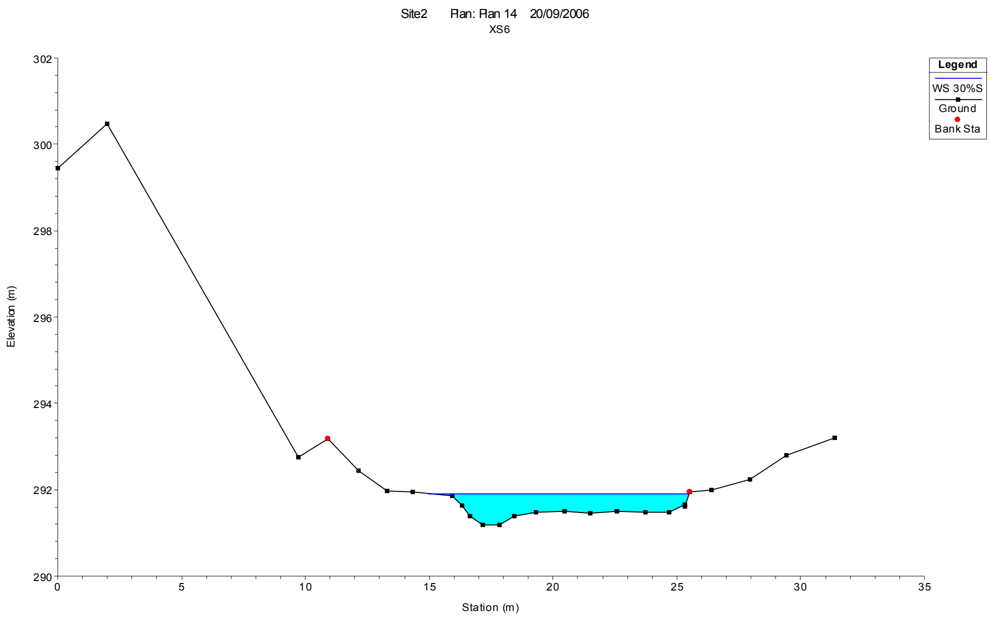
Figure 3-23: Water level at cross-section 6, at study site, Reach 2, under a summer low flow of 60 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.



- **Figure 3-24 Duration (top left), frequency (top right) and start month (left) for flows below the summer low flow threshold of 60 ML/d at Reach 2.**

Summer fresh

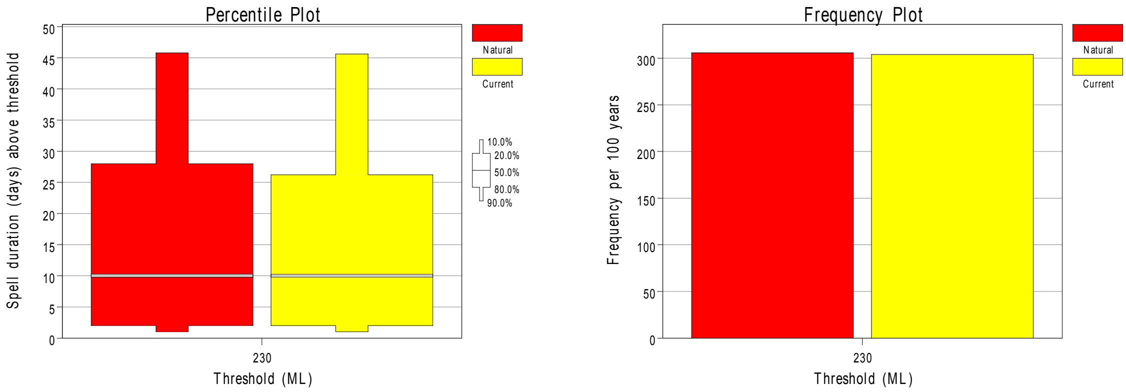
Three summer freshes of 230 ML/day each have been recommended for Reach 2. Each fresh should last at least 10 days. Summer freshes will create deeper water over riffles at cross section 6 and scour biofilms from rocks and cobbles (Figure 3-25). Summer freshes will also help maintain water quality, the current diversity of aquatic flora and fauna and preserve flow variability.

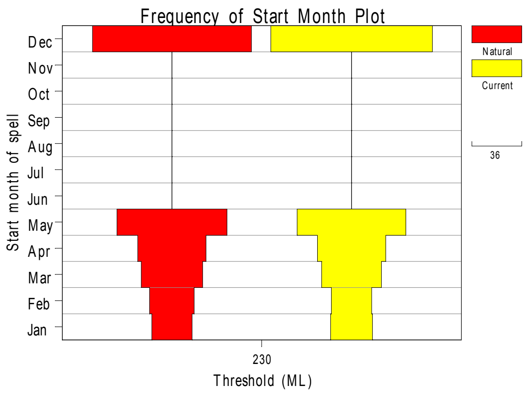


- **Figure 3-25: Water level at cross-section 6, at study site, Reach 2, under a summer fresh of 230 ML/day.**

There is little difference between the duration and frequency of summer freshes under current and natural flow conditions. Flows greater than 230 ML/day occur on average three times each summer, last for a median duration of approximately 11 days and are most common in December and May (Figure 3-26).

No specific recommendation has been made for a summer high flow in this reach of the Ovens River as it will have little ecological value in the confined gorge. However, higher flows will naturally occur and should be allowed to pass through this reach to contribute to flows and help meet ecological objectives further downstream.

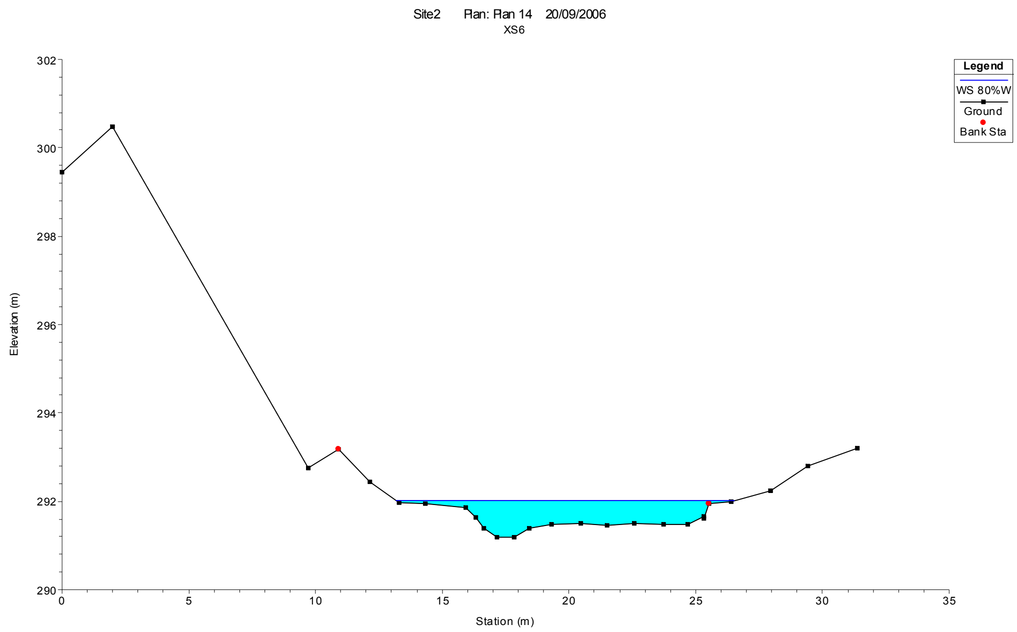




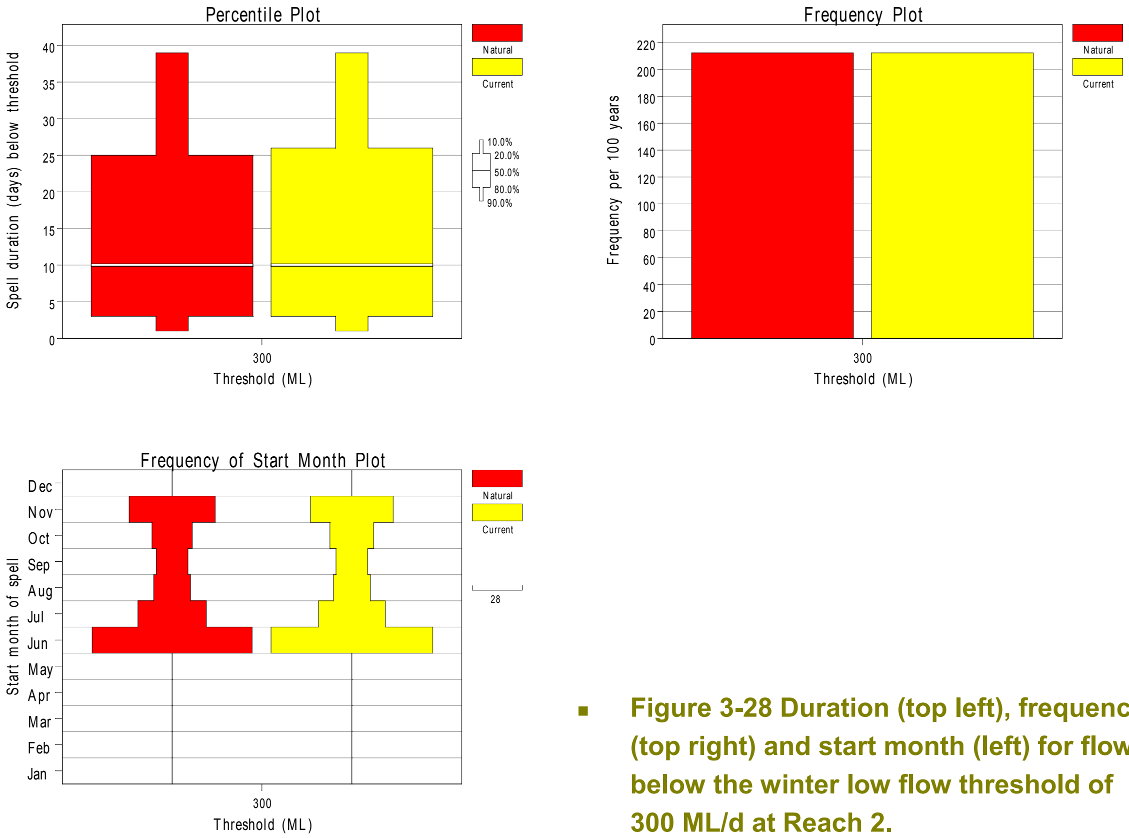
- **Figure 3-26 Duration (top left), frequency (top right) and start month (left) for flows above the summer fresh flow threshold of 230 ML/d at Reach 2.**

Winter low flow

A winter low flow of 300 ML/day or as naturally occurs has been recommended for Reach 2. A flow of this magnitude will be sufficient to provide water over the riffle area and low benches in cross section 6 (Figure 3-27). Flows of this size have a median duration of approximately 10 days and occur most often in early winter (Figure 3-28). Current water harvesting has had little effect on winter low flows. Under both natural and current conditions, flows less than 300 ML/day occur approximately two times each winter and have a median duration of 10 days (Figure 3-28).



- **Figure 3-27: Water level at cross-section 6, at study site, Reach 2, under a winter low flow of 300 ML/day.**



- **Figure 3-28 Duration (top left), frequency (top right) and start month (left) for flows below the winter low flow threshold of 300 ML/d at Reach 2.**

Winter fresh

Two winter freshes have been recommended for Reach 2. Each fresh should be at least 677 ML/day in magnitude and last for up to 15 days. Flows of this size will cover the channel up to the vegetation line in cross section 3 (Figure 3-29). Winter freshes are important for maintaining general channel complexity, specific channel features such as the thalweg and for providing disturbances that will turn over substrate elements and help mix organic material through the middle and upper layers of the streambed. Disturbance is important for maintaining diversity of aquatic flora and fauna communities.

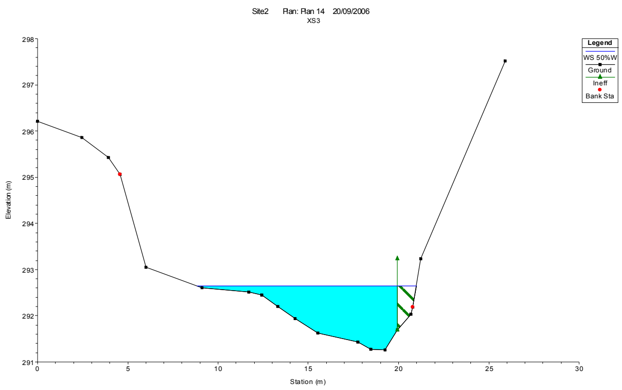
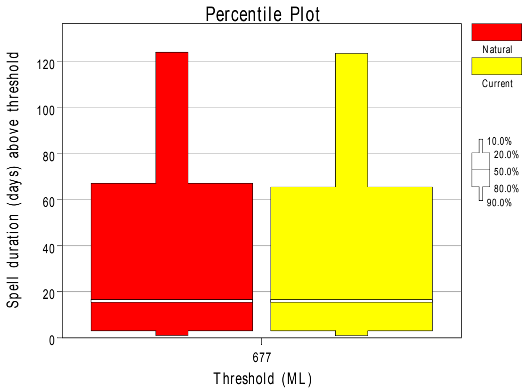
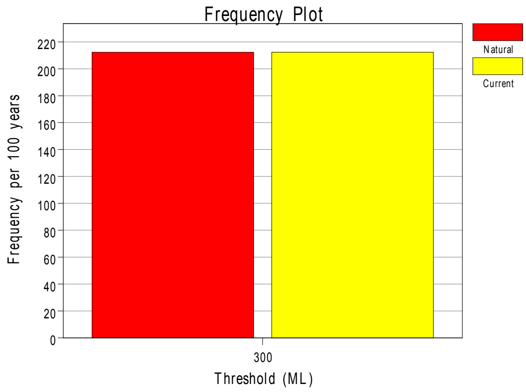
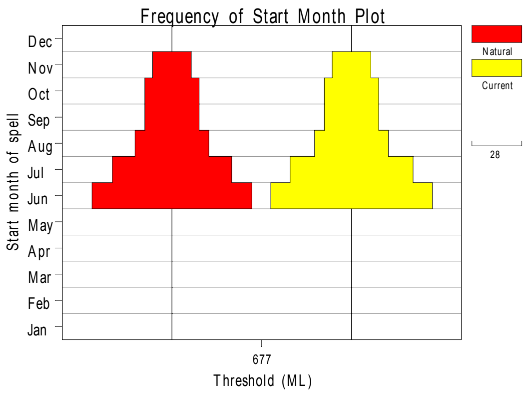


Figure 3-29: Water level at cross-section 3, at study site, Reach 2, under a winter fresh of 677 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.

There is little difference in the duration and frequency of winter freshes under current and natural flow conditions. Winter freshes generally occur twice per year and last for a median duration of 15 days (Figure 3-30). Winter freshes in reach 2 most commonly occur in June and July.



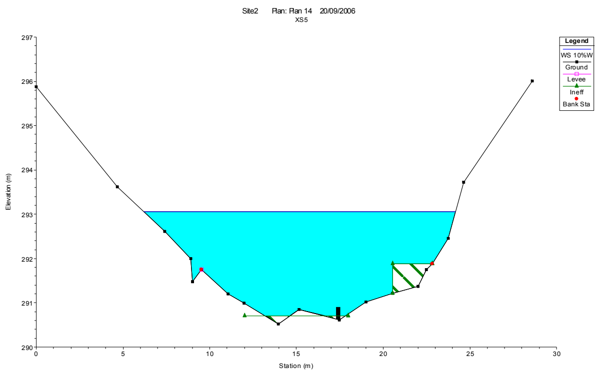




- **Figure 3-30 Duration (top left), frequency (top right) and start month (left) for flows above the winter fresh flow threshold of 677 ML/d at Reach 2.**

Winter high flow

Two winter high flows of 2120 ML/day that last for up to six days have been recommended for Reach 2. These high flows will fill the channel up to the exotic shrub line that is evident at cross section 5 (Figure 3-31) and is expected to help prevent further encroachment of exotic plant species to lower parts of the channel. Flows greater than 2120 ML/day will also provide channel maintenance and disturb the substrate to scour biofilms and turn rocks and cobbles.



- **Figure 3-31: Water level at cross-section 5, at study site, Reach 2, under winter high flow of 2120 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

There is no difference between the frequency and duration of winter high flows under the current and natural flow regimes (Figure 3-32). Flows greater than 2120 ML/day occur slightly less than twice per year on average and have a median duration of six days (Figure 3-32). Winter high flows are most common in August and September and may coincide with periods of snow melt higher in the catchment.

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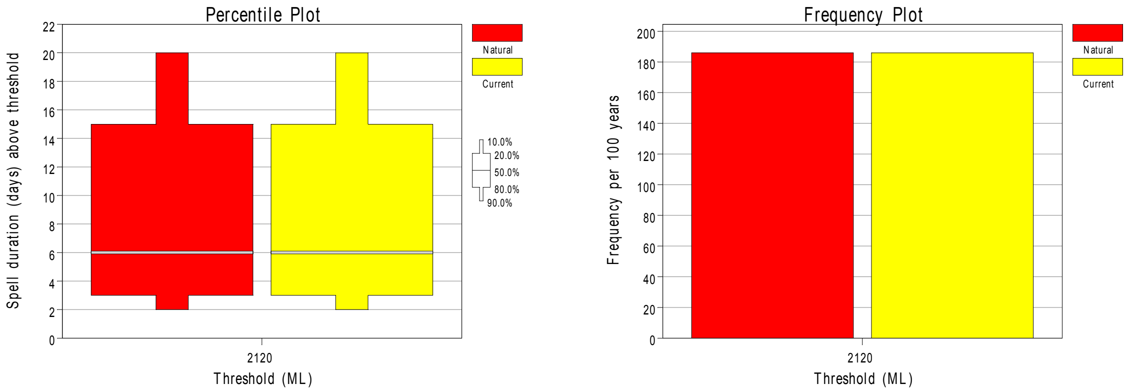

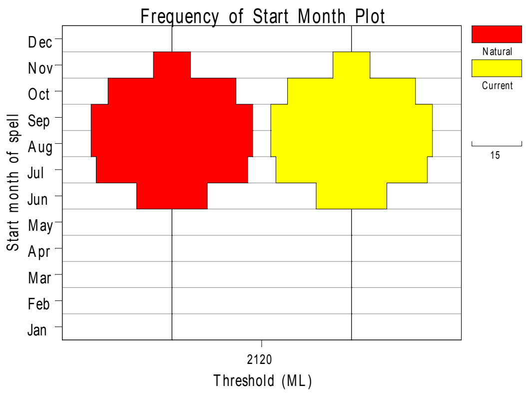

- **Figure 3-32 Duration (top left), frequency (top right) and start month (left) for flows above the winter high flow threshold of 2120 ML/d at Reach 2.**

3.2.3 Comparison of current flows against the recommended flow regime

The flow recommendations for Reach 2 were compared with the natural and current flow regimes to determine the effect of current abstractions and to highlight the potential changes that may be required to deliver the recommended flow regime (Table 3-6). The flow recommendations are not met under the natural flow regime all of the time. This is to be expected and represents natural variability in the system. The comparison of most interest in Table 3-6 is the difference between the flows that are met under the natural and current flow regimes. The recommended environmental flows for Reach 1 are met nearly as often under the current flow regime as the natural flow regime (Table 3-6). The main difference relates the summer low flow. Under natural conditions the summer low flow recommendation of 60 ML/day is met 80% of the time, but under the current flow regime this recommendation is only met 76% of the time. During dry years, the summer minimum flow will naturally drop below 60 ML/day, but water harvesting in this reach means that summer flows now drop below this level more often or for a longer period. Current water harvesting has no detectable effect on other flow components in this reach.

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- **Table 3-6 Assessment of the extent to which flow recommendations for Reach 2 are met under the current and natural flow regimes.**

Component	Months	Flow Rec		Current Compliance	Natural Compliance	Ratio of Current to Natural Compliance
Summer low	Dec - May	Volume	60	76%	80%	*95%*
Summer fresh	Dec - May	Volume	230	100%	100%	*100%*
		Number	3	61%	61%	*99%*
		Duration	10	50%	50%	*100%*
Winter low	Jun - Nov	Volume	300	80%	80%	*100%*
Winter fresh	Jun - Nov	Volume	677	99%	99%	*100%*
		Number	2	78%	78%	*100%*
		Duration	15	52%	53%	*98%*
Winter high	Jun - Nov	Volume	2120	78%	78%	*100%*
		Number	2	53%	53%	*100%*
		Duration	6	54%	54%	*100%*

Legend							
Mostly complies			Greater than	**95**	%		
Frequently complies			Between	**76**	&	**95**	%
Often complies			Between	**51**	&	**75**	%
Occasionally complies			Between	**26**	&	**50**	%
Rarely complies			Between	**5**	&	**25**	%
Never complies			Between	**0**	&	**5**	%

3.3 Reach 3 – Ovens River from Buckland River to Buffalo River

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: Ovens River from Buckland River to Buffalo River.

Asset	Current condition
Hydrology	▪ Water extractions can reduce summer flow. Significant urban and rural demands upstream of site therefore noticeable difference between natural and current flow regimes.
Geomorphology	▪ Capacity of river reduced leading to breakout of flood flows. Increased sinuosity. Concerns of an avulsion into Happy Valley Creek.
Water quality	▪ Water quality very good but badly affected by 2003 bushfires. Nutrient levels tend to be slightly high near urban centres. Low summer flows may temporarily increase nutrient concentrations.
Fish	▪ Good abundance of small bodied fish, but predicted large bodied fish absent from reach. Good to moderate habitat. Low abundance of snags. Barriers to fish at Tea Garden Creek. Exotic fish
Macroinvertebrates	▪ Generally in good to moderate condition with excellent habitat. Potential threats include urban impacts and point source pollution.
Instream and riparian flora	▪ Riparian vegetation severely reduced in extent. Dense blackberry and well established willows on banks and instream bars. In stream vegetation good.

3.3.2 Flow recommendations

The environmental flow recommendations for Reach 3 are summarised in Table 3-8. No specific cease-to-flow recommendation has been made as under natural conditions cease-to-flow would not occur in most years. The flow duration curves for the winter and summer current and natural flows are shown in Figure 3-33.

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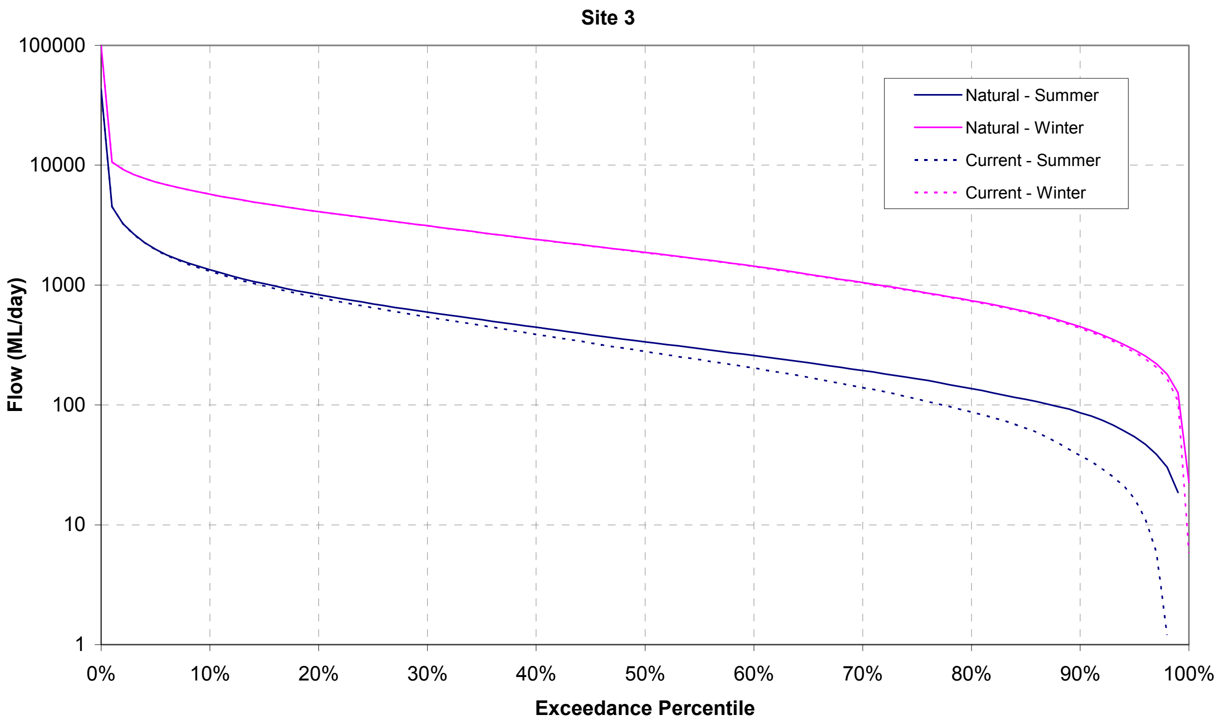
- **Table 3-8 Summary of flow recommendations for Reach 3: Ovens River from Buckland River to Buffalo River.**

Reach 3 Ovens River from Buckland River to Buffalo River				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	137 ML/day or natural		
	Freshes	595 ML/day	2 per year	7 days
	High	2000 ML/day	1 per year	4 days
Winter	Low flow	740 ML/day or natural		
	Freshes	1870 ML/day	1 per year	15 days
	High	8500 ML/day	1 per year	4 days
	Bankfull	As natural		
	Overbank	No specific recommendation		



- **Figure 3-33: Natural and Current summer and winter percentage exceedance curves for Reach 3.**

Summer low flow

A summer low flow of 137 ML/day or as naturally occurs has been recommended for Reach 3 of the Ovens River. This flow is equivalent to the 80th percentile summer natural flow for this reach (Figure 3-33). A summer low flow will provide water to the root zone of riparian plants on the gravel bars at cross section 5 but does not inundate the gravel bar (Figure 3-34). A summer low flow also maintains pool depth and some longitudinal connectivity for fish movement, maintains water quality and provides wetted riffle habitat for aquatic macroinvertebrates.

Under natural conditions, flows less than 137 ML/day would have occurred on average 1.6 times per year and had a median duration of 14 days (Figure 3-35). Current water harvesting means that flows now drop below 137 ML/day approximately twice per year on average for a median duration of 17 days (Figure 3-35). Very low summer flows are also more likely to occur in January under current flow conditions, which is probably due to high irrigation demand and increased urban demand during the peak tourism season. Differences between current and natural flow patterns are greater than for reaches further upstream and indicates that current water harvesting is having an effect on summer flows in this part of the Ovens River.

The summer low flow recommendation for this reach is substantially lower than the minimum flow (200 ML/day) recommended in the previous environmental flow assessment for the upper Ovens River (SKM 2001). The main reason for this discrepancy is that the recommendations in the previous study were based on conditions that were directly observed in the field. The lowest flow observed in this reach by the environmental flow assessment team in the previous study was 200 ML/day and they did not have any information to enable them to estimate conditions and ecological responses to flows below 200 ML/day. The HEC-RAS model used in the current study allows conditions to be more reliably estimated for a range of flows and therefore the summer low flow recommendation of 137 ML/day is a more accurate assessment of the minimum flow that is required through this reach of the Ovens River.

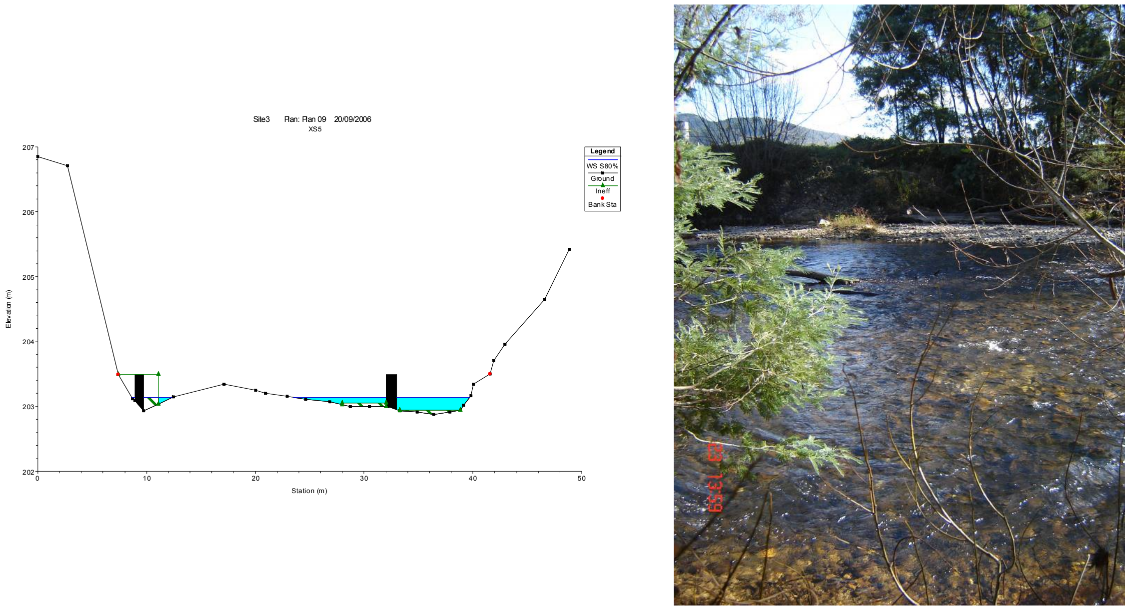
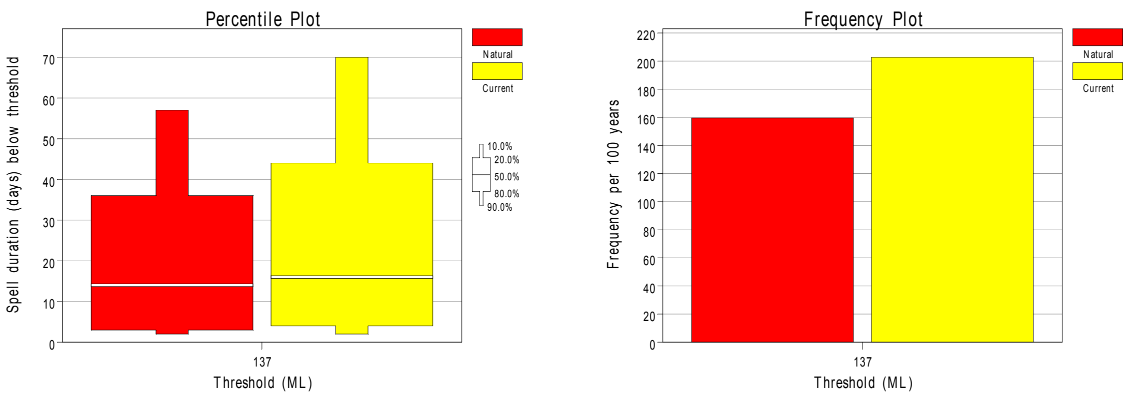
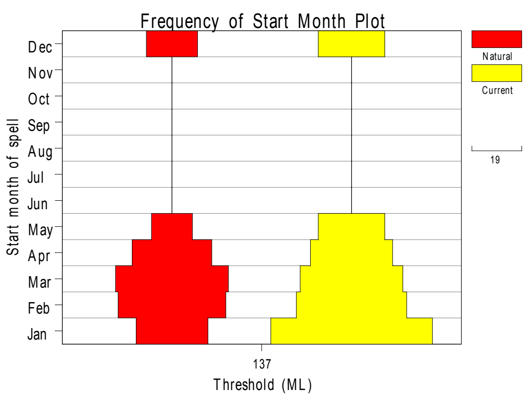


Figure 3-34: Water level at cross-section 5, at study site, Reach 3, under a summer low flow of 137 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.

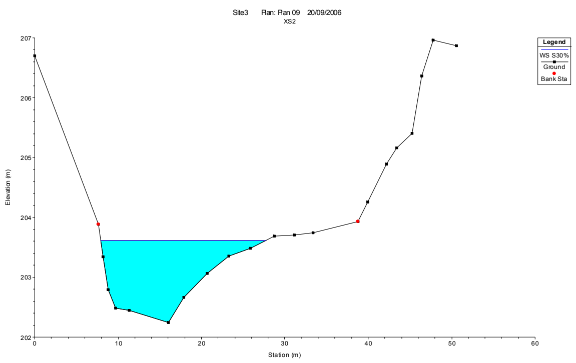




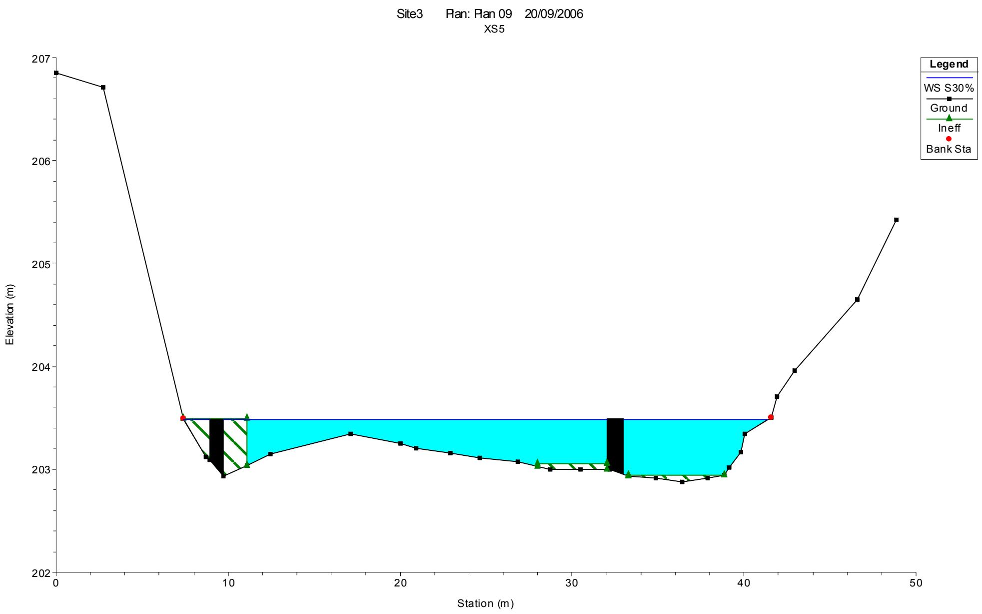
- **Figure 3-35 Duration (top left), frequency (top right) and start month (left) for flows below the summer low flow threshold of 137 ML/d at Reach 3.**

Summer fresh

Two summer freshes of 595 ML/day each have been recommended for Reach 3. Each fresh should last for up to eight days. The summer freshes will fill the channel to the vegetation line at cross section 2 and cover the gravel bars at cross sections 5 and 6 (Figure 3-36 and Figure 3-37). The aim of a summer fresh is to water bank vegetation to reduce water stress during summer and to disturb the substrate to help mix oxygen and organic material through the upper layers of the streambed. Summer freshes will also mix pools and generally assist in maintaining water quality.

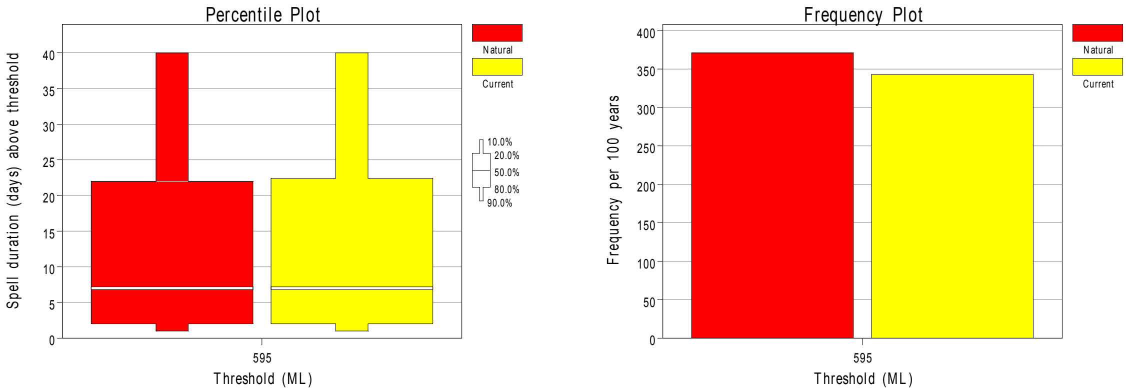


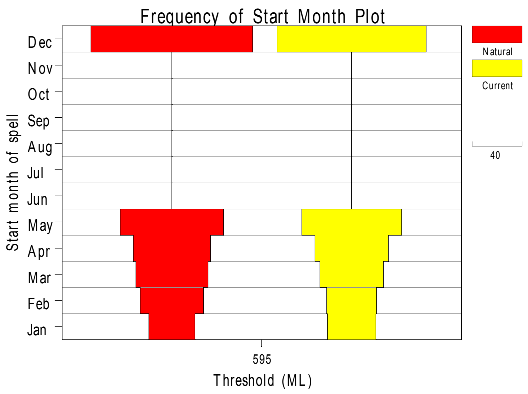
- **Figure 3-36: Water level at cross-section 2, at study site, Reach 3, under summer fresh of 595 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



- **Figure 3-37: Water level at cross-section 5, at study site Reach 3 under a summer fresh of 595 ML/day.**

Summer freshes occur slightly less often, but have a slightly higher duration under the current flow regime compared to the modeled natural flow regime. Under natural conditions, flows greater than 595 ML/day would have occurred 3.7 times per summer on average and had a median duration of seven days, but under current conditions, these flows occur approximately 3.4 times per summer and have a median duration of seven days (Figure 3-38). Two of the flows greater than 595 ML/day are recommended to be retained as freshes, with the third flow being a high flow, which is described separately below. Summer freshes occur most often in December and May (Figure 3-38).

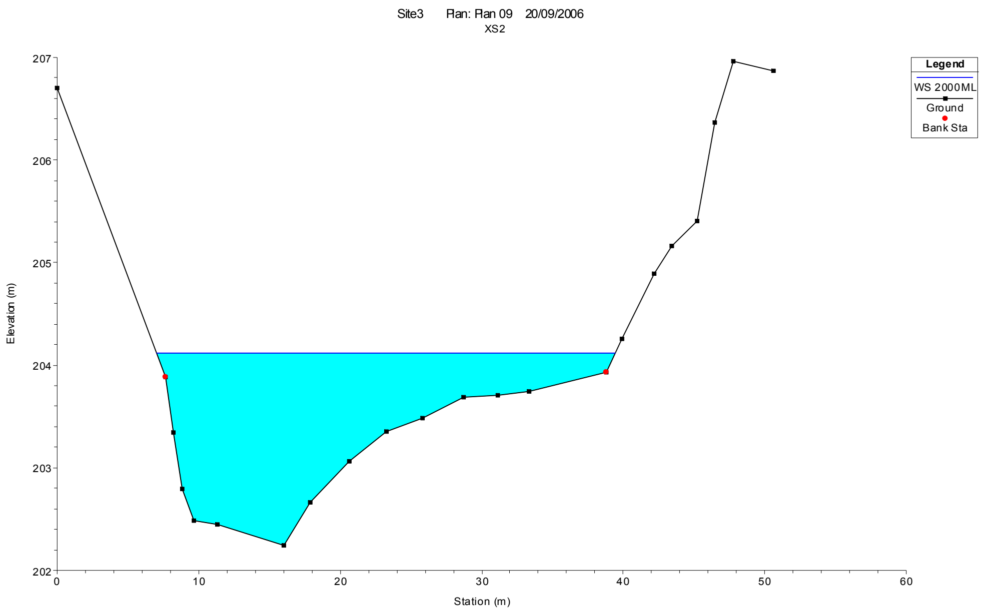




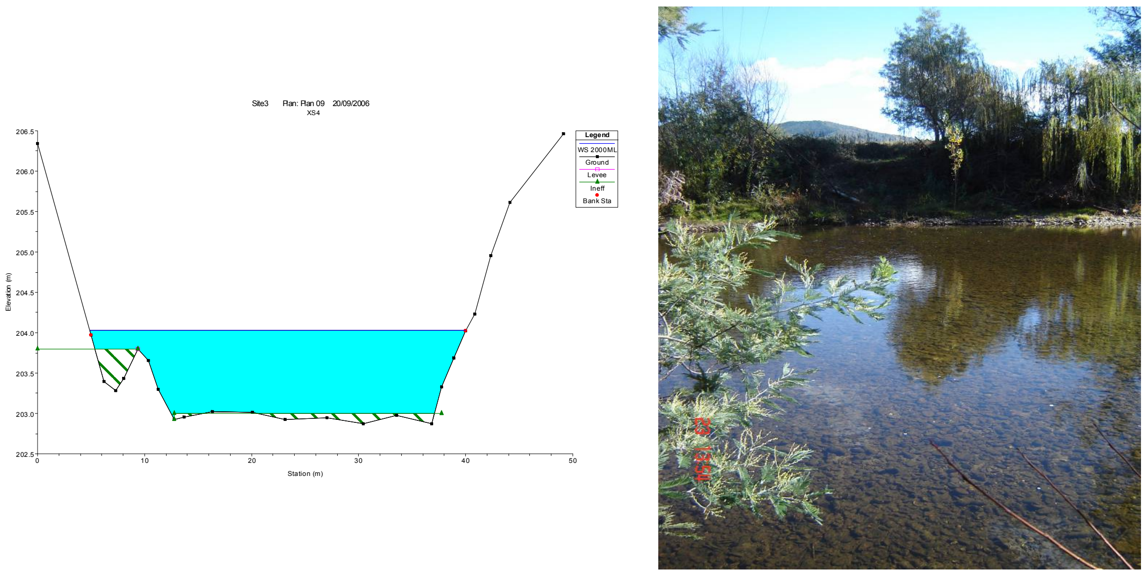
- **Figure 3-38 Duration (top left), frequency (top right) and start month (left) for flows above the summer fresh flow threshold of 595 ML/d at Reach 3.**

Summer high flow

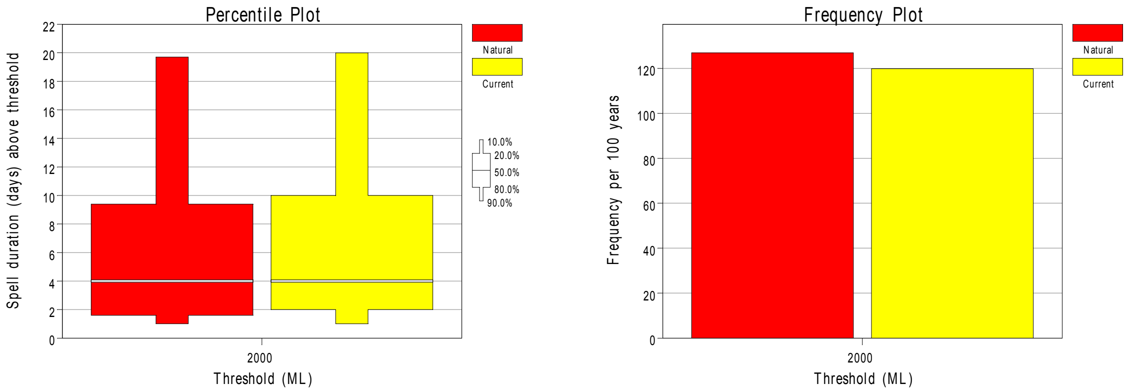
A summer high flow of 2000 ML/day has been recommended for Reach 3. A flow of this size should occur once a year and last for a minimum of four days. A summer high flow will completely fill the bottom of the channel in this reach. Specifically it will cover the bench at cross section 2 (Figure 3-39) and provide flow through the secondary flow path at cross section 4 (Figure 3-40). Current water harvesting has had a very slight effect on the frequency and duration of summer high flows in this reach of the Ovens River. Under natural conditions, flows greater than 2000 ML/day would have occurred approximately 1.25 times per summer and had a median duration of four and a half days (Figure 3-41). Under current conditions, these flows occur on average 1.2 times per summer and have a median duration of five days (Figure 3-41). These flows are most likely to occur in December or May.

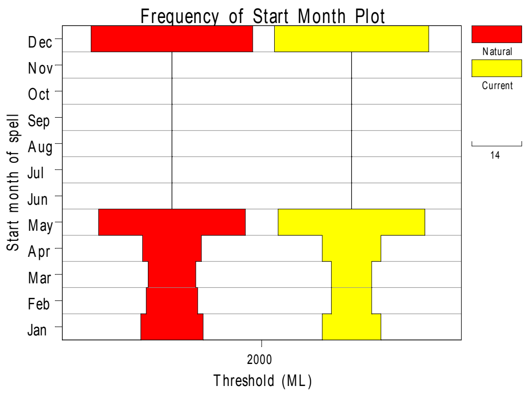


- **Figure 3-39: Water level at cross-section 2, at study site, Reach 3, under a summer high flow of 2000 ML/day.**



- **Figure 3-40: Water level at cross-section 4, at study site, Reach 3, under summer high flow of 2000 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**





- **Figure 3-41 Duration (top left), frequency (top right) and start month (left) for flows above the summer high flow threshold of 2000 ML/d at Reach 3.**

Winter low flow

A winter low flow of 740 ML/day or as naturally occurs has been recommended for Reach 3. A winter low flow of this size will wet the bottom of the channel and start to inundate the bench at cross section 2 and provide flow over the bar at cross section 6 (Figure 3-42 and Figure 3-43). Winter low flows will prevent terrestrial vegetation colonisation of the instream bars and maintain pool depth and longitudinal connectivity for fish movement.

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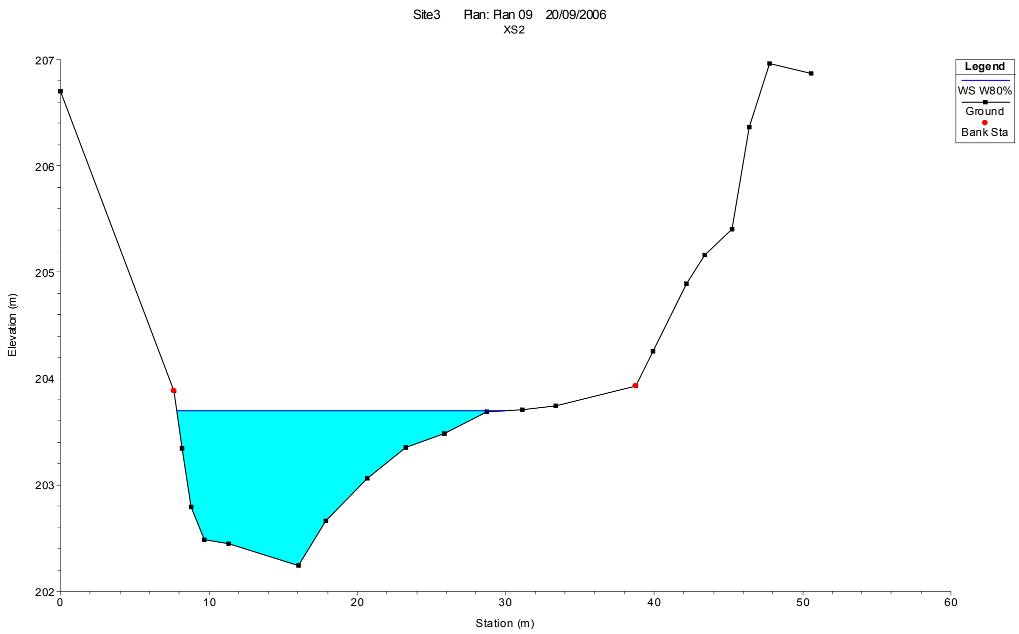
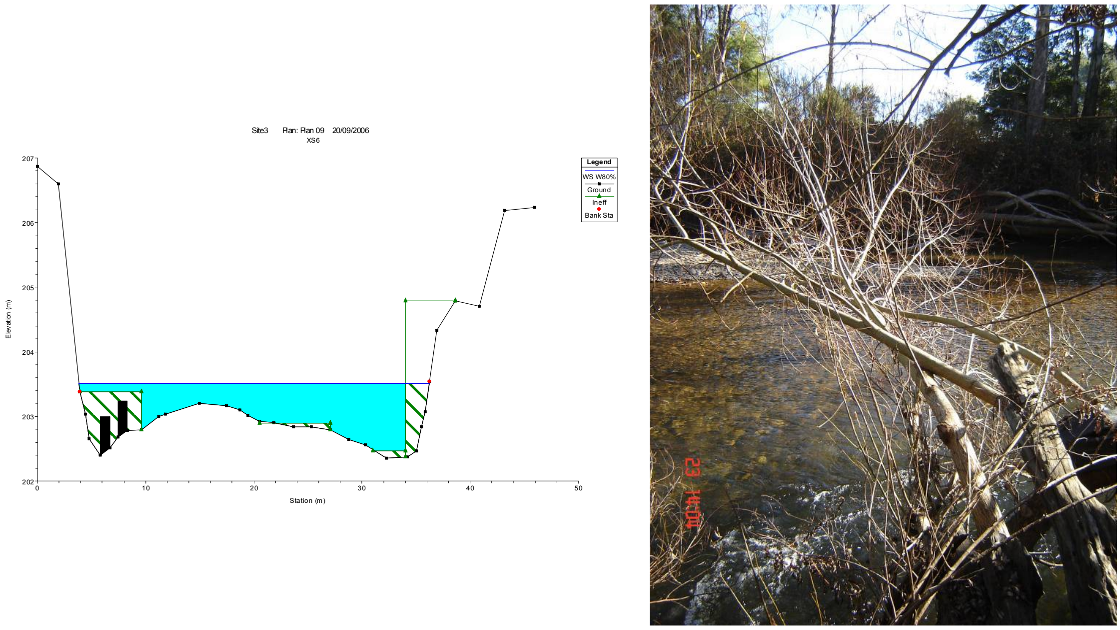


- **Figure 3-42: Water level at cross-section 2, at study site, Reach 3, under winter low flow of 740 ML/day.**



- **Figure 3-43: Water level at cross-section 6, at study site, Reach 3, under winter low flow of 740 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

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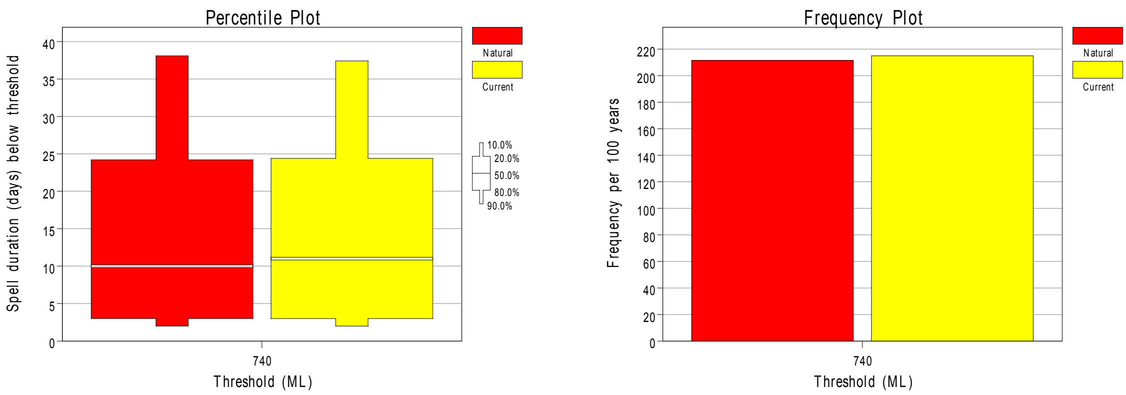
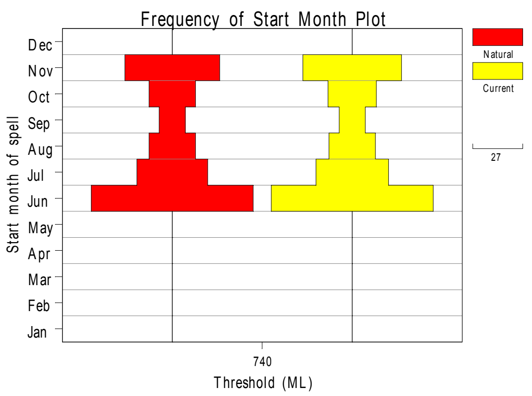
Current water harvesting has had little effect on the winter low flow through this reach. Winter flows drop below 740 ML/day approximately twice per year on average and have a median duration of 10 days under natural conditions and 12 days under current conditions (Figure 3-44). Flows less than 740 ML/day are most likely to occur in June or November.

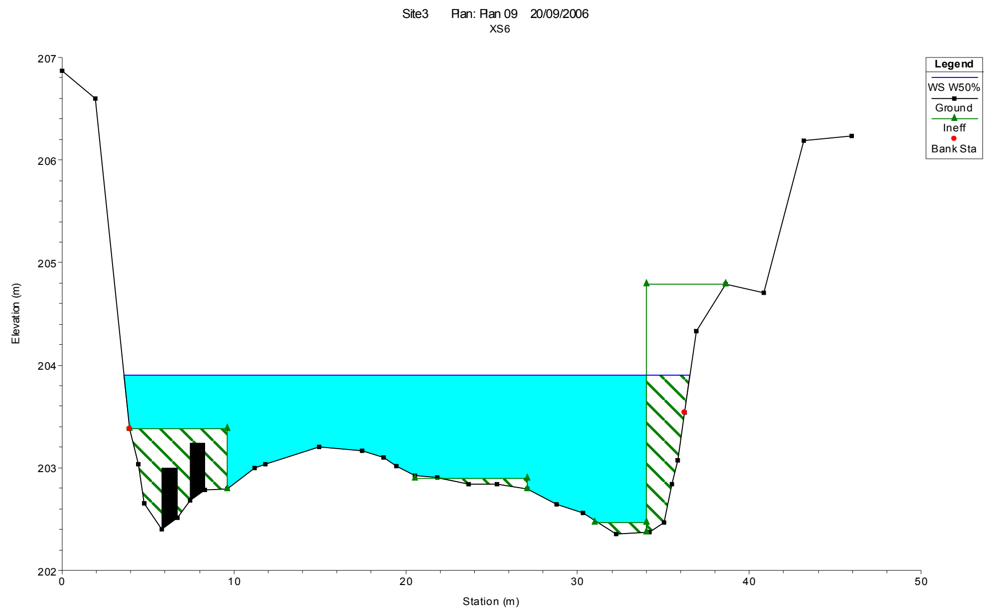




- **Figure 3-44 Duration (top left), frequency (top right) and start month (left) for flows below the winter low flow threshold of 740 ML/d at Reach 3.**

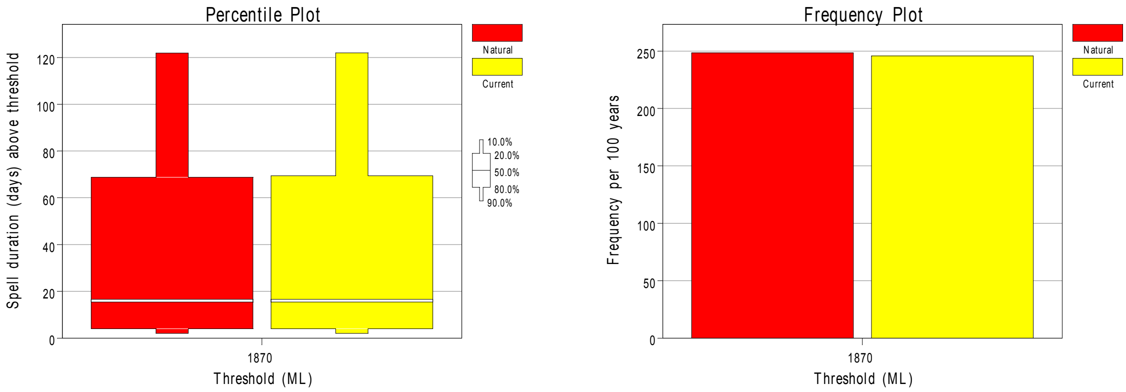
Winter fresh

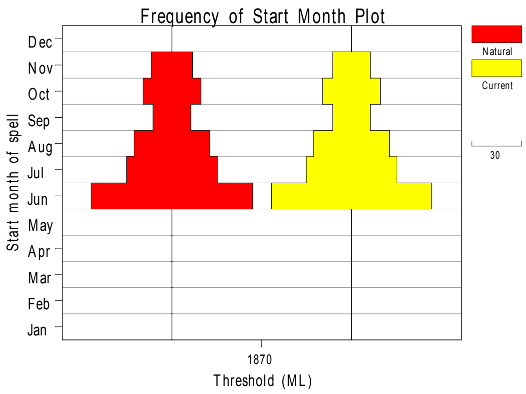
One winter fresh of 1870 ML/day lasting for up to 15 days has been recommended for Reach 3. A winter fresh will disturb substrate elements such as rocks and cobbles and will help mix organic material through the upper layers of the streambed. Freshes will also temporarily increase water depth over gravel bars, such as those shown in cross section 6 (Figure 3-45) and help maintain vegetation zonation. Winter freshes and winter high flows are important for maintaining natural flow variability through this reach.



- **Figure 3-45: Water level at cross-section 6, at study site, Reach 3, under winter fresh of 1870 ML/day.**

The current water regime has little effect on the duration and frequency of winter freshes. Flows greater than 1870 ML/day occur on average 2.5 times per winter and have a median duration of 17 days (Figure 3-46). It is expected that one of these flow events will be a summer fresh, but the other flow will be a higher flow and is discussed in more detail under winter high flows. Flows greater than 1870 ML/day are most common in June (Figure 3-46).

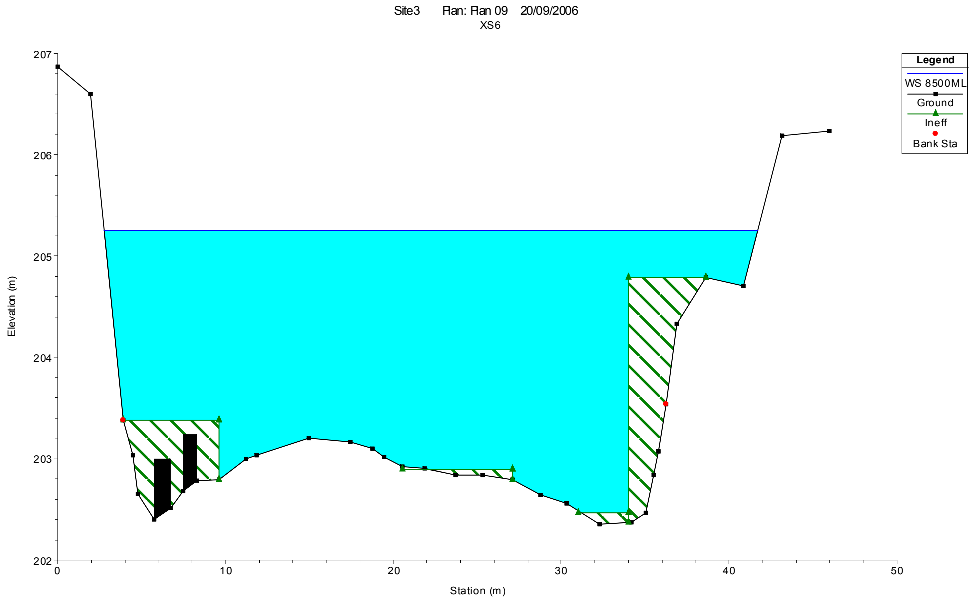




- **Figure 3-46 Duration (top left), frequency (top right) and start month (left) for flows above the winter fresh flow threshold of 1870 ML/d at Reach 3.**

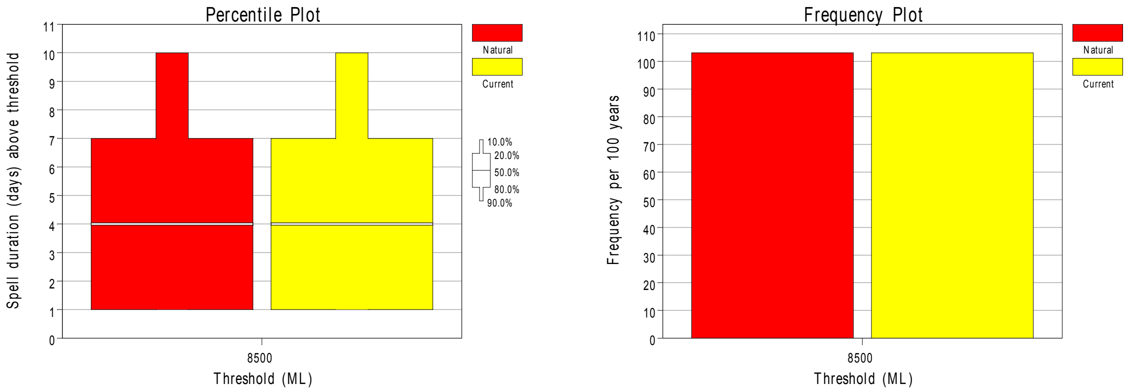
Winter high flow

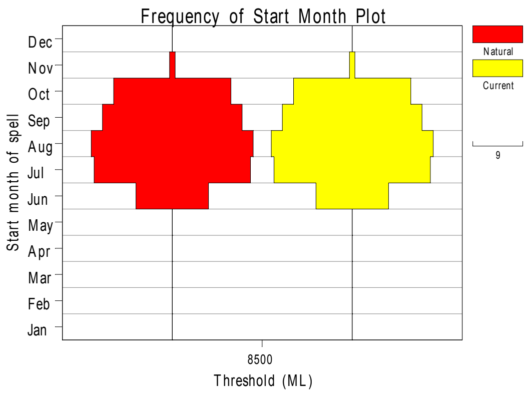
One winter high flow of 8500 ML/day lasting for four days has been recommended for Reach 3. However, a flow of approximately 7200 ML/day could potentially lead to a breakout at the avulsion point near Selzers Lane, and therefore winter high and bankfull flows may not occur in the Ovens River at Myrtleford. Where the recommended flow does occur it is expected to cover high benches within the channel such as the one shown on the left bank of cross section 6 at the flow assessment study site (Figure 3-47). Flows of this magnitude would help maintain the channel thalweg and channel complexity and create an important disturbance that would turn over substrate elements, scour biofilms and in-channel vegetation. Winter high flows may also facilitate fish movement and deliver water to wetland habitats through the gravel lens. A mix of large winter flows is important for maintaining flow variability in the Ovens River.



- **Figure 3-47: Water level at cross-section 6, at this site, Reach 3, under winter high flow of 8500 ML/day.**

Current water harvesting has no detectable effect on the duration or frequency of high winter flow events. Flows greater than 8500 ML/day occur in Reach 3 of the Upper Ovens River approximately once per year (most commonly between July and September) and have a median duration of four days (Figure 3-48).





▪ **Figure 3-48 Duration (top left), frequency (top right) and start month (left) for flows above the winter high flow threshold of 8500 ML/d at Reach 3.**

Bankfull and overbank flows

In general, bankfull and overbank flows at this site should be allowed to occur as natural. However, there would be limitations to any recommendations for bankfull and overbank flows at this site due to the potential for a breakout at the upstream avulsion.

3.3.3 Comparison of current flows against the recommended flow regime

The flow recommendations for Reach 3 were compared with the natural and current flow regimes to determine the effect of current abstractions and to highlight the potential changes that may be required to deliver the recommended flow regime (Table 3-9). The flow recommendations are not met under the natural flow regime all of the time. This is to be expected and represents natural variability in the system. The comparison of most interest in Table 3-9 is the difference between the flows that are met under the natural and current flow regimes. Most of the recommended environmental flows for Reach 3 are met as often under the current flow regime as the natural flow regime, but the magnitude of summer low flows and frequency of summer freshes is slightly reduced under the current flow regime (Table 3-9). The recommended summer low flow of 137 ML/day is met 80% of the time under the natural flow regime, but water harvesting means that this minimum flow recommendation is only met 71% of the time (Table 3-9). Current water harvesting has also reduced the frequency of summer freshes by 4% compared to the natural flow regime. Flow changes in this reach of the Ovens River reflect cumulative extractions in upstream reaches and tributaries as well as direct extractions from Reach 3 and these extractions are likely to exacerbate flow stresses in the river during dry years. The analysis presented in Table 3-9 suggests that current water harvesting has no detectable effect on summer high flows or winter flow components in this reach.

- **Table 3-9 Assessment of the extent to which flow recommendations for Reach 3 are met under the current and natural flow regimes.**

Component	Months	Flow Rec		Current Compliance	Natural Compliance	Ratio of Current to Natural Compliance
Summer low	Dec - May	Volume	137	71%	80%	*89%*
Summer fresh	Dec - May	Volume	595	100%	100%	*100%*
		Number	2	91%	95%	*96%*
		Duration	8	51%	50%	*102%*
Summer high	Dec - May	Volume	2000	65%	66%	*99%*
		Number	1	65%	66%	*99%*
		Duration	4	63%	61%	*102%*
Winter low	Jun - Nov	Volume	740	80%	80%	*100%*
Winter fresh	Jun - Nov	Volume	1870	98%	98%	*100%*
		Number	1	98%	98%	*100%*
		Duration	20	52%	52%	*101%*
Winter high	Jun - Nov	Volume	8500	55%	55%	*100%*
		Number	1	55%	55%	*100%*
		Duration	4	54%	54%	*100%*

Legend						
Mostly complies		Greater than	**95**	%		
Frequently complies		Between	**76**	&	**95**	%
Often complies		Between	**51**	&	**75**	%
Occasionally complies		Between	**26**	&	**50**	%
Rarely complies		Between	**5**	&	**25**	%
Never complies		Between	**0**	&	**5**	%

3.4 Reach 4 – Morses Creek

3.4.1 Current condition

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

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

Asset	Current condition
Hydrology	▪ Water extractions can reduce summer flow. Significant irrigation demands. Number of farm dams in this reach
Geomorphology	▪ Erosion of underlying tailings, straightened channel, extensive willows, past mining influences.
Water quality	▪ Water quality generally very good to excellent but conditions deteriorate near Bright and Wandilgong.
Fish	▪ Excellent to good habitat, good abundance of small native fish, predation by trout, extractions may exacerbate stress on community during summer.
Macroinvertebrates	▪ Generally excellent to good condition with excellent to good habitat values. Extractions may exacerbate stress in communities during summer low flow periods. Urban impacts and point source pollution main threats.
Instream and riparian flora	▪ Riparian vegetation reduced in extent with medium cover, native understorey and shading stream. Dense blackberries. Instream vegetation good at site.

3.4.2 Flow recommendations

The environmental flow recommendations for Reach 4 are summarised in Table 3-11. No specific cease-to-flow recommendation has been made as these events would only occur in very dry years under natural flow conditions. The flow duration curves for the winter and summer current and natural flows are shown in Figure 3-49.

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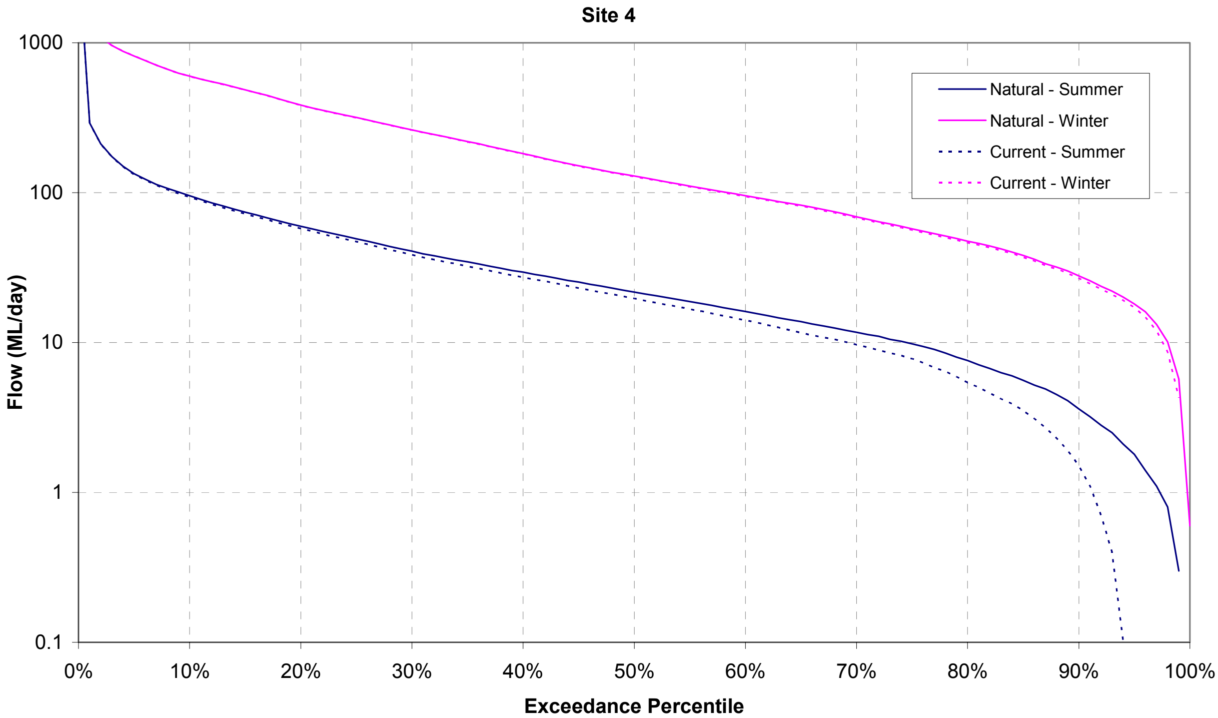
▪ Table 3-11 Summary of flow recommendations for Reach 4: Morses Creek.

Reach 4 Morses Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	8 ML/day or natural		
	Freshes	60 ML/day	2 per year	8 days
	Summer high	145 ML/day	1 per year	5 days
Winter	Low flow	48 ML/day or natural		
	Freshes	130 ML/day	1 per year	10 days
	High	383 ML/day	1 per year	12 days
	Bankfull	1000 ML/day	1 per year	4 days
	Overbank	>1000 ML/day or natural		

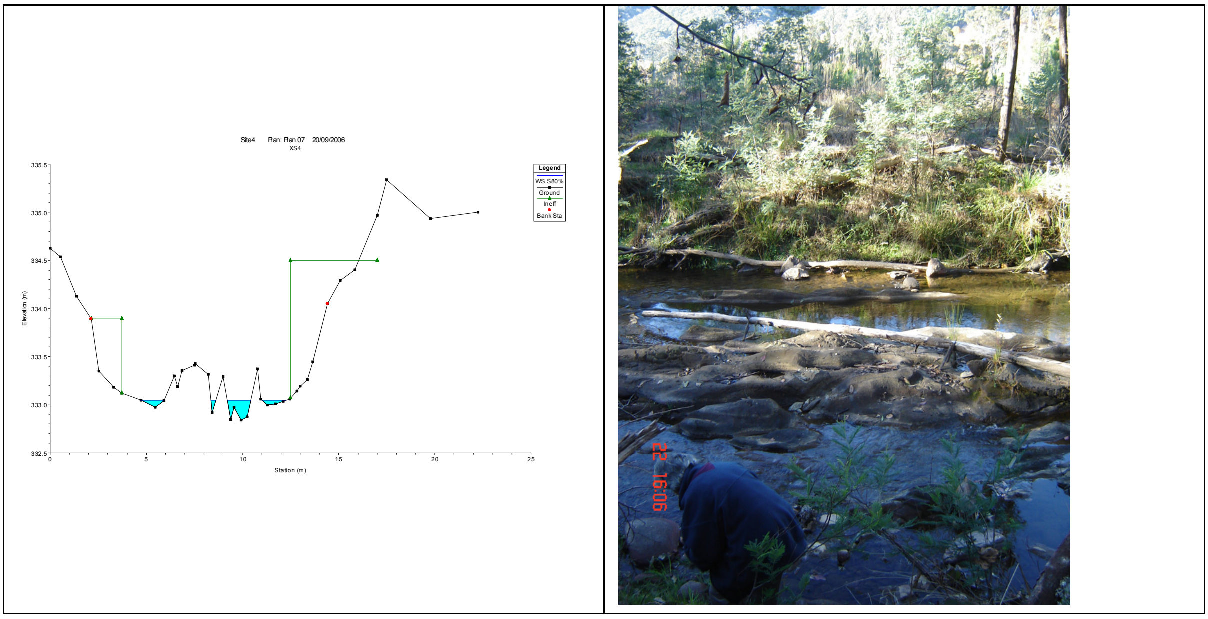


▪ Figure 3-49: Natural and Current summer and winter percentage exceedance curves for Site 4.

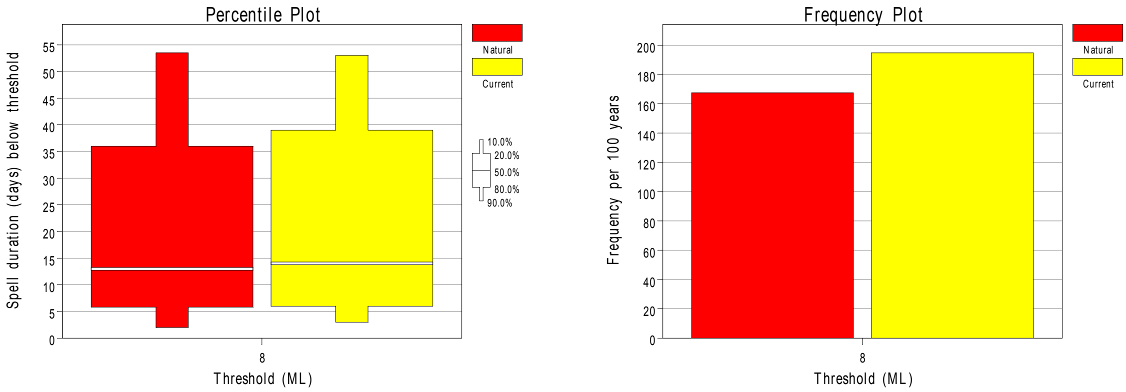
Summer low flow

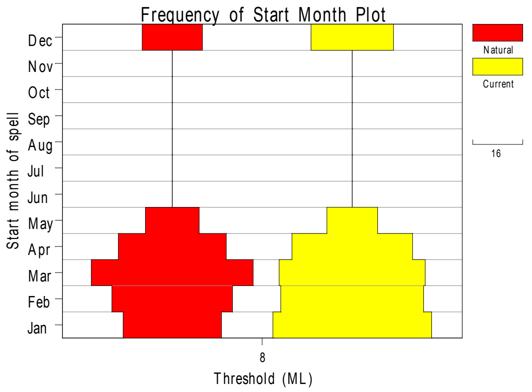
A summer low flow of 8 ML/day has been recommended for Reach 4. A flow of this size is equivalent to the 80^{th} percentile natural summer flow (Figure 3-49). A summer low flow will maintain depth through the multiple flow paths at cross section 4 (Figure 3-50) and suitable depth in pools for fish.

Under natural conditions, flow would drop below 8 ML/day on average 1.65 times per summer for a median duration of 13 days. Water harvesting means that under current conditions, summer low flows drop below 8 ML/day approximately 1.95 times per year with a median duration of 14 days (Figure 3-51). Cease to flow events are also much more common under current conditions compared to natural (Figure 3-49). Summer low flows less than the recommended level are most likely to occur in January, February or March under the current flow regime (Figure 3-51).



- **Figure 3-50: Water level at cross-section 4 at study site, Reach 4, under summer low flow of 8 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

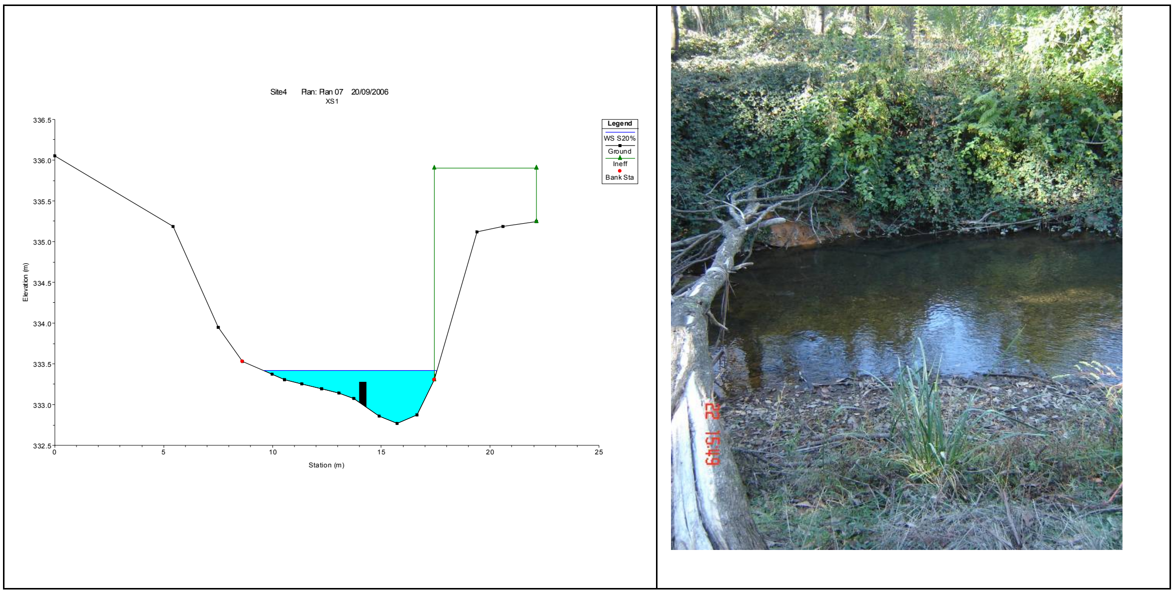




- **Figure 3-51 Duration (top left), frequency (top right) and start month (left) for flows below the summer low flow threshold of 8 ML/d at Reach 4.**

Summer fresh

Two summer freshes are recommended for Reach 4. Each fresh should be 60 ML/day and last for 10 days or as naturally occurs. The flow magnitude is equivalent to the 20th percentile summer flow under a natural flow regime (Figure 3-49). Summer freshes will provide flow over the bench at cross section 1 and assist in controlling nuisance vegetation growth (Figure 3-52). Summer freshes will also maintain water quality by mixing pools, preventing water stress in grasses and herbs at the waters edge and scour biofilms.



- **Figure 3-52: Water level at cross-section 1 at study site, Reach 4, under summer fresh of 60 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

There is little difference in the frequency and duration of summer freshes under current and natural flow regimes. Flows greater than 60 ML/day naturally occur in Morses Creek approximately 2.5 times per summer and have a median duration of 8 days (Figure 3-53). One or more of these flow events is likely to be much larger and is discussed in the summer high flow recommendation below. Summer freshes are most likely to occur in Morses Creek during December (Figure 3-53).

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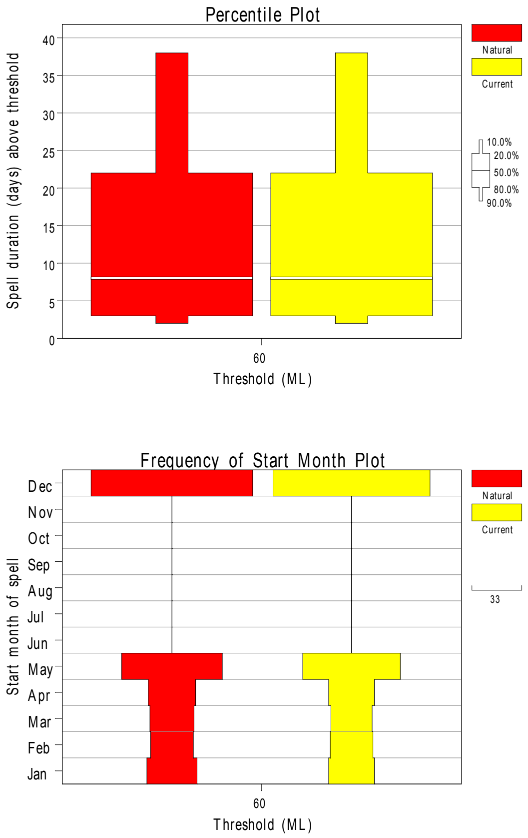

- **Figure 3-53 Duration (top left), frequency (top right) and start month (left) for flows above the summer fresh flow threshold of 60 ML/d at Reach 4.**

Summer high flow

The summer high flow recommendation for Reach 4 is 145 ML/day once a year for up to five days. A flow of this magnitude is slightly higher than the mean annual flow for Morses Creek at this site. Summer high flows in this reach are expected to maintain flow variability and to help maintain a mosaic of in-channel and riparian vegetation at different states of development at the edge of the channel as shown in cross section 2 (Figure 3-54).

Summer flows greater than 145 ML/day would be expected to occur just under once a year and have a median duration of five days under natural and current conditions (Figure 3-55), which suggests that current water harvesting has little effect on these types of flow. Summer high flows are most likely to occur in December or May (Figure 3-55).

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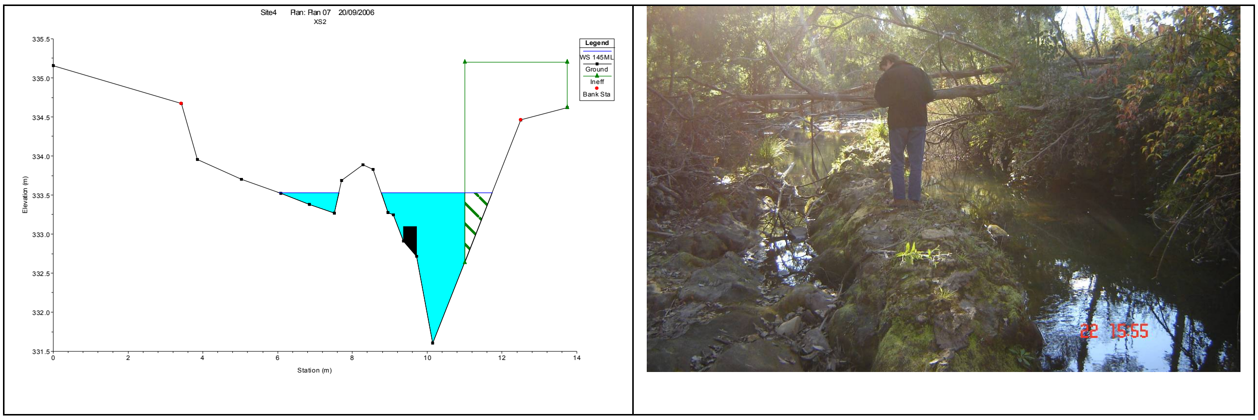
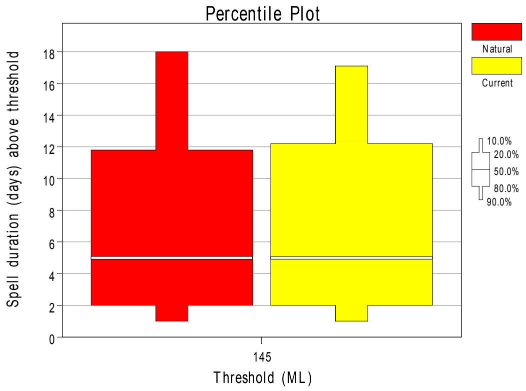
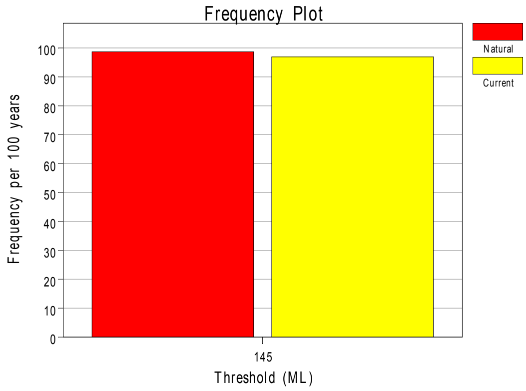
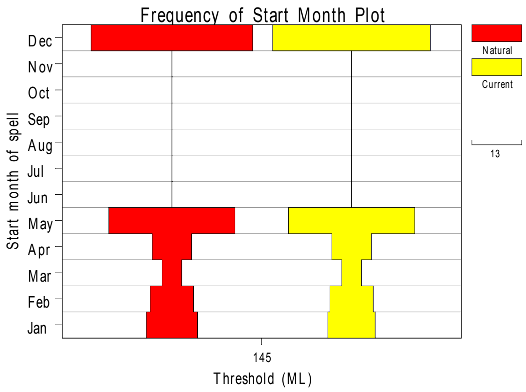


- **Figure 3-54: Water level at cross-section 2 at study site, Reach 4, under summer high flow of 145 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



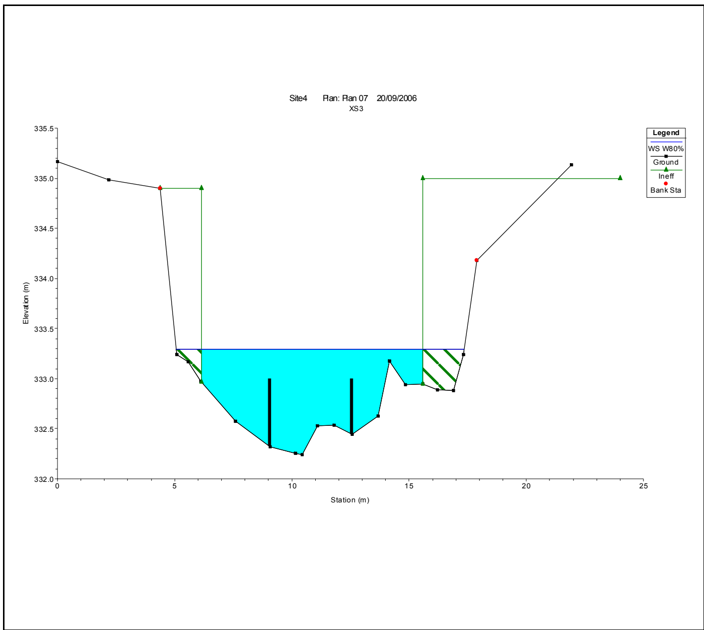




- **Figure 3-55 Duration (top left), frequency (top right) and start month (left) for flows above the summer high flow threshold of 145 ML/d at Reach 4.**

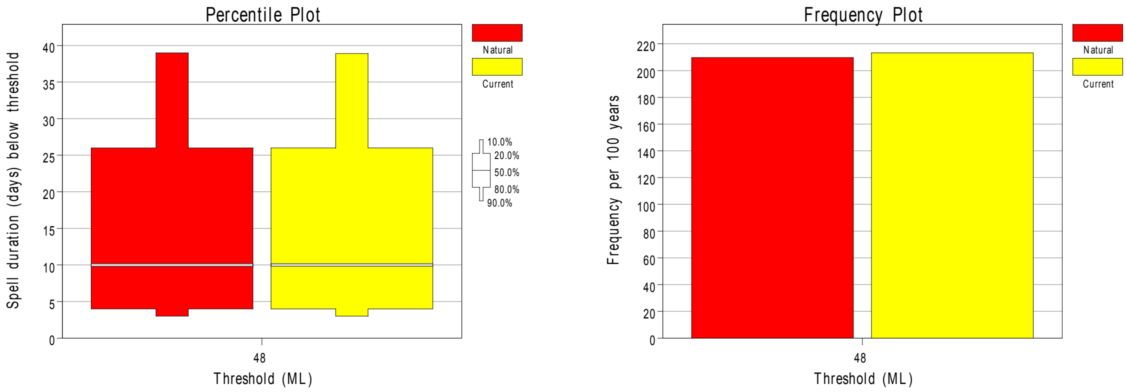
Winter low flow

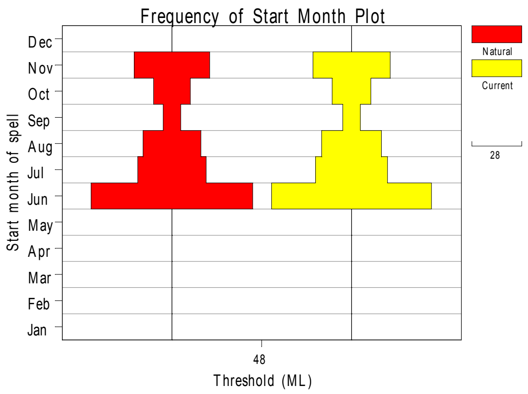
A winter low flow of 48 ML/day or as naturally occurs has been recommended for Reach 4. The winter low flow will cover large boulders such as seen in cross section 3 (Figure 3-56). Winter low flows will help to maintain the mosaic of in-channel and riparian vegetation at different states of development and maintain vegetation diversity. The velocity created by a flow of this size will assist the management of the growth of terrestrial vegetation on in-channel bars.



- **Figure 3-56: Water level at cross-section 3 at study site, Reach 4, under winter low flow of 48 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

The current flow regime has had little effect on the frequency or duration of winter low flows. Winter flows in Morses Creek drop below 48 ML/day approximately two times per year for a median duration of 10 days under natural and current flow regimes (Figure 3-57). Lower than recommended flows are most likely to occur in June (Figure 3-57).





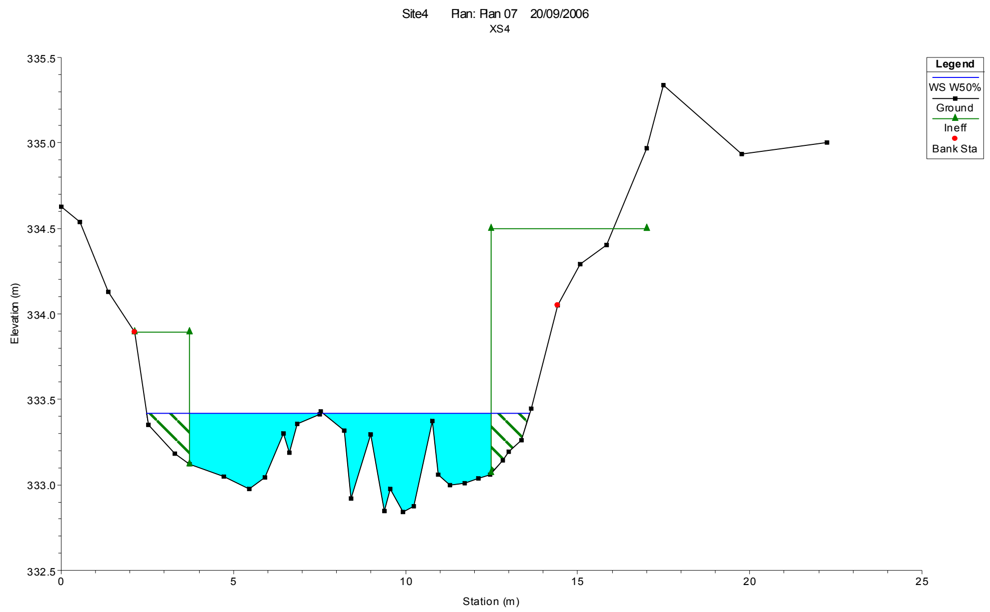
- **Figure 3-57 Duration (top left), frequency (top right) and start month (left) for flows below the winter low flow threshold of 48 ML/d at Reach 4.**

Winter fresh

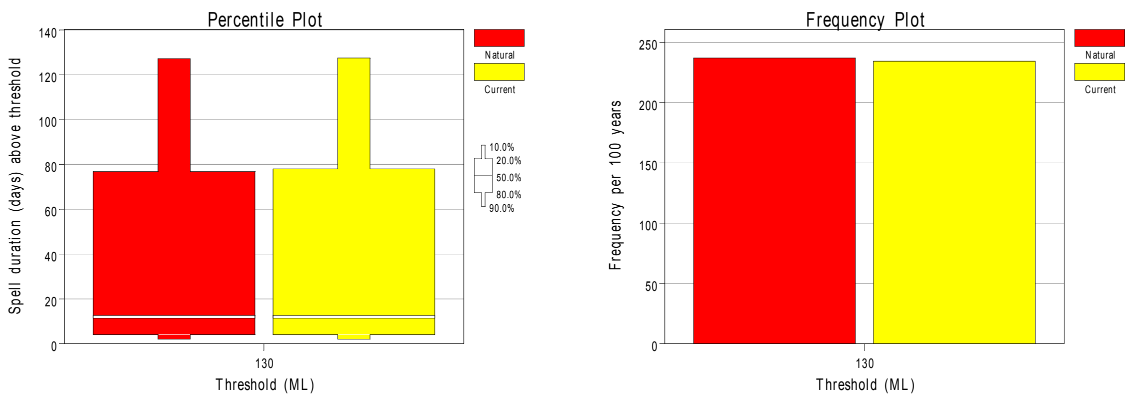
One winter fresh of 130 ML/day lasting for 10 days has been recommended for Morses Creek. The fresh and the following high flow and bankfull recommendations have been developed as part of a flow ‘package’. The successful delivery of all three recommendations will provided the most benefit to this site.

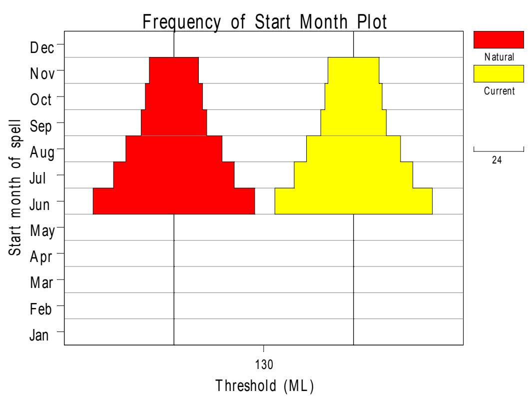
The winter fresh would fill the bottom of the channel (as illustrated for cross section 4 Figure 3-58) and assist in maintaining channel complexity. The velocity of a fresh is sufficient to create a disturbance to the stream bed, turning rocks and providing access to the substrate for benthic macroinvertebrates and fish, entrains organic material and scours biofilms.

Under natural and current conditions, winter flows greater than 130 ML/day would occur in Morses Creek 2.4 times per year and last for a median duration of 18 days (Figure 3-59). Flows of this magnitude occur most often in June and July.



■ **Figure 3-58: Water level cross-section 4 at study site, Reach 4, under winter fresh of 130 ML/day.**

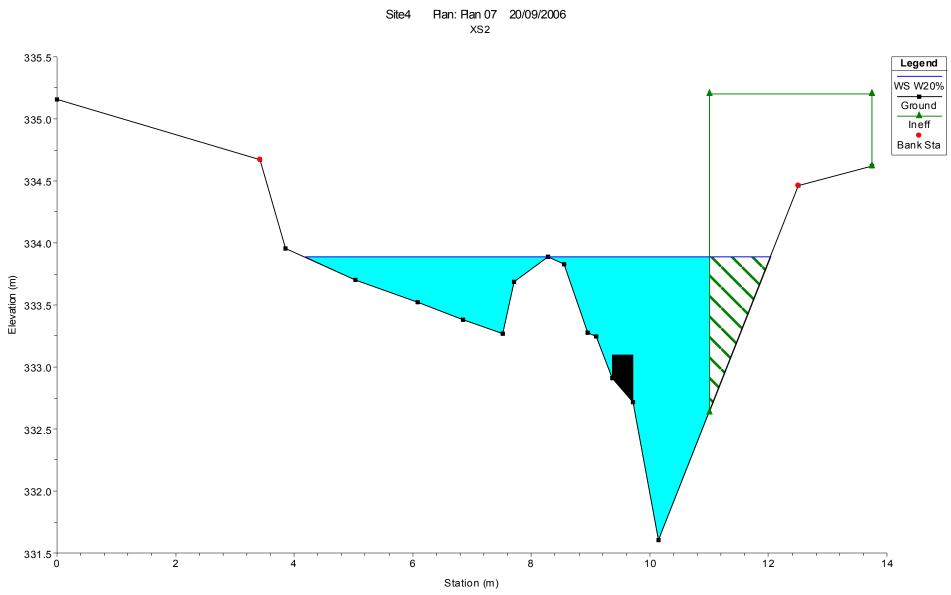




■ **Figure 3-59 Duration (top left), frequency (top right) and start month (left) for flows above the winter fresh flow threshold of 130 ML/d at Reach 4.**

Winter high flow

A winter high flow of 383 ML/day once a year for up to 12 days has been recommended for Morses Creek. A flow of this size is required to cover the rocks across the full width of the channel (see cross section 2 Figure 3-60), scour biofilms and mobilise interstitial material between rocks and boulders. Winter flows greater than 383 ML/day occur in Morses Creek nearly twice per year and have a median duration of 14 days (Figure 3-61). Flows of this size are most likely to occur between July and October.



- **Figure 3-60: Water level, cross-section 2 at study site, Reach 4, under winter high flow of 383 ML/day.**

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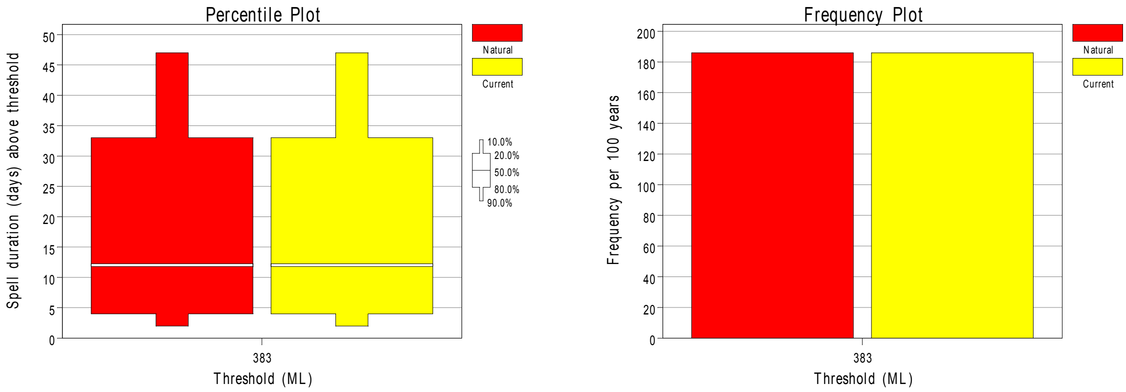
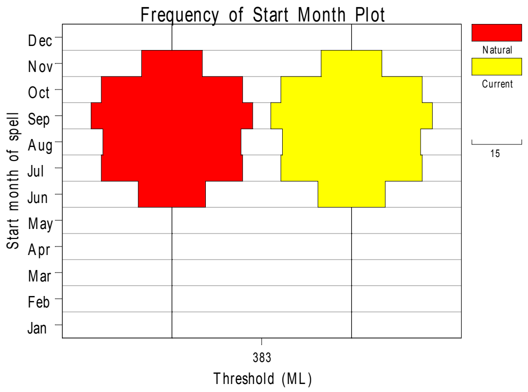


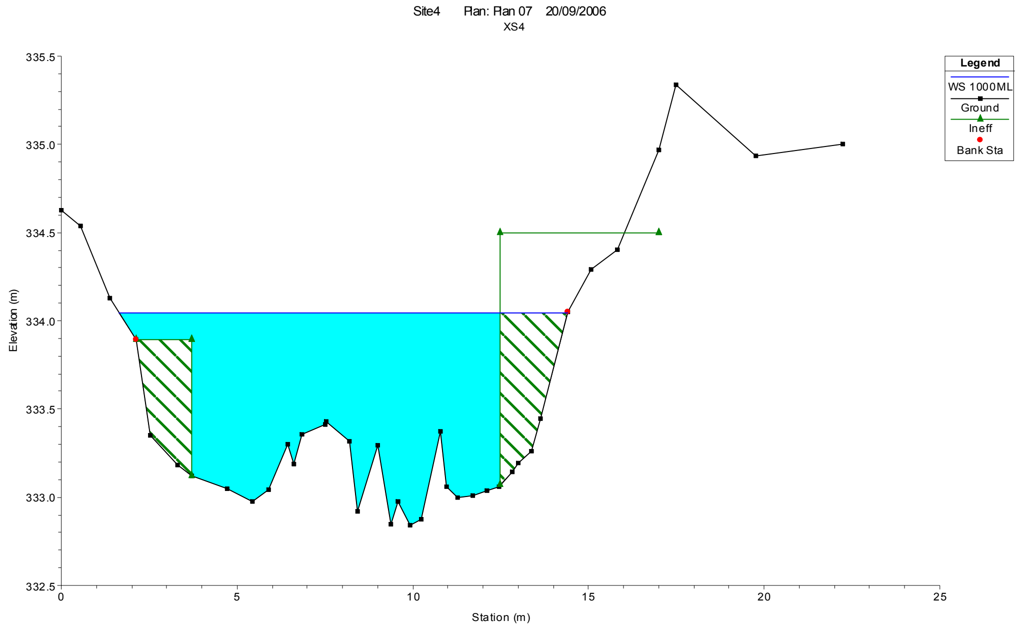


- **Figure 3-61 Duration (top left), frequency (top right) and start month (left) for flows above the winter high flow threshold of 383 ML/d at Reach 4.**

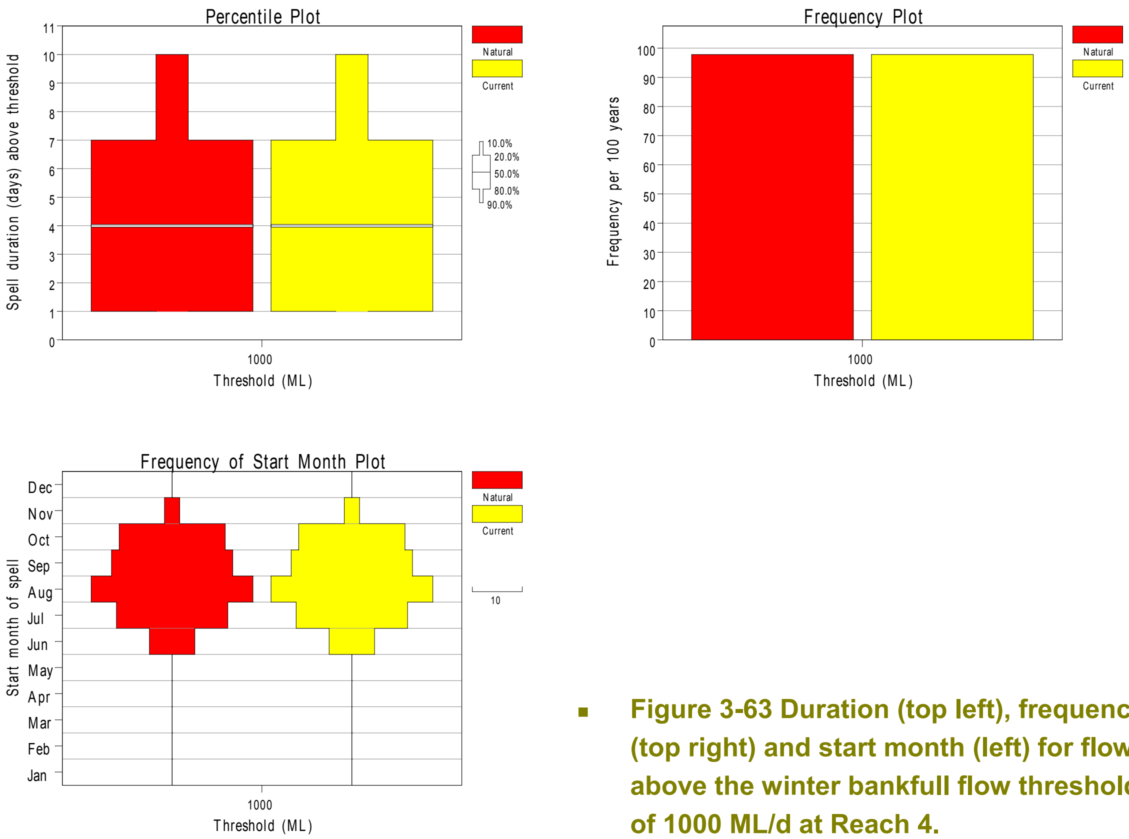
Winter bankfull flow

A bankfull flow of 1000 ML/day lasting up to four days has been recommended for Morses Creek and is part of a flow 'package' including winter fresh and winter high flow recommendations. A bankfull flow of this size provides water up to the bank vegetation at cross section 4 (Figure 3-62) and maintains flow variability and diversity through the site.

Bankfull flows occur on average once every year in Morses Creek, have a median duration of 4 days and are most common in August (Figure 3-63). There is no difference in the frequency, duration or timing of any of the components in the high flow package under the natural and current flow regimes, which indicates that current water harvesting has little effect on these flows.



- **Figure 3-62: Water level cross-section 4 at study site, Reach 4, under winter bankfull flow of 1000 ML/day.**



- **Figure 3-63 Duration (top left), frequency (top right) and start month (left) for flows above the winter bankfull flow threshold of 1000 ML/d at Reach 4.**

Overbank flow

Overbank flows greater than 1000 ML/day should be allowed to occur as natural in this reach to protect larger flows further downstream.

3.4.3 Comparison of current flows against the recommended flow regime

The flow recommendations for Reach 4 were compared with the natural and current flow regimes to determine the effect of current abstractions and to highlight the potential changes that may be required to deliver the recommended flow regime (Table 3-12). The flow recommendations are not met under the natural flow regime all of the time. This is to be expected and represents natural variability in the system. The comparison of most interest in Table 3-12 is the difference between the flows that are met under the natural and current flow regimes. Most of the environmental flow recommendations are met as often under the current flow regime as the natural flow regime, but current water harvesting reduces the magnitude of summer low flows (Table 3-12). Under natural flow conditions, the recommended summer low flow of 8 ML/day occurs approximately 79% of the time, but under current conditions this flow recommendation is only met 74% of the time (Table 3-12). Extractions may have little effect on summer flows in Morses Creek during wet years, but may substantially increase flow stress in dry years. Current water harvesting has no detectable effect on other flow components in this reach.

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- **Table 3-12 Assessment of the extent to which flow recommendations for Reach 4 are met under the current and natural flow regimes.**

Component	Months	Flow Rec		Current Compliance	Natural Compliance	Ratio of Current to Natural Compliance
Summer low	Dec - May	Volume	8	74%	79%	*94%*
Summer fresh	Dec - May	Volume	60	95%	96%	*99%*
		Number	2	75%	76%	*98%*
		Duration	8	52%	51%	*102%*
Summer high	Dec - May	Volume	145	57%	58%	*98%*
		Number	1	57%	58%	*98%*
		Duration	5	55%	56%	*97%*
Winter low	Jun - Nov	Volume	48	79%	80%	*99%*
Winter fresh	Jun - Nov	Volume	130	96%	96%	*99%*
		Number	1	96%	96%	*99%*
		Duration	10	55%	56%	*101%*
Winter high	Jun - Nov	Volume	383	80%	80%	*100%*
		Number	1	80%	80%	*100%*
		Duration	12	56%	56%	*100%*
Bankfull	Jun - Nov	Volume	1000	56%	56%	*100%*
		Number	1	56%	56%	*100%*
		Duration	4	50%	50%	*100%*

Legend						
Mostly complies		Greater than	**95**	%		
Frequently complies		Between	**76**	&	**95**	%
Often complies		Between	**51**	&	**75**	%
Occasionally complies		Between	**26**	&	**50**	%
Rarely complies		Between	**5**	&	**25**	%
Never complies		Between	**0**	&	**5**	%

3.5 Reach 5 – Buckland River

3.5.1 Current condition

A detailed description of the current condition of Reach 5 was provided in the *Issues* Paper . A summary is provided in Table 3-13 below.

Table 3-13 Current condition of Reach 5: Buckland River.

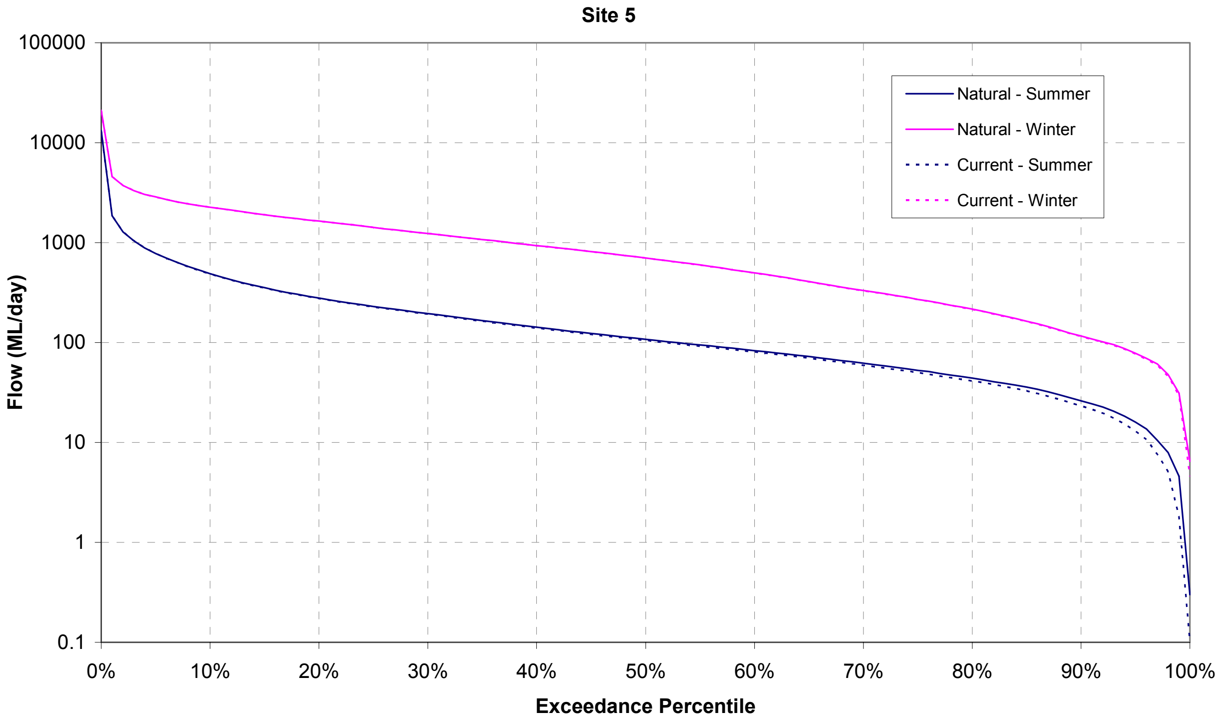
Asset	Current condition
Hydrology	▪ Water extractions can reduce the level of summer flows. Limited upstream demands.
Geomorphology	▪ Straightened channel. Relatively stable (confined by bedrock). Well connected to floodplain. Deep pools and runs. Influenced by mine tailings and past sluicing.
Water quality	▪ Water quality is excellent in the upper sections of the reach but deteriorates further downstream as the river passes through agricultural areas. Turbidity and nutrient concentrations extremely high after the 2003 bushfires. Some evidence of filamentous algae near confluence with Ovens River.
Fish	▪ Good abundance of small native fish, habitat is excellent to good. Native fish populations are recovering from 2003 bush fires. Maybe some impact from low summer flows if pool depth is reduced.
Macroinvertebrates	▪ Communities may be recovering from 2003 bushfires but generally excellent to good. Habitat excellent to good. Extractions may exacerbate stress on community during summer low flow periods. Threats included urban impacts and point source pollution.
Instream and riparian flora	▪ Riparian vegetation reduced in extent and diversity. Ground cover dominated by non-native species. Good instream vegetation at site.

3.5.2 Flow recommendations

The environmental flow recommendations for Reach 5 are summarised in Table 3-14. No specific cease-to-flow recommendation has been made as under natural conditions the river would only cease to flow in very dry years. The flow duration curves for the winter and summer current and natural flows are shown in Figure 3-64.

■ **Table 3-14 Summary of flow recommendations for Reach 5: Buckland River.**

Reach 5 Buckland River				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	64 ML/day or natural		
	Freshes	195 ML/day	4 per year	4 days
	Summer high	1150 ML/day	1 per year	2 days
Winter	Low flow	216 ML/day or natural		
	Freshes	700 ML/day	2 per year	10 days
	High	3700 ML/day	1 per year	2 days
	Bankfull	No specific recommendation. As natural		
	Overbank	No specific recommendation. As natural		



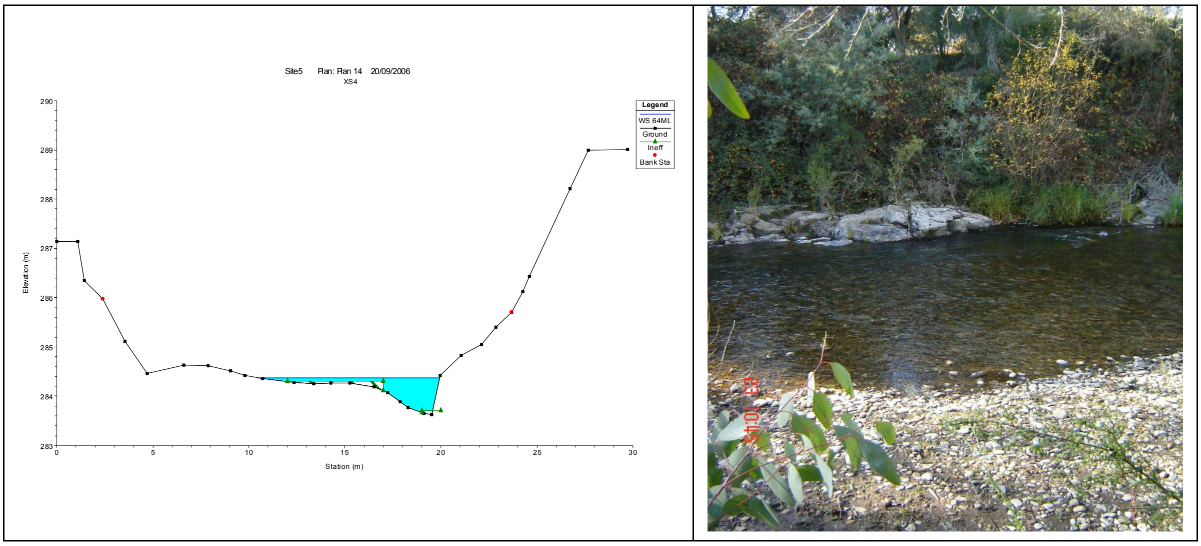
■ **Figure 3-64: Natural and Current summer and winter percentage exceedance curves for Site 5.**

Summer low flow

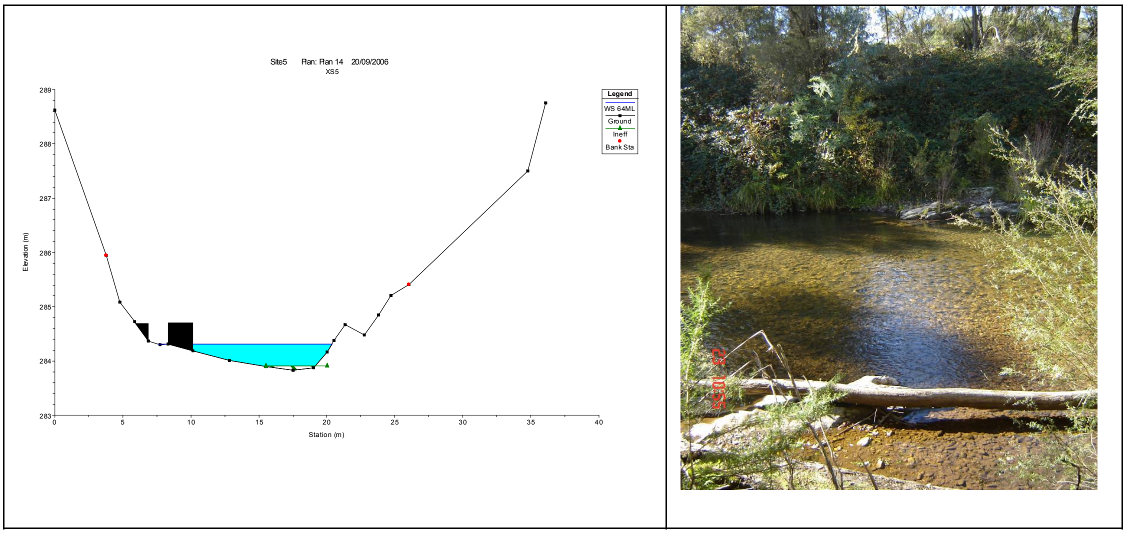
A summer low flow of 64 ML/day or as naturally occurs has been recommended for Reach 5. A flow of this magnitude will wet riffle habitats (such as illustrated in cross section 4 Figure 3-65) and create some backwater habitats (see cross section 5 in Figure 3-66). This reach has high values for water quality and a summer low flow will assist in maintaining water quality within the pools and preserve the riffle habitat at all times of the day and night.

Summer flows less than 64 ML/day will naturally occur in the Buckland River approximately twice per year and last for a median duration of 12 days (Figure 3-67). There is little difference in the frequency and duration of summer low flows in the Buckland River under current conditions compared to natural flow conditions (Figure 3-67). This result suggests that current water harvesting has little effect on summer flows in this reach. Irrigation pumping can reduce flow in the Buckland River during very dry summers, but these effects may only last for several hours at a time and are not shown in the modeled daily flow data.

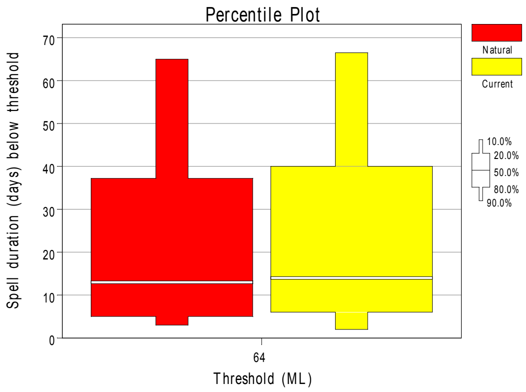
The summer low flow recommendation for the Buckland River is very similar to the minimum flow (60 ML/day) recommended for this reach in the previous environmental flow assessment study (SKM 2001). The recommendation from the previous flow assessment study was estimated from flows that were directly observed in the field. The lowest flow observed in the Buckland River during the previous flow assessment was 57 ML/day and the team working on that project considered that a slightly higher flow would be required to maintain habitat for blackfish. The HEC-RAS model used in the current study allows conditions to be estimated for all flow magnitudes and is therefore provides a more reliable estimate of minimum flow requirements.

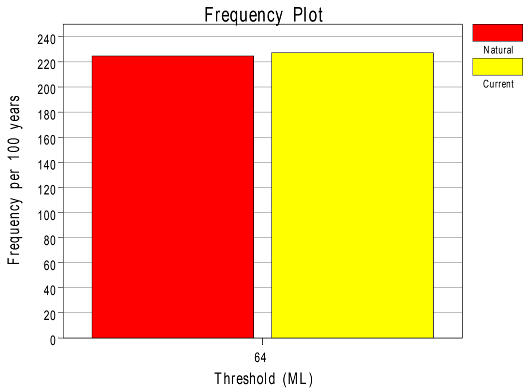


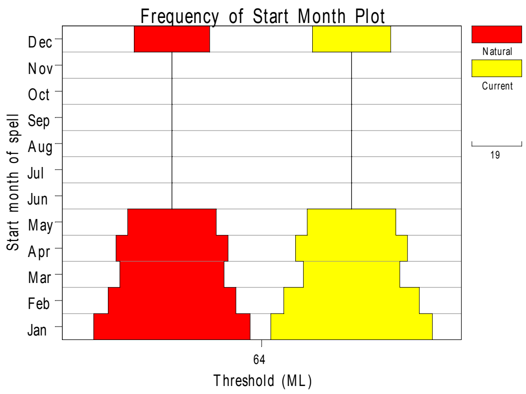
■ **Figure 3-65: Water level at cross-section 4 at study site, Reach 5, under summer low flow of 64 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



■ **Figure 3-66: Water level at cross-section 5 at study site, Reach 5, under summer low flow of 64 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**





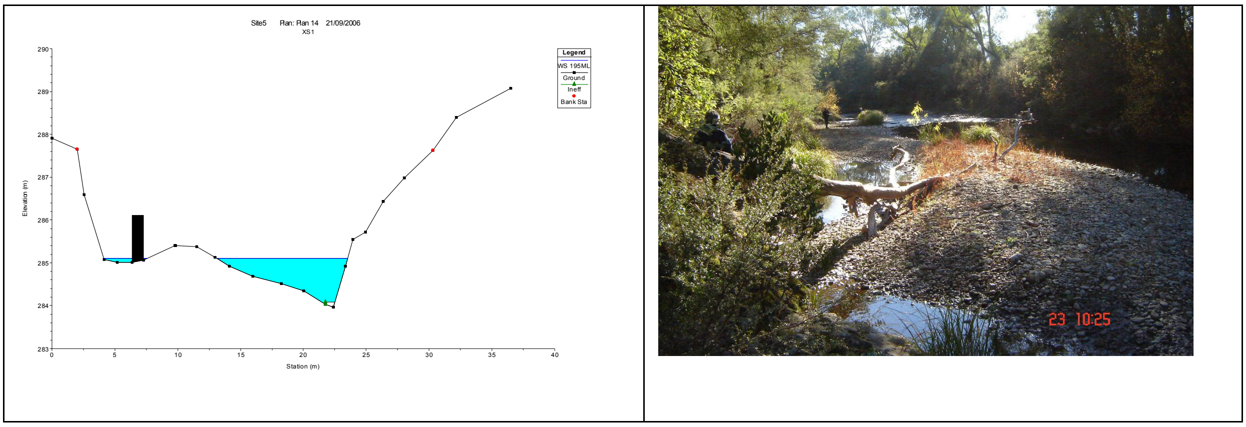


- **Figure 3-67 Duration (top left), frequency (top right) and start month (left) for flows below the summer low flow threshold of 64 ML/d at Reach 5.**

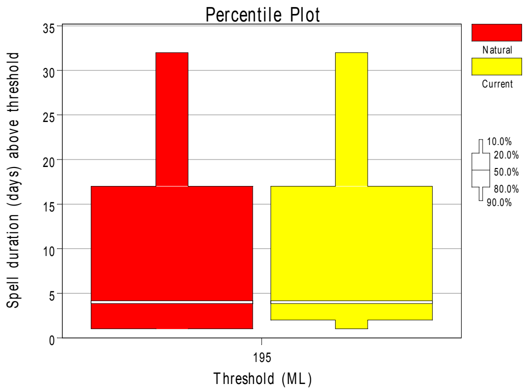
Summer fresh

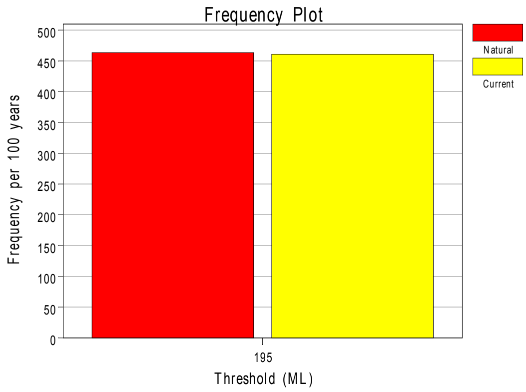
Four summer freshes have been recommended for Reach 5. Each fresh should be 195 ML/day and last for up to four days. A flow of this size is approximately equivalent to the 30th percentile summer flow under natural flow conditions (Figure 3-64). Summer freshes will generate flow through backwaters such as the one surveyed at cross section 1 and inundate gravel bars (Figure 3-68). Summer freshes are aimed at maintaining the mosaic of in-channel and riparian vegetation by preventing water stress and providing a disturbance that will prevent excessive vegetation growth in-channel.

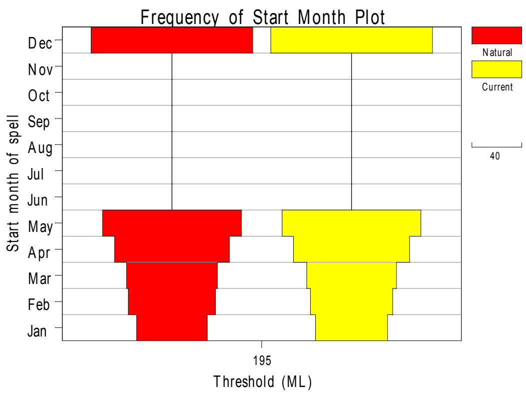
Flows greater than 195 ML/day occur in the Buckland River approximately 4.6 times per summer, have a median duration of 4 days and are most common in December and May (Figure 3-69). There is little difference in the frequency and duration of summer freshes under natural and current conditions, which suggests that water harvesting has little effect on these flows.



- **Figure 3-68: Water level at cross-section 1 at study site, Reach 5, under summer fresh of 195 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



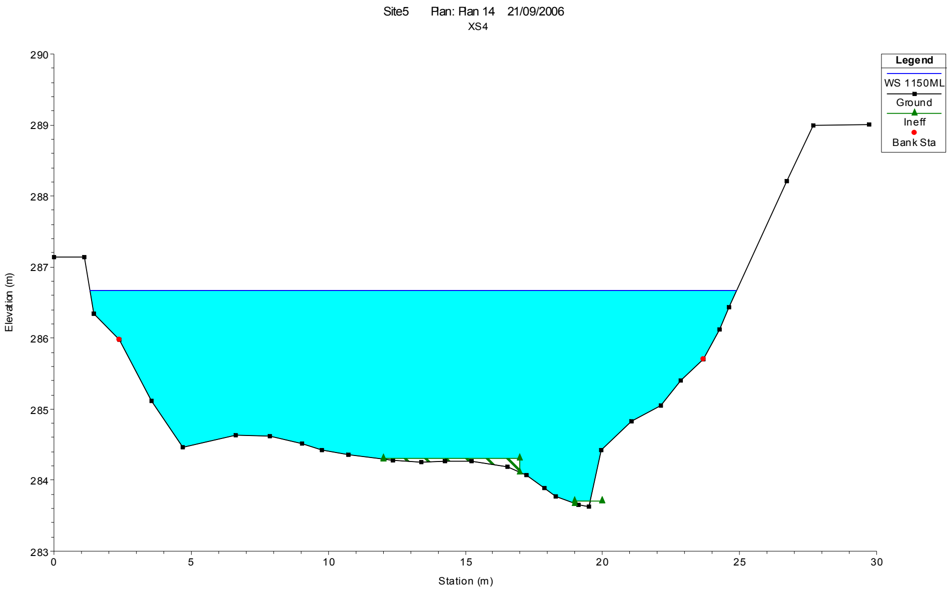




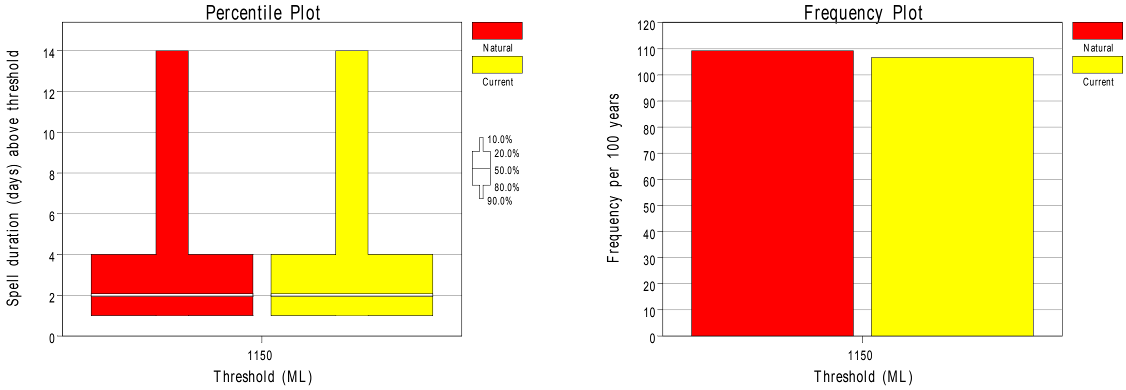
- **Figure 3-69 Duration (top left), frequency (top right) and start month (left) for flows above the summer fresh flow threshold of 195 ML/d at Reach 5.**

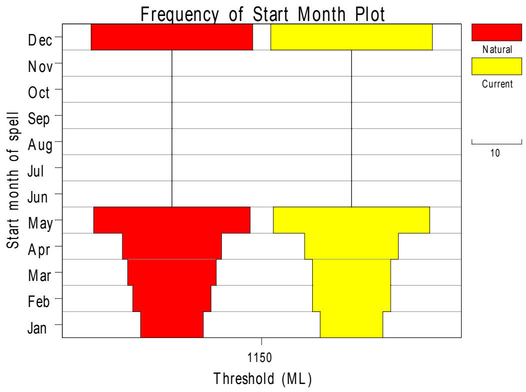
Summer high flow

One summer high flow of 1150 ML/day lasting for two days has been recommended for Reach 5. A flow of this size is not only important for the environmental condition of this reach but also contributes to high flows further downstream in the Ovens River. A summer high flow will inundate the channel in cross section 4 (Figure 3-70) and create sufficient disturbance to turn over small rocks, scour biofilms and entrain organic material. Flows greater than 1150 ML/day occur approximately once per summer, have a median duration of two days and are most common in December and May (Figure 3-71). There is no difference in the frequency or duration of summer high flows under current and natural conditions, which suggests that current water harvesting has no effect on this flow component.



- **Figure 3-70: Water level at cross-section 4 at study site, Reach 5, under summer high flow of 1150 ML/day.**

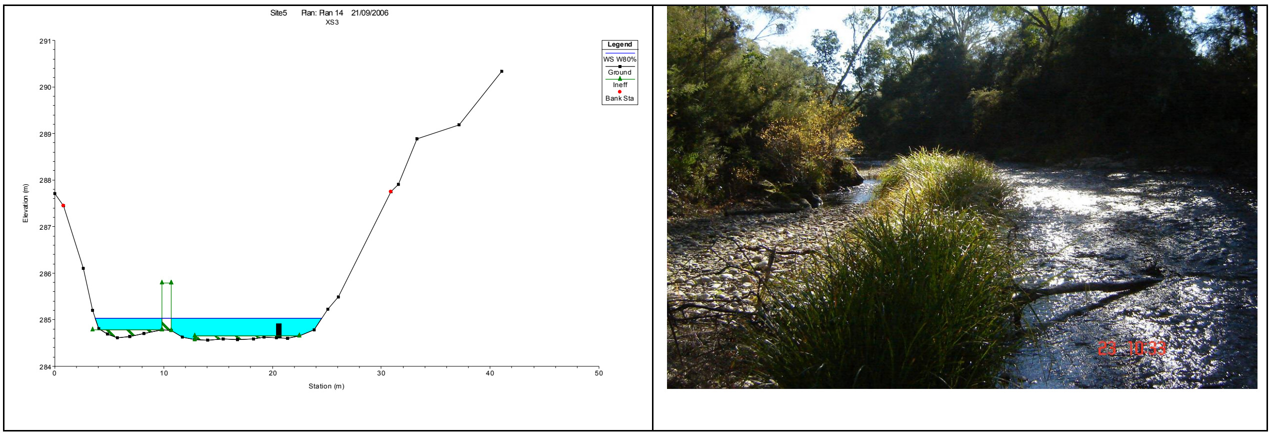




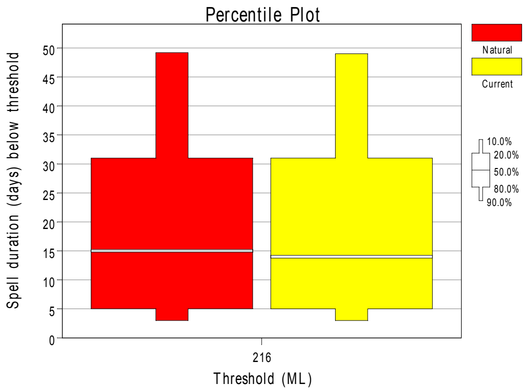
- **Figure 3-71 Duration (top left), frequency (top right) and start month (left) for flows above the summer high flow threshold of 1150 ML/d at Reach 5.**

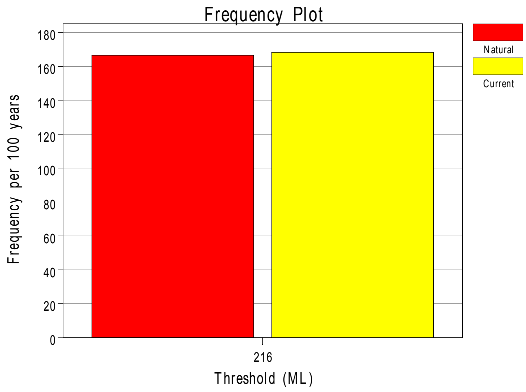
Winter low flow

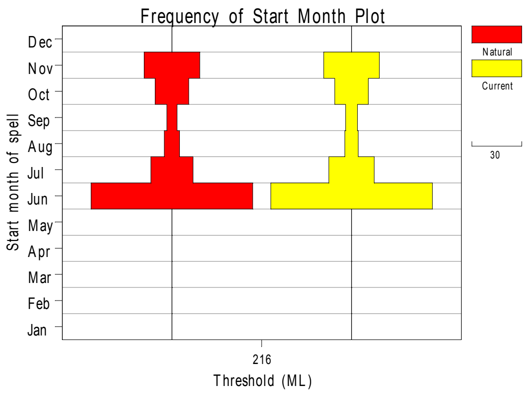
A winter low flow of 216 ML/day or as naturally occurs has been recommended for this site. A winter low flow will inundate the channel and the *Carax sp.* growing on the gravel bar in cross section 3 (Figure 3-72). A winter flow will also generate flow in some backwater habitats. In the Buckland River, winter flows less than 216 ML/day occur approximately 1.6 times per year, have a median duration of 15 days and are most common in June (Figure 3-73). The current frequency and duration of winter low flows is similar to the natural flow regime (Figure 3-73), which suggests that current water harvesting has little effect on these flows.



- **Figure 3-72: Water level at cross-section 3 at study site, Reach 5, under winter low flow of 216 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



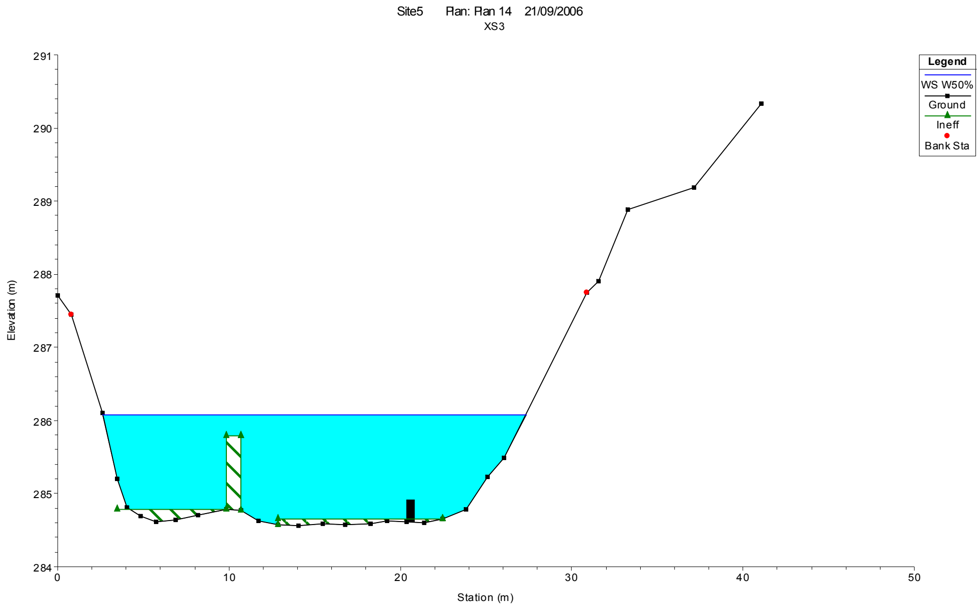




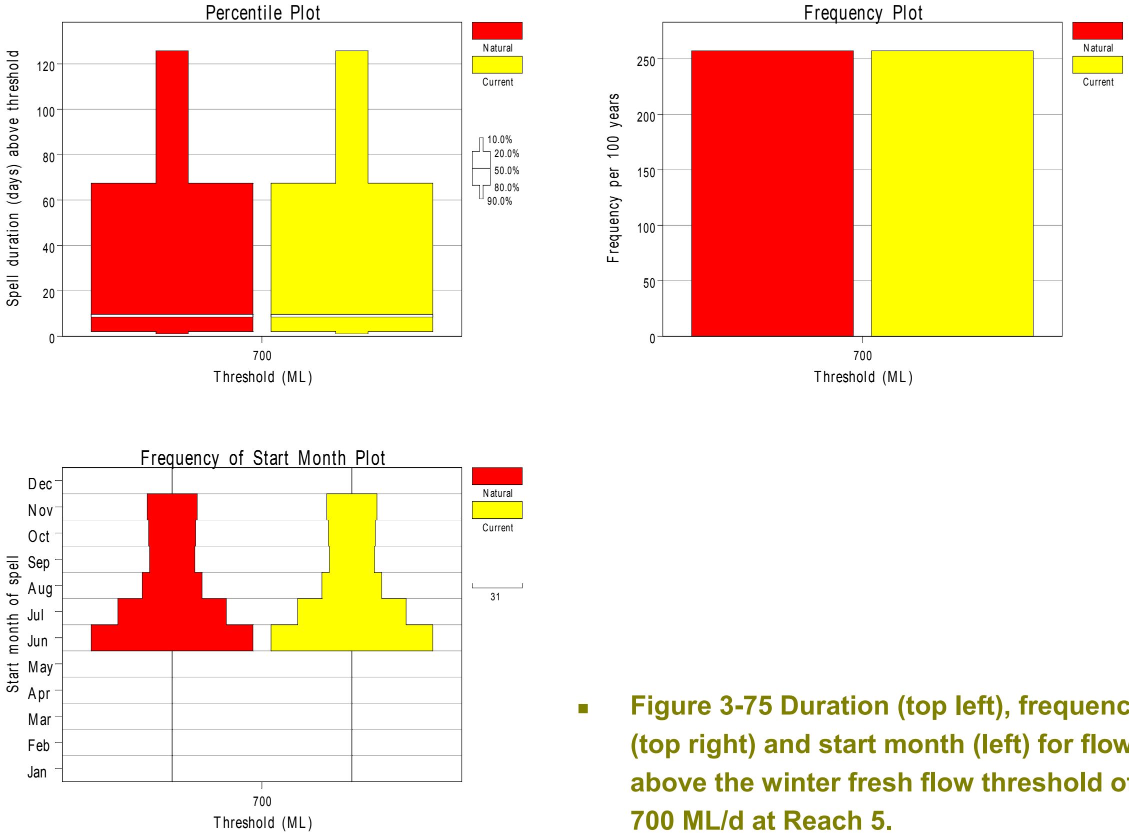
- **Figure 3-73 Duration (top left), frequency (top right) and start month (left) for flows below the winter low flow threshold of 216 ML/d at Reach 5.**

Winter fresh

Two winter freshes of 700 ML/day lasting for up to 10 days have been recommended for the Buckland River. Winter freshes will reach the mid banks and inundate the gravel bar at cross section 3 (Figure 3-74). These flows will scour the streambed and turn over some small rocks which will help to maintain channel diversity and complexity and also mix organic material through the upper layers of the streambed. Flows greater than 700 ML/day occur approximately 2.5 times each winter, have a median duration of 10 days and are most common in June (Figure 3-75). There is no difference in the frequency or duration of winter freshes under natural and current flow conditions (Figure 3-75).



- **Figure 3-74: Water level at cross-section 3 at study site, Reach 5, under winter fresh of 700 ML/day.**

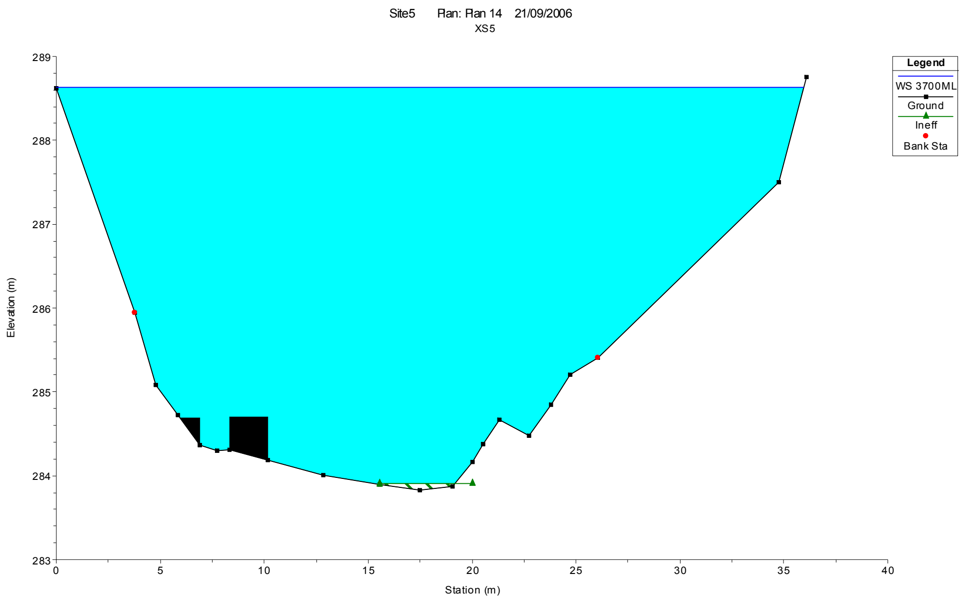


- **Figure 3-75 Duration (top left), frequency (top right) and start month (left) for flows above the winter fresh flow threshold of 700 ML/d at Reach 5.**

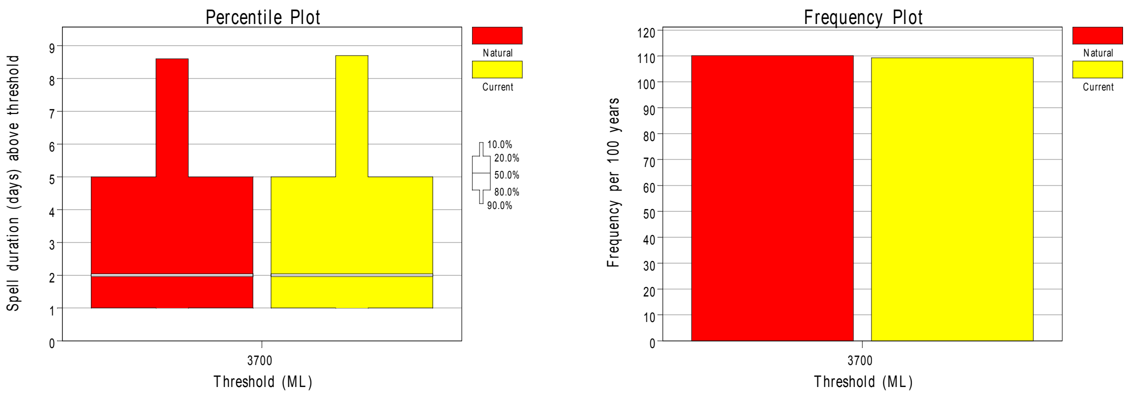
Winter high flow

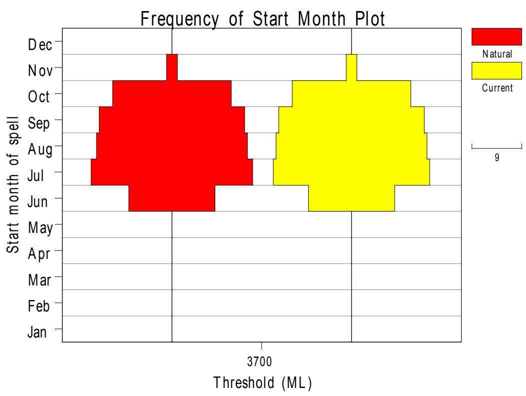
A high winter flow of 3700 ML/day that lasts for two days has been recommended for this site with the aim of providing a high degree of disturbance through the reach and filling much of the channel (Figure 3-76). A flow of this magnitude should help with general channel maintenance, scour biofilms and nuisance plant growth and provide opportunities for fish movement over structures that would be barriers at lower flows. Winter high flows also contribute to high flows further downstream in the Ovens River.

Flows greater than 3700 ML/day occur in the Buckland River approximately once per year, have a median duration of two days and are most common between July and September (Figure 3-77). There is no difference in the frequency or duration of winter high flows under the current and natural flow regimes.



■ **Figure 3-76: Water level at cross-section 5 at study site, Reach 5, under winter high flow of 3700 ML/day.**





■ **Figure 3-77 Duration (top left), frequency (top right) and start month (left) for flows above the winter high flow threshold of 3700 ML/d at Reach 5.**

Bankfull flows

Winter high flows will serve all of the main ecological functions that a bankfull flow would deliver in the Buckland River and therefore a specific bankfull flow has not been recommended for thish reach. Bankfull flows will occur naturally in the Buckland River, but are expected to be relatively infrequent (i.e. occur much less than once per year). Natural bankfull flows should be protected when they do occur as they will contribute to overall flow variability and will help deliver high flows to the Ovens River further downstream.

3.5.3 Comparison of current flows against the recommended flow regime

The flow recommendations for Reach 5 were compared with the natural and current flow regimes to determine the effect of current abstractions and to highlight the potential changes that may be required to deliver the recommended flow regime (Table 3-15). The flow recommendations are not met under the natural flow regime all of the time. This is to be expected and represents natural variability in the system. The comparison of most interest in Table 3-15 is the difference between the flows that are met under the natural and current flow regimes. This assessment suggests that all of the environmental flow recommendations are met as often under the current flow regime as the natural flow regime (Table 3-15). However, this assessment does not specifically compare the magnitude of flows under current and natural flow regimes when the recommended flow is not met and anecdotal reports suggest that pumping can stop flow in the Buckland River at times. This assessment also uses a daily flow estimate and so will not detect flow changes over shorter intervals, which may occur if irrigators in this catchment use their pumps for only a few hours each day. So, while this assessment indicates that current water harvesting practices in the Buckland River are having less effect on flows than in other reaches of the upper Ovens River, it is likely that water harvesting in this catchment will exacerbate flow stress in dry years.

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- **Table 3-15 Assessment of the extent to which flow recommendations for Reach 5 are met under the current and natural flow regimes.**

Component	Months	Flow Rec		Current Compliance	Natural Compliance	Ratio of Current to Natural Compliance
Summer low	Dec - May	Volume	64	68%	69%	99%
Summer fresh	Dec - May	Volume	195	99%	99%	100%
		Number	4	66%	67%	99%
		Duration	4	56%	56%	100%
Summer high	Dec - May	Volume	1150	57%	57%	100%
		Number	1	57%	57%	100%
		Duration	2	55%	54%	102%
Winter low	Jun - Nov	Volume	216	80%	80%	100%
Winter fresh	Jun - Nov	Volume	700	98%	98%	100%
		Number	2	76%	76%	100%
		Duration	10	50%	50%	100%
Winter high	Jun - Nov	Volume	3700	54%	54%	100%
		Number	1	54%	54%	100%
		Duration	2	65%	64%	101%

Legend						
Mostly complies		Greater than	**95**	%		
Frequently complies		Between	**76**	&	**95**	%
Often complies		Between	**51**	&	**75**	%
Occasionally complies		Between	**26**	&	**50**	%
Rarely complies		Between	**5**	&	**25**	%
Never complies		Between	**0**	&	**5**	%

3.6 Reach 6 Buffalo Creek

No detailed survey was carried out at this site due to heavy blackberry growth and access difficulties. The information provided below is a general assessment of the flow requirements that is based on the modelled natural and current flow regimes.

3.6.1 Flow recommendations

The environmental flow recommendations for Reach 6 are summarised in Table 3-16. No specific cease-to-flow recommendation has been made because under natural and current conditions Buffalo Creek would only cease-to-flow in very dry years. The flow duration curves for the winter and summer current and natural flows are shown in Figure 3-78.

Table 3-16 Summary of flow recommendations for Reach 6: Buffalo Creek.

Reach 6 Buffalo Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	7 ML/day or natural		
	Fresh	55 ML/day	3 per year	10 days
Winter	Low flow	54 ML/day or natural		
	Fresh 1	156 ML/day	3 per year	15 days
	Fresh 2	270 ML/day	1 per year	7 days
	High	1000 ML/day	1 per year	2 days
	Bankfull	No specific recommendation		
	Overbank	No specific recommendation		

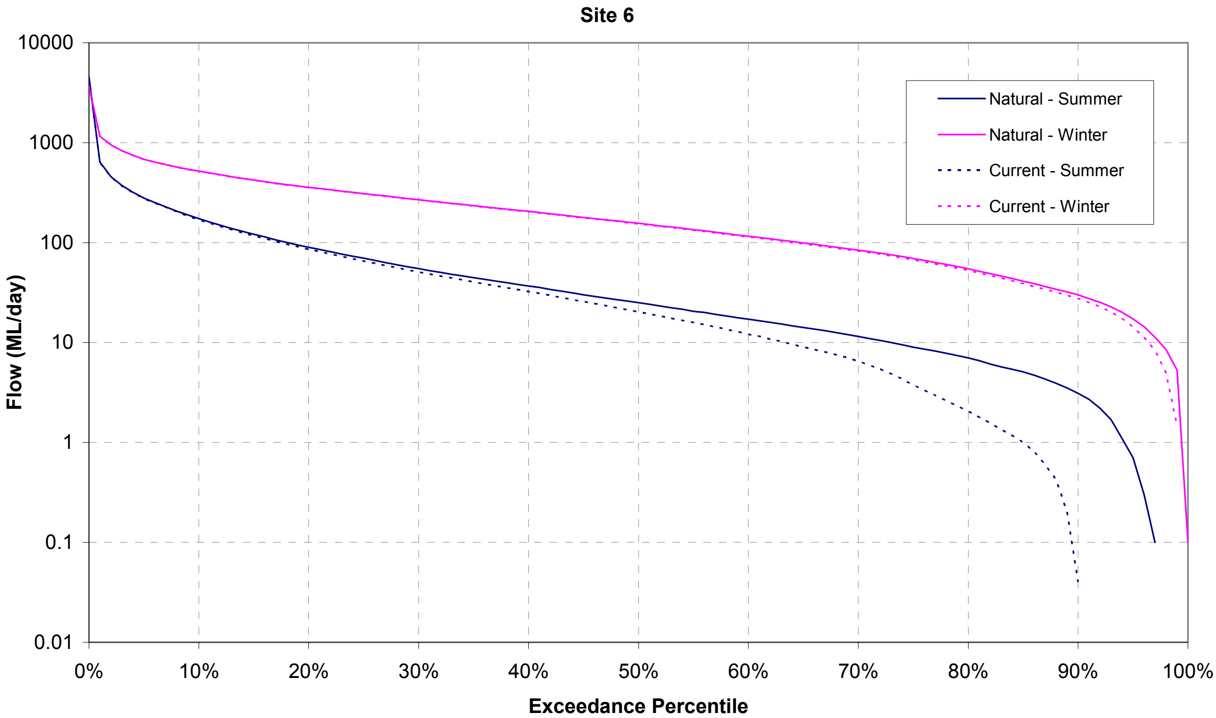


Figure 3-78: Natural and Current summer and winter percentage exceedance curves for Site 6.

Summer low flow

A summer low flow of 7 ML/day or as naturally occurs has been recommended for Buffalo Creek. This is equivalent to the 80th percentile summer flow. Naturally occurring summer low flows may result in some periods of cease-to-flow.

Summer fresh

Three summer freshes of 55 ML/day (30th percentile summer flow) lasting for up to 10 days have been recommended for Reach 6. This recommendation assumes that upstream flows, where variability is important, are unaffected if freshes of this magnitude occur.

Summer high flow

No recommendation has been provided for a summer high flow as the channel at this site has steep incised banks.

Winter low flow

A winter low flow of 54 ML/day (the 80th percentile winter flow) or as naturally occurs, has been recommended for Reach 6.

The winter flow drops below this amount naturally two to three times per year and there is little difference between the natural and current flows at this magnitude.

Winter fresh

Three winter freshes of 156 ML/day lasting up to 15 days and one winter fresh of 270 ML/day lasting seven days have been recommended for this site in Buffalo Creek.

Winter high flow

An annual winter high flow of 1100 ML/day, or as naturally occurs, is recommended for Buffalo Creek. A flow of this size needs to last for up to two days.

3.7 Reach 7 – Happy Valley Creek

3.7.1 Current condition

A detailed description of the current condition of Reach 5 was provided in the *Issues Paper* . A summary is provided in Table 3-17 below.

- **Table 3-17 Current condition of Reach 7: Happy Valley Creek.**

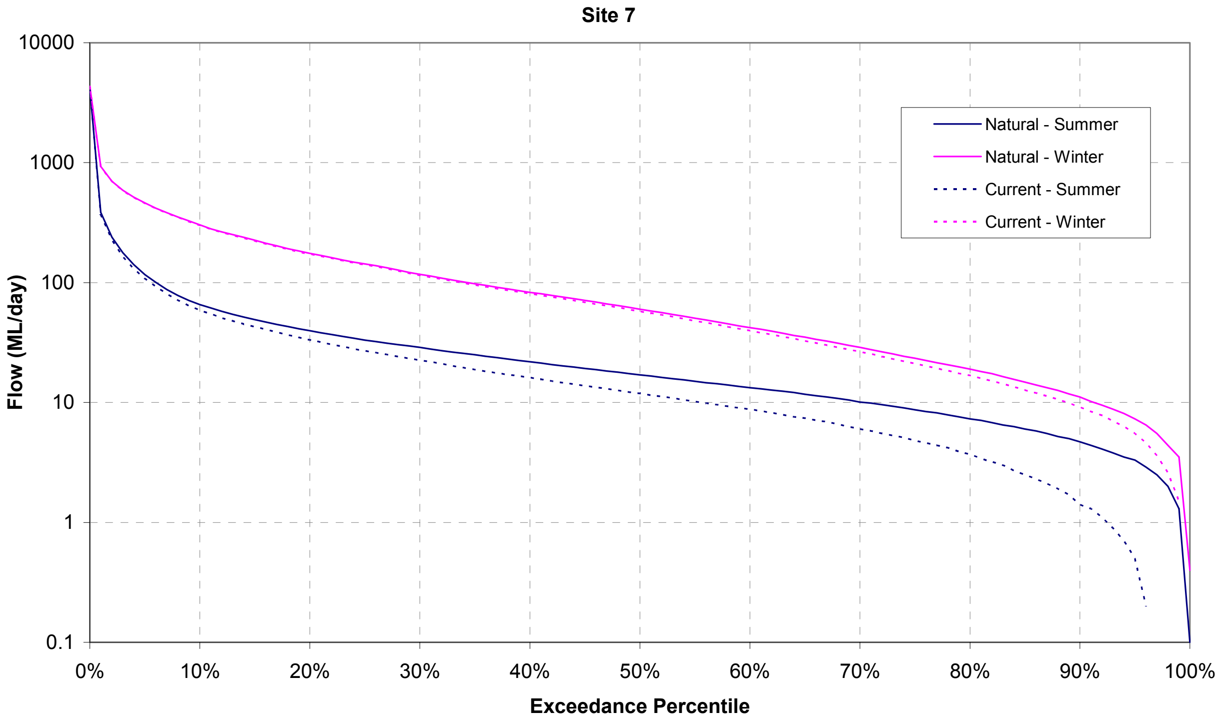
Asset	Current condition
Hydrology	▪ High concentration of farm dams. Water extractions can reduce summer flows.
Geomorphology	▪ Willow encroachment has undermined sections of channel. Lower part of creek lower than Ovens River and will eventually capture Ovens River.
Water quality	▪ Water quality generally poor. Nutrient concentrations affected by stock access to stream, erosion and cropping to stream edge. Salinity is higher than other sites and may be exacerbated in summer as a result of reduced low flows.
Fish	▪ Moderate to poor habitat with low abundance of small native fish. Evidence of siltation. Stock access and nutrient inputs. Exotic fish.
Macroinvertebrates	▪ Condition and habitat availability is moderate to poor. Threats include stock access to stream channel, nutrient inputs, catchment erosion and willows. Summer low flow periods may induce stress in community.
Instream and riparian flora	▪ Riparian vegetation reduced in extent and diversity. Evidence of past control of well established willows. Instream vegetation good at site.

3.7.2 Flow recommendations

The environmental flow recommendations for Reach 7 are summarised in Table 3-18. No specific cease-to-flow recommendation has been made because cease-to-flow periods would not occur under natural conditions in most years. The flow duration curves for the winter and summer current and natural flows are shown in Figure 3-79.

■ **Table 3-18 Summary of flow recommendations for Reach 7: Happy Valley Creek.**

Reach 7 Happy Valley Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	7 ML/day or natural		
	Freshes	35 ML/day	3 per year	2 days
	Summer high	200 ML/day	1 per year	2 days
Winter	Low flow	19 ML/day or natural		
	Freshes	117 ML/day	4 per year	5 days
	High	950 ML/day	1 per year	1 day
	Bankfull	1500 ML/day	1 every 5 years	1 day
	Overbank	No specific recommendation. As natural		

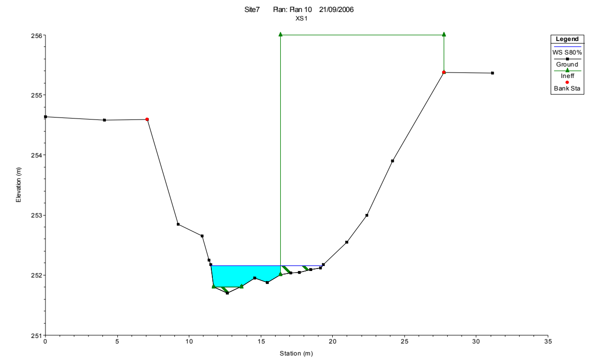


■ **Figure 3-79: Natural and Current summer and winter percentage exceedance curves for Site 7.**

Summer low flow

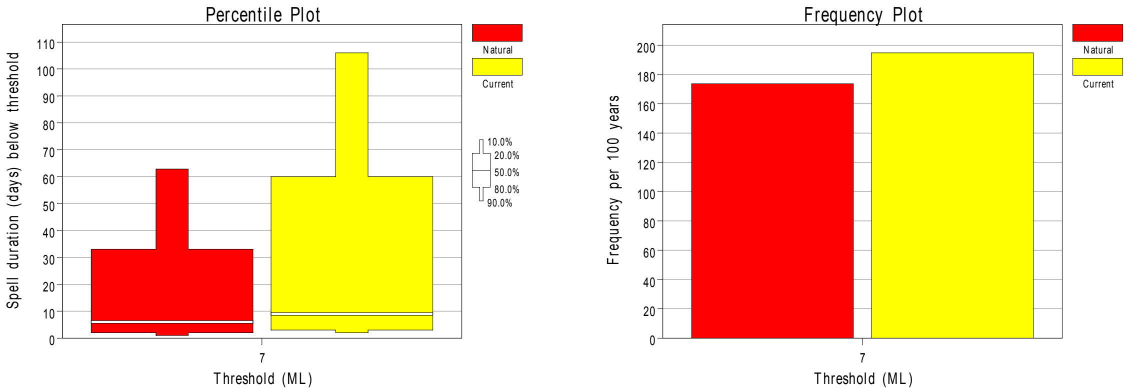
A summer low flow of 7 ML/day or as naturally occurs has been recommended for Happy Valley Creek. A flow of 7 ML/day is equivalent to the 80th percentile summer flow at the assessment site (Figure 3-79) and provides a depth of approximately 10cm over the shallowest riffle at cross section 1 (Figure 3-80).

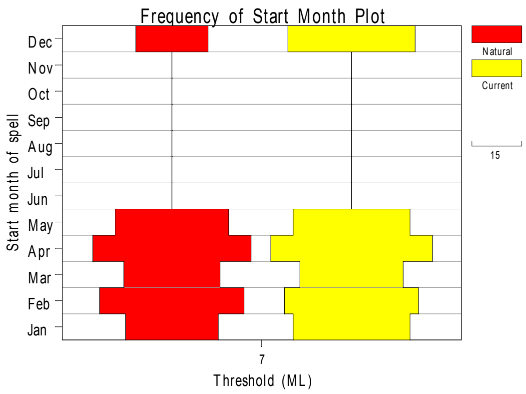
The low summer flow recommendation for this site is aimed at maintaining root zone moisture in the riparian plants, pool depth and longitudinal connectivity for fish movement through the reach.



- **Figure 3-80: Water level at cross-section 1 at study site, Reach 7, under summer low flow of 7 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

Under natural conditions, summer flows drop below 7 ML/day on average 1.7 times per year for a median duration of 10 days (Figure 3-81). Under current conditions, summer flows drop below 7 ML/day approximately 1.9 times per year for a median duration of 9 days (Figure 3-81). Lower than recommended flows are most common in February and April (Figure 3-81). The greater frequency and duration of flows less than 7 ML/day is due to water harvesting through direct extraction and farm dams in the Happy Valley catchment.



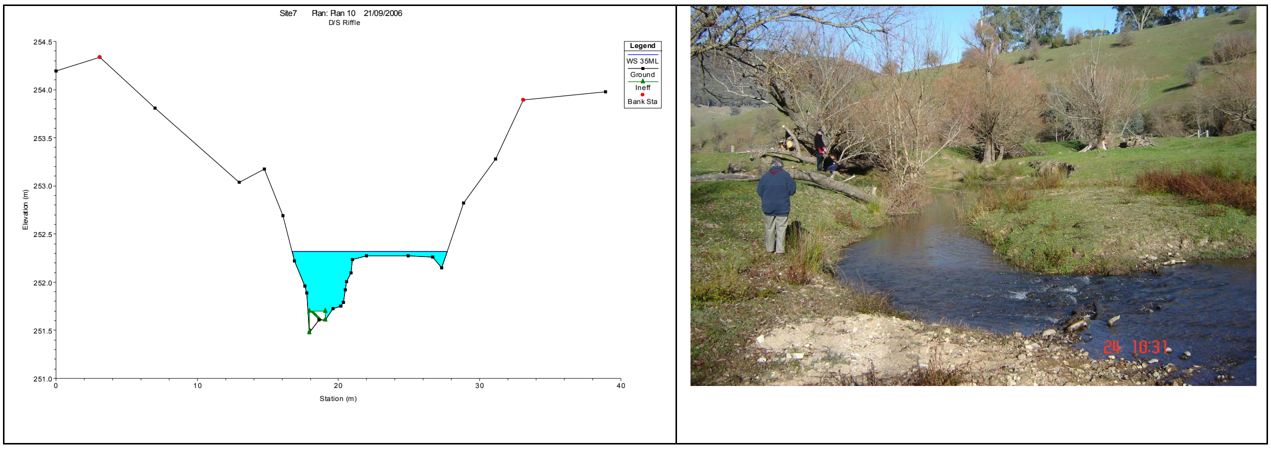


- **Figure 3-81 Duration (top left), frequency (top right) and start month (left) for flows below the summer low flow threshold of 7 ML/d at Reach 7.**

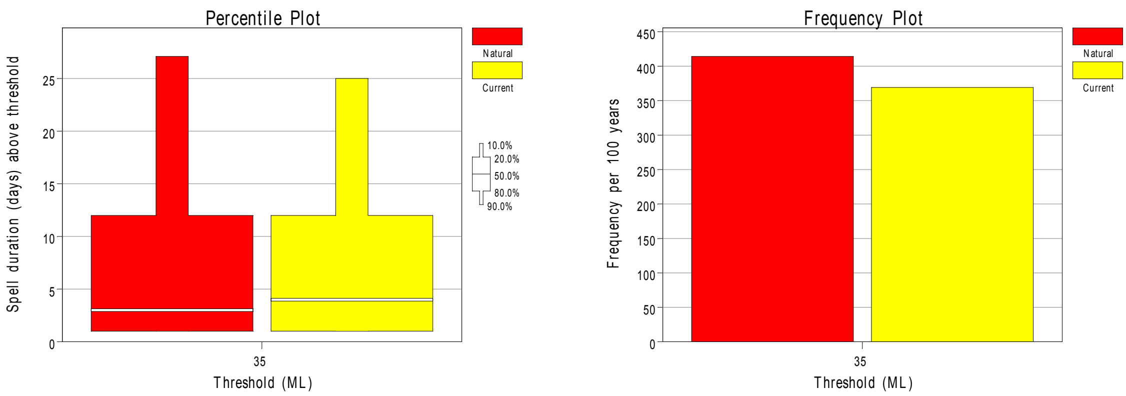
Summer fresh

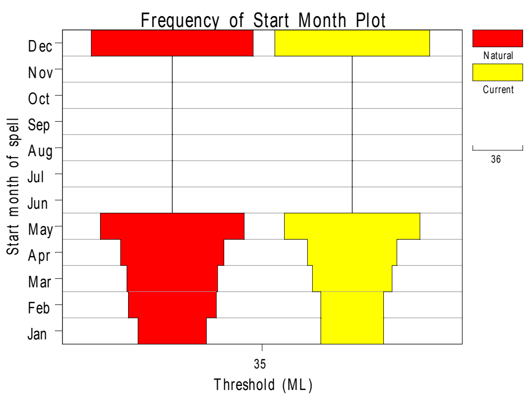
Three summer freshes have been recommended for Happy Valley Creek. Each fresh should be 35 ML/day and last up to two days. Summer freshes will provide a depth of approximately 5 cm over the gravel bar at the cross section upstream of cross section 6 (Figure 3-82) and will provide a disturbance sufficient to mix water and organic material through the substrate, improve water quality and prevent unwanted vegetation growth within the channel.

Under natural conditions, flows greater than 35 ML/day would have occurred on average 4.1 times per summer, had a median duration of 4 days and been most common in December or May (Figure 3-83). Under current conditions, summer freshes are less frequent, but have a slightly longer duration (Figure 3-83).



- **Figure 3-82: Water level at cross-section upstream of cross-section 7, at study site, Reach 7 under summer fresh of 35 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



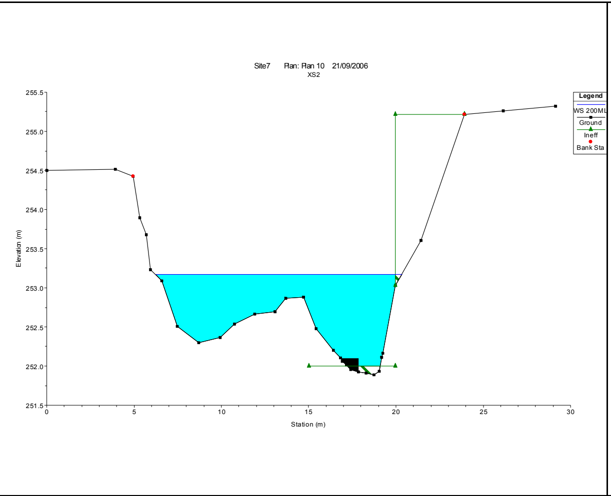


- **Figure 3-83 Duration (top left), frequency (top right) and start month (left) for flows above the summer fresh flow threshold of 35 ML/d at Reach 7.**

Summer high flow

A summer high flow of 200 ML/day lasting for up to two days has been recommended for Happy Valley Creek. A flow of this size will inundate most of the in-channel bed features at cross section 2 (Figure 3-84).

Flows greater than 200 ML/day would have naturally occurred approximately 1.6 times per summer in Happy Valley Creek and had a median duration of two days (Figure 3-85). The recommended summer high flow is not as large as the maximum annual summer flow event, but flows up to 300 ML/day are not expected to serve any additional ecological function in this system. The recommended summer high flow has a slightly lower frequency, but similar duration under current conditions compared to natural, which suggests that water harvesting in this system has little effect on this flow component.



- **Figure 3-84: Water level at cross-section 2 at study site, Reach 7, under summer high flow of 200 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

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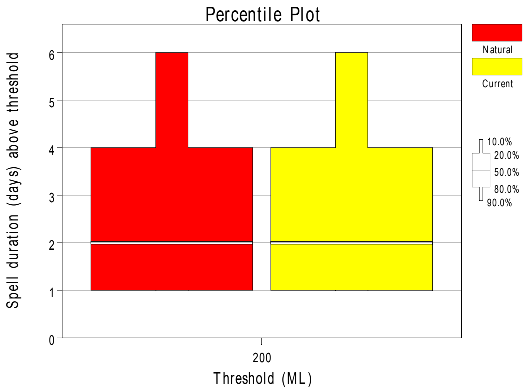
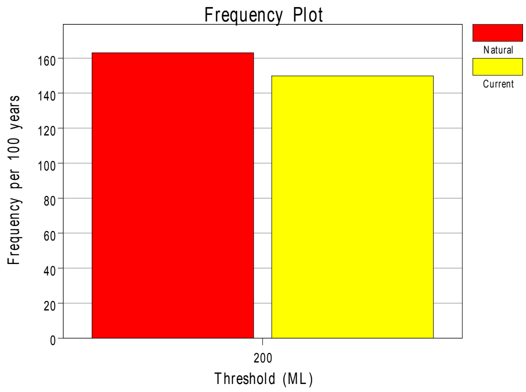
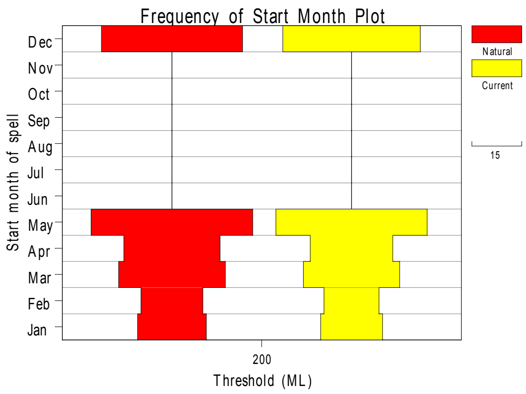




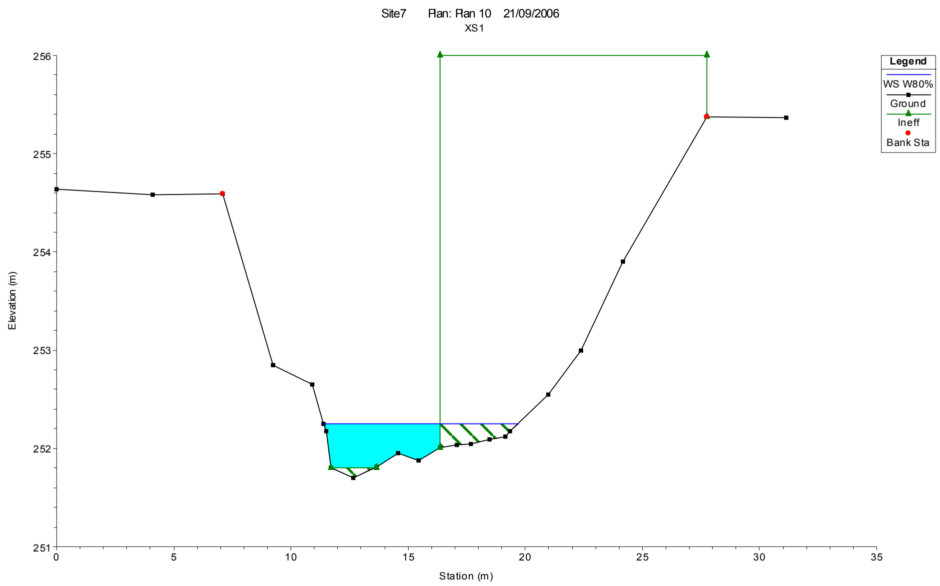


- **Figure 3-85 Duration (top left), frequency (top right) and start month (left) for flows above the summer high flow threshold of 200 ML/d at Reach 7.**

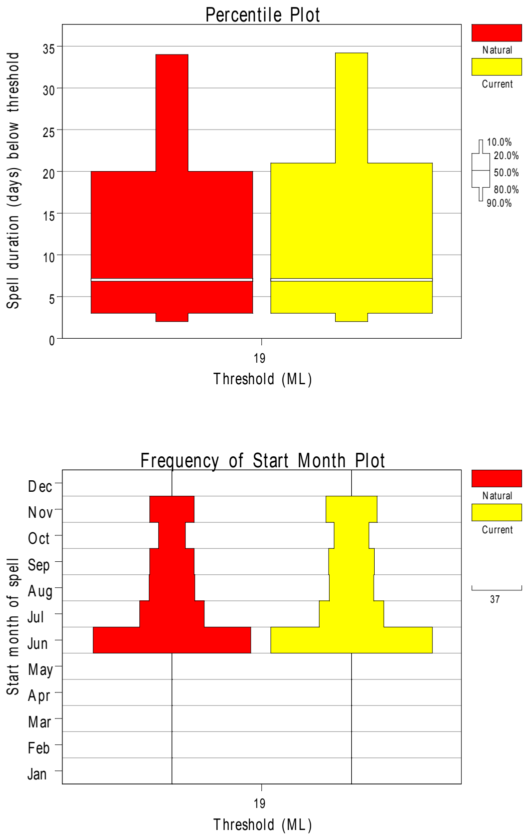
Winter low flow

A winter low flow of 19 ML/day or as naturally occurs has been recommended for Happy Valley Creek. This flow will provide a depth of approximately 15cm through riffle habitats (e.g. cross section 1 in Figure 3-86), prevent terrestrial colonisation of bars and benches and maintain connectivity through the reach.

Under natural conditions, winter flows in Happy Valley Creek drop below 19 ML/day approximately 2.5 times per year with a median duration of seven days (Figure 3-87). Under current conditions, winter flows less than 19 ML/day occur approximately 2.6 times per year and have a median duration of seven days (Figure 3-87). These results suggest that farm dams and winter fill licences slightly reduce winter flow levels in this system.



- **Figure 3-86: Water level at cross-section 1 at study site, Reach 7, under winter low flow of 19 ML/day.**



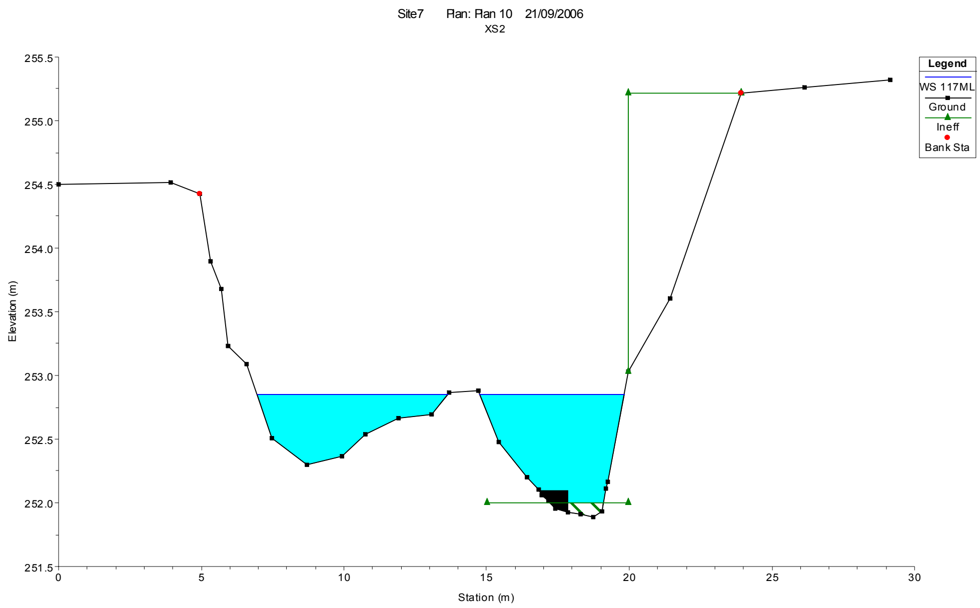
- **Figure 3-87 Duration (top left), frequency (top right) and start month (left) for flows below the winter low flow threshold of 19 ML/d at Reach 7.**

Winter fresh

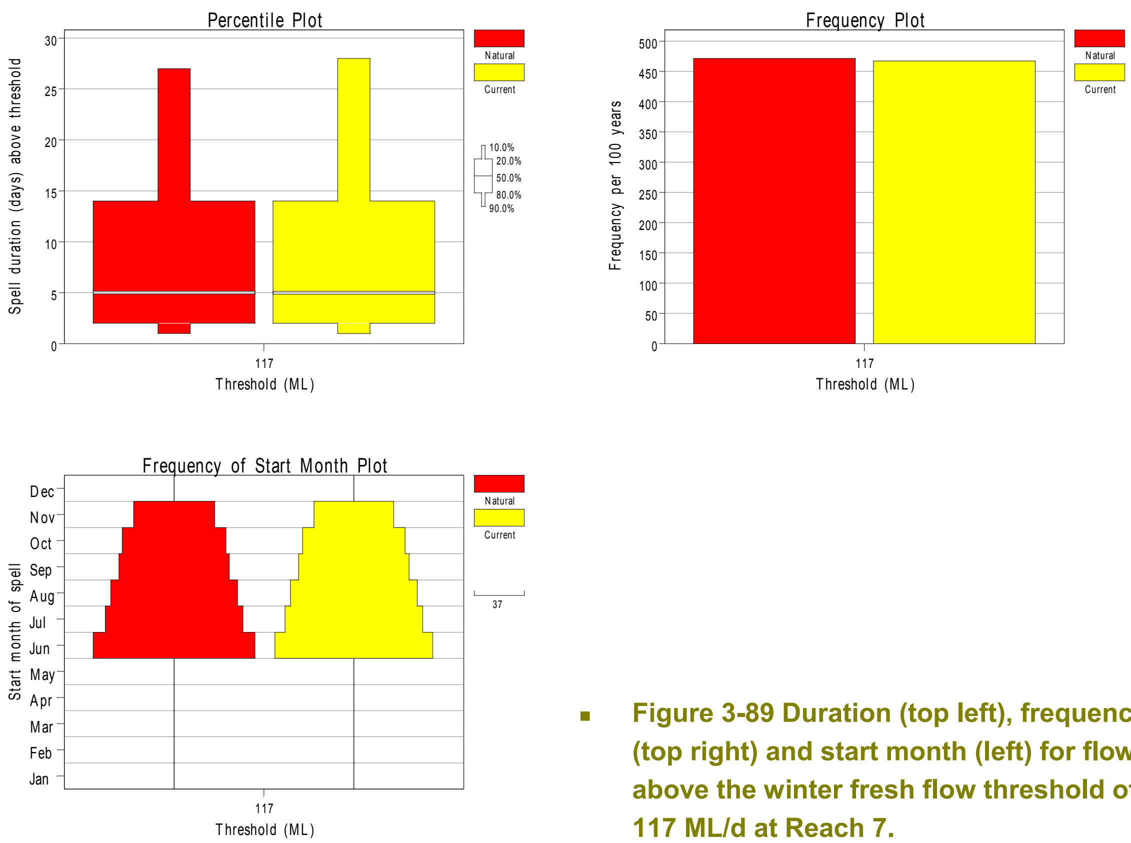
Four winter freshes of 117 ML/day lasting for six days have been recommended for Happy Valley Creek. Figure 3-88 shows the flow of this size will fill the higher side channel at cross section 2 but barely inundates the gravel bar.

Winter freshes have been recommended with the aim of achieving the geomorphology and macroinvertebrate flow objectives for this site (see Appendix A) which are to maintain the current hydraulic geometry of the site and to rehabilitate the diverse macroinvertebrate community.

There is little difference in the frequency and duration of winter freshes under current and natural flow conditions. Flows greater than 117 ML/day occur in Happy Valley Creek approximately 4.7 times per year and have a median duration of six days (Figure 3-89). Winter freshes are most common in June and their likelihood of occurrence decreases from June to November.



- **Figure 3-88: Water level at cross-section 2 at study site, Reach 7 under winter fresh of 117 ML/day.**

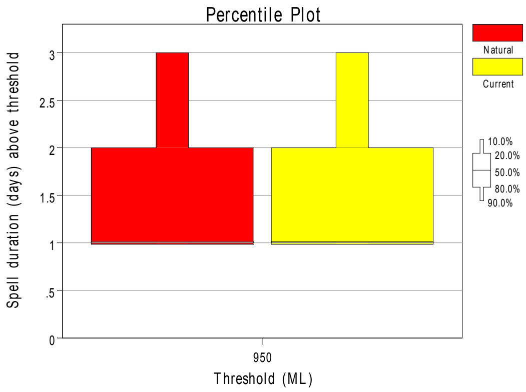


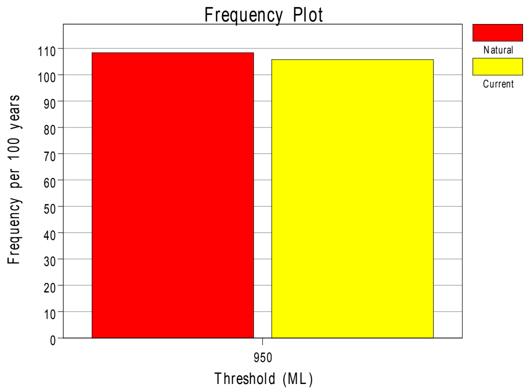
- **Figure 3-89 Duration (top left), frequency (top right) and start month (left) for flows above the winter fresh flow threshold of 117 ML/d at Reach 7.**

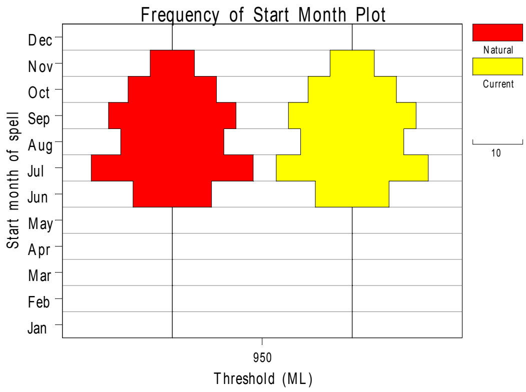
Winter high flow

An annual winter high winter flow of 950 ML/day lasting for one day has been recommended for this site in Reach 7. This flow is aimed at maintaining channel complexity and creating sufficient disturbance to turn rocks and loosen interstitial material from the bed.

Flows greater than 950 ML/day occur in Happy Valley Creek once per year on average and have a median duration of one day (Figure 3-90). These flow events are most common in July. There is no difference between the frequency and duration of winter high flows under current and natural flow conditions, which suggests that current water harvesting has little effect on this flow component.



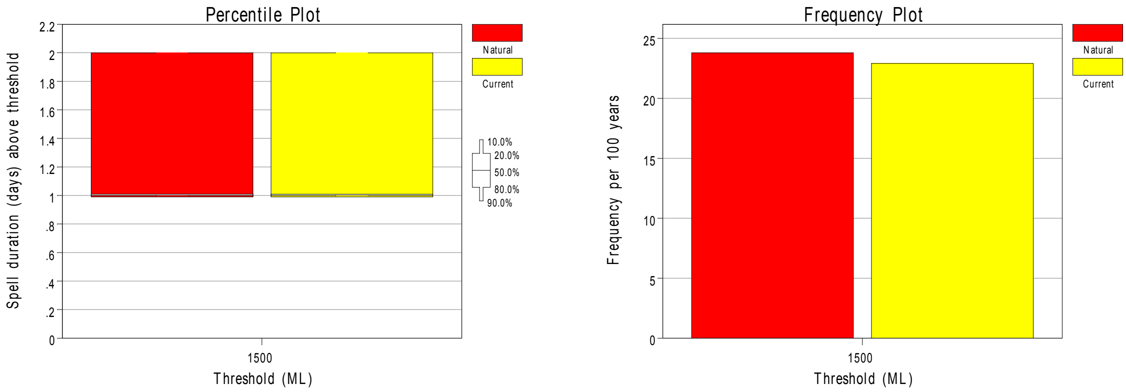


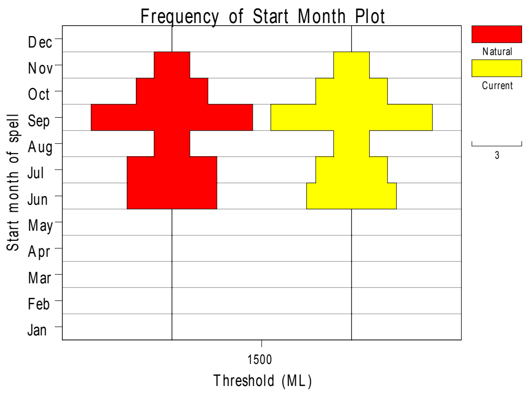


- **Figure 3-90 Duration (top left), frequency (top right) and start month (left) for flows above the winter high flow threshold of 950 ML/d at Reach 7.**

Winter bankfull flow

Bankfull flows of 1500 ML/day occur on average once every five years in Happy Valley Creek and generally last for one day (Figure 3-91). They usually occur as a result of heavy rainfall in September and there is no difference in their frequency or duration under current conditions compared to natural. It is recommended that bankfull flows of 1500 ML/day be protected in Happy Valley Creek to maintain channel forming processes and preserve riffle-pool habitat sequences. These flows will most likely break out of the bank and cause minor flooding at isolated points throughout the reach.





- **Figure 3-91 Duration (top left), frequency (top right) and start month (left) for flows above the winter bankfull flow threshold of 1500 ML/d at Reach 7.**

3.7.3 Comparison of current flows against the recommended flow regime

The flow recommendations for Reach 7 were compared with the natural and current flow regimes to determine the effect of current abstractions and to highlight the potential changes that may be required to deliver the recommended flow regime (Table 3-19). The flow recommendations are not met under the natural flow regime all of the time. This is to be expected and represents natural variability in the system. The comparison of most interest in Table 3-19 is the difference between the flows that are met under the natural and current flow regimes. Most of the winter environmental flow recommendations are met as often under the current flow regime as the natural flow regime, but current water harvesting reduces the magnitude, frequency and duration of summer flows (Table 3-19). Under natural flow conditions, the recommended summer low flow of 7 ML/day occurs approximately 81% of the time, but under current conditions this flow recommendation is only met 66% of the time (Table 3-19). There are also fewer summer freshes and fewer and smaller summer high flow events under the current flow regime compared to the current flow regime. This is the only reach in the upper Ovens River system where summer freshes and high flows appear to be affected by the current flow regime. This is probably due to the relatively high number of farm dams that have the potential to reduce run-off in this catchment. This analysis suggests that Happy Valley Creek is the most flow stressed reach in the upper

Ovens River system and current water harvesting practices are therefore likely to be having a substantial effect on the ecological values of this reach and in reaches further downstream.

- **Table 3-19 Assessment of the extent to which flow recommendations for Reach 7 are met under the current and natural flow regimes.**

Component	Months	Flow Rec		Current Compliance	Natural Compliance	Ratio of Current to Natural Compliance
Summer low	Dec - May	Volume	7	66%	81%	*81%*
Summer fresh	Dec - May	Volume	35	98%	100%	*98%*
		Number	3	75%	82%	*91%*
		Duration	2	77%	74%	*104%*
Summer high	Dec - May	Volume	200	66%	71%	*93%*
		Number	1	66%	71%	*93%*
		Duration	2	59%	63%	*94%*
Winter low	Jun - Nov	Volume	19	77%	80%	*96%*
Winter fresh	Jun - Nov	Volume	117	97%	97%	*100%*
		Number	4	68%	69%	*97%*
		Duration	5	57%	57%	*100%*
Winter high	Jun - Nov	Volume	950	55%	55%	*100%*
		Number	1	55%	55%	*100%*
		Duration	1	100%	100%	*100%*
Bankfull	Jun - Nov	Volume	1500	83%	88%	*95%*
		Number	0.2	83%	88%	*95%*
		Duration	1	100%	100%	*100%*

Legend						
Mostly complies		Greater than	**95**	%		
Frequently complies		Between	**76**	&	**95**	%
Often complies		Between	**51**	&	**75**	%
Occasionally complies		Between	**26**	&	**50**	%
Rarely complies		Between	**5**	&	**25**	%
Never complies		Between	**0**	&	**5**	%

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3.8 Reach 8 – Barwidgee Creek

3.8.1 Current condition

A detailed description of the current condition of Reach 8 was provided in the *Issues Paper* . A summary is provided in Table 3-20 below.

Table 3-20 Current condition of Reach 8: BarwidgeeCreek.

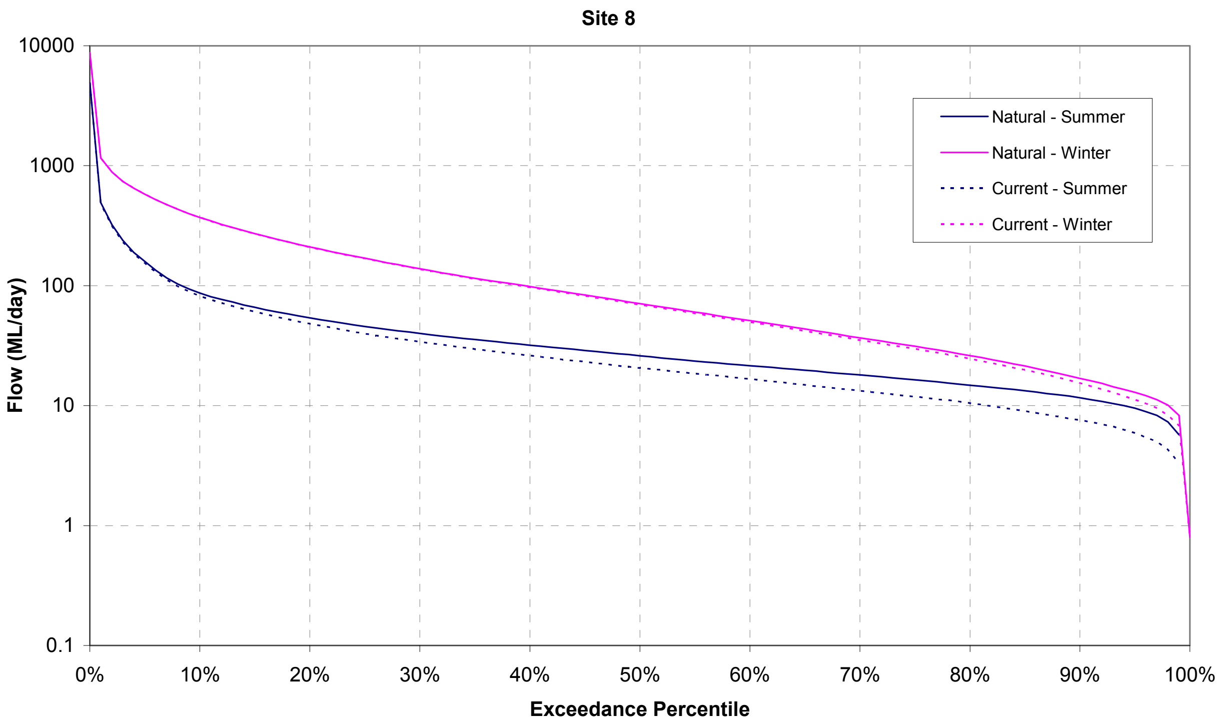
Asset	Current condition
Hydrology	▪ Water extractions can reduce summer flows. Irrigation and livestock demands.
Geomorphology	▪ River prone to breakout and course adjustment. Gully and stream bank erosion identified as key issue in past. Willow infestations cause sinuous thalweg and bifurcate channel.
Water quality	▪ Water quality generally poor. Catchment erosion, stock access to stream channel and cropping to stream edge contribute to nutrient enrichment. Salinity is high compared to other parts of the catchment.
Fish	▪ Habitat in moderate to poor condition with low abundance of small native fish. No snags, evidence of siltation. Extractions may stress community during summer if pool depth reduced
Macroinvertebrates	▪ Habitat and condition is moderate to poor. Extractions may stress community during summer low flow period. Threats include nutrient enrichment, stock access, willows and catchment erosion.
Instream and riparian flora	▪ Riparian vegetation reduced in extent and diversity. Dense willows. Lack of riparian shade. Good instream vegetation at site.

3.8.2 Flow recommendations

The environmental flow recommendations for Reach 8 are summarised in Table 3-21. No specific cease-to-flow recommendation has been made because cease-to-flow events are not expected to occur in most years under natural conditions. The flow duration curves for the winter and summer current and natural flows are shown in Figure 3-92.

- **Table 3-21 Summary of flow recommendations for Reach 8: Barwidgee Creek.**

Reach 8 Barwidgee Creek				
Season	**Component**	**Magnitude**	**Frequency**	**Duration**
Summer	Cease-to-flow	No specific recommendation. As natural		
	Low flow	15 ML/day or natural		
	Freshes	54 ML/day	2 per year	3 days
	Summer high	200 ML/day	2 per year	2 days
Winter	Low flow	26 ML/day or natural		
	Freshes	138 ML/day	4 per year	5 days
	High	1250 ML/day	1 per year	1 day
	Bankfull	No specific recommendation. As natural		
	Overbank	No specific recommendation. As natural		



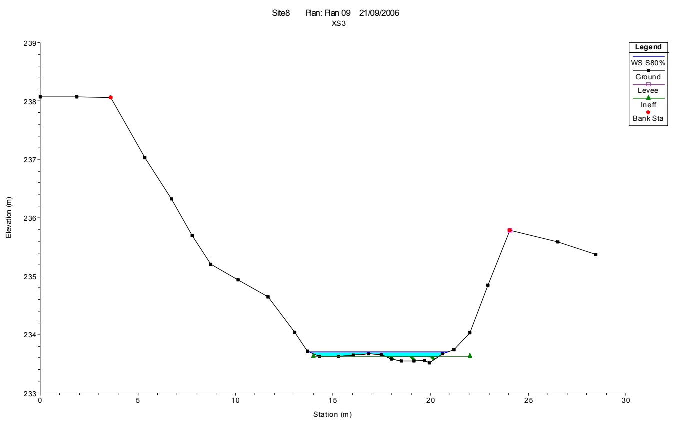
- **Figure 3-92: Natural and Current summer and winter percentage exceedance curves for Site 8.**

Summer low flow

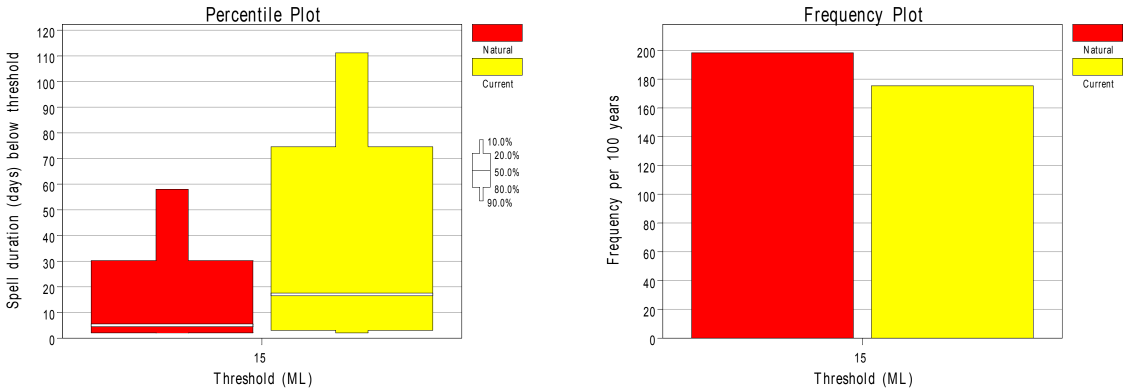
A summer low flow of 15 ML/day or as naturally occurs has been recommended for Barwidgee Creek. This is equivalent to the 80th percentile summer natural flow (Figure 3-92). A flow of this size will provide approximately 5 to 20cm of water over the bed in cross section 3 (Figure 3-93). Summer low flows are aimed at rehabilitating the native fish community, water quality and the macroinvertebrate community through this reach.

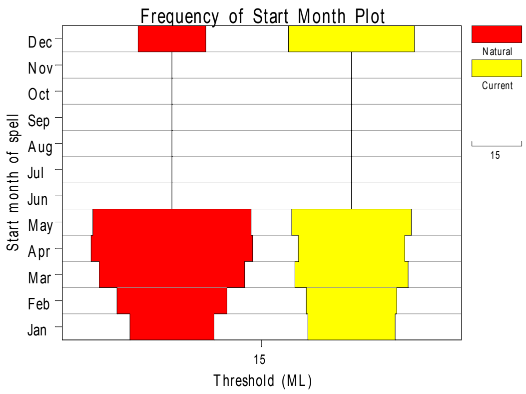
Under natural conditions flows less than 15 ML/day would have occurred in Barwidgee Creek approximately 1.95 times per year, with a median duration of five days (Figure 3-94). Under current conditions summer flows less than 15 ML/day occur approximately 1.75 times per year, but have a median duration of 18 days (Figure 3-94). The extended duration of low flows is primarily due to water harvesting throughout the catchment and has the potential to exacerbate water quality problems in the reach.

The summer low flow recommendation for this reach is slightly higher than the minimum flow (10 ML/day) recommended in the previous environmental flow assessment (SKM 2001). The previous environmental flow study based its recommendations on flows that were directly observed in the field and used minimum water depth as the main criteria determining the minimum flow recommendation. The authors of the previous study selected a site that had a deep lateral channel and large areas of shallow water at the channel margins. They concluded that flows greater than 10 ML/day would wet these channel margins, but would not substantially increase habitat for blackfish (SKM 2001). Flows of 15 ML/day would increase the area of available riffle habitat compared to flows of 10 ML/day. Increased riffle area will help support macroinvertebrate communities, which was a consideration in the current study but not in the previous flow study. In addition the HEC-RAS model used in the current study allows conditions for non-observed flows to be more reliably estimated and therefore the summer low flow recommendation of 15 ML/day is considered a more accurate assessment of the flow that is required in Barwidgee Creek during summer.



- **Figure 3-93: Water level at cross-section 3 at study site, Reach 8, under summer low flow of 15 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**



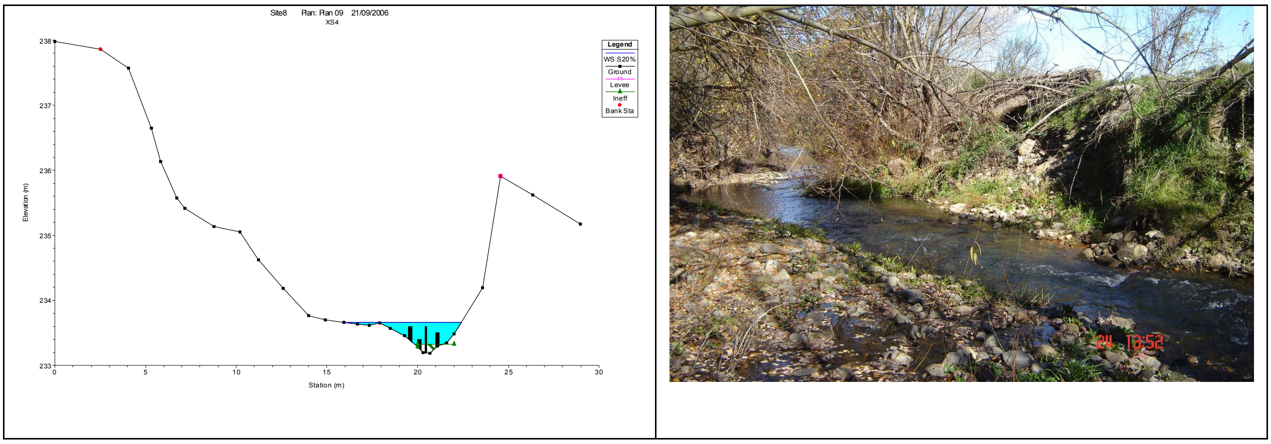


- **Figure 3-94 Duration (top left), frequency (top right) and start month (left) for flows below the summer low flow threshold of 15 ML/d at Reach 8.**

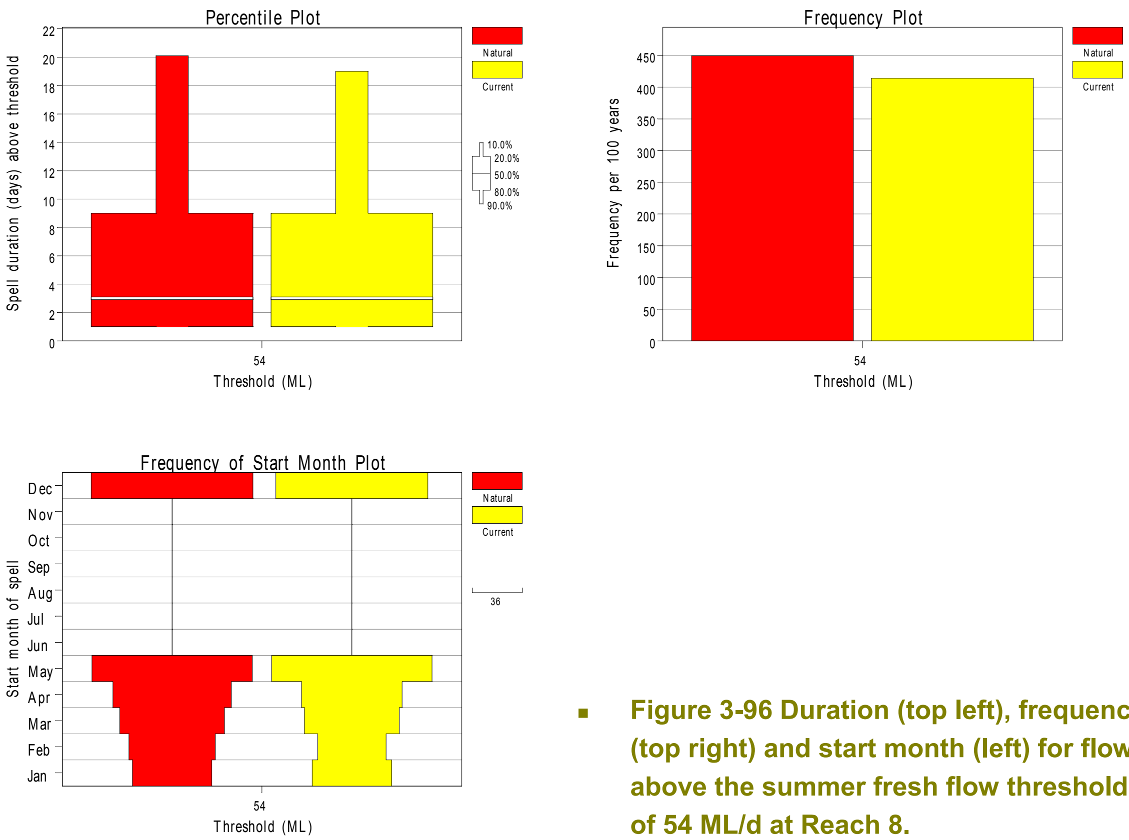
Summer fresh

Two summer freshes of 54 ML/day lasting up to three days have been recommended for this site. Summer freshes will inundate the bench on the right bank at cross section 4 of the study site (Figure 3-95). Summer freshes are aimed at maintaining the mosaic of in-channel vegetation at different states of development and to rehabilitate riparian vegetation, the native fish community and water quality through this reach.

Summer flows greater than 54 ML/day would have naturally occurred 4.5 times per year in Barwidgee Creek and had a median duration of three days (Figure 3-96). Summer freshes are slightly less frequent under current flow conditions, but the duration and timing of these flows has not changed (Figure 3-96).



- **Figure 3-95: Water level at cross-section 4 at study site, Reach 8, under summer fresh of 54 ML/day. Note water level in photograph does not necessarily reflect level shown in cross section.**

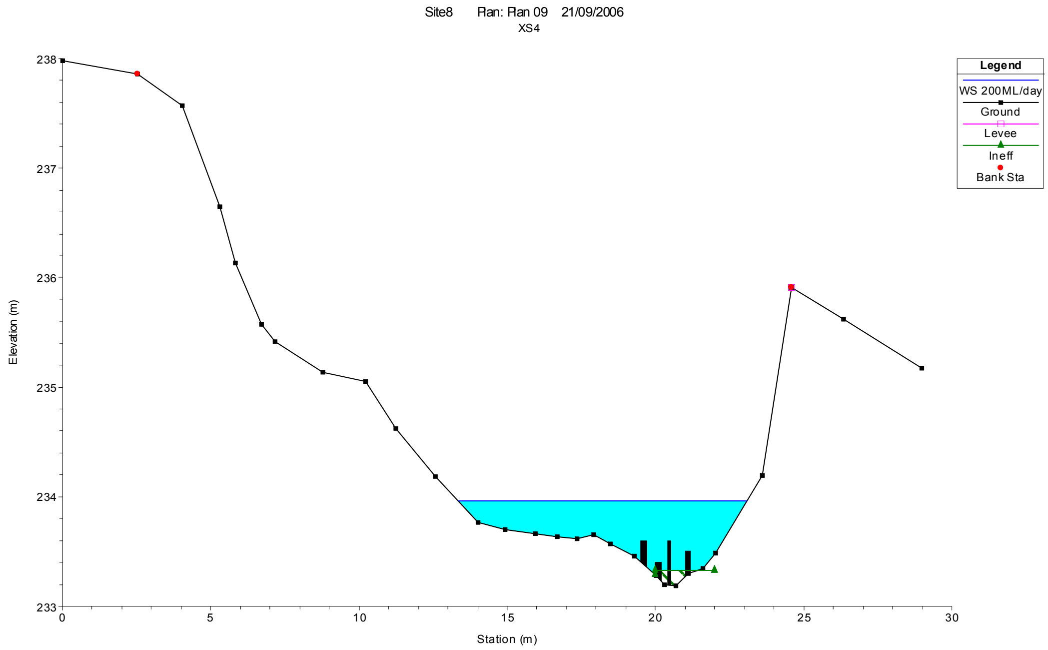


- **Figure 3-96 Duration (top left), frequency (top right) and start month (left) for flows above the summer fresh flow threshold of 54 ML/d at Reach 8.**

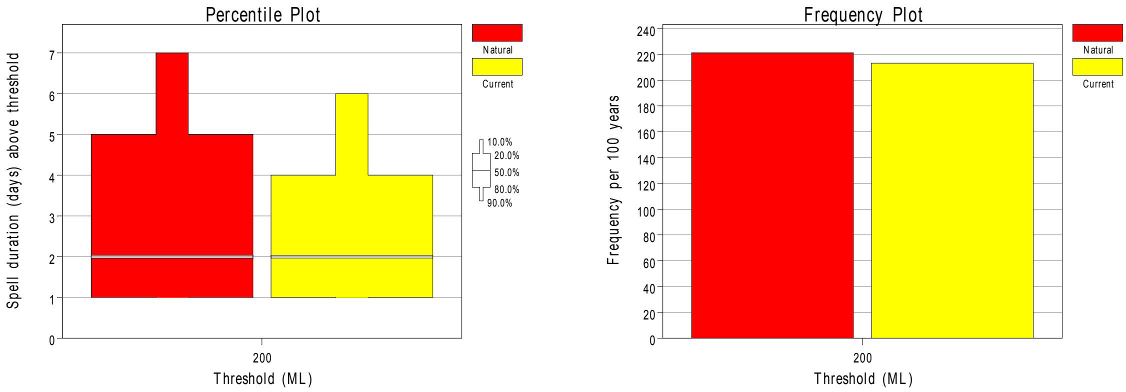
Summer high flow

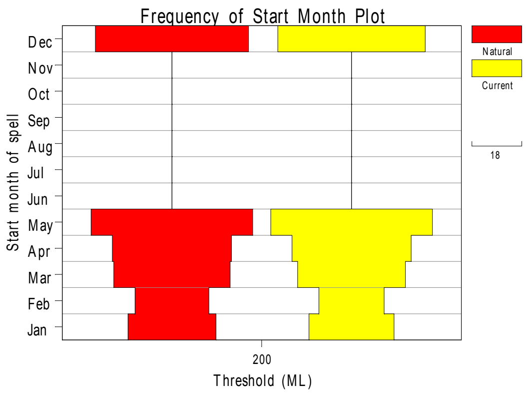
Two high summer flows of 200 ML/day lasting for two days have been recommended for Barwidgee Creek. Summer high flows will completely inundate low lying benches, such as those present in cross section 4 of the study site (Figure 3-97) and will wet the lower banks of the main channel. A summer high will provide sufficient velocity to scour biofilms from rocks, redistribute organic material through the bed and improve water quality. If willows were removed from the banks, a summer high flow would also provide a benefit to any existing native riparian vegetation along the banks.

Flows greater than 200 ML/day occur approximately 2.2 times per year in Barwidgee Creek and have a median duration of two days (Figure 3-98). There is little difference in the frequency and duration of these flows under current and natural conditions, which suggests that water harvesting has little effect on this flow component.



- **Figure 3-97: Water level at cross-section 4 at study site, Reach 8, under summer high flow of 200 ML/day.**



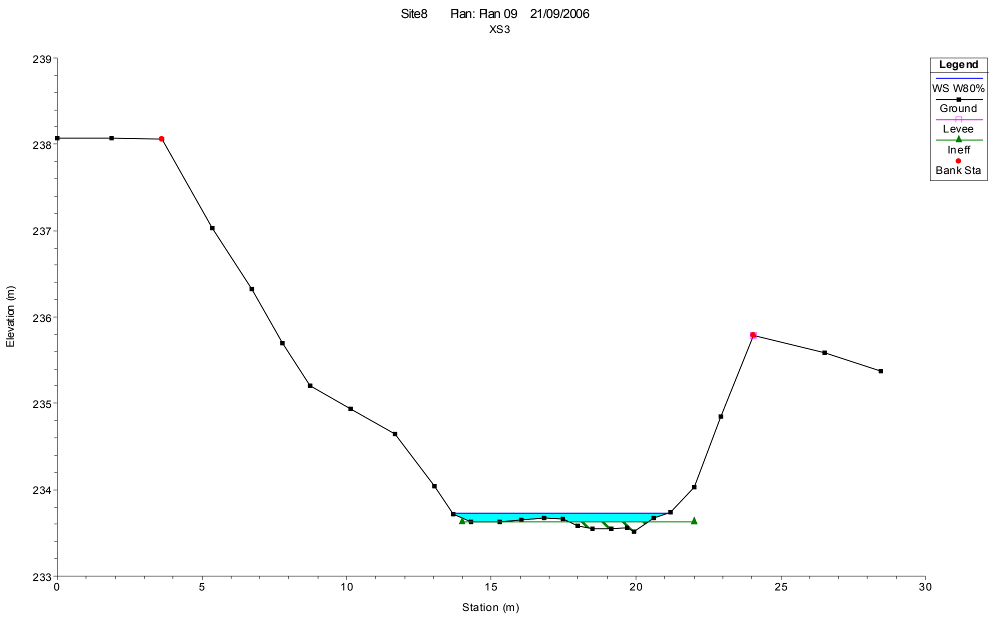


- **Figure 3-98 Duration (top left), frequency (top right) and start month (left) for flows above the summer high flow threshold of 200 ML/d at Reach 8.**

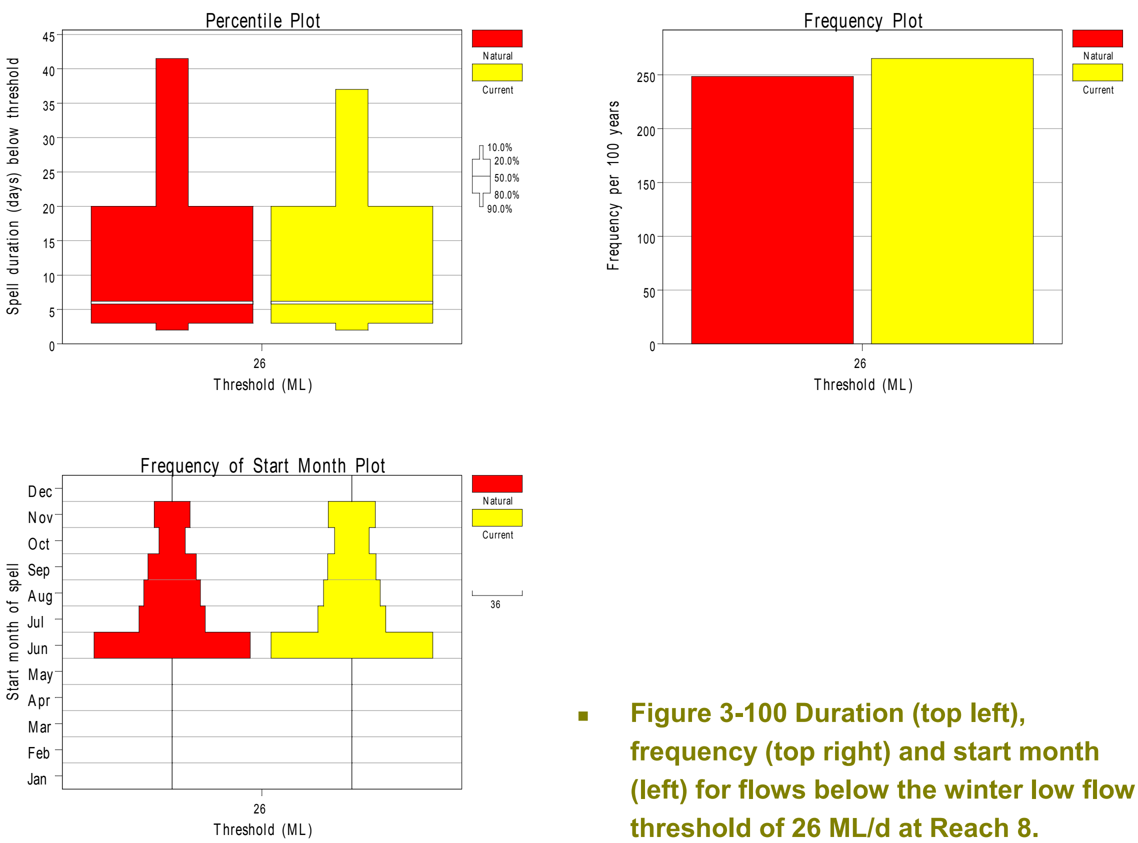
Winter low flows

A winter low flow of 26 ML/day or as naturally occurs has been recommended for Barwidgee Creek. This is equivalent to the 80th percentile winter flow under natural conditions (Figure 3-92). A winter low flow will inundate the channel to a depth of approximately 10 to 20 cm at cross section 3 (Figure 3-99). Winter low flows are aimed at preventing terrestrial plants colonising the gravel bars and maintaining the in-channel vegetation.

Under natural conditions, winter flows in Barwidgee Creek drop below 26 ML/day approximately 2.5 times per year for a median duration of six days. This pattern is very similar under the current flow regime, but these lower flows are slightly more frequent (Figure 3-100). Lower than recommended flows are most common in June and probably reflect a late start to winter.



- **Figure 3-99: Water level at cross-section 3 at study site, Reach 8, under winter low flow of 26 ML/day.**



- **Figure 3-100 Duration (top left), frequency (top right) and start month (left) for flows below the winter low flow threshold of 26 ML/d at Reach 8.**

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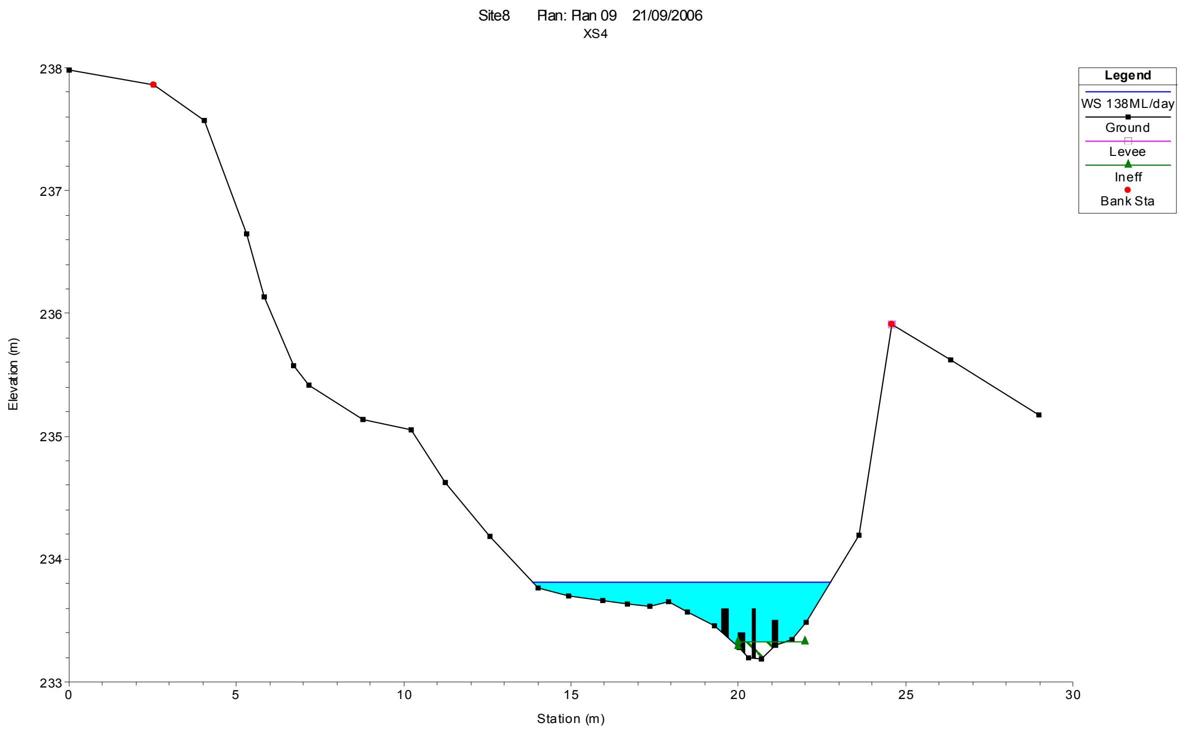
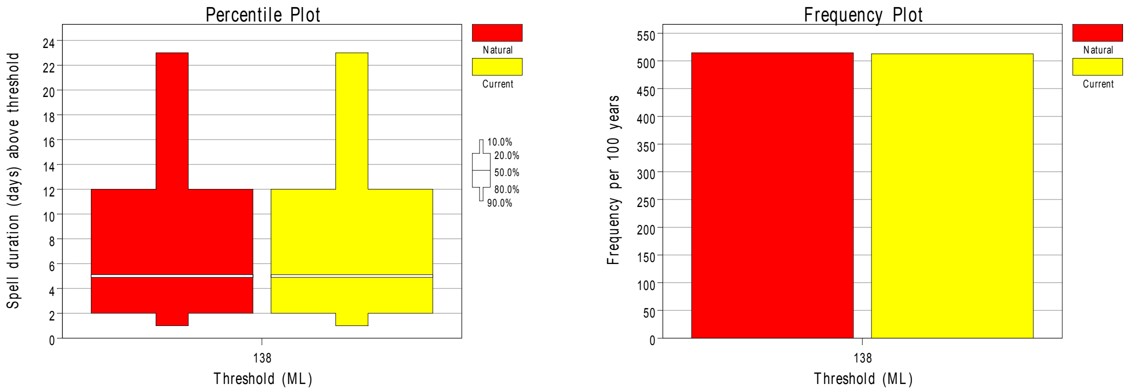
Winter fresh

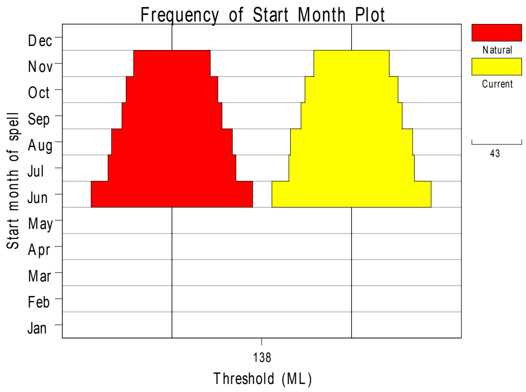
Four winter freshes of 138 ML/day and six day duration have been recommended for Barwidgee Creek. Winter freshes will fully inundate the low lying benches (e.g. see right hand side of cross section 4 Figure 3-101), will assist channel maintenance processes and will turn over substrate elements thereby preventing bed armouring. These responses will improve aquatic fauna diversity by providing access to the substrate for benthic macroinvertebrates and fish.

Under natural and current conditions, flows greater than 138 ML/day occur approximately five times per year, have a median duration of five days and are most common in June (Figure 3-102). This suggests that current water harvesting has little effect on winter freshes in the Barwidgee Creek catchment.



- **Figure 3-101: Water level at cross-section 4 at study site, Reach 8, under winter fresh of 138 ML/day.**



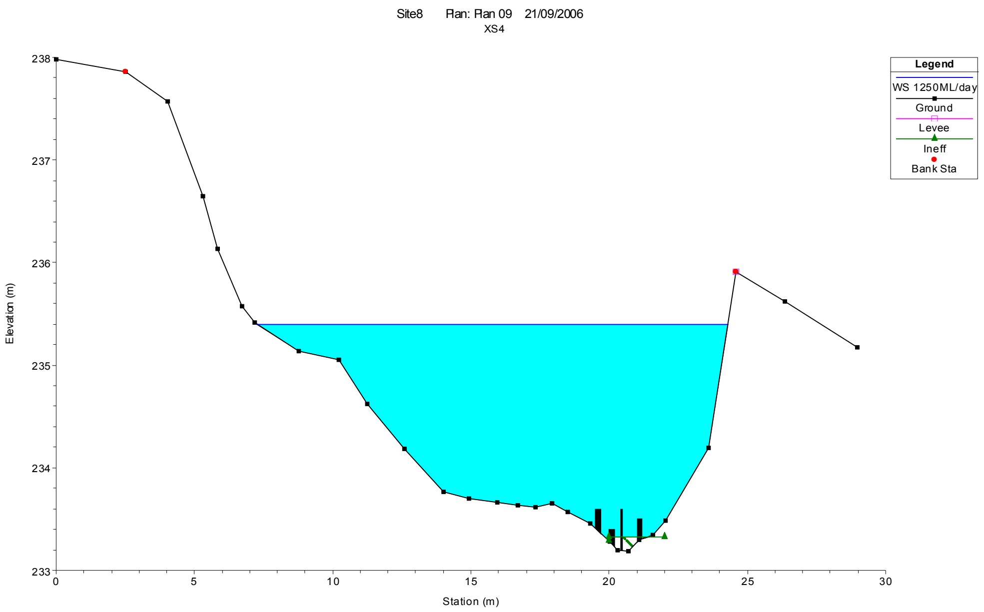


- **Figure 3-102 Duration (top left), frequency (top right) and start month (left) for flows above the winter fresh flow threshold of 138 ML/d at Reach 8.**

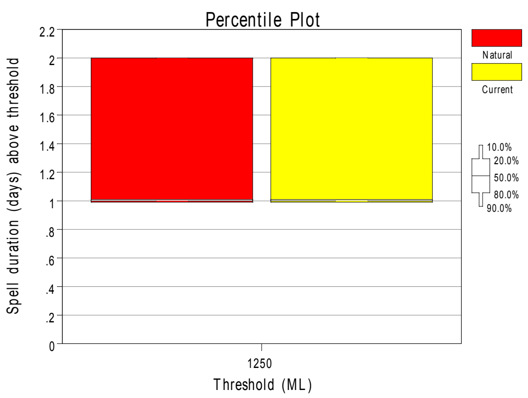
Winter high flow

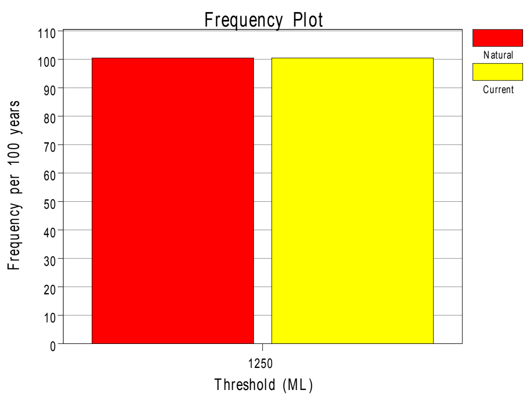
One winter high flow of 1250 ML/day lasting for up to one day has been recommended for Barwidgee Creek. A winter high flow will inundate all channel features at cross section 4 (Figure 3-103) and is aimed at providing channel maintenance, sufficient disturbance to scour biofilms and unwanted vegetation from the channel, provide opportunities for fish movement through fish barriers, turn rocks and entrain organic material.

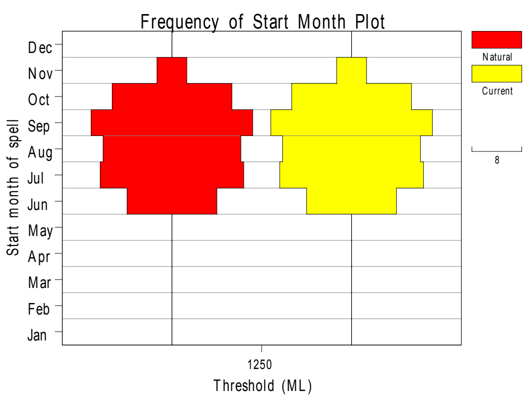
Flows greater than 1250 ML/day occur in Barwidgee Creek approximately once per year and have a median duration of one day under natural and current flow conditions (Figure 3-104). Winter high flows are most common between July and October, but do not appear to be affected by water harvesting in the catchment.



- **Figure 3-103: Water level at cross-section 4 at study site, Reach 8, under winter high flow of 1250 ML/day.**







- **Figure 3-104 Duration (top left), frequency (top right) and start month (left) for flows above the winter high flow threshold of 1250 ML/d at Reach 8.**

Bankfull flows

No specific recommendation has been provided for bankfull flows in Barwidgee Creek. The EFTP did not identify any particular ecological function for bankfull flows in this reach, but these flows will occasionally occur and should be allowed to pass through the system to contribute to higher flows in the lower reaches of the Ovens River.

3.8.3 Compliance of flow recommendations against current flow regime

The flow recommendations for Reach 8 were compared with the natural and current flow regimes to determine the effect of current abstractions and to highlight the potential changes that may be required to deliver the recommended flow regime (Table 3-22). The flow recommendations are not met under the natural flow regime all of the time. This is to be expected and represents natural variability in the system. The comparison of most interest in Table 3-22 is the difference between the flows that are met under the natural and current flow regimes. Most of the environmental flow recommendations are met as often under the current flow regime as the natural flow regime, but current water harvesting reduces the magnitude of summer low flows (Table 3-22). Under natural flow conditions, the recommended summer low flow of 15 ML/day occurs approximately 79% of the time, but under current conditions this flow recommendation is only met 65% of the time (Table 3-22). Extractions may have little effect on summer flows in Barwidgee Creek during wet years, but may substantially increase flow stress in dry years. Current water harvesting has no detectable effect on other flow components in this reach.

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- **Table 3-22 Assessment of the extent to which flow recommendations for Reach 8 are met under the current and natural flow regimes.**

Component	Months	Flow Rec		Current Compliance	Natural Compliance	Ratio of Current to Natural Compliance
Summer low	Dec - May	Volume	15	65%	79%	*82%*
Summer fresh	Dec - May	Volume	54	99%	100%	*99%*
		Number	2	95%	95%	*100%*
		Duration	3	56%	55%	*102%*
Summer high	Dec - May	Volume	200	87%	89%	*97%*
		Number	2	54%	55%	*97%*
		Duration	2	61%	60%	*103%*
Winter low	Jun - Nov	Volume	26	79%	80%	*99%*
Winter fresh	Jun - Nov	Volume	138	99%	99%	*100%*
		Number	4	74%	74%	*100%*
		Duration	5	53%	54%	*98%*
Winter high	Jun - Nov	Volume	1250	51%	51%	*100%*
		Number	1	51%	51%	*100%*
		Duration	1	100%	100%	*100%*

Legend						
Mostly complies		Greater than	**95**	%		
Frequently complies		Between	**76**	&	**95**	%
Often complies		Between	**51**	&	**75**	%
Occasionally complies		Between	**26**	&	**50**	%
Rarely complies		Between	**5**	&	**25**	%
Never complies		Between	**0**	&	**5**	%

4. Supporting recommendations

In addition to implementing environmental flow recommendations, complementary waterway works create additional opportunities for improvements in ecological health independent of flows and also maximise the opportunity to achieve the full ecological advantage of environmental flow provisions. Further investigations are needed where there is insufficient data or understanding to enable objective assessment of flow requirements or to be confident in predicted ecological responses to flow or complementary waterways works. A number of key issues are discussed in the following sections.

4.1 Willow and weed management

Willows are present and are a major problem throughout the upper Ovens River catchment. Most of the sites visited during our initial site inspection had extensive willow infestation and in many cases native riparian species have been completely replaced. Willows have also altered the morphology of the channel in places. Some willow removal works have been undertaken in parts of the catchment, particularly along Barwidgee Creek, Happy Valley Creek and some sections of the Ovens River downstream of the Buckland River. However, this work needs to continue and a dedicated willow removal program is needed in many areas before environmental flows and other associated catchment management works are to be effective.

Blackberries are another major issue throughout the upper Ovens River valley. Many sites visited during the initial catchment inspection had severe blackberry infestation, and a detailed flow assessment could not be undertaken in Buffalo Creek because the blackberries completely obscured visual and physical access to channel bank features. Without effective blackberry removal, very few of the flow recommendations to improve native vegetation will have no effect.

The removal of weeds that are altering channel morphology and natural channel forming processes-should be considered high priority for this catchment in general but should be undertaken with assessment of the underlying channel stability of target reaches.

4.2 Land clearing and stock access

Historic mining activities, land clearing and current stock access have substantially impacted the riparian vegetation and bank stability throughout the upper Ovens River system. In many places the floodplain has been cleared to the top of the river bank and where present, the floodplain riparian zone is only one tree wide. Some sections of the Ovens River and its tributaries are not adequately fenced, which means that stock are eroding the river bank and trampling or grazing on riparian plant species, thereby preventing substantial regeneration. This impact is particularly evident in Happy Valley Creek, parts of Barwidgee Creek and Buffalo Creek. The delivery of higher flows to promote regeneration of native riparian species will have little effect unless stock are excluded from these areas.

The presence of stock and pasture has also allowed exotic grasses and other pasture species to encroach into the river channel and these plants now dominate the understorey throughout the system. Revegetation works have been implemented in various places throughout the catchment, particularly along the Barwidgee Creek. Much of this work is in its early stages, but should continue to help improve the condition of these rivers.

4.3 Fish passage

Several structures restrict fish passage throughout the Upper Ovens River. Bright and Porepunkah Weirs prevent fish passage during summer, but are removed during winter. Other structures such as the water supply weir upstream of Bright provide more permanent barriers. Only some of the fish species that are indigenous to the Upper Ovens River need to migrate throughout the system, but barriers are likely to prevent seasonal movement of larger species such as Murray Cod into the system and are also likely to restrict the movement of Trout Cod and Macquarie Perch, which have been stocked in some parts of the system.

4.4 Water Quality

Water quality is generally good throughout the upper Ovens River catchment, but can be poor near urban areas and downstream of wastewater treatment plants. Environmental flows are not intended to be used to specifically dilute water quality impacts and therefore other measures should be adopted to limit pollution. High nutrient levels are a particular issue in some parts of the catchment and proposed upgrades to wastewater treatment plants, which will allow wastewater to be re-used on land will have the double benefit of reducing nutrient inputs to the river and reducing demand for river water. The other main source of water pollution is due to run-off from agricultural land, which is a major problem in Happy Valley and Barwidgee Creek. This problem is exacerbated in areas with high erosion, as mobile sediments carry efficiently transport sediments to the stream. Stock control and riparian planting will help reduce agricultural impacts on water quality and should be considered a management priority.

5. References

DNRE. 2002. *The FLOWS method: a method for determining environmental water requirements in Victoria.* Sinclair Knight Merz, CRC Freshwater Ecology, Freshwater Ecology (NRE), and Lloyd Environmental Consultants report to the Department of Natural Resources and Environment, Victoria.

SKM. 1999. *User manual for GetSpells program*. Developed for the Department of Natural Resources and Environment, Sinclair Knight Merz, Melbourne.

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Appendix A Environmental objectives – Upper Ovens River

Table A-1: Reach 1 – Ovens River upstream of Morses Creek confluence.

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry	G1-1	Channel forming processes	Bankfull	Winter	▪ Maintain channel form and low floodplain features as a bankfull flow in this reach will engage some flood runners.
		G1-2	Channel maintenance	Freshes / High flows	Winter	▪ Maintain thalweg / channel complexity
Vegetation	Maintain the mosaic of in-channel and riparian vegetation at different states of development and so maintain diversity	V1-1	Maintain moisture in root zone of riparian plants	Low	Summer	▪ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. Stable flows can encourage the establishment and persistence of non-native species; if in spring, there is a risk of favouring self seeding willow species, which will further degrade riparian zone.
		V1-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths	Freshes	Summer	
		V1-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V1-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes	High	Winter	
Fish	Maintain current small bodied native fish community	F1-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	▪ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning. Maintaining flow diversity will help maintain the current diversity of native fish, particularly two-spined blackfish and mountain galaxias.
		F1-2	Maintain water quality	Fresh	Summer	
		F1-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	
Water quality	Maintain current water quality	W1-1	Connecting flow sufficient to maintain water quality	Low	Summer	▪ The current flow elements should be protected to maintain the existing high water quality conditions.
		W1-2	Turn over pools for re-oxygenation and to oxygenate the substrate	Fresh	Summer	
Macroinvertebrates	Maintain current diverse macroinvertebrate community	M1-1	Preserve riffle habitat at all times of day and night	Low	Summer	▪ The current flow diversity should be protected to maintain habitat diversity and to replenish resources underneath substrate elements to maintain the current macroinvertebrate community.
		M1-2	Disturbance to oxygenate and mix organic material through the substrate	Fresh	Summer	
		M1-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	

- **Table A-2: Reach 2 – Ovens River from Morses Creek to the Buckland River.**

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry *	G2-2	Channel maintenance	Freshes / High flows	Winter	■ Maintain thalweg / channel complexity
Vegetation	Maintain the mosaic of in-channel and riparian vegetation at different states of development and so maintain diversity	V2-1	Maintain moisture in root zone of riparian plants	Low	Summer	■ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. Stable flows can encourage the establishment and persistence of non-native species; if in spring there is a risk of favouring self seeding willow species, which will further degrade riparian zone.
		V2-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths Prevent terrestrial colonisation of bars and other channel elements	Freshes	Summer	
		V2-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V2-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes	High	Winter	
Fish	Maintain current small bodied native fish community	F2-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	■ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning. Maintaining flow diversity will help maintain the current diversity of native fish, particularly two-spined blackfish and mountain galaxias.
		F2-2	Maintain water quality	Fresh	Summer	
		F2-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	
Water quality	Maintain current water quality	W2-1	Connecting flow sufficient to maintain water quality	Low	Summer	■ The current flow elements should be protected to maintain the existing high water quality conditions.
		W2-2	Turn over pools for re-oxygenation and to oxygenate the substrate	Fresh	Summer	
Macroinvertebrates	Maintain current diverse macroinvertebrate community	M2-1	Preserve riffle habitat at all times of day and night	Low	Summer	■ The current flow diversity should be protected to maintain habitat diversity and to replenish resources underneath substrate elements to maintain the current macroinvertebrate community.
		M2-2	Disturbance to oxygenate and mix organic material through the substrate	Fresh	Summer	
		M2-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	

* This reach is predominantly bedrock controlled or under the influence of impoundment and therefore channel forming processes are not flow related over human time scales. Bank full flows will still need to occur through this reach to assist channel forming processes further downstream.

▪ **Table A-3: Reach 3 – Ovens River from the Buckland River to Buffalo River confluence.**

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry	G3-1	Channel forming processes	Bankfull	Winter	▪ Floodwaters will l spill into the Happy Valley Creek before creating a bankfull flow at the field assessment site for this reach. We therefore cannot determine the magnitude of bankfull flows through this reach, but flows that spill into Happy Valley Creek will be important to maintain channel evolution – which will ultimately cause the river to avulse.
		G3-2	Channel maintenance	Freshes / High flows	Winter	▪ Maintain thalweg / channel complexity
Vegetation	Maintain the mosaic of in-channel and riparian vegetation at different states of development so maintain diversity. Maintain wetland habitats	V3-1	Maintain moisture in root zone of riparian plants	Low	Summer	▪ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. Stable flows can encourage the establishment and persistence of non-native species; if in spring there is a risk of favouring self seeding willows species, which will further degrade riparian zone. ▪ This reach has important wetland habitats on the floodplain. High flows will deliver water to these wetlands through the gravel lens, bankfull and overbank flows will wet flood runners and flush material into wetlands and from wetlands back to the stream.
		V3-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths Prevent terrestrial colonisation of bars and other channel elements	Freshes	Summer	
		V3-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V3-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes and deliver water to wetlands through gravel lens	High	Winter	
		V3-5	Fill flood runners, maintain wetlands and assist with vegetation zonation on banks	Bankfull	Winter	
		V3-6	Flush organic material into and out of wetlands	Overbank	Winter	
Fish	Maintain current small bodied native fish community (eg two-spined blackfish, river blackfish, mountain galaxias and southern pygmy perch) and rehabilitate large bodied native	F3-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	▪ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning, but high and overbank flows will facilitate movement and enhance recruitment success. ▪ Maintaining flow diversity will help maintain the
		F3-2	Maintain water quality	Fresh	Summer	
		F3-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	

	fish community (eg Murray cod, trout cod and golden perch).	F3-4	Inundate wetlands and parts of the floodplain to promote zooplankton production and enhance larval survival and recruitment success	Bankfull / Overbank	Winter / Spring	current diversity of small native fish. ■ Removal of downstream barriers and habitat restoration is required to facilitate rehabilitation ie. movement of Murray cod, golden perch and trout cod into Reach 3 ■ Protection of high and flood flows will aid successful recruitment of large bodied fish if they return to this reach
Water quality	Maintain current water quality	W3-1	Connecting flow sufficient to maintain water quality	Low	Summer	■ The current flow elements should be protected to maintain the existing high water quality conditions.
		W3-2	Turn over pools for re-oxygenation and to oxygenate the substrate	Fresh	Summer	
Macroinvertebrates	Maintain current diverse macroinvertebrate community	M3-1	Preserve riffle habitat at all times of day and night	Low	Summer	■ The current flow diversity should be protected to maintain habitat diversity and to replenish resources underneath substrate elements to maintain the current macroinvertebrate community.
		M3-2	Disturbance to oxygenate and mix organic material through the substrate	Fresh	Summer	
		M3-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	

▪ Table A-4: Reach 4 – Morses Creek.

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry	G4-1	Channel forming processes	Bankfull	Winter	▪ The channel through this reach has been substantially modified through historic mining activities. Current channel form is relaxing from this impact and bankfull flows will help maintain these channel forming processes.
		G4-2	Channel maintenance	Freshes / High flows	Winter	▪ Maintain channel complexity
Vegetation	Maintain the mosaic of in-channel and riparian vegetation at different states of development and so maintain diversity	V4-1	Maintain moisture in root zone of riparian plants	Low	Summer	▪ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. ▪ Low flows of greater importance in this reach compared to main stem of the Ovens River because of small catchment capacity.
		V4-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths Prevent terrestrial colonisation of bars and other channel elements	Freshes	Summer	
		V4-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V4-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes	High	Winter	
Fish	Maintain current small bodied native fish community	F4-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	▪ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning. Maintaining flow diversity will help maintain the current diversity of native fish
		F4-2	Maintain water quality	Fresh	Summer	
		F4-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	
Water quality	Maintain current water quality	W4-1	Connecting flow sufficient to maintain water quality	Low	Summer	▪ Water quality may deteriorate if the system ceases to flow therefore the current flow elements should be protected to at least maintain current conditions.
		W4-2	Turn over pools for re-oxygenation and to oxygenate the substrate	Fresh	Summer	
Macroinvertebrates	Maintain current diverse macroinvertebrate community	M4-1	Preserve riffle habitat at all times of day and night	Low	Summer	▪ The current flow diversity should be protected to maintain habitat diversity and to replenish resources underneath substrate elements to maintain the current macroinvertebrate community.
		M4-2	Disturbance to oxygenate and mix organic material through the substrate	Fresh	Summer	
		M4-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	

▪ TableA-5: Reach 5 – Buckland River.

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry	G5-1	Channel forming processes	Bankfull	Winter	▪ The lower Buckland River has been substantially modified through historic mining activities. Current channel form is relaxing from this impact and bankfull flows will help maintain these channel forming processes (assessment site partially protected by bedrock control and therefore not likely to see substantial change at this site).
		G5-2	Channel maintenance	Freshes / High flows	Winter	▪ Maintain thalweg / channel complexity
Vegetation	Maintain the mosaic of in-channel and riparian vegetation at different states of development and so maintain diversity	V5-1	Maintain moisture in root zone of riparian plants	Low	Summer	▪ This reach has diverse in-channel habitat elements. It is important to preserve variable flows that engage and disengage habitats such as bars, benches, logs and deep pools. ▪ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. Stable flows can encourage the establishment and persistence of non-native species; if in spring there is a risk of favouring self seeding willow species, which will further degrade riparian zone.
		V5-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths Prevent terrestrial colonisation of bars and other channel elements	Freshes	Summer	
		V5-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V5-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes	High	Winter	
Fish	Maintain current small bodied native fish community	F5-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	▪ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning. ▪ Maintaining flow diversity will help maintain the current diversity of native fish and will also ensure flow conditions are suitable for recolonisation of Macquarie perch should any future management decisions be made to stock this reach.
		F5-2	Maintain water quality	Fresh	Summer	
		F5-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	
Water quality	Maintain current water quality	W5-1	Connecting flow sufficient to maintain water quality	Low	Summer	▪ The current flow elements should be protected to maintain the existing high water quality conditions.
		W5-2	Turn over pools for re-oxygenation and to oxygenate the substrate	Fresh	Summer	
Macroinvertebrates	Maintain diverse macroinvertebrate community	M5-1	Preserve riffle habitat at all times of day and night	Low	Summer	▪ The current flow diversity should be protected to maintain habitat diversity and to replenish resources underneath substrate elements to maintain the current macroinvertebrate community.
		M5-2	Disturbance to oxygenate and mix organic material through the substrate	Fresh	Summer	
		M5-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	

Table A-6: Reach 6 – Buffalo Creek.

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry	G6-2	Channel maintenance *	Freshes / High flows	Winter	■ Increase channel complexity
Vegetation	Maintain the mosaic of in-channel vegetation at different states of development and so maintain diversity Riparian zone is dominated by blackberries and these should be addressed before flow related issues	V6-1	Maintain moisture in root zone of riparian plants	Low	Summer	■ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. Stable flows can encourage the establishment and persistence of non-native species; if in spring there is a risk of favouring self seeding willow species, which will further degrade riparian zone.
		V6-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths Prevent terrestrial colonisation of bars and other channel elements	Freshes	Summer	
		V6-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V6-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes	High	Winter	
Fish	Maintain current small bodied native fish community	F6-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	■ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning. Maintaining flow diversity will help maintain the current diversity of native fish ■ The streambed is relatively flat and it is likely that small flow reductions below a minimum summer low flow will cause large sections of the stream to quickly dry without leaving any refuge pool habitats.
		F6-2	Maintain water quality	Fresh	Summer	
		F6-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	
Water quality	Maintain current water quality	W6-1	Connecting flow sufficient to maintain water quality	Low	Summer	■ The current flow elements should be protected to maintain the existing high water quality conditions.
		W6-2	Turn over pools for re-oxygenation and to oxygenate the substrate	Fresh	Summer	
Macroinvertebrates	Maintain current diverse macroinvertebrate community	M6-1	Preserve riffle habitat at all times of day and night	Low	Summer	■ The current flow diversity should be protected to maintain habitat diversity and to replenish resources underneath substrate elements to maintain the current macroinvertebrate community. ■ Especially important to protect summer low flows to maintain riffle and pool habitats.
		M6-2	Disturbance to oxygenate and mix organic material through the substrate	Fresh	Summer	
		M6-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	

* We expect a bankfull flow to be a very rare event in this reach due to the incised channel, therefore we have not made any recommendation for a bankfull or attached any specific objectives to such a flow.

Table A-7: Reach 7 – Happy Valley Creek.

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry	G7-1	Channel forming processes	Bankfull	Winter	■ Maintain channel form especially pool – riffle sequence. Without these flows, the pools would fill with sediment.
		G7-2	Channel maintenance	Freshes / High flows	Winter	■ Maintain thalweg / channel complexity
Vegetation	Maintain the mosaic of in-channel vegetation at different states of development to maintain diversity and rehabilitate riparian vegetation.	V7-1	Maintain moisture in root zone of riparian plants	Low	Summer	■ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. Stable flows can encourage the establishment and persistence of non-native species; if in spring there is a risk of favouring self seeding willow species, which will further degrade riparian zone. ■ Freshes are particularly important to flush nutrients and prevent excessive in-channel vegetation growth.
		V7-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths Prevent terrestrial colonisation of bars and other channel elements	Freshes	Summer	
		V7-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V7-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes	High	Winter	
Fish	Rehabilitate small bodied native fish community	F7-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	■ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning. Maintaining flow diversity and improving summer flows will help improve habitat quality for small native fish.
		F7-2	Improve water quality	Fresh	Summer	
		F7-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	
Water quality	Rehabilitate water quality	W7-1	Connecting flow sufficient to maintain water quality	Low	Summer	■ Higher summer low flows and freshes may help improve water quality (i.e. reduce nutrient concentrations and salinity) in this reach.
		W7-2	Turn over pools for re-oxygenation and dilute nutrients	Fresh	Summer	
Macroinvertebrates	Rehabilitate diverse macroinvertebrate community	M7-1	Preserve riffle habitat at all times of day and night	Low	Summer	■ Summer low flows and freshes should be increased to improve water quality and improve conditions for pollution sensitive macroinvertebrate taxa.
		M7-2	Disturbance to oxygenate and mix organic material through the substrate and improve water quality in pools	Fresh	Summer	
		M7-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	

- **Table A-8: Reach 8 – Barwidgee Creek.**

Asset	Objective	No.	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current hydraulic geometry	G8-1	Channel forming processes	Bankfull	Winter	▪ Maintain channel form.
		G8-2	Channel maintenance	Freshes / High flows	Winter	▪ Maintain thalweg / channel complexity
Vegetation	Maintain the mosaic of in-channel vegetation at different states of development and so maintain diversity and rehabilitate riparian vegetation.	V8-1	Maintain moisture in root zone of riparian plants	Low	Summer	▪ Preserving flow variability and seasonal patterns will maintain the diverse vegetation community in the reach. Stable flows can encourage the establishment and persistence of non-native species, if in spring there is a risk of favouring self seeding willow species, which will further degrade riparian zone. ▪ Freshes are particularly important to flush nutrients and prevent excessive in-channel vegetation growth.
		V8-2	Prevent water stress in grasses and herbs at water's edge and on low benches Provide disturbance to prevent accumulation of in-channel growths Prevent terrestrial colonisation of bars and other channel elements	Freshes	Summer	
		V8-3	Prevent terrestrial colonisation of bars and other channel elements	Low	Winter	
		V8-4	Disturbance to scour annuals, maintain dynamics and reset ecological processes	High	Winter	
Fish	Rehabilitate small bodied native fish community	F8-1	Maintain pool depth and provide some longitudinal connectivity	Low	Summer	▪ Native fish in the upper Ovens are not obligate migrators, nor do they rely on high flows to trigger spawning. Maintaining flow diversity and improving summer flows will help improve habitat quality for small native fish.
		F8-2	Improve water quality	Fresh	Summer	
		F8-3	Protect opportunities for movement and assist movement through barriers	High	Winter / Spring	
Water quality	Rehabilitate water quality	W8-1	Connecting flow sufficient to maintain water quality	Low	Summer	▪ Higher summer low flows and freshes may help improve water quality (i.e. reduce nutrient concentrations and salinity) in this reach.
		W8-2	Turn over pools for re-oxygenation and dilute nutrients	Fresh	Summer	
Macroinvertebrates	Rehabilitate diverse macroinvertebrate community	M8-1	Preserve riffle habitat at all times of day and night	Low	Summer	▪ Summer low flows and freshes should be increased to improve water quality and improve conditions for pollution sensitive macroinvertebrate taxa.
		M8-2	Disturbance to oxygenate and mix organic material through the substrate and improve water quality in pools	Fresh	Summer	
		M8-3	Disturbance to turn rocks and prevent substrate from becoming tightly packed	Fresh / High	Winter	