Environmental Flow Determination for Painkalac Creek

Site Paper

Prepared by

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for the

Corangamite Catchment Management Authority

July 2007

The Painkalac Creek Environmental Flows Technical Panel

Tim Doeg	Invertebrate Ecology, Fish Ecology, Hydrology
Geoff Vietz	Geomorphology, Hydraulic Modelling
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Acknowledgements

Thanks are due to the Steering Committee, the Community Advisory Committee, and Mark Turner of the Corangamite CMA for some of the information provided for this report.

The Painkalac Creek Steering Committee

Greg Williams	Corangamite Catchment Management Authority
Rowan Mackenzie	Barwon Water
Frances Northeast	Surf Coast Shire

The Painkalac Creek Community Advisory Committee

Rachel Fagatter, Michael Noelker, Dale Antonyson, Tim Gibson, Ros Gibson, Dennis Leavesley, Graeme McKenzie, Greg Day, Tim Wood.

Abbreviations used in this report

CMA	Catchment Management Authority
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EPA	Environment protection Authority
EVC	Ecological Vegetation Class
ha	hectares
ML	Megalitres (1,000,000 litres)
NRE	Department of Natural Resources and Environment

Please cite this document as:
Doeg, T.J., Vietz, G. and Boon, P.I. (2007) Painkalac Creek *Environmental Flow Investigation: Site Paper.* Prepared for the Corangamite Catchment Management Authority, Colac.

Cover Photo: Painkalac Creek (Photo: G. Vietz)

Contents

1. Introduction

In 2004, the Surf Coast Shire developed the Painkalac Estuary Management Plan[1] to help improve the health and management of the Painkalac Creek estuary. The plan also included actions to maintain and improve the health of Painkalac Creek downstream of the reservoir. During the production of the plan, the Aireys Inlet community raised concerns about the effects of the reservoir on river health.

A key action identified in the plan was to:

> *Undertake an investigation into environmental flow requirements for fresh water and estuarine systems to the Painkalac Creek from the Aireys Inlet Reservoir, with a view to reviewing the Bulk Entitlement held by Barwon Water. The investigation should also consider the potential role of the Aireys Inlet Reservoir in flood management downstream.* (p. 25)

Subsequently, Tim Doeg, Paul Boon and Geoff Vietz were contracted by the Corangamite Catchment Authority to conduct an environmental flow study of the freshwater reach of Painkalac Creek between the reservoir and the upper limits of the estuary reach.

The objectives of the project are to:

- Identify water dependant environmental and social values within the reach;
- Gauge the current health of the environmental values;
- Recommend an environmental flow regime that will sustain the identified environmental values; and
- Develop recommendations to address issues that may complement or could reduce the efficacy of the flow recommendations

The method for determining environmental flow recommendations is the FLOWS method – the standardised Statewide Method For Determining Environmental Water Requirements in Victoria (NRE, 2002[2]).

The FLOWS Site Paper

This Site Paper represents the first output from the Painkalac Creek FLOWS project. Its purpose is to:

- present an initial description of the Painkalac Creek system;
- present a list of flow dependent environmental assets for which environmental flow recommendations will be developed;
- identify reaches for further study;
- present a brief description of the FLOWS method; and
- elicit additional information from the Steering Committee and Community Advisory Committee.

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[1] Surf Coast Shire (undated) *Painkalac Estuary Management Plan*. Surf Coast Shire.

[2] NRE (2002) *FLOWS- a method for determining environmental water requirements in Victoria*. Catchment and Water Division, Department of Natural Resources and Environment, East Melbourne.

The Site Paper is based on available information that has been gathered rapidly in the early stages of the study. During the preparation of the more detailed Issues Paper, further information (usually unpublished or difficult to obtain) may come to light that causes a revision of the conclusions of this paper.

The Study Area

Painkalac Creek rises in the eastern limits of the Otway Ranges and flows in an generally easterly direction for about 20 km where it enters Bass Strait on the western side of the township of Aireys Inlet (Figure 1). The catchment has a total area of 39.6 km^2, including the Distillery Creek sub-catchment (17.7 km^2) which meets Painkalac Creek about 200 m south west of the Old Coach Road crossing.

The annual rainfall average is approximately 615 mm[3]. Highest rainfall is in the months between April and November, with the wettest month being August and the driest being January.

The lower part of the Painkalac Creek valley was largely cleared of woody vegetation early in the 19th Century and much of the cleared land was used for grazing stock.

Figure 1: Painkalac Creek catchment (from Estuary Management Plan).

The boundary between the estuary reach and the freshwater reach has been initially identified as the Old Coach Road crossing near the Distillery Creek/Painkalac Creek junction. GHD (2005[4]) suggests that the tidal influence of the estuary extends "approximately to the junction of Distillery and Painkalac Creek" (p. 4), and spot water quality results (GHD, 2005) show a distinct difference between the salinity at Old Coach Road and further downstream.

[3] Aireys Inlet climate station (1994-2007) www.bom.gov.au/climate/averages/tables/cw_090180.shtml (accessed 27/8/07)

[4] GHD (2005) *Painkalac Creek and Estuary Pollution Source Investigation.* Report to Surf Coast Shire.

2. Catchment Information

2.1 Geology and Geomorphology

Painkalac Creek rises in the deeply-dissected rolling hills at the north-eastern end of the Otway Ranges. The main channel flows from an elevation of 430 m to sea-level at the estuary. The geology of the catchment consists of Lower Cretaceous felspathic sandstone and mudstone parent material with Tertiary era sedimentation[5]. The weathered base material forms sands, silts and clays with some gravels – which drives the form and function of the channel habitat.

Painkalac Creek has a history of instability and channel change with a fairly recent avulsion forming the present channel. The flow split between the main channel and the anabranch is not certain but is both geomorphically and ecologically important. More recently a rock chute has been constructed downstream of the Old Coach Road to maintain bed stability (M. Turner, Corangamite CMA, pers. com.).

A detailed description of the geomorphology of the creek channel will be provided in the Issues Paper following the site inspection.

2.2 Hydrology and Diversions

In 1978, the Painkalac Creek reservoir was constructed (capacity 514 ML) to supply the townships of Aireys Inlet and Fairhaven. The catchment of the reservoir extends in a westerly direction for about 11 km and has a total area of about 3,420 ha[6]. The two communities are entirely reliant on the reservoir for ongoing water supply. Barwon Water's current Bulk Entitlement allows a maximum of 317 ML a year to be harvested from the reservoir through the *Bulk Entitlement (Aireys Inlet) Conversion Order 1997*.

Under the Bulk Entitlement, the maximum diversion rate allowed is 2.94 ML/day. Passing flows are specified as follows:

- March to November, the lesser of 0.5 ML/day or inflow;
- December to February, entire flow.

Therefore, no storage of water is permitted during the December to February period, and the passing flow during this period must match the inflow to the reservoir. This is difficult to achieve in practice as the outlet from the weir does not have adequate capacity. Therefore, between December and February, the release of passing flows equivalent to inflows cannot occur until the storage has reached full capacity and started spilling.

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[5] Forsyth, D.A. and Ransome, S.W. (1978) *Painkalac Creek (Aireys Inlet) Catchment. A proposal for proclamation prepared for consideration by the Land Conservation Council.* Soil Conservation Authority, Kew, Victoria

[6] Forsyth, D.A. (1980). *Report on a land use determination for the Painkalac Creek water supply catchment.* Report to Soil Conservation Authority, Kew.

A broad picture of the impacts of the reservoir operation on streamflow was presented in the project brief:

> *The impact of damming Painkalac Creek on the seasonality of the surface flows has been to extend the period of nil or very low flow in autumn (despite some low flow releases) until the reservoir is filled to overflowing. The length of this period of low flow downstream depends entirely on the degree of drawdown due to the high summer-autumn seasonal consumption, evaporation and losses to groundwater, plus the intensity of rainfall or runoff volume during the autumnal onset period.*
>
> *Consequently, the seasonality of flows mimics the rainfall fairly well, with very low base flows in non-rain periods. Although the flows can be highly variable due to unseasonal falls, there is a definite trend for the streams to have nil or only nominal flows in the summer-autumn period. This ephemerality is fairly common for Victorian streams on rapidly draining soils and can extend from November into May.*

A detailed description of the resulting flow regime will be presented in the Issues Paper, once flow data are obtained from Barwon Water.

2.3 Fish

According to the Painkalac Estuary Management Plan (Surf Coast Shire, undated), a survey in 2001 collected 6 species of native freshwater fish from the Painkalac Creek catchment (excluding estuarine species): Short-finned Eel, Tupong, Small-mouthed Hardyhead, Flat-headed Gudgeon, Common Galaxias and Australian Smelt. A number of other species that are primarily estuarine, but may be found in the lower parts of freshwater reaches included Sea mullet, Yellow-eyed mullet, Tamar River goby and Black bream (G. Peters, Corangamite CMA, unpublished data).

Despite extensive searching, no formal description or documentation on the 2001 survey has been found.

An extensive survey of Otway coast streams in the late 1980's (Koehn and O'Connor, 1990[7]) found only 4 species in Painkalac Creek: Pouched Lamprey, Short-finned Eel, Common Galaxias and Spotted Galaxias. In nearby streams along the coast to Wye River, these four species were consistently found. In nearby Grassy Creek, four additional freshwater species were recorded: Broad-finned galaxias, Australian grayling, Tupong and Flat-headed gudgeon.

The Estuary Management Plan claims that Mountain galaxias has been recorded in the creek, although no documented record of this species has been located. Koehn and O'Connor (1990) state that Mountain galaxias is missing from all of the coastal Otway streams from Anglesea to Apollo Bay.

A DPI recreational fishing website states that Painkalac Creek "contains short-finned eel, pouched lamprey, flat-headed gudgeon, common galaxias, broad-finned galaxias, and spotted galaxias"[8].

[7] Koehn, J.D. and O'Connor, W.G. (1990) Distribution of freshwater fish in the Otway region, South-western Victoria. *Proceedings of the Royal Society of Victoria* **102(1)**: 29-39.

[8] www.dpi.gov.au/angling/35-Otway/ Basin%20TEMPLATE%20Waters.htm#Painkalac (accessed 9/7/07)

The lack of recent documentation makes a final list of species to be included in the flow study difficult. As an interim, 8 freshwater fish species are considered to potentially inhabit Painkalac Creek (Table 1).

Table 1. Freshwater native fish species found in, and potentially found in Painkalac Creek

Common name	Scientific name	Comment
Pouched Lamprey	*Geotria australis*	Found in creek
Short-finned Eel	*Anguilla australis*	Found in creek
Common Galaxias	*Galaxias maculatus*	Found in creek
Spotted Galaxias	*Galaxias truttaceus*	Found in creek
Broad-finned galaxias	*Galaxias brevipennis*	Found in nearby Grassy Creek
Tupong	*Pseudaphritis urvilli*	Found in nearby Grassy Creek
Flat-headed gudgeon	*Phylipnodon grandiceps*	Found in nearby Grassy Creek
Australian smelt	*Retopinna semoni*	Likely to be present

While Australian grayling is found in nearby streams, it has not been recorded in Painkalac Creek. While a species with high conservation significance it is likely that the short length of the freshwater reach in Painkalac Creek is not large enough to support a sustainable population, unless passage to the upper reaches of the catchment is provided.

Objectives for the creek regarding Australian grayling will need to be discussed and will be based on decision by the Steering Committee and the Community Advisory Group.

None of the species on the list (Table 1) has a conservation status in Victoria (DSE, 2003)[9].

The condition of the fish populations – in terms of population size and sustainability – is not known due to the relatively low number of sampling effort over time. However, the diversity of the fish community is high for a small coastal stream.

2.4 Other water dependent vertebrates

There are no water-dependent vertebrates (other than fish) that have been recorded in the freshwater reach between the reservoir and the upper limits of the estuary. However, many vertebrates have been associated with the wetlands and the estuary section. According to the Painkalac Estuary Management Plan (Surf Coast Shire, undated):

> *The wetlands immediately surrounding Aireys Inlet attract Long-necked tortoises, Marbled Geckos, Mourning Skinks, Water Skinks, Common Blue-tongued Lizard, Lowland Copperhead, Red-bellied Black and Tiger snakes. They also support populations of Common Eastern Froglet, the Spotted Green Frog, Eastern Banjo Frog (Pobblebonk) and the Brown Tree Frog. These species are classified as common and widespread.* (p. 15)

The Estuary Management Plan also suggests that over 100 bird species used the Painkalac Estuary during 2000-2005, including 36 waterbird species.

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[9] DSE (2003) Advisory list of threatened vertebrate fauna in Victoria. Department of Sustainability and Environment, Melbourne.

While not part of the environmental flow study, it is important to realise that flows in the creek contribute to the health of the estuary and the flora and fauna it supports.

2.5 Aquatic macroinvertebrates

There are few macroinvertebrate data recorded for the freshwater reach of Painkalac Creek.

As part of an Honours project at Monash University, Yule (1978) sampled the creek. Data from this study is considered too old to be valuable for the purposes of this study.

A single site was sampled by the EPA in April and October 1997 as part of the Monitoring River Health Initiative[10]. While the location of the site was given as "at Aireys Inlet", the grid co-ordinates of the site (38°26.9'S 144°05'E) suggests it to be between the Old Coach Road and the reservoir. Twenty-two families of freshwater invertebrates were collected (Table 2 – EPA, unpublished data). The fauna contained families typically found in flowing streams (mayflies and stoneflies), but also contained taxa more typically associated with slow flowing areas (some beetles and dragonflies).

In October 2006, a further sample was collected in the upper Painkalac Creek at the Iron Bark Spur Track crossing. While a similar fauna was found, some of the taxa typical of slow flowing areas were not recorded (Table 2).

Whether this is a result simply of the different locations of the creek, or reflects the impact of lower flows downstream of the reservoir cannot be established.

Apart from these data, no information on aquatic macroinvertebrates has been found.

Table 2. Macroinvertebrate taxa found in 1997 and 2006 (EPA, unpublished data)

Taxon	Common name/type	Aireys Inlet (1997)	Iron Bark Spur Track (2006)
Hydrobiidae	Snail		+
Sphaeriidae	Snail		+
Oligochaeta	Worm		+
Mites	Aquatic spider	+	+
Ceinidae	Crustacea	+	+
Atyidae	Shrimp	+	+
Dytiscidae	Beetle	+	+
Gyrinidae	Beetle		+
Hydrophilidae	Beetle	+	
Elmidae	Beetle	+	
Dixidae	Fly larvae	+	+
Culicidae	Mosquito		+
Ceratopogonidae	Midge	+	
Psychodidae	Fly larvae	+	
Tanypodinae	Midge	+	+
Orthocladiinae	Midge	+	+
Chironominae	Midge	+	+
Baetidae	Mayfly	+	+
Leptophlebiidae	Mayfly	+	+
Veliidae	Water bug	+	+
Corixidae	Water bug	+	+

[10] Metzeling, L. (2001) Australia Wide Assessment of River Health: Victoria Bioassessment Report. Monitoring River Heath Initiative Technical Report no 4, Commonwealth of Australia and VIC Environment Protection Authority

Taxon	Common name/type	Aireys Inlet (1997)	Iron Bark Spur Track (2006)
Coenagrionidae	Damsel fly	+	
Megapodagrionidae	Damsel fly	+	+
Synlestidae	Damsel fly		+
Hemicorduliidae	Dragonfly	+	
Anisoptera	Dragonfly	+	
Gripopterygidae	Stonefly	+	+
Odontoceridae	Caddisfly	+	
Atriplectididae	Caddisfly	+	+
Leptoceridae	Caddisfly	+	+

2.6 Vegetation

There are relatively good descriptions available for terrestrial vegetation in the study region, particularly for those parts of the catchment protected in reserves. Little information, however, is available for aquatic or fringing riparian vegetation.

Before European settlement, Painkalac and Distillery Creeks flowed through a complex mix of EVCs (Ecological Vegetation Classes), including[11]:

- Riparian Forest (EVC 18) and Sedgy Riparian Woodland (EVC 198) immediately along the creek sides;
- Swampy Riparian Woodland (EVC 83) in nearby low-lying areas;
- Lowland Forest (EVC 16), Shrubby Dry Forest (EVC 21) and Heathy Woodland (EVC 48) in more elevated areas;
- Shrubby Foothill Forest (EVC 45) on higher land to the west of the two creeks; and
- Coastal Tussock Grassland (EVC 163) along the estuarine parts of the creek.

Currently the main EVCs in the study region include:

- creeklines bordered by linear strips of Riparian Forest (EVC 18) and Sedgy Riparian Woodland (EVC 198);
- a small area of Swampy Riparian Woodland (EVC 83) along Distillery Creek and in small patches downstream of the Painkalac Creek-Distillery Creek confluence;
- large areas of Lowland Forest (EVC 16) and Shrubby Dry Forest (EVC 21) to the north and south of the creek;
- a strip of Shrubby Foothill Forest (EVC 45) extending up a creekline near Dam Road, just downstream of the Painkalac Reservoir;
- Heathy Woodland (EVC 48) communities found in large areas just south of Painkalac Creek; and
- Coastal Tussock Grassland (EVC 163) near the estuarine mouth.

A number of these current EVCs are either classified as Endangered, Vulnerable or Threatened. Of particular note are:

- the Swampy Riparian Woodland (EVC 83) communities along Distillery Creek and the lower sections of Painkalac Creek, which are classified as Endangered;

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[11] Information from Biodiversity Interactive Map online at www.nremap-sc.nre.vic.gov.au/Mapshare.V2/imf.jsp?site=bnr-V1

- the Riparian Forest (EVC 18) that borders creeklines immediately downstream of Painkalac Reservoir and near the Painkalac Creek-Distillery Creek confluence is classified as Vulnerable;
- the surrounding Lowland Forest (EVC 16) is classified as Depleted.

The other EVCs as of least concern for biodiversity conservation.

The distributions of these various EVCs aligns approximately with patterns of land tenure in the catchment. A large extent of the highland sections upstream of Painkalac Reservoir, is located in the Great Otway National Park. Vegetation in Park ranges from cool temperate rainforest to dry heathland, reflecting changes in climate, aspect, soil and fire history[12]. The northern area of the Park around Aireys Inlet is one of the drier regions and vegetation consists mostly of a mixture of heathland and dry sclerophyll forest. The heathlands in particular are among the most diverse vegetation communities in Victoria: 282 native plant species, including 46 species of orchid, have been reported in an area of only 226 ha near Anglesea[13].

Lowland forests in the Park and immediate catchment of Painkalac Reservoir are dominated by Brown Stringybark (*E. baxteri*) or, less commonly, by Messmate (*E. obliqua*), Narrow-leaved Peppermint (*E. radiata*), Southern Blue Gum (*E. globulus*) and the rarer Swamp Gum (*E. ovata*). The foothill forests are dominated by Messmate, Mountain Grey Gum (*E. cypellocarpa*) or Red Ironbark (*E. tricarpa*), and the shrubby wet forests by Messmate, Mountain Grey Gum and Manna Gum (*E. vinimalis*)[14].

From Painkalac Reservoir to the downstream estuarine sections, Painkalac Creek flows through large areas of private land, much of which has been cleared for agricultural and residential use. Willows often characterise the riparian zone in these agricultural sections[15].

A more detailed description of vegetation in the reach between Painkalac Reservoir and the downstream estuarine sections will be presented in the Issues Paper, once the field inspection has been undertaken.

The estuarine section below Old Coach Road is partly enclosed within the Painkalac Creek Reserve. The Coastal Tussock Grassland (EVC 163) vegetation here is characterised by Common Tussock Grass (*Poa labillardieri*) and smaller areas of salt-marsh complexes and saline herbfields. Aquatic species include Common Reed (*Phragmites australis*), Spike Rush (*Eleocharis acuta*) and Sea Rush (*Juncus krausii*). The *Poa* grassland is considered to be of State significance.

The estuarine section contains a wide range of weedy species in addition to the approximately 185 reported indigenous taxa: notable weed species include Boneseed (*Chrysanthemoides monilifera* ssp. *m.*), Blackberry (*Rubus* spp.), Flax-leaf Broom (*Genista linifolia*), Sweet Pittosporum (*Pittosporum undulatum*), Arum Lily (*Zantedeschia aethiopica*), New Zealand Mirror Bush (*Coprosma repens*) and Pampas Grass (*Cortaderia* spp.) [16, 17].

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12 Forsyth, D.A. and Ransome, S.W. (1978). *A report on the Painkalac Creek (Aireys Inlet) catchment.* Report to Soil Conservation Authority, Kew.

13 Parks Victoria (1999). *Angahook-Lorne State Park Management Plan.*

14 Forsyth, D.A. (1980). *Report on a land use determination for the Painkalac Creek water supply catchment.* Report to Soil Conservation Authority, Kew.

15 Saw, D. (2005). Painkalac Creek catchment area: a land use investigation. *Interaction* (Journal of the Geography Teachers' Association of Victoria Inc) **33**: 35-42.

16 Moulton, P. (2003). *Painkalac Creek fire management plan.* Report to Surf Coast Shire.

2.7 Water Quality

No permanent water quality monitoring station has been established in the freshwater reach of Painkalac Creek. Water quality has been measured upstream of the reach at the Painkalac reservoir site (Station 235232), but it would appear this was discontinued in 1987.

GHD (2005) reviewed previous intermittent water quality records for the creek, few of which have been conducted in the study reach. They concluded that "none of the parameters that have been measured at this site ..." [Old Coach Road] ... "in the past were consistently outside of ANZECC guidelines." (p. 13).

GHD (2005) also sampled a number of water quality parameters in 2005 at the Old Coach Road site, at the lower extent of the freshwater reach – *E. coli*, *Enterococci*, nitrogen, phosphorous, BOD, Electrical conductivity, dissolved oxygen, pH and turbidity.

They concluded that dissolved oxygen levels at the site were "well below the recommended levels for supporting diverse aquatic biota" (p. 18) and that nitrogen levels and *Enterococci* levels were both high. All other parameters were within ANZECC guidelines, although "the overall water quality at this site appears to have decreased since the previous studies" (p. 18).

They seem to attribute this decline to upstream land use:

> *The land upstream of this site is privately owned farmland that is used for cattle and horses, which have access to the creek. In many places the creek and riparian zone is severely degraded and denuded. This would certainly increase erosion of the banks and surrounding landscape, and contribute to elevated sediment and nutrient load and turbidity of the creek during rainfall events.* (p. 18).

It is not intended in this study to recommend flows to improve water quality in Painkalac Creek where the cause is due to catchment conditions, as it is considered more desirable to solve water quality issues at their source, rather than use valuable water resources. However, flows that prevent flow related water quality decline will be included in the recommendations.

[17] Surf Coast Shire (undated) *Painkalac Estuary Management Plan*. Surf Coast Shire.

2.8 Reach selection

Despite the paucity of data on in-stream biota, Painkalac Creek can be easily divided into 4 reaches on the basis of land tenure, hydrology, water resource development and water quality (Table 3).

Table 3. Proposed reaches in the Painkalac Creek catchment

Reach	Location	Rationale
1	Painkalac Creek upstream of Painkalac Reservoir	Forested catchment in National Park; No water resource development; Freshwater reach; Fast-flowing macroinvertebrate taxa; Presumed natural water quality
2	Painkalac Creek from the reservoir to Old Coach Road	Private land tenure; Disturbed or altered riparian vegetation; Subjected to water resource use; No major tributary inflows; Includes anabranch; Freshwater reach; Some slow-flowing macroinvertebrate taxa; Water quality impacts from landuse.
3	Distillery Creek	Major tributary of Painkalac Creek; Forested catchment; Freshwater reach; No water resource development.
4	Estuary (Old Coach Road to sea)	Estuary reach

In terms of the required environmental flow study, only reach 2 needs to be included as Reaches 1 and 3 have no water resource development (and hence natural flows), and the environmental water requirements of the estuary reach (Reach 4) cannot be determined using the current FLOWS method.

The Representative Reach for the study area between the reservoir and the estuary will be selected during the site inspection.

3. FLOWS method

The recommendations for environmental flows in Painkalac Creek will be developed using the standardised Statewide Method For Determining Environmental Water Requirements in Victoria, referred to as the FLOWS method (NRE, 2002). The major steps in applying the FLOWS method to environmental flow studies are shown in Figure 1.

Flows Method - Stage 1

Environmental flow recommendations are established in two stages. Stage 1 involves the collection of available data on ecology and hydrology of the study area, from published work and unpublished sources, that are required for environmental flow recommendations.

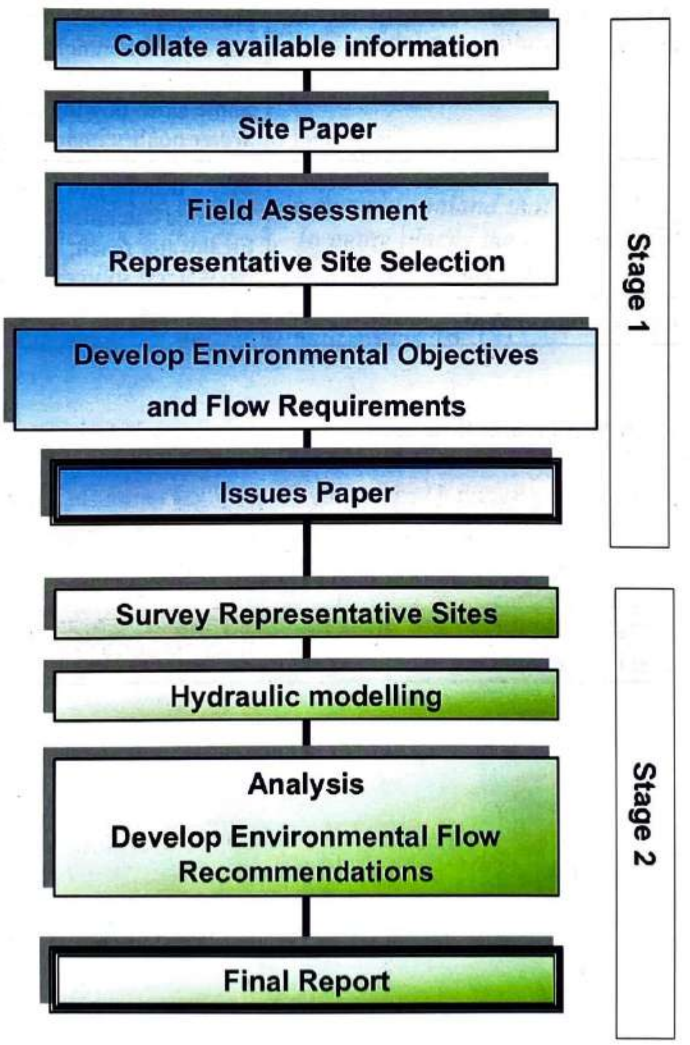

Figure 1 Outline of the steps in the FLOWS method. This Issues Paper represents the final output of Stage 1 of the process.

From this information, the catchment is divided into reaches for further study. Natural discontinuities in biodiversity values (primarily fish, macroinvertebrates and vegetation), hydrology (e.g. tributary inflows, water resource structures), geology and geomorphology are identified and examined to determine areas of the catchments with similar environmental attributes. The suggested reach delineation is presented in a **Site Paper**. These results are presented above, suggesting that only a single reach needs to be selected in Painkalac Creek for further study.

A field inspection of reach is conducted by the Technical Panel within each reach. One or more "Representative Sites" are selected for further study in each reach. Representative Sites are those determined to have features present (e.g. pool-riffle sequences, in channel benches, levees, inflows to anabranches) that need to be assessed to determine environmental flow recommendations for the entire reach.

The particular features of the Representative Sites are marked by pegs for later survey.

From the environmental information, Environmental Objectives will be established for each of the major flow-dependent environmental assets (in this case: geomorphology, fish, aquatic macroinvertebrates, in-stream and riparian vegetation) in the reach.

The objectives may be to return an asset back to its natural condition, to a state pre-determined according to various requirements (e.g. State Environment Protection Policies, the objectives of regional management plans), or to a state that represents the best possible environmental condition given prevailing management limitations.

For each of these objectives, the types of flows required to achieve the objective are determined. These include the flow component (see below), time of year, the frequency (if known) and the duration (if known). For each flow type, criteria for assessment are developed (e.g. depth of water required to allow fish passage for certain species, velocity of water to prevent water quality decline in pools).

A broad description of the flow regime that would achieve all the objectives for environmental assets can then be determined.

The description of the field inspection, the representative sites, and the Environmental Flow Objectives are detailed in the **Issues Paper**, which completes the output of the first stage of the FLOWS study.

The objectives set for each asset, and the issues identified, are confirmed by the Steering Group and Community Advisory Committee as being suitable for each reach before the project continues.

Flows Method - Stage 2

In the second stage of the project, the Representative Site is studied in more detail, with cross-sections surveyed across the creek. Cross section include particular features identified in the field inspection which have environmental significance (e.g. pools, riffles, in-channel benches).

A computer-based hydraulic model of each Representative Site is then constructed, which related the channel structure and features to different flows in the creek.

The key output from the hydraulic modelling is a graphic presentation of each cross-section (Figure 2). In these, the black line ("Ground" in the legend) represents the ground surface, reflecting the channel shape at 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).

Horizontal blue lines within the cross-section represent the water surface at the various flows (which are detailed in the legend).

The outputs used from the model included the flows (ultimately expressed in ML/d) required to cover specified parts of the stream bed to a certain depth, or inundate identified channel units such as benches, or to provide for fish passage.

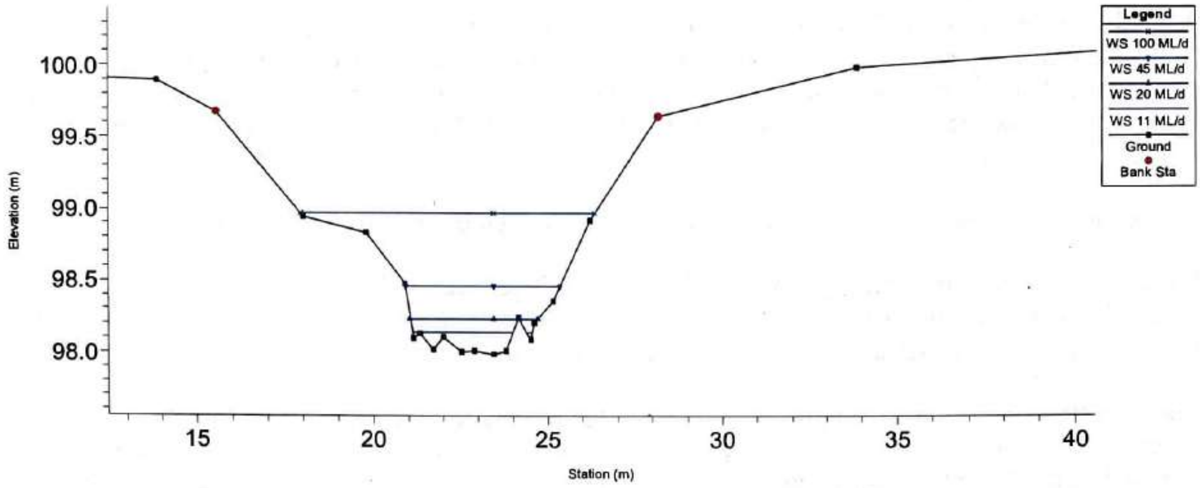

Figure 2. Typical output from a hydraulic model showing cross-section of creek and depth of water at different flow rates.

Based on the flow types and criteria identified in the Issues Paper, reach specific environmental flow recommendations are then developed and presented in a **Final Recommendations** report.

Flow Components

The FLOWS method requires recommendations to be made for a number of different flow components. Each of these have identified environmental "functions" and can be influenced by the diversion of water. The exact environmental flow recommendations can only be evaluated once data collected in Stage 2 of the project are collected, but some general comments on each of the flow components can be made here.

- **Zero Flows** (also called "cease-to-flows") – Defined as periods where no flows are recorded in the channel. During these periods, the river may contract to a series of pools that act as a refuge for in-stream biota. There are plants and animals specifically adapted to zero flows, and zero flows may also assist in preventing the spread of some exotic species. Zero flows may, or may not, occur naturally during the drier summer/autumn months.
- **Low Summer Flows** – In the FLOWS method, low flows are defined as "the low minimum flow that provides a continuous flow through the channel. The flow may be limited to a narrow area of the channel in the high points of the stream, but will provide flow connectivity between habitats within the channel" (NRE, 2002, p. 22). This refers to the natural summer/autumn baseflow that maintains water flowing through the channel, keeping in-stream habitats wet and pools full.
- **Low Flow Freshes** – A "Low Flow Fresh" refers to a small and short duration high flow event that lasts for one to several days as a result of localised rainfall during the low flow period. These are important to refresh water quality in pools after periods of low or zero flow flows, flushing sediment deposited during low flows, or to allow temporary movement of animals through the reach.

- **Low Winter Flows** – this component refers to the persistent increase in baseflow that occurs with the onset of the wet season. These are flows that cover the bed and maybe some low in-channel benches or bars. This allows full connection between all habitats in the river, important for fish passage during migration.
- **High Flow Freshes** – "High Flow Freshes" refer to long sustained increases in flow during the high flow period as a result of heavy rainfall events. High flow freshes can inundate benches in the channel, may act as triggers for fish migration/breeding, and create important scour disturbance in the channel.
- **Bankfull Flows** – These flows fill the channel, but do not spill onto the floodplain. They have mainly geomorphological functions, maintaining the channel shape and form (e.g. preventing in-filling of pools or channel contraction).
- **Overbank Flows** – Overbank flows are higher than the bankfull flows, and spill out of the channel onto the floodplain. These are ecologically important for wetlands, and for bringing food (either carbon dissolved from the floodplain floor, or in the form of leaves and twigs) from the floodplain to the stream channel.

These different components can be visualised by the depth of water they produce in a channel cross-section (Figure 3). Each has different ecological functions in a river, and characteristics that need to be identified in any environmental flow study.

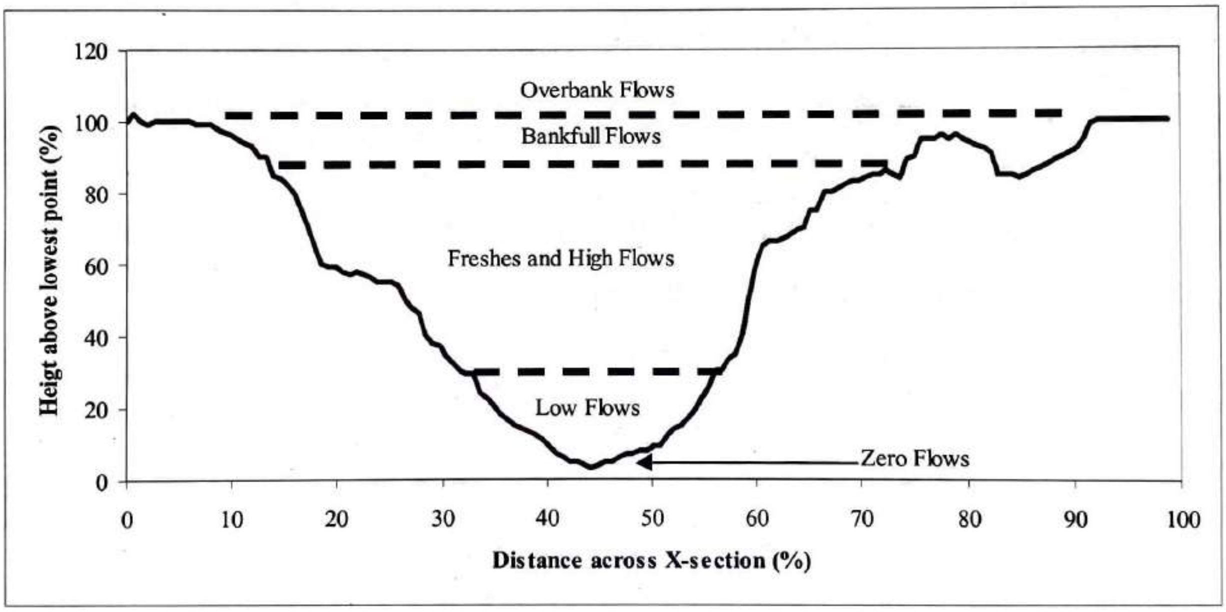

Figure 3 Hypothetical cross-section of a stream channel showing where each flow component is located

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