AN ASSESSMENT OF ENVIRONMENTAL FLOW REQUIREMENTS FOR HODDLES CREEK

for
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by

Brenton Zampatti
&
Tarmo A. Raadik

Freshwater Ecology Division

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EXECUTIVE SUMMARY

Melbourne Water, the responsible authority for waterway management in the Yarra catchment, is developing a Streamflow Management Plan (SMP) for Hoddles Creek as part of the State Environment Protection Policy (Waters of Victoria) Draft Schedule F7 (Waters of the Yarra Catchment). The SMP will provide guidelines for the effective management of Hoddles Creek, and establish flow regimes that will protect the environmental values of the system. This report documents the environmental values of the Hoddles Creek system, outlines necessary environmental management objectives, and also recommends environmental flows that will protect the fish fauna and associated values of the system.

Demand for water from Hoddles Creek is highest during the summer/autumn months (December to April) when flows in the creek are low. During other times of the year demand is decreased and flows are higher. Therefore, this study primarily addresses the possible impacts of low summer flows on the fauna and flora of Hoddles Creek and identifies appropriate flows for the creek during the summer low flow period.

Data on the environmental values of Hoddles Creek was obtained from relevant literature, the Victorian Fish Data Base, the Atlas of Victorian Wildlife, and from a fish survey and field inspections of the Hoddles Creek system. Short-term water quality in the system was assessed and barriers to fish migration were investigated. Environmental flows were determined using an adaptation of the Instream Flow Incremental Method (IFIM), where field measurements of potential habitat availability for river blackfish (juveniles and adults) and mountain galaxias, the most ubiquitous fish species in the system, were conducted at varying flows. Potential habitat availability was measured at six sites located throughout the Hoddles Creek catchment and calculated using the RHABSIM hydraulic and habitat simulation system.

The fauna of Hoddles Creek is characteristic of that found in small streams in the upper Yarra catchment, and as such represents a diverse biological community that is reliant upon the instream and riparian zones of the creek. The river blackfish and mountain galaxias which occur in Hoddles Creek are considered threatened in Victoria. The creek also provides significant potential habitat for other threatened fish species, including the spotted galaxias and Australian grayling that may recolonise the upper Yarra River now that a fishway is operational on Dights Falls. While the introduced exotic brown trout is found throughout the mid to lower reaches of Hoddles Creek, its abundance is relatively low compared with the total abundance of native fish.

Other vertebrates which rely on instream and riparian zones and may occur in the catchment include the threatened swamp skink and large-footed myotis, as well as more widespread species such as the platypus and water rat. No threatened species of macroinvertebrates or instream flora are known from the Hoddles Creek catchment. Nevertheless, macroinvertebrates provide an integral part of the food chain in aquatic systems and are in turn dependent on the provision of sufficient flows to maintain riffle areas and diverse and complex riparian habitat. Instream and riparian fauna are also dependent on sufficient flows.

Instream habitat varied considerably throughout Hoddles Creek, with most sites showing evidence of disturbance including clearing and degradation of riparian vegetation, cattle access and associated trampling and previous mining. Siltation was also obvious throughout the system with silt comprising 20 to 40% of substrate at all sites. Although siltation was evident at all sites, those sites with intact riparian vegetation and diverse instream habitat, were found to have the highest abundances of river blackfish, particularly juveniles.

Overall water quality in Hoddles and Blackleather Creek during the four weeks of sampling (8/5/97 - 29/5/97) was good, with all parameters meeting either parks and forests, or rural eastern waterways objectives as outlined in the Yarra catchment SEPP (EPA, 1995). However, the results do not provide an indication of water quality during higher flows, nor throughout the rest of the year. Of the water quality parameters measured, suspended solids are likely to have the greatest impact on the fish and macroinvertebrate fauna of Hoddles Creek. Previous mining activity, clearing of riparian vegetation, cattle access, and run-off from roads and stock crossings, all appear to be increasing the sediment load in the system. It is likely that sedimentation may adversely affect fish and aquatic invertebrate abundances in the lower reaches of Hoddles Creek.

A number of instream barriers were found in the mid to upper reaches of Hoddles Creek. While the barriers do not currently prevent migratory movements of any of the fish species that occur in Hoddles Creek, they may prove to be a problem in the future, if species such as Australian grayling, broad-finned galaxias and tupong recolonise the system. Currently, the greatest impact of the onstream storages on Hoddles Creek may come from increased downstream sedimentation when they are flushed.

Limited discharge data was available for Hoddles Creek. Consequently, Melbourne Water provided historical flow records modelled on discharges in the nearby Olinda Creek. Discharge measurements conducted during the current study, and gauge readings during the study period, indicate that there are a number of discrepancies in the modelled data and in previous gauge readings from Hoddles Creek. The flow data available for the period 30/04/97 to 26/08/97 indicates that the base flow of the creek was approximately 6.9 ML/d.

Habitat availability was measured at three flows (corresponding to 6.9, 16.4 and 34.6 ML/d at site 1). At all sites, with the exception of site 2, potential habitat availability (m^2) was greatest at the lowest flow. At most sites, habitat decreased as velocities increased and became unsuitable for river blackfish and mountain galaxias. Whilst the habitat availability curves suggested that at some sites a considerable amount of habitat was lost at high flows this may not be the case. The complexity of undisturbed instream habitat provides numerous microhabitats where velocities are significantly reduced. Consequently, fish may have considerably more suitable habitat available than can actually be measured.

Habitat availability curves were not extrapolated to flows below the lowest flow measured. To determine a minimum environmental flow (i.e. a flow that retains not less than 80% of the habitat of an optimum flow) habitat availability must be measured at a flow less than the lowest flow measured in this study (i.e. 6.9 ML/d at site 1). During the period 30/4/97 to 26/8/97, it appears that flows did not fall below this level.

From the available data, the following optimum environmental flows for 6 sites in Hoddles Creek have been recommended as the flows that maximise potential habitat. The flow that should be maintained in the creek should be the optimum environmental flow or the natural 50th percentile exceedence flow, whichever is least. However, 50th percentile flows are unavailable for Hoddles Creek.

Location	Instantaneous Flow (ML/d)
Gauging Station 22922A (Launching Place)	6.9
Glenview Road	6.9
Bells Property	6.0
Immediately upstream of Blackleather Creek	6.0
Off Yellow Gum Road	4.3
Hazeldenes Road	3.5

By protecting sufficient habitat for juvenile and adult river blackfish, and mountain galaxias during the summer/autumn low flow period, the recommended flows should also protect macroinvertebrate habitat, instream flora and any vertebrates that are dependent on instream processes.

The primary environmental management objectives for Hoddles Creek should include the following:

- *Maintain the existing species diversity and populations of aquatic fauna, and where possible, provide conditions that will encourage recolonisation of Hoddles Creek by fish species that can now utilise the upper Yarra system due to the Dights Falls fishway.*

- *Maintain water quality in accordance with SEPP (Waters of Victoria) - draft Schedule F7 Waters of the Yarra Catchment (EPA, 1995), whilst decreasing the sediment load entering the system, particularly from sources such as roads, secondary stream crossings (e.g. stock crossings) and onstream dams*.

- *Maintain, and where possible, restore diverse and complex instream habitat (e.g. woody debris).*

- *Maintain remnants, and rehabilitate degraded areas, of indigenous riparian vegetation along the banks of Hoddles Creek and its tributaries, and ensure adequate buffer strips between cleared land and the creeks.*

- *Maintain suitable river blackfish and mountain galaxias habitat over the summer/autumn low flow period, through the provision of environmental flows of the magnitude specified in this report.*

A number of actions pertaining to the environmental management objectives have also been recommended.

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1. INTRODUCTION

Development of a Streamflow Management Plan (SMP) for Hoddles Creek is required as part of the State Environment Protection Policy (Waters of Victoria) Draft Schedule F7 (Waters of the Yarra Catchment). Melbourne Water, being the authority responsible for waterway management in the Yarra catchment, is developing a SMP for Hoddles Creek to enable the formulation of guidelines for the effective management of Hoddles Creek, and to establish flow regimes that will protect the environmental values of the system. The SMP will enable Melbourne Water to address issues such as the clarification of rights to water resources, the development of environmental management objectives and action plans to meet or maintain environmental flows, and the development of sharing, restriction and rotation arrangements for diverters. As part of the SMP for Hoddles Creek, the Marine and Freshwater Resources Institute (MAFRI) has been contracted to assess the environmental values of Hoddles Creek and determine the environmental management objectives and environmental flow requirements of the creek.

Demand for water from Hoddles Creek is highest during the summer/autumn months (December to April) when flows in the creek are low. During other times of the year demand is decreased and flows are higher. For these reasons this study is primarily concerned with the possible impacts of low summer flows on the fauna and flora of Hoddles Creek and the determination of appropriate flows for the creek during the summer low flow period. The specific objectives of the study are to:

- identify the environmental values of Hoddles Creek;
- recommend environmental management objectives for Hoddles Creek;
- comment on the biological significance of changes to the flow regime (natural vs regulated) of Hoddles Creek;
- identify other impacts on the environmental values of Hoddles Creek; and
- through an environmental flow study recommend minimum and optimum environmental flows for Hoddles Creek.

2. STUDY AREA

Hoddles Creek, a tributary of the upper Yarra River, is located on the northern western slopes of the Yarra Ranges. The creek rises on the southern side of Sale Hill then travels in a north-westerly direction past the townships of Hoddles Creek and Launching Place to its confluence with the Yarra River (Figure 3-1). Hoddles Creek falls steeply (480 m to 200 m) from its upper reaches above Hazeldenes Rd down to an area at the end of Yellow Gum Road. Downstream of this point the gradient of the creek decreases, falling only another 80 m to its junction with the Yarra River downstream of the Warburton Highway. Hoddles Creek has three main tributaries; Blackleather, Wombat and Wet Lead Creeks (Figure 3-1). The catchment drains an area of 34 km^2 and is comprised of remnant eucalypt forest, cleared grazing land and areas of intensive horticulture.

There are a total of 21 licensed diverters on Hoddles Creek and a further 10 on the major tributaries. Water is diverted for stock and domestic use, as well as market garden, vineyard and tree farm irrigation. A total volume of 528 ML is allocated annually to diverters, however, data obtained from metered diversion points suggests that water use is lower, at an estimated 265 ML/annum (Steve Hosking, Melbourne Water, pers. comm.). Accurate monthly diversion volumes for the Hoddles Creek system are unavailable, although estimates provided by Melbourne Water for the months of December to March are 42.7, 47.4, 49.8 and 49.8 ML/month respectively.

Flow data for Hoddles Creek is also limited. Recordings from two staff gauges located immediately upstream of the Warburton Highway have only been made on an ad hoc basis since April 1996. As of May 1997, a total of only 13 flow readings were available for Hoddles Creek, mainly covering the period January 1997 to May 1997. During this period flows varied from 3.53 to 8.19 ML/day. The lowest flows appear to occur in February whilst data is unavailable for the high flow months.

3. ENVIRONMENTAL VALUES OF HODDLES CREEK

There is a paucity of biological data available for the Hoddles Creek catchment. Consequently, a review has been undertaken of significant species that occur in the upper Yarra region with the assumption that these species may also occur in the Hoddles Creek catchment. Data was obtained from relevant literature, the Victorian Fish Database (Department of Natural Resources and Environment - DNRE) and the Atlas of Victorian Wildlife (DNRE). Only species that may be dependent on the instream environment will be discussed.

3.1. Fish

Fourteen species of fish have been recorded in the Yarra River system upstream of Healesville (Table 3-1). Seven of these are native and seven are acclimatised exotic species. Until the commencement of the current project, the fish fauna of Hoddles Creek was unsurveyed, however, two of native species, river blackfish (*Gadopsis marmoratus*) and mountain galaxias (*Galaxias olidus*), have incidentally been recorded in the creek.

Figure 3-1

Of the species previously recorded from the upper Yarra River system, three are considered threatened in Victoria: the pouched lamprey (*Geotria australis*) is considered rare and the river blackfish and mountain galaxias as insufficiently known[1]. No species are listed on the Victorian *Flora and Fauna Guarantee Act* 1988.

Table 3-1 Native and acclimatised exotic fish species previously recorded from the upper Yarra River system, including their conservation status (CNR, 1995a).

Scientific Name	Common Name	Conservation Status
Native species		
Anguilla australis	Short-finned eel	Common
Gadopsis marmoratus	River blackfish	Insufficiently known
Galaxias olidus	Mountain galaxias	Insufficiently known
Geotria australis	Pouched lamprey	Rare
Mordacia mordax	Short-headed lamprey	Common
Nannoperca australis	Southern pygmy perch	Common
Retropinna semoni	Australian smelt	Common
Exotic species		
Carassius auratus	Goldfish	
Gambusia holbrooki	Gambusia	
Misgurnus anguillicaudatus	Oriental weatherloach	
Oncorhynchus mykiss	Rainbow trout	
Perca fluviatilis	Redfin	
Rutilus rutilus	Roach	
Salmo trutta	Brown trout	

In the past Dights Falls has represented a major barrier to fish movement in the Yarra River. A fish ladder has now been incorporated into this structure to facilitate upstream movement. Consequently, it is likely that a number of native species that have been restricted from the upper Yarra River for many years may be able to recolonise this area (Table 3-2). These fish include two species which are threatened, namely the spotted galaxias (*Galaxias truttaceus*) which is classified as rare in Victoria, and the Australian grayling (*Prototroctes maraena*) which is considered vulnerable in Victoria and Australia and is listed on the Victorian *Flora and Fauna Guarantee Act* 1988 and the Commonwealth *Endangered Species Protection Act* 1992. It is possible that these fish, along with the common galaxias (*Galaxias maculatus*), broad-finned galaxias (*Galaxias brevipinnis*) and tupong (*Pseudaphritis urvillii*), may also move into Hoddles Creek as their numbers increase in the upper Yarra River. This in turn will increase the conservation value of the creek. Therefore, it is important that the life history requirements of these species are taken into account when determining environmental flows for Hoddles Creek.

[1] suspected Rare, Vulnerable or Endangered.

Table 3-2 Native fish species that may occur in the Upper Yarra as a result of the Dights Falls fish ladder, including their conservation status (CNR, 1995a).

Scientific Name	Common Name	Conservation Status
Galaxias brevipinnis	Broad-finned galaxias	Common
Galaxias maculatus	Common galaxias	Common
Galaxias truttaceus	Spotted galaxias	Rare
Prototroctes maraena	Australian grayling	Vulnerable, FFG Act listed
Pseudaphritis urvillii	Tupong	Common

3.2. Aquatic Macroinvertebrates

Numerous macroinvertebrate surveys have been conducted in the Yarra River and its tributaries, including studies by Campbell *et al.* (1982), Pettigrove (1989) and Doeg and Saddlier (1992). These studies have shown that the diversity and composition of macroinvertebrate populations in the upper Yarra catchment varies throughout the system, with a general trend to more depauperate communities towards the lower sections of the river.

Diverse macroinvertebrate populations and significant macroinvertebrate habitat are found above regulatory structures in the upper catchment (Campbell, 1982). Below regulatory structures, downstream of towns, and in areas with degraded riparian vegetation, the invertebrate fauna is often dominated by taxa that are tolerant to disturbance and nutrient enrichment (Campbell, 1982; Pettigrove, 1989, and Doeg and Saddlier, 1992).

With regards to threatened invertebrates, the damselfly *Hemiphlebia mirabilis* has been found near the confluence of Woori Yallock Creek and the Yarra River. This species is considered endangered worldwide and is classified as vulnerable in Victoria (CNR, 1995a). The distribution of freshwater crayfish in the genus *Euastacus* and *Engaeus* in Victoria is discussed by Morgan (1986) and Horwitz (1990). Of the species occurring in the upper Yarra River system none are considered threatened.

Whilst many of the aquatic invertebrates occurring in the upper Yarra River system and possibly Hoddles Creek are not considered threatened, it is important to recognise their environmental requirements and value. Many macroinvertebrates inhabit structurally complex areas of the stream, such as riffles or riparian vegetation. Consequently, the preservation of riparian habitat and the provision of sufficient flows to maintain riffle areas is important. In addition, many animals higher in the food chain are reliant on aquatic invertebrates as a food source (e.g. platypus and fish).

3.3. Reptiles and Amphibians

Numerous frogs have been recorded in the upper reaches of the Yarra River (Table 3-3) including Lesueur's (Rocky River) tree frog (*Litoria lesueuri*). Within the Yarra catchment this frog is only found in the upper Yarra where its tadpoles are dependent on running water (CNR, 1995b). The swamp skink (*Egernia coventryi*) has also been found in the Upper Yarra catchment and is classified as rare in Victoria (DNRE, 1997).

Table 3-3 Amphibians that have been recorded in the upper Yarra catchment.

Scientific Name	Common Name
Geocrina victoriana	Victorian smooth froglet
Limnodynastes dumerili	Southern bullfrog (Pobblebonk frog)
Limnodynastes tasmaniensis	Spotted marsh frog
Ranidella signifera	Common froglet
Litoria ewingii	Southern brown tree frog
Litoria lesueuri	Lesueur's (Rocky River) tree frog
Litoria verreauxii verreauxii	Whistling Tree Frog

3.4. Other Vertebrates

The platypus (*Ornithorhynchus anatinus*) and the water rat (*Hydromys chrysogaster*) have both been recorded in the upper Yarra catchment (DNRE, 1997). These animals rely directly on the instream environment for their survival and, as such, need to be considered in the determination of environmental flows. The large-footed myotis (*Myotis adversus*) has also been recorded in the upper Yarra catchment, and is classified as rare in Victoria. The large-footed myotis has populations in the upper and lower Yarra catchment and depends on the instream environment for aquatic macroinvertebrates and small fish that comprise a large part of its diet (Richards, 1993 in CNR, 1995b).

3.5. Instream Flora

Of the species of instream flora that occur in the upper Yarra catchment, none are considered threatened in Victoria (CNR, 1995b). Nevertheless, instream flora provides essential habitat for fish and macroinvertebrates and the loss of such habitat may be detrimental to fish and macroinvertebrate populations. Therefore, it is important that the flow requirements of aquatic and semi-aquatic flora present in Hoddles Creek be considered when determining the magnitude and timing of environmental flows.

4. METHODS

4.1. Fish Survey

The fish and decapod crustacean fauna of Hoddles Creek, and its tributaries, was sampled at 8 sites (Figure 3-1) over two days (12 - 13/5/97) using a Smith - Root Model 12-A backpack electrofisher. The technique used at all sites was the same, with the operator moving slowly upstream fishing both edges and the middle of the stream, targeting all habitats, stunning and retrieving fish and crustacea. An assistant followed behind the operator collecting any missed individuals with a dip net. A single electrofishing run was conducted at each site between 0800 and 1800 hours.

The length of stream fished at each study site ranged from 50 to 107 m and contained all available habitat types (e.g. pools, riffles, etc.) in that reach of stream. Additional information collected for each study site included the time taken to sample the site, the average stream width (m) from 5 or more transects across the section, and the average stream depth (m) from 5 or more locations within the section. An assessment was also made of general riparian and instream habitat present at each site including substrate, flow type, predominant instream habitat, landuse and disturbance rating.

All fish and freshwater crayfish were identified, counted, and measured to the nearest 1 mm (caudal fork (LCF) or total length (TL) for fish and occipital carapace length (OCL) for freshwater crayfish). They were also weighed to 1 or 0.1 g on either of two electronic field balances. Freshwater mussels were identified and counted.

Most fish and crays were returned alive to the water at the point of capture, though sub-samples of the smaller fish species and some crayfish species were fixed in 10% formalin solution for further identification in the laboratory. Nomenclature follows Allen (1989) Paxton *et al*. (1990) for fish species and Morgan (1986) for freshwater crayfish.

4.2. Water Quality

Electrical conductivity (µS/cm), pH, and water temperature (°C) were measured *in situ* during the aquatic fauna survey of Hoddles Creek. In addition, as stipulated by Melbourne Water, three sites on Hoddles Creek (WQ1 - 3) and one site on Blackleather Creek (WQB1) were sampled once a week for 4 consecutive weeks (8/5/97 to 29/5/97) for suspended solids, ammonia, nitrate, total kjeldhal nitrogen, phosphorus, orthophosphate and *E. coli*. Water samples were analysed by WSL Consultants Pty Ltd.

4.3. Barriers to Fish Migration

Possible barriers to fish migration were investigated during the survey of Hoddles Creek. Barriers, such as instream dams, were located by consultation with local landholders and discussions with Melbourne Water. Each structure was investigated and assessed for its potential as a barrier to fish migration.

4.4. Determination of Environmental Flows

Despite numerous reviews and critiques of methodologies for determining environmental flows (see Koehn, 1986; Walker, 1986; Kinhill, 1988; Arthington *et al.*, 1992, and Arthington and Pusey, 1993) there is still no consensus on the techniques that should be adopted for determining environmental water requirements in Australia.

A number of techniques have been developed for assessing the environmental water requirements of rivers, including the Tennant (rule of thumb) method, flow duration curve analysis, multiple transect analysis, Instream Flow Incremental Method (IFIM), the holistic method, and the expert panel approach (Tennant, 1976; Stalnaker, 1976; Bovee, 1982 and Arthington *et al.*, 1992). These techniques are comprehensively discussed with respect to Australian conditions by Kinhill (1988) and Arthington and Pusey (1993). The most widely used techniques in Victoria, and those used in the past by the Freshwater Ecology Division of the Department of Natural Resources and Environment, have been ‘available habitat’ methods (Kinhill, 1988 and Tunbridge 1997). These methods have been an adaptation or combination of transect analysis and IFIM methods.

The IFIM method was developed in Colorado by the United States Fish and Wildlife Service and is now one of the best known and sophisticated techniques for assessing environmental flows. The technique is based on the relationship between discharge and the amount of useable habitat available for a given species (Bovee, 1982). There are three basic components, or data requirements, for IFIM:

1) The hydraulic characteristics (depth and velocity) of representative reaches of the stream must be measured at known discharges. This data can then be used to develop hydraulic simulation models using programs such as PHABSIM (Physical HABitat SIMulation) or RHABSIM (Riverine HABitat SIMulation). As a result, changes in depth and velocity can be determined at varying stream discharges.

2) Habitat preferences (depth and velocity) for selected fish species (or life history stages) have to be defined. From this information, suitability of use curves are constructed to provide a weighted index of habitat suitability over a range of values for a given parameter such as velocity.

3) Suitability of use curves are combined with the hydraulic characteristics of the stream to determine the way in which habitat variables vary with discharge. The weighted useable area (WUA) for a given species or life history stage may then be calculated for a range of discharges. Changes in WUA may be calculated from field measurements made over a range of discharges or by hydraulic simulation.

Assumptions made by the model include: stream morphology and channel stability remain constant over time; physical attributes of depth and velocity independently influence habitat suitability; and, a positive linear relationship exists between size of WUA and fish biomass.

A number of criticisms have been made of the IFIM method and the associated PHABSIM and RHABSIM programs (Mathur *et al.*, 1985; Gordon *et al.*, 1992 and Arthington *et al.*, 1992). It is important that these criticisms and limitations be taken into account when using the model to determine environmental flows. A number of the pertinent criticisms and limitations are outlined below.

- A paucity of knowledge exists on the flow and habitat requirements of many fish species and the various life stages of these species, resulting in a lack of well defined habitat-suitability curves.
- Hydraulic simulation may be restricted by the hydraulic characteristics of the stream. Models may be difficult to calibrate in complex stream channels, in streams with a steep gradient or under low flow conditions when rocks and woody debris are exposed.
- The assumption that the maintenance of habitat (velocity, depth and substrate) will maintain fish populations does not take into account factors such as predation, competition, food supply, water quality and availability of microhabitats (e.g. woody debris, macrophytes and bank overhang). All of these factors may be of similar, or greater, importance to velocity and depth in determining species abundance.
- Suitability of use curves for use in PHABSIM and RHABSIM have been calculated from proportional scaling of fish catches and observations. These proportional values (between 0 and 1.0) have been incorrectly treated as probabilities in weighted useable area calculations (Mathur *et al*., 1985).

Not withstanding these criticisms, the IFIM technique should be considered one of a number of tools that can be used by ecologists as part of the overall process for determining environmental flows. The IFIM provides a methodology for comparing the relative effects of different flow scenarios and as such should be incorporated within a more holistic process.

4.4.1. Technique used to determine environmental flows in Hoddles Creek

Care must be taken in applying techniques developed in northern hemisphere streams to Australian waterways. Australian streams are more variable than streams in Europe and North America and consequently experience more extreme floods and droughts (McMahon, 1986). Despite the differences in stream variability, Kinhill (1988) suggest that, of the techniques available for determining environmental flows, available habitat methods, such as IFIM, should be readily transferable to perennial Australian streams. However, it is important that the variability of Australian streams is considered when prescribing environmental flows.

We have used an adaptation of the IFIM to determine the availability of fish habitat at a range of flows in Hoddles Creek. The decision to base our method on the IFIM was driven by the need for a quantifiable and defendable method for assessing environmental flows. Our method employs the IFIM along with modelled historical flows and expert knowledge to determine a minimum and optimum environmental flow for Hoddles Creek.

As water abstraction in Hoddles Creek only impacts upon low summer/autumn flows (Steve Hosking, Melbourne Water, pers. comm.), the current study is primarily concerned with flows that occur from approximately January to April. Flows that occur outside of this period are considered to be largely unregulated (Steve Hosking, Melbourne Water, pers. comm.) and therefore should be sufficient to maintain stream morphology or stimulate life history processes of any of the fish species that occur in the creek. However, if water is to be abstracted from Hoddles Creek outside of the low flow period, further environmental flow investigations will be necessary.

Implementation of the IFIM method and the construction of suitability of use curves requires a sound knowledge of the flow and habitat requirements of the fish species of concern. This type of information is lacking for many species of Australian native fish and, although recognised for many years (Jackson, 1986; Koehn, 1986 and Arthington *et al.*, 1991), little new data is available.

Native fish were used to determine the availability of fish habitat in Hoddles Creek. Introduced exotic brown trout (*Salmo trutta*) were not used, as trout fishing is not recognised as a high value within Hoddles Creek, and trout are considered to pose a threat to small bodied native fish (see review by Cadwallader, 1996). In order to determine habitat availability for native fish species in Hoddles Creek, the river blackfish and mountain galaxias were selected as key species, being the most ubiquitous native species in the creek. River blackfish have been used to model habitat availability at all sites except the uppermost site at Hazeldene Road, where the fish fauna was comprised solely of mountain galaxias.

The depth and velocity requirements of river blackfish have been derived from a study by Koehn *et al.* (1994) on the habitat preferences of this species in Armstrong Creek, a tributary of the upper Yarra River. Additional information was obtained from observations made by experienced field staff from the Freshwater Ecology Division, DNRE in previous field studies. The habitat requirements of river blackfish were divided into two life stages, juveniles (fish < 150 mm in length) and adults (fish > 150 mm in length) (Table 4-1). The depth and velocity requirements for mountain galaxias were based on observations made by experienced field staff from the Freshwater Ecology Division, DNRE and extensive previous work on streams throughout Victoria, particularly the Yarra River system (Table 4-1).

Table 4-1 Depth and velocity requirements of river blackfish and mountain galaxias.

Species	Life Stage	Depth (m)	Velocity (m/s)
River Blackfish	Juvenile	>0.1	<0.2
	Adult	>0.2	<0.2
Mountain Galaxias	All	>0.1	<0.3

Unlike previous Victorian studies, we did not divide habitat requirements into rearing, resting, passage and spawning requirements (Tunbridge and Glenane, 1988; Hall, 1989). The current scientific data available for the depth and velocity requirements of river blackfish and mountain galaxias is not comprehensive enough to enable the modelling of habitat availability, with regards to all requirements, in small systems such as Hoddles Creek. The habitat requirements we have used to determine environmental flows for the creek encompass both rearing and resting activities. This habitat covers the largest component of stream area and is considered the most important habitat over the January to April low flow period. Whist we have not differentiated between rearing and resting habitat it is likely that if habitat is lost through increases in velocity there will be many microhabitats in the stream that infact retain resting habitat, however, these areas cannot be quantified.

The flows that are suggested as maintaining blackfish and galaxias habitat will also maintain habitat for other fish species (currently present or likely to occur in the future), invertebrates and aquatic vegetation in Hoddles Creek. The flows will also provide enough water for fish passage, although during the summer period migration is generally not an issue and only localised movements will occur.

4.4.1.1. Field measurements of hydraulic parameters and habitat

Six sites were selected on Hoddles Creek to establish reaches where habitat availability could be measured at a range of flows (Figure 3-1, Table 4-2). Sites were located along the entire length of Hoddles Creek, thus providing detailed information on discharge and habitat availability throughout the catchment.

Table 4-2 Location of flow sites on Hoddles Creek (see also Figure 3-1).

Site Number	Location
Site 1	Launching Place, upstream of Warburton Highway
Site 2	Immediately downstream of Glenview Road
Site 3	Upstream of Wet Lead Creek at Bells Property
Site 4	Upstream of Blackleather Creek at Blackleather Creek Road
Site 5	Off Yellow Gum Road
Site 7	Downstream of Hazeldene Road

At each flow site a series of transects was established in areas of habitat that were representative of that particular reach of river. The number of transects (7 to 16) was determined by the number required to provide a representative sample of all habitat types and associated hydrological characteristics. Transects were placed perpendicular to the channel (from bank to bank), each end being identified by a permanent marker to facilitate future measurements at a range of flow conditions. A measuring tape was extended across the stream and, depending on the width and uniformity of the stream, velocity (m/s), depth (m) and substrate type were measured at 0.1 to 0.6 m intervals. Depth was measured to the nearest 0.01 m using a 1 m steel ruler and velocity was measured using a Hydrological Services OSS PC-1 current meter with a CMC 20 digital counter.

4.4.1.2. Modelling using RHABSIM

The amount of habitat available to river blackfish and mountain galaxias, at a range of flows, was calculated using the RHABSIM hydraulic and habitat simulation system (Payne and Associates, 1994). Criteria curves were constructed for adult and juvenile river blackfish and mountain galaxias. The habitat preferences for these species were not weighted (Mathur *et al.*, 1985). Instead a binary approach was used and habitat was classified as being present or absent. When combined with the hydraulic characteristics of the stream section this approach predicts how much habitat (user defined) will be potentially available to a particular species. It is important to note that predictions made with RHABSIM do not suggest that system productivity will be altered through changes in habitat availability.

Changes in habitat availability at a range of flows were measured in the field rather than by hydraulic simulation. Due to an absence of stage/discharge data for Hoddles Creek, it was considered impractical to calibrate a hydraulic simulation model of the stream sections. In addition, low flows in Hoddles Creek, and the structural complexity of the stream reaches, may have resulted in an inaccurate hydraulic calibration of the model (Gordon *et al.*, 1992; Courot, 1989).

4.4.1.3. Determining a minimum and optimum environmental flow

In order to recommend minimum and optimum environmental flows for Hoddles Creek it is necessary to have an indication of the likely range of flows that occur in the system during the summer/autumn low flow months. Long-term flow records do not exist for Hoddles Creek, therefore Melbourne Water supplied modelled flows based on gauged flows from Olinda Creek, a tributary of the Upper Yarra River. Three levels of flow were calculated: 1) a natural flow with no abstractions, 2) flows with the current level of abstractions and 3) flows with abstractions at full allocation. Unfortunately discrepancies in the modelled flows (see section 5.5 and 6.3.1) make them unsuitable for accurately assessing the historical flow regime of Hoddles Creek.

Until a more accurate time series of flow data is available and, until we are able to measure habitat availability at a flow less than what we believe the base flow to be (6.9 ML/d at site 1), only an optimum environmental flow will be recommended. This flow will aim to maintain maximum possible habitat with regards to the flow regime which appears to exist over the low flow period, based on observations from the current study. These recommendations may need to be modified when further hydrological information is available for Hoddles Creek (see section 6.3).

5. RESULTS

5.1. Site Descriptions

Fish and decapod crustacean surveys were conducted at 7 sites on Hoddles Creek and one site on Wombat Creek (Figure 3-1 and Table 5-1). In addition, habitat availability was measured at 6 sites on Hoddles Creek that overlapped with the fish survey sites (Figure 3-1 and Table 5-1). Water quality samples were collected at three sites that corresponded with fish and habitat survey sites and at one site on Blackleather Creek (Figure 3-1).

Table 5-1 Sites on Hoddles Creek and Wombat Creek surveyed for aquatic fauna (fish and crays), and habitat availability.

Site Number	Location	Activity
Site 1	Launching Place, upstream of Warburton Highway	Fauna and Habitat
Site 2	Immediately downstream of Glenview Rd	Fauna and Habitat
Site 3	Upstream of Wet Lead Creek at Bells Property	Fauna and Habitat
Site 4	Upstream of Blackleather Creek at Blackleather Rd	Fauna and Habitat
Site 5	Off Yellow Gum Rd	Fauna and Habitat
Site 6A/B	Downstream / upstream of Prices Rd crossing	Fauna
Site 7	Hazeldene Rd crossing	Fauna and Habitat
Site 8	Wombat Creek at unnamed track off Parkinsons Rd	Fauna

Average stream width in Hoddles Creek varied from 1.9 to 4.2 m, whilst the one site on Wombat Creek had an average width of 1.2 m. All sites were relatively shallow with average depth ranging from 0.16 to 0.42 m. The deepest pool areas were found at sites 2 and 4 on Hoddles Creek with average depths of 0.61 and 0.51 m and maximum depths of 1.25 and 0.74 m respectively. Shallow riffles (average depth <0.1 m) were found throughout Hoddles Creek at both upper and lower sites.

Flow type was predominantly riffle/run/glide interspersed with pools in the mid to lower sections and runs and rapid/cascades in the upper, steeper sections of the catchment. Substrate type at the lower sites (1 to 4) was comprised of clay, silt, coarse sand and gravel. At sites 5 to 7, higher in the catchment, pebbles and some areas of boulder were also present. Siltation was obvious throughout Hoddles and Wombat Creeks, with silt comprising 20 to 40% of substrate at all sites. Sites 4 and 5 were noted for having a considerable amount of silt that smothered woody debris and gravel/sand substrates.

Bank overhang, vegetation overhang and branches were the predominant forms of instream cover at sites 1 to 4 on Hoddles Creek. At these sites, bank and vegetation overhang each comprised 5 to 10 % of instream cover. At sites 5 to 7 larger woody debris, such as logs, became more prevalent and vegetation overhang comprised a greater percentage of cover. At the same time, bank overhang became less important at sites 6 and 7. At the site surveyed on Wombat Creek, branches and logs, and bank and vegetation overhang were the predominant forms of instream cover. Instream vegetation was negligible at all sites in both Hoddles Creek and Wombat Creek, except for a small area of water ribbon (*Triglochin procerum*) upstream of Glenview Road at site 2, and a large area of cumbungi (*Typha* sp.) upstream of the culvert at site 5 off Yellow Gum Road.

Disturbance at most sites was high to very high, with erosion, culverts, urban rubbish and parallel roads being the most common types. Site specific disturbance included riparian clearing at site 1, previous mining at site 2, cattle access and trampling at site 5, and onstream dams and pump inlets at site 6. Site 3 was the least disturbed of the lower sites on Hoddles Creek, with only a moderate level of disturbance. Instream cover at this site was diverse (e.g. bank overhang, woody debris and leaf packs) and riparian disturbance was minimal. Similarly, site 7, the uppermost site on Hoddles Creek, had a low level of disturbance with diverse and abundant instream cover, and intact riparian habitat.

5.2. Fish Survey

Six species of fish were recorded from Hoddles and Wombat Creeks (Table 5-2). Four of these species were native and two were acclimatised exotic species. In addition, two species of decapod crustacea and one species of aquatic bivalve were collected (Table 5-2). Detailed site and catch information is provided in Appendix 1. All of the species sampled have previously been recorded in the upper Yarra catchment. Blackleather Creek was not surveyed due to the small size of the creek and difficulty of access, however, it is expected to have a similar faunal composition to Hoddles and Wombat Creeks.

Table 5-2 Native and acclimatised exotic freshwater fish, decapod crustaceans and aquatic bivalves collected in Hoddles and Wombat Creeks, including their conservation status (CNR, 1995a).

Specific Name	Common Name	Conservation Status
Native Fish		
Mordacia mordax	Short-headed Lamprey	Common
Anguilla australis	Short-finned Eel	Common
Galaxias olidus	Mountain Galaxias	Insufficiently known
Gadopsis marmoratus	River Blackfish	Insufficiently known
Acclimatised Exotic Fish		
Salmo trutta	Brown Trout	
Rutilus rutilus	Roach	
Decapod Crustaceans		
Euastacus yarraensis	Yarra Spiny Cray	
Euastacus woiwuru	Central Highlands Spiny Cray	
Aquatic Bivalves		
Alathyria jacksoni	River Mussel	

5.2.1. Distribution and abundance

Mountain galaxias was the most ubiquitous species, being found at all sites surveyed. River blackfish and brown trout were also wide spread, although river blackfish were not found above site 5 and brown trout were absent upstream of the culvert on Prices Road (Site 6B). The highest densities of mountain galaxias were found at the sites where brown trout were absent (Site 6B and 7). At these sites densities ranged from 0.17 to 0.25 fish/m^2, compared with 0.01 to 0.05 fish/m^2 at downstream sites where trout were present. Brown trout are known to adversely affect mountain galaxias through predation and competition (Raadik, 1995; Raadik *et al*., 1996). This leads to the fragmentation of mountain galaxias populations and the restriction of individuals to areas of the stream that are inaccessible to trout. Consequently, the mountain galaxias populations in Hoddles Creek, above the Prices Road culvert are significant in being free from exotic predators.

The highest densities of river blackfish were found at sites 3 and 4 on Hoddles Creek, with 0.12 and 0.15 fish/m^2 respectively. Site 3 also had a high abundance of juvenile blackfish. At all other sites on Hoddles Creek river blackfish densities ranged from <0.01 to 0.06 fish/m^2. At the one site sampled on Wombat Creek, river blackfish were captured at a density of 0.1 fish/m^2.

Short-finned eels were caught at numerous sites on Hoddles Creek and due to their mobility are likely to occur throughout the creek and its tributaries. Short-headed lamprey were only caught at site 1 on the lower section of Hoddles Creek but would also be likely to occur throughout the catchment.

There is a distinct change in the fish and cray fauna of Hoddles Creek with progression upstream. River blackfish are most abundant in the mid to lower part of the catchment, but cease to occur upstream of site 5 where the gradient of the creek increases rapidly. Likewise the Yarra spiny cray extends from the lower catchment up to site 5 where it is replaced by the cental highlands spiny cray. Mountain galaxias and short-finned eels occur throughout the catchment and brown trout are found at all sites except above site 6 where a culvert prevents any upstream movement. Although brown trout are widespread their abundance is relatively low in the Hoddles Creek system when compared with the total abundance of native fish (Appendix 1).

5.2.2. Conservation status

The majority of the species captured in Hoddles Creek and Wombat Creek are classified as common and/or widespread in Victoria, with the exception of river blackfish and mountain galaxias. Both these species are classified as insufficiently known[2] in Victoria (CNR, 1995a). Currently, river blackfish and mountain galaxias are composed of species complexes of undescribed forms. Some of these forms may be valid species which, when formally described, may be found to be threatened. Others may be found to be common and/or widespread. Consequently, as a precautionary measure, the complexes are considered threatened.

5.3. Instream Barriers

A number of instream barriers were found in the mid to upper reaches of Hoddles Creek (Table 5-3). This list of barriers is comprised only of those that could be observed in the current study and consequently may not be complete. The culvert on the track off Yellow Gum Road has a 3 - 4 m drop on the downstream side and would prevent the upstream movement of all fish species except short-finned eels and short-headed lampreys. A large amount of silt has been deposited on the upstream side of the crossing and extensive stands of the aquatic macrophyte cumbungi extend upstream for approximately 100 m. The next major barrier is located downstream of Prices Road and is a small weir of wooden slat construction. There is a small opening in the bottom of the weir, through which fish may move upstream during low flows, but only if the gate is open.

[2] suspected of being Rare, Vulnerable or Endangered.

Further upstream where Prices Road crosses Hoddles Creek, a culvert with a drop of approximately 3 m presents an insurmountable barrier to brown trout which were not found further upstream. Consequently, good populations of mountain galaxias occur upstream of Prices Road. Two smaller barriers were also found upstream of Prices Road, both consisting of small weirs, constructed to provide pools for irrigation pumps. The first of the two weirs was constructed from sandbags and the second from timber slats. During low flow periods these structures may restrict localised movements of mountain galaxias, though during high flow events these structures would be less effective.

Table 5-3 Significant instream barriers on Hoddles Creek

Location	Structure
Off Yellow Gum Road	Earth road crossing with culvert
Downstream of Prices Road (Hoddles Creek Winery)	Weir: slat construction, approximately 1.2 m high, small gate in bottom
Prices Road	Culvert
Immediately upstream of Prices Road	2 small weirs: 1) wooden slats and 2) sandbags

5.4. Water Quality

Electrical conductivity (EC) and water temperature were measured at each site at the time of the fish survey (Table 5-4). Electrical conductivity was low and ranged from 67 to 115 µS/cm with a general increase in conductivity with distance downstream.

Table 5-4 Electrical conductivity (EC), salinity and water temperature measured at fish survey sites

Site	EC at 25°C (µS/cm)	Water Temperature (°C)
Site 1	98	7.9
Site 2	115	8.1
Site 3	89	9.0
Site 4	78	10.1
Site 5	73	9.9
Site 6	67	9.2
Site 7	75	9.3
Site 8	77	10.0

Dissolved oxygen (DO) and pH were measured at sites WQ1, WQ2 and WQ3 on Hoddles Creek and at a site on Blackleather Creek (WQB1) during the collection of water samples for nutrient analysis (Table 5-5). Dissolved oxygen ranged from 9.0 to 9.5 mg/L and pH ranged from 6.3 to 6.9. All parameters, with the exception of pH, fall within the objectives for parks and forests (Appendix 3) as proposed in the State Environment Protection Policy (SEPP) - draft Schedule F7 (Waters of the Yarra Catchment) (EPA, 1995). The SEPP objective for pH in parks and forests in the Yarra Catchment is 6.5 to 9.0. Two of the sites monitored in the current study were within this range, whilst sites WQ2 and WQ3 on Hoddles Creek had pH values of 6.3 and 6.4 respectively. Despite falling outside the SEPP range, these values are considered acceptable due to the often acidic nature of upland streams in forested catchments.

Table 5-5 Dissolved oxygen concentration, water temperature and pH at selected sites on Hoddles and Blackleather Creeks (29/5/95).

Site	pH	Dissolved Oxygen (mg/L)	Water Temperature (°C)
WQ1	6.9	9.0	10.4
WQ2	6.3	9.2	10.3
WQ3	6.4	9.5	9.9
WQB1	6.7	9.0	10.6

Nutrient concentrations, suspended solid (SS) concentrations and *E. coli* levels were monitored weekly for four weeks at three sites on Hoddles Creek (WQ1, WQ2 and WQ3) and one site on Blackleather Creek (WQB1). A median value for each parameter (except *E. coli*) was calculated for the purpose of comparison with SEPP objectives. It is recognised that the median is only calculated from a small data set. Nevertheless, the calculation of a median does enable a 'snap-shot' comparison of water quality in Hoddles and Blackleather Creeks with SEPP objectives.

Table 5-6 Suspended solid, nutrient and *E. coli* concentrations monitored weekly (8-29/5/97) at three sites on Hoddles Creek and one site on Blackleather Creek.

Parameter		Site WQ1	Site WQ2	Site WQ3	Site WQB1
	N	4	4	4	4
Suspended Solids	**Median**	**7**	**10**	**19.5**	**5**
(mg/L)	Min.	3	6	15	2
	Max.	11	40	31	8
Ammonia	**Median**	**0.05**	**0.05**	**0.05**	**0.05**
(mg/L)	Min.	0.05	0.05	0.05	0.05
	Max.	0.05	0.05	0.05	0.05
Nitrate	**Median**	**0.52**	**0.35**	**0.24**	**0.48**
(mg/L)	Min.	0.46	0.30	0.21	0.42
	Max.	0.74	0.47	0.30	0.53
Total Kjeldhal	**Median**	**0.1**	**0.18**	**0.2**	**0.08**
Nitrogen (mg/L)	Min.	0.05	0.05	0.05	0.05
	Max.	0.4	0.4	0.3	0.4
Total Nitrogen	**Median**	**0.72**	**0.59**	**0.47**	**0.57**
(mg/L)	Min.	0.56	0.39	0.26	0.54
	Max.	0.9	0.7	0.54	0.82
Phosphorus	**Median**	**0.06**	**0.033**	**0.013**	**0.005**
(mg/L)	Min.	0.005	0.005	0.005	0.005
	Max.	0.14	0.07	0.08	0.03
Ortho-phosphate	**Median**	**0.005**	**0.005**	**0.005**	**0.005**
(mg/L)	Min.	0.005	0.005	0.005	0.005
	Max.	0.04	0.03	0.005	0.005
E. coli	**Geometric Mean***	**182**	**38**	**9**	**38**
(cells/100 mL)	Min.	70	10	5	10
	Max.	520	140	14	90

*required by Yarra Catchment SEPP draft Schedule F7 (1995)

All parameters were compared with the water quality objectives for parks and forests and rural eastern waterways as outlined in the SEPP (Waters of Victoria) - Draft Schedule F7 Waters of the Yarra Catchment (EPA, 1995) (Appendix 2). Suspended solid (SS) objectives are expressed as an annual mean and 90th percentile in the SEPP objectives (EPA, 1995), thus a comparison with the current data may be misleading. The site on

Blackleather Creek exhibited the lowest SS concentrations throughout the study, with a median SS concentration equal to the SEPP annual objective for parks and forests (<5 mg/L) and less than the annual objective for rural eastern waterways (<20 mg/L). Suspended solid concentrations at sites on Hoddles Creek exceeded the SEPP annual objective for parks and forests but were less than the objective for rural eastern waterways. There was a decrease in SS concentrations with distance downstream in Hoddles Creek, median values ranged from 19.5 mg/L at Prices Road (WQ3) to 7 mg/L immediately upstream of Warburton Highway (WQ1). The highest SS concentrations were recorded at sites WQ2 and WQ3, with concentrations of 40 and 31 mg/L respectively.

Total nitrogen (TN) concentrations exceeded SEPP park and forest objectives for TN (0.2 mg/L) at all sites. However, all sites, except WQ1, recorded median TN concentrations that were less than the SEPP rural eastern waterways TN objective of 0.6 mg/L. Total phosphorus (TP) concentrations exceeded the SEPP park and forest objective for TP (0.03 mg/L) at sites WQ1 and WQ2 and the SEPP rural eastern waterways objective for TP (0.05 mg/L) at site WQ1. Ortho-phosphate concentrations were low at all sites (0.005 mg/L) suggesting that most of the phosphorus is not biologically available and is likely to be transported attached to suspended particulate matter.

The geometric mean of *E. coli* concentrations (as required by Yarra SEPP) was below the SEPP parks and forests and rural eastern waterways objective (<200 organisms/100 ml) at all sites. However, *E. coli* concentrations were highly variable and increased with distance downstream. The SEPP (Waters of Victoria) - Draft Schedule F7 Waters of the Yarra Catchment (EPA, 1995) requires that *E. coli* concentrations be reported as the geometric mean of at least 5 samples across 6 weeks. *E. coli* concentrations were measured in Hoddles and Blackleather Creeks on 4 occasions over a 4 week period and may require further monitoring to establish reliable *E. coli* levels.

5.5. Modelled and Historical Flows in Hoddles Creek

Historical discharge data for Hoddles Creek has only been collected on an ad hoc basis (n = 13) since April 1996. Data has been obtained from one of two gauging stations immediately upstream of Warburton Highway. Unfortunately, the discharges measured at each gauging station for the same time period reveal a number of inconsistencies in the data. For example, the last reading made by Melbourne Water was on the 5/5/97 from the lower gauge (0.18 m = 7.6 ML/d). However, the rating table used at this time was not current, the current rating table was for the upstream gauge. On the 3/5/97, MAFRI staff took readings from both gauges, downstream (0.14 m= 5.4 ML/d) and upstream (0.32 m = 6.3 ML/d). A discrepancy of 0.9 ML was observed between the two gauges, consequently, previous readings from the downstream gauge may have been inaccurate.

It appears that the most consistent flow record for Hoddles Creek is available from levels obtained from the upstream gauge (229224A) on an ad hoc basis from 24/04/97 to 26/08/97. During this period flows varied from 6.3 to 22.9 ML/d, with the minimum flow of 6.3 ML/d being recorded on 5 occasions (Figure 5-1). However, discharge measurements conducted during the current study were, on two occasions, substantially different from those read off the rating table for the upstream gauge (see Table 5-8). This suggests that the upstream gauge may also be inaccurate.

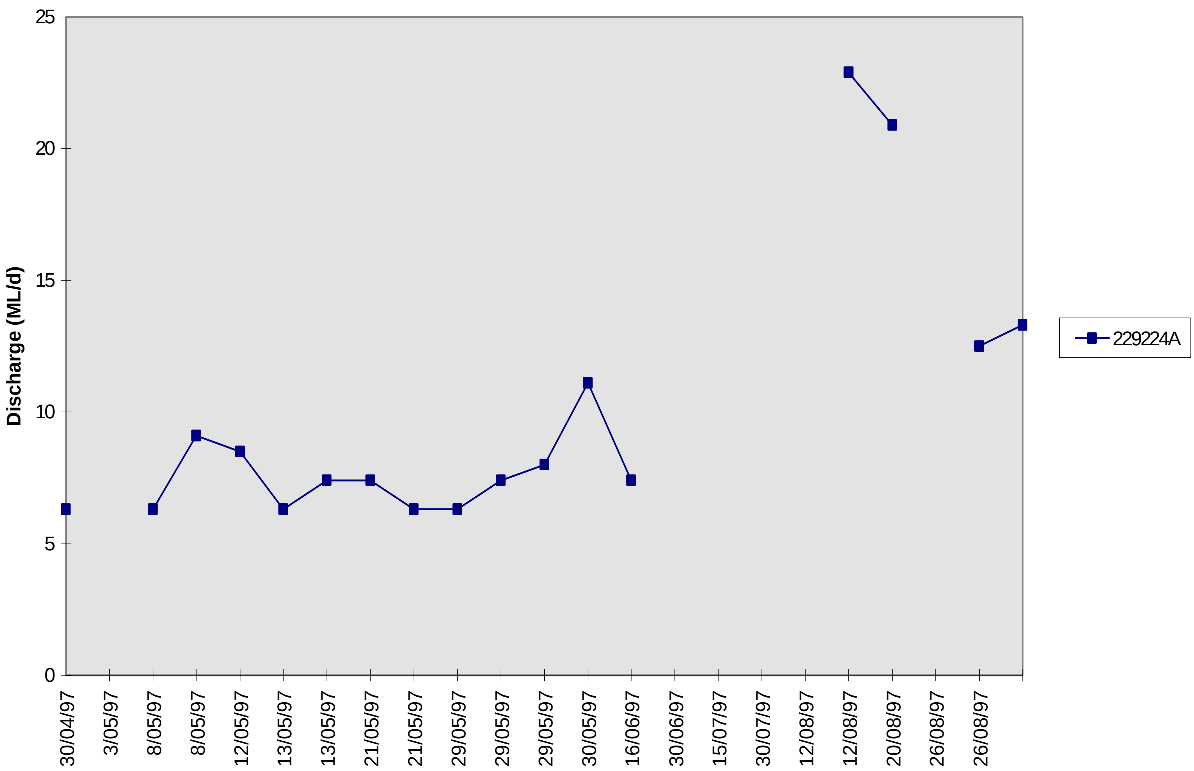

Figure 5-1 Discharge measured at upstream gauge (229224A) on Hoddles Creek.

The period during which these discharges were recorded was characterised by the lowest rainfall on record (Shelley Heron, Melbourne Water, pers. comm.) and could reasonably be expected to be the lowest flows that would naturally occur in Hoddles Creek. It appears from our observations that 6.3 ML/d, as measured on the upstream gauge, is approximately the base flow of Hoddles Creek. However, flows below this level may occur when pumping is conducted upstream of the gauge or when the level of the aquifer decreases.

Due to the lack of historical flow data for Hoddles Creek, Melbourne Water has used long-term data from the nearby Olinda Creek to model a historical flow record for Hoddles Creek. This data (Table 5-7) suggests that median flows in the period January to April are higher than any observed up until June during the current survey and that minimum flows are lower than those observed. However, this data was modelled using the limited flow records that are available from Hoddles Creek which in-turn may be inaccurate. Consequently, discharge in Hoddles Creek needs to be accurately measured over a number of years. Until this occurs, the errors that may be inherent in the modelled historical flows may bias the determination of environmental flows for Hoddles Creek. We cannot be sure of the likely minimum flows that occur in Hoddles Creek or of their recurrence intervals, thus making the determination of minimum environmental flows impractical.

Table 5-7 Hoddles Creek daily flows (ML/d) modelled from Olinda Creek

	January	February	March	April
	Natural Flows 1987 - 1997 (ML/d)			
median	14.5	13.3	13.1	12.0
minimum	3.0	2.5	2.7	2.2
maximum	44.5	42.5	36.7	93.0
	Flows with diversions (current use) 1987 - 1997 (ML/d)			
median	13.2	11.8	11.7	11.5
minimum	1.7	1.0	1.3	1.7
maximum	43.1	41.0	35.4	92.4

5.6. Habitat Availability and Environmental Flows

Habitat availability for river blackfish and mountain galaxias was measured at three distinct flows in Hoddles Creek. The volumes of these flows at each site are outlined in Table 5-8.

Table 5-8 Flows (ML/d) at which habitat availability was measured.

	Discharge (ML/d)		
Site	22/04/97	12/08/97	26/08/97
229224A*	6.3	22.9	12.5
1	6.9	34.6	16.4
2	6.9	25.1	14.7
3	6.0	19.0	15.6
4	6.9	14.7	9.5
5	4.3	10.4	7.8
7	3.5	6.0	4.3

*The flow at the gauging station has been determined from rating table 3.00 19/03/97 to present.

The total area of each reach and the area of the reach available as potential habitat to juvenile and adult blackfish (sites 1 - 5) and mountain galaxias (site 7) are presented in Table 5-9 and Figure 5-2 to Figure 5-7.

Table 5-9 Total area of stream reach (m^2) and area of reach available as potential habitat to juvenile and adult blackfish (sites 1 to 5) and mountain galaxias (site 7).

			Area of reach available as habitat(m^2)		
Site	**Flow (ML/d)**	**Total Area (m^2)**	Juvenile Blackfish	Adult Blackfish	Mountain Galaxias
1	6.9	225.0	95.2	45.8	-
	16.4	248.2	81.1	43.7	-
	34.6	249.9	75.2	50.6	-
2	6.9	346.6	134.2	95.4	-
	14.7	366.8	128.5	104.2	-
	25.1	386.2	112.8	98.0	-
3	6.0	181.0	107.4	77.2	-
	15.6	206.9	78.3	57.1	-
	19.0	211.4	69.8	56.5	-
4	6.9	130.9	98.6	78.9	-
	9.5	146.2	52.9	44.4	-
	14.7	146.2	69.8	61.7	-
5	4.3	78.6	25.6	6.4	-
	7.8	99.1	19.9	2.9	-
	10.4	100.3	24.2	4.9	-
7	3.5	56.4	-	-	30.1
	4.3	62.7	-	-	28.4
	6.0	67.5	-	-	27.3

Habitat availability curves have not been extrapolated below the lowest flow at which habitat was measured (e.g. 6.9 ML/d at site 1). Habitat availability curves cannot be extrapolated assuming that at zero flow the water level decreases by the same amount at or along all transects in a section, nor can changes in velocities simply be implied for flows of less than 6.9 ML/d. In a small stream such as Hoddles Creek, there is no accurate way of estimating habitat availability without measuring available habitat at lower flows. Considering that the baseflow of the creek was stable at around 6.9 ML/d, we were unable to measure habitat availability at lower flows.

At site 1 (immediately upstream of Warburton Highway) the amount of habitat potentially available to juvenile river blackfish was greatest at a flow of 6.9 ML/d and decreased by approximately 20% as flows increased from 6.9 to 34.6 ML/d. At the same time, the amount of habitat potentially available to adult river blackfish remained relatively constant (Figure 5-2).

At site 2 (Glenview Road) the amount of habitat potentially available to juvenile river blackfish was greatest at a flow of 6.9 ML/d but decreased by approximately 16% as flows increased from 6.9 to 25.1 ML/d. The amount of habitat potentially available to adult river blackfish was greatest at a flow of 14.7 ML/d but decreased by approximately 9% at a lower flow of 6.9 ML/d and 6% at a higher flow of 25.1 ML/d (Figure 5-3).

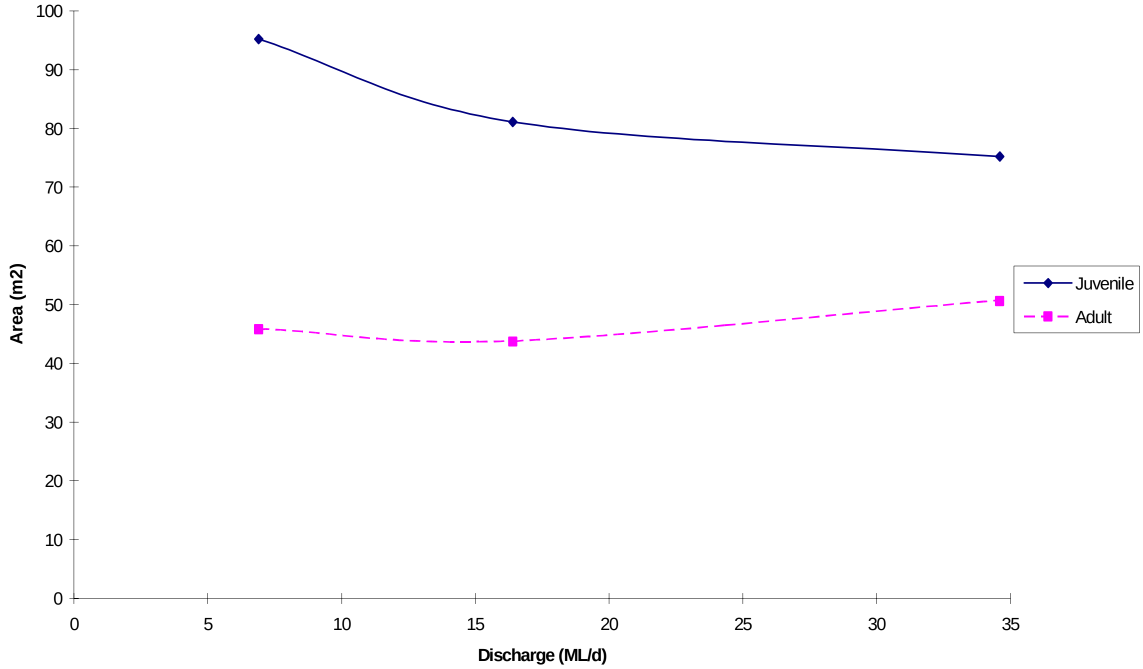

Figure 5-2 Area of potential habitat available with respect to flow for juvenile and adult river blackfish at site 1.

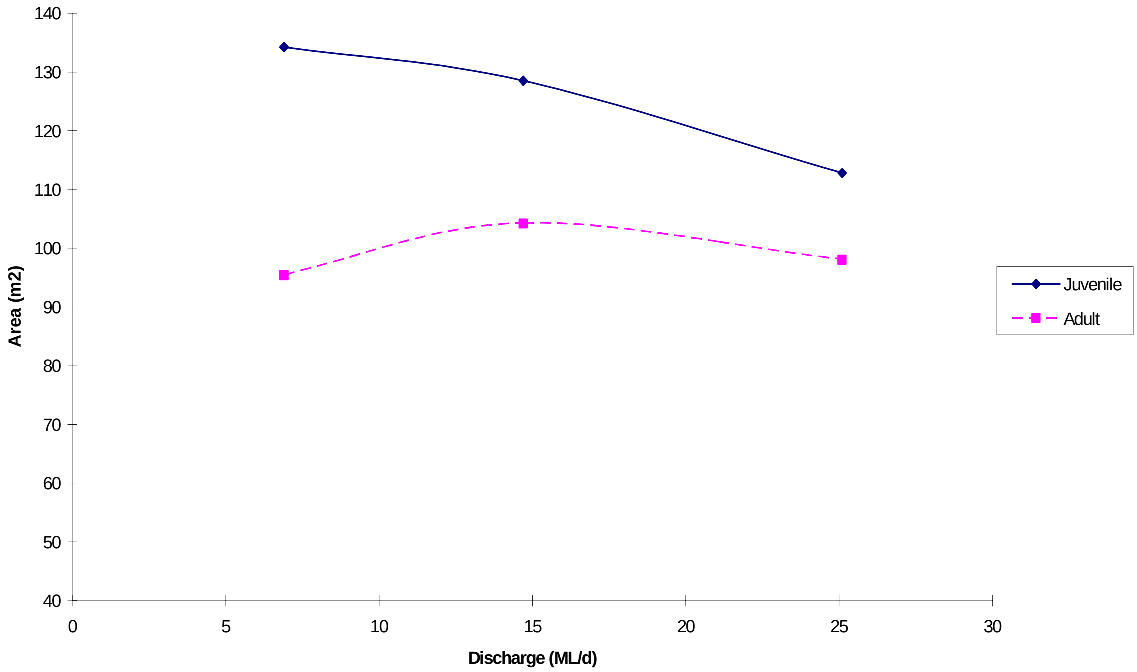

Figure 5-3 Area of potential habitat available with respect to flow for juvenile and adult river blackfish at site 2.

At site 3 (Bells property) the amount of habitat potentially available to juvenile river blackfish was greatest at a flow of 6.0 ML/d but decreased by approximately 35% as flows increased from 6.0 to 19.0 ML/d. Habitat potentially available for adult river blackfish was also greatest at a flow of 6.0 ML/d and decreased by approximately 27% as flow increased from 6.0 to 19.0 ML/d (Figure 5-4).

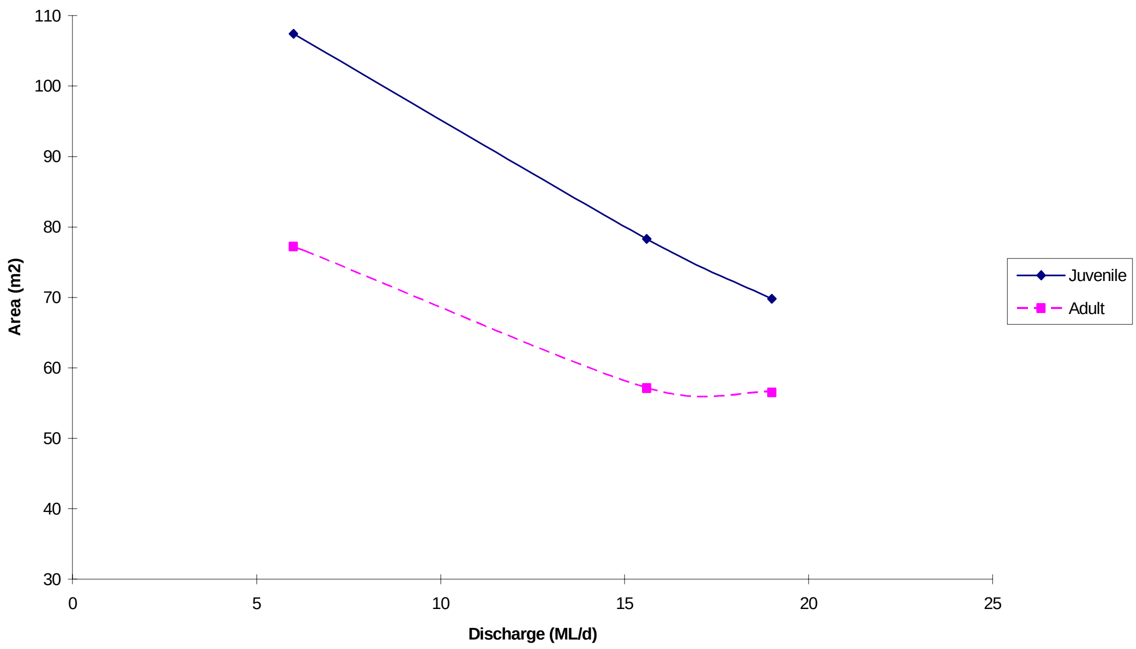

Figure 5-4 Area of potential habitat available with respect to flow for juvenile and adult river blackfish at site 3.

At site 4 (upstream of the confluence of Blackleather Creek) potential habitat availability for both juvenile and adult river blackfish was greatest at a flow of 6.9 ML/d. Habitat availability then decreased by 46% for juveniles and adults at a flow of 9.5 ML/d then increased by 32% for juveniles and 38% for adults at a flow of 14.7 ML/d (Figure 5-5).

Site 5 (off Yellow gum Road) was characterised by low levels of habitat availability for both juvenile and adult river blackfish (Figure 5-6). Potential habitat availability for juvenile river blackfish was approximately equal at both low (4.3 ML/d) and high (10.4 ML/d) flows with a small decrease in area (20%) at a flow of 7.8 ML/d. Potential habitat availability for adult river blackfish was greatest at the low flow of 4.3 ML/d but decreased by 55% at a flow of 7.8 ML/d. Habitat availability then increased by 69% as flow increased to 10.4 ML/d

Losses in potential juvenile and adult habitat were most often associated with increases in velocities, in the lower water column, as discharges increased. At sites where adult habitat initially increased (e.g. site 2), there was an increase in the area of stream with suitable depth (> 0.2 m). However, as discharge increased further, some of this area was lost due to unsuitable velocities. At site 4, potential juvenile and adult habitat at first decreased due to unsuitable velocities, but then increased as water depth increased and velocities in the lower water column decreased.

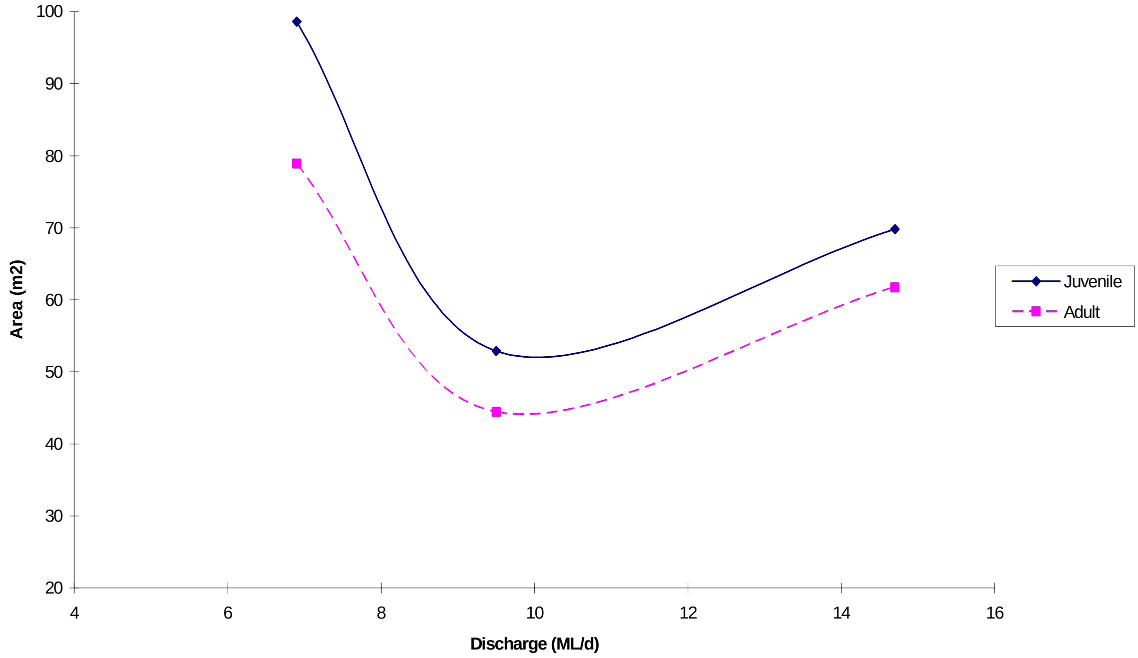

Figure 5-5 Area of potential habitat available with respect to flow for juvenile and adult river blackfish at site 4.

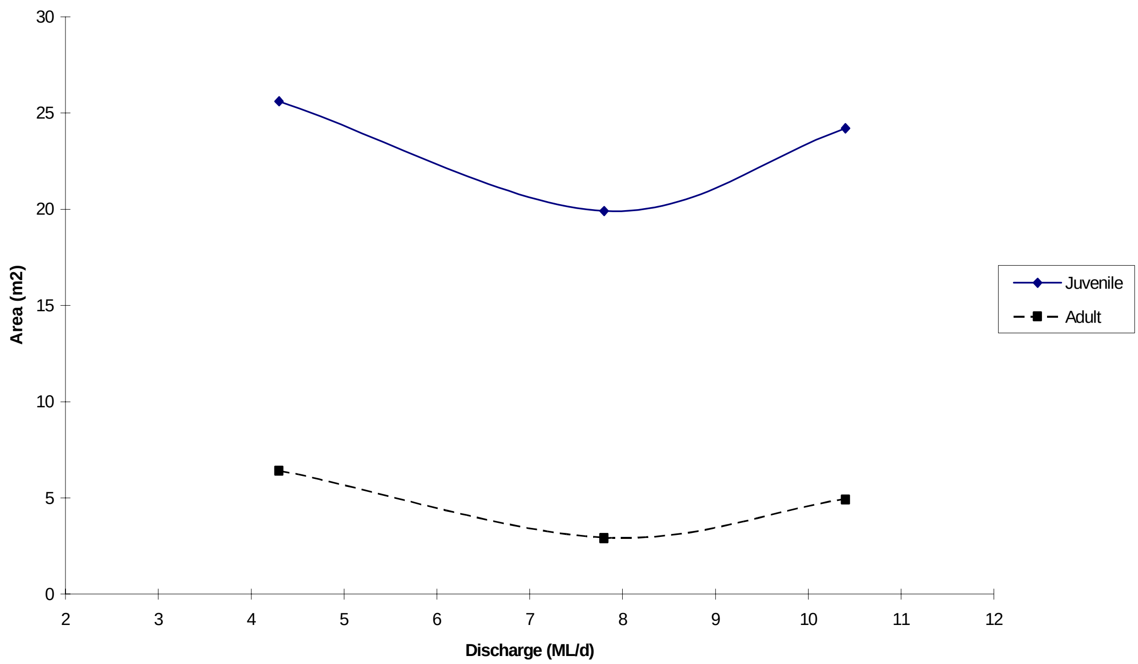

Figure 5-6 Area of potential habitat available with respect to flow for juvenile and adult river blackfish at site 5.

At site 7 (downstream of Hazeldene Road), potential habitat availability was determined for the mountain galaxias due to the absence of river blackfish in the upper reaches of Hoddles Creek. Habitat availability was greatest at the low flow of 3.5 ML/d and decreased only slightly (10%) as flow increased to 6.0 ML/d and velocities also increased (Figure 5-7).

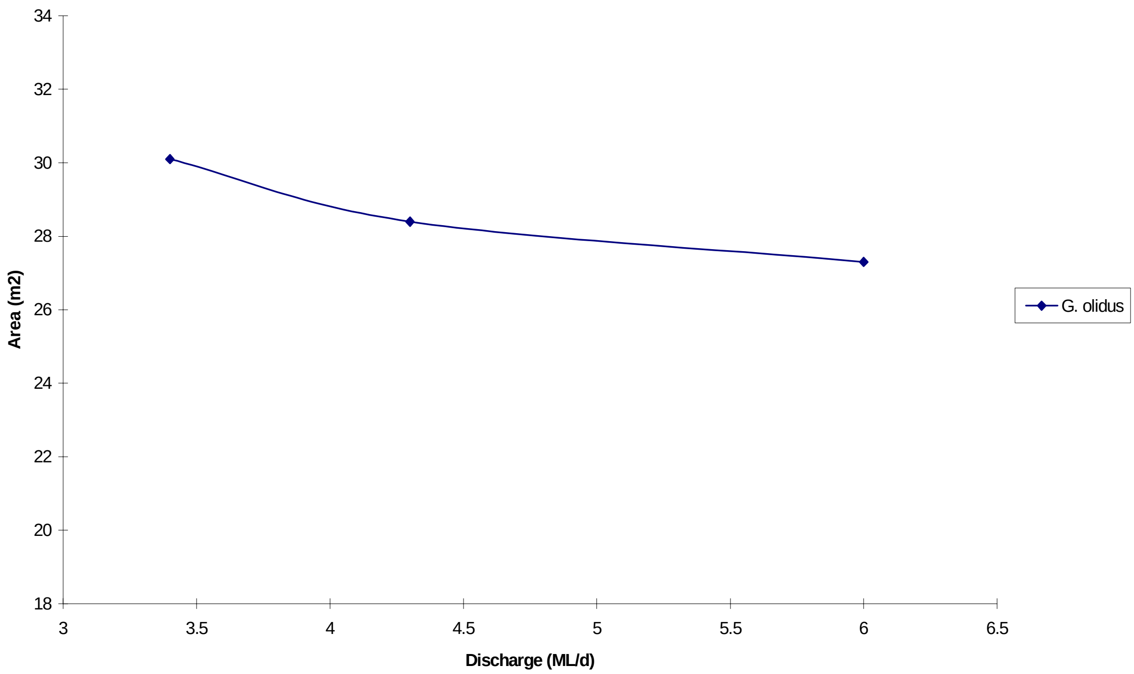

Figure 5-7 Area of potential habitat available with respect to flow for mountain galaxias at site 7.

6. DISCUSSION

6.1. Environmental Values

6.1.1. Fauna and instream flora

The review of significant species which occur in the upper Yarra region suggests that there are a number of significant fish and vertebrates which occur or may occur in the Hoddles Creek catchment. The fauna of Hoddles Creek is characteristic of that found in small streams in the upper Yarra catchment, and as such represents a diverse biological community that is reliant upon the instream and riparian zones of the creek.

Two fish species that are found in Hoddles Creek are considered threatened in Victoria, namely the river blackfish and the mountain galaxias. In addition, Hoddles Creek provides significant potential habitat for other species, including the threatened spotted galaxias and Australian grayling, that may recolonise the upper Yarra River now that a fishway is operational on Dights Falls. These species would add considerably to the conservation value of Hoddles Creek.

Introduced exotic brown trout were found throughout the mid to lower reaches of Hoddles Creek, however, their abundance was relatively low when compared with the total abundance of native fish. In addition, the mountain galaxias populations in Hoddles Creek, above Prices Road, are significant in that they are free from introduced predators such as brown trout. This is reflected in the greater abundance of mountain galaxias at these sites compared to the downstream sites where trout were present.

Other vertebrates of significance that may occur in the Hoddles Creek catchment, and that are dependent on the instream environment, include, the swamp skink, the large-footed myotis, which is classified as rare in Victoria (CNR, 1995a). Although not threatened in Victoria, the platypus and water rat may also occur in Hoddles Creek.

With regards to macroinvertebrates, it is likely that Hoddles Creek may contain diverse populations in some of the undisturbed parts of the catchment, although surveys have not been conducted. It is unlikely that any threatened species of macroinvertebrates occur in Hoddles Creek, however this does not lessen its environmental value. Macroinvertebrates provide an integral part of the food chain in aquatic ecosystems and are in turn dependent on the provision of sufficient flows to maintain riffle areas and diverse and complex riparian habitat.

Instream flora in Hoddles Creek was minimal, with only two species observed (*Triglochin procerum* and *Typha* sp.) at separate locations. Neither of these species are considered threatened, nor are any of the other species of aquatic fauna that are known to occur in the upper Yarra catchment (CNR, 1995b). Nevertheless instream and riparian flora provides essential habitat for fish and macroinvertebrates, and stabilises substrate. Therefore, flows in Hoddles Creek must be suitable to maintain this flora.

6.1.2. Instream habitat

Instream habitat varied considerably throughout Hoddles Creek. Most sites in the catchment showed evidence of disturbance, including the clearing and degradation of riparian vegetation (in the lower catchment), cattle access and associated trampling (mid catchment) and previous mining (lower catchment). All of these activities lead to erosion and subsequently an increase in sediment accession into the creek. Siltation was obvious throughout the system with silt comprising 20 to 40% of substrate at all sites.

Although siltation was evident at all sites, those sites with intact riparian vegetation and diverse instream habitat, such as woody debris and leaf packs, were found to have the highest abundances of river blackfish, particularly juveniles (e.g. site 3 at Bells Property). Woody debris and bank overhang provide essential cover for river blackfish, especially in small, relatively shallow streams such as Hoddles Creek. These types of cover also provide microhabitats where water velocities may be significantly lower than those in the surrounding water column. In addition, woody debris (free of silt) is the preferred substrate for blackfish to deposit their eggs. The uppermost site in the catchment (site 7) where the highest abundance of mountain galaxias was caught, also had diverse and abundant instream cover (e.g. woody debris and vegetation overhang), and intact riparian vegetation.

The least disturbed sites on Hoddles Creek had the most abundant fish populations. Consequently, factors such as siltation, riparian clearing and the removal of woody debris from the water way, may all have detrimental effects on the fish and macroinvertebrate fauna of Hoddles Creek. All of these factors are listed as potentially threatening processes in the Victorian *Flora and Fauna Guarantee Act* 1988. As such, they are recognised as posing or have the potential to pose a significant threat to the survival of a range of flora and fauna.

6.2. Environmental Issues

6.2.1. Water quality

Overall water quality in Hoddles and Blackleather Creek, during the four weeks of sampling (8/5/97 - 29/5/97) was good, with all parameters meeting either parks and forests, or rural eastern waterways objectives as outlined in the SEPP (Waters of Victoria) - draft Schedule F7 Waters of the Yarra Catchment (EPA, 1995). However, the samples collected in the current study were collected over a four week period during low flows. Whilst the results show that the water quality during this period is relatively good, they do not provide an indication of water quality during higher flows, nor throughout the rest of the year. For example, the highest suspended sediment loads are likely to occur during high flow events (O'Shanassy *et al*., 1997).

As mentioned in section 6.1.2, siltation is evident throughout the Hoddles Creek system and, of the water quality parameters measured, suspended solids are likely to have the greatest impact on the fish and aquatic invertebrate fauna of Hoddles Creek. Sedimentation decreases the amount of habitat available for spawning and reduces habitat variation (e.g. smothers substrate and fills pools) thus affecting the health of populations of aquatic biota (Lloyd *et al*., 1987; Doeg and Koehn, 1994). Historical mining activity, clearing of riparian vegetation, cattle access, and run-off from roads and stock crossings, all appear to be increasing the sediment load in Hoddles Creek. At most road crossings on

Hoddles Creek, sediment runoff was evident, and during habitat measurements at the high flow event, the creek was visibly carrying a high suspended sediment load.

6.2.2. Instream barriers

A number of instream barriers were found in the mid to upper reaches of Hoddles Creek. These include onstream storages and pipe culverts at road crossings. At present the barriers do not prevent migratory movements of any of the fish species that occur in Hoddles Creek, although they may restrict localised movements of the small, non-migratory, mountain galaxias. The culvert at Prices Road does prevent the upstream movement of brown trout and this is considered beneficial to the mountain galaxias populations upstream. The barriers may prove to be a problem in future, if species such as Australian grayling, broad-finned galaxias and tupong recolonise Hoddles Creek. All of these species undergo migrations downstream to lower elevation freshwater or estuarine reaches before returning upstream. In these cases the barriers would impede fish movement.

At present the greatest impact of the onstream storages on Hoddles Creek may come from increased downstream sedimentation when they are desilted (flushed) (Doeg and Koehn, 1994). It is possible that sedimentation may have an adverse impact on fish and aquatic invertebrate abundances in the lower reaches of Hoddles Creek. Consequently, the process by which these onstream storages are desilted, should be monitored by Melbourne Water.

6.3. Environmental Flows

6.3.1. Historical flows

Due to the limited discharge data that is available for Hoddles Creek, and apparent discrepancies in the data modelled from Olinda Creek, it has been difficult to determine a historical flow regime for Hoddles Creek. A historical flow record is a necessary component of determining environmental flows as it enables an analysis of the natural variation in flows for a particular system (e.g. flow duration curves, recurrence intervals of low flows, etc.). Without a reliable historical flow record we have been unable to assess and comment upon the impact of natural versus regulated flows on the availability of potential fish habitat in Hoddles Creek.

From the flow data that is available for Hoddles Creek for the period 30/04/97 to 26/08/97, it appears that the natural base flow of the creek is approximately 6.9 ML/d. This volume has been calculated from discharge transects at site 1 (immediately upstream of staff gauge 229224A). However, at this flow the staff gauge at station 229224A measured 0.32 m (6.3 ML/d), which is 0.6 ML/d less than the flow that was calculated at site 1. More significant discrepancies in discharges measured from the staff gauge were noted at higher flows (e.g. discharge at site 1 = 34.6 ML/d, discharge at staff gauge = 22.9 ML/d). In order to accurately determine discharges in Hoddles creek it may be necessary to install a staff gauge in a more suitable location. All environmental flows recommended in this report will be the flows as they were measured at discharge transects at each site.

6.3.2. Habitat availability and environmental flows

Habitat availability was measured at 3 flows over the period 30/04/97 to 26/08/97. The lowest flow (measured at site 1) was 6.9 ML/d and the highest flow was 34.6 ML/d. At all sites where habitat was assessed for juvenile and adult river blackfish (sites 1 to 5), with the exception of site 2, potential habitat availability (m^2) was greatest at the lowest flow. At site 2, juvenile habitat was greatest at the lowest flow, whilst adult habitat was greatest at a flow of 14.7 ML/d. At site 7, mountain galaxias habitat was greatest at the lowest flow with only a negligible decrease at higher flows.

At sites 1 and 2 juvenile habitat decreased at higher flows whilst adult habitat remained relatively constant. At site 3 both juvenile and adult habitats decreased at higher flows, and at sites 4 and 5 juvenile and adult habitats decreased initially at higher flows and then increased again as flow increased. In most cases habitat decreased as flow increased because velocities became less suitable. However, at site 4 where the stream had steep banks, bottom velocities initially increased as flow increased, however, as water depth increased, bottom velocities decreased making habitat once again available.

Whilst the habitat availability curves suggest that at some sites (e.g. site 3) a considerable amount of habitat is being lost at high flows, this may not necessarily be the case. The complexity of the undisturbed instream habitat (e.g. woody debris, undercut banks and riparian vegetation) provides numerous microhabitats where velocities are significantly reduced. Consequently, fish may have considerably more habitat available than is actually measured. If this instream habitat is removed or disturbed, fish may experience considerable stress during high flow events.

Habitat availability curves have not been extrapolated to flows below the lowest flow measured. In small, complex streams, with high gradients, it cannot be assumed that at zero flow the water surface level will fall constantly over an entire reach. In addition, the changes in velocity, at flows between zero and the lowest flow measured, cannot be determined. To determine a minimum environmental flow (i.e. a flow that retains not less than 80% of the habitat of an optimum flow) it will be necessary to measure habitat availability at a flow less than the lowest flow measured in the current study (i.e. 6.9 ML/d at site 1). This was not possible in the current study and it appears that water may need to be abstracted upstream during a low flow event for flows to fall below this level.

From the available data, the optimum environmental flow for Hoddles Creek is recommended as the flow that maximises potential habitat. At all sites this approximately corresponds to the lowest flow at which habitat availability was measured. In past studies the prescribed environmental flow has been the optimum environmental flow or the natural 50 percentile (median) exceedence flow, which ever is least (Hall, 1989). However, we are unable to compare the proposed environmental flows with median historical flows. Consequently, it is unknown if the proposed environmental flows exceed the median natural flows, for the months of concern (approximately January to April).

The following environmental flow recommendations (Table 6-1) relate to the summer/autumn low flow period in Hoddles Creek. The flows are instantaneous flows and are expressed in ML/d. Optimum environmental flows are recommended for six sites throughout the Hoddles Creek catchment, however, at present flows can only be measured at the staff gauge immediately upstream of Warburton Highway (site 1). This staff gauge appears to be inaccurate and cannot be used to monitor flows at sites in the mid to upper catchment (due to tributaries and onstream storages). An accurate gauging station at site 1 may be suitable for determining flows from site 1 to 3 under low flow conditions. However, Melbourne Water may need to install more than one gauging station in the Hoddles Creek catchment.

Table 6-1 Optimum environmental flows recommended for six locations on Hoddles Creek.

Location	Instantaneous Flow (ML/d)
Gauging Station 22922A (Launching Place)	6.9
Glenview Road	6.9
Bells Property	6.0
Immediately upstream of Blackleather Creek	6.0
Off Yellow Gum Road	4.3
Hazeldenes Road	3.5

By protecting sufficient habitat for juvenile and adult river blackfish, and mountain galaxias, during the summer/autumn low flow period, the recommended environmental flows should also protect macroinvertebrate habitat, instream flora and any vertebrates that are dependent on instream processes.

The environmental flow recommendations for Hoddles Creek have been determined using available biological data and a limited set of hydrological data. Ongoing biological monitoring and habitat availability assessment should be undertaken to assess the suitability of these flows. As new data becomes available it may be necessary to modify the recommended flows.

7. RECOMMENDATIONS

7.1. Environmental Management Objectives

The primary environmental management objectives for Hoddles Creek should include the following:

1. Maintain the existing species diversity and populations of aquatic fauna, and where possible, provide conditions that will encourage recolonisation of Hoddles Creek by fish species that can now utilise the upper Yarra system due to the Dights Falls fishway.

2. Maintain water quality in accordance with SEPP (Waters of Victoria) - draft Schedule F7 Waters of the Yarra Catchment (EPA, 1995), whilst decreasing the sediment load entering the system, particularly from sources such as roads, secondary stream crossings (e.g. stock crossings) and onstream dams.

3. Maintain, and where possible, restore diverse and complex instream habitat (e.g. woody debris).

4. Maintain remnants, and rehabilitate degraded areas, of indigenous riparian vegetation along the banks of Hoddles Creek and its tributaries, and ensure adequate buffer strips between cleared land and the creeks.

5. Maintain suitable river blackfish and mountain galaxias habitat over the summer/autumn low flow period, through the provision of environmental flows of the magnitude specified in this report. These flows should also be suitable for macroinvertebrates, instream flora and other vertebrates that are dependent on instream processes.

7.2. Actions

With regards to the environmental management objectives and environmental flows (Table 6-1), the following actions are recommended:

- Ongoing biological monitoring and habitat assessment should be undertaken to assess the suitability of the recommended environmental flows. This should include an annual survey of fish populations in Hoddles Creek to determine their composition and recruitment success.

- In order to determine habitat availability at flows lower than 6.9 ML/d (at site 1) it will be necessary to measure habitat at a time when the creek is flowing at less than its base flow (approximately 6.9 ML/d). This may only occur when a sufficient amount of water is being abstracted from the creek during low flow periods.

- The gauging station immediately upstream of Warburton Highway may need to be recalibrated or replaced. Once this occurs, the gauge will need to be read on a regular basis (preferably daily) so an accurate flow record can be established for Hoddles Creek.

- As new data becomes available it may be possible to recommend minimum environmental flows for Hoddles Creek and it may also be necessary to modify the recommended optimum environmental flows.

- A long term water quality monitoring program should be established in the Hoddles Creek catchment. In addition, new stream crossings should be designed to minimise sediment run-off into the system.

- Buffer strips of approximately 30 m in width are recommended between cleared land and the creeks (Dignan *et al*., 1996). Riparian vegetation should also be adequately fenced to prevent cattle access.

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APPENDIX 1

TABLE 1. Fish survey data for Hoddles Creek at site 1, just upstream of the Warburton Highway at Launching Place.

SITE DETAILS			
Stream name:	HODDLES CREEK	**Site No.**	1
Location:	from 30 to 137 m upstream from bridge on Warburton Highway, Launching Place		
AMG:	8022 745177	**Distance upstream:**	1.0 km
Date sampled:	12 May 1997	**Altitude:**	105 masl
Instantaneous discharge:	6.3 ML	**Gauge name and height:**	upper 0.32 m

SAMPLE DETAILS			
Sample length:	107 m	**Average width:**	4.16 m
Total area sampled:	445.12 m^2	**Duration:**	40 min
Average depth:		**Maximum depth:**	
overall	0.26 m	**overall**	0.87 m
run	0.23 m	**run**	0.33 m
riffle	0.08 m	**riffle**	0.14 m
pool	0.42 m	**pool**	0.87 m

PHYSICO-CHEMICAL DATA			
Conductivity:	98 EC units (μ Siem. cm^{-1} @ 25 °C)	**Temp. and time:**	7.9 °C 0900 hrs

COLLECTION DATA

Species	**Abundance**		**Length (mm)**		**Weight (gms)**	
	total	**/m^2**	**Mean**	**Range**	**Mean**	**Range**
Shortfinned Eel	4	<0.01	460	380 - 580	220.6	120 - 415
River Blackfish	4	<0.01	245.2	135 - 291	170	27 - 239
Mountain Galaxias	25	0.05	59.1	46 - 83	1.9	0.7 - 5.6
SH Lamprey	2	<0.01	243.5	127 - 360	26.8	2.6 - 51.0
Brown Trout	17	0.04	206.4	104 - 312	140.5	15 - 339
Yarra Spiny Cray	6	0.01	19.5	12 - 23	5.0	1.1 - 7.7

FAUNA CHARACTERISTICS ##					
Total no. fish	52	**Total no. crays**	6	**Total no. mussels**	0
Fish species	5	**Cray species**	1	**Mussel species**	0
#Fish density:	0.13 fish m^{-2}	**#Total fish biomass:**	9.16 gm m^{-2}		
#CPUE:	87.88 fish/hour	**#Native: exotic ratio**	5:1		
#Numerical abundance of exotic species:			29.3 %		

 # - excludes mussels but includes freshwater crays.

TABLE 2. Fish survey data for Hoddles Creek at site 2, at Glenview Road.

SITE DETAILS			
Stream name:	HODDLES CREEK	**Site No.**	2
Location:	from culvert on Glenview Road to 100 m downstream.		
AMG:	8022 753155	**Distance upstream:**	3.75 km
Date sampled:	12 May 1997	**Altitude:**	130 masl

SAMPLE DETAILS			
Sample length:	100 m	**Average width:**	4.38 m
Total area sampled:	438 m^2	**Duration:**	30 min
Average depth:		**Maximum depth:**	
overall	0.42 m	**overall**	1.25 m
run	0.32 m	**run**	0.61 m
riffle	0.08 m	**riffle**	0.11 m
pool	0.61 m	**pool**	1.25 m

PHYSICO-CHEMICAL DATA			
Conductivity:	115 EC units (μ Siem. cm^{-1} @ 25 °C)	**Temp. and time:**	8.1 °C 1100 hrs

COLLECTION DATA

Species	**Abundance** total	**Abundance** /m^2	**Length (mm)** Mean	**Length (mm)** Range	**Weight (gms)** Mean	**Weight (gms)** Range
Shortfinned Eel	3	<0.01	515	285 - 780	424.3	33 - 1040
River Blackfish	3	<0.01	231.3	126 - 288	146	23.0 - 212.0
Mountain Galaxias	24	0.05	53.3	45 - 77	1.2	0.3 - 3.8
Brown Trout	4	<0.01	205.7	105 - 286	135.1	17.5 - 277.0
Yarra Spiny Cray	11	0.02	14.8	9 - 23	2.7	0.5 - 8.2

FAUNA CHARACTERISTICS ##					
Total no. fish	34	**Total no. crays**	11	**Total no. mussels**	0
Fish species	4	**Cray species**	1	**Mussel species**	0
#Fish density:	0.10 fish m^{-2}	**#Total fish biomass:**	5.28 gm m^{-2}		
#CPUE:	90.0 fish/hour	**#Native: exotic ratio**	4:1		
#Numerical abundance of exotic species:			8.9 %		

 # - excludes mussels but includes freshwater crays.

TABLE 3. Fish survey data for Hoddles Creek at site 3, at Bell's property.

SITE DETAILS							
Stream name:	HODDLES CREEK			**Site No.**	3		
Location:	from 5 m upstream to 100 m downstream of bridge on track to Bell's property, off Launching Place/Gembrook Road.						
AMG:	8022 759141			**Distance upstream:**	5.2 km		
Date sampled:	12 May 1997			**Altitude:**	150 masl		
SAMPLE DETAILS							
Sample length:	105 m			**Average width:**	3.0 m		
Total area sampled:	315 m^2			**Duration:**	35 min		
Average depth: overall	0.27 m			**Maximum depth:** overall	0.80 m		
run	0.31 m			run	0.45 m		
riffle	m0.1			riffle	0.17 m		
pool	m0.42			pool	0.80 m		
PHYSICO-CHEMICAL DATA							
Conductivity:	89 EC units (μ Siem. cm^{-1} @ 25 ºC)			**Temp. and time:**	9.0 ºC 1245 hrs		
COLLECTION DATA							
	Abundance		**Length (mm)**		**Weight (gms)**		
Species	**total**	**/m^2**	**Mean**	**Range**	**Mean**	**Range**	
River Blackfish	39	0.12	115.3	34 - 358	51.9	0.3 - 352	
Mountain Galaxias	10	0.03	52.4	38 - 67	1.3	0.4 - 3.1	
Brown Trout	4	0.01	207.2	168 - 280	117.0	58.8 - 238.0	
Roach	1	<0.01	-	192	-	119	
Yarra Spiny Cray	7	0.02	14.5	8 - 22	2.2	0.2 - 5.3	
FAUNA CHARACTERISTICS ##							
Total no. fish	54	**Total no. crays**	7	**Total no. mussels**	0		
Fish species	4	**Cray species**	1	**Mussel species**	0		
#Fish density:	0.19 fish m^{-2}			**#Total fish biomass:**	8.38 gm m^{-2}		
#CPUE:	105.17 fish/hour			**#Native: exotic ratio**	3:2		
#Numerical abundance of exotic species:				8.2 %			

 # - excludes mussels but includes freshwater crays.

TABLE 4. Fish survey data for Hoddles Creek at site 4, at Blackleather Road near Hoddles Creek township.

SITE DETAILS			
Stream name:	HODDLES CREEK	**Site No.**	4
Location:	from 10 m upstream to 90 m downstream of old bridge on Blackleather Road, on private property, near Hoddles Creek township.		
AMG:	8022 770126	**Distance upstream:**	7.2 km
Date sampled:	13 May 1997	**Altitude:**	170 masl

SAMPLE DETAILS			
Sample length:	100 m	**Average width:**	2.23 m
Total area sampled:	223 m^2	**Duration:**	35 min
Average depth:		**Maximum depth:**	
overall	0.38 m	**overall**	0.74 m
run	0.35 m	**run**	0.55 m
pool	0.51 m	**pool**	0.74 m

PHYSICO-CHEMICAL DATA			
Conductivity:	78 EC units (μ Siem. cm^{-1} @ 25 °C)	**Temp. and time:**	10.1 °C 1440 hrs

COLLECTION DATA						
	Abundance		**Length (mm)**		**Weight (gms)**	
Species	**total**	**/m^2**	**Mean**	**Range**	**Mean**	**Range**
Shortfinned Eel	1	<0.01	-	555	1	269
River Blackfish	33	0.15	151.3	34 - 340	72.2	0.5 - 311.0
Mountain Galaxias	8	0.03	48.1	33 - 59	0.8	0.2 - 1.4
Brown Trout	1	<0.01	-	206	-	106
Yarra Spiny Cray	2	<0.01	16.5	15 - 18	1.9	1.5 - 2.3

FAUNA CHARACTERISTICS ##					
Total no. fish	43	**Total no. crays**	2	**Total no. mussels**	0
Fish species	4	**Cray species**	1	**Mussel species**	0
#Fish density:	0.20 fish m^{-2}	**#Total fish biomass:**	12.41gm m^{-2}		
#CPUE:	77.58 fish/hour	**#Native: exotic ratio**	4:1		
#Numerical abundance of exotic species:	2.2 %				

 # - excludes mussels but includes freshwater crays.

TABLE 5. Fish survey data for Hoddles Creek at site 5, off Yellowgum Road near Hoddles Creek township.

SITE DETAILS			
Stream name:	HODDLES CREEK	**Site No.**	5
Location:	in private property, off Yellowgum Road, near Hoddles Creek township.		
AMG:	8022 776119	**Distance upstream:**	8.2 km
Date sampled:	12 May 1997	**Altitude:**	180 masl
SAMPLE DETAILS			
Sample length:	75 m	**Average width:**	2.55 m
Total area sampled:	191.25 m^2	**Duration:**	35 min
Average depth:		**Maximum depth:**	
overall	0.22 m	**overall**	0.69
run	0.21 m	**run**	0.31
riffle	0.10 m	**riffle**	0.16
pool	0.34	**pool**	0.69
PHYSICO-CHEMICAL DATA			
Conductivity:	73 EC units (µ Siem. cm^{-1} @ 25 °C)	**Temp. and time:**	9.9 °C 1420 hrs

COLLECTION DATA						
	Abundance		**Length (mm)**		**Weight (gms)**	
Species	**total**	**/m^2**	**Mean**	**Range**	**Mean**	**Range**
River Blackfish	12	0.06	164.6	45 - 257	61.6	1.3 - 154.0
Mountain Galaxias	4	0.02	52.5	31 - 61	1.4	0.2 - 2.0
River Mussel	6	-	-	-	-	-

FAUNA CHARACTERISTICS ##					
Total no. fish	16	**Total no. crays**	0	**Total no. mussels**	6
Fish species	2	**Cray species**	0	**Mussel species**	1
#Fish density:	0.08 fish m^{-2}	**#Total fish biomass:**	3.9 gm m^{-2}		
#CPUE:	27.58 fish/hour	**#Native: exotic ratio**	2:0		
#Numerical abundance of exotic species:	0 %				

 # - excludes mussels but includes freshwater crays.

TABLE 6. Fish survey data for Hoddles Creek at site 6A, just downstream of Prices Road.

SITE DETAILS			
Stream name:	HODDLES CREEK	**Site No.**	6 A
Location:	from 100 to 150 m downstream from culvert on Prices Road.		
AMG:	8022 794083	**Distance upstream:**	12.4 km
Date sampled:	12 May 1997	**Altitude:**	360 masl
SAMPLE DETAILS			
Sample length:	50 m	**Average width:**	1.93 m
Total area sampled:	96.5 m^2	**Duration:**	30 min
Average depth:		**Maximum depth:**	
overall	0.16 m	**overall**	0.37 m
cascade	0.13 m	**cascade**	0.26 m
plunge pool	0.32 m	**plunge pool**	0.37 m
run	0.33 m	**run**	0.33 m
riffle	0.04 m	**riffle**	0.05 m
PHYSICO-CHEMICAL DATA			
Conductivity:	67 EC units (μ Siem. cm^{-1} @ 25 °C)	**Temp. and time:**	9.2 °C 1550 hrs

COLLECTION DATA						
	Abundance		**Length (mm)**		**Weight (gms)**	
Species	**total**	**/m^2**	**Mean**	**Range**	**Mean**	**Range**
Mountain Galaxias	1	0.01	-	35	-	0.4
Brown Trout	4	0.04	219.5	188 - 250	121.5	77 - 159
CH Spiny Cray	4	0.04	24.5	20 - 30	9.5	5.0 - 17.6

FAUNA CHARACTERISTICS ##					
Total no. fish	5	**Total no. crays**	4	**Total no. mussels**	0
Fish species	2	**Cray species**	1	**Mussel species**	0
#Fish density:	0.09 fish m^{-2}	**#Total fish biomass:**	5.43 gm m^{-2}		
#CPUE:	18.00 fish/hour	**#Native: exotic ratio**	2:1		
#Numerical abundance of exotic species:	11.1 %				

 # - excludes mussels but includes freshwater crays.

TABLE 7. Fish survey data for Hoddles Creek at site 6 B, just upstream of Prices Road.

SITE DETAILS							
Stream name:	HODDLES CREEK				**Site No.**	6 B	
Location:	from culvert on Prices Road to 70 m upstream.						
AMG:	8022 794038			**Distance upstream:**	12.4 km		
Date sampled:	12 May 1997			**Altitude:**	360 masl		
SAMPLE DETAILS							
Sample length:	70 m			**Average width:**	3.2 m		
Total area sampled:	226.9 m^2			**Duration:**	40 min		
Average depth: overall / run / riffle / pool	0.16 m / 0.18 m / 0.09 m / 0.36 m			**Maximum depth:** overall / run / riffle / pool	0.64 m / 0.23 m / 0.17 m / 0.64 m		
PHYSICO-CHEMICAL DATA							
Conductivity:	67 EC units (µ Siem. cm^{-1} @ 25 °C)			**Temp. and time:**	9.2 °C 1550 hrs		
COLLECTION DATA							
Species	**Abundance**		**Length (mm)**		**Weight (gms)**		
	total	**/m^2**	**Mean**	**Range**	**Mean**	**Range**	
Mountain Galaxias	39	0.17	73.9	34 - 123	5.7	0.2 - 22.0	
CH Spiny Cray	1	<0.01	-	14	-	1.9	
FAUNA CHARACTERISTICS ##							
Total no. fish	39	**Total no. crays**	1	**Total no. mussels**	0		
Fish species	1	**Cray species**	1	**Mussel species**	0		
#Fish density:	0.17 fish m^{-2}			**#Total fish biomass:**	0.51 gm m^{-2}		
#CPUE:	60.6 fish/hour			**#Native: exotic ratio**	2:0		
#Numerical abundance of exotic species:	0 %						

 # - excludes mussels but includes freshwater crays.

TABLE 8. Fish survey data for Hoddles Creek at site 7, upstream of Hazeldene Road.

SITE DETAILS			
Stream name:	HODDLES CREEK	**Site No.**	7
Location:	from culvert on Hazeldene Road to 60 m upstream.		
AMG:	8022 802075	**Distance upstream:**	13.8 km
Date sampled:	13 May 1997	**Altitude:**	395 masl
SAMPLE DETAILS			
Sample length:	60 m	**Average width:**	2.05 m
Total area sampled:	123 m^2	**Duration:**	40 min
Average depth:		**Maximum depth:**	
overall	0.17 m	**overall**	0.47 m
run	0.17 m	**run**	0.42 m
riffle	0.08 m	**riffle**	0.15 m
pool	0.34 m	**pool**	0.47 m
PHYSICO-CHEMICAL DATA			
Conductivity:	75 EC units (µ Siem. cm^{-1} @ 25 °C)	**Temp. and time:**	9.3 °C 1030 hrs

COLLECTION DATA						
Species	**Abundance**		**Length (mm)**		**Weight (gms)**	
	total	**/m^2**	**Mean**	**Range**	**Mean**	**Range**
Shortfinned Eel	1	<0.01	-	450	-	238
Mountain Galaxias	31	0.25	61.4	39 - 79	2.6	0.4 - 5.6
CH Spiny Cray	42	0.34	17.0	14 - 27	3.2	1.6 - 13.0
River Mussel	31	-	-	-	-	-

FAUNA CHARACTERISTICS ##					
Total no. fish	32	**Total no. crays**	42	**Total no. mussels**	31
Fish species	2	**Cray species**	1	**Mussel species**	1
#Fish density:	0.6 fish m^{-2}	**#Total fish biomass:**	11.41 gm m^{-2}		
#CPUE:	112.12 fish/hour	**#Native: exotic ratio**	3:0		
#Numerical abundance of exotic species:	0 %				

 # - excludes mussels but includes freshwater crays.

TABLE 9. Fish survey data for Wombat Creek at site 8, upstream of the junction with Hoddles Creek.

SITE DETAILS			
Stream name:	WOMBAT CREEK	**Site No.**	8
Location:	off unnamed track off Parkinsons Road, upstream of junction with Hoddles Creek.		
AMG:	8022 781123	**Distance upstream:**	8.8 km
Date sampled:	13 May 1997	**Altitude:**	190 masl
SAMPLE DETAILS			
Sample length:	50 m	**Average width:**	1.22 m
Total area sampled:	61.1 m^2	**Duration:**	20 min
Average depth:		**Maximum depth:**	
overall	0.19 m	**overall**	0.45 m
run	0.24 m	**run**	0.49 m
riffle	0.07 m	**riffle**	0.15 m
pool	0.35 m	**pool**	0.45 m
PHYSICO-CHEMICAL DATA			
Conductivity:	77 EC units (µ Siem. cm^{-1} @ 25 °C)	**Temp. and time:**	10.4 °C 1330 hrs

COLLECTION DATA						
	Abundance		**Length (mm)**		**Weight (gms)**	
Species	**total**	**/m^2**	**Mean**	**Range**	**Mean**	**Range**
River Blackfish	1	0.1	-	119	-	18.9
Mountain Galaxias	5	0.08	56	37 - 68	1.5	0.2 - 1.7
Brown Trout	2	0.03	226.5	221 - 232	131.5	118 - 145
Yarra Spiny Cray	1	0.01	-	11	-	0.6

FAUNA CHARACTERISTICS ##					
Total no. fish	8	**Total no. crays**	1	**Total no. mussels**	0
Fish species	3	**Cray species**	1	**Mussel species**	0
#Fish density:	0.15 fish m^{-2}	**#Total fish biomass:**	4.75 gm m^{-2}		
#CPUE:	27.27 fish/hour	**#Native: exotic ratio**	3:1		
#Numerical abundance of exotic species:			22.2 %		

 # - excludes mussels but includes freshwater crays.

APPENDIX 2

Objectives for water quality indicators from the State Environment Protection Policy (Waters of Victoria) - Draft Schedule F7 Waters of the Yarra Catchment.

	Segment	
Parameter	**Parks and Forests**	**Rural Eastern Waterways**
pH (range) (maximum variation)	6.5 - 9.0 0.5	6.5 - 9.0 0.5
Salinity (mg/L) max (maximum variation) (%)	<200 10	<500 10
Dissolved oxygen (mg/L)	>8.0	>6.0
Suspended solids (mg/L) annual 50th percentile annual 90th percentile	 <5 <10	 <20 <40
E. coli (organisms/100mL) geometric mean	 <200	 <200
Total phosphorus (mg/L) **Total nitrogen** (mg/L)	0.03 0.2	0.05 0.6