AN ASSESSMENT OF ENVIRONMENTAL FLOW REQUIREMENTS FOR THE PLENTY RIVER CATCHMENT

for
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Waterways and Drainage

by

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SUMMARY

Melbourne Water is developing a Streamflow Management Plan (SMP) for the Plenty River system to enable the formulation of guidelines for the effective management of this system. The guidelines will include the establishment of flow regimes that will protect the environmental values of the Plenty River catchment. This report documents the environmental values of the Plenty River system, outlines necessary environmental management objectives, and also recommends environmental flows that will protect the fish fauna and associated values.

Demand for water from the Plenty River system is year round, with direct irrigation diversions predominantly over the summer/autumn low flow period (December to May) and off and on-stream dam diversions (winter-fill) over the higher flow winter/spring period (May to October), with topping up only in November/December. Consequently, two issues have been addressed in this study: 1) the need for a minimum environmental flow over the summer/autumn low flow period and 2) a maximum extraction rate over the winter-fill period. The recommendations for both periods are such that they will support the environmental management objectives that have been recommended for the system.

Environmental Values

The fauna of the Plenty River represents a diverse biological community that relies on the instream and riparian zones of the streams in the catchment. The river may also provide habitat for vulnerable species such as the Australian Grayling (*Prototroctes maraena*) which may recolonise the region by means of the Dights Falls fishway on the Yarra River.

The Glossy Grass Skink (*Pseudemoia rawlinsoni*), which is considered lower risk and near threatened, and the Swamp Skink (*Egernia coventryi*) which is classified as vulnerable are two threatened vertebrates occurring in the catchment.

Of the species of aquatic macroinvertebrates that occur in the Plenty River, none are considered threatened in Victoria, nevertheless it is important to recognise their environmental requirements and value.

Two species of instream flora that occur in the Plenty River are listed as threatened in Victoria. The Slender Bitter-cress (*Cardamine tenuifolia*) is classified as insufficiently known[1] and the Short Water-starwort (*Callitriche brachycarpa*) is considered vulnerable.

Hydrology of the Plenty River System

The low flow period in the Plenty River occurs from December to May. During January, February and March, the 80th percentile exceedence flow at gauging station 229216 (Plenty River at Mernda) is 0 ML/d, while median flows are 0.7, 0.2 and 0.1 ML/d respectively. In May, 80th percentile exceedence flows are 0.44 ML/d and median flows are 1.6 ML/d. Flows then begin to increase in June with maximum

[1] Suspected Rare, Vulnerable or Endangered

flows occurring during August and September, with 80th percentile exceedence flows greater than 5.5 ML/d and median flows greater than 17 ML/d.

Analysis of flow data suggests that during the lowest flow month (March), median flows at gauging station 229216 may have been 8.0 ML/d greater prior to water abstraction (includes Toorourrong Reservoir and irrigation diversions).

Stream Condition

Stream condition varies from good in the forested areas in the upper catchment to poor and degraded in the middle to lower reaches. The upper parts of the catchment are characterised by intact riparian vegetation, more complex instream habitat and abundant native fish species. Disturbance in the lower sections is high with riparian vegetation extensively cleared for grazing, agriculture and light industry. Exotic species such as Willows and Blackberries are abundant. Flow type is characterised by long pools with little or no flow and poor water quality particularly in the warmer months when water temperatures increase and dissolved oxygen concentrations are low. Macroinvertebrate SIGNAL scores also indicate that much of the catchment is in poor condition (Hardwick and Waller, 1999). The exception to the poor stream condition in the middle to lower catchment is the Plenty Gorge, between South Morang and Plenty. This section of river is in a relatively natural state with an intact riparian zone and a rich diversity of flora and fauna (Coleman 1999).

Water Quality

Past studies have shown water quality, especially dissolved oxygen concentrations, to be poor in the Plenty River. Dissolved oxygen (% saturation levels), pH, suspended solids, surface water temperatures, E. coli and nutrients (Phosphorous and Nitrogen) do not meet SEPP objectives at many sites along the Plenty River (Coleman 1999, McGuckin, 1999). Water quality measurements during the environmental flow study indicate that low flows and the lack of a high flushing flow have caused thermal stratification in pools. Stratification causes very low levels of dissolved oxygen and elevated temperature and electrical conductivity. Unless a flushing flow of a sufficient magnitude occurs, large amounts of stream may be unavailable to fish and other aquatic fauna due to poor water quality.

Habitat Availability and Environmental Flow Recommendations

Minimum environmental flows for the summer/autumn low flow period were determined using an adaptation of the Instream Flow Incremental Method (IFIM). Field measurements of potential habitat availability for juvenile and adult River Blackfish (*Gadopsis marmoratus*) were conducted at varying flows. Potential habitat availability was measured at two sites on Plenty River and calculated using the RHABSIM hydraulic and habitat simulation system. Habitat availability was measured at four flows at site S1 and three flows at site S2.

S3, an ephemeral site, located on the Plenty River West Branch was visually assessed, taking into consideration stream morphology, flow type and habitat availability. Water depths and discharges were measured when the river was flowing.

Location of habitat availability survey sites in the Plenty River catchment

Site No.	Location	Map No.	AMG
S1	Gordons Road, Yarrambat (Nioka Bush Camp)	7922-55	58324 3324
S2	C. Mc Donald Reserve, Whittlesea	7922-55	58462 3343
S3	Wildwood Road, Whittlesea	7923-55	58496 3334

From an analysis of hydrological data and habitat availability the following minimum environmental flows have been recommended for the three sites in the Plenty River system. In all cases the recommended environmental flow protects River Blackfish and other native fish species habitat with regards to natural variations in habitat availability as determined from gauged or derived data. Due to the likely ephemeral nature of the middle reaches of the system, site S3 is not expected to have a continuous flow throughout the summer/autumn period.

Recommended minimum environmental flows for three locations in the Plenty River system.

Site No.	Location	Month	Flow (ML/d)
S1	Gordon's Road, Yarrambat (Nioka Bush Camp)	December	1.5
		January	1.0
		February	0.8
		March	0.8
		April	0.5
		May	1.5
S2	C. Mc Donald Reserve, Whittlesea	December	1.0
		January	0.5
		February	0.4
		March	0.4
		April	0.3
		May	1.0
S3	Wildwood Road, Whittlesea	December	0.2*
		January	0.1*
		February	0.1*
		March	0.1*
		April	0.1*
		May	0.2*

* Or natural, whichever is least

In the Plenty River system, flows during May and December appear relatively low. Consequently, it is recommended that May and December are regarded as low flow months and that winter-fill diversions should be from June to November only. The high rates of winter-fill diversions may also need to be reviewed in these months, with the possibility of allowing higher extraction rates during August, with topping up only in October and November.

It is recommended that winter-fill diversions may only commence once the 80th percentile daily exceedence flow for any given month (June to November inclusive) has been attained at site 229216 (Plenty River at Mernda). At flows above this level 20% of the daily flow rate may be diverted for winter-fill dams.

Environmental Management Objectives

The primary environmental management objectives for the Plenty River system 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 the Plenty River system by migratory native fish species that can now utilise the Yarra system by means of the Dights Falls fishway.*

2. *Maintain water quality in accordance with SEPP (Waters of Victoria) Schedule F7 Waters of the Yarra Catchment (Victorian Government, 1999).*

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 Plenty River and its tributaries. In addition, ensure adequate buffer strips between cleared land and the streams.*

5. *Maintain suitable River Blackfish habitat from January to May through the provision of environmental flows of the magnitude specified in this report.*

6. *Ensure that winter-fill diversions are set at a level that does not impact upon migration and spawning of native fish species or essential stream forming processes such as channel scouring and silt removal.*

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 Plenty River is required as part of the State Environment Protection Policy (Waters of Victoria) Schedule F7 Waters of the Yarra Catchment (Victorian Government, 1999). Melbourne Water, being the authority responsible for waterway and diversion management in the Yarra catchment, is developing a SMP for Plenty River. SMP's define rules and agreements that allow water to be transferred, provide certainty for new developments and introduce a clear understanding of flow sharing rules in times of drought. The aim of the SMP is to provide a long term management plan for Take and Use Licenses (TUL's) that has provisions in it to maintain and where necessary, restore current environmental values in the system.

As part of the SMP for the Plenty River, Freshwater Ecology (Department of Natural Resources and Environment) has been contracted to assess the environmental values of the Plenty River system, determine environmental management objectives and investigate environmental flow requirements. The specific objectives of the study are to:

- identify significant environmental values of the Plenty River that need to be protected by adequate flows
- identify other significant impacts on the environmental values of the Plenty River
- recommend environmental management objectives for Plenty River
- comment on the biological significance of changes to the flow regime (natural versus regulated) of the Plenty River
- through an environmental flow study, recommend minimum environmental flows for the Plenty River to aid in providing long term environmental sustainability in the Plenty River catchment.

2. STUDY AREA

The Plenty River system is located north of Melbourne and drains a catchment of 351 km^2 (MMBW, 1976). The east and west branches of the river rise at an altitude of approximately 790 m on a plateau north-east of Mount Disappointment in the Great Dividing Range. The west branch flows south and the east branch flows south-east to a confluence approximately 2 km upstream of Whittlesea. From this point the main stem of the Plenty River continues to flow in a southerly direction to the Yarra River at Heidelberg. The major tributaries of the Plenty River are Jack Creek, Barber Creek, Scrubby Creek and Bruce's Creek, all of which join the system upstream of Mernda (Figure 2-1).

Toorourrong Reservoir is located on the Plenty River East Branch and receives inputs from the Plenty River, Jack Creek and an interbasin transfer from Wallaby Creek (including Silver Creek and its tributaries) in the Goulburn River basin (Figure 2-1). The interbasin transfer increases the size of the Plenty catchment by 48 km^2 (total 399 km^2). Toorourrong Reservoir has a capacity of 273 ML and was constructed in 1884 as a water storage facility and silt trap. Once the capacity of Toorourrong Reservoir is reached during periods of high flow, excess water overflows into the Plenty River East Branch. Water is transported from Toorourrong Reservoir to Yan Yean Reservoir via an aquaduct known as the "Clear Water Channel". Yan Yean Reservoir is an off-stream storage dam with a capacity of 30 227 ML and is situated between Whittlesea and Mernda. Water in Yan Yean is used to supply the northern suburbs of Melbourne (Coleman, 1999).

The upper parts of the Plenty River catchment include an area of State Forest, which is used as a water supply catchment for Melbourne Water. Vegetation within the State Forest consists predominantly of mountain ash (*Eucalyptus regnans*) and mixed woodland. Downstream of Toorourrong Reservoir the Plenty River flows through a floodplain until Mernda. This section of the catchment has been extensively cleared for livestock grazing. Between Mernda and South Morang and from Plenty to Greensborough the catchment is only lightly timbered with some development in light industry and agriculture. The Plenty Gorge, between South Morang and Plenty is an exception to the poor stream condition in the middle to lower catchment. This section of river is in a relatively natural state with an intact riparian zone and a rich diversity of flora and fauna (Coleman 1999). The lower portion of the river, downstream of Greensborough to the Yarra River confluence, has undergone extensive development and complete urbanisation.

There are a total of 21 licensed diverters in the Plenty River catchment, including 15 located on the main stem of the Plenty River and one on the Plenty River West Branch. Five diverters are also located on two tributaries of the Plenty River; three on Scrubby Creek and two on Bruce's Creek. Water is diverted for direct irrigation, on and off-stream dam filling, and stock and domestic use. A total of 453 ML was allocated to diverters in 1999, an increase from 1998 where 393ML was allocated (Melbourne Water, 1998). 335 ML/a is allocated for winter-fill for on and off-stream dams. Winter fill is conducted over the higher flow winter/spring period from May to December. Off-stream dam filling is the only type of diversion on the Plenty River West Branch.

The three gauging stations on the Plenty River system are: station 229216 (Plenty River at Mernda), 229615 (Plenty River at Greensborough) and 229614 (Plenty River at Lower Plenty). There are no streamflow gauging sites on the tributaries of the Plenty River, therefore natural flows in these streams are difficult to determine. For the purpose of this study, flow data from the gauging station at Mernda (229216) has been used. This station is situated downstream of the major diverters and main tributaries on the Plenty River and has the most extensive hydrological record.

Figure 2-1. Location of habitat availability survey sites and gauging stations in the Plenty River Catchment.

3. ENVIRONMENTAL VALUES OF THE PLENTY RIVER CATCHMENT

A review was undertaken of significant species of flora and fauna that occur in the Plenty River catchment. Data was obtained from relevant literature, the Victorian Fish Database (NRE, 1999), the Atlas of Victorian Wildlife (NRE, 1999a) and the Victorian Flora Information System (NRE, 1999b). Only species that may be dependent on the instream environment have been discussed.

3.1. Fish

Fifteen species of fish have been recorded in the Plenty River system (Table 3-1, Raadik and Lieschke, 1999). Eight of these are native and seven are acclimatised exotic species. None of the native species previously recorded from the Plenty River system are considered threatened in Victoria. In recent fish surveys of the Plenty River catchment Raadik and Lieschke (1999) collected the exotic species Carp (*Cyprinus carpio*) in the system for the first time.

Table 3-1. Native and acclimatised exotic fish species previously recorded from the Plenty River system, including their conservation status (NRE, 1999, 1999a, 1999c).

Scientific Name	Common Name	Conservation Status
Native species		
Anguilla australis+	Short-finned Eel	Common
Gadopsis marmoratus	River Blackfish	Common
Galaxias maculatus+	Common Galaxias	Common
Galaxias olidus	Mountain Galaxias	Common
*Galaxias truttaceus**+	Spotted Galaxias	Common
*Mordacia mordax**+	Shortheaded Lamprey	Common
Nannoperca australis	Southern Pygmy Perch	Common
Philypnodon grandiceps	Flatheaded Gudgeon	Common
Exotic species		
Carassius auratus	Goldfish	
*Cyprinus carpio**	Carp	
Gambusia holbrooki	Gambusia	
Misgurnus anguillicaudatus	Weatherloach	
Perca fluviatilis	Redfin	
Rutilus rutilus	Roach	
Salmo trutta	Brown Trout	

* species previously unrecorded in the Plenty River system (Raadik and Lieschke, 1999). (+ migratory species)

Four of the native fish recorded in the catchment are migratory (Table 3-1). Two of these species, namely Spotted Galaxias (*Galaxias truttaceus*) and Shortheaded Lamprey (*Mordacia mordax*), have only been recorded in recent surveys of the Plenty River system (Raadik and Lieschke, 1999).

In the past, Dights Falls, located on the Yarra River downstream of the eastern freeway overpass in Abbortsford (Melway p 44 -58147 3239) has represented a major barrier to fish movement in the Yarra River system. A fish ladder was incorporated

into this structure in 1993 and modified in 1994 (Tim O'Brien pers. comm. Freshwater Ecology, NRE) to assist in upstream and downstream movement of fish. Consequently, it is likely that a number of native species that have been restricted from the Yarra River and its tributaries for many years may now be able to recolonise this area (Table 3-2), (Raadik and Lieschke, 1999). The presence of Spotted Galaxias and Shorthead Lamprey in the Plenty River suggests that these species are utilising the Dights Falls fish ladder.

There are three other native fish species that may recolonise the Plenty River. 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 (FFG) and *The Australian and New Zealand Environment and Conservation Council List of Threatened Australian Vertebrate Fauna* 1995 (ANZECC). Also the Tupong (*Pseudaphritis urvillii*), and Broad-finned Galaxias (*Galaxias brevipinnis*) may move into Plenty River as their numbers increase in the Yarra River. The re-colonisation of the Plenty River system by previously excluded migratory species will increase the conservation value of the river. Therefore, it is important that the life history requirements of these species, such as the timing of migration, are taken into account when determining environmental flows for the Plenty River and its tributaries.

Table 3-2. Native fish species that may increase in numbers or re-establish in the Plenty River as a result of the Dights Falls fish ladder, including their conservation status (Modified from Raadik and Lieschke, 1999).

Scientific Name	Common Name	Conservation Status
Galaxias brevipinnis	Broad-finned Galaxias	Common
*Galaxias truttaceus**	Spotted Galaxias	Common
*Mordacia mordax**	Shortheaded Lamprey	Common
Prototroctes maraena	Australian Grayling	Vulnerable, FFG Act & ANZECC listed
Pseudaphritis urvillii	Tupong	Common

* species recently collected in Plenty River (Raadik and Lieschke, 1999)

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 Yarra River catchment varies throughout the system, with a general trend to more depauperate communities towards the lower sections of the system. 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). This trend has been demonstrated in the Plenty River by Reed and Newall (1990) and Hardwick and Waller (1999). Both studies show a dramatic decrease in macroinvertebrate species numbers in and just downstream of Whittlesea. Further downstream of Whittlesea macroinvertebrate diversity and water quality gradually improved until the river reached urban areas,

where water quality and species numbers once again declined. SIGNAL scores were below those required by draft SEPP objectives as listed in EPA (1995), with the highest SIGNAL scores above Toorourrong Reservoir and in the Plenty Gorge Park (Hardwick and Waller, 1999). The Plenty River above Toorourrong Reservoir is a State Forest and Plenty Gorge is a Melbourne Parks and Waterways Conservation Area. The invertebrates collected by Reed and Newall (1990) are those typically found in waters which are slow flowing, low in oxygen and nutrient enriched (Metzeling and Newall, 1988).

Whilst many of the aquatic macroinvertebrates occurring in the Yarra River system and possibly Plenty River 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 are important. In addition, many animals higher in the food chain are reliant on aquatic invertebrates as a food source (e.g. Platypus and fish).

Morgan (1986) and Horwitz (1990) discuss the distribution of freshwater crayfish in the genera *Euastacus* and *Engaeus* in Victoria. None of the species of freshwater crayfish that occur in the Plenty River system are considered threatened.

3.3. Reptiles and Amphibians

The Glossy Grass Skink (*Pseudemoia rawlinsoni*) has been recorded in the Plenty River catchment (NRE, 1999a) and is classified as lower risk and near threatened in Victoria (NRE, 1999c). In southern Victoria the Glossy Grass Skink has been collected in salt marshes, boggy creek valleys, margins of permanent lakes and swamps and in wet heathlands, with these habitats densely vegetated at ground level (Hutchinson and Donnellan, 1988). It is often sympatric with the vulnerable Swamp Skink (*Egernia coventryi*), also known to be an obligate swamp/wet heathland species (Clemann, 1997).

3.4. Other Vertebrates

Common species such as the Platypus (*Ornithorhynchus anatinus*) and the Water Rat (*Hydromys chrysogaster*) have both been recorded in the Plenty River catchment (NRE, 1999a). These species rely directly on the instream environment for their survival and as such, need to be considered in the determination of environmental flows (Grant and Bishop, 1998).

3.5. Instream Flora

Of the species of instream flora that are known to occur in the Plenty River catchment, two are considered threatened in Victoria (NRE, 1999b). The Slender Bitter-cress (*Cardamine tenuifolia*) is classified as insufficiently known, and the Short Water-starwort (*Callitriche brachycarpa*) is considered vulnerable in Victoria. Instream flora provides essential habitat for fish and macroinvertebrates and the loss of such habitat may be detrimental to fish and macroinvertebrate populations. Consequently, environmental flows need to be of a sufficient magnitude to maintain aquatic flora.

4. HYDROLOGY OF THE PLENTY RIVER SYSTEM

Stream gauging records from the Plenty River system indicate the system is ephemeral, with low flows and/or isolated pools during summer and early autumn. Anecdotal historical information, however, indicates the system may have been perennial, with a persistent flow during the summer months. In 1867, papers presented to Parliament suggested that water driven flour mills on the Plenty River were usually able to operate through the driest of years (Closs, 1984). Ultimately, shortages of water caused by Yan Yean Reservoir made the Carome (Willis') flour mill unecenomical to run (Hicks, 1988).

It appears that water extracted from Toorourrong Reservoir (Plenty River East Branch) and water diverted from the Plenty River for irrigation and on and off-stream dam filling, may have altered the hydrology of the stream. This together with changes in land use such as from rainforest, open timber forest and wetlands prior to European settlement, to deforestation, agricultural, pastoral use and urbanisation post European settlement (Spears *et. al*. 1992) and the construction of Yan Yean Reservoir has changed the stream from perennial to ephemeral (Hicks, 1988). The construction of off-stream dams to capture overland run-off is also likely to have altered the hydrological regime of the Plenty River. Consequently, the potential impacts of new off-stream dams in the catchment should be assessed.

The low flow period in the Plenty River occurs from December to May. During this period, the highest 80th percentile exceedence flow at gauging station 229216 (Plenty River at Mernda) is 0.44 ML/d during May, while the median flow for May is 1.6 ML/d (Figure 4-1). During the months of January, February and March, 80th percentile exceedence flows of 0 ML/d are recorded, with median flows of 0.7, 0.2 and 0.1 ML/d respectively. Flows begin to increase in June with maximum flows occurring during August and September, when 80th percentile exceedence flows are greater than 5.5 ML/d and median flows are greater than 17 ML/d (Figure 4-1).

In order to provide an indication of the approximate magnitude of median natural flows over the summer/autumn low flow period, diversion rates[2] (only those upstream of gauging station 229216) have been added to the median (50th percentile) flow for each month (Figure 4-1). Additionally, water diverted from Toorourrong Reservoir has been included, highlighting the difference in current flows and flows that may have naturally occurred.

Analysis of flow data suggests that during the lowest flow month (March), median flows at gauging station 229216 may have been 8.0 ML/d greater prior to water abstraction (includes Toorourrong Reservoir and irrigation diversions).

During the last 20 years the 50th percentile water inflow into Toorourrong Reservoir during the driest month (March) has been greater than 7.5 ML/d (Melbourne Water data). Field observations of ungauged streams indicate that during the summer/autumn period, ground-water derived base flows persist in the headwater reaches of the Plenty River system above Toorourrong Reservoir. This is supported by the presence of River Blackfish (*Gadopsis marmoratus*) and two species of Spiny

[2] data supplied by Melbourne Water (also see Appendix 1)

Cray, Central Highlands Spiny Cray (*Euastacus woiwuru*) and Yarra Spiny Cray (*Euastacus yarraensis*), which are likely to require continuous flows in these headwater streams.

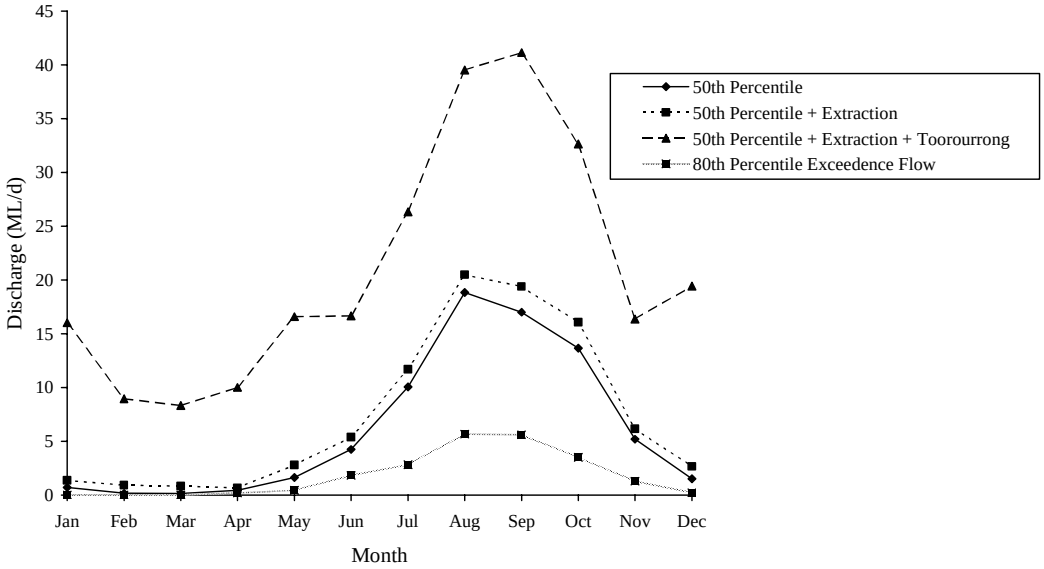

Figure 4-1. 50th percentile exceedence flows at Station 229216 (Plenty River at Mernda), including 50th percentile plus diversions, 50th percentile plus diversions and extractions from Toorourrong Reservoir and 80th percentile exceedence flows. N.B. This figure was produced from 1979-1998 data.

5. METHODOLOGY FOR ENVIRONMENTAL FLOW STUDIES

A habitat availability technique has been used only to recommend environmental flows over the summer/autumn low flow period (December to May) in the Plenty River system. The issue of environmental flows with regards to the winter-fill period (June-November) is discussed in Section 7.1.

An adaptation of the instream flow incremental method (IFIM) (Bovee, 1982) was used to determine the availability of fish habitat at a range of flows. The decision to base our method on the IFIM was driven by the need for a quantifiable and defensible method for assessing environmental flows. The method employs the IFIM along with historical flows and expert knowledge to recommend environmental flows that aim to protect the environmental values of the Plenty River system.

Implementation of the IFIM method and the construction of suitability of use curves require 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.

In order to determine habitat availability for native fish species in the Plenty River system, River Blackfish was selected as the key species. River Blackfish are the deepest bodied native fish species found in the Plenty River system and it is assumed that providing a suitable amount of potential habitat for River Blackfish will also provide habitat for the smaller native species present. River blackfish have been used to model habitat availability at sites S1 and S2 (Table 5-2). No River Blackfish were collected from these sites in recent surveys (NRE, 1999 and Raadik and Lieschke, 1999), nevertheless, using the habitat requirements of River Blackfish should benefit other native fish species.

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 Freshwater Ecology, NRE 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 5-1).

Table 5-1. Depth and velocity requirements of River Blackfish

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

Unlike previous Victorian studies, we have not divided 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 is not comprehensive enough to enable the modelling of habitat availability with regards to all requirements. The habitat requirements we

have used encompass both rearing and resting activities. This habitat covers the largest component of stream area and is considered the most important habitat over the low flow period.

The flows that are suggested as maintaining River Blackfish habitat during the summer/autumn low flow period will also maintain habitat for other fish species (currently present or likely to occur in the future), macroinvertebrates and aquatic vegetation in the Plenty River system. The flows should also provide enough water for fish passage, although during the summer period migration is generally rare with only localised movements occurring.

5.1. Field measurements of hydraulic parameters and habitat

Three sites were selected in the Plenty River system to establish reaches where habitat availability could be measured at a range of flows (Table 5-2). Two sites were located on Plenty River and one on Plenty River West Branch. This arrangement of sites provided detailed information on discharge and habitat availability throughout the catchment.

Table 5-2. Location of habitat availability survey sites in the Plenty River catchment (see also Figure 2-1)

Site No.	Location	Map No.	AMG
S1	Gordons Road, Yarrambat (Nioka Bush Camp)	7922-55	58324 3324
S2	C. Mc Donald Reserve, Whittlesea	7922-55	58462 3343
S3	Wildwood Road, Whittlesea	7923-55	58496 3334

At flow sites S1 and S2, a series of transects were established in areas of habitat that were representative of that particular reach of river. The number of transects (12 and 14 respectively) 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) and depth (m) were measured at 0.1 to 0.5 m intervals. Depth was measured to the nearest 0.01 m using a 1.5 m steel ruler and at depths greater than 1.5 m, a 4 m steel ruler was used. Velocity was measured using a Hydrological Services OSS PC-1 current meter with a CMC 20 digital counter.

At flow site S3, environmental flow recommendations were developed in a different manner to sites S1 and S2. Site S3 is ephemeral and was dry and congested with vegetation when the environmental flow study commenced. It was therefore difficult to assess habitat availability using a transect method. As an alternative, a visual assessment of the stream condition, morphology, flow type and habitat availability was conducted. Water depths and discharges were also measured at this site when the river was flowing.

5.2. Modelling using RHABSIM

The amount of habitat available to River Blackfish, at a range of flows, was calculated using the RHABSIM hydraulic and habitat simulation system (Payne and Associates, 1994). Criteria curves were constructed for juvenile and adult River Blackfish. 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) is 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.

For sites S1 and S2, changes in habitat availability at a range of flows were measured in the field rather than by hydraulic simulation. Due to an absence of accurate stage/discharge data for the sites in the Plenty River system, it was considered impractical to calibrate a hydraulic simulation model of the stream sections. In addition, the structural complexity (woody debris, aquatic vegetation etc.) of the stream reaches, may have resulted in inaccurate hydraulic calibration of a model and large errors in habitat area predictions (Courot, 1989; Gordon *et al*., 1992; Gippel and Stewardson, 1998).

5.3. Water Quality

Water quality in the Plenty River has been shown to be poor in the past (Reed and Newall, 1990) and fair to poor below Toorourrong Reservoir in a recent survey (Coleman, 1999). In order to assess the effect of discharge on water quality, a number of parameters were measured at sites S1 and S2. Depth profiles of dissolved oxygen (mg/L), water temperature (°C), and electrical conductivity (µS/cm) were measured at the deepest point at each site. Measurements were conducted each time habitat availability was measured (i.e. under different flow conditions). Dissolved oxygen was measured using a WTW OXI 320 meter, while electrical conductivity and water temperature were measured using a WTW LF 320/SET meter.

6. RESULTS AND RECOMMENDATIONS

6.1. Site Descriptions

S1. Plenty River at Gordon's Road, Yarrambat (Nioka Bush Camp)

Site S1 was located upstream of the culvert on Gordons Road at Yarrambat, within the boundary of the 'Nioka Bush Camp' managed by Parks Victoria. The river was relatively wide compared to the other two sites, ranging from 8 to 17 m in width with the majority of bank being 1.0-2.0 m high and undercut. Riparian vegetation was relatively intact, consisting mainly of Eucalypts (*Eucalyptus* spp.), Tea-tree *(Leptospermum* spp.), Blackwood (*Acacia melanoxylon*), native shrubs, grasses and a few Willows (*Salix* spp.). Extensive patches of Blackberries (*Rubus fruticosis* spp. agg.) were also present. Disturbance was moderate with a culvert present downstream and urban rubbish consisting of dumped engine parts.

The survey reach was comprised primarily of long, wide pools with clay and silt substrates. Small glide and riffle sections with bedrock, boulder and cobble substrates separated pools. Instream habitat consisted of undercut banks, rock substrate, abundant woody debris and relatively dense amounts of aquatic vegetation flanking the upper pool area. Aquatic vegetation was comprised of Cumbungi (*Typha* sp.) and the Common Reed (*Phragmites australis*).

S2. Plenty River at C. Mc Donald Reserve, Whittlesea

Site S2 was situated within C. Mc Donald Reserve in Whittlesea, approximately 40 m upstream of the lower footbridge. The river had an average width of 6.5 m with banks 0.5- 1.5 m high. Native riparian vegetation was cleared, except for narrow strips along the bank edges. Native trees such as Eucalypts (*Eucalyptus* spp.), Black Wattle (*Acacia mearnsii*), Silver Wattle (*Acacia dealbata*), Blackwood and Prickly Moses (*Acacia verticillata*) dominated the small areas of riparian vegetation remaining. There were also grasses, Willows, native shrubs, Blackberries and the exotic Buttercup (*Renunculus repens*) blanketing patches of bank area. The site was highly disturbed being located in a recreational reserve with areas of bank erosion and urban rubbish such as aluminium cans, bottles and plastic present.

Pools were predominant during the low flow period, with pools and glides present at higher flows. Substrate was primarily silt with clay banks. Instream habitat was comprised of dense amounts of aquatic vegetation such as Cumbungi, common reed and small amounts of Slender Knotweed (*Persicaria decipens*), especially along the bank edge. Woody debris was also dispersed in small patches throughout the section.

S3. Plenty River at Wildwood Road, Whittlesea

Site S3 was situated on private property, immediately upstream of the culvert on Wildwood Road, Whittlesea. This section of the Plenty River West Branch appeared to be ephemeral possibly due to an on-stream dam situated immediately upstream of the site. On 23rd April a flow of approximately 1 ML/d was observed at the culvert on Mornmoot Stud North property (end of Towts Road), immediately above the dam. On the same day no flow was observed at site S3 upstream of Wildwood Road.

The site was dry when first inspected, the channels were ill defined and congested by grasses, sedges and small amounts of the common reed. Grasses dominated the riparian vegetation with small patches of Blackwoods (*Acacia melanoxylon*), Poplars (*Populus* sp.), Willows and Blackberries on the right-hand bank.

When a flow of 1 ML/d was recorded, the river was split into two shallow channels. Sedges dominated the riparian vegetation between the two channels. The main channel averaged 1 m in width and 0.12 m in depth with a flow type of pool and glide. The smaller channel averaged 0.3 m in width and 0.05 m in depth with little to no flow. The instream habitat was predominantly grass and sedges.

At a higher flow of 6 ML/d the channel was flooded with shallow water starting to spread across the floodplain. Flow type consisted of glide with very small sections of pool. The average depth of the main channel was 0.25 m with the smaller channel having a low flow and an average depth of 0.10 m. Under high flow conditions, shallow water spread across the floodplain for approximately 50 m in width.

6.2. Summary of Stream Condition

Overall the Plenty River is in poor condition with regards to water quality (Reed and Newall, 1990 and McGuckin, 1999), riparian vegetation and instream habitat. Stream condition varies from good in the forested areas high in the headwaters to degraded in urban areas in the lower section of the catchment. SIGNAL scores derived from a macroinvertebrate study by Hardwick and Waller (1999) suggest that the whole of the catchment is degraded, as no sites met draft SEPP objectives. The sites with the highest scores were above Toorourrong Reservoir and in the Plenty Gorge Park.

Only 10-20% of the Plenty River catchment is forested and the majority of this area occurs in the upper parts of the catchment from Mount Disappointment to Toorourrong Reservoir (McKenzie and O'Connor, 1989). In this section of the upper catchment, native riparian vegetation is relatively intact and instream habitat in the form of woody debris and vegetation overhang is diverse and abundant. It is important to note that this was the only region of the Plenty River that contained populations of River Blackfish (Raadik and Lieschke, 1999).

Below Toorourrong Reservoir, and in the tributaries of the Plenty River above Whittlesea, stream condition declines. Riparian vegetation has been cleared for grazing, and stream-bank erosion is common. Unrestricted cattle access to the river is further deteriorating the stream banks and instream environment.

The middle section of the catchment from Whittlesea to Greensborough is in a relatively poor condition. Disturbance is high with riparian vegetation extensively cleared for grazing, agriculture and light industry. Exotic species such as Willows and Blackberries are abundant. Flow type is characterised by long pools with little or no flow and water quality is poor, particularly in the warmer months when water temperatures increase and dissolved oxygen concentrations are low. It is possible that these conditions may have contributed to past fish kills (Closs, 1984). The exception to this section of stream is the Plenty Gorge. The Plenty Gorge supports a rich diversity of fauna, with a high proportion considered to be at least of regional significance (Coleman, 1999).

The lower reaches of the Plenty River, downstream of Greensborough to the Yarra River confluence is in a poor to degraded condition. This section has undergone extensive development due to urbanisation and is generally characterised by a lack of riparian vegetation. This has resulted in increased erosion, sedimentation and degraded water quality. The extensive urban development has had a negative impact on species composition, resulting in a depauperate invertebrate and native fish fauna, and an abundance of introduced exotic fish species (Reed and Newall, 1990; Raadik and Lieschke, 1999).

6.3. Habitat Availability

At site S1 (Plenty River at Gordon's Rd, Yarrambat) the area potentially available to juvenile and adult blackfish increased by 11% when flow increased from 0 to 8.3 ML/d (Table 6-1, Figure 6-1). Further increases in flow of up to 67.9 ML/d resulted in only minor increases in habitat availability.

Table 6-1. Total area of stream reach (m^2) and area of reach available as potential habitat to juvenile and adult River Blackfish.

			Area of reach available as habitat (m^2)	
Site	Flow (ML/d)	Total Area (m^2)	Juvenile Blackfish	Adult Blackfish
S1	0.0	1166.04	1118.93	1074.75
	8.3	1238.56	1213.83	1194.44
	25.6	1261.82	1239.89	1222.21
	67.9	1270.49	1247.98	1227.16
S2	0.0	231.35	208.95	199.51
	3.7	298.41	261.5	234.7
	39.2	404.32	392.31	382.08
S3	0.0	*	*	*
	1.0	*	*	*
	6.0	*	*	*

*visual assessment approach to assess habitat

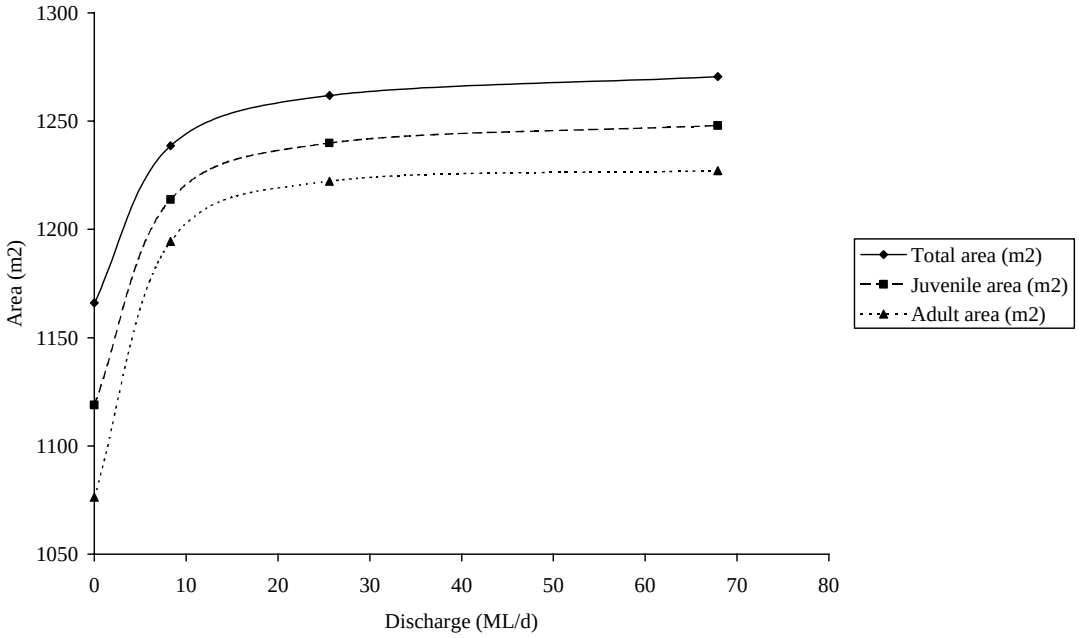

Figure 6-1. Total area and area of habitat potentially available to juvenile and adult River Blackfish at a range of flows at Site S1.

At site S2 (C. McDonald's Reserve in Whittlesea) the area potentially available to juvenile and adult River Blackfish increased by 20 % when flows increased from 0 to 3.7 ML/d (Table 6-1, Figure 6-2). The presence of large amounts of Cumbungi reduces bottom velocities, thus increasing potential blackfish habitat availability.

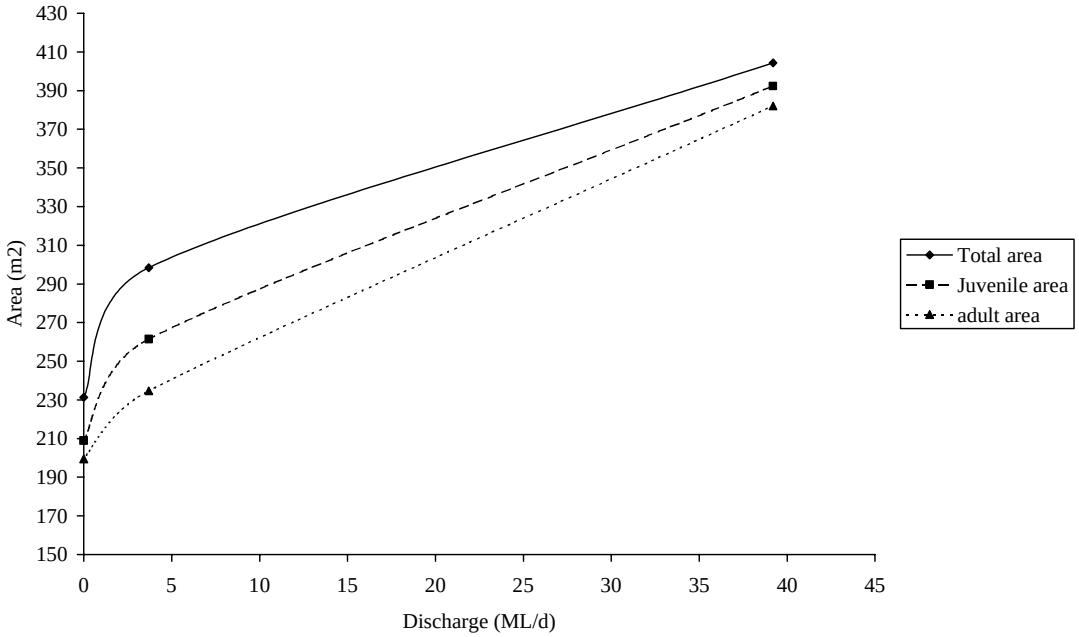

Figure 6-2. Total area and area of habitat potentially available to juvenile and adult River Blackfish at a range of flows at Site S2.

Site S3, which is situated in an ephemeral section on the Plenty River West Branch, was dry from December to May. In June, a flow of 1.0 ML/d was recorded and although it was unsuitable for adult blackfish (depths less than 20 cm), it is possible that juvenile blackfish and other smaller native fish could use this area for feeding or as a refuge. At a flow of 6 ML/d it appeared that site S3 could potentially support both juvenile and adult blackfish. A high proportion of the stream contained depths greater than 0.2 m with velocities less than 0.2 m/s. The abundant vegetation at this site would provide fish with refuge areas from both high velocities and predators. Nevertheless, woody debris, an essential component of River Blackfish habitat, was sparse at this site.

After the first major flow at site S3, drowned terrestrial invertebrates were abundant both in the water column and on the banks where the water had started receeding. The first flows passing down an ephemeral stream can carry large amounts of organic debris and terrestrial invertebrates which aquatic fauna are likely to utilise as a food source.

6.4. Water Quality

Water quality has been shown to be poor in the Plenty River in the past (Closs, 1984; Reed and Newall, 1990). Nutrients (Phosphorous and Nitrogen), pH, E. coli, suspended solids, surface water temperatures and dissolved oxygen (% saturation levels) do not meet the SEPP objectives at many locations in the Plenty River (Coleman, 1999; McGuckin, 1999). Above Toorourrong Reservoir water quality can be regarded as very good, but below it was fair to poor (Coleman, 1999). Conductivity was found to be very high in stratified pools (up to 5,150 µs/cm) (see Appendix 2) during flow measurements. Water quality problems may have been exacerbated by the high level of water extractions (both irrigation and Toorourrong Reservoir water diversions) and increased urbanisation (Reed and Newall 1988). No water passes down the Plenty River East Branch when Toorourrong Reservoir is low. Additionally, the reservoir also reduces the size and duration of any flushes, with only large flushes spilling over the dam wall.

Results from water quality profiles indicate that low flows and the lack of higher flushing flows cause stratification in pools (Appendix 2). Stratification causes very low levels of dissolved oxygen (Figure 6-3) and elevated levels of salinity. Excessive water abstractions in the system may prolong the dry period and therefore extend the time dissolved oxygen concentrations are low in pools. A flow of over 25 ML/d was not sufficient to cause a mixing of layers in the deeper pools at site S1. After a more substantial flush of greater than 155 ML/d (Gauging station 229216, just upstream of site S1), mixing had occurred. Unless a flushing flow of this magnitude is reached, large amounts of stream may be unavailable to fish and other aquatic fauna due to low dissolved oxygen levels, high temperatures and elevated salinity levels. Flushes are also important environmental cues for fish migration, spawning and for geomorphological processes (see section 7.1).

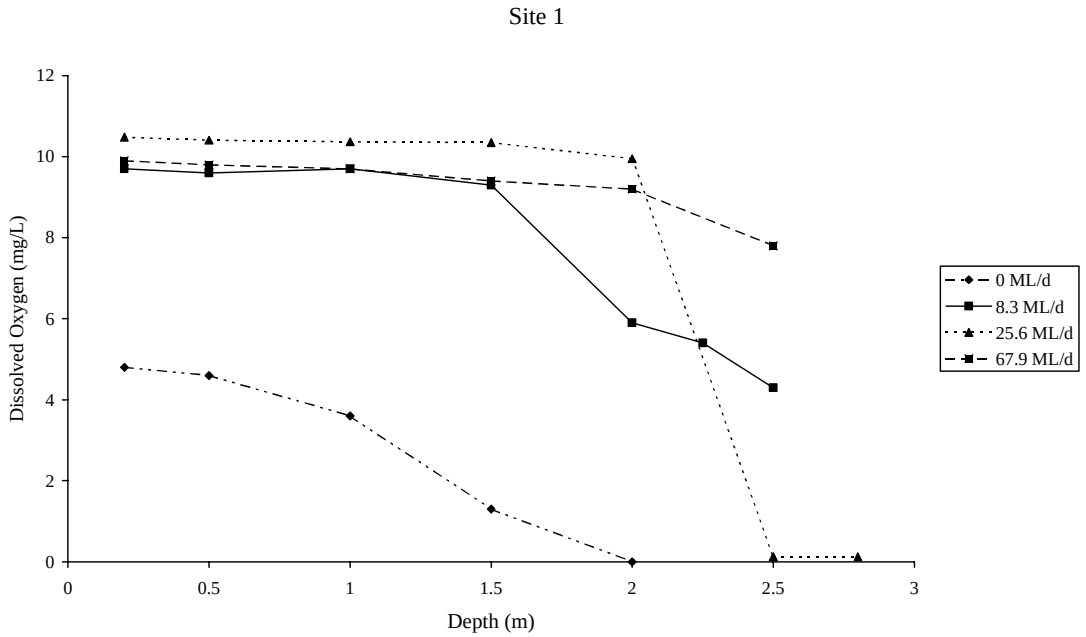

Figure 6-3. Dissolved oxygen profile for four discharges at S1.

The technique used to determine useable River Blackfish habitat does not take into account habitat loss due to poor water quality (low levels of dissolved oxygen and increased levels of electrical conductivity and temperature in stratified pools). River Blackfish have been shown to require a well-oxygenated environment (Koehn and O'Connor, 1990), and the dissolved oxygen levels measured in pools in the Plenty River were very low (Appendix 2). Changes in flows from 0 to 8.3 ML/d at site S1 and from 0 to 3.7 ML/d at site S2 did not destratify pools. Therefore the area available to blackfish may have been overestimated at lower flows, due to larger pools containing low oxygen levels. Nevertheless, flows greater than 67.9 ML/d at site S1 and 39.2 ML/d at site S2 destratified pools. Consequently, available River Blackfish habitats measured after the flush were not effected by low dissolved oxygen levels.

The depth profile results highlight the importance of the first flushing flow at the beginning of the high flow period in May/June. These flushing flows will improve water quality by mixing the stratified layers, therefore maximising habitat available to blackfish and other native species in the system. It also highlights the fact that any flushing flow occurring during the low flow (summer) months will reduce the stress the system is under and therefore should be allowed to pass.

6.5. Instream Barriers

The only large barrier found in the Plenty River system is the wall of Toorourrong Reservoir, which is located high in the catchment on the east branch of the river. This structure appears to be restricting the upstream movement of native fish, as migratory species such as the Short-fin Eel (*Anguilla australis*) and Common Galaxias (*Galaxias maculatus*) collected below the reservoir wall were not collected upstream (Raadik and Lieschke 1999).

Another two smaller barriers are known in the system. In Greensborough a concrete weir is located at the disused Maroondah Aqueduct crossing. Between Mernda and South Morang, within the gorge behind the Yarrambat Golf Course, there is a natural rock barrier (Closs, 1984). It appears that under higher flows, passage would be available to migrating fish. This is supported by fish survey data, which indicates the presence of the two migratory species, Common Galaxias and Short-fin Eel, upstream of these barriers (Raadik and Lieschke, 1999). Fish passage in the Plenty River could also be restricted during periods of low or zero flow when fish are confined to isolated pools. The removal of willows on the Plenty River, upstream of Arthurs Creek Road may benefit the native fish community by preventing the formation of willow root barriers.

6.6. Potential Effects of Irrigators and Toorourrong Reservoir

In comparison to the effects of Toorourrong Reservoir, diversions for irrigation and winter-fill are minimal. Nevertheless, the system is under such stress that any diversion may have an affect. During the summer low flow period, no water should be diverted for irrigation once the recommended minimum low flows are reached and especially during times of zero flow. The diversions in the winter-fill period are a high proportion of the 80th percentile daily exceedence flow (see section 7.1) and may require review.

7. ENVIRONMENTAL FLOW RECOMMENDATIONS

7.1. Summer/Autumn Low Flow Period (December to May)

The following environmental flow recommendations (Table 7-1) have been made using habitat availability plots (section 6.3), available flow gauging data from station 229216 (Plenty River at Mernda), derived inflows, extractions and outflows from Toorourrong Reservoir and observations made during fish and habitat surveys. In the case of the uppermost site, located on the West Branch of the Plenty River (S3), discharges were measured at a range of flows and an expert opinion was formed.

Large amounts of water are diverted from the Plenty River East Branch into Toorourong Reservoir throughout the year. This diversion of water, along with irrigation diversions, may have altered the flow regime of the Plenty River from perennial to ephemeral. The environmental flow recommendations we have made do not take into account water diverted from Toorourrong Reservoir into Yan Yean Reservoir. Water harvesting rights and passing flows in the Plenty River East Branch and Toorourrong Reservoir are currently being converted to a Bulk Water Entitlement, which is an agreement between the Victorian Government and Melbourne Water. This process is near completion and may facilitate increased passing flows from Toorourrong Reservoir.

The recommended environmental flows protect River Blackfish and other native fish habitat with regards to natural variations in habitat availability as determined from gauged or derived flow data. The flow recommendations are similar to those that may have naturally occurred (not including Toorourrong Reservoir extractions) during periods of very low flow. If the recommendations take into account Toorourrong Reservoir extractions a much higher volume of water is available. For example, in March (the driest month) an estimated 7.5 ML/d is extracted from Toorourrong Reservoir (see section 4) and 0.7 ML/d is extracted by licensed diverters (see section 7.1). Consequently, natural flows during this period may have been in the order of 8.2 ML/d.

With regards to the small volume of the recommended environmental flows, it appears that current discharges from the Whittlesea Sewage Treatment Plant (STP) (0.3 to 0.4 ML/d) may be important in maintaining at least some flow in the Plenty River. In future, it may be preferable that these discharges continue, particularly if the sewage is treated to a tertiary level. The alternative of disposing this water to land may further stress the Plenty River over the low flow period.

The small magnitude of the environmental flows is unlikely to destratify the pools in the mid to lower reaches of the Plenty River, consequently, low dissolved oxygen concentrations may remain a problem over the summer/autumn low flow period. Therefore it is essential that any flushes during the low flow period and the first high flows during May and June are allowed to pass through the system in an attempt to flush the mid to lower reaches of the Plenty River.

Table 7-1. Recommended minimum environmental flows for three locations in the Plenty River system.

Site No.	Location	Month	Flow (ML/d)
S1	Gordon's Road, Yarrambat (Nioka Bush Camp)	December	1.5
		January	1.0
		February	0.8
		March	0.8
		April	0.5
		May	1.5
S2	C. Mc Donald Reserve, Whittlesea	December	1.0
		January	0.5
		February	0.4
		March	0.4
		April	0.3
		May	1.0
S3	Wildwood Road, Whittlesea	December	0.2*
		January	0.1*
		February	0.1*
		March	0.1*
		April	0.1*
		May	0.2*

* Or natural, whichever is least

7.2. Winter-Fill Diversions

Water abstraction for winter-fill dams is conducted in the Plenty River system from May to December inclusive. Median flows during this period at station 229216 (Plenty River at Mernda) range from 1.5 ML/d during December to 18.8 ML/d during August (Figure 4-1). All flows during the winter-fill period are greater than 4.0 ML/d, except for December and May, when flows are less than 2.0 ML/d. The Plenty River appears to have a low annual discharge in relation to its catchment size when compared to other streams in the Yarra catchment such as Woori Yallock Creek (Zampatti *et al.*, 1999). Therefore, alterations to the naturally low flow regime through water abstraction will have a more pronounced impact on the aquatic flora, fauna and water quality in the system.

Many species of native fish require specific seasonal flow events to stimulate life history processes such as spawning and migration. For example, the threatened Australian Grayling spawns during the first high flow events at the end of autumn and juveniles migrate upstream during the high flow period of October to November (Koehn and O'Connnor, 1990). It is likely that a number of migratory fish species previously restricted from the Plenty River system (eg. Australian Grayling and Tupong (*Pseudaphritis urvillii*) may now recolonise the system by means of the Dights Falls fishway. Consequently, the recommended environmental flow regime for the Plenty River system must protect the requirements of these species.

In order to protect the environmental values of the Plenty River system and ensure that essential stream forming processes occur, (e.g. channel scouring, silt removal, mixing of stratified layers etc.) flows of a sufficiently large magnitude are essential

during the May to December period. It is not possible to quantify these flows using fish habitat availability data, however, a precautionary approach that maintains flow magnitude and variability during this important period may be used. It is recommended that winter-fill extraction not be conducted in the months of December and May. These months should be classed as low flow months and recommendations for their low flow requirements have been made in section 7.0.

It is recommended that winter-fill diversions may only commence once the 80th percentile daily exceedence flow for any given month (June to November) has been attained at station 229216 (Plenty River at Mernda) (Table 7-2). At flows above this level, 20% of the daily flow rate may be diverted for winter-fill dams and irrigation.

Table 7-2. 80th and 50th percentile exceedence flows at station 229216 (not including diversions) and daily winter-fill extraction rates (diversions upstream of gauging station 229216).

	May	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
80th percentile exceedence flow (ML/d)	0.4	1.8	2.8	5.7	5.6	3.5	1.3	0.2
50th percentile flow (ML/d)	1.6	4.2	10.1	18.8	17.0	13.6	5.2	1.5
Recommended extraction rate (ML/d)*	0.1	0.4	0.6	1.1	1.1	0.7	0.3	0.04
Current extraction rate (ML/d)	1.2	1.1	1.6	1.7	2.3	2.4	0.9	1.1

Based on 80th percentile exceedence flows.

The extraction rates in Table 7-2 include direct irrigation from May to December inclusive. These volumes have not been differentiated from winter-fill as they are a part of the overall demand for water from the Plenty River system during the higher flow months (see Appendix 1). Presently in the Plenty River system the demand for water from May to December is excessive, with no months having volumes within the recommendation of 20% of the daily flow at flows greater than the 80th percentile exceedence flow (Table 7-2). In addition to the removal of December and May from the winter-fill period, it is recommended that the winter-fill diversion rates from June to November be reviewed with the possibility of allowing higher extraction rates during August and topping up only in October and November.

7.3. Environmental Management Objectives

The primary environmental management objectives for the Plenty River system 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 the Plenty River system by migratory native fish species that can now utilise the Yarra River system by means of the Dights Falls fishway.*

2. *Maintain water quality in accordance with SEPP (Waters of Victoria) Schedule F7 Waters of the Yarra Catchment (Victorian Government, 1999).*

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

4. *Maintain remnants, and rehabilitate degraded areas, of indigenous riparian vegetation along Plenty River and its tributaries. In addition, ensure adequate buffer strips between cleared land and the streams.*

5. *Maintain suitable river blackfish habitat from December to May through the provision of environmental flows of the magnitude specified in this report.*

6. *Ensure that winter-fill diversions are set at a level that does not impact upon migration and spawning of native fish species or essential stream forming processes such as channel scouring and silt removal.*

7.4. Actions

With regards to the environmental management objectives, the following actions are recommended:

- May and December should be classified as low flow months and winter-fill extraction rates from June to November should be reviewed so as to minimise possible adverse effects on instream biota. It may be preferable to commence winter-fill diversion in August and possibly increase the level of diversion during this month only. Additionally, October and November should be used for top-up only.

- Ongoing biological monitoring and habitat assessment should be undertaken to assess the suitability of the recommended environmental flows. As new data becomes available it may be necessary to modify the environmental flow recommendations.

- Buffer strips of approximately 30 m in width are recommended between cleared land and the creeks (Dignon *et al*., 1996). Riparian vegetation should also be adequately fenced to prevent cattle access. Whilst most sites surveyed had some riparian vegetation, a number of areas, particularly the floodplain area from Whittlesea to Mernda, had a paucity of riparian vegetation or were dominated by exoitic species (e.g. downstream of Greensborough). These areas should be rehabilitated with suitable endemic vegetation and fenced.

8. ACKNOWLEDGEMENTS

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10.APPENDIX 1. DIVERSION DATA

PERMIT NO	ML YR	PURPOSE	PC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
464/610/0001	10	Irrigation	Ir	1.79	1.88	1.88	0.58	0.14	0.00	0.00	0.07	0.34	0.65	1.06	1.62	10
464/610/0003	3	Irrigation	Ir	0.54	0.56	0.56	0.17	0.04	0.00	0.00	0.02	0.10	0.20	0.32	0.49	3
464/610/0005	12	Irrigation	Ir	2.15	2.26	2.26	0.70	0.17	0.00	0.00	0.08	0.41	0.78	1.27	1.94	12
464/610/0007	2	Domestic & Stock	Do	0.23	0.23	0.20	0.16	0.13	0.12	0.13	0.12	0.13	0.15	0.17	0.22	2
464/610/5000	2	Domestic & Stock	Do	0.23	0.23	0.20	0.16	0.13	0.12	0.13	0.12	0.13	0.15	0.17	0.22	2
464/620/0002	5	Irrigation	Ir	0.90	0.94	0.94	0.29	0.07	0.00	0.00	0.04	0.17	0.33	0.53	0.81	5
464/620/0003	90	Off-Stream Dam Filling	Of	0.00	0.00	0.00	0.00	9.00	9.00	13.50	13.50	18.00	18.00	4.50	4.50	90
464/620/0005	73	Off-Stream Dam Filling	Of	0.00	0.00	0.00	0.00	7.30	7.30	10.95	10.95	14.60	14.60	3.65	3.65	73
464/620/0006	8	Irrigation	Ir	1.43	1.50	1.50	0.46	0.11	0.00	0.00	0.06	0.27	0.52	0.85	1.30	8
464/620/0007	6	Irrigation	Ir	1.07	1.13	1.13	0.35	0.08	0.00	0.00	0.04	0.20	0.39	0.64	0.97	6
				8.3	8.7	8.7	2.9	17.2	16.5	24.7	25.0	34.4	35.8	13.2	15.7	211.0
				0.27	0.31	0.28	0.10	0.55	0.55	0.80	0.81	1.15	1.15	0.44	0.51	0.58
466/000/0001	12	Irrigation	Ir	2.15	2.26	2.26	0.70	0.17	0.00	0.00	0.08	0.41	0.78	1.27	1.94	12
466/000/0004	50	Irrigation	Ir	8.95	9.40	9.40	2.90	0.70	0.00	0.00	0.35	1.70	3.25	5.30	8.10	50.1
466/000/0005	19	Off-Stream Dam Filling	Of	0.00	0.00	0.00	0.00	1.90	1.90	2.85	2.85	3.80	3.80	0.95	0.95	19
466/000/0006	7	Off-Stream Dam Filling	Of	0.00	0.00	0.00	0.00	0.70	0.70	1.05	1.05	1.40	1.40	0.35	0.35	7
466/000/5000	50	Off-Stream Dam Filling	Of	0.00	0.00	0.00	0.00	5.00	5.00	7.50	7.50	10.00	10.00	2.50	2.50	50
				11.1	11.7	11.7	3.6	8.5	7.6	11.4	11.8	17.3	19.2	10.4	13.8	138.1
				0.36	0.42	0.38	0.12	0.27	0.25	0.37	0.38	0.58	0.62	0.35	0.45	0.38
466/060/0001	15	On-Stream Dam Filling	On	0.00	0.00	0.00	0.00	1.50	1.50	2.25	2.25	3.00	3.00	0.75	0.75	15
466/060/0002	2	Domestic & Stock	Do	0.23	0.23	0.20	0.16	0.13	0.12	0.13	0.12	0.13	0.15	0.17	0.22	2
466/060/5000	4	Domestic, Stock & Commercial	Do	0.47	0.47	0.40	0.32	0.27	0.25	0.25	0.25	0.26	0.30	0.34	0.44	4
				0.7	0.7	0.6	0.5	1.9	1.9	2.6	2.6	3.4	3.4	1.3	1.4	21.0
				0.02	0.03	0.02	0.02	0.06	0.06	0.08	0.08	0.11	0.11	0.04	0.05	0.06
466/070/0001	24	Off-Stream Dam Filling	Of	0.00	0.00	0.00	0.00	2.40	2.40	3.60	3.60	4.80	4.80	1.20	1.20	24
466/100/5000	2	Domestic & Stock	Do	0.23	0.23	0.20	0.16	0.13	0.12	0.13	0.12	0.13	0.15	0.17	0.22	2
				0.2	0.2	0.2	0.2	2.5	2.5	3.7	3.7	4.9	4.9	1.4	1.4	26.0
				0.01	0.01	0.01	0.01	0.08	0.08	0.12	0.12	0.16	0.16	0.04	0.05	0.84

PERMIT NO	ML YR	PURPOSE	PC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
466/100/0001	57	Off-Stream Dam Filling	Of	0.00	0.00	0.00	0.00	5.70	5.70	8.55	8.55	11.40	11.40	2.85	2.85	57
	453			0.0	0.0	0.0	0.0	5.7	5.7	8.6	8.6	11.4	11.4	2.9	2.9	57.0
				0.00	0.00	0.00	0.00	0.18	0.19	0.28	0.28	0.38	0.37	0.10	0.09	0.16
				20.4	21.3	21.1	7.1	35.8	34.2	51.0	51.7	71.4	74.8	29.0	35.2	453.1
				0.7	0.7	0.7	0.2	1.2	1.1	1.6	1.7	2.3	2.4	0.9	1.1	14.6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Co	0.117	0.117	0.100	0.079	0.067	0.062	0.063	0.062	0.065	0.074	0.084	0.110	1.000
Do	0.117	0.117	0.100	0.079	0.067	0.062	0.063	0.062	0.065	0.074	0.084	0.110	1.000
In	0.090	0.090	0.090	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.090	1.000
Ir	0.179	0.188	0.188	0.058	0.014	0.000	0.000	0.007	0.034	0.065	0.106	0.162	1.001
Of	0.000	0.000	0.000	0.000	0.100	0.100	0.150	0.150	0.200	0.200	0.050	0.050	1.000
On	0.000	0.000	0.000	0.000	0.100	0.100	0.150	0.150	0.200	0.200	0.050	0.050	1.000
Fi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

APPENDIX 2. DEPTH PROFILES FOR EC AND DO AT SITES S1 AND S2

Plenty River S1 Gordons Rd						
Discharge	**Date**	**Depth**	**EC (µs/cm)**	**Temp (°C)**	**DO (mg/L)**	**Temp (°C)**
0 ML/d	12/03/99	2	5150	17.1	0	18
		1.5	2850	18.4	1.3	18.8
		1	1630	18.7	3.6	18.8
		0.5	1570	18.8	4.6	19.8
		0.2	1600	20	4.8	20.3
8.3 ML/d	17/06/99	2.5	1470	9.6	4.3	9
		2.25	720	8.8	5.4	8.4
		2	580	8.5	5.9	8.5
		1.5	415	8.3	9.3	8.3
		1	415	8.3	9.7	8.3
		0.5	413	8.3	9.6	8.4
		0.2	414	8.3	9.7	8.4
25.6 ML/d	17/08/99	2.8	2460	10.4	0.12	10.7
		2.5	2000	10	0.12	10
		2	470	8.8	9.95	9
		1.5	427	8.8	10.35	8.9
		1	428	8.8	10.37	8.8
		0.5	428	8.8	10.41	9
		0.2	427	8.8	10.48	9
67.9 ML/d	1/09/99	2.5	322	14.1	7.8	14.5
		2	322	14.1	9.2	14.2
		1.5	322	14.1	9.4	14.2
		1	320	14.1	9.7	14.2
		0.5	320	14.1	9.8	14.2
		0.2	319	14	9.9	14.3
Plenty River S2. C. McMillan Reserve, Whittlesea						
0 ML/d	11/03/99	1.15	419	16.7	0	16.7
		0.75	411	16.5	0	16.6
		0.5	401	16.4	0	16.6
		0.25	390	17	0	16.8
		0.15	384	17.1	0	17.1
		0.1	375	18.5	1.1	18.2
		0.05	364	20	2.8	20.1
3.7 ML/d	16/06/99	1.4	285	8.7	0.6	8.6
		1	240	8.5	6.02	8.6
		0.6	230	8.5	6.12	8.6
		0.2	213	8.5	6.19	8.6
		0.05	213	8.5	6.19	8.6
39.2 ML/d	31/08/99	2	246	15.3	7.05	15.5
		1.5	247	15.3	7.01	15.4
		1	247	15.3	7.05	15.4
		0.5	247	15.3	7.25	15.4
		0.2	247	15.3	7.27	15.4

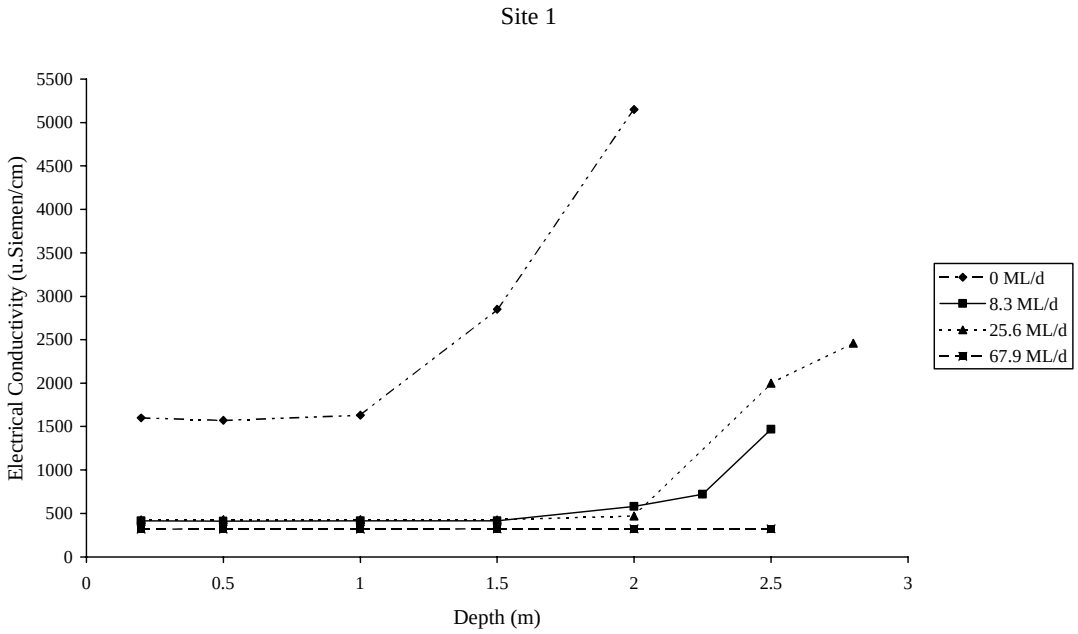

Figure A1. Electrical conductivity profile for four discharges at S1.

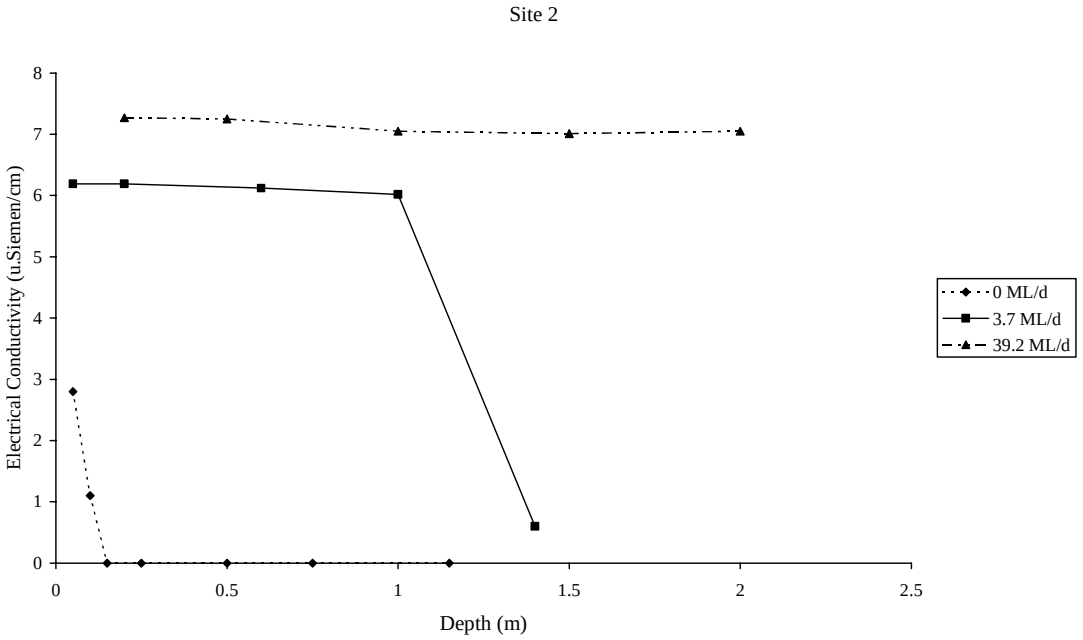

Figure A2. Dissolved oxygen profile for three discharges at S2

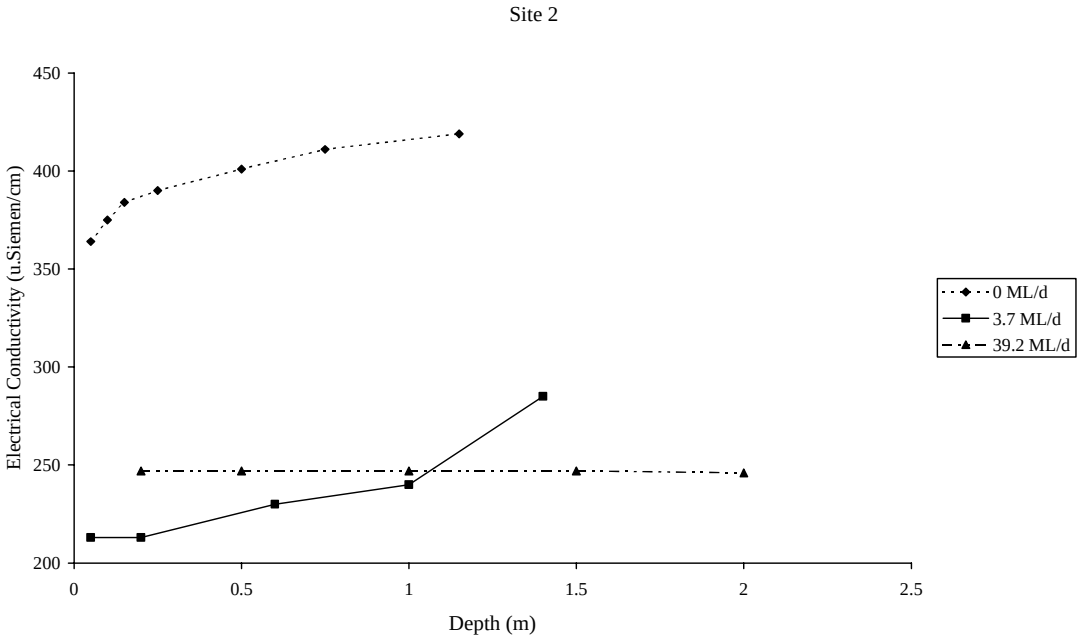

Figure A3. Electrical conductivity profile for three discharges at S2.