FRAMEWORK FOR PROVIDING ENVIRONMENTAL WATER FROM WESTERN MOUNT LOFTY RANGES STORAGES

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CONTENTS

Executive Summary

In 2006, a total of 15GL/yr was approved for trial releases of Environmental Water Provisions (EWPs) below SA Water supply reservoirs in the Western Mount Lofty Ranges. Trial release patterns and monitoring protocols were developed for:

- The South Para River between the Barossa Diversion Weir and Gawler;
- The Torrens River between Gumeracha Weir and Kangaroo Creek Reservoir;
- The Torrens River between Gorge Weir and Torrens Lake; and
- The Onkaparinga River between Clarendon Weir and the estuary.

The trial commenced in late June 2006, but was halted in October 2006 with the declaration of drought conditions in the Mount Lofty Ranges. Recently, water has become available to re-commence the trials, and the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB) and its partners (Department for Water and SA Water) decided to review the trial conditions in the light of recent information.

A workshop of relevant stakeholders was held in June 2011 to review ecological objectives to be achieved by the trial EWP releases and adjust the original trial release patterns and monitoring protocols to accommodate the review outcomes. The review used the following overarching objective:

> *… to deliver an EWP flow regime that maximises the probability of achieving self sustaining populations of biota that currently exist within the area. This involves improving environmental assets where they are in poor condition, and maintaining assets where they are in good condition. Where possible, the EWP will promote conditions for the support of environmental assets that have been lost (i.e. they are currently absent, but are predicted to have been present prior to water resource development).*
>
> *The EWP flow regime will reduce the likelihood of future degradation of assets, and increase their resilience to future drought conditions (including any temporary reduction in the EWP).*
>
> *to determine local environmental objectives and release patterns*.

Environmental Water Requirements for processes required to achieve the local environmental objectives were identified and from these, revised trial release patterns (compared to the 2005 protocols) were developed for each reach. The revised trial EWP releases involve the use of up to 16.74 GL/yr.

South Para River

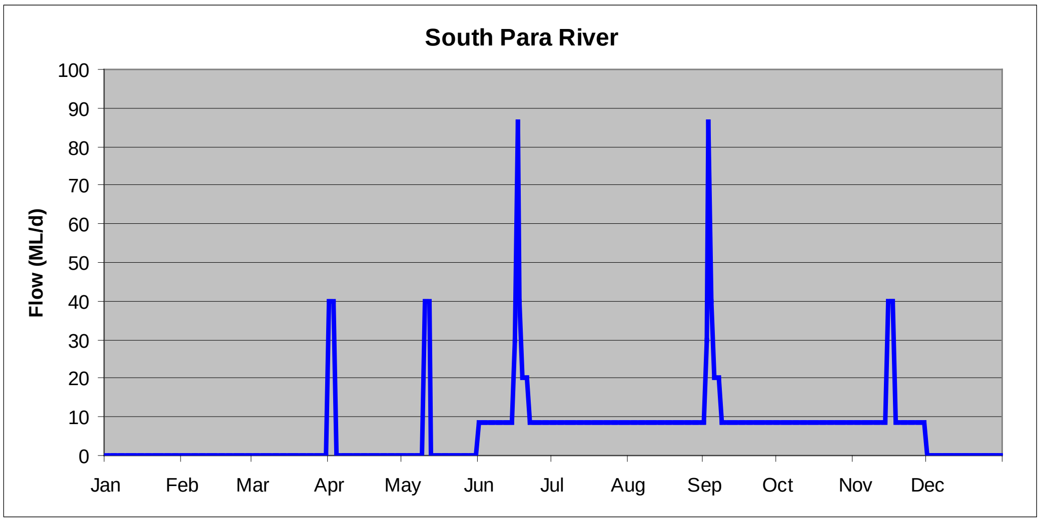
Environmental objectives identified for the EWP releases in the South Para River between the Barossa Diversion Weir and Gawler were:

- Water quality in isolated pools maintained at levels suitable for aquatic life over cease to flow periods;
- No degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction);
- A self sustaining population of Flathead gudgeon with higher abundances than currently present, and regular breeding and recruitment;
- An expanded Mountain galaxias distribution, with regular breeding and recruitment in the main channel of the South Para River;
- A reduced Redfin population in the upper part of the reach;
- No expansion in the distribution of Eastern gambusia;
- A reference condition macroinvertebrate community (typical of ephemeral streams in this habitat type);
- Sustainable in-stream vegetation communities; and
- Provision of a water source for riparian redgum communities in the lower part of the reach.

The revised trial EWP (2.25 GL/yr) consists of:

- An extended cease to flow periods from December to May;
- Two freshes, one in April and one in May (120 ML each over 2 days);
- A baseflow of 8.64 ML/d between June and November inclusive);

- Two flushes, one in June and one in September (231 ML each over 5 days);
- A fresh in November (72 ML over 1 day).



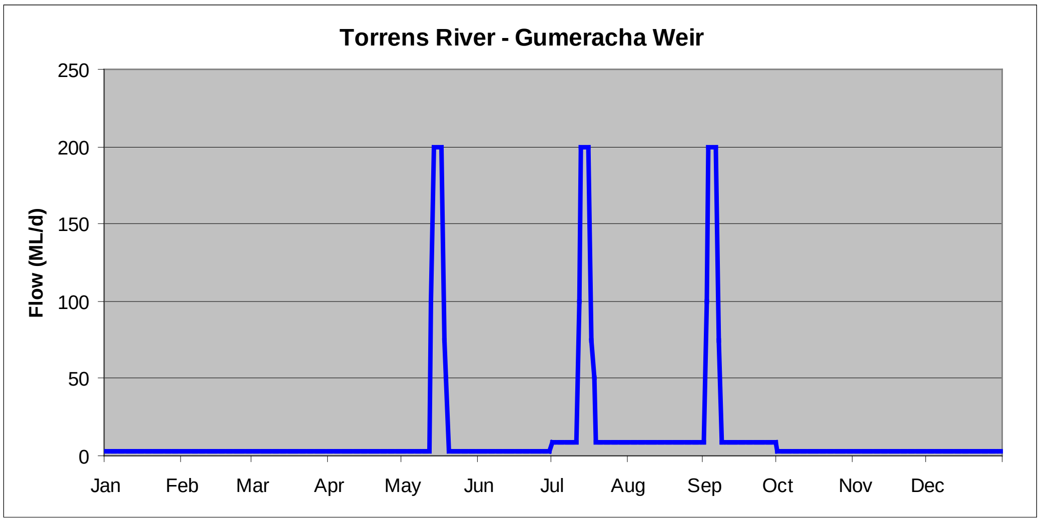
Torrens River - Gumeracha Weir to Kangaroo Creek Reservoir

Environmental objectives identified for the EWP releases in the Torrens River between Gumeracha Weir and Kangaroo Creek Reservoir were:

- Water quality in pools maintained at levels suitable for aquatic life during low flow periods;
- No degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction);
- Reduced *Typha* and/or *Phragmites* distribution in riffle/run areas;
- A self sustaining population of Climbing galaxias, which exhibits regular breeding and recruitment;
- Self-sustaining populations of Flathead gudgeons, Dwarf flathead gudgeons and Mountain galaxias with higher abundances than currently present, which exhibit regular breeding and recruitment;
- A reference condition macroinvertebrate community (typical of permanent streams in this habitat type); and
- Sustainable in-stream vegetation communities.

The revised trial EWP (4.49 GL/yr) consists of:

- A low flow of 2.5 ML/d continuous low flow from 1 October to 31 June;
- A low flow of 9 ML/d continuous low flow from 1 July to 30 September;
- Two flushes, over 5 days each, rising to a peak of 200 ML/d, one in May and one in July;
- A flush, over 5 days, rising to a peak of 200 ML/d, in September.



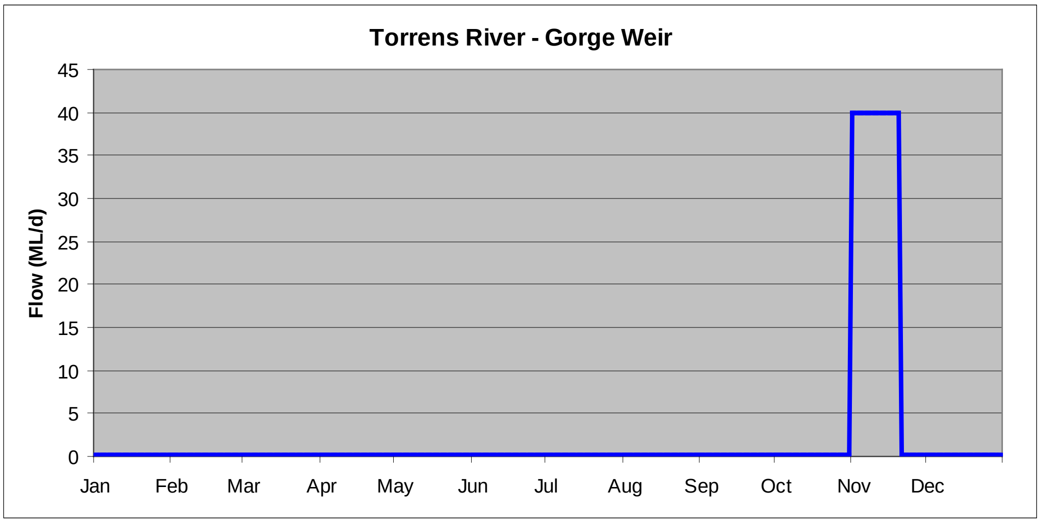
Torrens River - Gorge Weir to Torrens Lake

Environmental objectives identified for the EWP releases in the Torrens River between Gorge Weir and Torrens Lake were:

- Water quality improved to levels conducive for aquatic life survival during the year.
- No further degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction).
- Increased survival of adult native fish.
- Reduced Eastern gambusia populations.
- A macroinvertebrate community with increased representation of flowing water taxa.
- Sustainable in-stream vegetation communities.

The revised trial EWP (0.89 GL/yr) consists of:

- A low flow of 0.25 ML/d continuous low flow all year;
- A higher sustained flow of 40 ML/d for 20 days in November.



Onkaparinga River

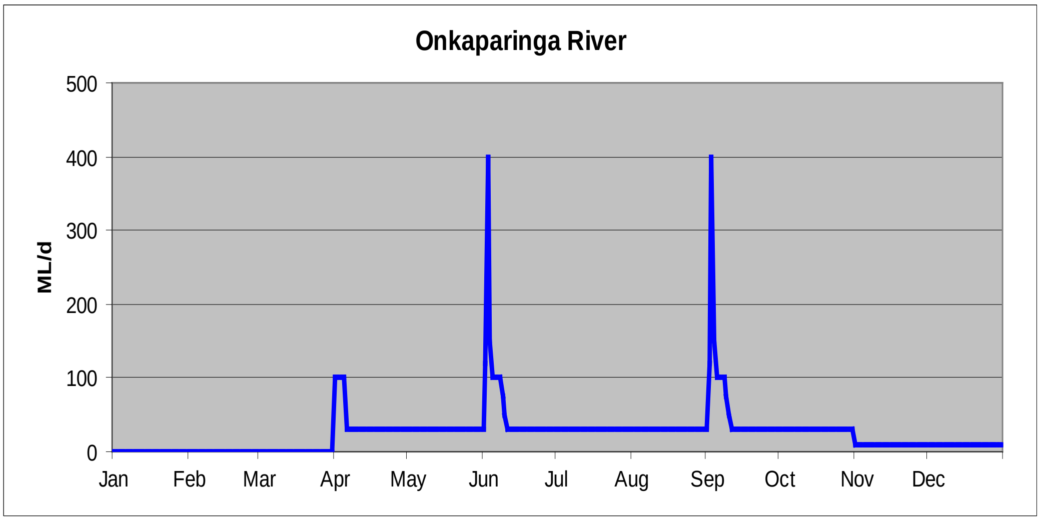
Environmental objectives identified for the EWP releases in the Onkaparinga River between Clarendon Weir and the Onkaparinga River estuary were:

- Water quality in isolated pools maintained at levels suitable for aquatic life during cease to flow periods;
- No further degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction);
- Regular recruitment into populations of diadromous native fish with species collected as far upstream as Clarendon Weir;
- Mountain galaxias, Dwarf flathead gudgeon, Flathead gudgeon populations with regular breeding and recruitment in the main channel;
- More stable populations of native fish species (preventing large swings in abundance and increased risk of localised extinctions);
- Discourage expansion of exotic fish species (range, abundance and population structure);
- A reference condition macroinvertebrate community (typical of ephemeral streams in this habitat type);
- Sustainable in-stream vegetation communities;
- Maintenance of native terrestrial species near the channel; and
- Reduced terrestrial plant species (particularly African fountain grass) within the main channel.

The revised trial EWP (9.11 GL/yr) consists of:

- Cease to flow from 1 January to 31 March

- A fresh of 100 ML/d for 4 days triggered by the first rainfall after 15 March, or 1 April (whichever is earlier);
- A low flow of 30 ML/d continuous from 1 April to 31 October;
- A low flow of 10 ML/d continuous from 1 November to 31 December;
- Two flushes, over 9 days each, rising to a peak of 400 ML/d, one in June and one in September (1195 ML each);



Monitoring

Monitoring components and evaluation metrics required to assess the impact of the trial EWP flow regime were developed for each reach. The monitoring components are adequate to evaluate all of the objectives of the trial in each reach. However, the design and scope of the actual final monitoring program will depend on the ability to streamline some of the components by finding surrogate properties of some for others and the amount of available funds for the process. If inadequate funds are available, variations to the program will need to be evaluated by the trial partners.

1 Introduction

In 2006 a total of 15 GL was made available for Environmental Water Provisions (EWPs) below SA Water supply reservoirs in the Western Mount Lofty Ranges, with an understanding that up to 16.7 GL/yr were the desired total volume at that time. The environmental water was to support aquatic ecological processes along river reaches downstream of the 4 in-stream weirs:

- Barossa Diversion Weir on the South Para River;
- Gumeracha Weir on the Torrens River;
- Gorge Weir on the Torrens River; and
- Clarendon Weir on the Onkaparinga River (Figure 1).

The releases were planned as a trial to evaluate draft conditions for the SA Water licence under the Western Mount Lofty Ranges Water Allocation Plan, to determine environmental responses to the flows, and to help inform the development of EWP regimes in other Mount Lofty Ranges rivers and streams. The trial commenced in late June 2006, but was halted in October 2006 with the declaration of drought conditions in the Mount Lofty Ranges.

Due to good rainfall during 2010, water has become available to provide EWPs below the four water supply weirs. In the time since the trials were first proposed, additional surveys have added to knowledge of the environmental values in each of the four trial reaches, and additional work on environmental water requirements and environmental responses to altered flows has been conducted in South Australia and elsewhere. In order that the EWP Program remain a current and best practise approach, it was decided to review the original trial conditions in the light of recent information. The focus of the review, instigated by the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB) and its partners (Department for Water and SA Water) is to develop a detailed framework for the trial that articulates the following:

- High level objectives and outcomes from EWPs in the Western Mount Lofty Ranges.
- Specific ecological objectives and outcomes of the trial.
- Prioritisation of reaches with respect to EWPs on the basis of ecological condition and likely responses to provisions.
- Determination of the best use/distribution of the 15GL/yr EWPs across trial reaches to ensure best "bang-for-buck".
- Appropriate hydrological and ecological data to inform the development of hydro-ecological relationships which can in turn be used to test and refine the achievement of trial objectives and outcomes.

A workshop of relevant experts (see Appendix A) was held between 15-16 June at the SA Water offices in Adelaide that looked in detail at each of the four trial reaches, assessed new information, set environmental objectives, evaluated and modified (where necessary) the 2005 trial EWP protocols, and set monitoring requirements.

In this report, each trial reach is described with the following information:

- A brief description of the physical nature of the reach and the impacts of current water resource development on the flow regime and any Environmental Water Requirements (EWR) that have been determined.
- A brief description of the environmental values of the reach. Values concentrate on fish, aquatic macroinvertebrates and in-stream and fringing vegetation. While other values may be present (such as biofilms), little information is available on the composition and condition of these values. It is expected that the EWPs will enhance these values, or at least, have no detrimental impact on the values.
- The environmental objectives for the reach, outlining the impact of the EWP on individual assets in the reach. The objectives have been developed with consideration of the constraints of the total EWP volume available in the reach, so some objectives that could be considered desirable are omitted. For example, no consideration is given to channel forming bankfull flows, or flows that connect the floodplain as these simply cannot be delivered in the EWP volume available (although they may occur in the reach due to natural floods and spillage from storages). Environmental Water Requirements

(EWRs) for the objectives are developed, based on recent work, including conceptual models developed for determining EWRs for the Mount Lofty Ranges and Kangaroo Island.

- A critical assessment of the 2005 EWP regimes as to whether they are likely to achieve the objectives.
- A statement of the proposed EWP, if different from the 2005 regime, with justifications based on the EWRs of the target biota.
- Monitoring and evaluation requirements to assess the success of the EWP in achieving the environmental objectives along with metrics that can be used to assess the success of the objectives.

Figure 1. Location of the four diversion weirs

2 Environmental Objectives

Setting environmental objectives is a critical stage in the EWP process. Without knowing what the EWP is meant to achieve at a regional and local scale, it is impossible to determine the appropriate flows, volumes and regimes required in a reach. For the Western Mount Lofty Ranges, the following high level objective has been adopted to inform the determination of EWP trial release patterns at each reach scale:

> *The goal is to deliver an EWP flow regime that maximises the probability of achieving self sustaining populations of biota that currently exist within the area. This involves improving environmental assets where they are in poor condition, and maintaining assets where they are in good condition. Where possible, the EWP will promote conditions for the support of environmental assets that have been lost (i.e. they are currently absent, but are predicted to have been present prior to water resource development).*
>
> *The EWP flow regime will reduce the likelihood of future degradation of assets, and increase their resilience to future drought conditions (including any temporary reduction in the EWP).*

In each of the four trial reaches, this objective was used to determine detailed local environmental objectives, which can be evaluated through the monitoring program. These local objectives can be described as one of two types: Habitat Objectives or Biodiversity Objectives. Habitat Objectives describe the physical changes in the stream system that arise as a result of introducing flows into the system (e.g. water quality, sediment regime). Biodiversity Objectives describe the outcomes for the flora and fauna in the stream as a result of the flow and habitat changes.

The objectives developed here need to be seen in the light of the volume of water available for the EWPs. There is insufficient water available to meet the full EWRs at a low level of risk. Therefore, the objectives represent the best possible predicted outcomes for assets that are present, within the available water.

Pre-trial data for native fish communities indicate that populations tend to either go through boom-bust phases, with irregular large increases in populations followed by dramatic decreases, or are found only at low population sizes. Both of these increase the risk of localised extinctions, and decrease the resilience of the communities to future periods of poor flow conditions. Therefore, one goal of the EWP is to increase the resilience of the native fish community present by “stabilising” the population changes with regular recruitment and increased survival rates to breeding age.

3 South Para River

Description and hydrology

The trial reach on the South Para River extends from the Barossa Diversion Weir downstream of the South Para Reservoir to Gawler at the junction of the South and North Para Rivers. The reach can be conveniently divided into two sections – upstream and downstream of the main tributary (Tenefeate Creek) – which have different land uses and stream structure.

Figure 2. South Para River trial reach showing locations mentioned in the text.

Between the Barossa Diversion Weir and Tenefeate Creek, the river mainly flows through the Para Wirra Recreation Park. Here, the river flows through dense riparian vegetation, primarily of Wattles, Callistemon and Redgum. The stream consists of relatively shallow pools (up to 2.5 m deep), with a substrate dominated by bedrock and cobbles. Pools are mainly separated by relatively steep cascades through boulders and cobbles.

Downstream of Tenefeate Creek to Gawler, the river flows through farmland and the surrounding vegetation is either cleared completely or impacted by grazing. Riparian vegetation, where present, consists predominantly of large remnant redgums and fringing reeds and sedges. The stream bed in pools remains predominantly bedrock and cobble, but with more deposits of finer sediments. Some riffle areas of gravels and cobbles can be found separating the pools.

During dry summers, the South Para River would have naturally stopped flowing, resulting in isolation of pools along the system. Water resource development has extended the duration and frequency of these cease to flow periods. It is estimated that regulation by the reservoir system had reduced flows below the

South Para Reservoir by 90%, with no flows at all between January and July (Pikusa and Bald 2005[1]). Currently, the upper part of the reach only receives flushing flows after the South Para Reservoir spills, about every 5 years (Figure 3, top).

Further downstream, inflows from Tenefeate Creek produce small seasonal winter flows (Figure 3, bottom), but still with generally negligible or no flows over the drier months (December/January to March/April.)

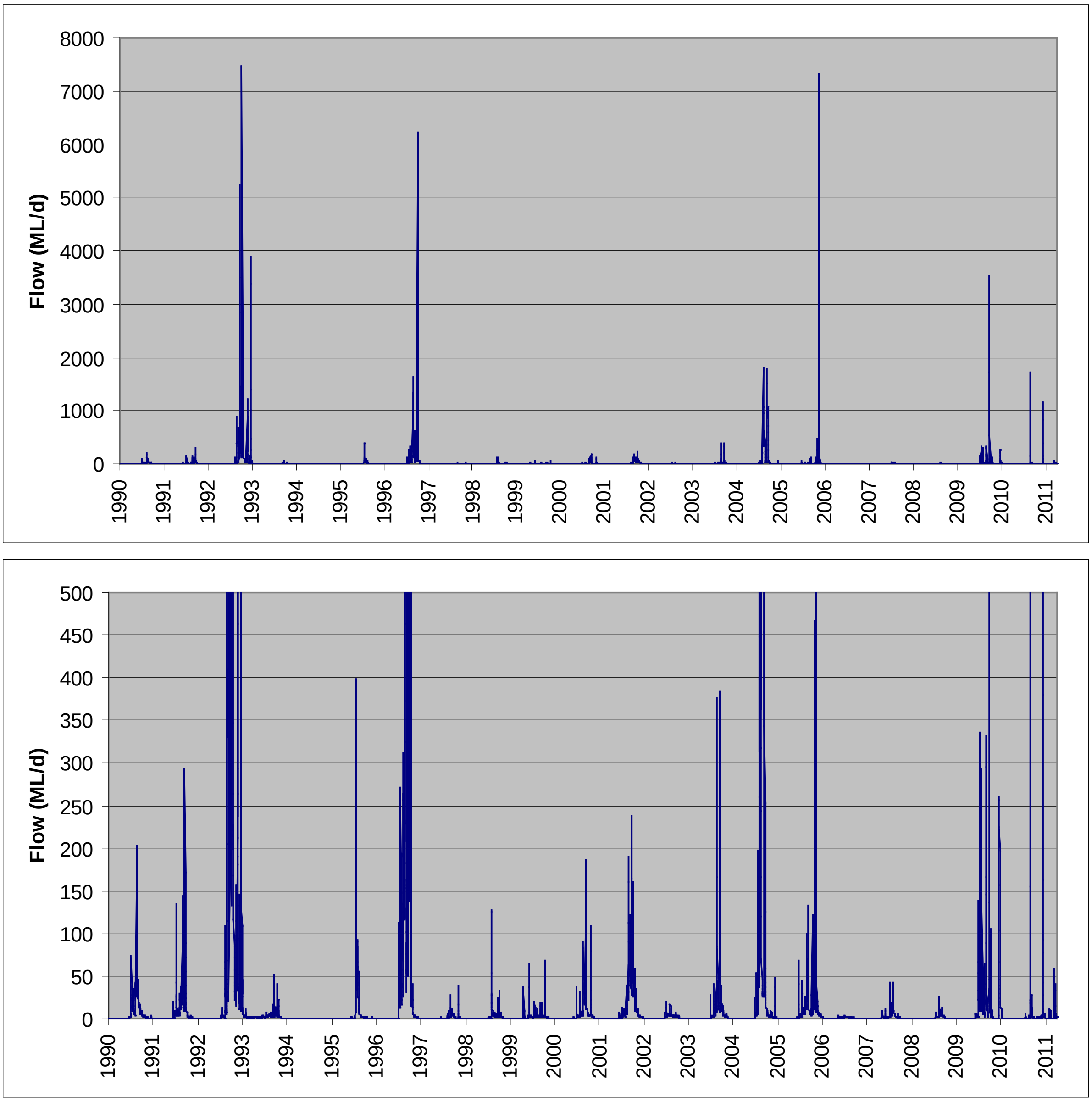


Figure 3. Hydrograph recorded upstream of Gawler (AW505503) between 1990 and 2011. Top – full hydrograph showing irregular spills from South Para Reservoir; Bottom – detail showing annual flows mainly from Tenefeate Creek.

An EWR for the South Para River was determined in 1998 by Philpott *et al*. (1999[2]) using a Scientific Panel Habitat Assessment Method (SPHAM). The EWR consisted of the need for four flow bands – Baseflow, Pool connection, Mid flow and Bankfull.

[1] Pikusa, E. and Bald, M. (2005) Environmental Water Provisions from SA Water Reservoirs in the Mount Lofty Ranges, South Australia. Department of Water, Land and Biodiversity Conservation, Adelaide.
[2] Philpott A, Rixon S and Pikusa E (1999) Determination of Environmental Water Requirements for the Gawler River System. Environment Protection Agency, Adelaide.

While flow rates were attached to each of the flow components, the EWR report indicates that an information gap that needed to be addressed was to determine the South Para Reservoir discharges required to achieve connective flows (Philpott *et al*. 1999, p. 42).

In 2004, the Barossa Diversion Weir was emptied for maintenance and the effects of the release (120 ML over 3 days) was evaluated (Walter 2005[3]). That suggested a flow rate of only 0.1 cumecs (8.6 $ML.day^{-1}$) was needed to achieve pool connection. The release of 120 ML traversed the entire reach, being noted upstream of Gawler (Station AW505503) with little transition losses, suggesting that all the pools in the reach had been filled.

Environmental values

Four native freshwater fish species and five introduced species were recorded in the reach between Autumn 2006 and Spring 2008.

In the upper part of the reach (Parra Wirra Recreation Park), only Flathead gudgeon and the introduced Redfin were found between Autumn 2006 and Spring 2008 (McNeil *et al*. 2011[4]). Further downstream at Nolan's, Flathead gudgeon and Eastern gambusia were the dominant component of the fish community, but low numbers of Common galaxias, Mountain galaxias and Redfin were also collected. At Woodlands Weir in the lower part of the reach, Flathead gudgeon, Common galaxias and small numbers of Congolli were the only native species captured, with a diverse array of introduced species – large numbers of Eastern gambusia, with smaller numbers of European carp, Goldfish, Tench and Redfin. The Congolli and Common galaxias recorded at the time (2006-2008) are understood to have been translocated into the reach from below Woodlands Weir, and the Mountain galaxias may be derived from tributary populations. Apart from the Flathead gudgeon, none of the native species seem to have viable populations in the reach under present conditions (possibly due to the current flow regime, or the presence of introduced species).

EPA health assessments in May and December 2005 showed the macroinvertebrate population to be in good condition in both edge and riffle habitats (although riffles were not present in May 2005).

There are few data on submerged and emergent in-stream vegetation. In-stream vegetation in the upper parts of the reach is restricted by the bedrock and cobble nature of the bed, with only a few observations of *Vallisneria* in upstream pools. Downstream sections, where the substrate is finer, more emergent stream flora can be found (such as *Schoenoplectus*, *Bolboschoennus*, *Typha*, *Juncus* and *Cyperus* – from transect drawings in Philpott *et al*. 1999).

Environmental Objectives and EWR

Because of the likely natural pre-development ephemeral nature of the flow regime, and the ephemeral regime in tributaries that may be a source of colonists to the reach, it is appropriate to maintain the ephemeral flow regime in the reach (as opposed to introducing a permanent baseflow throughout the year). It was considered that providing a low baseflow over the summer/autumn months could be ineffective as the lower parts of the reach are "losing", that is, any summer flows may move from the channel to recharge shallow aquifers. A permanent baseflow over summer may not be desirable as it could also have the deleterious effect of promoting the growth, recruitment and distribution of exotic fish species, which have been shown to have a deleterious impact on native fish species (e.g. Wilson *et al*., 2008[5]).

The Environmental Objectives identified for this reach are:

- Water quality in isolated pools maintained at levels suitable for aquatic life over cease to flow periods;
- No degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction);

[3] Walter M, (2005) South Para Reservoir Release, Department of Water, Land and Biodiversity Conservation, Report DWLBC 2005/10.
[4] McNeil, D., G., Schmarr, D. W., Wilson, P. J. and Reid D. J. (2011) Fish Community and Flow Ecology in the Western Mount Lofty Ranges. Final report to the SA Department for Water and the Adelaide and Mount Lofty Natural Resources Management Board. SARDI.
[5] Wilson, P.J., McNeil, D.G. and Gillanders, B.M. (2008) Impacts of introduced Redfin perch on native Flathead gudgeon in the South Para River. SARDI Aquatic Sciences Publication Number F2007/000882-1. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

- A self sustaining population of Flathead gudgeon with higher abundances than currently present, and regular breeding and recruitment;
- An expanded Mountain galaxias distribution, with regular breeding and recruitment in the main channel of the South Para River;
- A reduced Redfin population in the upper part of the reach;
- No expansion in the distribution of Eastern gambusia;
- A reference condition macroinvertebrate community (typical of ephemeral streams in this habitat type);
- Sustainable in-stream vegetation communities; and
- Provision of a water source for riparian redgum communities in the lower part of the reach.

While not included as a specific objective of the trial EWP flow releases, providing support for other native fish species in the reach (Congolli and Common galaxias), or other diadromous fish species that could potentially colonise the reach from below Woodlands Weir, has been a secondary consideration of the EWP flow regime. Under the EWP, it is hoped that these other native fish species present in the reach will at least survive the three year trial period, and may even reproduce.

With the barrier at Gawler Weir now removed, there is an opportunity to reconnect the trial reach with downstream, forming a complete link from the Barossa Diversion Weir to the sea. Future EWP discussions should consider flows in the Gawler River downstream of Gawler to the sea.

Environmental Water Requirements for processes required to achieve the objectives are listed in Table 1. These have been derived from recent work, including conceptual models developed for determining EWRs for the Mount Lofty Ranges and Kangaroo Island.

Table 1. EWRs for environmental objectives in the South Para River.

<table>
<tr><th>Process</th><th>Target taxa</th><th>EWR</th></tr>
<tr><td>Habitat availability</td><td>All taxa</td><td>Persistence of water in pools throughout the cease to flow period</td></tr>
<tr><td rowspan="3">Habitat quality</td><td rowspan="3">All taxa</td><td>High flow flushes[6] that scour pools and riffles</td></tr>
<tr><td>Persistence of water with sufficient depth to prevent excessive temperatures and salinity, and insufficient dissolved oxygen</td></tr>
<tr><td>Sustained higher flows that drown out terrestrial vegetation colonising channels</td></tr>
<tr><td>Recolonisation of vacant habitats and mixing of extant populations</td><td>Mountain galaxias, Flathead gudgeon</td><td>Periods of high flow that connect pools</td></tr>
<tr><td rowspan="2">Successful fish spawning</td><td>Mountain galaxias</td><td>Increase in flows over transitional period between Low and High Flow Season</td></tr>
<tr><td>Flathead gudgeon</td><td>Warm water temperatures during the Low Flow season combined with persistence of water</td></tr>
<tr><td>Discourage colonisation and establishment of exotic fish species</td><td>Redfin</td><td>Extended periods of zero flows</td></tr>
<tr><td rowspan="2">Ephemeral macroinvertebrate community</td><td rowspan="2">Macroinvertebrates</td><td>Persistence of water in pools</td></tr>
<tr><td>Six months flowing water over riffles (depth ≥10 cm)</td></tr>
<tr><td rowspan="2">In-stream vegetation</td><td rowspan="2">All taxa present</td><td>Persistence of water in pools</td></tr>
<tr><td>Variable depth on edges for germination (decline in flows in late spring)</td></tr>
<tr><td>Water source for riparian redgum</td><td>Redgums</td><td>Persistence of water in pools that maintains bank moisture</td></tr>
</table>

[6] Throughout this report, the term “flush” is used to refer to a large short-term flow increase that results in substantial increases in water depth and may fill most of the channel and generally occur over the winter/spring months. The alternative term “fresh” is used for smaller shorter flow increases that generally occur over the summer/autumn period.

2005 proposed EWP trial releases

The proposed 2005 trial releases consisted of:

- No flow releases from 1 January to 31 May;
- A 0.1 $m^3.s^{-1}$ (8.64 ML/d) continuous low flow from 1 Jun to 31 Dec; and
- Periodic 1 $m^3.s^{-1}$ (86.4 ML/d) flushes (5 events of 1 day each between June and October).

The ecological objectives of the EWP, outlined in Pikusa and Bald (2005) were to:

- Connect in-stream pools to increase aquatic habitat diversity and improve water quality; and
- Restore components of natural seasonality including high flow flushing events.

The total volume of the trial release was 2.24 GL/yr.

The resultant flow regime immediately downstream of the Barossa Diversion Weir is shown in Figure 4. Of course, with increasing distance downstream, inflows from groundwater and tributaries (particularly Tenefeate Creek) would modify this flow regime. Increasing distance would also attenuate the peak flows, lowering the peak volume and extending them over time.

However, a number of issues were identified associated with this regime. Over the five months of the no flow release, both water volume and water quality in the isolated pools would decline. The 12 pools used for the survey of fish populations in the reach had maximum depths of between 1.2 – 2.5 m deep (McNeil *et al*., 2011). Using a loss rate through evaporation or groundwater recharge of 1 cm per day[7], pools would decline to dryness in 120-250 days (4 months to 8 months). However, water quality deterioration to unsuitable levels would probably occur in a shorter time. Therefore, it could be predicted that water quality issues may arise in the latter part of the cease to flow period, probably in April or May.

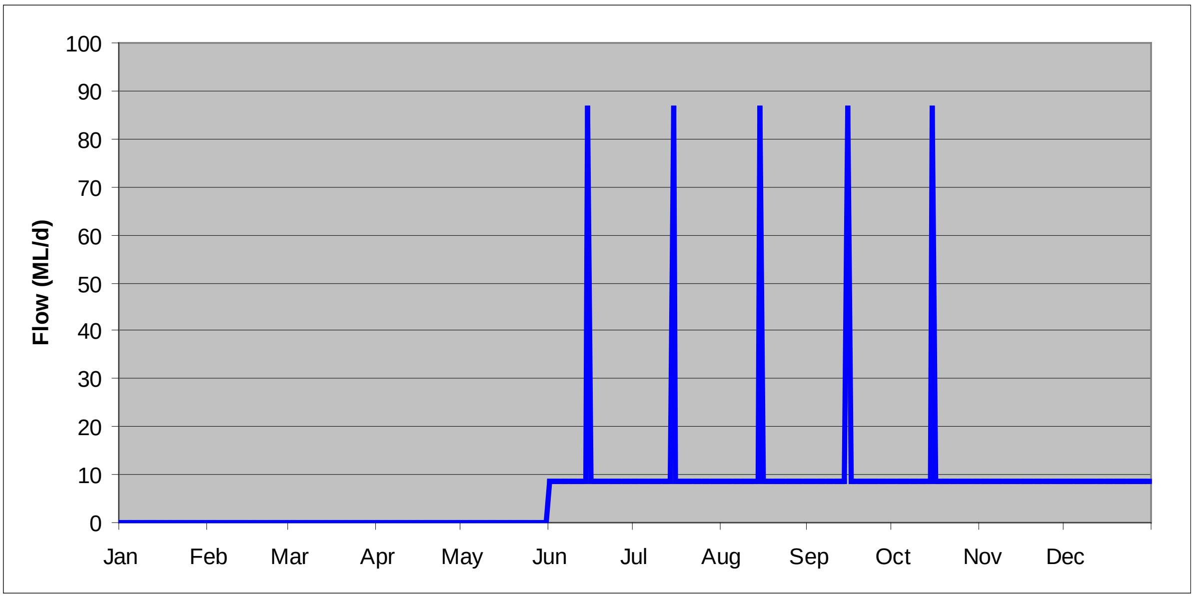


Figure 4. Proposed 2005 EWP trial releases for the South Para River.

While distance from the release point would attenuate the flush flow over time, each June to October flush still represent only a short period of high flows (1 day each). The sudden cessation of the flow would mean a rapid descending limb of the hydrograph near the weir, potentially causing stranding of moving fish and macroinvertebrates, and a large increase in macroinvertebrate drift. Such observations are common below hydro-electric dams with a pulsed release flow and rapid drawdowns.

Although not a specific objective of the EWP, flushes at this time of year usually are designed to allow local scale fish movement between pools to colonise areas that may have become vacant over the cease

[7] From data collected in the gorge section of Middle River, Kangaroo Island, the loss of water during the hotter months of January to April was estimated as up to 1 cm per day (P. McEvoy, unpublished data).

to flow period, or for wider movement at the reach scale. Such movement of fish occurs in late autumn/early winter and spring, so the August flush, at least, would seem to have no specific function. The short nature of the flush flow (1 day) would also restrict the distance that fish could move while the flows were high.

Revised EWP trial releases

At the 15-16 June workshop, the EWP trial releases were redesigned to more align with the objectives noted above. The revised monthly trial release is described in Table 2 and graphically depicted in Figure 5. Each of the individual flow components can be linked to all or part of the individual objectives above.

The revised trial EWP consists of:

- An extended cease to flow periods from December to May;
- Two freshes, one in April and one in May (120 ML each over 2 days);
- A baseflow of 8.64 ML/d between June and November inclusive);
- Two flushes, one in June and one in September (231 ML each over 5 days);
- A fresh in November (72 ML over 1 day).

The total annual volume of the revised EWP is the same as the 2005 EWP at 2.25 GL.

It was considered desirable to maintain a degree of stress in the system over the drier months. Maintaining an extended cease to flow period between December (starting the cease to flow earlier than the 2005 EWP) and May, should produce conditions unsuitable for the introduced Redfin survival and recruitment. Redfin recruitment has been shown in this reach to have a detrimental impact on Flathead gudgeon populations (McNeil *et al*. 2011).

Redfin have been shown to be more susceptible to extended water quality and pool volume decline than Flathead gudgeon. However, reduced water quality condition can be expected in the April and May period, so relief flows should be introduced during this period, with the objective of refilling all the pools with fresh water. A fresh with a total volume of 120 ML has been shown to refill all pools in the reach (Walter 1995). It would be desirable that the fresh occurs over a short time period (2 days) to restrict the ability of exotic species (especially gambusia which is absent in the upper reach) to colonise further up the reach, and to reduce the possibility of a blackwater event (seen after long dry periods with the introduction of low level baseflows).

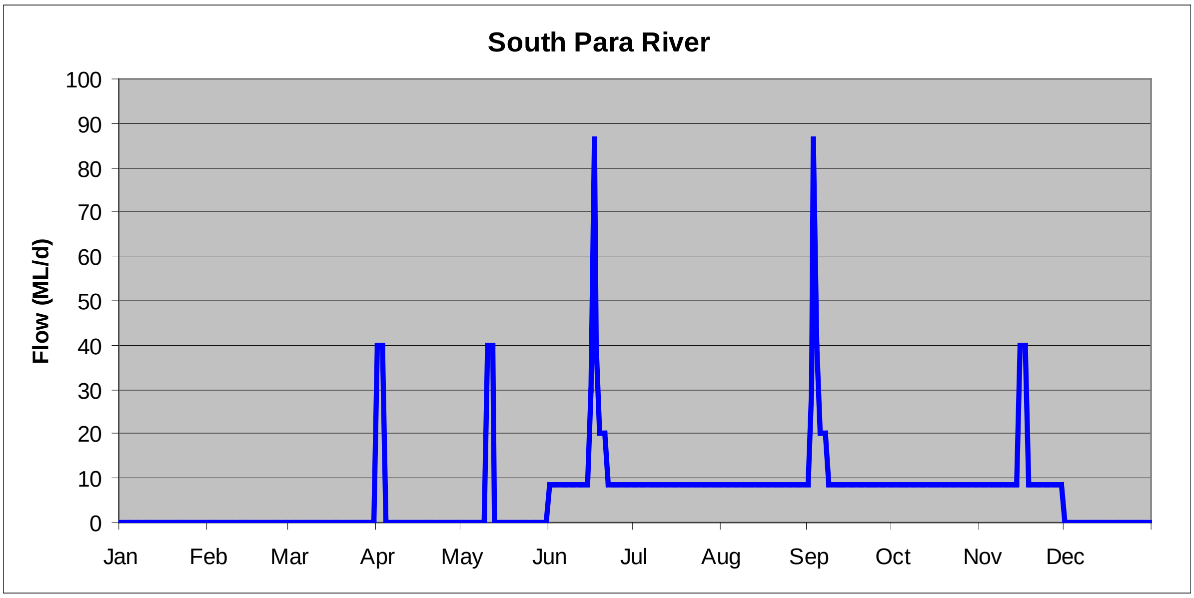


Figure 5. Revised EWP trial releases for the South Para River

Table 2. Revised EWP trial releases for the South Para River

Month	EWP Band	Volume (ML) Total	Volume (ML) ML/day	Frequency	Duration	Comments/triggers
Jan	Cease to flow	0	0	n.a.	All of month	
Feb	Cease to flow	0	0	n.a.	All of month	
Mar	Cease to flow	0	0	n.a.	All of month	
Apr	Cease to flow	0	0	n.a.	All of month except fresh	
	Fresh	120		One	2 days	1st rainfall event after 1 Mar, otherwise 1 Apr
May	Cease to flow	0	0	n.a.	All of month except fresh	
	Fresh	120		One	2 days	1st two weeks May after rain, by 15 May latest
Jun	Baseflow	216	8.64	Daily	All of month except flush	Delivered through weir valve
	Flush	231		One	5 days	1st rainfall event after 1 June, otherwise 30 June
Jul	Baseflow	268	8.64	Daily	All of month	Delivered through weir valve
Aug	Baseflow	268	8.64	Daily	All of month	Delivered through weir valve
Sep	Baseflow	216	8.64	Daily	All of month except flush	Delivered through weir valve
	Flush	231		One	5 days	1st rainfall event after 1 Sep, otherwise 30 Sep
Oct	Baseflow	268	8.64	Daily	All of month	Delivered through weir valve
Nov	Baseflow	242	8.64	Daily	All of month except fresh	Delivered through weir valve
	Fresh	72		One	2 days	1st three weeks Nov after rain, by 21 Nov latest
Dec	Cease to flow	0	0	n.a.	All of month	Delivered through weir valve
	Total	**2,252**				

Within the current EWP volume, two flushes of 120 ML each could be delivered in April and May. Operationally, this can be achieved by simply opening the scour valve on the weir 50 turns and allowing the weir to drain over 2 days (as in Walter 1995). For the trial, the timing of the first fresh should coincide with the first natural rainfall event in the catchment after 1 March, but should be delivered on 1 April if this does not occur. The second can be delivered in the first two weeks of May, again triggered by rainfall, but by 15 May if this does not occur. However, it may be that water quality concerns arise earlier or later, so the timing of releases in subsequent years should be informed by monitoring data collected in the first year.

The baseflow over the June to December can be delivered through the knife gate valve installed for flow delivery at Barossa Diversion Weir. Maintaining a baseflow over the June to December period allows riffle macroinvertebrates to complete their life cycle, wets the banks for redgum watering, and provides suitable conditions for in-stream and fringing vegetation. It is unsure whether this level of flow allows for broad scale fish movement, but is unlikely given the boulder/cascade nature of the bed.

There is the possibility that the duration of the cease to flow period may result in local extinctions of all fish species in shallow pools, including Flathead gudgeon. In order to allow re-colonisation of native species into these habitats, periods of fish passage need to be provided. To achieve fish movement, higher flows over extended periods need to be released from the South Para Reservoir. To prevent stranding, the flow needs to decline slowly on the receding limb as in Figure 6. While the design of the flow in Figure 6 is precise, there may need to be operational considerations taken into account before a final flush design is adopted.

The peak rate of the flush flow is constrained by the capacity of the culvert at the Bassnet Road crossing. Two such flows, with elevated flow rates over a period of five days are suggested at the times of greatest fish activity – June and September. The precise timing of the flows should coincide with local rainfall events after the start of June and September, but if these do not occur, should be delivered at the end of these months.

A final fresh (72 ML) should be delivered just before the re-introduction of the cease to flow period in December. This has the function of refreshing water quality and providing a degree of scour to ensure habitats (particularly gudgeon spawning areas) are in the best condition prior to the cease to flow.

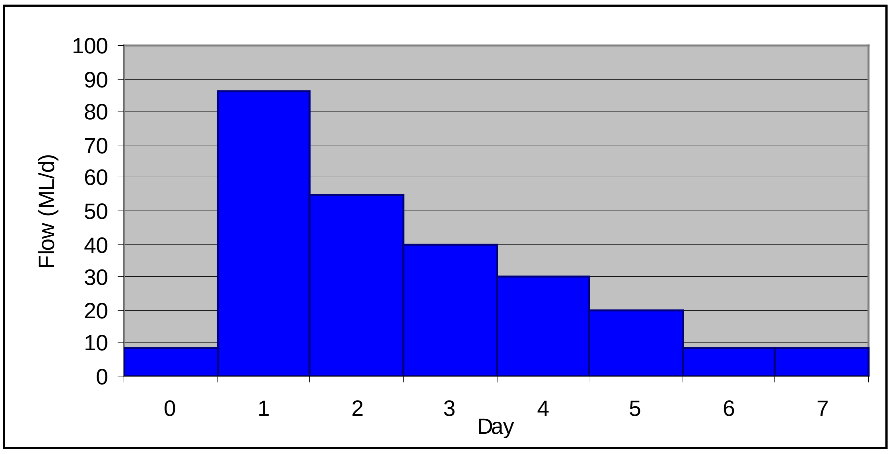


Figure 6. Recommended high flow flush designed for a 5 day period (volume = 231 ML).

Each of the flow components of the revised EWP can be linked to water requirements necessary to achieve one or more of the environmental objectives (Table 3).

Limiting factors

In the upper sections of the reach (above Tenefeate Creek in the Para Wirra recreation Park), there would seem to be no external influences that could cause the failure of the objectives. Further downstream, the poor state of the riparian vegetation, along with cattle access to the stream channel, could result in degraded water quality, reductions in leaf-fall access to the stream, low levels of shading (and therefore elevated stream water temperatures, higher evaporation and lower dissolved oxygen). Riparian fencing and revegetation would seem to be the best catchment activity to assist the objectives.

Table 3. Flow components of the EWP for the South Para River and functions towards achieving the objectives

Flow Component	Function
Cease to Flow (Jan-Mar)	Reduce breeding, recruitment, growth and survival of Redfin
120 ML Freshes (April – May)	Refill pools and improve water quality
Baseflow (June to December)	Allow for macroinvertebrate growth and breeding Provide for in-stream and fringing vegetation Wet the banks for redgum watering
June Flush	Fish movement through the reach
September Flush	Fish movement through the reach
November Fresh	Reset habitat conditions in preparation for cease to flow period Scour surface silt from Flathead gudgeon spawning sites

Removing the barrier to fish passage at Woodlands Weir (and other barriers identified) would seem to be a potential benefit to achieving the objectives by providing a larger source of fish colonists to the reach. However, as stated, providing support for other native fish species in the reach (Congolli and Common galaxias), or other diadromous fish species is not included as a specific objective of the trial EWP flow releases.

Other in-stream barriers in the reach may restrict the movement of native fish. A survey of instream barriers and threats is currently being undertaken by SARDI and the AMLRNRMB.

Additional inflows from Tenefeate Creek would provide valuable support to the EWP. Some flows in the lower parts of the reach can be attributed to the creek (Figure 3), but farm dams on the creek may limit this support, although the true extent of flows from the creek remains unknown. Prioritisation of any planned low flow bypass installations within this catchment as part of Water Allocation Plan implementation process should be considered.

Monitoring

The monitoring components and evaluation metrics required to assess the impact of the trial EWP flow regime in the South Para River are shown in Table 4. The monitoring components shown are adequate to evaluate all of the objectives of the trial. However, the design and scope of any monitoring program will depend on the amount of available funds for the process. If inadequate funds are available, variations to the program will need to be evaluated by the trial partners.

There is also a need to develop evaluation criteria for the metrics, along with reporting an feedback arrangements in conjunction with the monitoring program.

Table 4. Monitoring components linked to objectives and evaluation metrics for the South Para River.

Hydrological components	Monitoring	Metrics
Cease to flow (December to May)	Gauging at Barossa Diversion Weir A5050501 (to evaluate releases) Gauging at Woodlands Weir gauge A5050503 (to evaluate losses, transmission and tributary inputs)	% of time with no recorded flow (compared to inflow)
April fresh (120 ML)		Target volume delivered (Y/N) Total volume delivered (ML) Highest flow achieved (ML/d) Duration of elevated flows (days/hours)
May fresh (120 ML)		Target volume delivered (Y/N) Total volume delivered (ML) Highest flow achieved (ML/d) Duration of elevated flows (days/hours)
8.64 ML/d baseflow (June to November)		% of time with recorded flow => 8.64 ML/d
June flush (231 ML)		Target volume delivered (Y/N) Total volume delivered (ML) Highest flow achieved (ML/d) Duration of elevated flows (days/hours)
September flush (231 ML)		Target volume delivered (Y/N) Total volume delivered (ML) Highest flow achieved (ML/d) Duration of elevated flows (days/hours)
November fresh (72 ML)		Target volume delivered (Y/N) Total volume delivered (ML) Highest flow achieved (ML/d) Duration of elevated flows (days/hours)

Hydraulic components	Monitoring	Metrics
Habitat availability (cease to flows)	Continuous depth monitoring. Multiple sites covering a range of pool sizes and maximum depths	Rate of depth reduction over time Volume of pool compared to drying time
Habitat increase due to pool refilling (April and May freshes)	Gauging at Woodlands Weir (A5050503)	Increase in flow at Woodlands Weir (A5050503) due to releases (Y/N)
Fish passage (June and September flushes)	Depth of water over shallow restrictions	Provision of connecting depth >10 cm between pools (Y/N). Tied with Response monitoring (movement) of Mountain galaxias (see below)

Environmental Objective	Monitoring	Metrics
Water quality in isolated pools maintained at levels suitable for aquatic life	Continuous (preferably) water quality sampling throughout the cease to flow period, measuring water temperature, salinity and dissolved oxygen. Multiple sites covering a range of pool sizes and maximum depths	Water temperature (maximum) Salinity (maximum) Dissolved oxygen (minimum) % of time, and absolute duration, above or below known tolerance thresholds (%, days)
No degradation of in-stream habitat conditions	Physical habitat condition monitoring during biotic surveys (substrate condition etc) as outlined in the Design Report (McEvoy 2006[8]). Index of Riverine Condition (IRC) at the start and end of the trial	Change in habitat variables Change in IRC value
A self sustaining population of Flathead gudgeon with higher abundances than currently present, and regular breeding and recruitment	Bi-annual sampling of fish community at three large pool sites used in the 2006-2008 survey, plus 3 smaller pool sites Response monitoring (movement) of Mountain galaxias to June and September flushes Assessment of native fish condition	Number of years with recruitment Population size Population structure (number of age classes present) Fish Condition Index
An expanded Mountain galaxias distribution, with regular breeding and recruitment in the main channel of the South Para River		Presence/absence of Mountain galaxias Frequency of recruitment Population size Population structure (number of age classes present) Fish Condition Index Presence and abundance in directional netting
A reduced Redfin population		Presence/absence Frequency of recruitment Population size Population structure
No expansion in the distribution of gambusia		Presence/absence
A reference condition macroinvertebrate community (typical of ephemeral streams in this habitat type)	Spring and Autumn condition assessment of macroinvertebrate communities using established standard assessment techniques (3 sites)	Taxonomic richness Life form diversity Similarity to assemblages in reference streams
Sustainable in-stream vegetation communities	Spring and Autumn transect based survey at 3 sites using the protocol based on the methods used in the Onkaparinga as described by Nicol and Bald (2006[9])	Presence/absence of in-stream species % cover Presence and condition of recruits (young plants)
Provision of a water source for riparian redgum communities	Redgum leaf condition index at start and end of trial	Visual assessment of redgum condition (see Souter *et al*. 2009[10])

[8] McEvoy, P. (2006) Design and Implementation of a Monitoring Program to Quantify Ecological Responses to Flow in the Mount Lofty Ranges. Australian Water Quality Centre, Salisbury.
[9] Nicol, J. and Bald, M. (2006) In-stream and Riparian Vegetation of the Onkaparinga River between Clarendon Weir and Old Noarlunga. Implications for Environmental Water Provisions. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 62pp. SARDI Publication Number RD 04/0199
[10] Souter, N.J., Watts, R.A., White, M.G., George, A.K., McNicol, K.J (2009) Method manual for the visual assessment of lower River Murray floodplain trees. River red gum (*Eucalyptus camaldulensis*), DWLBC Report 2009/25, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

4 Torrens River – Gumeracha Weir to Kangaroo Creek Reservoir

Description and hydrology

The trial reach on the Torrens River extends from Gumeracha Weir to the head of the Kangaroo Creek Reservoir. The reach can be conveniently divided into two sections based on land use, stream structure and hydrology, with the dividing point located at the junction of the Torrens River and Millbrook Creek.

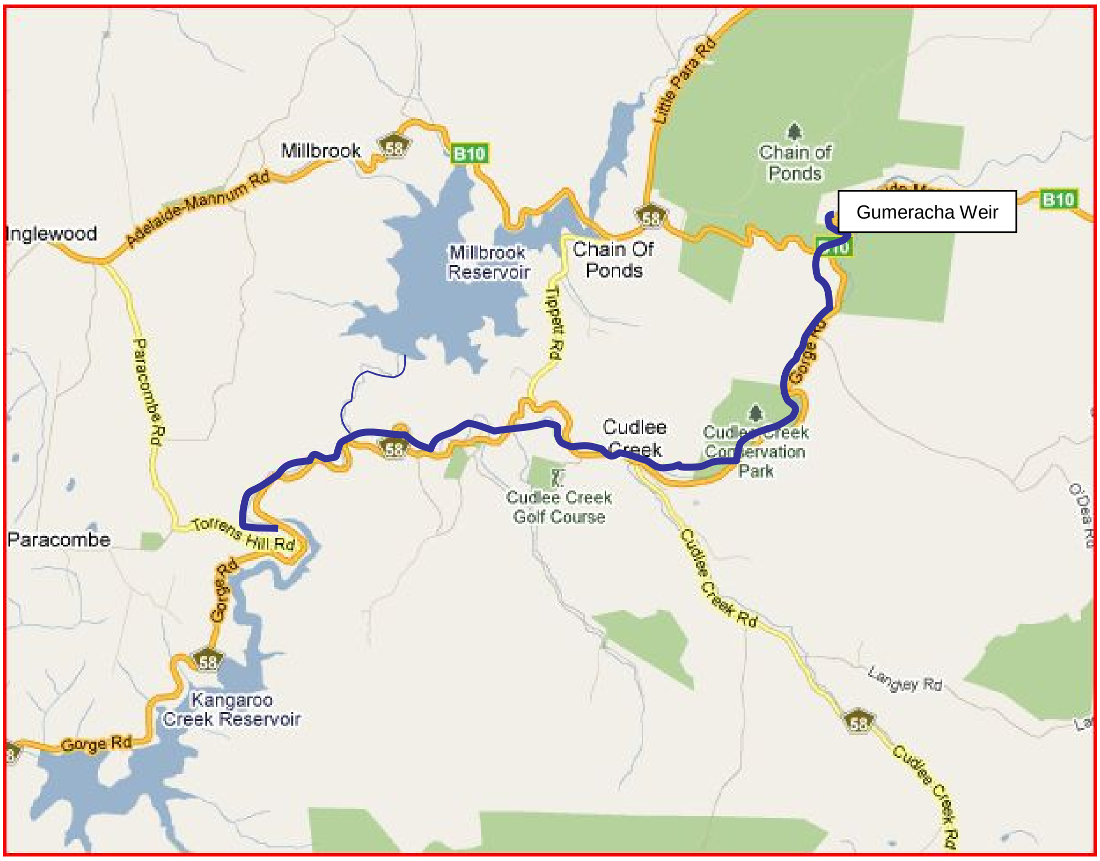


Figure 7. Torrens River trial reach between Gumeracha Weir and Kangaroo Creek Reservoir.

Downstream of Gumeracha Weir, the Torrens River streambed has deep pools (to 2 m deep) with bedrock and cobble to boulder sediments. Riparian cover is reasonable, with an overstorey of redgums, wattle and callistemon. Cumbungi and/or Phragmites beds are present around the edges of pools, but have also become established in intervening run/riffle areas. In part, the section runs through the well-vegetated Cudlee Creek Conservation Park, and is augmented by flows from a number of smaller tributaries (including Cudlee Creek).

The 2 km section of the reach downstream of Millbrook Creek is used as a transfer for water from Millbrook Reservoir to Kangaroo Creek Reservoir. While there is no flow gauging in the section of the reach, according to water level records for Millbrook Reservoir, the storage is drawn down from late each year to the following mid year, suggesting regular flows through this small section of reach.

Gumeracha Weir collects all but the highest natural inflows for transfer to Millbrook Reservoir (along with water diverted from the Murray River), so flows immediately downstream of the weir are severely affected. The diversion capacity of 800 ML/d (Schultz 2004[11]) means only inflows higher than this spill over the weir (Figure 8) or where water is released from Gumeracha Weir to be transferred to Kangaroo Creek reservoir. Millbrook Reservoir is generally kept at a low level at the start of the wet season to allow maximum capture of water, so downstream of Gumeracha Weir flows are regularly zero during the drier

[11] Schulz, P. (2004) A proposal for the provision of environmental flows in the River Torrens catchment. Briefing Note Environmental Flows River Torrens Technical & Planning Committee Jan 04.

months, with periods of cease to flow even in wetter months when inflows are below the diversion capacity.

The lack of flows over much of the year results in severe drawdowns in pool volume during the drier months. In one pool downstream of Cudlee Creek, water depth fell from 2 m maximum depth in Spring 2007 to only 0.3 m depth in Autumn 2008 (McNeil *et al*. 2011[12]).

No formal EWR study has been conducted in this reach. Schultz (2004) suggested an EWR for the reach should include "a minimum summer entitlement and a maximum period of no-flow for all seasons".

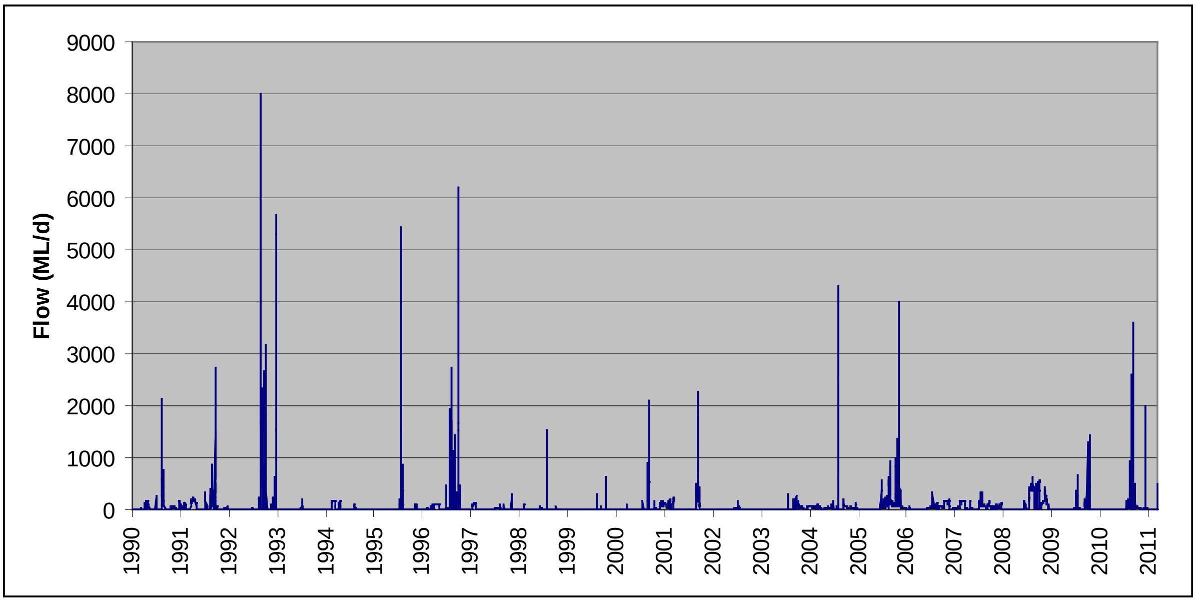


Figure 8. Hydrograph recorded downstream of Gumeracha Weir (A5040500) between 1990 and 2011.

Environmental values

Between 2006 and 2008, five native fish species were captured in the reach – Climbing galaxias, Mountain galaxias, Dwarf flathead gudgeon, Flathead gudgeon and Bony herring. Exotic fish species in the reach consisted of European carp, Redfin, Eastern gambusia and Brown trout (McNeil *et al*. 2011).

The population of Climbing galaxias is particularly significant. It is the only occurrence of the species in the Torrens River displaying regular recruitment. As a diadromous species, the population in this reach is believed to be landlocked, restricted from accessing the sea by the Kangaroo Creek Reservoir. It may be that the reservoir is being used as a surrogate for the sea, or the species may have adapted by losing the requirement to migrate and breeds and recruits locally.

In general, numbers of individuals of most native species were low, with the community dominated by Flathead gudgeon, Redfin and Eastern gambusia. Population sizes fluctuated wildly between seasons (e.g. over 3000 individuals in Autumn 2006 to less than 50 individuals in Spring 2007 at a site downstream of the weir), and the relative proportions also changed greatly between sampling occasions.

The presence of a single individual of Bony herring in the reach is the first record of this species in the South Australian Gulf drainage basin. This is almost certainly the result of translocation from the neighbouring Murray River catchment, possibly through bird vectors, but more likely as a result of a transfer through Murray water pipeline, which enters the Torrens River just upstream of the capture site (McNeil *et al*. 2011). Despite being a native species to Australia, there is the potential for the species to become established in the Torrens River to the detriment of local native species (see Section 0 below).

Three sites sampled for macroinvertebrates demonstrated good quality communities are present in the reach, either equivalent to reference condition or more diverse than expected.[13]

[12] Depending on the timing of sampling, this is broadly in line with the 1 cm per day decline seen in pools on Kangaroo Island.
[13] http://www.environment.gov.au/water/publications/environmental/rivers/nrhp/health/pubs/mt-lofty-ranges.pdf

Little work has been conducted on the aquatic plants in the reach. *Typha* and *Phragmites* were present at most of the pools sampled for fish, but also in riffle/run areas between pools. From anecdotal evidence (J. Nicol, PIRSA-SARDI, pers. comm.) aquatic plants like *Triglochin* are present.

Environmental Objectives and EWRs

It is likely that the reach once had a permanent flow regime with few periods of cease to flows prior to regulation. Given the presence of a significant Climbing galaxias population, which has a habitat preference for riffle areas, introducing a permanent flow would allow access to these areas (also producing a refuge from predation by exotic species if not too deep). A permanent regime may also benefit riffle/run habitat by preventing the spread of *Typha* and *Phragmites* in these areas.

The Environmental Objectives identified for this reach are:

- Water quality in pools maintained at levels suitable for aquatic life during low flow periods;
- No degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction);
- Reduced *Typha* and/or *Phragmites* distribution in riffle/run areas;
- A self sustaining population of Climbing galaxias, which exhibits regular breeding and recruitment;
- Self-sustaining populations of Flathead gudgeons, Dwarf flathead gudgeons and Mountain galaxias with higher abundances than currently present, which exhibit regular breeding and recruitment;
- A reference condition macroinvertebrate community (typical of permanent streams in this habitat type); and
- Sustainable in-stream vegetation communities.

Environmental Water Requirements for processes required to achieve the objectives are listed in Table 5. These have been derived from recent work, including conceptual models developed for determining EWRs for the Mount Lofty Ranges and Kangaroo Island.

Table 5. EWRs for environmental objectives the Torrens River downstream of Gumeracha Weir.

Process	Target taxa	EWR
Habitat availability	All taxa	Persistence of water in pools throughout the year
	Macroinvertebrates, galaxiids	Persistence of flow over riffles (depth ≥15 cm)
Habitat quality	All taxa	High flow flushes that scour pools and riffles
		Persistence of water with sufficient depth to prevent excessive temperatures and salinity, and insufficient dissolved oxygen
		Sustained higher flows that drown out terrestrial vegetation colonising channels
Recolonisation of vacant habitats and mixing of extant populations	All fish taxa	Periods of high flow that connect pools (depth ≥15 cm)
Successful fish spawning	Climbing galaxias	Successive moderate to high flows during the transitional and winter flow season (access to riffle and/or bank habitat).
	Mountain galaxias	Increase in flows over transitional period between Low and High Flow Season
	Flathead gudgeon	Warmer temperatures during the Low Flow season combined with persistence of water
Discourage colonisation and establishment of exotic fish species	Redfin	Variable flows and zero flows
Permanent macroinvertebrate community	Macroinvertebrates	Persistence of water in pools
		Persistence of flow over riffles (depth ≥10 cm)
In-stream vegetation	All taxa	Persistence of water in pools
		Variable depth on edges for germination

2005 proposed EWP trial releases

The proposed 2005 trial EWP consisted of:

- A low flow of 0.028 $m^3.s^{-1}$ (2.5 ML/d) continuous low flow from 1 Jan to 31 Dec;
- 2 large events of 8.96 $m^3.s^{-1}$ (800 ML/d for two days), one in April-June and one in August-October.

Detailed objectives for each component of the EWP were outlined in Pikusa and Bald (2005):

The low flow was expected to:

- Increase permanent pools habitat for macroinvertebrates, frogs and fish;
- Decrease temperature fluctuations;
- Reduce salinity;
- Increase dissolved oxygen;
- Increase fish movement; and
- Increase area and diversity of submerged macrophytes.

The large events were expected to:

- Arrest current stream contraction and infilling;
- Control encroachment by emergent macrophytes (reeds and rushes);
- Facilitate sediment transport;
- Creation of deeper pool habitat;
- Provide appropriate breeding cues for native fish;
- Improve health of riparian vegetation; and
- Restore connection between river and floodplain.

The total volume of the trial release was 4.41 GL/yr.

While the low flow component, in part, is considered appropriate for the objectives, a number of issues were identified associated with the large events proposed for the EWP. The flow of 800 ML/d is a very large volume. It is unclear where the figure was derived from, but spills associated with the reach (see Figure 8) rarely reach a rate of 800 ML/d (the value is equivalent to the 97th percentile of all non-zero flows, so only 3% of flow days have flows higher than this).

One of the objectives of the EWP is to provide appropriate breeding cues for native fish. Of the fish species present, Climbing galaxias require successive flushes – one to allow access to riparian egg laying sites and a second flush to stimulate egg hatching and larval fish transport – and Mountain galaxias spawning occurs as a result of an increase in flows over transitional period between Low and High Flow Season in June/July. The 2005 EWP large events do not provide for these. Other native species present do not require flushes as breeding cues.

The short duration of the proposed EWP flushes also seems unlikely to allow for adequate spawning opportunities, and may result in stranding of species in shallow areas following a rapid drawdown.

Additionally, it is considered likely that the large event flows will not arrest stream contraction, nor control encroachment by emergent macrophytes. Once established, emergent macrophytes like reeds are difficult to move through high flow scouring. Much higher flows released in Spring 2010 (SA Water and AMLRNRMB 2011[14]) removed some reeds from within the channel, but most remained, simply being flattened by the high flows. Current opinion is that the removal of reeds by flow is best achieved where constant flows cause anoxic conditions around the roots, leading to plant death (J. Nicol, SARDI, at workshop).

Revised EWP trial releases

At the 15-16 June workshop, the EWP flow downstream of Gumeracha Weir was redesigned to more align with the environmental objectives above. The revised monthly trial release is described in Table 6 and graphically depicted in Figure 9. Each of the individual flow components can be linked to all or part of the individual objectives above.

[14] SA Water and AMLRNRMB (2011) Monitoring of the Environmental Effects of releases from Reservoirs in Early Spring 2010. SA Water and Adelaide and Mount Lofty Ranges Natural Resources Management Board.

The revised trial EWP consists of:

- A low flow of 2.5 ML/d continuous low flow from 1 October to 31 June;
- A low flow of 9 ML/d continuous low flow from 1 July to 30 September;
- Two flushes, over 5 days each, rising to a peak of 200 ML/d, one in May and one in July (1025 ML each);
- A similar flush, over 5 days, in September (1,025 ML).

The total annual volume of the revised EWP is similar to the 2005 EWP at 4.49 GL.

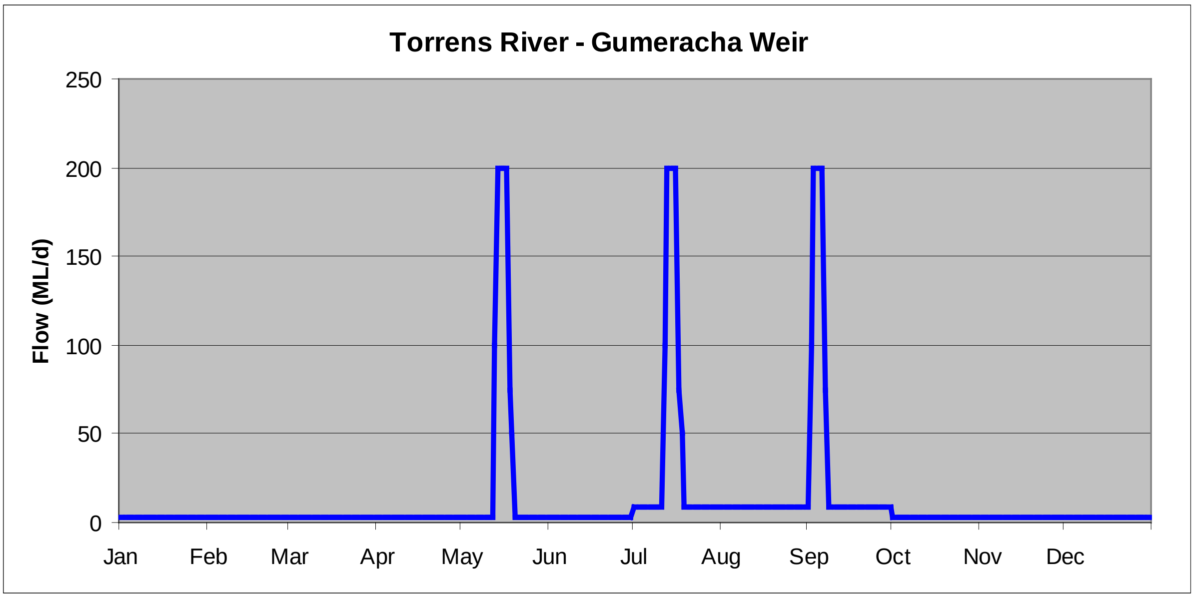


Figure 9. Revised EWP trial releases for the Torrens River downstream of Gumeracha Weir.

The low flow baselines can be delivered through the outlet pipe on the weir. Higher flows need to be delivered from overtopping the weir by restricting the diversions and allowing flushes to pass. Therefore, higher flows cannot be expressly delivered to a flow rate schedule, but depend on inflows.

The May flush is designed to allow access by Climbing galaxias to spawning habitats in fringing riparian areas, followed by the July fresh to stimulate egg hatching. Operationally, the flush should be delivered on the first occasion after 1 May that inflows reach 50 ML/d as a result of natural rainfall in the local catchment. On this trigger, diversions should cease and flows allowed to pass the weir for a period of 5 days when diversions can recommence. If the passing flows exceed 200 ML/d during this period, excess flows above this can be harvested. If flows do not reach 50 ML/d by 31 May, diversions should cease for 5 days and any natural flows be allowed to pass the weir.

Similarly, the July flush should be triggered by inflows greater than 50 ML/d after 1 July, and if flows do not reach this level by 31 July, diversions should cease for 5 days and any natural flows be allowed to pass the weir.

The increase in baseflow to 9 ML/d in July is designed to stimulate Mountain galaxias spawning (assisted by the July fresh) and provide additional riffle habitat for small galaxiids (which are hypothesised to provide refuge from predation). Maintaining the increased baseflow over the July to September period may assist in reducing emergent macrophyte coverage of riffles/runs (while still maintaining edge based reeds important for fish habitat and refuge). It also increases the amount of riffle habitat to allow macroinvertebrates to complete their life cycle.

The September flush is designed as an attractant for juvenile fish from downstream and as a habitat maintenance mechanism (scouring sediments, biofilms and gudgeon spawning sites) in preparation for the on-coming low flow period. As for the other flushes, the September flush should be triggered by inflows greater than 50 ML/d after 1 September, and if flows do not reach this level by 30 September, diversions should cease for 5 days and any natural flows be allowed to pass the weir.

Table 6. Revised EWP trial releases for the Torrens River downstream of Gumeracha Weir.

Month	EWP Band	Volume (ML)		Frequency	Duration	Comments/triggers
		Total	ML/day			
Jan	Baseflow	78	2.5	Daily	All of month	Delivered through outlet pipe
Feb	Baseflow	70	2.5	Daily	All of month	Delivered through outlet pipe
Mar	Baseflow	78	2.5	Daily	All of month	Delivered through outlet pipe
Apr	Baseflow	75	2.5	Daily	All of month	Delivered through outlet pipe
May	Baseflow	65	2.5	Daily	All of month except flush	Delivered through outlet pipe
	Flush	1,025		One	5 days	1st inflow >50 ML/d, or 31 May latest
Jun	Baseflow	75	2.5	Daily	All of month	Delivered through outlet pipe
July	Baseflow	234	9.0	Daily	All of month except flush	Delivered through outlet pipe
	Flush	1,025		One	5 days	1st inflow >50 ML/d, or 31 July latest
Aug	Baseflow	279	9.0	Daily	All of month	Delivered through outlet pipe
Sep	Baseflow	225	9.0	Daily	All of month except flush	Delivered through outlet pipe
	Flush	1,025		One	5 days	1st inflow >50 ML/d, or 30 Sep latest
Oct	Baseflow	78	2.5	Daily	All of month	Delivered through outlet pipe
Nov	Baseflow	75	2.5	Daily	All of month	Delivered through outlet pipe
Dec	Baseflow	78	2.5	Daily	All of month	Delivered through outlet pipe
	Total	**4,485**				

It is likely that some of these flows will be provided by natural spills over the weir. A SPELLS analysis of flows downstream of Gumeracha Weir between 1971 and 2011 shows that September flows over 50 ML/d downstream of the weir occurred in 25 out of the 41 years of record, and in 21 of these years flows increased to over 200 ML/d. In May and July, flows downstream of the weir greater than 50 ML/d occurred in 10 and 27 years. In all cases, the median duration of spells above 50 ML/d was greater than 5 days, suggesting in many years, intervention to provide the flows may not be required.

Each of the flow components of the revised EWP can be linked to water requirements necessary to achieve one or more of the environmental objectives (Table 7).

Table 7. Flow components of the EWP and functions towards achieving the objectives for the Torrens River downstream of Gumeracha Weir.

Flow Component	Function
2.5 ML/d Low Flow (Oct-June)	Provide permanent habitat for riffle invertebrates Allow access to riffle habitats for galaxiid fish species Provide permanent habitat for instream vegetation
1025 ML flush (May)	Provide access to riparian spawning sites for Climbing galaxias Flush silt from riffles for mountain galaxias spawning
1025 ML flush (July)	Trigger Climbing galaxias egg hatching
9 ML/d Low Flow (July to September)	Trigger Mountain galaxias spawning Discourage in-channel emergent vegetation
1025 ML flush (September)	Attract juvenile fish from downstream Fish movement through the reach Reset habitat conditions in preparation for low flow period

Limiting factors

The operation of the channel as a conduit for River Murray water to Kangaroo Creek Reservoir may affect the chance of achieving the EWP objectives by increasing water flow at inappropriate times of the year. The elevated turbidity of River Murray water, and the potential for interbasin transfer of non-indigenous species (such as Bony herring or other species that have invaded the lower Murray River), viruses or diseases from the Murray-Darling Basin may be important. An assessment of the translocation potential of Murray River pipelines should be undertaken to evaluate the risk of unwanted future species movements into the region.

Other in-stream barriers in the reach may restrict the movement of native fish. A survey of instream barriers and threats is currently being undertaken by SARDI and the AMLRNRMB.

Monitoring

The monitoring components required to assess the impact of the EWP flow regime in the upper Torrens River are shown in Table 8. The monitoring components shown are adequate to evaluate all of the objectives of the trial. However, the design and scope of any monitoring program will depend on the amount of available funds for the process. If inadequate funds are available, variations to the program will need to be evaluated by the trial partners.

There is also a need to develop evaluation criteria for the metrics, along with reporting an feedback arrangements in conjunction with the monitoring program.

Table 8. Monitoring components linked to objectives and evaluation metrics for the Torrens River downstream of Gumeracha Weir.

<table>
<tr><th>Hydrological components</th><th>Monitoring</th><th>Metrics</th></tr>
<tr><td>2.5 ML/d baseflow (October to June)</td><td rowspan="5">Gauging at Gumeracha Weir gauge A5040500 (to evaluate releases)

Gauging d/s Hollands Creek Weir gauge A5041003 (to evaluate losses, transmission and tributary inputs)</td><td>% of time with recorded flow => 2.5 ML/d</td></tr>
<tr><td>May flush (1,025 ML)</td><td>Target volume delivered (Y/N)
Total volume delivered (ML)
Highest flow achieved (ML/d)
Duration of elevated flows (days/hours)</td></tr>
<tr><td>July flush (1,025 ML)</td><td>Target volume delivered (Y/N)
Total volume delivered (ML)
Highest flow achieved (ML/d)
Duration of elevated flows (days/hours)</td></tr>
<tr><td>9 ML/d baseflow (July to September)</td><td>% of time with recorded flow => 9 ML/d</td></tr>
<tr><td>September flush (1,025 ML)</td><td>Target volume delivered (Y/N)
Total volume delivered (ML)
Highest flow achieved (ML/d)
Duration of elevated flows (days/hours)</td></tr>
</table>

Hydraulic components	Monitoring	Metrics
Habitat availability (2.5 ML/d baseflow)	One off pool depth at multiple sites covering a range of pool sizes and maximum depths. One off riffle depth at multiple sites.	Pools throughout reach at maximum volume and depth (Y/N) Median riffle depth => 10 cm (Y/N) Median riffle depth (cm)
Access to spawning sites by Climbing galaxias (May and July freshes)	Extent of potential spawning sites inundated during freshes.	Spawning habitat inundated (Y/N) Width of spawning habitat inundated (m)
Habitat increase due to seasonal baseflow increase (9 ML/d baseflow)	One off riffle depth at multiple sites.	Median riffle depth > 10 cm (Y/N) Median riffle depth (cm)
Fish passage (July and September flushes)	Depth of water over shallow restrictions.	Provision of connecting depth >10 cm between pools (Y/N) Width of wetted perimeter >10 cm deep (m) Median riffle depth during flushes (cm)

<table>
<tr><th>Environmental Objective</th><th>Monitoring</th><th>Metrics</th></tr>
<tr><td>Water quality in pools maintained at levels suitable for aquatic life</td><td>Annual water quality sampling in selected pools during summer for water temperature, salinity, dissolved oxygen, turbidity and stratification.</td><td>Water temperature (maximum)
Salinity (maximum)
Dissolved oxygen (minimum)
% of time, and absolute duration, above or below known tolerance thresholds (%, days)
Stratification present (Y/N)</td></tr>
<tr><td>No degradation of in-stream habitat conditions</td><td>Physical habitat condition monitoring during biotic surveys (substrate condition etc) as outlined in the Design Report (McEvoy 2006).

Index of Riverine Condition (IRC) at the start and end of the trial.</td><td>Change in habitat variables

Change in IRC value</td></tr>
<tr><td>A self sustaining population of Climbing galaxias, and regular breeding and recruitment</td><td rowspan="2">Bi-annual sampling of fish community at three sites used in the 2006-2008 survey.

Response monitoring (spawning and migration) of Climbing galaxias to June and September freshes.

Assessment of native fish condition.</td><td>Number of years with recruitment
Population size
Population structure (number of age classes present)
Fish Condition Index
Presence of eggs in inundated spawning habitat
Presence and abundance in directional netting</td></tr>
<tr><td>Self-sustaining populations of Flathead gudgeon, Dwarf flathead gudgeon, Mountain galaxias with higher abundances than currently present, and regular breeding and recruitment</td><td>Presence/absence of Mountain galaxias
Frequency of recruitment
Population size
Population structure (number of age classes present)
Fish Condition Index</td></tr>
<tr><td>A reference condition macroinvertebrate community (typical of permanent streams in this habitat type)</td><td>Spring and Autumn condition assessment of macroinvertebrate communities using established standard assessment techniques (3 sites).</td><td>Taxonomic richness
Life form diversity
Similarity to assemblages in reference streams</td></tr>
<tr><td>Sustainable in-stream vegetation communities</td><td rowspan="2">Annual transect based survey using the protocol based on the methods used in the Onkaparinga as described by Nicol and Bald (2006).</td><td>Presence/absence of in-stream species
% cover
Presence and condition of recruits (young plants)</td></tr>
<tr><td>Reduced Typha and/or Phragmites distribution in riffle/run areas</td><td>% Reduction in cover of Typha and/or Phragmites in riffle/run areas</td></tr>
</table>

5 Torrens River – Gorge Weir to Torrens Lake

Description and hydrology

The trial reach on the lower Torrens River extends from the small Gorge Weir (a capacity of only 20 ML) to the start of Torrens Lake in the centre of Adelaide. A short distance below the weir, the river enters the suburbs of Adelaide, although the riparian strip is entirely contained within the Torrens Linear Park, a largely cleared and heavily modified public space (the channel was excavated as a flood mitigation scheme).

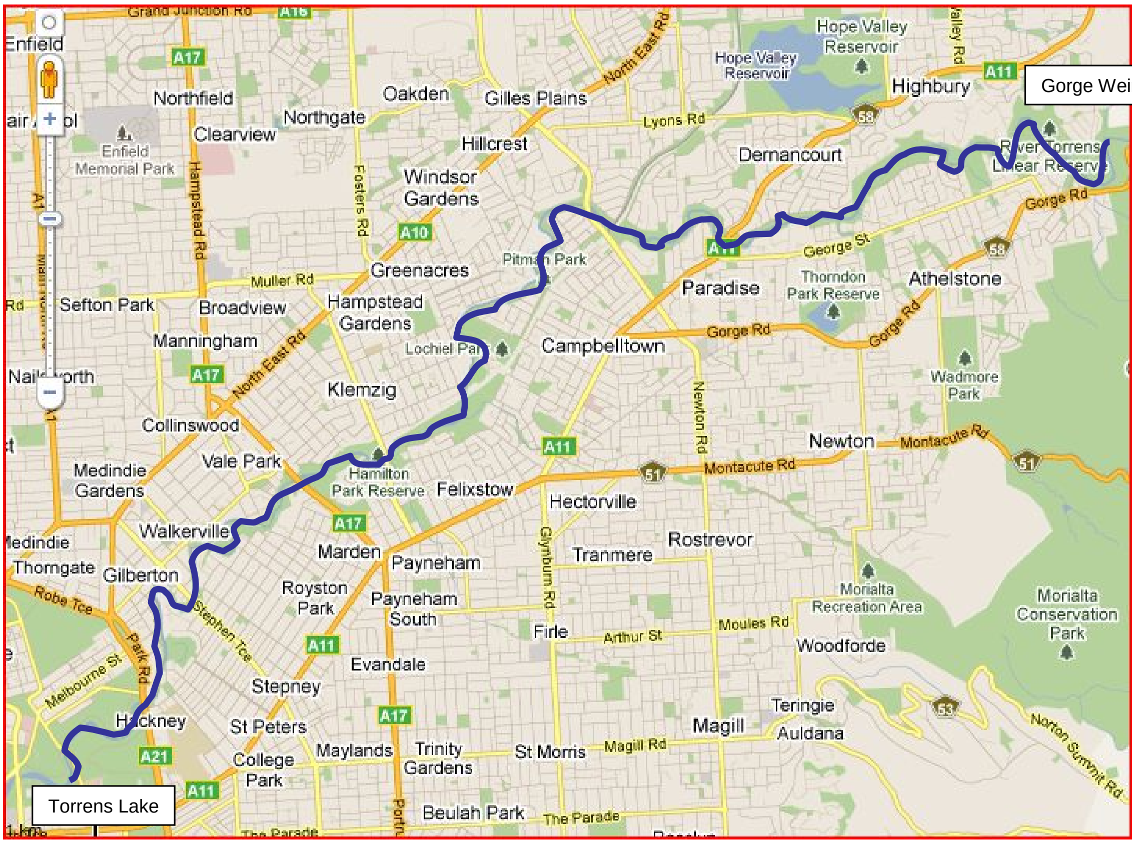


Figure 10. Torrens River trial reach between Gorge Weir and Torrens Lake.

Gorge Weir collects inflows for transfer to the major off-stream storage at Hope Valley Reservoir, so flows immediately downstream of the weir are severely affected (Figure 11). No flows are recorded for over 84% of the time (1970-2011) but big spills still occur every 5 years or so. Further downstream, there is a more steady baseflow, maintained by spring-fed inflows that start 1.5 km downstream of the weir, but water quality is affected by urbanisation and stormwater runoff.

As a result of the low flows, the channel has become choked due to reed beds trapping sediment from stormwater flows and local run-off. Pools are decreasing in depth due to sediment accumulation, with consequent greater ranges of temperature and salinity in summer. Habitat diversity is decreasing as reeds colonise areas that were originally deep pools and fast flowing riffles (Schulz 2004).

Despite the heavily modified stream channel, there are still areas of good in-stream habitat values, with a cobble bed in many locations.

Environmental values

Six native fish species were captured in the upper parts of the reach (downstream of Gorge Weir and at Silke's Road in Athelstone) between 2006 and 2008 – Common galaxias, Mountain galaxias, Dwarf flathead gudgeon, Flathead gudgeon, Congolli and climbing galaxias. Only single individuals of Congolli and Climbing galaxias were collected (McNeil *et al*. 2011).

Numerous exotic fish species have been recorded, with Eastern gambusia the most abundant and widespread species.

Of concern is that recent sampling indicated the presence of low numbers of adult Mountain galaxias, despite large numbers of juveniles, indicating successful recruitment, but a poor survival rate. The reasons for this are unclear, but has been attributed to the relatively sparse areas of adult riffle habitat under low flow conditions (D. McNeil, PIRSA-SARDI, pers. comm.).

Macroinvertebrate communities downstream of Gorge Weir have been rated as in poor condition (DWLBC 2005[15]).

In-stream plants have largely been unstudied, but dense beds of *Typha* and *Phragmites* are present in the channel.

No formal EWR seems to have been established for the trial reach from Gorge Weir downstream to Lake Torrens. Schulz (2004) suggests a flow regime where 2–4 ML of natural flow from Sixth Creek is released downstream for 2 days every fifteen days, but provides no justification for the flow regime.

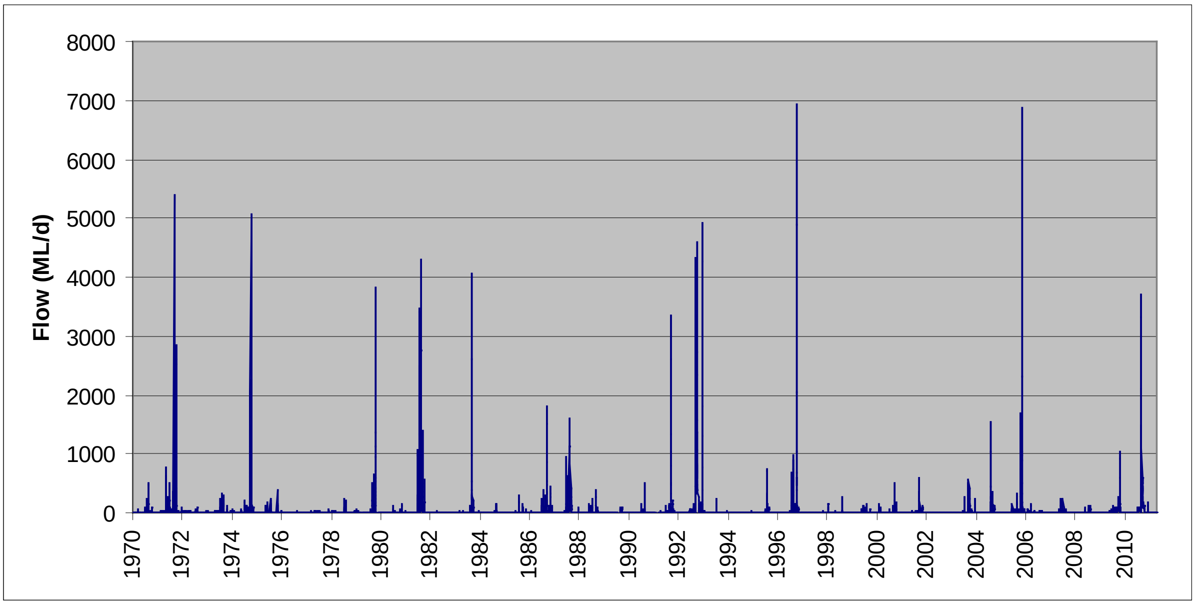


Figure 11. Hydrograph recorded at Gorge Weir (A5040501) between 1970 and 2011.

Environmental Objectives and EWRs

Given the artificial nature of the channel form, and issues associated with water quality and the impacts of urbanisation, there seems little opportunity to improve environmental conditions to a "natural" state. Hence, the main objectives of the EWP are to produce conditions that ameliorate specific environmental concerns in the reach – particularly water quality, the apparent lack of survival of native fish species to the adult stage, and the influence of exotic species.

With no standard with which to compare macroinvertebrate communities, the overall objective is simply to improve habitat conditions, and aim for a reduction in still water species and an increase in species typical of faster flows.

The volume of the trial EWP would seem insufficient to introduce a higher baseflow over a sufficient time to reduce infestations of *Typha* and *Phragmites*, so physical control may be the only option to reduce the channel clogging.

The Environmental Objectives identified for this reach are:

[15] DWLBC (2005) Mt Lofty Ranges Water Resources Assessment Program: Macroinvertebrate and Fish Survey and Analysis below water supply reservoirs. Department of Water, Land and Biodiversity Conservation and the Australian Water Quality Centre, Adelaide.

- Water quality improved to levels conducive for aquatic life survival during the year.
- No further degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction).
- Increased survival of adult native fish.
- Reduced Eastern gambusia populations.
- A macroinvertebrate community with increased representation of flowing water taxa.
- Sustainable in-stream vegetation communities.

Environmental Water Requirements for processes required to achieve the objectives are listed in Table 9. These have been derived from recent work, including conceptual models developed for determining EWRs for the Mount Lofty Ranges and Kangaroo Island.

Table 9. EWRs for environmental objectives for the Torrens River between Gorge Weir and Torrens Lake.

Process	Target taxa	EWR
Habitat availability	All taxa	Persistence of water in pools throughout the year
	Adult fish	Increase in habitat area (suitable habitat and depth) to increase survival
	Macroinvertebrates, galaxiids	Persistence of flow over riffles (depth ≥15 cm)
Habitat quality	All taxa	Low flows that improve existing water quality
		Persistence of water with sufficient depth to prevent excessive temperatures and salinity, and insufficient dissolved oxygen
Discourage colonisation and establishment of exotic fish species	Eastern gambusia	Permanent flow and high flow periods
Permanent macroinvertebrate community	Macroinvertebrates	Persistence of water in pools
		Persistence of flow over riffles (depth ≥10 cm)
In-stream vegetation	All taxa present	Persistence of water in pools

2005 proposed EWP trial releases

The proposed 2005 trial EWP consisted of:

- A low flow of 0.0028 $m^3.s^{-1}$ (0.25 ML/d) continuous low flow from 1 Jan to 31 Dec;
- 2 large events of 2.3 $m^3.s^{-1}$ (200 ML/d for two days), one in April-June and one in August-October.

No fresh flows were specified under the trial release, as these are assumed to be provided from stormwater inputs.

The objectives of the EWP are outlined in Pikusa and Bald (2005):

- Maintain and further improve water quality, visual amenity, and macroinvertebrate and fish habitat with low flows.
- Scour sediment build up and control encroaching vegetation with winter pulse flows.

The total volume of the trial release was 0.89 GL/yr.

While the low flow allocations seems small (only 0.25 ML/d), it may have the desired effect to somewhat improve water quality (by dilution), may produce conditions less conducive for Eastern gambusia, should favour flowing water macroinvertebrate taxa in riffle areas, but may not provide adequate additional habitat for adult native fish.

As suggested previously, the high flow events in April-June and August-October are unlikely to have a significant impact on the in-channel vegetation. Very high flows released in Spring 2010 (SA Water and AMLRNRMB 2011) removed some reeds from within the channel, but most remained, simply being flattened by the high flows. These flows were orders of magnitude higher than the proposed trial flushes.

It is also unlikely that the higher flows will increase habitat availability for native fish species for sufficient time to allow for growth.

Revised EWP trial releases

At the 15-16 June workshop, the EWP flow downstream of Gorge Weir was redesigned to more align with the objectives above. The revised monthly trial release is described in and graphically depicted in Figure 12. Each of the individual flow components can be linked to all or part of the individual objectives above.

The revised trial EWP consists of:

- A low flow of 0.25 ML/d continuous low flow all year;
- A higher sustained flow of 40 ML/d for 20 days in November.

The total annual volume of the revised EWP is the same as the 2005 EWP at 0.89 GL.

The baseflow will need to be released from a scour valve in the Gorge Weir to Hope Valley transfer line as the scour valves at Gorge Weir are both inoperable.

Table 10. Revised EWP trial releases for the Torrens River between Gorge Weir and Torrens Lake.

Month	EWP Band	Volume (ML)*		Frequency	Duration	Comments/triggers
		Total	ML/day			
Jan	Baseflow	8	0.25	Daily	All of month	
Feb	Baseflow	7	0.25	Daily	All of month	
Mar	Baseflow	8	0.25	Daily	All of month	
Apr	Baseflow	8	0.25	Daily	All of month	
May	Baseflow	8	0.25	Daily	All of month	
Jun	Baseflow	8	0.25	Daily	All of month	
July	Baseflow	8	0.25	Daily	All of month	
Aug	Baseflow	8	0.25	Daily	All of month	
Sep	Baseflow	8	0.25	Daily	All of month	
Oct	Baseflow	8	0.25	Daily	All of month	
Nov	Baseflow	3	0.25	Daily	10 days	
		800	40	Daily	20 days	
Dec	Baseflow	8	0.25	Daily	All of month	
	Total	**890**				

* rounded up to nearest ML

The low flow, as in the original EWP, is designed to maintain and further improve water quality, and provide macroinvertebrate and fish habitat. While it is recognised that this is a particularly public reach, the provision of visual amenity is not an environmental objective. However, another forum outside of this workshop is discussing flows for public amenity, and that should be considered in conjunction with the provision of the EWP.

The November period of elevated flow (40 ML/d over 20 days) is designed specifically to increase the amount of adult fish habitat, particularly in riffle areas, during a period that would historically have a declining amount of habitat. Periods of additional habitat may be available during the year due to inflows, but establishing healthy adult individuals prior to the onset of hot dry conditions may increase the chance of survival. Without adequate hydraulic modelling of habitat availability at different flows, the flow rate (40 ML/d) has been subjectively selected. It is possible that after the first year of delivery and monitoring of habitat availability, that the volume and duration may need to be modified to obtain the optimum amount of adult habitat over the longest duration (e.g. it may be required reduce the volume and provide it over a longer period).

Each of the flow components of the revised EWP can be linked to water requirements necessary to achieve one or more of the environmental objectives (Table 11).

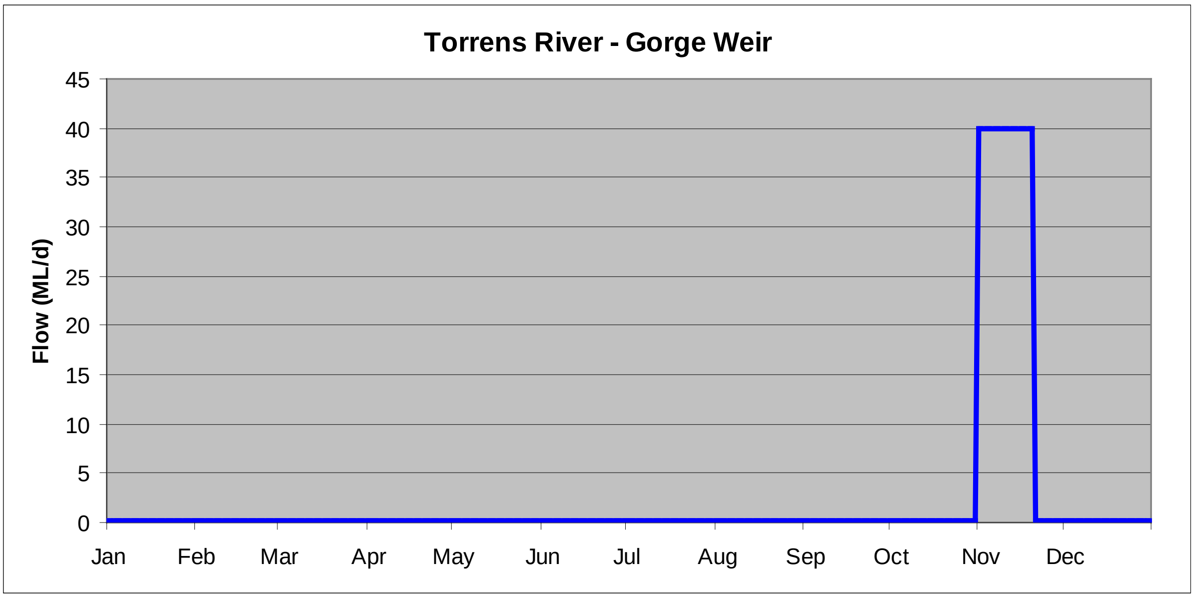


Figure 12. Recommended EWP regime for the Torrens River between Gorge Weir and Torrens Lake.

Table 11. Flow components of the EWP and functions towards achieving the objectives for the Torrens River between Gorge Weir and Torrens Lake.

Flow Component	Function
0.25 ML/d Low Flow (all year)	Improve water quality by dilution Provide permanent habitat for riffle invertebrates Allow access to riffle habitats for galaxiid fish species Provide permanent habitat for in-stream vegetation
40 ML/d high flow (November)	Increase habitat availability for adult fish

Limiting factors

The major limiting factor that would preclude achievement of the flow-related objectives in the reach is the changes in hydrology and water quality due to urbanisation.

Other in-stream barriers in the reach may restrict the movement of native fish. A survey of instream barriers and threats is currently being undertaken by SARDI and the AMLRNRMB.

Monitoring

The monitoring components required to assess the impact of the EWP flow regime in the Torrens River are shown in Table 12. The monitoring components shown are adequate to evaluate all of the objectives of the trial. However, the design and scope of any monitoring program will depend on the amount of available funds for the process. If inadequate funds are available, variations to the program will need to be evaluated by the trial partners.

There is also a need to develop evaluation criteria for the metrics, along with reporting an feedback arrangements in conjunction with the monitoring program.

Table 12. Monitoring components linked to objectives and evaluation metrics for the Torrens River between Gorge Weir and Torrens Lake.

Hydrological components	Monitoring	Metrics
0.25 ML/d baseflow (all year)	Gauging downstream of Gorge Weir to Hope Valley scour outlet (to evaluate releases). Inactive AMLRNRMB site A5041018 900 m downstream of Gorge Weir may need to be re-activated.	% of time with recorded flow => 0.25 ML/d
November high flow (40 ML/d, 20 days ML)		40 ML/d delivered (Y/N) Duration achieved (Y/N) Total volume delivered (ML) Highest flow achieved (ML/d) Duration of elevated flows (days/hours)
Hydraulic components	**Monitoring**	**Metrics**
Habitat availability (0.25 ML/d baseflow)	One-off pool depth and area at multiple sites covering a range of pool sizes and maximum depths. One-off riffle depth at multiple sites	Pools throughout reach at maximum volume and depth (Y/N) Median riffle depth => 10 cm (Y/N) Median riffle depth (cm)
Habitat increase due to November high flow (9 ML/d baseflow)	One-off assessment of adult fish habitat at multiple sites covering a range of riffles	Area of suitable habitat at 0.25 ML/d (m^2) % Increase in adult habitat area (between 0,25 ML/d and 40 ML/d)
Environmental Objective	**Monitoring**	**Metrics**
Water quality improved to levels conducive for aquatic life survival	Water quality sampling at selected sites through the year for water temperature, salinity and dissolved oxygen (using existing and/or additional sampling equipment).	Water temperature (maximum) Salinity (maximum) Dissolved oxygen (minimum) % of time, and absolute duration, above or below known tolerance thresholds (%, days)
No further degradation of in-stream habitat conditions	Physical habitat condition monitoring during biotic surveys (substrate condition, estimates of cover of *Typha* and *Phragmites* etc) as outlined in the Design Report (McEvoy 2006). Index of Riverine Condition (IRC) at the start and end of the trial.	Change in habitat variables % change in cover of *Typha* and *Phragmites* . Change in IRC value
Increased survival of adult fish, particularly , with regular breeding and recruitment in the main channel.	Bi-annual sampling of fish community at three sites used in the 2006-2008 survey. Assessment of native fish condition	Number of years with recruitment Population size Population structure (adult age classes present) Fish Condition Index
Reduced Eastern gambusia populations		Population size Population structure (number of age classes present)
A macroinvertebrate community with increased representation of flowing water taxa.	Spring and Autumn condition assessment of macroinvertebrate communities using established standard assessment techniques (3 sites).	Proportion of species present typical of flowing waters
Sustainable in-stream vegetation communities	Identification and cover estimates of in-stream plants during other biotic surveys	Presence/absence of in-stream species % cover Presence and condition of recruits (young plants)

6 Onkaparinga River

Description and hydrology

The trial reach on the Onkaparinga River extends from the Clarendon Weir downstream to the head of the estuary located immediately above Old Noarlunga (Figure 13). Below Clarendon Weir, the river flows through a series of incised gorges. These gorges become steeper downstream, as the river falls through prominent rocky outcrops towards the coastal plain. The river channel consists of a series of pools of variable depth with substrates dominated by cobbles and bedrock, separated by cascades of cobbles and boulders.

The Onkaparinga widens when it reaches the coastal plain at Old Noarlunga, with typical floodplain features evident. Shortly after flowing onto the coastal plain the river is subject to tidal influences, marking the end of the trial reach.

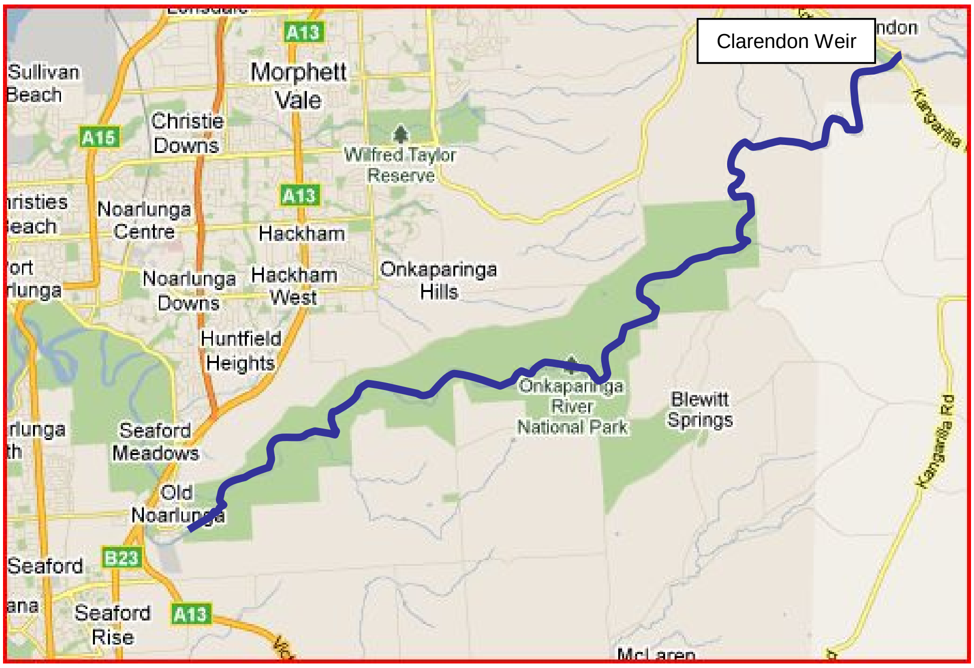


Figure 13. Map of the Onkaparinga River trial reach between Clarendon Weir and the estuary.

The trial reach is located predominantly in the Onkaparinga River National Park, and so the river setting is largely intact (although with a history of grazing in the park and a number of significant weed species). However, extended periods without high flows has resulted in vegetation encroachment into the channel, particularly in the riffle zones between pools, with a subsequent reduction in channel width. The channel therefore has an extensive in-channel "floodplain" which has been colonised by terrestrial vegetation and have stabilised (Figure 14).

Bankside springs that used to feed directly into the stream have produced small wetland areas within the in-channel floodplain.

While the channel has contracted in width, the remaining habitat would appear to be reasonably good, but further contraction may see a decline in these conditions.

Water from upstream (including releases from Mount Bold Reservoir) is diverted to Happy Valley from Clarendon Weir. Consequently, flows immediately downstream of Clarendon Weir experience long periods of no flow (over 90% of the time) particularly over the drier months, with higher flows from spills only during extreme events (Figure 15). Further downstream, the inflows from Kangarilla Creek provide some relief, but mainly during the wetter months, with no flows recorded for less than 10% of the time (SKM 2001a[16]).

[16] SKM (2001a) Determination of Environmental Water Requirements of the Onkaparinga River Catchment: Technical Report III: Site Location and Hydrology. Sinclair Knight Merz, Melbourne.

Figure 14. The contracted channel has produced small stable floodplain pockets colonised by terrestrial vegetation.

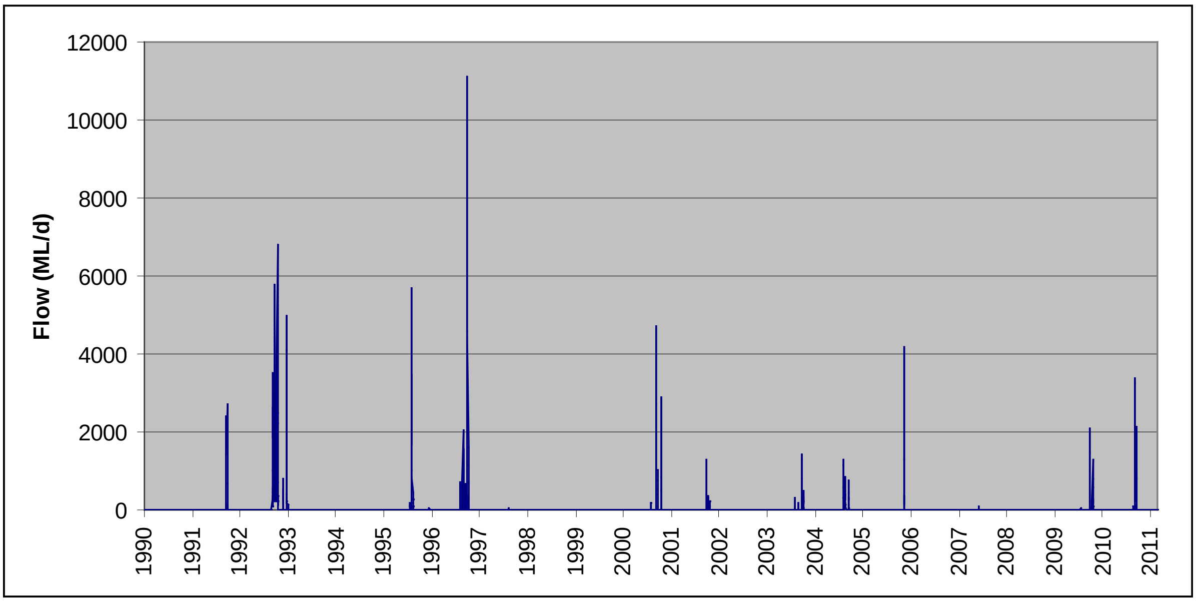


Figure 15. Hydrograph recorded downstream of Clarendon Weir (A5030500) between 1990 and 2011.

Environmental values

In terms of composition, the fish community is more diverse than any of the other EWP reaches. Seven species of native freshwater fish were identified at three sites between 2006 and 2008 – Shortfinned eel, Climbing galaxias, Common galaxias, Mountain galaxias, Dwarf flathead gudgeon, Flathead gudgeon and Congolli (McNeil *et al*. 2011). Only two Climbing galaxias individuals were recorded. Population sizes of more common species varied widely between sampling times and between different sites. Lamprey species are likely to be present but have not been recorded, possibly due to their general cryptic habits and low abundances (M.Hammer, pers. comm.). The record of smelt in the SKM survey (SKM 2002b[17]) is considered erroneous (Hammer and Walker 2004[18]). Seven estuarine species were also collected in the lower parts of the reach where the estuary has an influence on the river.

[17] SKM (2001b) Determination of Environmental Water Requirements of the Onkaparinga River Catchment: Technical Report V: Fish Survey. Sinclair Knight Merz, Melbourne.
[18] Hammer, M.P. and Walker, K.F. (2004) A catalogue of South Australian freshwater fishes including new records, range extensions and translocations. *Transactions of the Royal Society of South Australia* **128**: 85-97.

In 2006, Common galaxias were distributed throughout the reach, but had disappeared in upper sites by 2008. Congolli were only recorded at the lower site during the surveys. It was considered that species with marine dependant life history phases were unable to return to the upper reaches, possibly due to the low flows combined with the presence of a natural barrier in the system (McNeil *et al*. 2011).

Macroinvertebrate communities downstream of Clarendon Weir have been rated as in poor condition (DWLBC 2005)

Much more is known about the aquatic plants of the Onkaparinga River trial reach than the other EWP reaches (Nicol and Bald 2006). The reach is characterised by a high diversity of aquatic plants, with species such as Ribbonweed (*Vallisneria nana*), Curly pond weed (*Potamogeton crispus*), Water ribbon (*Triglochin procerum*) commonly recorded in pools in the reach. While the cover of aquatic plants varied seasonally, they remained present, even through dry months. Emergent plants such as Cumbungi and *Phragmites* were also common. Weeds are common in the reach with African fountain grass the dominant species which has substantially colonised some riparian and drier in-stream areas.

Of interest are the small wetland features in the contracted in-channel floodplain produced by springs that once fed into the main stream. The flora and fauna of these wetland areas are unknown, but they may contain species not found in the main channel, may form an additional refuge for fish species, and may be productive areas that contribute nutrients and food to the main stream during and after flooding.

While not part of the trial reach, the Onkaparinga estuary is a very significant environmental asset. The estuary, open all year but shallower than historically, is an important nursery for estuarine fish species, and is a refuge for marine species such as Yellow fin whiting and Mulloway in big storms. There are also significant samphire wetlands that have a freshwater requirement. It is regarded as one of the most significant freshwater influenced estuaries in the state. It would seem advantageous if the estuary could be included within the trial reach, and a joint freshwater/estuary/marine flow regime and monitoring program be established in the future.

Environmental Objectives and EWRs

A workshop held as part of the EWP process (Pikusa and Bald 2005) rejected the notion that the river could be run as a temporary system, with periods of no summer flows. This was “considered to be an ecologically undesirable long-term outcome, as an ephemeral system would not provide suitable habitat for recruitment and long-term population viability for many of the Onkaparinga’s fish and macroinvertebrate communities” (Pikusa and Bald 2005, p. 24).

At the 15-16 June workshop, the risk of providing a permanent flow regime was considered in the light of recent surveys of the fish communities of the lower Onkaparinga River. During those surveys there were periods of very low flows, and there was a general decline in the native fish community present. However, a number of considerations suggested that the sustainability of native fish populations appears to be better supported in the Onkaparinga than in the other EWP catchments:

- It is the only trial reach with a direct and unimpeded connection to the sea;
- Persistent populations of diadromous species remained despite periods of very low flows;
- Despite the periods of no flow recorded, the majority of the pools studied retained water;
- The present fish populations are numerically dominated by native species; and
- Numbers of introduced redfin, gambusia, carp, tench and goldfish remained relatively low throughout the study period.

Both a permanent and an ephemeral flow regime present risks to the fish communities present. In particular, permanent stable flows would provide better conditions for the recruitment and spread of exotic species, especially Redfin, and a subsequent increase in the threat to native species. An ephemeral system, if run in similar conditions to recent flows, would contribute to the continued decline in the native fish community. However, on balance, it was recommended at the 15-16 June workshop that the flow should remain temporary, with no EWP releases from December to March, but with a targeted flow regime over April to November to increase the populations and resilience of native fish species.

The Environmental Objectives identified for this reach are:

- Water quality in isolated pools maintained at levels suitable for aquatic life during cease to flow periods;

- No further degradation of in-stream habitat conditions (e.g. infilling of pools, sedimentation of riffles, channel contraction);
- Regular recruitment into populations of diadromous native fish with species collected as far upstream as Clarendon Weir;
- Mountain galaxias, Dwarf flathead gudgeon, Flathead gudgeon populations with regular breeding and recruitment in the main channel;
- More stable populations of native fish species (preventing large swings in abundance and increased risk of localised extinctions);
- Discourage expansion of exotic fish species (range, abundance and population structure);
- A reference condition macroinvertebrate community (typical of ephemeral streams in this habitat type);
- Sustainable in-stream vegetation communities;
- Maintenance of native terrestrial species near the channel; and
- Reduced terrestrial plant species (particularly African fountain grass) within the main channel.

No specific objectives have been developed for the spring-fed wetland areas on the in-channel floodplain. Their flora and fauna communities, and their contribution to the stream channel are unknown. However, it would seem desirable to connect these to the channel at some stages during the year, and it would be of value to include them in the monitoring program.

Environmental Water Requirements for processes required to achieve the objectives are listed in Table 13. These have been derived from recent work, including conceptual models developed for determining EWRs for the Mount Lofty Ranges and Kangaroo Island.

Table 13. EWRs for environmental objectives in the Onkaparinga River reach

Process	Target taxa	EWR
Habitat availability	All taxa	Persistence of water in pools throughout the Low Flow Season
Habitat quality	All taxa	High flow freshes that scour pools and riffles
		Persistence of water with sufficient depth to prevent excessive temperatures and salinity, and insufficient dissolved oxygen
		Sustained higher flows that drown out terrestrial vegetation colonising channels
Recolonisation of vacant habitats and mixing of extant populations	All fish species	Periods of high flow that connect pools
Diadromous native fish spawning and movement	diadromous native fish	Increase in flows to trigger migration
		Sustained elevated flows that allow downstream dispersal over relatively long distances, and
		Attractant flows for juveniles from estuary
		Sustained elevated flows that allow return movement of spent fish and juveniles
Successful spawning of resident fish species	Mountain galaxias	Increase in flows over transitional period between Low and High Flow Season
	Gudgeon	Warmer temperatures during the Low Flow season combined with persistence of water
Discourage expansion of exotic fish species	Exotic fish species	Permanent flow and high flow periods for Eastern gambusia Variable flows and zero flows for redfin[19]
Ephemeral macroinvertebrate community	Macroinvertebrates	Persistence of water in pools
		Six months flowing water over riffles
In-stream vegetation	All taxa present	Persistence of water in pools
		Variable depth on edges for germination (decline in late spring)
Maintenance of native terrestrial plant species	Various	High flows that temporarily inundate terrestrial habitat

[19] It is difficult to use flows to discourage the whole range of exotic species present.

2005 proposed EWP trial releases

The proposed 2005 trial EWP consisted of:

- A low flow release of 10 ML/d from January to May;
- A high flow release of 30 ML/d from July to November;
- Periodic 20 ML/d freshes (2 events of 10 days each between January and May);
- Periodic 100 ML/d freshes (2 events of 5 days each between July and November); and
- Periodic 650 ML/d freshes (3 events of 2 days each between July and November).

The volumes and durations are similar or the same as for the EWR developed in 2002 (SKM 2002), with only a reduction in frequency.

The total volume of the trial release was 9.24 GL/yr.

In the contracted channel, the flow of 100 ML/d represents a bankfull flow, filling the entire channel width (Figure 16).

The 650 ML/d freshes would inundate the floodplain created by the contracted channel. However, the frequency of 3 per year cannot strictly be justified. The recommended frequency of 3 per year was based on the natural pre-regulation frequency (SKM, 2002c[20]) and therefore could be seen only as appropriate for the original channel size. Frequent flooding of the terrestrial vegetation (such as Callistemons and Leptospermum), with sustained saturation of the soils could result in their decline, and subsequent destabilisation of the artificial floodplain. In most studies of EWRs, such “overbank” flooding frequencies are only once a year.

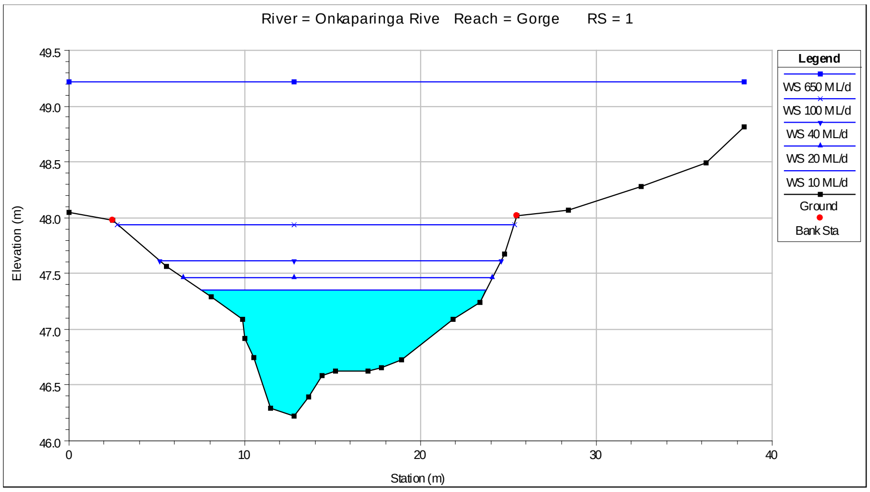


Figure 16. Cross section of a transect in the Onkaparinga River showing recommended flow levels (from SKM survey data). The red dots indicate the extent of the constricted channel, with bankfull at 100 ML/d.

Revised EWP trial releases

At the 15-16 June workshop, the EWP flow downstream of Clarendon Weir was redesigned (Figure 17) to more align with the objectives noted above. The revised monthly trial release is described in Table 14 and graphically depicted in Figure 17. Each of the individual flow components can be linked to all or part of the individual objectives above.

The revised trial EWP consists of:

- Cease to flow from 1 January to 31 March
- A fresh of 100 ML/d for 4 days triggered by the first rainfall after 15 March, or 1 April (whichever is earlier);

[20] SKM (2001c) Determination of Environmental Water Requirements of the Onkaparinga River Catchment: Technical Report VII: Environmental Water Requirements. Sinclair Knight Merz, Melbourne.

- A low flow of 30 ML/d continuous from 1 April to 31 October;
- A low flow of 10 ML/d continuous from 1 November to 31 December;
- Two flushes, over 9 days each, rising to a peak of 400 ML/d, one in June and one in September (1,195 ML each);

The total annual volume of the revised EWP is similar to the 2005 EWP at 9.11 GL.

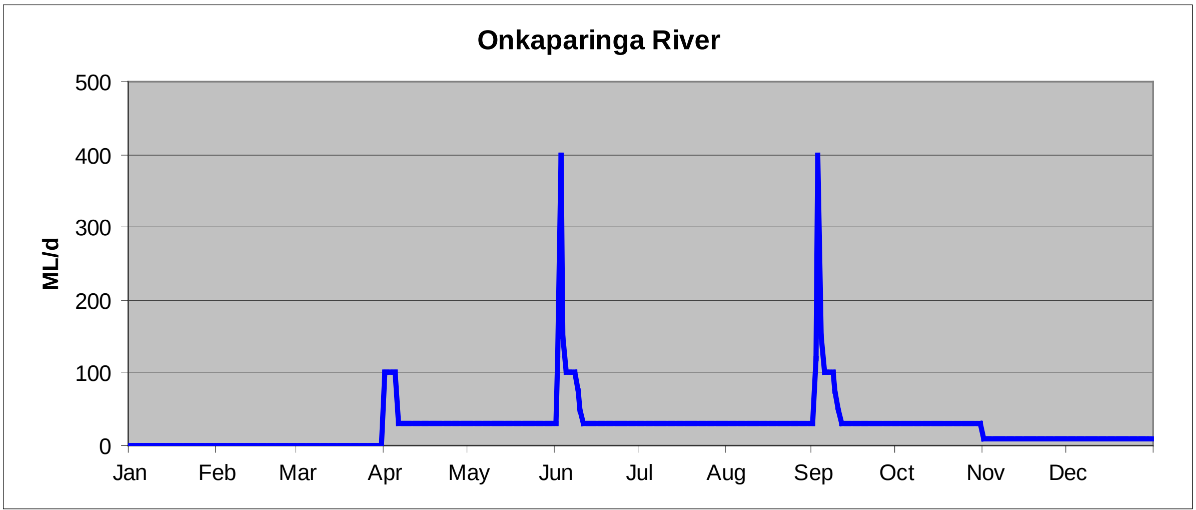


Figure 17. Recommended EWP regime for the Onkaparinga River downstream of Clarendon Weir

Table 14. Revised EWP trial releases for the Onkaparinga River downstream of Clarendon Weir

Month	EWP Band	Volume (ML) Total	Volume (ML) ML/day	Frequency	Duration	Comments/triggers
Jan	Cease to Flow	0	0	n.a.	All of month	
Feb	Cease to Flow	0	0	n.a.	All of month	
Mar	Cease to Flow	0	0	n.a.	All of month except fresh	
	Fresh	400	100	one	4 days	1st rain after 15 March or 1 April
Apr	Baseflow	900	30	Daily	All of month	
May	Baseflow	930	30	Daily	All of month	
Jun	Baseflow	630	30	Daily	All of month except flush	
	Flush	1,195		One	9 days	Peak of 400 ML/d
July	Baseflow	930	30	Daily	All of month except flush	
Aug	Baseflow	930	30	Daily	All of month	
Sep	Baseflow	630	30	Daily	All of month except flush	
	Flush	1,025		One	9 days	Peak of 400 ML/d
Oct	Baseflow	930	30	Daily	All of month	
Nov	Baseflow	300	10	Daily	All of month	
Dec	Baseflow	310	10	Daily	All of month	
	Total	**9,110**				

The period of no flows between January and March is designed to discourage exotic species in the reach, as in the South Para River, by reducing isolated pool volume and water quality. It is accepted that some of the smaller pools may dry completely, leading to the loss of some individuals of native fish species.

The period of high flow in late March/April (100 ML/d for 4 days) refills and refreshes the pools. It also triggers downstream migration of diadromous fish (Common galaxias and Congolli). The sustained bankfull nature of the flow will prevent blackwater events and allows time for the fish to move from the upper parts of the reach (where the only flow is the EWP) to further downstream where tributary inflows will sustain the higher flows for longer.

As with all freshes proposed, the flow needs to decline slowly on the receding limb as in Figure 18. While the design of the flow in Figure 18 is precise, there may need to be operational considerations taken into account before a final fresh design is adopted.

Maintaining a baseflow over the April to November period allows riffle macroinvertebrates to complete their life cycle, and provides suitable conditions for germination and growth of in-stream and fringing vegetation. The increase in flows also stimulates Mountain galaxias spawning (assisted by the June fresh). It is unsure whether this level of flow allows for broad scale fish movement, but is unlikely given the boulder/cascade nature of the bed, but localised movement to recolonise small pools that dried over summer may be possible.

Maintaining the increased baseflow over the April to October period may provide conditions unsuitable for the channel based terrestrial macrophytes (while still maintaining edge based reeds important for fish habitat and refuge).

Both the June and September high flows (peak of 400 ML/d over 9 days) have a number of functions. At the peak of the flow, the in-channel floodplain will be partly covered, connecting the channel to the spring-fed wetland areas. Whereas the baseflow may not provide longitudinal connectivity for adult fish through the whole reach (and particularly at the natural barrier identified), these higher flows should provide extended periods of whole reach connectivity (as the descending limb is based on bankfull discharge - Figure 18).

The September flush has the added function of attracting juvenile fish from downstream (with the continued baseflow after the flush allowing for movement throughout the reach – although the situation at the natural barrier will need to be established), and as a habitat re-setting mechanism (scouring sediments, biofilms and gudgeon spawning sites) in preparation for the on-coming low flow period.

In November and December, the baseflow is reduced to 10 ML/d. This is to allow a further period of growth for juvenile fish that have moved into the reach from downstream, increasing their chance of survival over the on-coming cease to flow period.

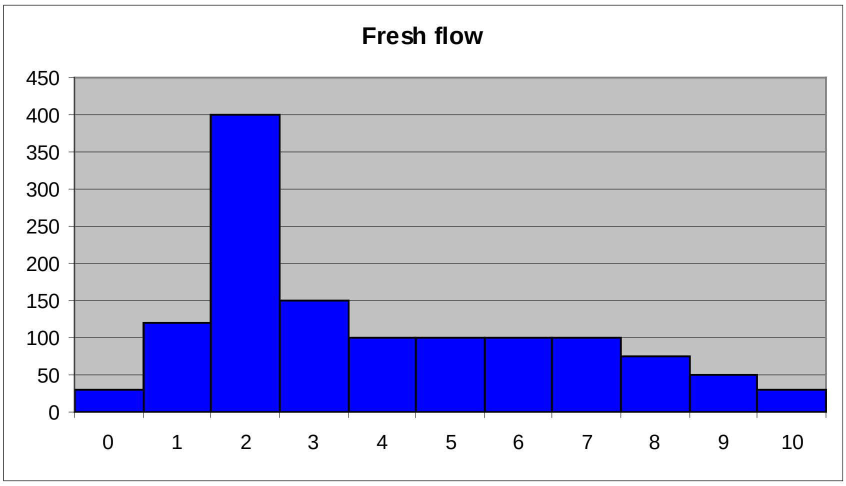


Figure 18. Recommended high flow fresh designed for a 9 day period (volume = 1195 ML)

It should be noted that the trial EWP releases do not include specific May and July flows for Climbing galaxias spawning and egg hatching, as were provided in the upper Torrens River (Table 7). Only two individuals of the species were collected between 2006 and 2008, and the flows required could not be accommodated within the available trial EWP volume (an additional two flushes, each of 5 days at 400 ML/d, or at least 4 GL/yr would be required). The volume of water available is better directed at the more common species. The March fresh and June flush may, in part, serve as Climbing galaxias triggers, and unregulated tributary inflows lower in the reach may also provide spawning opportunities.

Each of the flow components of the revised EWP can be linked to water requirements necessary to achieve one or more of the environmental objectives (Table 15).

Table 15. Flow components of the EWP and functions towards achieving the objectives

Flow Component	Function
Cease to Flow (Jan-Mar)	Reduce breeding, recruitment, growth and survival of exotic fish species
100 ML/d Fresh (Mar)	Refill pools and improve water quality Trigger downstream migration of diadromous fish species
Baseflow (April to October)	Allow for macroinvertebrate growth and breeding Provide for in-stream and fringing vegetation Stimulate Mountain galaxias spawning Localised fish movement
June Fresh	Stimulate Mountain galaxias spawning Fish movement through the reach Connect in-channel floodplain Sediment and biofilm scour
September Fresh	Attract juvenile diadromous species from estuary Fish movement through the reach Connect in-channel floodplain Sediment and biofilm scour Scour surface silt from Flathead gudgeon spawning sites
Baseflow (November to December)	Maintain growth of juvenile fish Ease the system into the cease to flow period

Limiting factors

Being located in a National Park, the prime limiting factor in the reach is the amount and invasive nature of the weeds in the riparian zone, and the channel.

In-stream barriers in the reach may restrict the movement of native fish. A survey of instream barriers and threats is currently being undertaken by SARDI and the AMLRNRMB.

Monitoring

The monitoring components required to assess the impact of the EWP flow regime in the Onkaparinga River are shown in Table 16. The monitoring components shown are adequate to evaluate all of the objectives of the trial. However, the design and scope of any monitoring program will depend on the amount of available funds for the process. If inadequate funds are available, variations to the program will need to be evaluated by the trial partners.

There is also a need to develop evaluation criteria for the metrics, along with reporting an feedback arrangements in conjunction with the monitoring program.

Table 16. Monitoring components linked to objectives and evaluation metrics

Hydrological components	Monitoring	Metrics
Cease to flow (January to March)	Gauging at Clarendon Weir gauge A5030500 (SAW/BOM site) and Onka R 300m d/s Clarendon Weir A5031004 (AMLRNRMB site) (to evaluate releases) Gauging at Old Noarlunga gauge A5031005 (to evaluate losses, transmission and tributary inputs)	% of time with no recorded flow (compared to inflow)
April fresh (100 ML/d, 4 days)		Peak flow achieved (Y/N) Duration achieved (Y/N)
May Fresh (120 ML)		Volume delivered (Y/N)
30 ML/d baseflow (April to October)		% of time with recorded flow => 30 ML/d
June Fresh (1,195 ML)		Volume delivered (Y/N) Peak flow achieved (Y/N) Duration achieved (Y/N)
September Fresh (1,195 ML)		Volume delivered (Y/N) Peak flow achieved (Y/N) Duration achieved (Y/N)
10 ML/d baseflow (November to December)		% of time with recorded flow => 30 ML/d

Hydraulic components	Monitoring	Metrics
Habitat availability (cease to flows)	Continuous depth monitoring. Multiple sites covering a range of pool sizes and maximum depths.	Rate of depth reduction over time Volume of pool compared to drying time
Habitat increase due to pool refilling (April and May freshes)	Gauging at Old Noarlunga gauge A5031005	Increase in flow at Old Noarlunga gauge A5031005 due to releases (Y/N)
Habitat availability (30 ML/d baseflow)	One-off pool depth and area at multiple sites covering a range of pool sizes and maximum depths. One-off riffle depth at multiple sites	Pools throughout reach at maximum volume and depth (Y/N) Median riffle depth => 10 cm (Y/N) Increase in flow at Old Noarlunga gauge A5031005 due to releases (Y/N)
Fish passage (June and September freshes)	Depth of water over shallow restriction yet to be identified	Provision of connecting depth >10 cm between pools (Y/N). Response monitoring (movement) of diadromous fish

<table>
<tr><th>Environmental Objective</th><th>Monitoring</th><th>Metrics</th></tr>
<tr><td>Water quality in pools maintained at levels suitable for aquatic life</td><td>Continuous water quality sampling in selected pools during summer for water temperature, salinity and dissolved oxygen.</td><td>Water temperature (maximum)
Salinity (maximum)
Dissolved oxygen (minimum)
% of time, and absolute duration, above or below known tolerance thresholds (%, days)</td></tr>
<tr><td>No degradation of in-stream habitat conditions</td><td>Physical habitat condition monitoring during biotic surveys (depth of pools, substrate condition, channel width etc) as outlined in the Design Report (McEvoy 2006).

Index of Riverine Condition at the start and end of the trial.</td><td>Change in habitat variables

Change in IRC value</td></tr>
<tr><td>Self sustaining populations of diadromous native fish with species collected as far upstream as Clarendon Weir</td><td rowspan="4">Bi-annual sampling of fish community at three sites used in the 2006-2008 survey.

Response monitoring (spawning and migration) of diadromous fish species to April baseflow, June and September freshes.

Assessment of native fish condition</td><td>Presence/absence in Clarendon Weir reach (Y/N)
Number of years with recruitment
Population size
Population structure (number of age classes present)
Fish Condition Index
Presence and abundance in directional netting</td></tr>
<tr><td>Mountain galaxias, Dwarf flathead gudgeon, Flathead gudgeon populations with regular breeding and recruitment in the main channel</td><td>Frequency of recruitment
Population size
Population structure (number of age classes present)
Fish Condition Index</td></tr>
<tr><td>More stable populations of native fish species (preventing large swings in abundance and increased risk of localised extinctions)</td><td>Subjective assessment of year to year variability</td></tr>
<tr><td>No expansion in the distribution of Eastern gambusia</td><td>Population size
Population structure (number of age classes present)</td></tr>
<tr><td>A reference condition macroinvertebrate community (typical of ephemeral streams in this habitat type)</td><td>Spring and Autumn condition assessment of macroinvertebrate communities using established standard assessment techniques (3 sites).</td><td>Taxonomic richness
Life form diversity
Similarity to assemblages in reference streams</td></tr>
<tr><td>Sustainable in-stream vegetation communities</td><td rowspan="3">Annual transect based survey using the protocol based on the methods used in the Onkaparinga as described by Nicol and Bald (2006).

Recruitment and condition assessment of native species near the channel</td><td>Presence/absence of in-stream species
% cover</td></tr>
<tr><td>Maintenance of native terrestrial species near the channel</td><td>Recruitment occurring (Y/N)
Survival from year to year</td></tr>
<tr><td>Reduced terrestrial plant species (particularly African fountain grass) within the main channel</td><td>% Reduction in cover of terrestrial plants in riffle/run areas</td></tr>
</table>

7 Design and Evaluation

The design of the monitoring program, and any subsequent evaluation, depends entirely on the amount of available funds for the process. In the original trial, the available budget was insufficient to adopt all of the monitoring components suggested here, so only a small subset was chosen for study (McEvoy 2006[21]). The original budget only allowed for 8 "observations" (a single set of measurements collected from one locality on one occasion) on this restricted set.

While the EWPs outlined in this report have a number of predicted outcomes (see for example Table 3) which can be measured as a set of monitoring metrics (Table 4), evaluating whether the flows themselves are the cause of any change in the metrics is a difficult task. Numerous documents and guidelines (e.g. Cottingham *et al*. 2005[22]) have described statistically robust designs to strengthen conclusions made between intervention and results. BACI designs (Before-After-Control-Impact) provide the strongest inference that an environmental flow causes a particular observed response.

In most environmental studies, Control sites (sites that are similar to test sites, except that there is no intervention) are either not available or are more often dissimilar to the test sites. For the EWPs, this would mean locating sites with similar habitat types, similar biotic communities, similar hydrological regimes, but no EWP. Such sites are unlikely to be found to support observations in the four reach types (e.g. there are no equivalent urban sites to the Torrens River downstream of Gorge Weir).

Less robust are simple Before-After designs, where sites are sampled before the intervention and then after. Any change in metric values can then be attributed to the intervention. But it is never clear whether the change would have occurred without the intervention, so the strength of the conclusion is diminished. For the EWP reaches, even the Before data is somewhat sketchy, with only detailed sampling of the fish communities over the 2006-2008 period in all the reaches, and vegetation surveys in the Onkaparinga River.

It is strongly advised that at least some baseline data be collected before the introduction of the EWPs (including habitat condition, macroinvertebrates and in-stream vegetation).

Cottingham *et al*. (2005) recognise that the BACI design often cannot be applied to EWP delivery assessments. They recommend that:

> *… response variables be measured at multiple sites within each river, representing different levels of a continuous 'treatment' along a continuum of environmental flow interventions. Thus, information will be collected on flow and response along a gradient, allowing us to build up a picture of the relationship between flow and response.* (p. 53)

Collecting data at different sites, and at different times, allows an evaluation of the responses of environmental variables to a number of different flows (determined by the releases, and groundwater and tributary inflows. Because of the nature of previous work, a minimum of three sites in each reach is recommended.

The analysis of collected data can be conducted in two phases.

Firstly, in the short term, any change in metrics from any one time period to the next time period can be compared with the predicted change (expressed as a direction, such as increase/decrease, and a scale, either absolute or a percentage). While a single observation may not demonstrate a causal link, multiple changes in the same direction will provide additional strength to the conclusions. We are assisted here by the similarities in flow regime (two reaches have permanent flows and two are ephemeral) and certain flow components (e.g. June and September flushes) that have similar functions. The assessment of success of the EWP at any one site will, however, rely on the expert opinion of the scientists involved in the data collection and evaluation.

[21] McEvoy, P. (2006) Ecological Responses to Flow in the Mount Lofty Ranges. Design Report. Version 2.
[22] Cottingham, P,, Quinn, G,, King, A,, Norris, R,, Chessman, B. and Marshall, C. (2005). *Environmental Flows Monitoring and Assessment Framework.* Technical Report. CRC for Freshwater Ecology, Canberra.

Secondly, in the longer term, data from multiple sites may be analysed at the end of the trial period by the use of a regression-based approach within a Bayesian hierarchical modelling (BHM) framework. Chee *et al*. (2006[23]) describe the use of the approach that describes a mathematical relationship between variables, rather than just comparing two sets of data (e.g. before and after).

The advantage of a BHM framework is that it can provide the strength of a relationship between the hydrological metrics collected and the responses in ecological metrics, and thus can be a useful predictive tool for evaluating the likely success of EWPs in other Western Mount Lofty streams.

There is insufficient space (and comprehension of the current author) to provide an adequate explanation of the BHM process. An explanation of the approach, with a worked example can be found in Appendix 3 of Chee *et al*. (2006).

[23] Chee, Y.E., Webb, J.A., Stewardson, M. and Cottingham, P. (2009) Victorian environmental flows monitoring and assessment program: Monitoring and evaluation of environmental flow releases in the Broken River. Report prepared for the Goulburn Broken Catchment Management Authority and the Department of Sustainability and Environment by eWater Cooperative Research Centre, Canberra.

8 Priorities

The prioritisation of reaches with respect to EWPs on the basis of ecological condition and likely response to flows has been investigated based on the fish and macroinvertebrate communities by DLWBC (2005). The priorities were based on a ranking system that evaluated ecological health, and expert opinion that evaluated the potential changes in health due to the introduction of an EWP.

They suggested that, on the basis of current condition and the potential for improvements, the reaches, in priority order were:

- Onkaparinga River;
- South Para River;
- Torrens River downstream of Gorge Weir.

The Torrens River between Gumeracha Weir and Kangaroo Creek Reservoir was not evaluated.

There seems little reason to change the priority order based on the revised EWPs in these reaches. The Onkaparinga River has the greatest potential for improvement (or responses) due to its connection with the estuary and the sea, and its remnant ecological assets. The potential to produce improvements in fish populations include all the species that could be expected to occur in the reach, with the exception of the presumed extinct Southern purple-spotted gudgeon, and likely present but undetected Shortheaded lamprey and Pouched lamprey. The National Park setting means that catchment activities and jurisdiction issues are more manageable.

The Torrens River downstream of Gorge Weir can be seen as the lowest priority of the reaches. The influence of urbanisation has often been as an impediment to restoration activities, and, along with the relatively small volume of water available for the EWP, the chance of significant improvements is the lowest in this reach.

The two remaining reaches both have a number of factors that may influence their priority. The Torrens River between Gumeracha Weir and Kangaroo Creek Reservoir contains Climbing galaxias, the only sustainable population in the catchment. As a landlocked population, it is of particular scientific interest. The diversity of fish species is higher and is relatively intact compared to expected pre-European reference condition (M. Hammer, pers. comm.). With the introduction of a permanent flow regime, the potential to improve populations would seem to be more probably than in the South Para River. The South Para reach has few native species, and there would seem to be an inherently higher risk of failure due to the presence of exotic fish species.

Therefore, the upper Torrens River reach, on the basis of ecological condition and likely response to flows, would seem to have a higher priority than the South Para River. This could change if fish barriers in the South Para River system were overcome, connecting the reach to the estuary and sea.

Therefore, the proposed priority order of the reaches is:

- Onkaparinga River;
- Torrens River between Gumeracha Weir and Kangaroo Creek Reservoir;
- South Para River;
- Torrens River downstream of Gorge Weir.

It should be noted that placing the reaches in a priority order in no way diminishes the environmental importance of any of the reaches. All have specific environmental assets and opportunities which justifies the allocation of an Environmental Water Provision. These priorities should only be used in the event of restricted water availability in subsequent years of the trial.

9 Other Issues

This section details a number of additional issues raised at the workshop.

Areas outside of the trial reaches

Three of the trial reaches can be seen as disconnected from the rest of the stream system in each catchment. Only the Onkaparinga River reach flows through to the estuary, and therefore the sea. Future EWP deliberations should consider areas outside of two of the remaining reaches.

The upper Torrens River is disconnected at both ends of the reach, bounded by the Gumeracha Weir at the upper limit and Kangaroo Creek Reservoir at the lower end. There seems to be little opportunity to consider the reach in a broader catchment context (note that this does not diminish its importance as there are distinct values in the reach).

The lower Torrens River is bounded at the bottom end by the Torrens Lake, and is thus separated from the estuary and the sea. Considerable work is being conducted in the lower ends of the reach – such as works on Breakout Creek (McNeil *et al*. 2010[24]), and the Waterproofing the West stormwater re-use scheme. There are opportunities to integrate the EWP work with these lower catchment activities, with benefits for both of the reaches.

The South Para River ends at Gawler, so that the lower sections of the catchment are excluded. Again, considering environmental conditions and flows in the lower section below Gawler in future EWP deliberations could provide multiple benefits, especially if the Woodlands Weir fish barrier is removed (physically, or with a suitable fishway).

Determining causality

Monitoring the response of an environmental variable (e.g. fish populations) to the introduction of an environmental flow is a relatively simple exercise. Far more difficult is establishing the reasons for the success or otherwise of the environmental response. That is, we can often tell what has happened, but cannot establish why it has happened (or more importantly, why it has not happened if there is no response).

There is a distinct advantage, therefore, to tie in ecological work on processes, rather than just looking at pattern (e.g. results). Such ecological work may be seen as additional to the monitoring program and would most likely require the development of specific research projects (but which could be run in conjunction to produce financial efficiencies). Alternatively, additional metrics may be developed that could add to the knowledge on flow-ecology responses.

Biofilm monitoring

Biofilm activity and composition monitoring was included as part of the monitoring program in the original trial (McEvoy 2006). In this review, there are no specific objectives for biofilms, and so monitoring has not been included. However, biofilms are likely to have the most rapid response to the introduction of the flows, and are the basis (primary producers) of aquatic food webs, so influence the successful response of other species of macroinvertebrate and fish that are present. If the intent is to demonstrate an early result from the trials, the original biofilm monitoring could be re-instated. Monitoring the condition, composition and response of biofilms would also aid in determining causality as indicated above.

Complementary works

Instream barriers and other threats in the riverine and riparian environment may impact upon the successful achievement of the EWP trial objectives identified in this report. Threats may include:

- In-stream barriers limited the lateral movement of fish species;
- Encroachment of terrestrial vegetation into the channel; and

[24] McNeil, D.G., Wilson, P.J., Fredberg, J.F. and Westergaard, S. (2010) Fish passage at the Breakout Creek Fishway, River Torrens, South Australia. Report to the AMLRNRMB. SARDI Publication No. F2009/000409-1. South Australia Research and Development Institute, Adelaide.

- Grazing livestock with unfettered access to the watercourse.

To this end, in 2011 the Adelaide and Mount Lofty Ranges Natural Resources Management Board and SARDI surveyed the EWP trial reaches to identify barriers and other threats that may impact on achievement of trial objectives. The survey identified numerous barriers and threats of varying significance. The extent to which trial objectives are achieved may in part be influenced by removal of significant barriers and threats as the trial progresses.

10 References

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Appendix A – Attendees at Workshop

Kane Aldridge	Adelaide University
Sonia Barter	SA Water
Tim Doeg	Consultant
Jacqueline Fritzenchaf	SA Water
Jackie Griggs	SA Water
Rehanna Halfyard	Adelaide Mount Lofty Ranges Natural Resources Management Board
Paul McEvoy	SA Water
Michael Hammer	Consultant
Dale McNeil	PIRSA-SARDI
Jason Nicol	PIRSA-SARDI
Stephen Smith	Adelaide Mount Lofty Ranges Natural Resources Management Board
Keith Smith	Adelaide Mount Lofty Ranges Natural Resources Management Board
Birgitte Sorensen	Adelaide Mount Lofty Ranges Natural Resources Management Board
Jason Vanlaarhoven	Department for Water

(Steven Gatti of the Adelaide Mount Lofty Ranges Natural Resources Management Board recorded an apology for the workshop).