MURRAY**FUTURES**

Lower Lakes & Coorong Recovery

9. Restoring Fish Passage

Technical Feasibility Assessment

February 2010

Government of South Australia

WATER FOR GOOD

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ACRONYMS

GCWLMP	Goolwa Channel Water Level Management Project
MDBA	Murray Darling Basin Authority
TLM	The Living Murray

1 CONTEXT

1.1 Project context and rationale

This paper outlines the proposal to install fishways on a number of structures that present obstacles to the migration of fishes within the Coorong, Lower Lakes and Murray Mouth (CLLMM). Fishways are engineered structures that facilitate the movement of fish between waterbodies that have become isolated by barrages, levees and similar structures. Fish migration between different water bodies is important to support a number of biological and ecological processes, and therefore barriers to fish migration can lead to ecological degradation. Research suggests this is currently the case at the CLLMM. Present water levels in Lakes Alexandrina and Albert are such that provision of fish passage or bio-passage between the Coorong and Lower Lakes is not possible and as such this paper does not seek to reinstate passage until water levels are restored to levels similar to historical values. Additionally, it is assumed that the barrages will continue to serve their existing function in the short to medium term.

Unimpeded movement between habitats is of utmost importance for fish, including potadromous species (obligate freshwater species that migrate within river reaches) and diadromous species (species that require movement between freshwater and estuarine/marine environments in order to complete their lifecycle) (Northcote, 1978; 1998, Harris 1984; 1988, Reynolds, 1983, Thorncraft and Harris, 2000, MDBC, 2008). Additionally, obligate freshwater and estuarine species often thought to be 'non-migratory' may also undertake substantial movements although these movements may not represent obligate components of their lifecycle. Thus, connectivity between estuarine and freshwater environments, between reaches of riverine environments and between river channel and off channel habitats is of utmost importance to fish (see MDBC, 2008, Bice, 2009).

The Murray barrages constructed between the Coorong and Lake Alexandrina present a barrier to fish passage (see Bice, 2009, Jennings *et al.,* 2007). Decreased freshwater discharge to the Coorong as a result of the drought, river regulation and upstream water extraction have resulted in sedimentation, constriction of the Murray Mouth, reduced tidal incursion, reduced depth and increased salinities (Geddes 1987; Walker 2002). Changes in water quality have the potential to alter the presence, distribution and abundance of fish species in the Coorong and Lower Lakes region. Additionally there has been no freshwater discharge over the barrages to the Coorong since March 2007. This lack of discharge and therefore connectivity along with changes in water quality is likely to alter not only the local fish community but also that of the Murray-Darling Basin more broadly.

The need for adequate fish passage has been demonstrated by the outcomes of research and monitoring undertaken by the South Australian Research and Development Institute (SARDI), through their fish movement and recruitment studies in the Coorong and Lower Lakes funded by the Murray-Darling Basin Authority (MDBA).

Recently-constructed fishways at the barrages have only partially restored connectivity between Lake Alexandrina and the Coorong (Jennings *et. al.,* 2008). Due to low lake levels resulting from low inflows these fishways have not been operable since early 2007. When water levels and flows were sufficient to enable their operation, monitoring of their effectiveness indicated that existing fishways were not sufficient to facilitate the passage of the entire range of diadromous fish species occurring in the CLLMM (Jennings et al 2008).

The fishways proposed to be constructed in the CLLMM under the Long Term Plan for the site (the subject of this paper) will improve fish passage between the Murray-Darling Basin and the Coorong/Southern Ocean for diadromous species and allow potodromous species to move between habitats or avoid unsuitable habitats.

The fishways will:

- help conserve existing listed threatened species by allowing them to avoid unfavourable habitats or facilitating migration between important habitats; and

- ensure significant ecological communities and species of fish are retained at the site and throughout the remainder of their range in the Murray-Darling Basin.

Several species that will benefit from additional fish passage opportunities contribute to the designation of the Lakes and Coorong region as a wetland of international importance under the Ramsar Convention (Phillips and Muller, 2006).

In this context, the fishways project will assist managers of the site to meet the objectives of higher level strategies such as the Commonwealth's (MDBA) Native Fish Strategy, the Living Murray Initiative, The Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Management Plan (MDBC, 2006) and the Long Term Plan for the CLLMM.

This Technical Feasibility Assessment of the project supports a preferred approach and provides indicative costs to inform the business case for the CLLMM region's Long Term Plan.

What are fishways?

A fishway, also known as fish ladder, fish pass, fish passage or fish steps, is a structure on or around artificial barriers (such as dams and locks) to facilitate fish movement. Most fishways enable fish to pass around the barriers by swimming (Barrett, et al., 2008).

1.2 Background to project

The Murray Mouth and the Coorong region comprise a modified estuary and lagoon system situated between the River Murray and Lakes Alexandrina and Albert. These assets form the terminal end of Australia's largest catchment, the Murray-Darling Basin.

In 1985 Australia designated the Coorong and the Lakes Alexandrina and Albert as a wetland of international importance under the Ramsar Convention. The designation under Ramsar carries with it certain responsibilities, one of which is to manage the site in a way that maintains its ecological character.

The Coorong, Lower Lakes and Murray Mouth region meets eight of Ramsar's nominating criteria. The Ramsar site is listed as a Wetland of International Importance partly because of its identified fish community, with identified species within the site contributing to it qualifying against five of Ramsar's eight criteria (Phillips and Muller, 2006). The site is a habitat for nationally-threatened fish species such as the Murray Hardyhead (*Craterocephalus fluviatilis*) and the Murray Cod (*Maccullochella peelii peelii*). The site supports the only population of Yarra Pygmy Perch (*Nannoperca obscura*) in the Murray-Darling Basin. The CLLMM provides a migratory pathway for diadromous species that inhabit the Murray-Darling Basin such as the shortheaded lamprey (*Mordacia mordax*) and the pouched lamprey (*Geotria australis*). Historically, the site's fish community may have been more unique than today, with several species likely to have become locally extinct in recent times (Phillips and Muller, 2006).

1.2.1 Significant fish species in the Coorong and Lower Lakes

Fifty-nine fish species have been recorded within the Coorong since barrage construction (Eckert and Robinson, 1990). Thirty-four of these are primarily marine and are irregular visitors to the region, eleven are estuarine and fourteen freshwater (Higham *et al.,* 2002). In total, 31 species have been collected that potentially migrate between the estuary and freshwater environments at the Murray Barrages (Jennings *et al*., 2008), while a further suite of species that includes Golden Perch (*Macquaria ambigua*) undertake regular migrations between freshwater environments of the lakes and the Murray River (Bice, 2009).

As of 2006, among the species recorded:

- Five species were listed as vulnerable at either global or national levels;

- 20 further species were classified as protected or had been provisionally listed of conservation concern within South Australia;
- 20 species utilised the site at critical stages of their lifecycle; and
- Four species were listed as noteworthy because they contribute to the overall biodiversity of the fish community.

Fish are highly mobile organisms and all species migrate to some degree for purposes of feeding, spawning, dispersal or avoidance of unfavourable conditions (Northcote, 1978). Movement may be longitudinal (up- or down-stream) or lateral (from channel to floodplain or deep water to fringing habitat) and may be an essential aspect of a species lifecycle.

An explanation of terms to describe fish migration

The following background information has been distilled from the literature review undertaken on fish of the region (Bice, 2009). Fish species which have been observed as requiring movement at the site include the following:

- Potamodromous: Fish that migrate wholly within fresh water environments;
- Diadromous fish require movement between fresh water and the estuarine/marine environments in order to complete their life cycle. Within this group are three further subdivisions of fish:
  - Anadromous: diadromous fish that spend most of their life in the sea and migrate to fresh water to breed;
  - Catadromous: diadromous fish that spend most of their life in freshwater and migrate to the sea to breed;
  - Amphidromous: diadromous fish that migrate between the sea and fresh water, but not for the purpose of breeding;
- Estuarine resident species generally complete their lifecycle within the estuaries and includes commercially important species; and
- Marine species often present in estuaries but may complete their lifecycle in coastal marine waters. This also includes commercially important species.

Further information on the terms described here can be found in Myers (1949), Harris (1984), McDowall (1988), Whitfield, (1999) and Thorncraft and Harris (2000) which acted as source material.

Catadromous and potamodromous life cycles are both common among Australian species, so both adult and juvenile fish commonly attempt to migrate past barriers (Thorncraft and Harris, 2000). Diadromous species are generally found in greater numbers at lower altitudes (McDowall 1988, 1996; Harris & Gehrke 1997 cited in Thorncraft and Harris 2000). The fish community of the Lower Lakes and Coorong is diverse and includes several diadromous and potamodromous species but also includes several estuarine species that are known to move between estuarine and freshwater environments (Higham et al. 2002; Bice, 2009). Several species at the site are considered to be indicators of environmental change or keystone species (Bice, 2009).

For fish with life cycles that include large-scale migrations (particularly anadromous and catadromous species) the prevention of fish passage can cause local extinctions upstream of barriers and greatly reduce population numbers downstream of these barriers (see Faragher & Harris 1994; Marsden et al. 1997; Harris et al. 1998; Pethebridge et al. 1998 cited in Thorncraft and Harris, 2000). For all fish species major barriers isolate and can fragment previously continuous fish communities, resulting in changes to such communities (Harris & Mallen-Cooper 1994; McDowall, 1996; Stuart 1997; Harris 1997; Harris et al. 1998 cited in Thorncraft and Harris, 2000).

Barriers to fish migrations in the lower reaches of a river system usually cause the greatest damage to fish populations because they can totally block the weaker swimming fish resulting in recruitment failure to all upstream habitats in a catchment (Harris 1984; Stuart 1997; Harris 1988 Cited in Thorncraft and Harris, 2000 and Jennings et al., 2008).

1.2.2 Barriers to fish passage

The River Murray is a highly modified river system hydrologically (Gippell and Blackburn, 2000). Since the early 1900s there have been a series of regulating structures constructed along the 2,500 km long River Murray below Hume Dam including:

- The five barrages that form a barrier between the freshwater environment of the Lower Lakes and the estuarine/marine environment of the Coorong (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere barrage).
- 12 low-level (<10 m high) locks and weirs (Locks 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 15).

Initially these weirs were constructed to maintain river navigation during periods of low inflow, however they now also store and re-regulate flows for irrigation and domestic water supplies (Barrett, et al. 2008). Figure 1 shows the location of the 4000 plus barriers documented across the Murray-Darling Basin (Lintermans, 2009). The Murray Barrages are particularly significant given their location and because during drought periods, when flows to the Coorong do not occur and therefore migration between these habitats is prevented, recruitment of diadromous fish species of the Murray-Darling Basin is prevented.

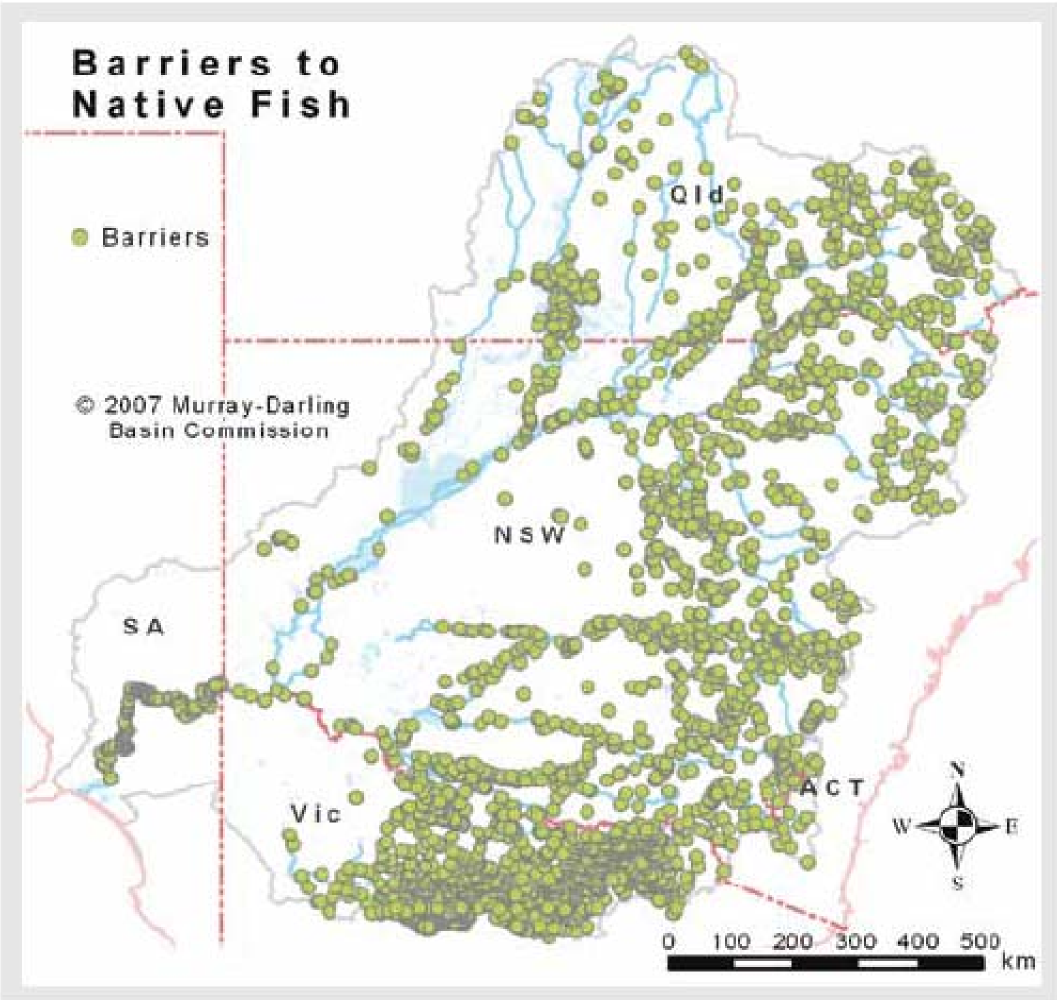


Figure 1: Barriers to Native Fish in the Murray-Darling Basin [Source: Lintermans (2009)].

Barrett et al., (2008) outlines the evidence that the construction of dams and weirs has had a profound impact on abundance and diversity of native fish within the Murray-Darling Basin, resulting in riverine fragmentation and disrupted longitudinal connectivity for many species. This is because regulating structures create physical barriers that restrict access to spawning grounds and preferred habitats, and prevent dispersal and recolonisation by fish. Barriers also interrupt the migrations of freshwater fish, an essential step for various life history stages (Reynolds, 1983; Mallen-Cooper and Brand, 1991; Harris et al, 1992; Mallen-Cooper, 1996 & 1999; Thorncraft and Harris, 2000 cited in Barrett et al., 2008).

The fish fauna of the Murray-Darling Basin is dominated by potamodromous species (Barrett et al., 2008). Barrett et al (2008) outline the evidence that for many species, migrations are an essential part of their life histories (Reynolds, 1983; Mallen- Cooper, 1999 cited in Barrett et al 2008), and are undertaken by both adult (Reynolds, 1983; Mallen-Cooper, 1999; Thorncraft and Harris, 2000 cited in Barrett et al., 2008) and juvenile life stages (Mallen- Cooper and Brand, 1991; Harris et al, 1992; Mallen- Cooper, 1996, Barrett et al., 2008). Barrett et al., (2008) demonstrate that evidence suggests migration of fish can also occur in an upstream and downstream direction, with substantial downstream movements of native fish being recorded (Reynolds, 1983; O'Connor et al, 2003 cited in Barrett et al., 2008).

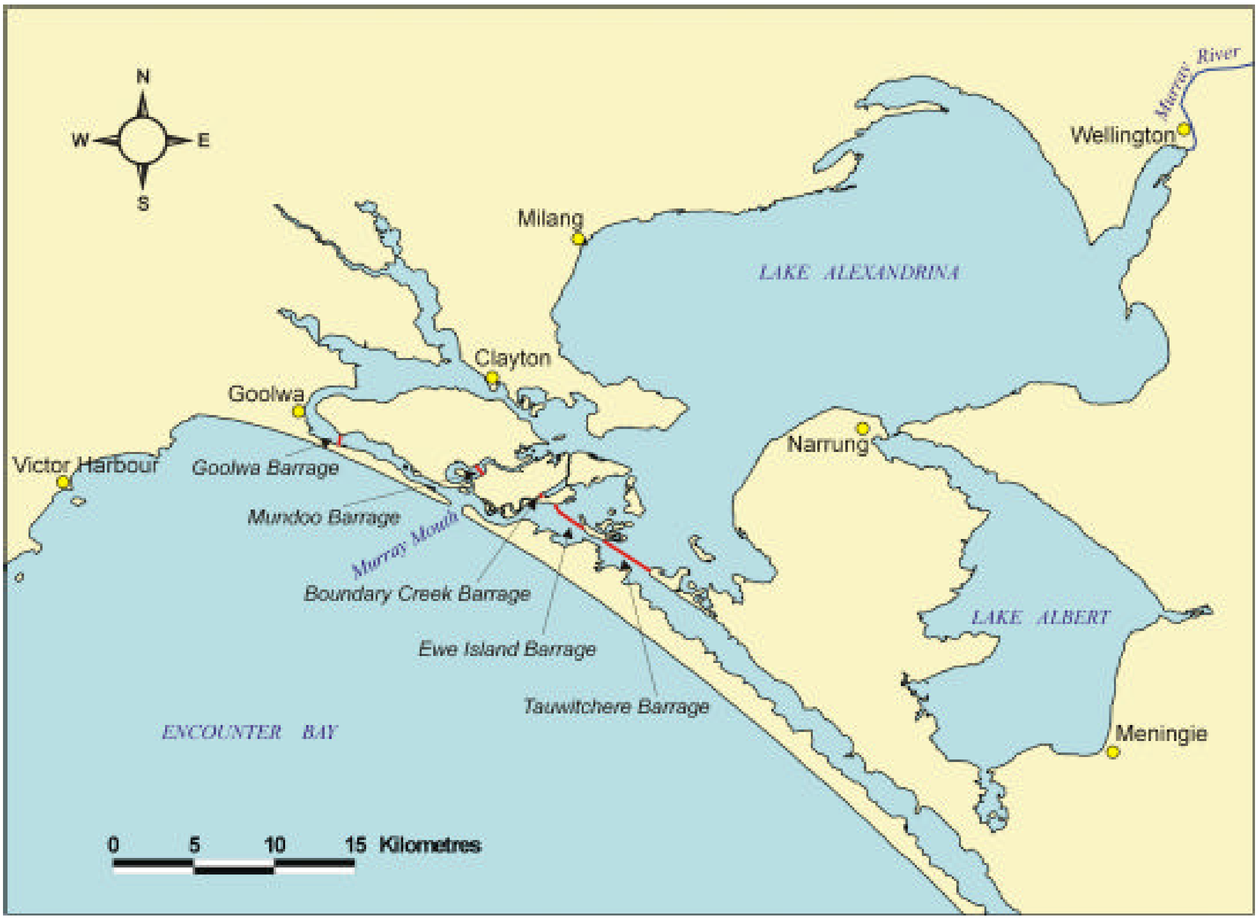


Figure 2: Map of the Coorong, Lower Lakes and Murray Mouth showing the barrages (Source: MDBC (2008).

The barrages have dramatically reduced the connectivity between the marine and freshwater environments by creating an impounded freshwater environment upstream and an abrupt ecological barrier between this environment and the estuarine/marine environments of the Coorong. Man-made physical barriers and the resulting loss of connectivity between freshwater and marine estuarine environments have been implicated in the reductions of diadromous fish populations in Australia (see Thorncraft and Harris, 2000). The continued lack of connectivity between the Coorong and the rest of the Murray-Darling Basin may have significant consequences for the Basin's diadromous fish species which require access to the sea to complete their lifecycle and maintain the population.

A major environmental impact of the successive barriers has been a serious contraction in the distribution and abundance of diadromous and potamodromous fishes (Barrett, et al., 2008). When the barrage gates were opened in the past, downstream fish movement from the Lakes to the Coorong was possible, but movement in the reverse direction was believed to be restricted due to the high flow velocities and physical structure of the gates (J. Higham, personal communication, 2009). Such movement is particularly important for diadromous species that require access to both marine and freshwater habitats to complete their life cycles or freshwater species that are washed downstream and would otherwise not survive in the Coorong (Higham et al., 2002). Small bodied and juvenile fish are crucial in the food chain because they are believed to be a major food source for piscivorous birds and larger bodied fish (Phillips and Muller, 2006).

The regulation of freshwater flow and the significant reductions and lack of flow more recently is believed to have had a detrimental impact on commercial and recreational fisheries of the region (see Ferguson, 2008 for information on present status of relevant stocks).

Fishways have the ability to mitigate the impacts of barriers on native fish movement and if designed properly will improve fish access to critical habitat and spawning areas.

1.3 Assessment of existing fishways

The following section provides an assessment of the effectiveness of existing fishways for native fish in the Murray-Darling Basin and learnings from recently constructed fishways in the CLLMM

A number of the pioneering fishways constructed in the Murray-Darling Basin were poorly built or used an inappropriate design and generally were not maintained (Lintermans, 2009). The design challenges confronting these earlier fishways included:

- Poor consideration of the behaviours of Australian native fish species most of which do not leap or have the swimming ability of northern hemisphere species on which early fishway designs were based.
- The challenge of integrating fishways, which had generally been designed for relatively consistent flow rates, with the highly variable flow rates of Australian rivers and streams.
- Catering for all of the expected differences in swimming ability and migration behaviour of Australian freshwater fish species.

Due to poor local knowledge, many of the earlier fishways in the Murray-Darling Basin provided only limited fish passage. The vision of providing improved fish passage along the Murray River began in the mid-1980s when the Murray-Darling Basin Commission (MDBC) (then River Murray Commission) established a Working Group of interstate scientists to examine the issue of fish passage (Barrett, et al., 2008). It was not until the early 1990's with work undertaken by Mallen-Cooper at Torrumbarry weir and other projects, for example at Yarrawonga, that progress was made in improving the design of fishways for the native fish of the Murray-Darling Basin (Barrett, et al., 2008). This has further progressed through the Sea to Hume Dam fishway program such that the fishways on the River Murray are now passing large numbers (>50,000 fish over 40 days), high diversity (13 species), and a wide size-range (31 mm to 1040 mm long) of fish (Barrett, et al., 2008).

The Barrages that separate the freshwater Lower Lakes of the River Murray from the estuarine Coorong and Goolwa Channel occur in a complex estuarine-freshwater environment that presents specific challenges in terms of fishway design (Jennings et al., 2008). There are five waterways between Lake Alexandrina and the Coorong, widely separated by islands and each is an important migratory route for native fish. Each waterway is crossed by a separate barrage creating essentially a single continuous barrier over 7.6km in length In general the daily flow of water through a fishway at any of the locks and weirs on the Murray is only a small portion of the total flow and therefore not of concern. The Barrages can have high flows but also experience long periods of very low flows or total closure (as upstream demand and evaporation draws down water levels in the Lower Lakes) and hence their operation and effectiveness is linked to the provision of adequate flows (Jennings et. al., 2008).

The MDBC Fish Passage Task Force (FPTF), in consultation with barrage operators and commercial fishers, recommended three fishways that were considered to offer the highest potential for effective fish passage at the Murray Barrages: vertical-slot, Denil and rock-ramp (Mallen-Cooper, 2001). A stepped implementation program was initiated commencing with the construction of a vertical-slot fishway at Goolwa Barrage and a vertical-slot and rock-ramp fishway at Tauwitchere Barrage (Jennings et. al., 2008). A Denil fishway was not constructed as this type of fishway is unable to operate effectively with variable headwater, a common scenario in the Lower Lakes (Jennings et. al., 2008).

Jennings et. al., (2008) outlines how the Murray Barrage Fish Passage Assessment Program commenced in 2001 and was divided into three phases:

- Stage I – Pre-fishway assessment of the migratory fish community.
- Stage II – Trial fishway assessment, comparison and fishway experiments.
- Stage III – Post-fishway optimisation.

Stage I was conducted between 2001–02 and 2003–04 and involved an assessment of fish communities in the Lower Lakes and Coorong to determine the presence of potential migratory fish species (Ye et al., 2002). Stage II commenced in 2005 following the completion of rock-ramp and vertical slot fishways at Tauwitchere Barrage. An initial performance assessment of the vertical-slot fishway was conducted in January and early February 2005 (Stuart et al., 2005).

Following improvements to the Tauwitchere rock-ramp fishway and the completion of a new partial depth vertical-slot fishway at Goolwa Barrage in 2005 a monitoring program during the 2005/06 spring-summer period was initiated to further assess the performance of the three trial fishways (Jennings et. al., 2008). Jennings et al. (2008) summarises the assessments of the three fishways including the species composition, size range and abundance of fishes attempting to utilise and successfully ascending the fishways. This assessment found that:

- Existing fishways have been utilised mainly by small-bodied fish and have not been as effective as anticipated for enabling the passage of large bodied species.
- There is a challenge in the design and operation of fishways to facilitate fish passage in a dynamic system that is experiencing significant variations in head and tail water levels.
- Fishways designed to facilitate fish passage while discharging low volumes of freshwater will be best in meeting the ecological requirements of migratory fish communities in this highly regulated system. The site however will also need to include high flow fishways to improve fish passage during future periods of high discharge from the Barrages.

When operating, existing fishways or fish passages enable fish to move between the freshwater and estuarine/marine parts of the site that have been disconnected through construction of barrages and other devices. Temporary regulators constructed in the last 3 years have limited to no fish passage opportunity and are likely to pose significant risk to fish communities in completing obligate movements or while attempting to escape poor water quality.

1.4 Considerations for the design of fishways in the CLLMM Region

In the Coorong, Lower Lakes region in particular, a number of key challenges need to be addressed when designing fishways to be suitable for local conditions. For fishways in the region, water levels upstream and downstream of them vary over broad ranges either due to tidal variation in the Coorong, or inflows to and losses from the Lakes as well as barrage operations but vary daily due to wind seiche in both environments. The variable water levels upstream and downstream of the structures pose significant challenges for provision of successful fish passage for all target species under all conditions.

Fishway Consulting Services (2006) and Jennings et al (2008) provide a summary of the considerations needed in any future proposed fishways at the barrages:

- Potential variations in water level, both on a daily (tidal) and annual (headwater) basis occur and need to be accommodated in proposed designs

- The need to provide fish passage during periods of future low water availability while also accommodating fish passage during periods of high barrage outflow
- The size and swimming ability and behaviour of the target species and
- The timing of peak migration periods and likely high biomass attempting to undertake migration.

Many of these apply to both the regulators (temporary or permanent) within the system as well as the Barrages.

1.4.1 Hydrological observations for fishways

The following hydrological observations of the Lower Lakes are of relevance to the design of fishways at the barrages:

- Lake levels historically are generally highest in spring and this is a major period of fish movement.
- Although full supply level (FSL) of the Lower Lakes is 0.75 mAHD, actual water levels at the barrages can be 0.85 - 1.0 mAHD due to the combined effects of wind and surcharge (i.e. 'topping up' the Lakes above FSL in anticipation of low inflows and high evaporation through late summer and autumn).
- Future lake levels under a more variable lake level regime are likely to necessitate the same design requirements for maximum lake levels although not as frequently (surcharge occurring on a 1 in 3 year return frequency). The more variable lake operating regime is also likely to necessitate the provision of fish passage at lower water levels, as low as +0.35m AHD (subject to constraints on minimum and maximum water levels) and so should accommodate this design eventuality.
- Minimum tailwater is 0.0 m to 0.1 m AHD at Tauwitchere and this is unlikely to change in the near term.
- Low tailwater can occur for long periods of time at Tauwitchere, but Goolwa fluctuates daily with the tides. Hence, the upper tidal range may be acceptable for fish passage at Goolwa but provides poor fish passage at Tauwitchere and hence the minimum tailwater level will require consideration to provide effective fish passage at this part of the site.
- In periods of low flows the water use of the fishways is a significant management issue. There is currently no permanent allocation of water to operate the fishways in periods of low flows.

Further examination of near term water levels in Lakes Alexandrina, Albert and the Goolwa Channel is required to enable the design of fishways at these structures now that they are hydrologically separated in the short-term by temporary structures. It is assumed that the regulators will continue to artificially alter water levels in these weir pools compared to Lake Alexandrina until such time as water levels 'recover'. It is also assumed that the need to provide fish passage at temporary regulators is required to maintain resident fish populations and enable repopulation of sections of the system should fish kills occur within them. The provision of fish passage to enable recovery may not be necessary depending on when they are removed (ie soon after water levels recover to those similar to pre 2006). As such fish passage at these sites should concentrate on facilitating fish passage to enable effective maintenance of populations (breeding movements).

Although full supply level (FSL) of the Lower Lakes is +0.75m AHD, actual water levels in Lake Alexandrina could drop to -1.5m AHD or lower depending on inflows and near term management strategies in response to water availability. Water levels in Lake Albert are targeted at being maintained above -0.75m AHD through pumping from Lake Alexandrina. Following initial pumping into the Goolwa Channel, a target minimum water level of +0.0m AHD will be maintained using inflows from tributaries of the Eastern Mount Lofty ranges. Unlike Lake Albert, it is likely that water from the tributaries will be greater than the volume needed to maintain the minimum water level in Goolwa Channel and so should spill either over the regulator or be released through Goolwa Barrage. With the spilling of water from the Goolwa Channel to Lake Alexandrina over the Goolwa Channel regulator, attraction of fish to this structure is likely and may result in mortality of fish downstream if no passage of fish into this weirpool is provided during the spill of water, while an existing fishway is present at Goolwa Barrage.

The water quality in Lake Albert is unlikely to support fish communities in the near term and as such there is likely to be a fish kill in the near future. Steps are underway to remove as much of this biomass as possible. These structures and potential near term water levels pose a significant challenge to construction of effective fishways, because of the significant difference in water level between weirpools is potentially greater than 2.0m. As such, feasibility of fishways as temporary mitigation strategies may not be possible, especially within the existing budget but requires further investigation. It may be that fishways that operate over part of the height range may be appropriate and meet objectives of maintaining fish populations within these waterbodies given possible water quality in the receiving water bodies.

Maintenance of existing populations will only occur in the short to medium term by the provision of fish passages at these structures given the necessity for many species to undertake migrations as a part of their lifecycle.

1.4.1.1 Hydrological recommendations for fishways in the CLLMM

- Fishways at the barrages need to be designed for operation over a range of lake levels from 1.0m AHD to +0.35 m AHD.
- At Tauwitchere barrages fishways should also be designed for the lowest observed tailwater of 0.0 m to 0.1 m AHD
- Designing a fishway that minimises water use, while preserving fishway function, is important for low flow periods.
- Water to operate the fishways in periods of low flows needs to be allocated and formally secured.

1.4.2 Functional Priorities for Fish Passage at the Barrages

Although the Goolwa and Tauwitchere vertical-slot fishways were designed for large-bodied fishes (>150 mm up to 1000 mm), no large bodied estuarine fish species (i.e. mulloway and black bream) were collected in the fishways despite their presence in the vicinity of the fishway entrances (Jennings et al., 2008). The vertical-slot fishways were effective, however, in facilitating the upstream passage of displaced large-bodied freshwater fish such as Golden perch (Jennings et al., 2008). The return migration of displaced potamodromous fishes is an important ecological consideration in large rivers (Stuart and Berghuis, 2002) and the current vertical-slot fishways appear to effectively facilitate this (Jennings et al., 2008)and hence fishway designs at the barrages will need to accommodate large bodies species.

The lack of flows in the recent past and lack of knowledge regarding the recruitment ecology of large bodied estuarine species should not result in provision of fish passage for these species as it is likely that they require access to upstream habitats. Under current conditions fish are confronted by a sudden change in salinity and the biological and behavioral effects of such abrupt gradients are generally unknown worldwide (Larinier, 2002 cited in Jennings et al., 2008). Prior to barrage construction, a gradual salinity gradient would have been present during these events and large–bodied estuarine fish may have followed this gradient (Jennings et al., 2008) hence with continual releases of freshwater flow, a gradient may be re-established. An investigation of the ecology of large-bodied estuarine species in the Coorong/Lower Lakes is required however given the need to provide passage for displaced potodromous fish, the requirements for estuarine species is likely to be met.

Monitoring undertaken at the barrages and summarised in Jennings et al., (2008) indicates that over 98% (57,446 individuals) of the fish collected across all barrage fishways were small-bodied species (<100 mm long). Many of these individuals were collected attempting to use the fishways though unable to ascend due to the design hydraulics, particularly at the vertical-slot fishways (Jennings et al., 2008).

Nevertheless, ascent of some small-bodied species was observed during periods of low or negative headloss between the Lower Lakes and Coorong. Given the high biomass of small-bodied fish species attempting to migrate, the construction of future fishways at the Murray Barrages will include a range of fishways that can facilitate the passage of small fish (from 20 to 150 mm in length).

Jennings et al., (2008) indicate that fishway types identified as being suitable to facilitate small-bodied fish passage include small fish locks, low-head vertical-slot and rock-ramp fishways. Mallen-Cooper (2000) indicates that modified culverts are also appropriate for providing fish passge where road crossing is necessary or where culverts already exist and conditions allow. To be effective and efficient at facilitating the passage of small-bodied fish over a long migration season (potentially August to March) these fishways will need to operate over a broad range of flow and headloss conditions as outlined above.

1.5 Recommendations for Fish Passage designs in the CLLMM region

The following outcomes are recommended:

- Fishways must be able to operate under a range of water levels, both for high variations in lake levels (headwater) and also for the lowest tailwater;
- Fishways should be able to operate during periods of low inflow, yet should also operate using minimum volumes of water;
- Monitoring and investigations should be ongoing, especially during moderate and flood flows, in order to assess their effectiveness and better understand migratory fish ecology;
- Fishways should provide for the movement of large bodied species, particularly during spawning. A monitoring program should also be implemented to better understand the ecology of large bodied species in relation to freshwater inflows, movement and recruitment; and
- Water to operate the fishways during periods of low flows needs to be allocated and formally secured for the site.

The three functional priorities for fish passage therefore become:

1 A fishway for small fish that minimizes water use – to operate when there is little water available);

2 A fishway for small fish that maximises water use – to provide sufficient behavioural cues to attract the fish to the fishway when there are high flows); and

3 A fishway for large fish that maximises water use – to provide sufficient behavioural cues to attract the fish to the fishway when there are high flows).

2 POLICY CONTEXT

The project links and contributes to the following policies and plans:

- Native Fish Strategy, including the Sea to Hume program;
- Living Murray Icon sites program;
- The CLLMM Long Term Plan (under development);
- EPBC Act 1999 ; and
- Water Act 2007.

2.1.1 Native fish strategy

In 2002 the Murray-Darling Basin Commission instigated the Native Fish Strategy (NFS). The overall goal of the NFS is to restore native fish communities in the Murray-Darling Basin to 60 per cent or greater of their estimated pre-European settlement levels after 50 years of implementation.

The Strategy seeks to achieve its goal by implementing six driving actions that include management, research and investigation, and community engagement interventions. These are:

1 rehabilitating fish habitat;
2 protecting fish habitat;
3 managing riverine structures;
4 controlling alien fish species;
5 protecting threatened native fish species; and
6 managing fish translocation and stocking.

The 13 objectives of the NFS aim to improve the status of native fish populations. Achievement of the 13 objectives will be by implementing actions that relate to management, research, investigation and community engagement. This project contributes to achieving the objectives of the NFS, particularly protecting threatened native fish species.

2.1.2 Sea to Hume Dam Program

In response to a dramatic decline in native fish populations and aquatic biodiversity due to the construction of dams, weirs and regulators, the Sea to Hume Dam program has been implemented to improve fish passage to over 2000 km of the Murray River, from the sea to the Hume Dam. The program which has been underway since 2001 aims to deliver effective fishways at key sites from the tidal barrages near the Murray Mouth to Lock 15 at Euston. The implementation has been coordinated as part of the The Living Murray initiative.

Under the Sea to Hume program between 2002 and 2008 three fishways were constructed to facilitate fish passage at the Murray River barrages in the CLLMM site. The works included:

- a rock-ramp fishway at Tauwitchere Barrage;
- a vertical slot fishway at Tauwitchere Barrage; and
- a vertical slot fishway at Goolwa Barrage.

A fishway was also constructed at Hunter's Creek as part of The Living Murray initiative.
In addition the MDBA Fish Passage Taskforce has recommended fishways at Mundoo and Boundary Creek Barrages be constructed along with additional fishways at Goolwa and Tauwitchere barrages.

2.1.3 Living Murray Icon Sites

The Living Murray Initiative established in 2002 is one of the most significant river restoration programs being undertaken nationally. The initiative is focusing on improving the environment at six icon sites chosen for their high ecological value. The Coorong, Lower Lakes and Murray Mouth is one of the six icon sites. The Living Murray Initiative has set a number of objectives for each of the Icon Sites.
As part of The Living Murray Initiative First Step Decision, the Murray-Darling Basin Ministerial Council established three broad ecological objectives for the Lower Lakes, Coorong and Murray Mouth Icon Site. In order to achieve a healthier Lower Lakes and Coorong estuarine environment, these objectives are:

- An open Murray Mouth;
- Enhanced migratory water bird habitat in the Lower Lakes and Coorong; and
- More frequent estuarine fish spawning and recruitment.

In order to further articulate the achievement of these broad objectives, a series of more detailed objectives were set, those interim targets relevant to the Barrage fishways are:

- Coorong - North Lagoon
  - Enhance and maintain benthic diversity in the estuarine-lagoonal invertebrate populations
  - Establish and maintain organic content for mudflats
- Murray Mouth Estuary and Coorong

  - Establish and maintain variable salinity regime with >30% of area below sea water salinity concentrations
  - Maintain the 1% flyway population level for Sharp-tailed Sandpiper, Curlew Sandpiper, Red-necked Stint, Sanderling, Common Greenshank and Banded Stilt
- Lakes and Coorong
  - Successful spawning and recruitment of Black Bream and Greenback Flounder
  - Improved connectivity between the Lower Lakes and Coorong to facilitate required fish passage between freshwater and estuarine habitats that provides for the improved spawning and recruitment success of diadromous fish species.

The proposed fishways, together with existing fishways and those under development at the site, are consistent with the above Living Murray Initiative targets.

2.1.4 The Long Term Plan for the Coorong, Lower Lakes and Murray Mouth

The Long Term Plan aims to secure a future for the CLLMM in spite of extreme low inflows to the site and predicted future climate change impacts. The Long Term Plan outlines a series of management actions designed to achieve the goal for the plan and predicated on a freshwater future for the site. Under the plan fishways will be installed at the barrages to permit fish species to move between the Coorong and the Lower Lakes system.

3 PROJECT SCOPE

3.1 Description of the project

The project proposes the construction of fish passages at eight sites defined within the CLLMM (Ramsar boundary) site. Locations of the proposed fish passages are shown in Figure 7. The proposed choice of fishway structure takes into account the findings of previous assessments at the barrages and elsewhere in the Murray-Darling Basin.

3.2 Project objectives

The project has the following key objectives:

1. To construct priority fishways for the protection of fish species within their natural range.
2. To incorporate fishways into the design and construction of new structures proposed under the Long Term Plan, and to retrofit them to existing temporary structures (such as the Narrung Bund & Clayton Regulator).
3. To monitor and undertake research on the effectiveness of the structures in ensuring the passage of native fish species.
4. Ensure that the fishways are properly maintained and operated over their lifetime.

4 TECHNICAL FEASIBILITY

4.1 Existing fishways in the CLLMM

Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere barrages separate fresh and salt water environments of the Lower Lakes and the Coorong. The barrages are operated by SA Water on behalf of the Murray-Darling Basin Authority.

There are four fishways associated with the barrages;

- a rock-ramp fishway at Tauwitchere Barrage;
- a vertical slot fishway at Tauwitchere Barrage; and
- a vertical slot fishway at Goolwa Barrage.
- a small vertical slot fishway at the terminal end of Hunters creek.

The installation of the rock-ramp fishway at Tauwitchere Barrage was initially completed in early 2004, situated adjacent to the eastern shoreline abutment of the barrage and was designed to complement the larger vertical-slot fishway and facilitate the passage of small-bodied fish (40-150 mm). The rock-ramp fishway was designed to an overall longitudinal grade of 1:27 and to be operational for the top 0.89 m (89%) of the tidal range (SKM, 2002). The fishway was constructed within the first barrage bay where two pre-cast concrete sills contain the rock-ramp and determine the top and bottom operating water levels (Jennings et al., 2008). The upstream sill effectively shuts off flow to the rock-ramp at lake levels of 0.65 m AHD (Jennings et al., 2008). The downstream sill prevents fish passage when the Coorong water level falls below 0.18 m AHD (Jennings et al., 2008). A pre-cast V shaped baffle in the middle of the fishway provides a point of closure using an existing automated radial gate (Jennings et al., 2008). Fishway Consulting Services (2006) indicates that

- the historical lake water levels result in the fishway not functioning effectively for the majority of the time, and
- the barrage gate in the middle of the rock-ramp disrupts the hydraulics for fish passage.

As such, the fishway requires modification or replacement to improve its effectiveness.

The installation of a partial-depth vertical-slot fishway to facilitate the passage of large bodied fish (>150 mm) at the Goolwa Barrage was completed in 2005. Four pre-cast vertical-slot baffles were installed in one barrage bay utilising the pre-existing concrete piers and floor. The vertical-slot baffles are sequentially raised above the flat barrage floor using pre-cast concrete stop-logs, creating sills below the baffles and a hydraulic gradient between pools (Jennings et al., 2008). Each of the three pools measures 2.7 m long and 3.6 m wide and depth averages 3.5 m depending on estuary and lake levels (Jennings et al., 2008). The vertical-slots are 2.0 m high and 0.3 m wide. The fishway was designed to operate with a head loss of 0.2 m between each baffle, corresponding to a maximum velocity of 2.0 m s-1 and a discharge rate at median flows of 40 ML/d. Based on the design hydraulics, the fishway was expected to pass fish from 0.15 m to 1.0 m in length for the top 0.8 m (80%) of the tidal range (SKM, 2002)

Assessment indicates the vertical slot fishway at Goolwa passes very few large-bodied fish, primarily passing displaced potodromous species (Jennings et al., 2008). However, the fishway has not yet been sampled during periods of higher flow, which may be an important period for the upstream migration of large-bodied fish (Jennings et al., 2008). Modifying the fishway to be a full depth vertical slot has already commenced however this has not yet been tested due to existing water levels but is expected to improve its fish passage over the entire tidal cycle (Fishway Consulting Services, 2006). Designing a fishway to operate only in the upper tidal range may provide acceptable fish passage at Goolwa barrage but it provides poor fish passage at Tauwitchere.

The installation of a full depth vertical-slot fishway to facilitate the passage of large bodied fish at Tauwitchere Barrage was completed in 2004. Three prefabricated concrete vertical-slot baffles were installed. These created two pools between existing concrete piers, each measuring 2.3 m long and 4.0 m wide. To create a hydraulic gradient on the flat floor, metal sills were placed within the bottom of the slots to achieve a head loss between the pools of 0.2 m, and a maximum water velocity of 2.0 m s-1 (Mallen-Cooper, 2001 cited in Jennings et al., 2008). The vertical-slots are 0.3 m wide and extend the full depth of the pool. The fishway was designed to operate at a pool depth of 0.8 m and at median flows discharge 31 ML/d. Based on the design hydraulics the fishway was expected to pass fish from 0.15 m to 1.0 m in length for the top 0.6 m (60%) of the tidal range (SKM, 2002).

The existing design of Tauwitchere (and Goolwa vertical slot) uses the stop-log bays to save on construction costs and as such the proportions of the fishway pools deviate from the standard of the Sea to Hume Dam fishway program. The hydraulics of the vertical slot design appears sensitive to pool changes and the flow patterns do not conform to other vertical slot fishways which may impact on fish passage (Fishway Consulting Services, 2006). The existing vertical slots designs use less water per day than other fishway structures such as rock-ramps and are also a more suitable structure for the passage of large-bodied fish. New vertical slot fishway designs at any of the sites would need to reduce the head loss and turbulence within the fishway, and increase the operational range to pass small bodied fish or adopt a different design al together.

Finally, the vertical slot fishway at Hunters Creek has not yet been assessed due to low water levels and therefore an inability to operate it.

4.2 New fishways proposed by this project

The location and type of fishways required most urgently in the region were assessed and prioritised at a workshop on fish passage at the Murray Barrages held in March 2006. These recommendations and the work of the Barrage Fishway Construction Team summarised in Fishway Consulting Services (2006) have been further assessed in the light of changes to the system during the water level crisis that commenced in early 2007. The resulting recommendations are summarised in Table 1.

Table 1. Fishway location and design recommendations for the CLLMM.

No.	Site	Rock-ramp	Modified box culverts	Vertical slot for large-bodied fish	Vertical slot for small-bodied fish	Fish lock for small-bodied fish	Needs further investigation*
1	Boundary Creek barrage			◆	◆		
2	Clayton regulator						◆
3	Ewe Island barrage			◆	◆		
4	Goolwa barrage			E		◆	
5	Mundoo barrage			◆	◆		
6	Mundoo Island		◆				
7	Narrung regulator						◆
8	Tauwitchere barrage	E ◆		E			

NB E existing fishway location
*further investigation will include hydrological, ecological and operational investigations to ascertain the most effective type of fishway(s) (if appropriate)

Fishway design options were assessed by Sinclair Knight Merz and SA Water in the *Feasibility Study for the Fish Passage at the Goolwa and Tauwitchere Barrages* (SKM and SA Water, 2002) and by the MDBC Fish Passage Reference Group (FPRG) in 2006, summarised in Fishway Consulting Services (2006). Options considered for this project draw on these investigations and assessment as well as results from fishways constructed elsewhere in the Murray-Darling Basin. The proposed fishway designs are summarised in the following sections.

4.3 Rock-ramps

Rock-ramp fishways are commonly used for barriers less than 2 m in height. They are essentially, as the name implies, a ramp of rocks placed below the barrier, creating a low slope with transverse small pools and falls. Larger rocks are placed throughout the rock-ramp to create pools of low flow and low turbulence to allow resting areas for fish as they move upstream from pool to pool. Rock ramp fishways can be either full width (Figure 3) or partial width (Figure 4) fishways depending on the width of the stream and structure on it. A significant advantage of rock-ramp fishways is that they provide high discharge and high fish attraction for small-bodied fish, which is important when any of the barrage gates are open. A standard rock-ramp fishway is illustrated in Figure 4.

There have been many different variations of rock-ramps constructed in the Murray-Darling Basin. Rock-ramps are able to pass a high biomass of small fish, but the effectiveness of the structure reduces with depth. During construction, consideration also needs to be given to size, and methods for fixing rocks in place. It is important that any rock fixing retains gaps between the rocks, as this is vital to fish movement across the ramp.

Rock-ramp fishways are more applicable at Tauwitchere than Goolwa, which is a deep site. The project recommends the construction of multiple rock-ramp fishways at Tauwitchere barrage.

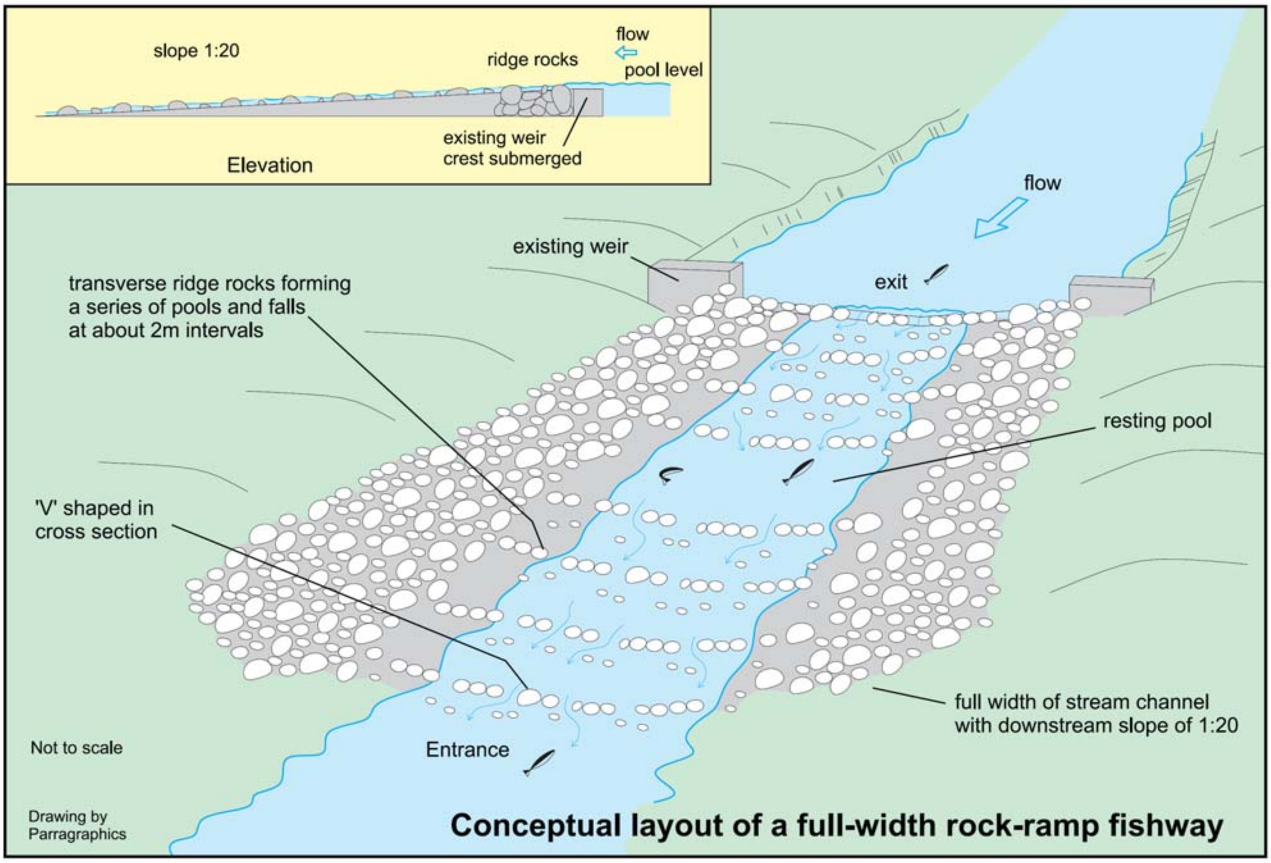


Figure 3: Conceptual layout of a full width rock ramp fishway

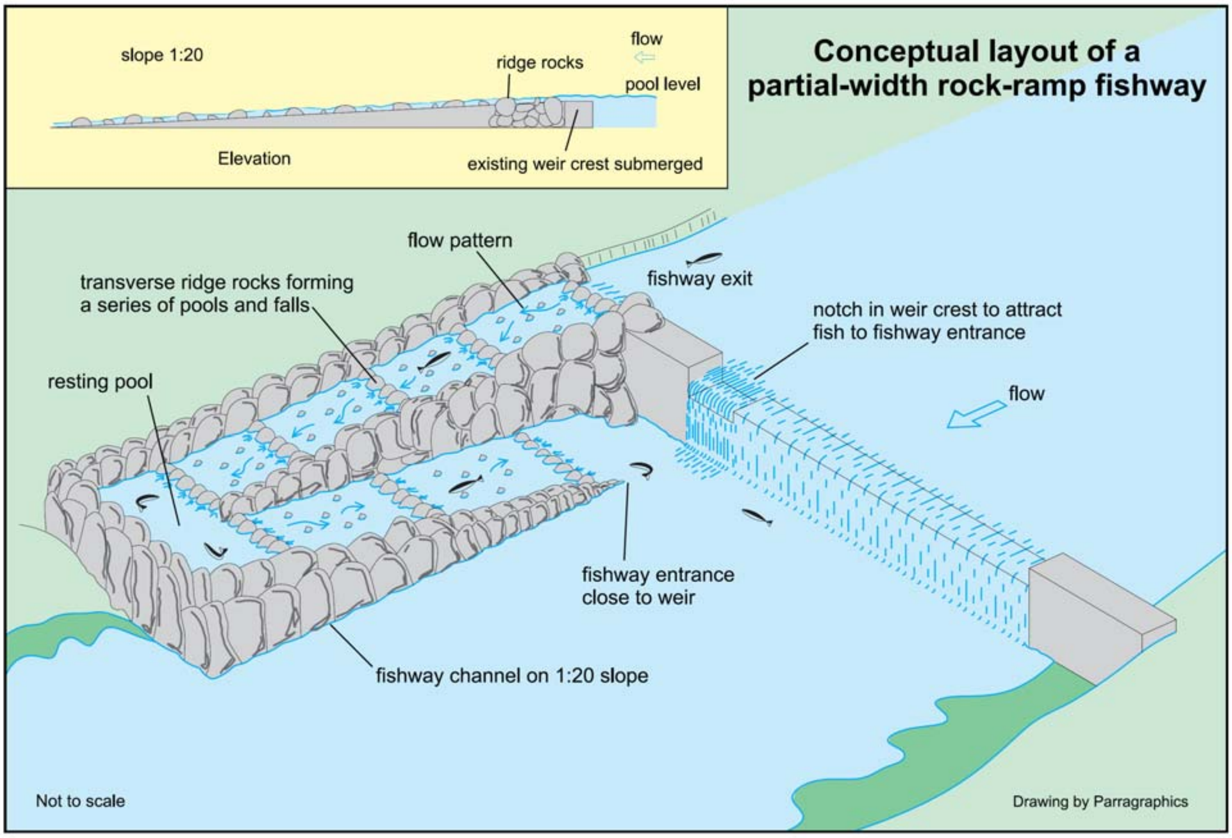


Figure 4: Conceptual layout of a partial-width rockway [Source: Thorncraft and Harris, 2000]

4.3.1 Tauwitchere rock-ramp

Monitoring undertaken demonstrates that the existing rock-ramp at Tauwitchere passes high numbers of some, but not all, small-bodied and juvenile fish species over a narrow range of headwater and tailwater levels (Jennings et al., 2008). The fishway has the following limitations:

- The historical water levels result in the fishway not functioning effectively for the majority of the time.
- The barrage gate in the middle of the rock-ramp disrupts the hydraulics for fish passage.

Recommended improvements from the 2006 FPRG workshop to the Tauwitchere rock-ramp include:

1 Increasing the headwater range over which the fishway is operable. It is recommended to investigate three rock-ramp fishways in three bays, each operating at different lake levels. Each rock-ramp would be optimised for 0.2 m of headwater (lake) variation thereby providing 0.6 m of total headwater range.

2 Using gates or stop-logs at the upstream end, so that the internal hydraulics of the rock-ramp fishway are not affected.

3 Using a slope of 1:16 or lower to pass small fish.

4 Increasing the tailwater range by extending the length.

4.4 Modified box culvert

There are a few minor obstructions to fish passage in small channels and floodways on Mundoo and Hindmarsh Islands. The project provides funding to investigate the use of rock-lined culverts to restore effective fish passage through these channels.

This project proposes modifying the existing culverts at Mundoo Island by the addition of rocks to the bottom of existing culverts to enhance their fish passage opportunity. Where steep gradients might inhibit fish passage at the terminal end of these channels, rock would be placed to provide scour protection and improve fish passage.

4.5 Vertical slot fishways

In vertical-slot fishways, water falls through a slot between each pool, with the downstream pool acting to dissipate hydraulic energy as well as providing resting areas for ascending fish (Figure 5) (Thorncraft and Harris, 2000). The slope of the channel and the intervals between the slots control the water velocity through each slot, so the fishway can be designed to suit the swimming ability of particular ascending fish (Thorncraft and Harris, 2000). Important features of the vertical-slot design are that it can operate in varying headwater and tailwater levels, and allow fish to pass through the fishway at any depth (Thorncraft and Harris, 2000). The vertical-slot design is suitable for weirs ranging from 1 to 6 m in height (Thorncraft and Harris, 2000).

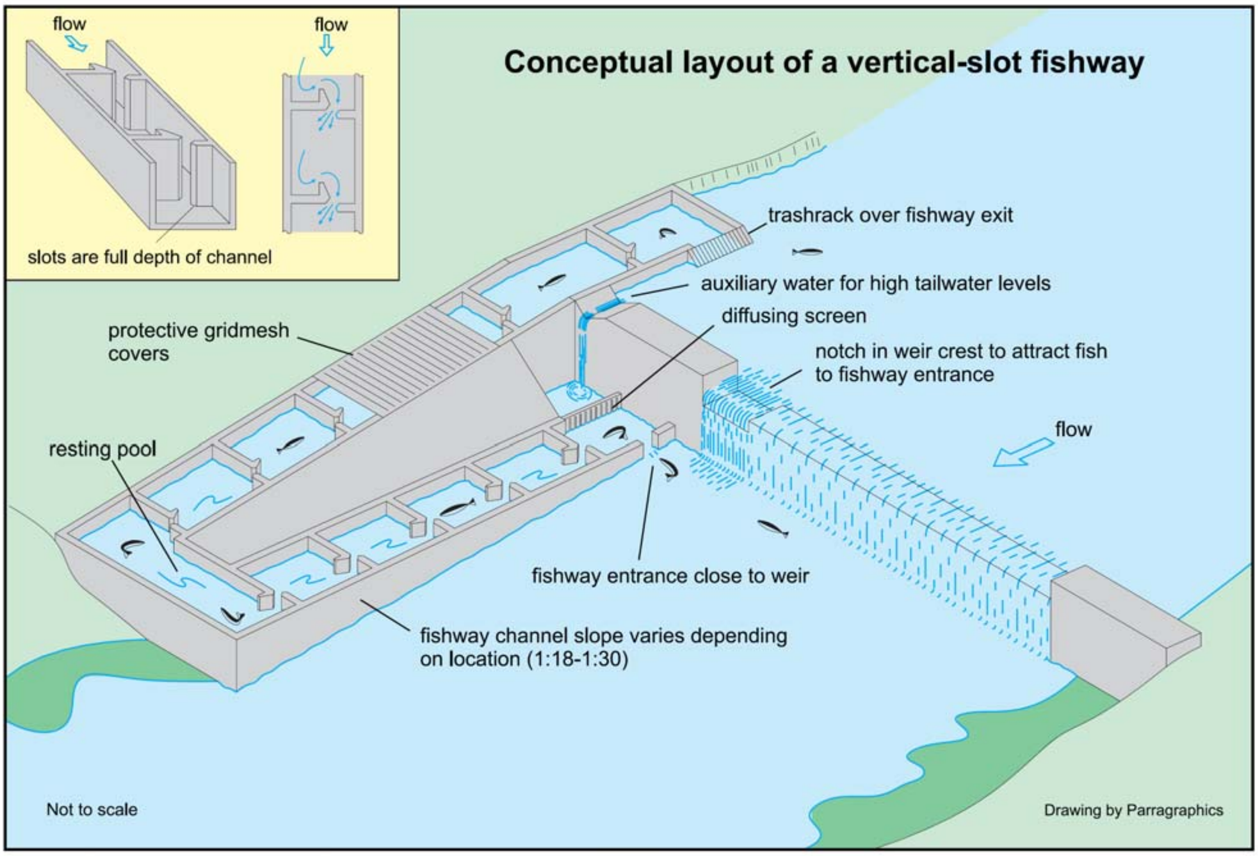


Figure 5: A typical vertical slot fishway (Source: Thorncraft and Harris, 2000).

Beyond the existing modifications to the Goolwa vertical slot fishway, it was recommended by the FPRG in 2006 that improvements to the design of future fishways include improving the flow patterns in the vertical-slot fishways to maximise passage of fish. Additionally, vertical slot fishway designs should develop and trial a vertical-slot design for small fish that has low water usage with options including single and dual-slot baffles.

For the above reasons, and to address the issue of ensuring the passage of large-bodied fish, the project proposess the construction of a number of large vertical slot structures at the following locations:

- Boundary Creek barrage

- Ewe Island barrage
- Mundoo barrage

In addition, vertical-slot fishways for small-bodied fish will be constructed at:

- Boundary Creek barrage
- Ewe Island barrage
- Mundoo barrage, as well as potentially at
- Clayton regulator

Further work is required to develop more detailed designs that allow implementation at these sites beyond simple concept designs. Design considerations for Boundary creek are partly progress in Fishway Consulting Services (2006) and can be summarised as follows:

- Flow is more tidal here than at Tauwitchere (as is closer to the mouth), so is subject to frequent reverse flows
- 2 logs deep: approx 1.8 - 2m
- Current management of this barrage is time and labour intensive
- Small amounts of water can be managed here to have a positive passage influence
- A good mix of fish are noted during releases
- Proposed design will result in 3 bays of of the existing barrages structure being amended. This is preferred over a channel and rock ramp around the barrage because it will be contained to the zone of securer water depth, will generate attraction flows and minimises re-working of existing road.
  - Bay 1: small vertical slot fishway (for small fish - EWMP)
  - Bay 2: traditional vertical slot fishway (for larger fish - EWMP)
  - Bay 3: Spindle gate (to improve current barrage operations – RMW (operational).

4.6 Fish locks

Lock fishways operate by attracting fish through an entrance similar to that of vertical slot type fishway, but instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris, 2008). This holding area is then sealed and filled with water to reach a level equal to the water upstream of the barrier (Thorncraft and Harris, 2008). A holding cage, containing the fish, is then transported vertically to the top of the chamber. The migrating fish exit the chamber into the upstream weir pool. A standard fish lock design is illustrated in Figure 5.

During the 2006 Fish Passage Reference Group workshop, a fish lock designed to pass small-bodied fish had significant support because it could be designed to:

1 pass a high biomass of small-bodied fish;
2 operate over fluctuating headwater and tailwater levels; and
3 use very little water.

The proposed concept utilised a barrage bay with installation of an upstream and downstream wall with an automated gate in each. A fixed weir would be located in the middle to dissipate the energy of incoming water from upstream. Water level sensors would automatically adjust gate openings to vary discharge.

A fish lock for small-bodied fish has been recommended for Goolwa and should be designed to:

- enable the passage of a high biomass of small-bodied fish;
- operate at fluctuating headwater and tailwater levels; and

- use very little water.

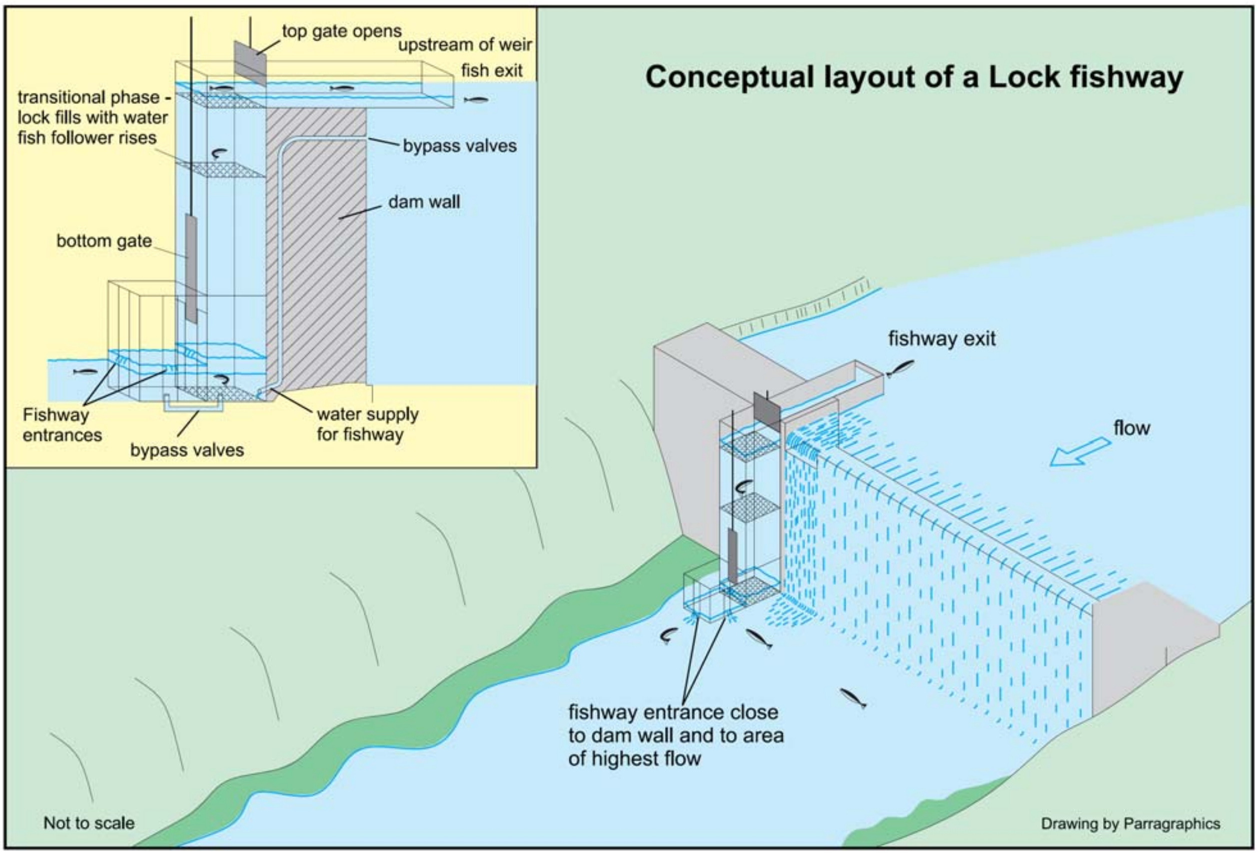


Figure 6: Conceptual layout of a fish lock [Source Thorncraft and Harris, 2000].

4.7 Construction of fishways at the Clayton regulator

As an emergency response to prevent the impacts of acid sulphate soils on the Goolwa Channel and its tributaries, the South Australian Government is constructing three temporary structures to regulate the flow of water and raise water levels. These are:

- A temporary flow regulator in the Goolwa Channel (completed in early August 2009)
- A temporary low-level flow regulator at the mouth of Currency Creek (completed in September 2009)
- A temporary low-level flow regulator at the mouth of the Finniss River (construction yet to begin)

These will be temporary structures and will be removed once fresh water flows improve and the Lower Lakes recover. Removal of the structures however may not occur for many years.

The current design of the structures does not include fishways. Surplus flows being released into the Goolwa Channel via the environmental flow regulator's siphons may act as an attraction flow to native fish. During freshwater releases into Lake Alexandrina, fish monitoring was proposed to be undertaken to identify any fish that may have been attracted by the flows and are attempting to move into the Goolwa Channel. It was proposed to capture these fish and relocate them into the Goolwa Channel pool.

It is proposed that a low cost vertical slot fishway be constructed at the regulators to enable passage between the channel and the pool. These structures will primarily be more relevant during the recovery period since at low lake Alexandrina water levels there is no connectivity between the remainder of the Goolwa Channel and Lake Alexandrina as a result of bathymetry.

4.8 Removal of structures

The project does not contemplate the removal of any existing structures (beyond temporary structures) although this is an option that will achieve the objectives of the project.

5 PROJECT LOCATIONS

The proposed fishway locations are illustrated in the following map.

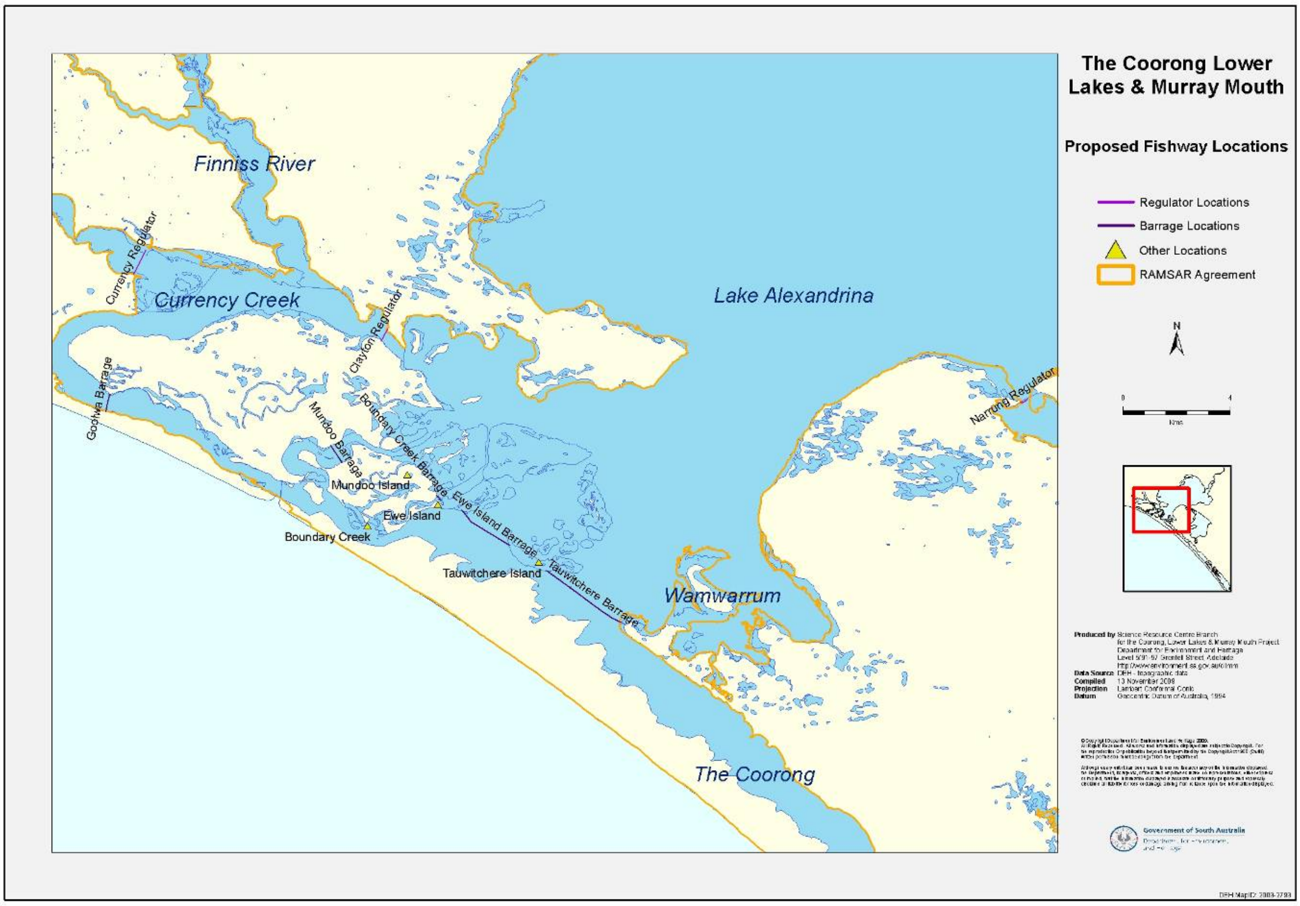


Figure 7: Map showing location of 8 proposed fishway sites [Source: DEH]

6 INPUTS AND COSTS

To assist in establishing a budget and enable comparisons between construction options the following preliminary cost estimates for the project are provided.

Costs for construction of various fishways will be further investigated as part of the project initiation for this project in 2010.

Indicative costs for a vertical-slot fishway for small-bodied fish are provided by the following recent budget for the Tauwitchere Fishway. These costs are based on SA Water RMO (River Murray Operations) construction of a small vertical slot fishway.

Item	Units	Cost per Unit	Total Cost	Comment
Baffles	18	$ 1,000.00	$ 18,000.00	Includes labour and materials
Baffle Bolts	144		$ 2,000.00	
Entry Baffles			$ 2,000.00	8m of Aluminium
Bianco Slabs			$ 40,000.00	Includes design, manufacture and delivery
Full height Brackets			$ 4,000.00	22m of Stainless Steel
Bolts and Nuts for Brackets			$ 1,000.00	Stainless Steel
Coffer Dam			$ 10,000.00	Includes design, manufacture, installation and dewatering.
Watergates			$ 36,000.00	Based on Quote from Watergates SP
Watergate Bolts and Anchors			$ 500.00	
Crane Hire			$ 12,500.00	
Concrete Floor - 9m3			$ 3,000.00	Average thickness of 200mm.
Gridmesh and Walkways			$ 10,000.00	For anti-predation and safety while accessing spindle gates
Concrete Pumps and Skips			$ 3,000.00	
Transition Pieces			$ 10,000.00	To allow transition from old deck units to new deck units
Steps or Ramp access to gridmesh			$ 2,000.00	
Handrails			$ 3,500.00	
Additional Labour Costs			$ 12,500.00	

TOTAL	$170,000.00
5% Sundries	$ 8,500.00
10% Contingency	$ 17,850.00
DWLBC PM	$ 15,000.00
TOTAL	**$211,350.00**

Detailed design and therefore costing of the fishways to be constructed has not yet been completed however the costs of a small vertical slot are assumed to be the average cost for the construction of each of the proposed fishways. A yet to be developed prioritisation framework will be applied across the proposed fishway program following the undertaking of concept designs and final costings

6.1 Key assumptions and constraints

Costs will be underpinned by the following assumptions:

- Costs are pre-design estimates based on available data and information
- Costs are expressed as an aggregate per site (various components to each fish passage have not been costed

- Assume a design life of 25 years for each fishways
- Assumes expenditure over five years
- Operating costs for program delivery will be provided following further project development. In the interim, a budget has been allocated for this work.
- A 20 percent contingency has been added to the capital and operating costs to cover additional costs that may be identified post design.

Without regular maintenance fishways are likely to become clogged with debris and their effectiveness declines. The environmental conditions at the Goolwa and Tauwitchere barrages ensure that regular maintenance and replacement of components of the fishway are necessary for the fishway to operate effectively. Maintenance costs have been included in the budget in section 7.

7 DURATION AND TIMELINES

The following timelines are proposed for the delivery of the project and are subject to approved funding being available in March 2010:

- Completion of detailed design for proposed fishways, final costings and prioritisation (March 2011)
- Project approvals (May 2011)
- Procurement process completed and contract awarded (September 2011)
- Construction commences (November 2011)
- Practical completion (November 2015)

This timeline assumes that the construction of fishways will not be a controlled action under the EPBC Act and therefore the referral requirements, if required, will not be onerous.

In general, the earlier fishways can be constructed, the better the ecological outcomes for the fish. In this case, the project may be finished earlier if possible.

8 TOTAL BUDGET

The following table outlines the total budget provided in the business plan for fishway construction, maintenance and monitoring during the next five years.

	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	Total
Development of fishway designs and costings		$120,000					
Construction costs	$0	$0	$560,000	$560,000	$560,000	$560,000	$2,240,000
Project management	0	$0	$20,000	$20,000	$20,000	$20,000	$80,000
Maintenance	$0	$0	$20,000	$20,000	$20,000	$20,000	$100,000
Monitoring	$0	$0	$100,000	$100,000	$100,000	$100,000	$500,000
Sub total	$0	$120,000	$700,000	$700,000	$700,000	$700,000	$2,920,000
Contingency (20%)	$0	$24,000	$140,000	$140,000	$140,000	$140,000	$584,000
Total Project Budget	**$0**	**$144,000**	**$840,000**	**$840,000**	**$840,000**	**$840,000**	**$3,504,000**

8.1 Budgetary implications

Funding for this project is being sought from the Commonwealth under the business case for the Coorong, Lower Lakes and Murray Mouth Long Term Plan. If funding is not available the project will not proceed.

In addition, the above budget will not be enough to construct all the recommended fish passages. A more detailed cost schedule will be prepared as part of the project initiation phase in 2010.

9 ECOLOGICAL BENEFITS OF PROJECT

9.1 Ecological Impacts if the project does not occur

In the absence of intervention, the inability of native fish to move between the Coorong and the Lower Lakes may lead to the local extinction of diadromous fish species such as

- lampreys,
- long-finned eels
- short-finned eels
- congolli, and
- common galaxias

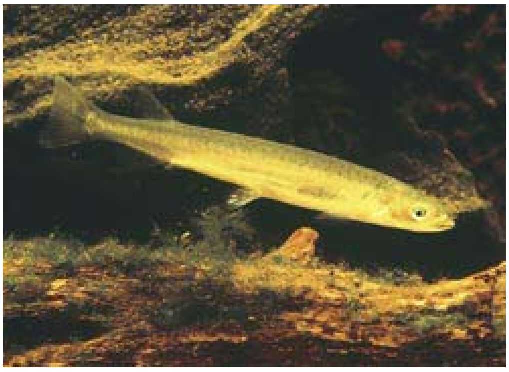
The Lower Lakes are considered to be an important habitat for these species and the loss of species from the lakes would greatly increase the risk of extinction. This would in turn impact on the ecological character of the site and its qualifications under Ramsar.

A summary of the characteristics of these significant species is provided by various publications, including the following pamphlet on the MDBA website:

- http://www2.mdbc.gov.au/__data/page/65/BarrageFishway_long.pdf

The following species synopses quote from the above pamphlet.

9.1.1 Common galaxias



Common galaxias [Source Gunther Schmida, http://www2.mdbc.gov.au/__data/page/65/BarrageFishway_long.pdf]

Common galaxias (*Galaxias maculatus*) grow to 25 cm long, but are commonly between 6 and 9 cm. They reside in the lower reaches of many coastal rivers. They can usually be found in waterways with plenty of aquatic and fringing vegetation.

Although they can complete their life cycle wholly in fresh water, common galaxias normally migrate between the fresh water and estuary to spawn. Juveniles spend their early months in the estuary before moving back into the Lower Lakes.

Fishways, especially the rock-ramp at Tauwitchere, now make this process much easier.

9.1.2 Lampreys

Lamprey [Source Gunther Schmida, http://www2.mdbc.gov.au/__data/page/65/BarrageFishway_long.pdf]

The bizarre life cycle of pouched lamprey (*Geotria australis*) and short-headed lamprey (*Mordacia mordax*) marks them as one of the curiosities of the fish world. Lampreys Grow to 60 cm long.

Larval lampreys are spawned in fresh water and burrow into fine silt where they feed on small algae. In the spring of their fourth year, juvenile individuals migrate from freshwater spawning grounds to the sea. Whilst living in the sea, lampreys attach themselves to other fish using their modified mouth and feed on the host's body tissues.

After several years, lampreys return to fresh water as young premature adults, climbing small obstacles using their mouth as a sucker. Once they have developed into sexually mature adults, lampreys stop feeding, spawn in fresh water and die soon afterwards.

The long journey of the lamprey between fresh and saltwater environments—and back again—will be easier with fish passage improvements.

9.1.3 Congolli

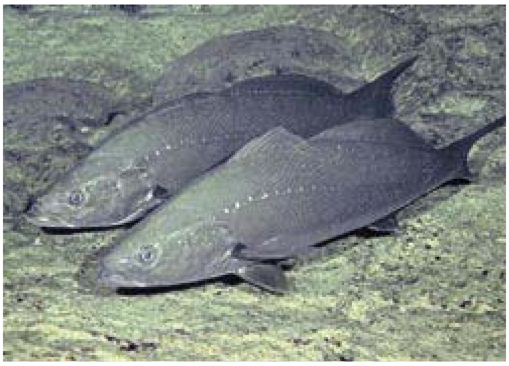
Congolli [Source Gunther Schmida, http://www2.mdbc.gov.au/__data/page/65/BarrageFishway_long.pdf]

Congolli (*Pseudaphritis urvillii*) reside in the Lower Lakes and estuarine section of the Coorong just inside the Murray Mouth.

Congolli are diadromous. This means they move between fresh and salt water environments. Small numbers of congolli are believed to still move between the freshwater lakes and estuary to spawn via small channels on Mundoo and Hindmarsh islands.

The fishways will significantly improve prospects for congolli and other fish that previously had difficulty moving between the salt and fresh waters of the Coorong and Lower Lakes.

9.1.4 Mulloway



Mulloway [Source Gunther Schmida, http://www2.mdbc.gov.au/__data/page/65/BarrageFishway_long.pdf]

Mulloway (*Argyrosomus japonicus*) is an important fish for the local commercial fishing industry and a prized catch for recreational anglers.

Adult mulloway in spawning condition gather in the surf zone adjacent to the Murray Mouth between October and December each year. Based on overseas studies, mulloway are thought to spawn in this zone around this period. Soon after spawning, juvenile mulloway are believed to move into the Coorong and use this and the adjacent near-shore environment as nursery habitat for the next two to five years. Freshwater flows establish estuarine conditions in the Coorong. This provides juvenile mulloway with their preferred habitat. The decline in local annual catches of mulloway following the construction of the barrages is thought to be the result of a reduction in estuarine conditions.

Operation of the fishways and establishment of an environmental flow to the Coorong may improve mulloway stocks in this area.

9.2 Positive Ecological Outcomes

The following beneficial outcomes have been identified for the construction of additional fishways under the Long Term Plan:

- Access by adult fish to and from spawning habitats at the site;
- Dispersal of juvenile fish to rearing habitats;
- Access to feeding habitats;
- Colonisation of habitat;
- Exploratory movements and habitat selection; and
- Access to and from refuge areas during times of drought or flood.
- Provision of flows to the Coorong in a measurable and controllable manner.

10 ECOLOGICAL RISKS OF PROJECT

The construction of fishways at key location in the CLLMM region will have significant benefits for some local fish populations. If the fishways are well monitored and maintained, there are unlikely to be any notable ecological risks.

11 PROJECT RISKS

There is sufficient biological and engineering expertise in Australia to design, build and operate successful fishways for native fish. Nevertheless fishways suffer initial problems in their operations that may risk their functionality and potentially impact on costs and outcomes.

Identified Risks	Probability	Impact	Rating	Mitigation
Design options inadequate to achieve outcomes	Unlikely	High	1	Ensure detailed design of the fishways prior to construction that takes into account.
Fishways funded but not the monitoring and research project.	Unlikely	High	1	DEH/technical committee to consider alternative ways to monitor the effectiveness of the fishways including resourcing.
Costs of the fishways program underestimated.	Likely	High	1	Procurement and construction options such as modular and prefabrication approaches will be explored to ensure value for money particularly for the vertical slot fishways.
The optimum design does not fit effectively with the existing barrage structures.	Unlikely	High	2	Technical committee would oversee and approve the final design work for the fishways and ensure this risk is mitigated.
Fishways are built to minimal design specifications to minimise costs or the wrong option is chosen to minimise costs.	Unlikely	Medium	2	Technical committee would oversee and approve the final design work for the fishways.
Low inflows mean that the fishways constructed are not effective.	Likely	High	2	Secure freshwater flows to the site. Ensure the design provides for the necessary variability of flows at the site.
EPBC Act and other approvals	Unlikely	Moderate	3	Early submissions.
Cultural and Heritage risks	Unlikely	Moderate	3	Early submissions and consultation.

12 PROJECT MANAGEMENT

The project will be delivered by DEH in consultation with the Murray Darling Basin Authority, SA Water and SARDI. DEH will oversee the design requirements and in conjunction with the Murray-Darling Basin Authority Fish Passage Task Force or SA Based members develop final design of the fishways at each of the eight sites, prior to seeking MDBA approval. DEH in conjunction with DWLBC Infrastructure and Business unit will be responsible for obtaining all the necessary approvals, consultation, and communication and will develop appropriate monitoring in conjunction with service providers such as SARDI Aquatic Sciences. The construction of the fishways will be subject to a tender process that takes into account the Environmental Management System requirements and value for money.

Final approval would be required from DEWHA prior to engaging consultants.

13 CLIMATE CHANGE AND GREENHOUSE GAS IMPLICATIONS

The implementation of this project will produce negligible carbon emissions, greenhouse gases and have a negligible impact on Climate Change.

13.1 Emissions from construction phase

During construction, indirect carbon emissions will be incurred for some types of fishways. These will include:

- Mining and manufacture of construction materials, including concrete (for some types of fishway) and metal (some vertical slot fishways will use metal baffles and doors)
- Transport of construction materials.

Where possible renewable energy sources will be examined as part of the design of the fishways and its operations. This will include the use of local rocks for rockways.

13.2 Ongoing emissions from operational phase

Direct carbon emissions from the operation of the fishways are not expected to be significant and will be confirmed during the design phase.

In terms of emissions, there will be some small operating costs for the fishways. Power will be needed to open and shut fish-gates, and this will be sourced from existing barrage generators.

13.3 Water usage

An additional factor which will have environmental implications is the movement of water through the fishways. Some fishways may transport up to 80 megalitres per day (large vertical slot), with smaller-scale fishways using about 5 ML per day. However, the passage of this water through the fishways will only move the water from one part of the system to another, and will not resulting in water loss from the system.

14 ENVIRONMENTAL MANAGEMENT PLAN

An Activity Environmental Management Plan (AEMP) will be required for the implementation of the Fishways. An AEMP will be prepared when the design and operational details of the project are finalised. The issues to be addressed in the AEMP include the following:

- Summarise the environmental condition of the site and adjacent areas and potential impacts of the fishways to be constructed
- Summarise the proposed development and works to be undertaken
- Describe the operation required for the fishway
- Outline the monitoring and research program, including frequency of sampling fish species
- Maintenance and replacement program for the structures
- Describe contingency procedures to deal with unexpected events and failure of management measures and remedial management plan.

15 COMPLIANCE AND APPROVALS

Approvals that will be required with this project include:

- EPBC Act
- Environment Protection Act
- Water Works Act
- Murray-Darling Basin Act
- River Murray Act
- Development Act
- Natural Resource Management Act
- Native Title and Aboriginal Heritage Act
- Native Vegetation Act
- DWLBC, DEH (Crown Land) and DTEI
- Private Land Access

15.1 EPBC Act

EPBC Act approval may be required if deemed a controlled action under the *Environment Protection and Biodiversity Conservation Act 1993*.

The South Australian Government would need to conduct a self assessment in accordance with EPBC Act Policy Statement 1.1 to determine the potential for the action to have a significant impact on matters of NES.

If the self assessment determines that the action is likely to have a significant impact, then the SA Government would be required to lodge a "referral" with the Commonwealth. The Australian Government Minister for the Environment, Heritage and the Arts (the Minister) makes a decision whether approval is required (controlled action, not controlled action 'particular manner", or not controlled action).

If the Minister determines that it is a controlled action then an environmental assessment must be carried out. The SA Government would be required to prepare documentation in keeping with the requirements of the level of assessment.

There are 5 assessment approaches — based on information provided in the referral; Based on preliminary documentation; Public environmental report; Environmental impact statement; or Public inquiry.

Most assessment approaches require a level of public consultation. It will generally take 12–18 months to prepare documentation and obtain approval from the Commonwealth for more complex assessments (eg EIS).

15.1.1 Emergency provisions in the EPBC Act

The Minister may declare certain actions that are necessary in preventing, mitigating or dealing with a national emergency exempt from the requirement to seek approval for actions that will have or are likely to have a significant impact on matters of NES.

The Minister may exempt a person proposing to take an action from the requirement to conduct an environmental assessment and/or obtain approval in relation to the action to which the exemption relates.

However, the Minister may only grant an exemption under s158 if he is satisfied that it is in the national interest to do so. In determining the national interest, the Minister may consider Australia's defence or security or a national emergency.
DEWHA officers have previously indicated that it is "unlikely" that the SA Government would be granted emergency exemption for any CLLMM projects.

15.1.2 Process for obtaining approvals and referrals

The CLLMM Approvals team have responsibility for obtaining the necessary approvals and referrals for any proposed activities associated with management of the Coorong.

15.2 Environment Protection Act

The *Environment Protection Act 1993* provides legislation for the protection of the environment, and the establishment and definition of the powers and functions of the Environment Protection Authority (EPA) in South Australia.

The Environment Protection Act, under Section 25, imposes a general environmental duty, which requires that a person must not undertake an activity that pollutes or might pollute the environment, unless taking all reasonable and practical measures to prevent or minimise and resultant harm. In the context of the Act 'pollute' includes discharging, disturbing, or depositing pollutants or failing to prevent the discharge, deposition or disturbance or escape of pollutants.

In addition, the Environment Protection (Water Quality) Policy 2003 sets out water quality criteria for protection of waters within South Australia. The Policy includes matters the EPA must take into account when making decisions relating to environmental authorisations, development applications referred to the EPA and other specified matters. This Policy also makes it an offence to deposit listed pollutants (including soil and gravel) into waters without authorisation. This has implications for weir construction.

A dredging and earthworks drainage licence may be required from the EPA if there is any dredging involved, this will most likely be granted in the form of an emergency authorisation

- To gain an authorisation and if there is a presence of ASS, the project will be required to provide a detailed Environmental Management Plan;
- If there is any dredging required, a methodology and monitoring framework for drainage discharge will need to be prepared.

15.3 Water Works Act

The *Waterworks Act 1932* consolidates all acts relating to water supply and provides for the management of the State's water resources. Under this Act, the Minister may impound the water of streams or springs for the purposes of supplying water to any district. Under this Act, the Minister may also temporarily possess land which is necessary for the construction or repair of waterways.

15.4 Murray-Darling Basin Act

The *Murray-Darling Basin Act 1993* provides for the implementation of the Murray-Darling Basin Agreement 1992.

The MDB Agreement 1992 was entered into between the Commonwealth, New South Wales, Victoria and South Australia to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the MDB.

Under clause 46 of the MDB Agreement, the MDBA must be informed of any proposal, which may significantly affect the flow, use, control or quality of any water in the River Murray in South Australia. An approval by MDBA is required in order to carry out any works not already provided for under the agreement (clause 57 of the Agreement). In considering an authorisation, MDBA must assess any possible effects on the water, land or other environmental resources within the MDB (clause 47 of the Agreement).

15.5 River Murray Act

The *River Murray Act 2003* provides for the protection and enhancement of the River Murray and related areas and ecosystems. The objectives for a Healthy River Murray are defined under section 7 of the Act and include:

River Health objectives which focus on the protection of the River Murray environment, in particular the projection of key habitat features, ecological processes, high value floodplains, wetlands of international importance and national significance and native species.

Environmental flow objectives which focus on ecologically significant natural flow regimes, fish passage areas and connectivity between and within environments within the River Murray System.

Water quality objectives which focus on overall improvement of water quality (including salinity, nutrient levels and pollutants) within the River Murray System to sustain ecological processes, environmental values and productive capacity.

Human dimension objectives which focus on management of the River Murray that includes community interests, community knowledge and the importance of a healthy river to the economic, social and cultural prosperity of communities.

If a proposal is deemed to be a "major project" under the Development Act, the relevant report will be referred to the Minister for the River Murray for assessment.

15.6 Development Act

The *Development Act 1993* is administered by the Minister for Urban Development and Planning. No development may be undertaken unless approved or exempted in accordance with the Act.

Section 49 (Schedule 14 3) of the Development Act 1993 states:

> The following forms of development are excluded from the provisions of section 49 of the Act, namely the construction, reconstruction, alteration, repair or maintenance of infrastructure within the meaning of the River Murray Act 2003 by the Minister for the River Murray (or by a person who is acting for or on behalf of that Minister) where the work is being undertaken in connection with the management of water flows within the River Murray system, as defined by that Act, for the purposes of the River Murray Act 2003 or the Murray-Darling Basin Act 1993.

15.7 Natural Resources Management Act

The *Natural Resources Management Act 2004* sets out a detailed scheme for the sustainable management and protection of natural resources including water. Amongst other things it regulates 'water affecting activities' and the allocation, taking and use of water. A permit is required to undertake a water affecting activity.

Water affecting activities under Section 127 of the Act include the erection or construction of structures that will collect or divert water flowing in a prescribed watercourse. The River Murray Prescribed Water course consists of the River Murray channel and associated watercourses as described in the Water Allocation Plan for the River Murray Prescribed Watercourse.

15.8 Aboriginal Heritage Act

This area is of significance to the Ngarrindjeri people. Prior to commencement of the project:

- consultation will occur with Ngarrindjeri representatives

- heritage and Native Title investigations will be undertaken (Native Title is a separate process and will be carried out through the Crown Solicitors Office).

It is also recommended that, if the project is undertaken, Ngarrindjeri heritage monitors should be invited to be present on site while works are occurring.

The exact process which will be undertaken for the fishways Project will be negotiated through the Crown Solicitors.

15.9 Native Vegetation Act

The *Native Vegetation Act 1991* requires that clearance of vegetation can only occur in accordance with Part 5 of the Act, subject to the consent of the Native Vegetation Council, if the vegetation is of a prescribed class or in prescribed circumstances.

Under the Act, clearance of vegetation is required to be offset through the implementation of a Significant Environmental Benefit (SEB). The Native Vegetation Council has developed an interim policy to guide the development of an SEB considered suitable in offsetting proposed impacts to vegetation.

15.10 Department of Water Land and Biodiversity Conservation

Approval may be needed for a Water Affecting Activity licence, should any material be discharged into a waterway.

15.11 Department of Transport Energy and Infrastructure

Given that the project will be operating partly within a navigation channel, the project will most probably require an Aquatic Activity Licence. This may impose additional conditions on the project. A ‘Notice to Mariners’ may be required advising of changes to the Gazetted navigation channels.

15.12 Crown Land

Specific advice pertaining to Crown Land should be sought to ensure that any approvals required are sought – *ie* Department for Environment and Heritage.

15.13 Private Land Access

Access agreements may be required for access and construction on private land. In particular if access tracks are required.

15.14 Other relevant stakeholders and notifications

Targeted consultation will also be undertaken to ensure that key stakeholders are kept well-informed and are able to make submissions regarding the proposals. Key stakeholders will include:

- Local Council (including Mayor and CEO)
- Local Fishermen (including Southern Fishermen’s Association)
- Local residents and businesses.

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