



Barwon River Lower Breakwater Management Options



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Cover Photo: Barwon River Breakwater (prior to second gate being refurbished)

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EXECUTIVE SUMMARY

The lower Barwon breakwater was constructed to prevent saline water extending upstream from the lower reaches of the Barwon River. It is located adjacent to Reedy Lake, part of the Lake Connewarre complex. The breakwater is deemed to require investigation at this stage due to the current failure of the flood gates to perform their automated task and the breakwater being a barrier to the migratory movement of fish.

This report seeks to:

- Determine requirements for flood mitigation (with consideration given to the social, economic and ecological consequences of possible flooding patterns associated with different breakwater management options);
- Consider the fish passage requirements and the needs of various stakeholders; and
- Determine the configuration and management of the lower breakwater including the preferred minimum water level for the reach between the upper breakwater and the lower breakwater.

Following consultation with the stakeholder group it was identified that there are several options that warrant investigation. Each of the options has differing effects on the water levels within the Barwon River and Reedy Lake/Hospital Swamp system, as well as a fishway design. The options include:

- Remove the Breakwater in its entirety;
- Enable the operation of the floating gates;
- Remove the floating gates and replace them with a standard weir; and
- Increase or reduce the height of the breakwater.

Risks to current values were identified that informed the investigation and modelling approach. These were:

- Saline water intrusion impact on irrigation water quality and native vegetation;
- Flooding of agricultural land in the lower floodplain;
- Hydrology of Reedy Lake and Hospital Swamp. These wetlands are reliant on the water level within the river to enable active ecological and recreational management; and
- Water level reduction impact of the waterskiing use.

The options were modelled to determine the potential impacts on the values using the MIKE Flood software suite.

The hydraulic modelling results demonstrated that modification or removal of the breakwater has a significant impact on the characteristics of minor localised floods and the operation of Reedy Lake and Hospital Swamp. However, the changes in hydrology and potential land use change reduce the requirements to protect the land from flooding. Complete removal of the breakwater will prevent the use of water from the river for irrigation or stock and domestic uses.

Modification of the breakwater has little potential impact on the ski club use of the Barwon River as the river is greater than 3 metres deep and has steep sides. Complete removal of the breakwater would however expose the banks to tidal fluctuation and potential erosion.

The key constraint on the modification of the breakwater is the ecological operation of Reedy Lake. Any reduction in the height of the breakwater will adversely impact on the ability to control water inputs to this Ramsar Convention listed lake and thus, current ecological processes.

Therefore, based on the assessment, the recommendation is to maintain the breakwater at the current height and decommission the floating gates, replacing them with a fixed crest weir. Further recommendations include undertaking a detailed review of the operation of the Reedy Lake and Hospital Swamp hydrological regime.

If this recommendation is adopted, provision is required to maintain passage for native fish. A range of options have been identified and modelled to determine the most suitable arrangement for this location.

The preferred option is a vertical slot fishway on the northern bank of the river. This will enable the passage of all target species of fish throughout the full tidal and flow range. Modifications to the slot arrangement have been considered to further enhance the ability of fish to traverse the fishway at very low flows. Separate consideration has been given to the passage of elvers. A preliminary design arrangement has also been prepared to enable the migration of elvers over the breakwater.

The recommendation from the fishway component of this report is to proceed with the design and implementation of the fishway.

1. SCOPE OF THE PROJECT

Water Technology, The Arthur Rylah Institute and Kingfisher Research have been engaged to develop and assess possible options to configure and manage the lower breakwater accounting for the social, economic and environmental needs of stakeholders. From this assessment, a preferred option is provided to Corangamite CMA together with a conceptual fishway design.

This report documents the technical investigations and stakeholder engagement to meet the following objectives;

- Determine requirements for flood mitigation (with consideration given to the social, economic and ecological consequences of possible flooding patterns associated with different options);
- Consider the fish passage requirements and the needs of various stakeholders; and
- Determine the configuration and management of the lower breakwater including the preferred minimum water level for the reach between the Upper Breakwater and the Lower Breakwater.

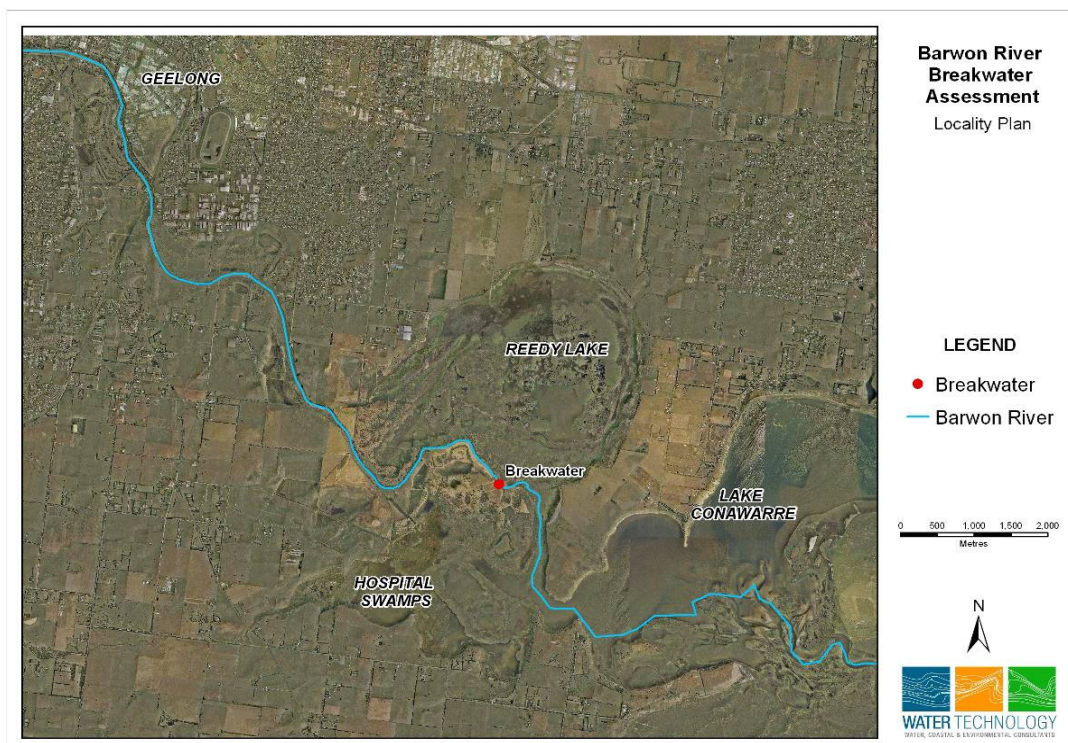


Figure 1 Location of the Barwon River Tidal Breakwater

The lower Barwon breakwater is deemed to require investigation at this stage due to the current failure of the flood gates to perform their automated task and the breakwater being a barrier to the migratory movement of fish. This investigation evaluates the values associated with the breakwater,

whether flood mitigation is still a function required, and the options for modification based on the findings.

2. VALUES ASSOCIATED WITH THE BREAKWATER

2.1 Maintaining freshwater in the reach

The original justification for the installation of the breakwater was to ensure that the development of a saline wedge in the Barwon River channel did not impact adversely on agriculture and other consumptive water uses, the breakwater therefore allows pumping of water from the river.

During the compilation of this study Southern Rural Water provided information that there are still ten permits that allow the pumping of water from the river within this reach for agricultural, commercial, stock and domestic purposes (Table 1). The breakwater enables the continuation of this use. Without the breakwater in place the tidal saltwater wedge will render the water unsuitable for irrigation and other purposes.

Table 1 extraction licences from the Barwon River Between the breakwaters

Volume (ML)	Type	Winter-fill/Direct
6.0	Irrigation	Direct
6.0	Irrigation	Direct
9.0	Irrigation	Direct
74.0	Irrigation	Direct
4.5	Irrigation	Direct
2.2	Domestic and Stock	Direct
2.2	Domestic and Stock	Direct
2.2	Commercial	W-F
2.2	Commercial	W-F
7.0	Irrigation	W-F

Whilst the breakwater protects economic values river salinity must also be considered in terms of the ecological impacts. Allowing the saline influence into the river will initiate a change in the vegetation and aquatic ecology. Whilst this will have some benefits, e.g., controlling the carp population, it will also change the vegetation assemblages. Determining the magnitude of these changes would require further study.

2.2 Flood mitigation

The modification to the breakwater to include the floating gates was undertaken to alleviate the frequency of minor flooding in the lower floodplain following the construction of the Woody Yaloak drainage scheme. This drainage scheme delivered additional water to the River during periods of high flow. The gates were designed to allow additional flow through the breakwater, thus preventing adjoining private agricultural land becoming frequently inundated.

2.3 Contaminated sediment retention

Although untested, there is a high likelihood of contaminated sediments in the reach of river upstream of the breakwater. Whilst the detailed bathymetric survey of the river has not identified significant deposits of sediment, the history of the industrial land use, such as the tanneries, adjoining the river and the age of the breakwater would indicate that contamination may be a risk.

Whilst the breakwater is in place this sediment is unlikely to be disturbed however the removal of the breakwater would provide conditions that would allow this material to be flushed into lake Connewarre. Testing of the sediment material behind the breakwater would be required prior to any proposed removal of the breakwater, if removal is the preferred option.

2.4 Hydrology of Reedy Lake and Hospital Swamp

Parks Victoria manage both Reedy Lake and Hospital Swamp with on-ground assistance of the Geelong Field and Game Association. Inflows can be regulated through a series of gates and channels from the Barwon River. Reedy Lake in particular is reliant on the water level within the river to enable this active management.

Under the “natural” situation, prior to the construction of channels, breakwater and regulators, the wetlands would have been engaged during the winter flooding and less frequent summer storms and also received tidal influences.

Reedy Lake, now altered by the breakwater, has adapted to the current water level and salinity. Changes to the breakwater will require careful consideration on the ecological values of Reedy Lake which, apart from forming an important part of the RAMSAR listed wetland, has a large population of Growling Grass Frogs (*Litoria raniformis*), a species listed as Vulnerable under the Federal Environment Protection and Biodiversity Conservation Act. Reedy Lake and Hospital Swamp are part of the Lake Connewarre State Game Reserve and as such Reedy Lake and Hospital Swamps are areas where waterfowl hunting occurs when a season is declared.

Reedy Lake has been drained twice within the last decade, with the purpose of controlling the European Carp population. There is a detailed plan on how the levels of Reedy Lake site are to be managed (PPK 2000). However, this is currently under review.

2.5 Waterskiing use

The Geelong water-ski club was established in the 1960s and has an active participation on the river throughout the year. Significantly reducing the water level in the river will be detrimental to the operation of the ski club and is likely to generate substantial opposition. Whilst removing the breakwater would most likely not completely prohibit the ski activities in the river there is a likelihood that the fluctuating tidal influence may limit the extent of the river that is available to them.

Discussions with the Ski Club indicate that the river does still fulfill their requirements for skiing when the water level drops by 400 mm at the breakwater, as was the case in January 2009. However, further reductions may adversely impact on the skiing activities.

2.6 Commercial and recreational fishing

Recreational fishing in both the estuary and the river are important social activities. The breakwater is currently creating a threat to the viability of this value by disrupting the migratory patterns of many of these species.

There is one commercial eel fishery licence within the estuary. Discussions with the licence holder as part of this study highlight a decline in the catch. He has attributed this decline to the inability of the elvers to migrate successfully through the river, specifically over the breakwater, and the hyper salinity in the estuary brought about by very low flows in the river.

2.7 Hunting

The ability to manipulate the water levels in Reedy Lake and Hospital Swamp have provided the opportunity to enhance duck hunting within the State Game Reserve. Without the breakwater in place the ability to undertake this would be limited.

3. BACKGROUND & LITERATURE REVIEW

The following information has been sourced from existing reports and studies that have occurred on the Breakwater, Reedy Lake and Lower Barwon River.

The Barwon River tidal breakwater weir was constructed in the late 1930s. The function of the weir was to prevent saline tidal water from moving upstream during periods of high tide and low river flow, thus permitting the river to be used for irrigation and water supply. Prior to its construction, salt water would occasionally penetrate a further eight kilometres to the upper breakwater located in South Geelong. This upper breakwater, in turn, prevented further saltwater movement upstream, as well as maintaining the Barwon River at a water level satisfactory for the pursuit of recreational activities through Geelong.

In the 1950s flood waters from Lake Corangamite were diverted into the river via the Woody Yaloak Diversion Scheme with a resulting increase in flows down the Barwon River. To minimise the flooding impact from the increased flow, a floating gate arrangement was designed and installed (Figure 2). The gates were designed to maintain the functionality of the breakwater preventing the saline water progressing up the river, whilst also increasing the volume of water that is able to pass during high flows.

As flow in the river increases, the gates are pushed flat, increasing the cross sectional area available for floodwater to pass. The floating gate system achieved the objectives during times of minor flow and flood events. However, when the river flow was very low and the tail water level was down, the gates did not maintain the water level in the upstream reaches of the river. During low-flow months, the gates were manually closed to maintain water levels.



Figure 2 breakwater gates, prior to second gate being refurbishment

Additional works were undertaken in 1971 when a balance weight assembly was installed to further automate the gates. The balance weight system is still in place today and responds to the upstream water level such that when the river drops below a predetermined level (225 mm below the breakwater crest, the gates are automatically raised, withholding flow. Discussions with the local landholder, who has operated the gates over the past 30 years, indicates that the automation has never been particularly successful and the gates are typically chained closed until flood waters rise at which time he would access the breakwater by boat and manually remove the chains enabling the gates to rotate flat.

In summary the components of the existing Breakwater are:

- **A fixed crest weir** - The fixed crest weir is comprised of steel sheet piling with reinforced concrete. The component of the weir extends from the southern embankment across the river until it intersects the twin gate weir structure. The crest height of the weir is 0.85 m AHD.
- **An adjustable weir structure, consisting of two floating steel gates** – The gates each comprise a door of 1.65 m height and 4.9 m wide hinged at the bottom edge and supporting a steel drum at the full width of the gate and 760 mm in diameter. The steel drum floats on the tail water pool (the downstream pool).
- **A counterweight** - The counterweight is a cylinder located at the head of each of the weir gates.

In 2005, Earth Tech assessed the functionality and integrity of the tidal breakwater structure. This resulted in a partial rebuild in 2008 when the floating gate components were replaced as per the original design specifications.

The 2008 refurbishment exposed that the counterweight assemblies also need replacing and that significant volumes of water can leak past the sides of the weir gates. At present, the gates are permanently closed during times of dry weather and one gate is manually opened upon wet

weather. The second gate is inaccessible due to the lack of safe access and occupational health and safety requirements.

3.1 Barwon River Fish Community

The lower breakwater on the Barwon River is the first of several weirs identified by the Corangamite CMA (CCMA) to be ineffective in providing free passage to fish between the estuary and the freshwater reach of the Barwon River. Restoring connectivity across the lower breakwater, and facilitating the movement of fish between the estuarine and freshwater regions of the Barwon River, is a high priority for the CCMA. (Hindell, *et al.* 2008; Environous 2009)

A rock ramp fishway was constructed adjacent to the breakwater in the mid 1990's to enable the passage of fish from the estuary into the river. A review of the fishway was undertaken by the Arthur Rylah Institute in 2008. The review found that the fishway was ineffective and recommended replacement or refurbishment.

The following information is from the report prepared by Hindell *et al.* (2008) on the effectiveness of the existing fishway. Fish were classified into four types, based on their habitat preference and migration habits. These are:

Freshwater species: Mountain Galaxias, Dwarf Galaxias, Yarra Pigmy Perch and Southern Pigmy Perch and Big-headed Gudgeons are generally restricted to the freshwater reaches of streams. Big-headed Gudgeons are sometimes found in the estuary. These species generally do not migrate, except for local habitat and feeding reasons. The exotic fish will be generally restricted to the freshwater reaches, although Eastern Gambusia are able to withstand highly saline environments. Three species of native Australian fish from the Murray-Darling Basin – Murray Cod, Golden Perch and Macquarie Perch have been translocated into the Barwon but are not known to have formed significant populations.

Euryhaline species: These are species that can live in both freshwater and estuarine habitats and include Blue Spot Goby, Congolli, and Small-mouthed Hardyhead. These fish can penetrate some distances upstream into freshwater and remain for their whole life cycle, although all tend to breed in estuarine waters.

Migratory species: Most of these fish live in freshwater and migrate downstream to breed in the estuary or the sea. In the Barwon basin, this group includes the Short-finned Eel, Australian Smelt, Common Jollytail and Spotted Galaxias. The Australian Grayling migrates up from the estuary to mature and breed in freshwater, with larvae returning to the estuary in the drift.

Estuarine and marine species: A large range of estuarine and marine species are found in the Barwon estuary complex although they may penetrate upstream into freshwater and can persist for some time: Black Bream, Estuary Perch, Yellow-Eyed Mullet, Small-mouthed Hardyhead, Flat-tailed Mullet, Bridled Goby and Lagoon Goby. Whiting species and marine Gobies are also likely to be present within the estuary on a regular basis.

A large number of exotic species are in the Barwon basin and its tributaries including Eastern Gambusia, Carp and Goldfish. Other significant exotic species which, along with Eastern Gambusia, are known to be effective fish predators, are Redfin Perch, Rainbow Trout and Brown Trout. These are most common above Buckley's Falls.

Black Bream and Australian Grayling have quite specific flow and salinity conditions for breeding. Blue Spot Goby is susceptible to predation and requires good vegetation to provide cover. The Mountain Galaxias is able to survive in pools over summer, provided some water remains in the pools.

Many of these fish species will require the opportunity to migrate upstream and downstream to either complete their life-cycle or to find suitable habitats. In-stream barriers, such as the breakwater, prevent fish from moving within the system. This increases the likelihood of local extinctions of species.

A review of the migration calendar published by the Victorian Department of Sustainability and Environment has identified that the late spring and summer months are the critical periods for the upstream migration of native fish in the Barwon River Catchment.

3.1.1 Fish Movement

The information on the fish movement has also been sourced from the report prepared by Hindell *et al.* (2008). The Breakwater is upstream of Lake Connewarre, which is likely a major spawning and nursery area where fish leave and enter the Barwon River. The ecology of fish in the whole Barwon River catchment is interrupted by the lower breakwater; it is therefore a major impediment on ecosystem function. There is approximately 8 km of ponded fresh water until the next breakwater barrier which also impedes fish movement in low flows. A portion of high flows coming down the Barwon River go into Reedy Lake upstream of the lower breakwater. This water moves through Reedy Lake and re-enters the Barwon River downstream of the breakwater. (Hindell *et al.*, 2008). This channel is controlled by an outlet gate that maintains the water levels in Reedy Lake but, as with the breakwater, does not allow the passage of fish.

Many of the freshwater species within the Barwon basin are small bodied species of less than 300 mm in length. In contrast, the estuarine species that are known to migrate between freshwater and estuaries are considerably larger, with species such as estuary perch, sea mullet, black bream and mulloway often greater in length than 400 mm, and deep-bodied in morphology. The size and shape of the species has important implications for the passage of fish across barriers. (Hindell *et al.*, 2008).

Many of the species are diadromous and must move between freshwater and estuaries to complete their lifecycle. The diadromous species can be classified as either catadromous (adult life-stage in freshwater and juvenile life-stage in the estuary/marine) or anadromous (adult life-stage in the estuary/marine and juvenile life-stage in freshwater). A major ecological process in coastal rivers is the downstream movement of freshwater fish during high flows. These freshwater-dependent (potamodromous) fish species then need to move upstream. Having a relatively low tolerance to elevated salinity levels, these species need to move upstream from estuarine areas as the freshwater flows recede.

In-stream structures may restrict access to freshwater for catadromous and anadromous species, resulting in rapid reductions in the distribution and abundance of those species unable to pass. Structures close to estuarine waters, such as the lower breakwater, exacerbate impacts by restricting fish to small areas of the total catchment.

Some fish species such as eels are able to negotiate barriers, as they can climb wet surfaces and move short distances over-land around the weir; other species that are strong-swimmers may be able to pass during periods of high flow that inundate barriers. However, the benefits of providing access past the Barwon breakwater for fish unable to negotiate this structure are significant in terms of both the aquatic and terrestrial ecosystem and for native fish conservation, especially when the large amount of potential habitat available upstream is considered.

3.1.2 Existing fishway design

The current fishway is a rock ramp on the southern bank, the opposite side of the weir from the floating gates (Hindell *et al.* 2008). The fishway is a rock chute type design with large rocks in the

lower end to dissipate the energy of the freshwater. The fishway is 27 m long, with a typical water depth of 0.2 to 0.3 m at the entrance (downstream).

Rock diameters within the fishway entrance are between 1.2 m and 0.2 m, and at the exit 0.2-0.5 m. Hence, the entrance channel is made up of larger rocks than the exit channel. The smaller (0.075 m) fill rock originally incorporated is largely missing and has been washed downstream.

The slope along the fishway was originally planned at 1V:20H but the construction diagrams specify a maximum slope of 1V:15H, with on-site observations of a relatively low slope at the entrance and exit, but greater slope through the 2.5 m wide cutting in the sheet pile. The middle section, which is cut through the sheet pile, has the steepest slope due to the cut invert being too high. The fishway entrance and exit are 2.8 m and 5.3 m wide, respectively. The river is about 25 m wide immediately upstream of the Breakwater.

The existing fishway is currently non-functional and requires major restoration. At low-flow, there is no movement of freshwater into the fishway due to heavy siltation and infestation by cumbungi and ingress of other plants in the upstream exit. The breakwater and non-functioning fishway now combine to form a significant barrier to the passage of fish between the lower estuarine waters and upper freshwater region of the Barwon River.

The key recommendation of the report is that there is a replacement fishway built or a complete refurbishment of the existing rock ramp fishway.

3.2 Recommendations from the environmental flow assessment relevant to the operation of the breakwater

The following information is taken from FLOWS study prepared by Lloyd (2006a). Recent wetland condition assessment carried out by the CCMA has shown that most wetlands (60%) are either degraded or severely degraded, with only 15% being intact or pristine. The estuary of the Barwon River, which includes Lake Connewarre, Reedy Lake and the lower Barwon River, are internationally significant wetlands and regional, Victorian and Australian government agencies have a responsibility to protect and enhance these values. The overall objective of the Barwon River Environmental Flows study was to determine the environmental water requirements of the Barwon River, including Lake Connewarre and the Barwon estuary, and to develop options to meet the environmental needs. The breakwater plays an important role in the flow delivery to both Reedy Lake and Hospital Swamp.

It is well understood that wetland flooding initiates a productive succession of potential food resources, which attracts waterbird species and stimulates breeding. Wetland productivity is tied to wetting and drying cycles associated with the growth and decay of aquatic plants (Maher and Carpenter 1984 as cited in Lloyd Environmental 2008c). On re-flooding, the vegetation is drowned, and the rich organic substrate and decaying vegetation supports the development of complex wetland flora and large invertebrate populations (Crome, 1986 as cited in Lloyd Environmental 2008c). In contrast, permanent water bodies with little fluctuation in water level do not promote large scale breeding of waterbirds (Frith, 1982 as cited in Lloyd Environmental 2008c). This has implications on the management of the Reedy and Hospital lakes systems.

There is no hydrological hydraulic or systematic, long-term water level records for the three main wetlands of the estuary to reliably relate water levels to ecological outcomes. Lloyd made the following recommendations are based on discussions with Field and Game representatives and the land and water resource managers responsible for managing the estuary.

Lake Connewarre, the current active estuary of the Barwon, is characterised by dynamic changes in water levels and salinity – this variability is required to maintain the diverse fish and

macroinvertebrate fauna. The principles of the water regime to support the aquatic ecosystem and its habitat for Lake Connewarre are:

- Complete flushing during winter to maintain salinities at or below seawater;
- Spring flushes of freshwater from upstream to lower salinity and flood marginal zones of the lake to trigger fish breeding and recruitment;
- Low discharge in autumn to minimise flushing; and,
- Flows over the fishway at lower breakwater to enable fish movement along the lower Barwon

Of importance for the FLOWS study to this current study is the recommendation to maintain flows of greater than 8 ML/day through the lower breakwater for the operation of the existing fishway. The other key recommendation is to initiate a drying regime in the Reedy Lake and Hospital Swamp wetlands. This is consistent with the PPK (2000) recommendation for a drying regime for Reedy Lake. The frequency and durations required for such drying cycles is being reviewed. Infrequent cycles of longer duration may be indicated, along with annual cycles of shorter duration.

3.2.1 Reedy Lake hydrology

The hydrology for Reedy Lake is currently managed by Parks Victoria with the support of representatives from Field and Game. The wetland water level reaches 0.8 m AHD in spring and remains at that level until evaporation overtakes inflow in summer, when levels usually fall to 0.3 m AHD through to the autumn break. The maintenance of an open channel into Reedy Lake will reduce the volume of water passing through the tidal barrage.

The 2006 Barwon River Environmental Flows study (Lloyd, 2006) proposed three flow regime options for the management of Reedy Lake. The water levels for each of the three options are shown in Table 2. The recommendations presented favour a drying regime in Reedy Lake to promote a modification of the vegetation structure to enhance the diversity and productivity for migratory bird species. These options would also have a favourable consequence in delivering more fresh water to the estuary and maintaining the operation of any proposed fishway throughout the summer period.

The drying options are recommended to promote the growth of submerged aquatic species and control the dominance of phragmites and typha species. These two latter species now dominate the previously open water areas of the lake. It is also anticipated that the annual drying regime will control carp that are prevalent in the lake.

Table 2 - Recommended Water Regime for Reedy Lake (Lloyd 2006)

MONTH	1st Option Water Level (m AHD)	2nd Option Water Level (m AHD)	3rd Option Water Level (m AHD)
May	0.4	0.4	0.4
June	0.4	0.4	0.4
July	0.6	0.6	0.6
August	0.9	0.9	0.9
September	0.9	0.9	0.9
October	0.5	0.9	0.9
November	0.3	0.5	0.9
December	0.1	0.3	0.5
January	0	0.1	0.3
February	0	0	0.1
March	0	0	0
April	0	0	0

The first option is most conservative and has a strong chance of resulting in a change in the vegetation structure to the desired system of open water with submergent macrophytes and diverse fringing vegetation.

The second option could be applied every year with the likelihood that the preferred vegetation objectives occur but the change may take a longer time to re-adjust. There is an increased, but still low, risk of summer growing macrophytes (such as *Typha* and *Phragmites species*) becoming more prevalent. This might better support waterbird breeding and an ideal water regime might see this option applied four out of five years and option one in the remaining year (with a low rainfall).

The third option could be applied but would have a low likelihood of change to the preferred ecological condition. It is perhaps an option that could be applied in high rainfall years only – based on a rainfall trigger of something like the 75th percentile rainfall, which might coincide with large waterbird breeding events once in a decade or similar frequency.

Active control of the water levels through the upgrade of the breakwater and seasonal closure of the flow to Reedy Lake is required in order to achieve each of the recommended water regimes for the lake.

In summary, the proposed water regime (Lloyd 2006) will result in:

- Flooding in early winter and drying out in mid-spring before the main growing season of reeds;
- Exclusion of reeds from the central area by saline groundwater, by flooding that is too deep for them in spring and by the absence of flooding in their main summer growth period;

- A drying phase to control exotic fish species and allow nutrient processing in the wetland bed;
- Flooding of the central lake to a depth of more than 1 m for 3 to 6 months, in which would grow emergent and semi-emergent water plants like *milfoil*, *Potamogeton*, *Triglochin* and *Lepilaena*. This will allow for aquatic invertebrates and fish populations to breed and expand with Reedy Lake;
- Persistence of reeds in a zone near the seasonal upper limit of water levels in winter and spring; and
- Intermittent flooding in winter and spring by rainfall and river flows every 2-3 years to allow extensive flooding, aquatic habitat creation and fish breeding events.

3.2.2 Hospital Swamp

Parks Victoria and former government agencies in collaboration with the Field and Game Association have also undertaken modifications to Hospital Swamp over a period of 20 years. A regulated channel from the river through Sparrowvale Farm, upstream of the breakwater, can deliver water to the Swamp and maintain water heights of 0.5 m AHD. The swamp can also be drained with a pipe through to Lake Connewarre. Following discussions with Field and Game representatives, this management has been primarily for the purpose of enhancing duck breeding.

The following information on the hydrology of Hospital Swamp is also sourced from the FLOWS study prepared by Lloyd, (2006). Hospital Swamp features a range of plant assemblages that correspond to soil and the various soil moisture, salinity and flooding environments present. Hospital Swamp comprises five basins which receive water both from the Barwon River estuary and from local runoff. The wetland is isolated from the estuary by a bund but has higher salinity than Reedy Lake. Other unregulated channels become active at Barwon River levels greater than 1.4 m AHD.

The limit of wetland vegetation is defined by *Muehlenbeckia florulenta* shrubland which occurs in association with *Distichlis distichophylla* and *Juncus kraussii*. This association lies at an elevation of more than 1 m AHD and is rarely flooded. It is likely to occur in soils that are seasonally waterlogged. Flooding would be tolerated, but is not a requirement to sustain this vegetation.

Elevations between the *Lignum* and the normal full level of the wetland (0.5 m AHD) support salt tolerant sedges and herbs. *Bolboschoenus caldwellii* was observed growing over *Sarcocornia quinqueflora* and *Selliera radicans*. Other species likely to be present include *Mimulus repens*, *Schoenoplectus pungens*, *Triglochin striata* and *Distichlis distichophylla*. *Bolboschoenus caldwellii* grows in saline areas subject to inundation with fresh or brackish water for a period of 1 month to 4 months in most years. The vegetation in this area most likely reflects a zone of permanent waterlogging where saline groundwater discharges to the surface, but soil salinities are reduced seasonally by flooding.

The normal full level of the wetland is marked by emergent macrophytes, particularly *Phragmites australis* and *Bolboschoenus caldwellii*. *Schoenoplectus validus* is also likely to be present. This association occurs at the fringe at the wetland at islands within the wetland that emerge above 0.5 m AHD.

Between elevations of 0.5 and 0.1 m AHD (the base of the wetland) the vegetation comprises a marshland assemblage. This area is regularly inundated to a largely stable maximum depth of 0.5 m AHD and supports a range of submerged and semi-emergent herbs and shrubs. Common species observed during the site inspection include *Sarcocornia quinqueflora*, *Ruppia maritima*, *Distichlis*

distichophylla, *Mimulus repens* and *Cotula coronopifolia*. Other species likely to be present include *Potamogeton sp.*, *Crassula helmsii*, *Rumex bidens*, *Triglochin procerum*, *Triglochin striata*, *Schoenoplectus pungens* and *Lilaeopsis polyantha*. This assemblage reflects the brackish conditions of the wetland, which are likely to be least saline when freshwater enters from the Barwon River, but becomes progressively more saline as water levels fall and groundwater discharge increases. Species such as *Triglochin procerum*, *Ruppia* and *Lilaeopsis* will tolerate permanent inundation or seasonal flooding. Species such as *Sacrocornia*, *Distichlis*, *Mimulus*, *Rumex* and *Triglochin striata* are favoured by seasonal inundation but will tolerate permanent waterlogging. The presence of the latter species suggests that drawdown of the wetland in late spring is important to this vegetation structure. Low water levels in November and December will provide an opportunity for these low-growing species to flower and set seed before excessive temperatures, high salinities or insufficient moisture in January and February inhibit further growth.

Recommended (Lloyd 2006) water management specifically involves:

- maintenance of a saline water table at or near the surface of the wetland bed. This will allow some areas of permanent low level pools providing fish habitat in which to survive over summer;
- fresh water inundation between June and November for a period of at least 3 months in most years to a depth of more than 0.4 m to support the growth of submerged aquatic plants such as *Lilaeopsis*, *Potamogeton* and *Ruppia*;
- fresh water inundation for 2 to 4 months to an elevation of 0.5 m AHD in winter and spring in most years to support the growth of emergent aquatic macrophytes such as *Phragmites australis* and the creation of extensive aquatic habitat, stimulate fish breeding and enable recruitment of fish larvae;
- intermittent inundation (events of 1 to 2 weeks, 2 to 4 times per year) of the *Bolboschoenus sedge*land and to enable extensive breeding events of fish such as *galaxiids* within the sedge
- drawdown in November or December in most years to provide a growing opportunity for lake bed herbland species; and
- drawdown of the wetland in late summer and all of autumn to maintain the salinity of soil water and to restrict emergent macrophytes to the wetland fringe.

As with Reedy Lake, the active management of the vegetation within Hospital Swamp requires flexibility in the ability to manipulate flows into and out of the wetland. However, unlike Reedy Lake, the height of the breakwater is less critical to the supply of water into Hospital Swamp as the elevation of the top water level is significantly lower. Therefore, modifications to the breakwater are less critical to the operation of the hydrology of this system compared to that in Reedy Lake.

3.3 Recreation and riparian management in the lower Barwon

In 2007, the Corangamite CMA and City of Greater Geelong commissioned Thompson Berrill Landscape Design to produce an updated Management Plan for the Barwon Catchment through to Geelong. The downstream reach of the study area extends from Boundary Road through the Lower Breakwater. The management plan has allocated a preliminary cost of \$121,000 for the management of this area over the next 1-10 years.

The key management objectives for the lower reach from Boundary Road through to the Barwon Breakwater are:

- Liaise with adjoining private landholders to improve land management practices and environmental values along the river;

- Maintain existing levels of water skiing use and monitor ongoing environmental impacts; and
- Commence active revegetation and regeneration of public land along the river to improve environmental links along the river to Reedy Lake and Lake Connearre.

Table 3 below summarises the, recommendations, relevant stakeholders and priority levels for the key management issues that relate to river health and the operation of the lower breakwater in the lower reach.

Table 3 - Key management issues in the lower reach between Boundary Road and the Barwon Breakwater

<u>Issue</u>	<u>Recommendation</u>	<u>Stakeholders</u>	<u>Priority</u>
There is limited indigenous overstorey vegetation through this reach and overgrazing, cropping and stock access right to the river in addition to water ski access that is contributing to bank erosion and reducing opportunities for natural regeneration of Floodplain Riparian Woodland Communities.	Liaise with adjoining landholders to investigate fencing and revegetation along the river to improve habitat values and reduce erosion.	CCMA	Moderate
Willows, Elms and Ash in several areas on private land may impact on high value vegetation areas at Reedy Lake and Lake Connearre.	Liaise with private landholders to remove invasive weed species along the river.	CCMA Landholders	High
Stock access to the fishway has reduced its effectiveness and the lower breakwater may be again a barrier to fish passage.	Review the design and construction of the fish way at the lower breakwater.	CCMA	Very High
Wash from ski boats is contributing to bank erosion especially where grazing has removed vegetation from the bank and at turnaround areas.	Liaise with adjoining private landholder to actively stabilise banks at boat turn around areas.	CCMA Geelong Water Ski Club Landholders	Ongoing
CCMA leased land along the river is currently being cropped. This could lead to substantial erosion in a flood event and is an inappropriate land use along the river floodplain.	Remove cropping and grazing from leased land along the river frontage. Investigate provision of offline stock watering points to reduce bank erosion. Commence revegetation with establishment of scattered overstorey and review opportunities to encourage natural regeneration of indigenous floodplain vegetation along the river.	CCMA	Very High
There is limited indigenous riparian vegetation on private land adjoining the	Liaise with landholders to investigate partnerships for	CCMA Landholder	Ongoing

<u>Issue</u>	<u>Recommendation</u>	<u>Stakeholders</u>	<u>Priority</u>
river and stock overgrazing and accessing the river banks is contributing to accelerated erosion in some areas.	establishment of fencing and revegetation to improve environmental values along the river as part of the Healthy Rivers Support Fund and Urban Stream Restorations Fund. Investigate provision of offline stock watering points to reduce bank erosion.		
There are several online channel off-takes diverting water from the river to private dams.	Liaise with landholders and review existing permits and conditions for water allocation along the river.	SRW CCMA Landholder	High
There is currently no active maintenance on the river through this reach.	Undertake annual inspection of the fishway at the lower breakwater to confirm operation of this critical link for fish migration.	CCMA	Ongoing
Management of the lower breakwater has been undertaken on a voluntary basis for over 35 years.	Review management requirements as part of proposed lower breakwater upgrade works.	CCMA Landholders	High

The management issues most relevant to the upgrade and operation of the breakwater are:

- Clarification of management responsibility and maintenance of the breakwater;
- Maintenance and inspection of the fishway;
- Review of existing water extraction rights; and
- Erosion associated with ski boats.

The last point is particularly relevant as any manipulation of the water level in the river may lead to further bank instabilities caused by boat wash or bank collapse.

4. FORMULATION OF MANAGEMENT OPTIONS LOWER BREAKWATER

4.1 Engagement process

With the multiple objectives and values associated with the management of the breakwater it has been important to seek significant input into the development and analysis of the options.

Input has been provided to the project by Victorian Government stakeholders including Parks Victoria, DPI Fisheries, Barwon Water, Southern Rural Water and the Corangamite Catchment Management Authority. The City of Greater Geelong represented local government whilst recreational and commercial information was provided by the VRFish, Field and Game Victoria, Geelong Water Ski Club, Sparrovale farm and commercial eel fisherman.

The short timeframe for the delivery of the first draft of the report required a truncated consultation process. A site meeting was held at the breakwater 6th July 2009 to discuss the current operation of the structure and the values associated with the river reach. Notes from this meeting are contained in Appendix A.

Additional contact after the meeting was initiated with Graeme Perkins (landholder and operator of the breakwater for 30 years), the Ski club, Bill Allan (commercial eel fisherman), John Hotchin (VRFish) and Ian McLachlan (Field and Game Victoria). Further meetings were also held with Parks Victoria and the CCMA. The key points from this site meeting are in Table 4.

Table 4 key points from meeting and other discussions and how they may influence the breakwater management

Key points	Use in determining management option
The automatic operation of the gates is currently compromised and has been for some time	Determine what role the gates have in flood mitigation and whether the gates are still required
Cease to flow condition is becoming more regular	A fishway design will need to account for the reduced flow conditions.
Northern side provides a good location for a new fishway as there is already a large scour pool on this side of the river downstream of the existing weir gates	Preference given for a fishway on the northern bank of the river
VRFish wants to see larger fish travel through the upgraded fishway. For example Estuary Perch in the order of 400mm in length	Fishway design to cater for large and small bodied fish (therefore preference for vertical slot fishway)
Plans for a recreational pathway exist with a preference for the southern bank of the river	Additional preference given for a fishway on the northern bank of the river
Bill Allan, a local commercial eel fisherman wants to see Eel/Elver access through the breakwater either by the fishway or some other structure	Design an elver pass to complement the fishway
Eel fisherman wants to see a more natural cycle for Reedy Lake as this would suit Eels better	Flexibility in the operation of water levels in Reedy Lake will be required
Reedy Lake begins to fill at a weir height of 0.7 m AHD	If flexibility of management of hydrology of Reedy Lake is required then the breakwater crest cannot be

Key points	Use in determining management option
	below 0.8 m AHD
Skiing on the river can still be undertaken with the river height at 0.4 m AHD	This is the minimum level to drop the river to without adversely affecting recreational use
Leakage around the gates results in the river dropping significantly during periods of cease to flow	Fix or remove the gates to prevent leakage. Minimise the discharge through any fishway to reduce the likelihood of the river dropping
Reducing the river height rapidly initiates bank collapse	Minimise the opportunity for the river height to fluctuate
The frequency of flooding of agricultural land has reduced significantly with the drought conditions	Maintaining the operation of the gates is not as critical as it once was
Land-use on the floodplain adjoining the river may change	Maintaining the operation of the gates is not as critical as it once was
Corangamite CMA will lead assessment of environmental flow needs for the Connewarre/Reedy/Hospital complex	Flexibility in the operation of water levels in Reedy Lake required
Typical tidal range at the breakwater is thought to be 100 mm although the greatest tidal range is up to 700 mm during king tides.	Fishway will be required to cater for broad range of tidal movement
There are upstream levee banks on the southern side of the river that protect land from frequent inundation. There was discussion that a long term outlook may see these removed and the lake Connewarre complex extended	Test the inundation regime of the additional areas in the hydraulic model
There are 10 licences for water extraction between the breakwaters	Protection of these licences requires the breakwater to remain in place
Who is going to maintain the weir/fishway? (It is anticipated that the CCMA will take ownership of the Breakwater once it has been upgraded although maintenance arrangements are still to be established)	Ownership, maintenance and access requirements need to be resolved. There are many examples of inoperative fishways around Victoria due to lack of maintenance and clarification of ownership.

The CCMA had, prior to the consultation, indicated that there were three primary options to be examined, these were:

- Remove the Breakwater in its entirety
- Enable the operation of the floating gates as per the original design
- Fix the gates shut or remove the floating gates and replace them with a standard weir

In addition to this it was also suggested to examine if there were any benefits in reducing the height of the breakwater and, as an additional option, the project team tested an alternative arrangement to increase the height of the breakwater to provide additional flexibility of flow management into Reedy Lake.

Each of these options has differing effects on the water levels within the Barwon River, inundation of adjoining land and the Reedy Lake system. They also impact upon the proposed fishway design. Additional detail on the options is presented below.

4.2 Completely remove the breakwater

The first option is to completely remove the breakwater and restore the channel back to its original depth. This will allow Barwon River flows to freely pass through this section of the channel, as well as allowing brackish water from Lake Connewarre to flow upstream back up through the Barwon River. Obvious benefits are that this provides unimpeded fish passage. This option required testing to see what impact it would have on the depth of the river at the ski club and the connectivity of the river with Reedy Lake and Hospital Swamp.

4.3 Enable the gates to function as per the original design

The second option is to retain the floating gates and enable them to work effectively, including preventing them from leaking. As detailed above, the gates were designed to mitigate flooding of the adjoining agricultural land. The gates have just been replaced and, with some additional investment, they could be enabled to undertake the flood mitigation task. To assess the relative benefits of this, an assessment is needed on the frequency and magnitude of the benefits.

4.4 Completely close off the breakwater gates to flow

The third option is to fix closed or replace the existing gates with a sheet pile wall directing all base flows through the proposed fishway/over the weir crest and allowing higher flows, that would have triggered the gates, to inundate the adjoining land. An assessment is required on the impact of this option on the adjoining agricultural land. To do this, an assessment of the range of flows the gates had an operational benefit on and the frequency of these flows is required.

4.5 Reduce the height of the breakwater wall and replace the gates with a fixed weir crest

The fourth option is to maintain the breakwater but reduce the height of the crest. This will reduce the inundation frequency of the adjoining land. An assessment of the impact of this on the water level in the river is required to determine if it will negatively impact on the ski club activities.

4.6 Raise the breakwater crest to 1.0 m AHD and replace the gates with a fixed weir crest

A final option is to raise the height of the existing breakwater crest from 0.85 m AHD to 1.0 m AHD. This will maintain a higher weir pool depth and allow less water to flow from the Barwon River through to Lake Connewarre by potentially diverting it through Reedy Lake. In this scenario, the flows from the Barwon River will not directly overtop the weir until a height of 1.0 m. Therefore, much more flow will be backed up against the weir and potentially flood the upstream land during high flow events. The effect and frequency of this inundation needs to be tested.

A hydraulic assessment of these options using the MIKE flood software was undertaken (see section 5 below) and a second meeting was held on 10th August 2009 to present the modelled options to the stakeholder group. Feedback was sought on the results of the assessment and the proposed fishway concept design. More information on this feedback is contained in conclusions and recommendations.

5. HYDRAULIC ANALYSIS OF THE BARWON BREAKWATER

In order to obtain reliable estimates of the flood flows and depths on the site, a two dimensional (2D) unsteady hydraulic model was developed for the river reach. The 2D hydraulic model was developed using DHI Software's MIKE 21 fully two-dimensional flow modelling package. MIKE 21 is a state of the art modelling tool for simulating the details of flows in complex river and floodplain systems.

5.1 Hydrology

To enable the assessment of the hydraulics of the floodplain an understanding of the hydrology is required to determine the frequency that inundation might occur.

Corangamite CMA supplied the recommended statistical peak flows for the river at Geelong (Table 5). These flows identify that the 1 year ARI is 10,800 ML/day, a flow significantly higher than the flow of interest to this assessment.

Table 5 Statistical analysis of peak flows

ARI Years	CMA Recommended peak flow (ML/day)
1	10,800
2	20,736
4	34,560
10	47,952
20	66,528
50	95,040
100	120,960

The critical flows for this assessment have been determined in the model as those below 3,456 ML/day. This is the maximum flow at which the flood gates alleviate flooding. The other critical component to the investigation for the operation of the fishway is the duration of cease-to-flow conditions which impact on the ability of the fishway to operate.

A review of the FLOWS issues paper for the Barwon River (Lloyd, 2005) identifies that the hydrology in the Barwon through Geelong has not had a significant modification to the natural flow components, although annual discharge has been reduced by 13%. In fact the report indicates that the base flows during summer exceed the natural condition and maintain a minimum flow above 8 ML/day. This is contrary to the anecdotal evidence of sustained cease to flow conditions at the lower breakwater over the past five years. Recent gauge data supports this cease to flow.

There are a couple of potential reasons for this discrepancy. Firstly, since the FLOWS study was undertaken there has been a sustained period of drought. A brief review of the flow data of the last four years identifies a significant reduction in the river flow, especially over the summer period. Secondly, the most reliable long-term flow dataset is sourced from the Pollocksford Gauge and this was utilised in the modelling for the FLOWS study. This gauge is approximately 20 km upstream of the breakwater and the river is wide, with limited overhanging vegetation and slow flowing for the majority of this distance. Evaporation in this reach of the river would be significant and this may have been underestimated in the model.

For the purpose of this report it was assumed that the historical flow dataset as presented in the FLOWS study is current to assess the land inundation frequency and the drought regime of base flows is to be utilised for the design of the fishway. This approach is precautionary in both cases providing the worst case scenario and presenting design approaches that address them.

5.2 Hydraulic model development

5.2.1 Model topography

The model topography was developed using a combination of survey data sets within the site and surrounds. These included:

- coarse survey data consisting of 10 m contour levels (interpolated from LIDAR information) from the Corangamite CMA. The 10 m contour intervals covered the area ranging from Breakwater Road in Breakwater through to the southern extent of Lake Connewarre;
- raw point data from the LiDAR which were utilised in the construction of a three dimensional terrain;
- detailed survey information supplied by Barwon Water for the breakwater site. The detailed survey information included the breakwater, retaining walls, water surface levels and contours downs to 0.5 m intervals for the immediate area;
- survey of the bed of Reedy Lake supplied by Barwon Water where LiDAR data coverage did not exist;
- existing bathymetry of Lake Connewarre from the hydrodynamic study; and
- additional in channel survey commissioned for the river channel upstream of the breakwater.

These various data sets were compiled into a single topographic layer for incorporation in the model. The 2D hydraulic model covered an area of approximately 1200 m by 1200 m in a 5 m grid size. The model topography for existing conditions in the area is presented in Figure 3.

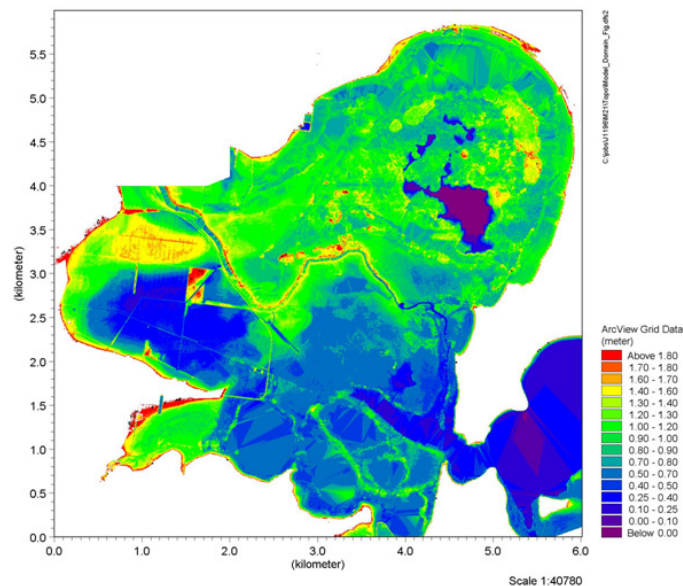


Figure 3– Hydraulic Model Extent

5.2.2 Roughness

Manning's coefficient (n) varies according to the bed friction of different surfaces. Adopted roughness values included 0.04 for the Barwon River Channel and 0.05 for the floodplain.

5.2.3 Evaporation

For the purposes of this study, the impact of evaporation on Reedy Lake has been simply accounted for by applying a time varying (negative) fresh water flux from the model surface area based on appropriately factored average monthly pan evaporation rates sourced from the Bureau of Meteorology.

5.2.4 Structures

Details of the regulator structures within the Study Area of the Barwon River were provided by Barwon Water and were included in the model setup. The structure type, locations and description details are provided in Table 6 below. The locations are also illustrated in Figure 4 below.

Table 6 Regulation structures

Structure	Location	Description
Inlet Regulator	Reedy Lake Inlet	3 x 1.2 m box culverts with concrete headwalls. Invert level 0.7 m AHD
Outlet Weir	Reedy Lake Outlet	Concrete dropboard weir, 5 m wide in two bays, drop-board at 100mm, height 1m
Inlet Regulator	Hospital Swamp	2 x 1.2m box culverts with concrete headwalls. Invert level 0.4 m AHD
Breakwater	Barwon River	Sheet pile wall with two floating gates at northern end. Piling crest height at 0.85 m AHD, gate range estimate 0.2 m to 0.9 m

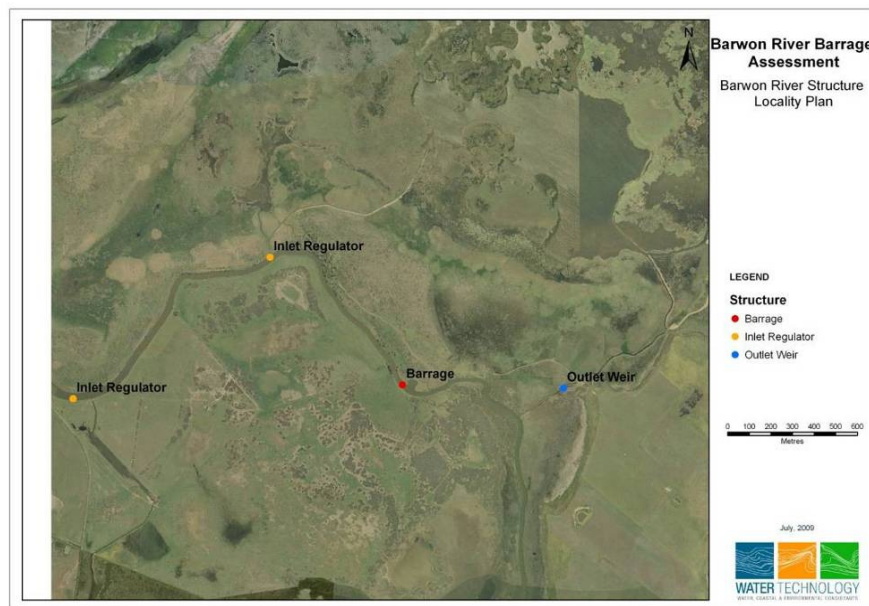


Figure 4 – Barwon River structure locations

6. MODEL SIMULATION RESULTS

In order to determine the effect of each of the proposed modifications to the Barwon Breakwater, numerous sets of model simulations were carried out. The model scenarios included:

- The Breakwater gates being completely closed off to flow
- The Breakwater gates remaining completely open to flow (gates working as they were designed)
- The Breakwater being completely removed
- The Breakwater Crest being raised to 1.0 m AHD

The option of reducing the crest height of the breakwater weir was not modelled as it would have a detrimental impact on the operation of Reedy Lake and a potential fishway.

6.1 Impact of scenarios on flooding

The scenarios were tested to determine their effect of the inundation regime of the adjoining private property. These results are presented below.

6.1.1 Breakwater gates closed

In this scenario, the model was run with the breakwater gates permanently closed. Various flow rates, ranging from 432 ML/day to 25,920 ML/day were used for the upstream boundary condition over a period of six days.

Figure 5 below illustrates the adjoining private land to the south of the river is beginning to become inundated (circled) at a flow rate of 691 ML/day. At this flow, water can also be seen flowing into Hospital Swamp.



Figure 5 – Inundation of agricultural land with fixed crest height of 0.8 m and flow rate of 691 ML/day

As the flow rate continues to increase the agricultural land becomes completely inundated when the flow reaches 2,246 ML/day, as shown below in Figure 6.

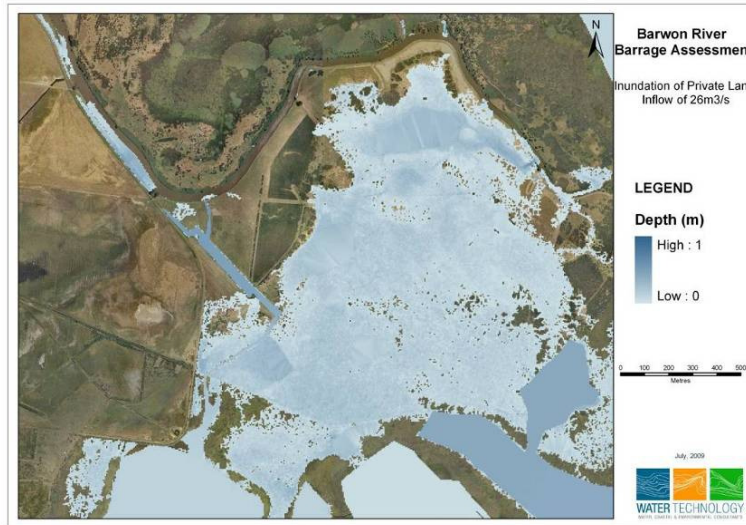


Figure 6 – Inundation of private land with fixed crest height of 0.8 m and flow rate of 2,246 ML/day

6.1.2 Breakwater gates functioning and open

In this model scenario, the breakwater gates were opened so that water could freely flow through the structure. The base level of the breakwater gates was fixed at a height of 0.0 m AHD. A range of flow rates were used to find the flow required to inundate the adjoining private land with the breakwater open.

The upstream boundary condition of inflow rate ranged between 432 ML/day and 25,920 ML/day over a period of six days. Figure 7 below illustrates the adjoining private land to the south of the river is beginning to become inundated at a flow rate of 864 ML/day.



Figure 7 – Inundation of Private Land with gates open and flow rate of 864 ML/Day

As the flow rate continues to increase, the private land becomes completely inundated when the flow reaches 3,456 ML/day (Figure 8).

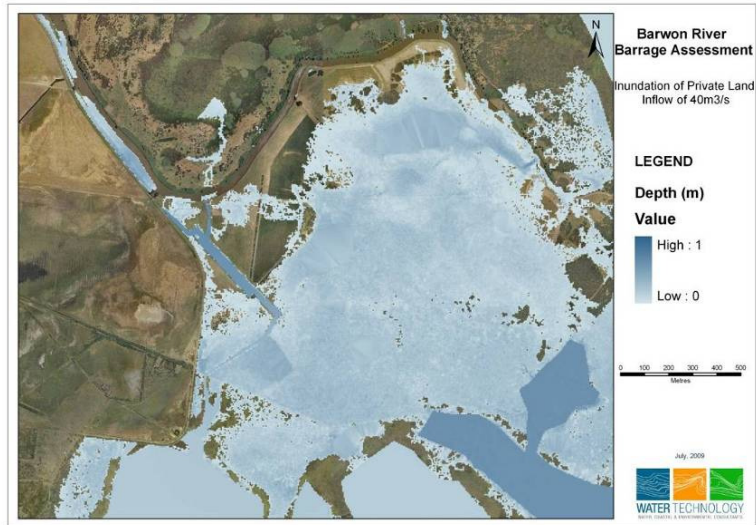


Figure 8 – Inundation of Private Land with gates open and flow rate of 3,456 ML/day

6.1.3 Increased Height of Breakwater Crest to 1 m AHD

In this model scenario the height of the breakwater crest was increased to 1 m AHD.

Increasing inflow rates were used at the upstream boundary condition over a period of six days as per the previous scenarios. Figure 9 below illustrates the adjoining private land to the south of the river is beginning to become inundated at a flow rate of 432ML/day.

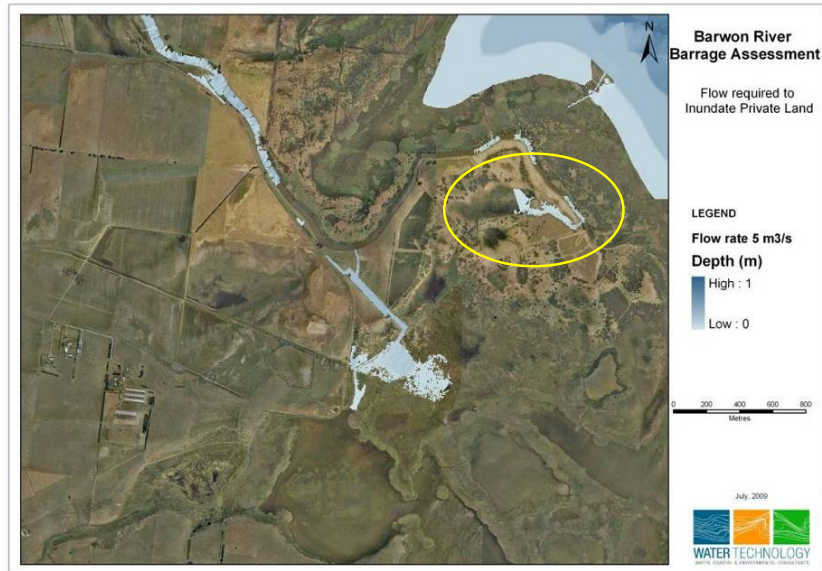


Figure 9 Inundation of private land with crest height of 1.0 m and flow rate of 432 ML/day

As the flow rate continues to increase the private land becomes completely flooded when the flow reaches 1,728 ML/day (Figure 10).

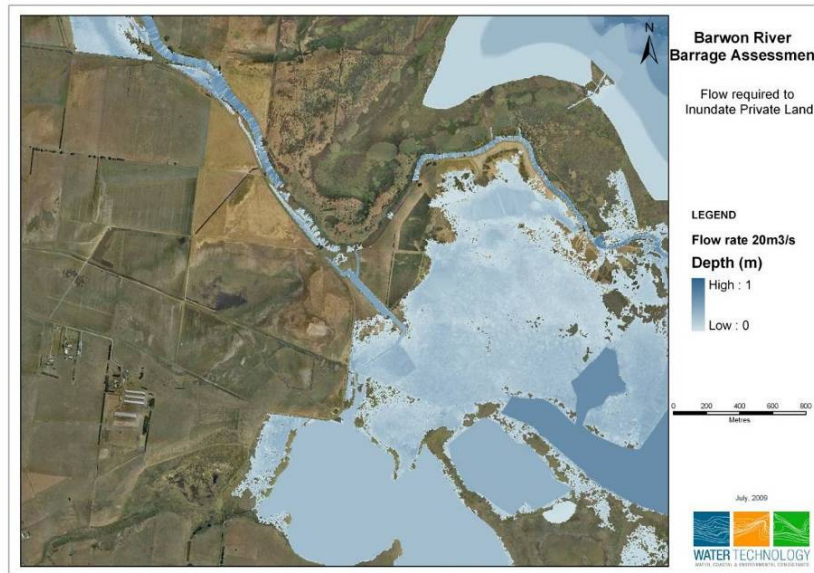


Figure 10 Inundation of private land with crest height of 1.0 m and flow rate of 1,728 ML/day

6.1.4 Discussion relating to local flooding

It is clear from the results that the breakwater gates, when operational, do have a notable impact on the inundation regime of the private land and Hospital Swamp. Table 7 below provides a comparison of the flow required to initiate inundation under the three scenarios and the approximate flow where complete inundation occurs.

Table 7 Comparison of results

Scenario	Inundation begins ML/day	Complete inundation ML/day
Breakwater operational*	864	3,456
Breakwater closed	691	2,246
Breakwater height increased	432	1,728

*It should be noted that the breakwater operational figures may overestimate their benefit as it assumes that they lie completely flat, whereas they would still occupy a proportion of the cross sectional area of the breakwater.

From this assessment, it can be determined that the flows where the breakwater gates are providing some benefit to the flood mitigation are between 691ML/day and 3,456ML/day. At any flow above the latter, the land is inundated whether the gates are operational or not. Increasing the height of the breakwater crest to 1m AHD has a considerable impact on reducing the flow required to initiate the flooding and complete inundation.

A review of the historical flow data reveals that the operation of the gates equates to a reduced inundation of private land benefit in the past four years of flow record of, on average, once every year. Whilst this period has been very dry, the benefit afforded by the gates has been minor. When compared to the flow record of the early 1980s however, the number of periods that the gates would have made a difference to the inundation of agricultural land equated to approximately 10 times in any one year.

It is clear to see that the justification for the gates in the 1970s and 80s was there when the clear intention was to maintain this land for grazing and the flow regime of the river produced a higher frequency of flows that initiated the flooding.

6.2 Impact of scenarios on Reedy Lake and Hospital Swamp

To assess the impacts of raising the breakwater crest or removing it completely on the inundation regime of Reedy Lake three model run scenarios were compiled;

- the existing condition;
- the breakwater crest raised; and
- the breakwater removed.

6.2.1 Breakwater height at 0.85 m AHD (existing conditions)

The Mike Flood model simulation was run for a period of one month over summer accounting for evaporation, with the upstream boundary condition consisting of an inflow at the rate of 8 ML/day. The downstream boundary condition incorporated a water level downstream of the breakwater crest of 0.15 m AHD. The objective here was to identify if, under these conditions, water levels in Reedy Lake dropped and if there was any flow over the breakwater crest.

6.2.2 Breakwater height increased to 1 m AHD

The objective of this assessment was to determine if there were any benefits with regard to the raising of the weir crest in providing water to Reedy Lake during low flows and to identify if, during very low flow conditions, water was still overtopping the weir or was lost to evaporation.

As per the previous scenario, the model simulation was run for a period of one month over summer, with the upstream boundary condition consisting of an inflow at the rate of 8 ML/day. The downstream boundary condition incorporated a water level of 0.15 m AHD downstream of the breakwater.

6.2.3 Results and discussion of effect of increased breakwater height on Reedy Lake

Whilst the increase in the breakwater crest had a minor impact on the starting top water level of Reedy Lake it provided few benefits with regard to the operation of the lake over summer. The top water level of Reedy Lake is governed by the outlet structure which is currently set at 1 m AHD.

The raising of the crest did have an impact on the operation of Hospital Swamp with additional water flowing through the inlet structure and bypassing flows that may operate over the breakwater. Losses associated with evaporation were high from Reedy Lake in both scenarios with little of the 8 ML/day flowing over the crest of the breakwater in either scenario. This has implications on the operation of the proposed fishway.

In summary, the raising the crest option would not provide any additional flexibility in the management of the lake and would most likely reduce the available water for the operation of a fishway.

Further work is required on the impacts of hydrology on ecological function and the losses associated with evaporation within the Reedy Lake system.

6.2.4 Breakwater completely removed

As detailed above, the breakwater acts as a control on the level of the water within Reedy Lake and Hospital Swamp. Without the breakwater in place the water level in the river is controlled by the tidal tail water conditions in Lake Connewarre. As these are considerably lower than the current pool of water behind the breakwater more flow is required to fill the channel to the equivalent height of 0.85 m AHD.

To assess how much flow is required the breakwater was removed from the topography and the flow sequence run to establish the changes compared to the base case with the breakwater in place.

6.2.5 Impact of breakwater removal on Reedy Lake

For the simulation flow rates were increased in the Barwon River ranging from 432 ML/day to 25,920 ML/day over a period of six days with a tail water at the average tidal extent. With the breakwater removed a flow rate of 3,100 ML/day was required to engage Reedy Lake at 0.85 m AHD.

Based on the flow duration curve published in the Barwon River FLOWS assessment a flow of this magnitude would be exceeded for about 5% of the time in any one year. However, during the recent drought conditions, a review of the limited Geelong gauge data for the past four years identifies that this flow has been exceeded only once, for four days, in the past four and a half years.

Under the flow conditions documented in the FLOWS study the Lake would fill over winter and maintain a water height at approximately 0.7 m AHD until progressive evaporation dries the Lake. However, if the conditions of recent years persist, the removal of the breakwater would isolate Reedy Lake and Hospital Swamp from the river and lead to both receiving significantly less, if any, water annually. Whilst this filling and drying regime may be closer to the natural situation in drought there would be a period of adjustment whereby the ecological values of the Reedy Lake would change. A comprehensive assessment of the potential impact of this regime on the ecological values of Reedy Lake, especially to migratory birds and Growling Grass Frog, would be required prior to this action being recommended.

6.3 Impact of breakwater options on social values

6.3.1 Waterskiing

To assess the potential impacts of modifying the breakwater on the operation of the ski club, a one-dimensional hydraulic model was constructed in MIKE11. Two scenarios: complete removal of the breakwater; and drawdown due to fishway, were reviewed to assess if they had the potential to impact on the water levels and therefore the operation of the club. The lower boundary condition of the breakwater removal incorporated the tidal fluctuation measured at the breakwater.

The removal of the breakwater has, as expected, the greatest impact on the water level in the river. Figure 11 below identifies that the water level at the ski club without the breakwater in place fluctuates between 0.06 m AHD and 0.35 m AHD. This compares with the current static water level of approximately 0.9 m AHD.

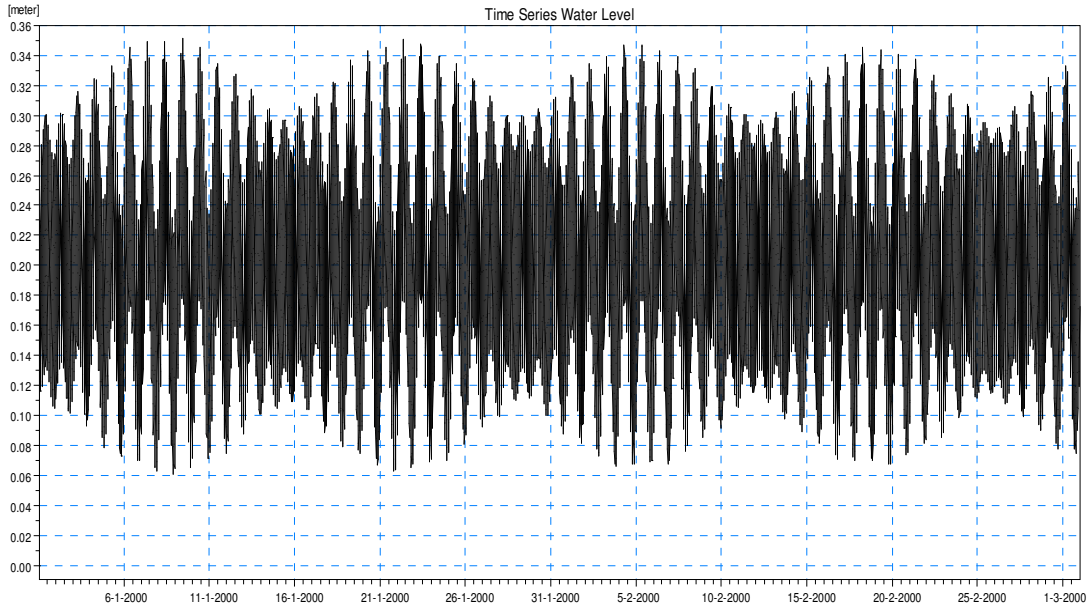


Figure 11 Tidal variation at the ski club with breakwater removed

Whilst this is a drop of water level up to 0.9 m AHD, the river depth at this location is up to 3.6 m with relatively steep banks. Therefore the loss of surface water width, and therefore skiable area, is only in the order of 10% (Figure 12).

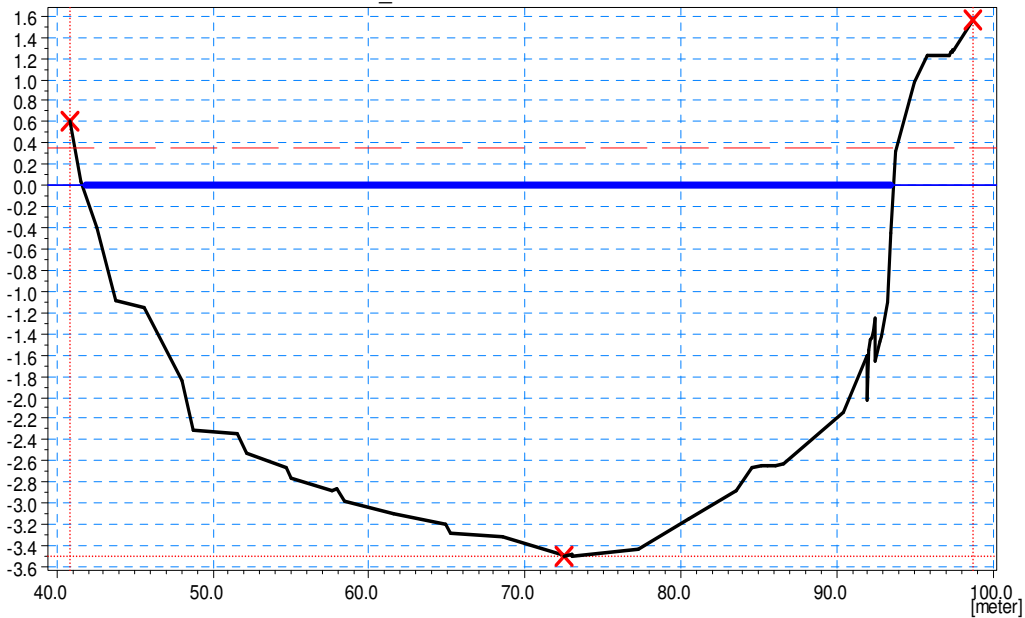


Figure 12 Cross section of minimum water level (m) at ski club with breakwater removed

To model the effect of the maximum drawdown of the proposed fishway the crest of the breakwater was set at 0.4 m AHD and a minimum flow represented in the model. This resulted in the water level at the ski club dropping to 0.47 m AHD from the current 0.9 m AHD. This lower water level represents a 4% reduction of skiable area in the river.

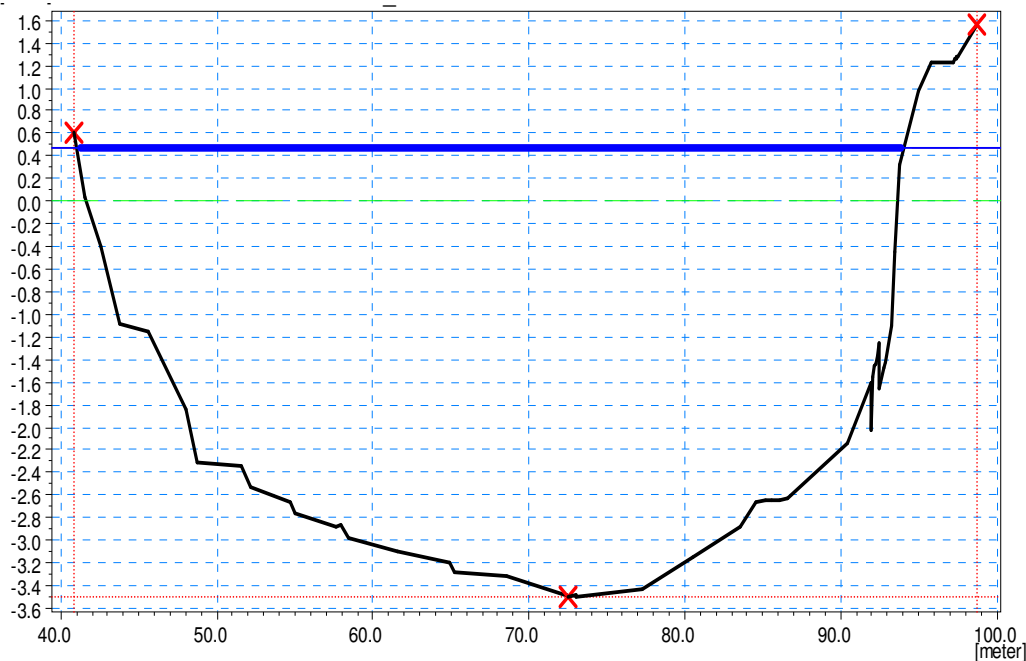


Figure 13 Cross section of the minimum water level (m) at the ski club with fishway

This is considered to be a worse case scenario following a prolonged period of dry weather (as per Table 4 – can drop by 0.4 m).

6.3.2 Hunting

Retention of breakwater crest at 0.85 m AHD

Maintaining the river height at 0.85 m AHD will not have any impact on the hunting activities within the State Game Reserve. Determination of the most appropriate management regime for the hydrology of Reedy Lake and Hospital Swamp requires additional work.

Increasing the breakwater crest height to 1 m AHD

Increasing the breakwater crest height will neither enhance or reduce the values associated with hunting in the State Game Reserve it still enables the active management of the water levels.

Removal of the breakwater

Removal of the breakwater will significantly reduce the opportunities to fill Reedy Lake and maintain a water level that reflects the regime favoured by recreational duck species. Therefore, the option of removing the breakwater will detrimentally impact on the duck hunting opportunities.

6.3.3 Fishing

Retention of breakwater crest at 0.85 m AHD

Whilst the breakwater is in place there is a barrier to the movement of fish reducing the opportunities for recreational fishing. Leaving the breakwater in place will necessitate the installation of a fishway to enable their passage. If the fishway is built, the retention of the breakwater will not negatively impact on recreational fishing.

Increasing the breakwater crest height to 1 m AHD

Increasing the breakwater height increases the cost of any proposed fishway and does not provide any benefits to fish.

Removal of the breakwater

Removal of the breakwater has the greatest benefit to fish populations as it completely removes the barrier to the migration of fish. From a recreational fishery perspective, it will have an impact as the salt intolerant European carp numbers may be reduced as the tidal influence extends up the river.

6.4 Impact of the breakwater operations on agricultural values

6.4.1 Irrigation

Retention of breakwater crest at 0.85 m AHD or 1 m AHD

Whilst the breakwater is in place, salt water is prevented from entering the river channel upstream and therefore irrigation is protected. Maintaining the breakwater therefore does not have an impact on the agricultural values.

Removal of the breakwater

Removal of the breakwater will allow salt water to progress upstream during periods of low flow. The continued use of the river between the two breakwaters for irrigation and other purposes would be in question.

6.4.2 Bank stability

Retention of breakwater crest at 0.85 m AHD or 1 m AHD

This will have little impact on the stability of the river banks as it maintains the status quo.

Removal of the breakwater

The tidal variation and lack of stabilising vegetation, compounded by the dieback of non salt tolerant species, may lead to some collapse of the riverbanks. During the consultation it was noted that this has been observed previously when the river level was reduced rapidly following vandalism of the breakwater gates. This could be mitigated in-time with the prevention of grazing and the establishment of suitable riparian vegetation. However, the wash from ski boats over a greater area of relatively steep bank during the tidal variation increase the likelihood of erosion and slumping.

7. TIDAL BREAKWATER – CONCLUSIONS AND RECOMMENDATIONS

7.1 The breakwater

Whilst the breakwater is a structure that has historically caused adverse ecological consequences, primarily the prevention of migration of fish and reversal of Reedy Lake from brackish marshland with tidal influence to that of a freshwater system, it does now provide a number of benefits to the social, environmental and economic management of the river.

The breakwater is still performing a task in preventing the progression of saline water into areas utilized for irrigation and other purposes. The total extraction is relatively minor and local land use changes may present opportunities to reduce this extraction, therefore prevention of the removal on these grounds is not warranted. However, the removal of the breakwater in its entirety has few

demonstrated benefits for floodplain wetland engagement and may impact on the recreational use of the river. In balance, the removal of the breakwater will cause more challenges for natural resource and recreational management than the benefits associated with fish passage.

Whilst more work is required on the operation of the hydrology and ecological functioning of Reedy Lake, the option of raising of the crest of the breakwater had little demonstrated benefits, similarly, lowering the crest serves only to limit the options available in providing water into Reedy Lake. Therefore, maintaining the existing crest height allows the greatest flexibility and is the recommended option.

7.2 The gates

The modelling undertaken as part of this investigation has demonstrated that the successful operation of the gates has a beneficial impact on reducing the minor localized flooding characteristics of the river immediately upstream of the breakwater. This reduction in inundation frequency and extent provides benefits to the landholder who grazes the property.

The information provided by the stakeholder group, and the landholder, has provided valuable information on the current challenges and future management of the Lake Connewarre complex. The information provided brings into question the long-term requirement for the operation of the flood gates. The observed reduction of flows in the river reducing flood frequency, and the possibility of land-use change adjacent to the barrage, further confirm that the requirement for the gate's operation is questionable.

Based on the review of the hydrology, the proposed non-operation of the Woody Yallock drainage scheme and the likely change in the land use, it is recommended that the gates are decommissioned. This may involve their removal, they may be fixed shut or sheet piling installed downstream, depending on cost. What is important is that the leakage that currently occurs around the gates no longer persists as this will jeopardise the successful operation of a fishway.

7.3 Further investigation

As the primary recommendation is the retention of the breakwater, and thus a barrier to fish passage, there is a requirement for a fishway. This is discussed further in Section 9 below.

A greater understanding of the ecology and hydrology of Reedy Lake and Hospital Swamp is also required to determine the future management regime and risks. This should take account of issues associated with threatened species and internationally-listed migratory species. However, there must also be consideration of the possible effects on the Barwon estuary that may result from any proposed flow regime management for Reedy Lake and Hospital Swamp, that will result in changed flows past the tidal barrage.

Discussion relating to the speculation on extension of the reserve system requires that the inundation of the areas to the west of the river, currently protected by a levee, be examined. Some preliminary information relating to this is explored below in Section 8.

8. ADDITIONAL INVESTIGATION – SPARROWVALE LEVEE

Although not required as part of this study, the effect of the removal of the Sparrowvale Levee was raised in the initial consultation. As this may have a bearing on the flooding regime, the opportunity was taken to assess what flows are required to inundate the area of land protected by the Sparrowvale levee.

To test this, the levee to the south of the Barwon River was removed from the initial topography and the breakwater set to a fixed crest weir at 0.85 m AHD. The upstream boundary condition of inflow rate ranged between 432 ML/day and 25,920 ML/day over a period of six days.

The model simulation demonstrated that inundation onto the floodplain south of the river, which is currently protected by the levee, begins at a flow rate of approximately 1,728 ML/day, as shown in Figure 14 below.

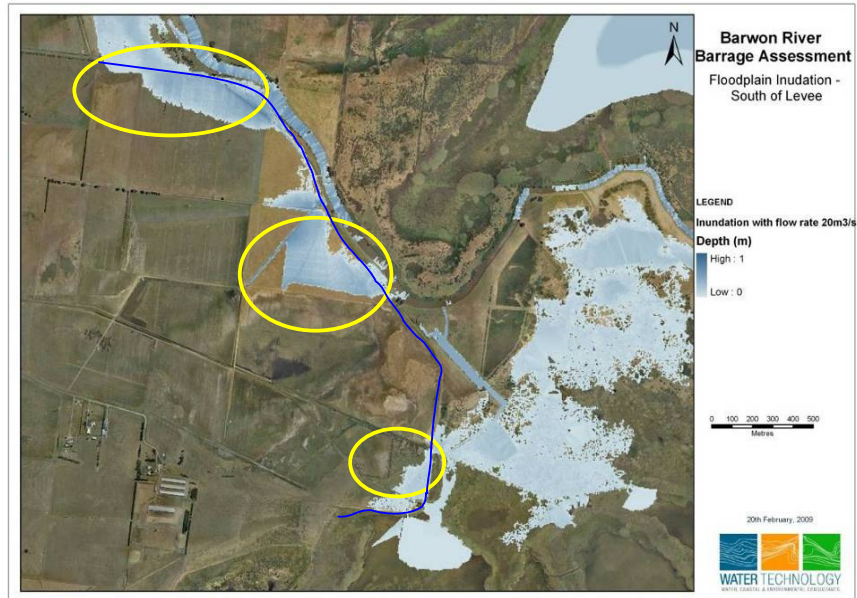


Figure 14 Inundation south of the Levee, flow rate 1,728 ML/day (blue line indicates location of levee)

As the flow rate continues to increase, the land protected by the levee becomes completely inundated when the flow reaches 3,456 ML/day, as shown in Figure 15.

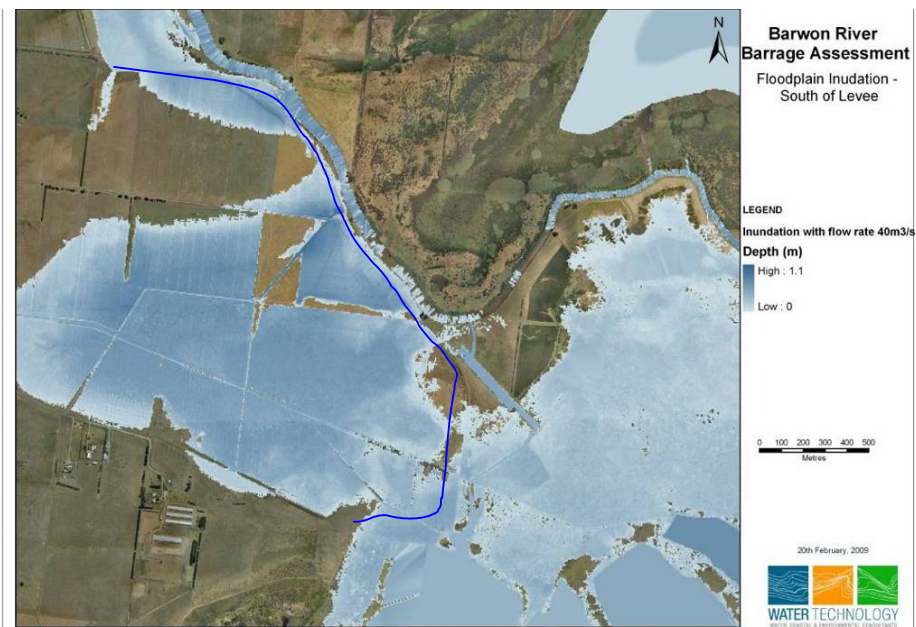


Figure 15 - Inundation south of the Levee, flow rate 3,456 ML/day

From this brief assessment, it can be determined that based on the flow record, this land would become inundated multiple times a year and, based on the topography, maintain a pool of water at a depth of approximately 0.5 m deep across 90 ha of land after every inundation event.

Given this brief assessment, if the levee were to be removed or become ineffective over time, the land would appear to be suitable for the establishment of an ephemeral wetland. Further work would be required to assess this with a degree of certainty to make significant investment decisions.

9. FISH PASSAGE OPTIONS

9.1 Background

Based on the conclusions and recommendations above, the preferred option to enable the ecological operation of Reedy Lake and Hospital Swamp and retain the social values of the river will necessitate the retention of a barrier across the river. Given this, consideration must be given to enabling the passage of fish.

The Barwon River Catchment has a diverse range of fish of both freshwater and estuarine species. Hindell *et al.* (2008) identified the river upstream of the Breakwater as likely being a major spawning and nursery area where fish leave and enter the Barwon River. The ecology of fish in the whole Barwon River catchment is interrupted by the Breakwater as it is a major impediment on the river and estuary's ecosystem function as many of the fish species in the Barwon River catchment must move between freshwater and estuaries to complete their lifecycle. In the current arrangement, it would be anticipated that there is fish passage around the breakwater during high flows when floodwaters cross the floodplain through Hospital Swamp connecting with Lake Connewarre. The focus of the proposed fishway therefore, is to maintain the passage of fish for the medium to low flows.

The benefits of providing fish passage past the Barwon Breakwater for fish is significant in terms of both the aquatic and terrestrial ecosystem and for native fish conservation.

9.2 Fish Movement

It is important to understand what species migrate through the Barwon River at what time of year to ensure that the fishway is designed to accommodate the most suitable flow regime and maximise the suitability of the fishway for key fish species.

The critical migration periods in the lower Barwon River are spring and summer for upstream migration and autumn for downstream migration. Some fish also migrate in winter, for example, Mullet (*Aldrichetta fosteri*). However, this period has sufficient flows and is not as important for the design of the fishway.

9.2.1 Target Species

The target fish size range is 20-400 mm long (Hindell *et al.* 2008). Some larger fish might be present such as Bream (*Acanthopagrus butcheri*), Estuary Perch (*Macquaria colonorum*) and Mulloway (*Agyrosomus japonicus*) and while these are not the main passage targets, design arrangement should cater for their passage at higher flows. It is also recommended that an elver passage be incorporated into the design of a separate fishway to facilitate the movement of elvers through the Barwon River. Elvers/eels are an important commercial fish species in the Barwon estuary and, following discussions with local eel fisherman, there has been identified a decline in the population of eels, potentially due to the breakwater inhibiting migratory movement.

9.3 Fishway location

The Hindell *et al.* report recommended two options for restoring fish passage at the breakwater. These were:

1. Construct a new vertical-slot fishway on the left bank of the weir near the floating gates, where most fish appear to accumulate; and

2. Re-construct the existing rock-chute fishway on the right bank using current best-practice fishway design.

With either of these options, the entrance of the fishway is best situated as close to the breakwater as possible which defines the physical limit of upstream migration. At this location, there will also be the audible attraction of the weir overflow. A small V-notch should be cut into the upgraded breakwater/weir in order to concentrate the flows through this point and increase the attraction to the entrance of the proposed fishway.

Although the fishway can conceivably be built on either the northern or southern side of the breakwater the preference is for the northern side due to:

- fish accumulation in the pool at the north;
- distance from passers-by, thus reducing potential interference; and
- topography lends itself to a fishway operational at a greater range of flows.

There is some concern that the existing outlet from Reedy Lake downstream of the breakwater directly into Lake Connewarre may be a distraction for some fish when flow is present. This outlet should be designed so that it does not distract the fish away from the proposed fishway at the breakwater unless it is also to be fitted with a fishway.

9.4 Design Criteria

9.4.1 Operating range

The fishway needs to be designed to cater for the widest range of headwater and tailwater conditions possible. It is proposed that the fishway cater for the full tidal range thereby enabling the movement of fish at all times that there is sufficient flow in the river. It is anticipated that at higher tides, the fishway will be partially drowned out. However, this will not have a detrimental effect on the operation of the fishway. Attraction water will continue from the weir notch. During king tides there is a likelihood that there will be a flow reversal in the fishway that will push water into the river from the estuary.

9.4.2 Critical levels and drop through the fishway

As detailed previously, the weir pool is currently maintained upstream of the breakwater at a minimum level of 0.85 m AHD, the crest height of the breakwater. In the last couple of years this has been subject to some variation due to the low flows and the leakage through the gates.

The tidal range below the breakwater is from 0 to 0.5 m AHD. Therefore, the maximum head differential that the fishway must cater for is 0.85 m.

To achieve the critical design velocities the fishway will require a minimum grade of 1v:30h. Whether this is vertical slot or rock ramp this equates to a fishway of at least 25.5 m in length with 14 control pools.

The potential for fish passage at tidal barriers occurs over a wide range of seasons and flows and therefore the design will be required to be flexible enough to operate in flows of less than 5 ML/day through to 9.6 ML/day through the fishway which equates to a combined 2,200 ML/day over the weir. At this flow, the water is 0.5 m deep over the breakwater and it would be expected that the breakwater is drowned out.

9.5 Options assessment

9.5.1 Rock chute

A rock chute fishway similar to the existing one is advantageous in terms of cost for construction and the natural look of the structure. Whilst these are proven to function satisfactorily in the passage of fish the experience with the existing structure, including the invasion of *Phragmites australis* and *Typha spp* and the movement of rock in high flows, demonstrate that there is a high likelihood that it will be difficult to maintain.

A further complication is the requirement for a reasonable flow to allow the structure to function effectively and the lack of control of the hydraulic performance.

Under moderate flows, a rock chute fishway will accommodate the smaller species but will require significantly higher flows to enable the passage of larger fish. A benefit of this style of fishway is that it could pass more flow and larger fish, with a better attraction than a vertical slot fishway when the weir is spilling.

9.5.2 Vertical slot

A vertical slot fishway made from concrete enables the greater control of flows, velocities and internal hydraulics within the fishway therefore allowing greater certainty that the design criteria will be met over the greatest range of flows. The disadvantage is that the costs associated with construction, especially de-watering and formwork, are considerably higher than for a rock fishway. Two options present themselves for a vertical slot fishway in this location.

- In-stream

An in-stream fishway would fit within the existing footprint of the flood gates and not inhibit access to the river. Whilst this is a neat arrangement it will require the de-watering of the construction area which would necessitate the construction of sheet pile bunds and forming a concrete base on a potentially unstable substrate. Whilst feasible this is will be prohibitively expensive.

- Off stream

An off-stream fishway is constructed around the barrier within the northern bank of the river. This method is not suitable in locations where there is a high likelihood of interference from many passers-by but does allow the construction in a dry worksite thus minimising the requirements for dewatering and makes maintenance safer.

This option is the preferred option as it limits the cost of the structure whilst also providing the greatest certainty that the hydraulic conditions will be met over the widest range of flows in the river and tidal cycle.

10. FISHWAY DESIGN

The major assumption (based on past and recent flow records) for the fishway design is that flow available for fishway operation will be 4-6 ML/day during spring, summer and autumn. Therefore, the fishway will be required to operate with highly efficient water use. This restriction has a number of implications for the fishway design and these are outlined below.

The fishway will require flexibility in its design to allow for future management changes for the Barwon River and the Reedy Lake/ Lake Connearre system, primarily associated with the flow regime in the river.

The optimal configuration for the fishway is to have a vertical slot that is 150 mm wide and greater than 600 mm deep. This allows large bodied fish to traverse the fishway. If the fishway had been designed 5-10 years ago when the base flow in the river was consistently higher this would have been the preferred arrangement. Recent flow records, however, have identified that the flow in the river has reduced and therefore the fishway design must take into account the lower base flow to avoid detrimentally impacting upon the recreational users.

The larger the cross sectional area of the fishway vertical-slot the more water that will pass through it and the greater the fishway discharge. If this amount exceeds the inflow to the river then the weir pool will slowly draw down until an equilibrium is met between the inflow and the discharge cross section. This will result in the weir pool being lower if inflows are significantly reduced.

It is proposed to set the absolute limit of this headwater drawdown at 0.45 m AHD, that is, 400 mm below the current crest of the breakwater. This means that if there is no flow in the river for an extended period of time the furthest the river will draw down is 400 mm. It also means that the depth of the fishway will be limited to 400 mm during typical base flows although this will increase to up to 900 mm deep during higher flows when the water is 500 mm over the weir.

There is an opportunity to further reduce the discharge through the fishway by narrowing the slot at the base. This will further restrict the passage of large fish during extreme low flows but will allow the smaller fish to move over a greater period during summer and autumn.

It should be noted that based on recent years' flow records there is sufficient flow to enable the operation of the fishway for up to 400 mm deep during the primary migration period of spring and early summer.

10.1 Hydrology for fishway

The flow record for the lower Barwon River is incomplete but does give an indication of the historic and current flows in the river. In the period of 1978 to 1985 the median flow in the Barwon River in Geelong was 125 ML/d. Between 2006 and 2008 the median flow was 14 ML/d. In the 18 months to June 2009 the median flow in the Barwon was only 0.015 ML/d, as a result of a significant period of low rainfall.

In the last case this would result in the fishway would be operational for only 170 days of the 460 day flow record. Whilst this particular year would be considered exceptional in regard to rainfall and runoff, the trend is towards a river with less flow and therefore the fishway design must seek to minimise the discharge and not impact on the other uses of the river.

11. FISHWAY – CONCLUSIONS AND RECOMMENDATIONS

As detailed above, the recommended style of fishway for this location is a vertical slot arrangement. This fishway will enable the passage of the largest range of fish species over the greatest range of flows and tidal range. Therefore the recommendations are:

- Prepare designs for a vertical slot fishway and eel pass for the northern side of the breakwater.
- Prepare a monitoring plan for the commissioning and implementation of the fishway and eel pass

A more detailed analysis of a proposed fishway arrangement is attached in Appendix B.

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APPENDIX A SITE INSPECTION NOTES

A site assessment was undertaken on the 6th July 2009. The objective of this meeting was to discuss the opportunities and constraints on the site and review the potential concepts with the key stakeholders. The following is a record of comments made and information received through the site inspection.

Attendees

- James Rennie Water Technology
- Annabel Sandery Water Technology
- Jacob White Water Technology
- Adam Rasmussen Water Technology
- Ivor Stewart Kingfisher Consulting
- Steve Harfield CCMA
- Mark Schirmer CCMA
- Tony Jones CCMA
- Des Peters Parks Victoria
- Andrew McKinnon Parks Victoria
- David Crook Arthur Rylah Institute (ARI)
- Rob Anderson Geelong City Council
- Angus Ramsey Southern Rural Water
- Peter Lawson DPI Fisheries

Apologies

- John Hotchin VR Fish
- Ian McLachlan Field and Game

The following are some of the notes taken and questions raised on the day:

Site Constraints

- Cease to flow is becoming more regular, therefore fishway will have no flow for some time of the year. Understood to be only be few days at a time.
- Management of Reedy Lake is yet to be resolved to meet the needs of both Field and Game and Parks Victoria. There is a process in place to initiate the development of a management plan that encompasses the regional lake Connewarre Wetland system.
- Reedy Lake is full of Typha and Phragmites. Concerns were raised that this impedes the LIDAR data accuracy.

- Typha and Phragmites will need to be managed and controlled to ensure it doesn't encroach upon the proposed fishway works. The management of water in Reedy lake should also be considered as a management tool to control reeds.
- Who is going to maintain the weir/fishway?
- What is the quality of the stored sediment behind the weir? If the weir is removed will this affect Lake Corangamite?
- There are upstream levee banks on the Southern side of the river that protect land from frequent inundation. It was mentioned that a long term outlook may see these removed and the lake Connewarre complex extended. This is currently a matter for Council and Parks Victoria planning.

Breakwater

- The automatic operation of the gates is currently compromised and has been for some time
- Graham Perkins (land holder south of the river) until recently, has operated the flood gates (now done by Barwon Water as contractors to CCMA). Gates are chained up during low flows and released during high flows.
- It is anticipated that the CCMA will take ownership of the Breakwater once it has been upgraded although maintenance arrangements are still to be established
- Weir pool water Level at the Breakwater, currently 0.85 m
- During the higher flows in the river the water backs up and inundates the private land. The size of the flow will be tested in the Hydraulic model.

Fishway

- Original Fishway was designed and constructed by ARI under the State Fishway Program in 1996. The fishway was monitored and probably functioning correctly for about 6 months, however it is no longer in a satisfactory condition and is most likely ineffective due to disturbance by cattle, high flows and typha
- It is understood that Barwon Water had a detailed vertical slot design for a fishway but due to funding constraints the rock chute design was used
- It is believed that the existing fishway is often used a canoe ramp when flows are high enough
- Northern side provides a good location for a new fishway as there is already a large scour pool on this side of the river downstream of the existing weir gates. There is also an audible signal coming from the flows running through the side of the weir.
- Any new fishway will need to be maintained so that the Phragmites does not take grow through the structure and block the fishway and/or compromise its structural integrity.
- Will the fishway be fixed, manually operated or automatic? This will impact on the cost, staffing and access requirements.
- Is there enough habitat and habitat complexity upstream to support an increase in fish numbers?

- Does the fishway need to operate for the full tidal range? Maybe the fishway could be automated with level sensors to work on the mid to high tides if the amount of water in the river is insufficient to operate it all the time?
- It was noted that there is an informal elver fishway/ramp at the Reedy Lake outlet

Fish Movement

- Victorian Recreational Fisheries wants to see larger fish travel through the upgraded fishway. For example Estuary Perch in the order of 400mm in length. The design must consider this requirement
- Bill Allan, a local commercial eel fisherman wants to see eel/elver access through the breakwater either by the fishway or some other structure. Eels require a rough surface, as they climb rather than swim.
- Need to allow passage for fish moving both upstream and downstream.
- Winter – Gaxlaxids moving downstream
- Spring Summer – Fish moving upstream

Irrigation Licences

- Graham Perkins, the local landholder, has an annual water licence for irrigation from the Barwon River.
- 2 other winter fill licences upstream of the breakwater – small scale
- 6 industrial licences within Geelong
- 1 licence between Geelong and Buckley Falls
- Overall, there are no major users of water from the river downstream of Buckley falls

Flows

- Last year had cease to flow on several occasions, a few months earlier this year there were months of cease to flow.
- Cease to flow has been increasing over the years
- When the flow reaches 4-5 ML/day SRW stop any extractions from the River
- Tidal range is thought to be 100 mm at the breakwater although the tidal range can be as much as 700 mm during king tides
- Storm surge has the potentially increase backflow from the Bass Strait; this will be looked at in the future by the CCMA.
- Leigh River always flows, average 4-5 ML/day.

Reedy Lake

- Reedy lake is occasionally drawn down and dry over summer. This helps control Phragmites and Carp within the Lake, and promotes macrophyte growth.
- Reedy does not dry out every year, *ad hoc* approach.
- Can Reedy Lake be manually drained for management purposes without the weir in place?
- Bill Allen (Eel fisherman) wants to see a more natural cycle for Reedy Lake as this would suit Eels better

- Reedy Lake begins to fill at a weir height of 0.7 m
- Water level in Reedy Lake may be dropping due to leakage but is more likely due to evaporation

Ski Club

- How much water does the Ski Club need in the Barwon? Although the river dropped to 0.4 m AHD at the breakwater they were still able to ski.
- The ski club should not come within approximately 2 km upstream from the breakwater

Other projects/Information

- Parks Victoria are to prepare a Reedy Lake/Lake Connewarre Masterplan
Currently the area is managed by Parks Victoria, Field and Game and private landholders.

APPENDIX B FISHWAY CONCEPTUAL DESIGN

VERTICAL SLOT DESIGN

For a vertical slot fishway to function to allow the passage of small fish certain hydraulic design criteria must be met, these are 18 W/m³ turbulence, 1.17 m/s maximum water velocity (assume $c_d=0.7$). To meet these the suggested parameters for the fishway are;

- 150 mm wide slots;
- 70 mm head drops between slots;
- Pools 2.2m square;
- Slope of at least 1v:29h;
- Depth 0.6m.

Hence the fishway might have 16 pools and be 35 m long. In this arrangement the hydraulics would result in a discharge of approximately 5.5 ML/d. However, as discussed above, the required flow of 5.5ML/d to operate the fishway may not be achievable. Therefore a revised arrangement of 400mm depth, 140 mm wide slots and 2.2 m long by 2 m wide m pools is to be adopted that will reduce the discharge to 4.1ML/d.

- 140 mm wide slots
- 70 mm head drops between slots
- Pools 2.2 m long by 2 m wide
- Turbulence 18 W/m³
- Maximum velocity 1.17 m/s
- Slope of 1v:31h

If it is determined that this discharge (4.1ML/d) is still too high this can be further reduced by altering the slot design to be narrower at the top or base. This reduces the cross sectional area of the slot and therefore discharge. It is uncertain how this will modify the hydraulics, especially turbulence during higher flows and this needs to be resolved. In this case the vertical slots can be either notched or stepped to have differing widths throughout their height. The differing widths would allow the channel to maintain a base flow level through a wider range of flows, in particular low flows. The proposed slot widths for the concept stage are 100mm or 150mm. In general 100mm slot widths can allow passage for fish up to 300mm in length, and slots of 150mm width can allow passage of fish up to 500mm in length. Figure 16 below identifies two slot arrangements for minimising the discharge through the fishway. The slot on the left would be the best arrangement for larger fish whilst the one on the right would best cater for the very low flows and small fish.

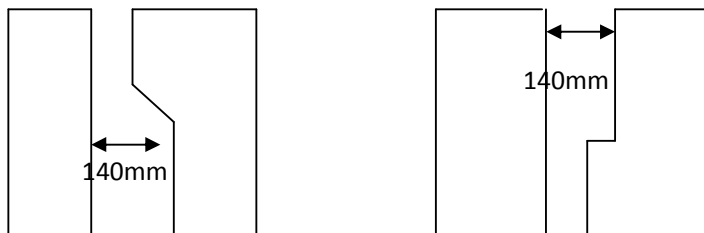


Figure 16 Potential modification to slot to reduce discharge

It is proposed that the fishway design will be a combination of a concrete channel with vertical slots and rock bed. The vertical slot component of the fishway will extend from the base of the channel up to 900mm in depth. It is also proposed that the vertical slots will be built into a precast concrete open culvert with a height of 900mm and a width of m. Having a precast unit will significantly reduce the cost of construction and installation.

Pool Design

It is proposed that the pools between each vertical slot will be 2.2m wide and 2m in length. The drop in height between each pool will be approximately 0.07m which will make the fishway a very low energy system suitable for small and large fish throughout the majority of flows. The pool size is of a standard size for tidal barriers and designed to keep the turbulence down in order to create a low energy environment so that the fish can rest between their ascent of each vertical slot. Corner pools are larger still and provide resting areas.

The turbulence within each pool with a water depth of 400mm has been kept below 17 Watts and the maximum velocity through the slots is to be below 1m/s.

To test the hydraulics of the fishway a detailed two dimensional hydraulic model has been constructed.

HYDRAULICS OVERVIEW

In order to obtain reliable estimates of discharge and flow velocities down the fishway, a two dimensional (2D) steady state hydraulic model was developed for the reach area. The 2D hydraulic model was developed using DHI Software's MIKE 21 fully two-dimensional flow modelling package. MIKE 21 is a state of the art modelling tool for simulating the details of flows in complex river and floodplain systems.

Following consultation with ARI and Kingfisher Research, a preliminary conceptual design has been agreed upon. This design is essentially a modified vertical slot fishway incorporated into traditional box culvert sections with a rock base allowing for minimum construction cost and complexity and hydraulic suitability. The final design modelled in MIKE 21 is a squared section box culvert vertical slot ramp fishway on the northern side of the Lower Barwon Breakwater.

Hydraulic model construction

Current passage conditions

A key input into the hydraulic analysis, is the study area's topography/terrain. The hydraulic model topography has been derived from detailed survey of the site. Survey data has been converted into the form of a TIN (Triangular Irregular Network). The TIN creates triangles between survey points which represent the ground surface in a 3D format. This TIN was created in the terrain modelling package 12D.

The TIN in 12D is then exported as a DEM (Digital Elevation Map) and is converted into a grid format which is read into the modelling software MIKE 21. A 0.2 m cell size was employed in the hydraulic modelling. The 0.2m cell grid is a limitation of the model and therefore slightly over estimates the velocities and flow discharges.

Figure 17 shows a contour map of the existing ground surface which has been used in the hydraulic model. The minor contours represent changes in the ground surface by 0.25 m.

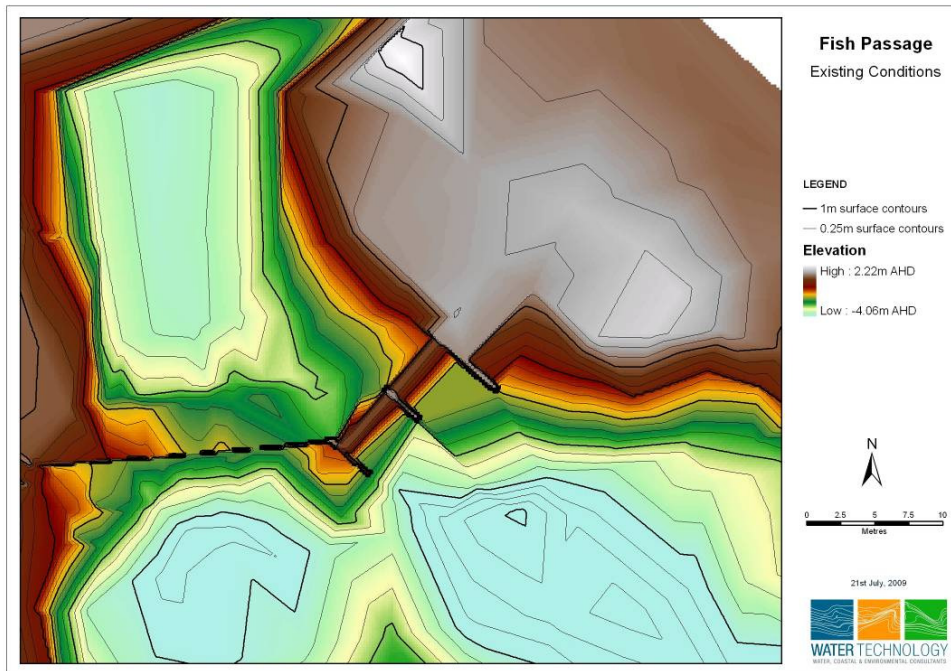


Figure 17: Existing surface contour map

Re-developed passage conditions

The developed model topography has also been created using a TIN from 12D. The existing conditions have been used as a base with a further TIN used to bring in the proposed redeveloped bed surface for the box culvert baffles.

As part of the preliminary design, a series of box culverts have been converted to vertical slot sections using CAD and placed into the existing terrain in order to obtain appropriate grades along the passage and head drops between slots as recommended by Kingfisher Research and ARI. Each vertical slot section consists of a traditional box culvert that has been modified to contain a pre-fabricated vertical slot section (see Figure 18) with a uniform slot width of 200mm and slot height of approximately 800mm. The 200mm slot width has been used instead of 140mm as this is a constraint of the model that utilises a 200mm grid size. These dimensions have been chosen for the purpose of preliminary investigation as they provide optimal hydraulic gradient control and accommodate the target fish size range (20-400 mm long). It is anticipated that the slot width for a final design will be reduced to 140mm to deduce the discharge volume accounting for the lack of flows in the river.

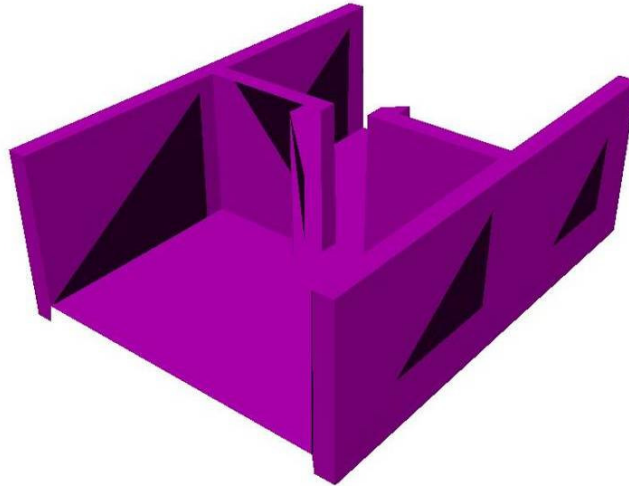


Figure 18 Single vertical slot box culvert

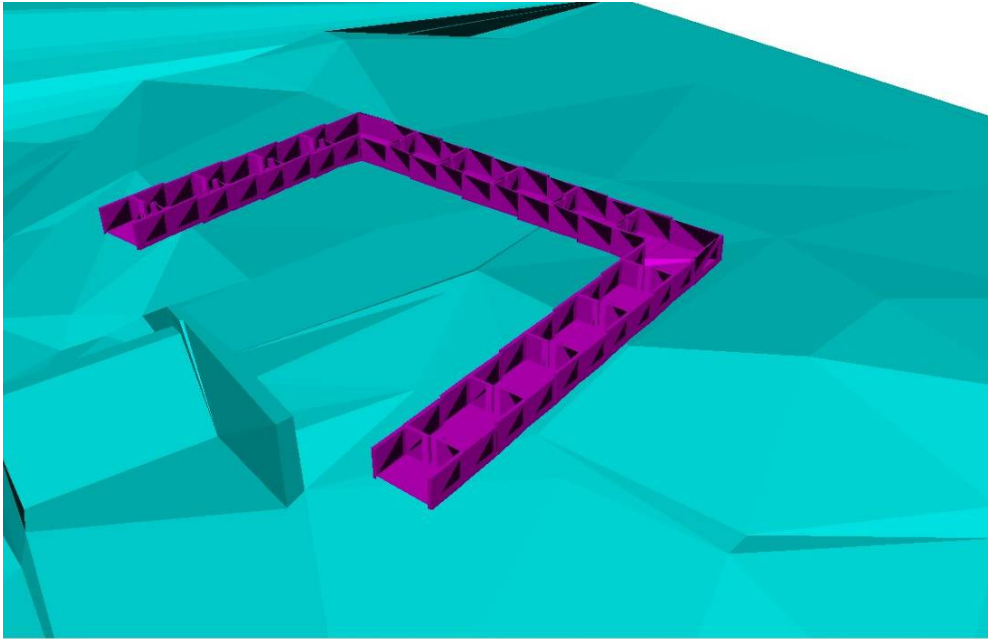


Figure 19 Complete culvert fishway (perspective)

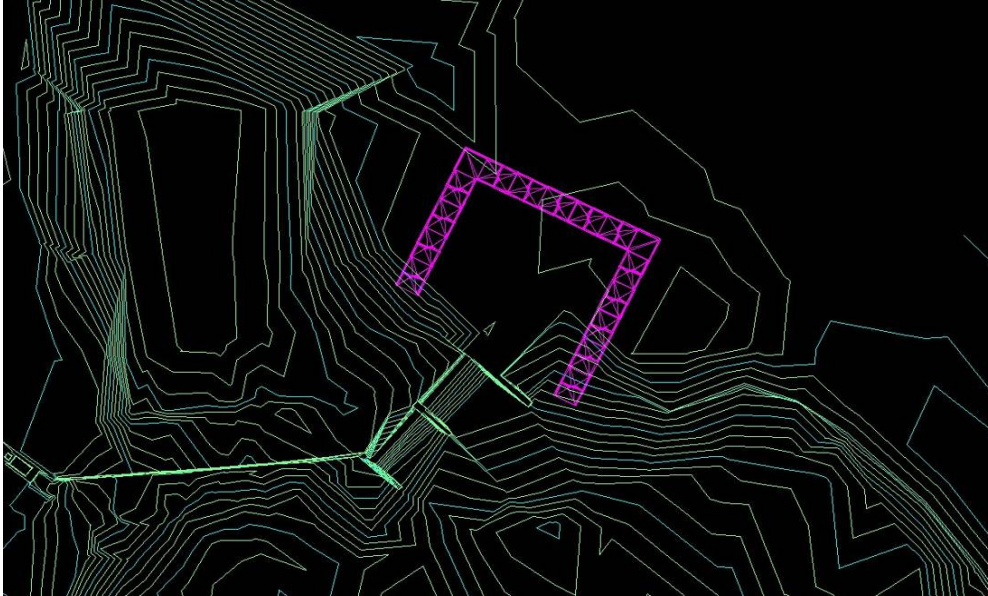


Figure 20 Complete culvert fishway (plan view)

Vertical slot sections have been placed in the current configuration (see Figure 20) to conform to the head loss and fishway grade requirements as determined by ARI and Kingfisher Research. The first section has been placed at a base level of 0.45m AHD and will act as the first hydraulic control for the fishway which will begin to operate in river level heights greater than 0.5m. Each subsequent section has been placed 0.07m below the previous with 16 sections dropping down to a final height of -0.55m AHD to ensure maximum head drops of less than 0.1 m. It is important to note that in periods of high tide a number of bottom pools will “drown out”, this is a significant design consideration as it will ensure maximum tidal operation range for the fishway while reducing the total fish migratory path length in high tide.

The following table presents a brief outline of frame elevations used in this TIN.

Table 8 Critical surface elevation for baffle frames

Culvert Section	Height (m AHD)
Section 1 (fishway exit)	0.45
Section 2	0.38
Section 3	0.31
Section 4	0.24
Section 5 (corner section)	0.17
Section 6	0.10
Section 7	0.03
Section 8	-0.04
Section 9	-0.11

Section 10	-0.18
Section 11 (corner section)	-0.25
Section 12	-0.32
Section 13	-0.39
Section 14	-0.46

Note: This design is flexible and can be varied to cater to various grade and head drop requirements. The preliminary design has been tailored to meet a 1:36 grade with the corner sections functioning as resting pools rather than hydraulic controls hence no vertical slots placed on them. Culvert numbers can be reduced while adhering to grade and head loss needs within this current design.

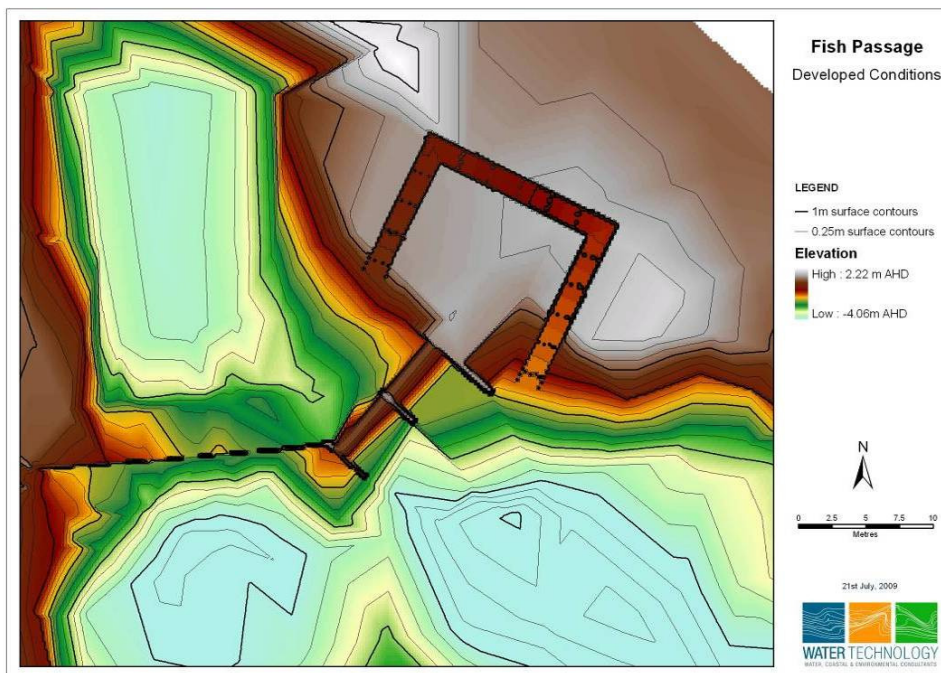


Figure 21: Developed surface contour map

This TIN was layered over the existing surface TIN and exported as a 0.2m grid for the hydraulic modelling.

Figure 21 shows a contour map of the developed ground surface which has been used in the hydraulic model. The minor contours represent changes in the ground surface by 0.25 m and the major contours changes by 1m.

Roughness, model inflows and downstream water levels

A uniform Manning’s ‘m’ (hydraulic roughness) of 20 was adopted (Mannings ‘n’ 0.05). This roughness value has been derived using Chow’s table in the development of uniform flow and its formulas and is considered to reflect a normal range of values for a natural stream bottom of cobbles with large boulders which are proposed for the base of the fishway.

The hydraulic model has been run using a fixed inflow of 8 ML/day. This flow has been selected based on flow data provided to Water Technology by the Corangamite CMA and representative of reduced flows along the Barwon River in recent years. At the bottom boundary, a constant water level has been set at 0.4 m representing an average tidal height below the breakwater.

Initial conditions are also important considerations in order to maintain model stability and as such have been set at a height of 0.45 AHD for the headwater and 0.4 m AHD for the tailwater. These values are simply initial input values to ensure maximum numerical stability and will be subject to change during the simulation.

Model application

This section discusses the model application to the existing terrain conditions at Site 1.

Re-developed passage conditions

This section discusses the hydrodynamic model application to developed terrain conditions.

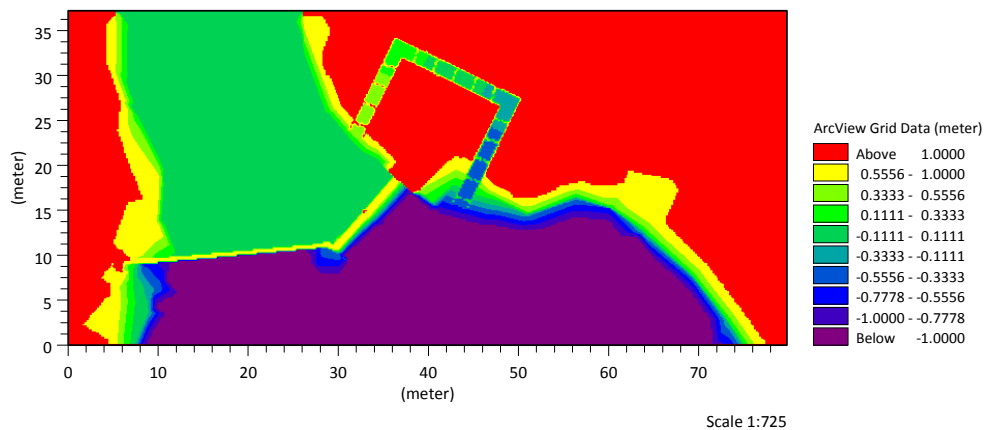


Figure 22 Developed bathymetry used in MIKE21

Developed topography as used in the 2D simulation is demonstrated in Figure 22. It is important to note that the terrain has been altered at both the upstream and downstream boundaries. This has been done for two reasons:

Land Values – For simulation purposes it is important to set a designated land value for all cells that will not be “wet” during the simulation period. By doing this we can stipulate which areas of the bathymetry will be involved in the simulation and thereby channel flow accordingly. By assigning land values to all cells not vital to the simulation we can reduce complexity and time of simulation. The maximum height of the culvert fishway is 1.3m AHD and is the highest necessary point on the terrain, therefore all values greater than 1.3m are land values.

Smoothing required for simulation – Survey data imported into 12D had to be converted to a grid format to be used in MIKE21, this meant that survey round off at the upstream boundary gave topographic values that were not real. In order to resolve this issue, all headwater topographic values below 0m AHD were assigned the height of 0m AHD and all tailwater values less than -1m AHD were assigned to -1m AHD. This ensures a downstream flow of water through the simulation whilst decreasing the complexity and instability associated with modelling large depths over a small grid size. This makes no change to the accuracy of the model.

As we can see from the developed topography significant alterations have been made to the northern side of the river, most notably:

- Removal of automatic gates and extension of 0.85m AHD weir crest
- Culvert flow path excavated on the northern bank

Topography within this channel has been modified in accordance with preliminary design specifications:

- Vertical slot control pools 2.2m in length and 2m in width with a vertical head drop of no greater than 0.07m between pools
- Vertical slots have been modelled in this simulation and are located in the middle of each culvert section
- Corner pools have not been fitted with vertical slot sections and serve as resting pools of reduced turbulence to aid fish migration

Outcome of 8 ML/d Flow

The developed topography was subjected to a constant 8 ML/day flow for a simulation period of two hours. Steady state conditions were achieved during the latter half of the simulation period, the following results have been obtained at the final timestep after steady state has been achieved.

Figure 23 demonstrates the predicted water depth over the terrain at peak flow. Looking at this figure we can see that the weir has been overtopped by the 8 ML/day flow at both the filled in breakwater and the existing sheet pile wall. This is to be expected given the water depth at this point is 0.88m 3mm higher than the breakwater wall. There is also a minimum water depth of 0.3 m along the entire length of the fishway.

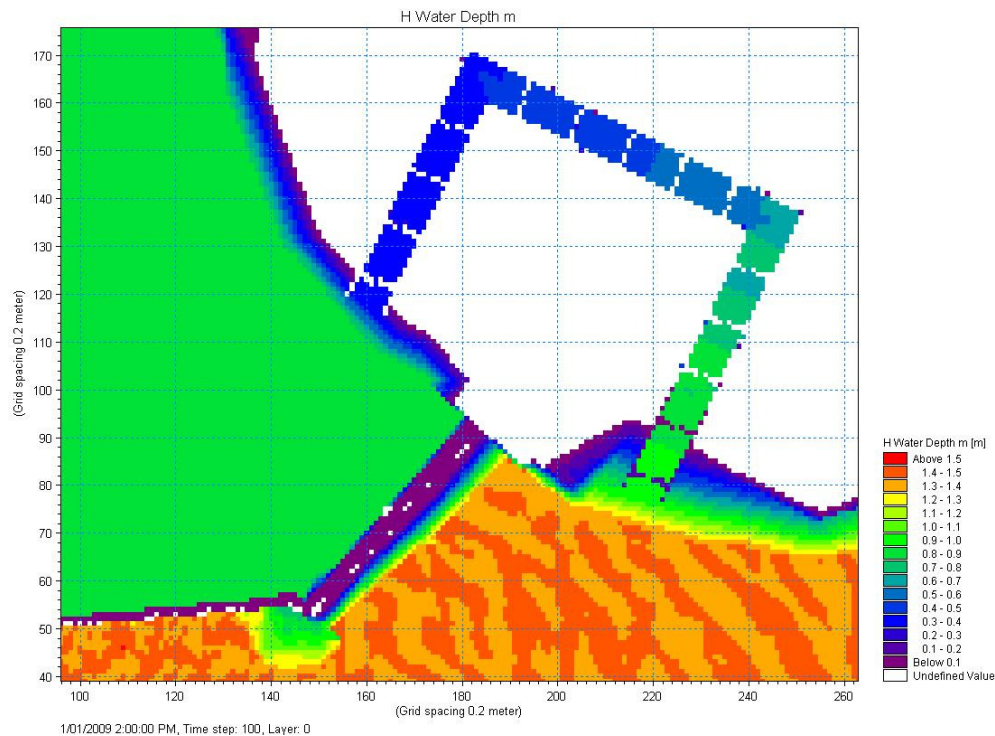


Figure 23 Predicted water depth from MIKE 21

Figure 24 shows the inundation of the filled in weir as well as the bottom section of the culvert fishway. The downstream boundary has been kept constant at 0.4 m AHD with the flow through the passage flooding out the lower reaches of the passage. In reality this will be a beneficial outcome as

the total length of fish passage will be reduced for migratory fish as the rising tide will essentially push the fish past the first sections of the passage.

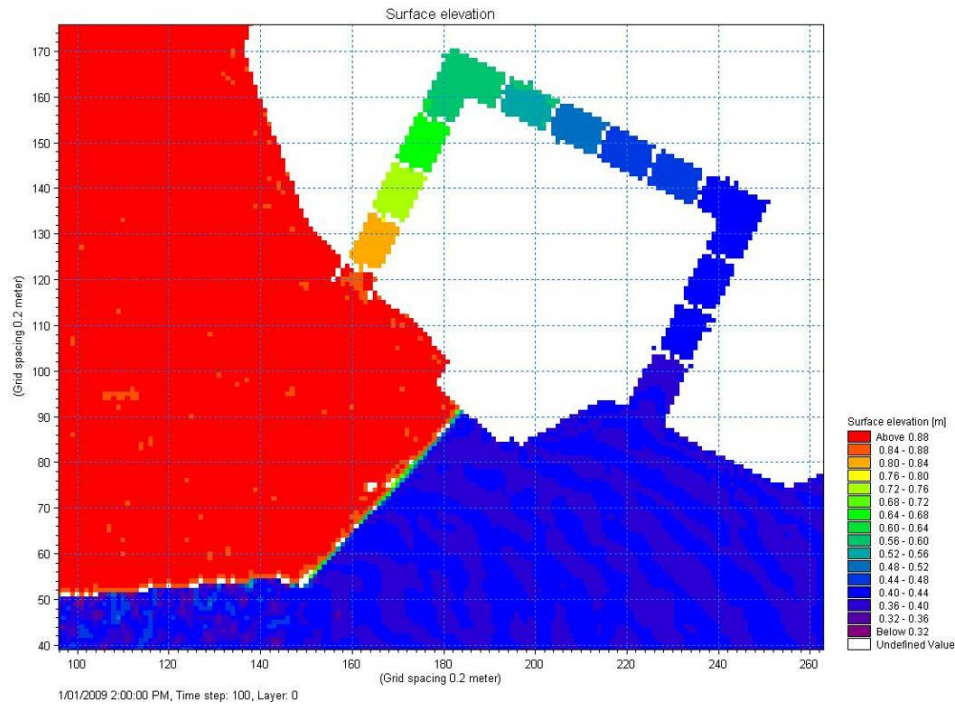


Figure 24 Predicted surface elevation from MIKE 21

Figure 25 highlight the maximum horizontal velocities predicted within the fishway for an 8 ML/day flow. Maximum horizontal velocities determined within the passage are in the middle section of the passage and peak at approximately 0.67 m/s in the east direction (defined as positive).

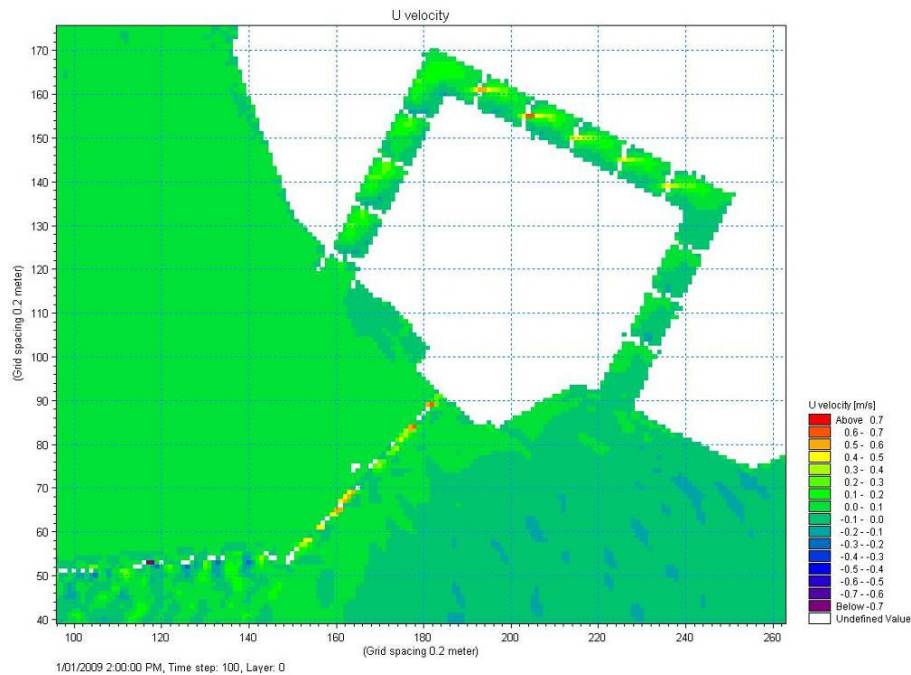


Figure 25 Predicted U velocity (horizontal) from MIKE 21

Figure 26 identifies the maximum vertical velocities predicted within the fishway for an 8 ML/day flow.

Maximum vertical velocities are most notably at the entrance of the fish passage in the north direction (positive) and at the exit of the fish passage heading south (negative). Velocities peak at the entrance to the fishway at approximately 0.77 m/s and are significantly lower at the exit of the fishway at approximately 0.35 m/s due to the significant degree of inundation due to tidal influence.

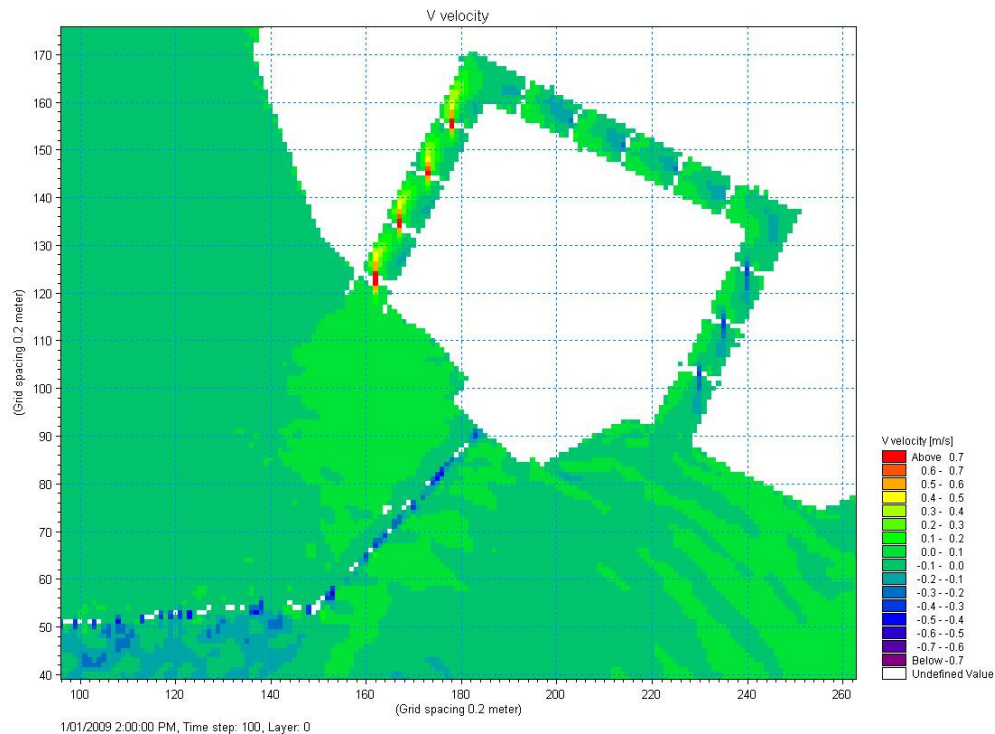


Figure 26 Predicted V velocity (vertical) from MIKE 21

Eel passage

Eels within the Barwon River are both ecologically and economically important. Whilst there is evidence that there is passage of eels through the existing fishway there is an opportunity to enhance the passage of the juvenile glass eels. Glass eels are not known to traverse vertical slot fishways particularly well but they are able to climb structures when the surface is rough enough and wet.

One option successfully used over seas is to provide a ramp with an expanded UV stabilized plastic mesh. The ramp will need to be in a location where the freshwater gradient attracts the eels and water running over the ramp enables them to remain moist (Figure 27).

There are not too many examples of eel passes in Victoria and this design arrangement would enable the testing of the efficiency of the structure.

Costs associated with the construction of such a device would be less than \$2,000.

It is recommended to make the structure very sound as there would be a very strong likelihood that kayakers would try to utilize it as a downstream passage.

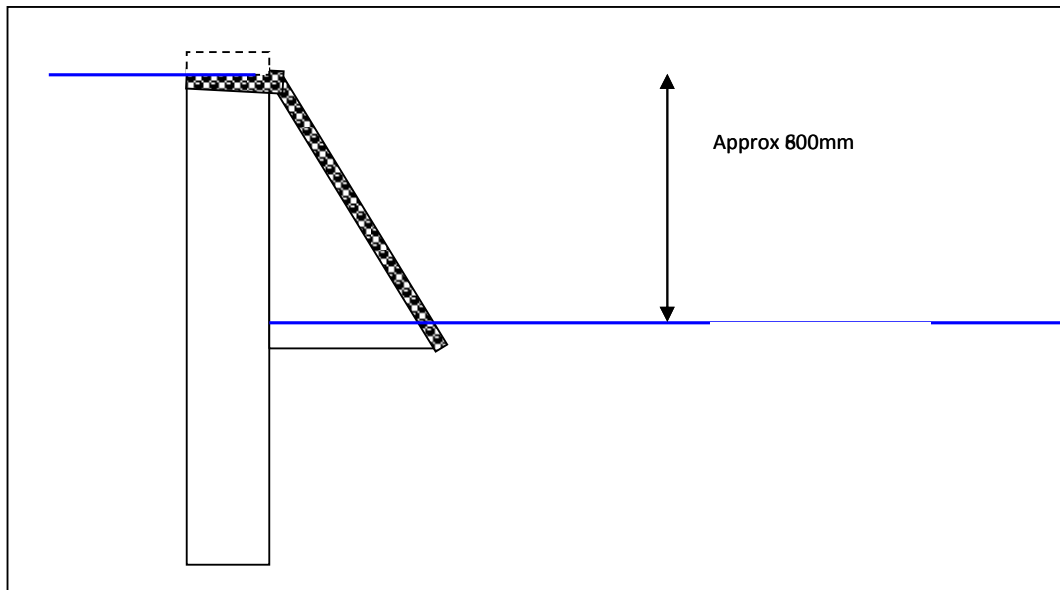


Figure 27 Conceptual design of eel pass

Conclusions

Whilst there is some question regarding the hydrology of the river, and the periods of cease to flow duration, the proposed design will function throughout the majority of the migration season. Minor modifications to the width at the base of the slots will, if deemed necessary, reduce the discharge and prolong the period of time that small fish are able to pass the breakwater.

Whilst the level in the river may drop during extended periods of no flow in the river, this will be limited to a level that will not detrimentally impact upon the recreational users of the river.

The modelling has demonstrated that the turbulence and velocity parameters are met, even with the 200 mm wide slots and there is a limited risk that the fishway will not function as proposed.

Utilising a construction method that minimizes the construction time on site with the use of precast units will significantly reduce the costs associated with the implementation and reduce construction risk.