Reducing the Impact of Weirs on Aquatic Habitat - New South Wales Detailed Weir Review – Murrumbidgee Region

Part of the Aquatic Biota Enhancement Project (BG16_04)

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NSW DEPARTMENT OF PRIMARY INDUSTRIES

Murrumbidgee CATCHMENT MANAGEMENT AUTHORITY

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Cover photo: Maude Weir on the mainstem Murrumbidgee River.

EXECUTIVE SUMMARY

This report forms part of the Murrumbidgee Catchment Management Authority Aquatic Biota Enhancement Project, funded under the Natural Heritage Trust 2 (NHT2). A priority weir report was to be completed based on the findings of detailed weir reviews carried out in the Murrumbidgee catchment through the NSW Environmental Trust project, "Reducing the Impact of Weirs on Aquatic Habitat". This report is to provide guidance for investment in the modification of weirs for improved native fish management.

The highly modified nature of catchments in the Murrumbidgee region presents many challenges in the way we protect the environment and manage its natural resources. In particular, setting goals and targets for aquatic habitat conservation in the region requires clear understanding of the extent of aquatic habitat degradation and where the best outcomes can be achieved. Within lotic systems, native Australian fish have evolved to be reliant on a variety of habitat types to complete their life cycle, thus requiring free movement within rivers and streams or between estuarine and freshwater environments. Unfortunately, riverine connectivity has been severely disrupted within Australia through the installation of numerous in stream structures that impede the natural flow regime and act as physical, hydrological, and behavioural barriers to fish movement. In NSW alone, there exists several thousand weirs and dams on rivers and streams, with the majority of these structures impeding fish passage and impacting on aquatic health.

In 1999, NSW Fisheries and the Department of Land and Water Conservation undertook the NSW Initial Weir Review (2002). The Initial Weir Review (2002) was commissioned by the State Weir Review Committee to provide a preliminary overview of the impact of weirs across the State. Due to the sheer number of weirs and dams in NSW, detailed assessments of each structure were not feasible. Therefore, the Initial Weir Review (2002) incorporated a rapid assessment of weirs in the State for the purpose of providing a 'snap shot' view of environmental considerations at each site, as well as to identify and shortlist priority structures that warranted further attention. It is under this premise that the Detailed Weir Review was conducted throughout NSW to provide a comprehensive assessment of the impacts and remediation options available for improving fish passage and waterway health at priority structures highlighted in the Initial Weir Review (2002).

A total of 30 structures in the Murrumbidgee CMA region were considered for inclusion in this project. Of these, 7 were selected for Detailed Weir Reviews, all of which were State Water owned. The individual review reports presented in this project provide a comprehensive overview of the structures' operational details, system hydrology, ecological considerations, and the preferred remediation option of NSW DPI for improving fish passage at the weir.

The Detailed Weir Review Project highlighted that the majority of weirs in the Murrumbidgee are large structures, with the majority being used primarily for re-regulation of flows for irrigational purposes. Stock, domestic, and urban uses were also commonly reported for structures assessed. Moreover, two of the weirs investigated have dual purposes; a diversionary and a re-regulatory role. As a result of the weirs still being required and their importance to the economy of the surrounding areas, removal was not a viable option. As such, the primary recommendation is the construction of a fishways at all seven of the weirs assessed. At four of the weirs, a Deedler Fishlock was the preferred option. A Deelder Fishlock is a low level lock fishway that operates in a similar manner to a boat lock and

consists of two chambers divided by an internal weir. At the remaining three, vertical slot fishways were recommended. Vertical slot fishways are considered one of the most effective fishway designs due to their ability to operate at sites with varying headloss, and is the preferred option where threatened species are present, as is the case at all seven weir locations. All recommendations within this review are consistent with the NSW *State Weirs Policy*. The results from this investigation, including management recommendations and estimated costs, are discussed herein.

ACKNOWLEDGEMENTS

This project was funded through contributions from the NSW Environmental Trust and the Murrumbidgee Catchment Management Authority (as part of the Natural Heritage Trust 2) and managed by the NSW Department of Primary Industries.

The NSW DPI Aquatic Habitat Rehabilitation Program Team managed the project including research, fieldwork and report preparation. Personnel involved in data collection and report collation were: Milly Hobson, Charlotte Grove, Scott Nichols, Sharon Molloy and Cameron Lay. DPI regional staff also involved included Ben Maddox and Anthony Townsend.

The Murrumbidgee Catchment Management Authority (MCMA), Department of Natural Resources (DNR), State Water, and local government councils provided extensive advice and assessment toward the project for which we are grateful.

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1. INTRODUCTION

The following report outlines the results of the "*Impact of Weirs on Environmental Flows, Water Quality and Fish Passage*" (herein the "NSW Detailed Weir Review Project") for the Murrumbidgee region of NSW. The collection of data and assessment of individual structures was funded in November 2003 through the NSW Environmental Trust and was managed by the NSW Department of Primary Industries (now incorporating NSW Fisheries). The development of this report detailing the findings within the Murrumbidgee catchment has been funded by the Murrumbidgee Catchment Management Authority through the Natural Heritage Trust.

1.1 Project scope and setting

In 1999, NSW Fisheries[1] and the Department of Land and Water Conservation[2] undertook the NSW Initial Weir Review. The process aimed to make a provisional assessment of all licensed dams and weirs within NSW regarding their impact on fish passage for the purpose of identifying priority sites for remediation. Catchment-based summary reports were prepared (in accordance with the former Catchment Management Board boundaries) recommending remediation options for priority sites. Following the production of the initial weir reviews, the State Weir Review Committee acknowledged that more comprehensive weir reviews were required to assess additional social, cultural, ecological, and logistical issues pertaining to highlighted priority sites prior to the implementation of on-ground works. NSW DPI therefore initiated the NSW Detailed Weir Review Project through funding provided by the NSW Environmental Trust that aimed to conduct thorough investigations into 80 high priority structures across NSW to better determine appropriate remediation actions.

1.2 Study aims and objectives

The detailed assessment of priority structures and subsequent development of a priority listing for the Murrumbidgee Catchment builds on the outcomes of the NSW Initial Weir Review (NSW, Fisheries, 2002) by undertaking detailed reviews for 7 high-priority structures within the Murrumbidgee CMA region. The reviews aim to facilitate future on-ground works by addressing the social, ecological, cultural and logistical issues that surround the modification of existing barriers, thereby providing a clear process towards mitigating the structure's environmental impact once funding is secured. Moreover, the Detailed Weir Review Project – Murrumbidgee will also serve to identify those structures where remedial works can achieve the greatest ecological benefit. As a result, these reviews will allow external-funding bodies to have greater confidence in proposed works given that a comprehensive assessment and consultation process has already been undertaken.

1 Now NSW Department of Primary Industries

2 Now NSW Department of Natural Resources

2. BACKGROUND

2.1 Fish passage in NSW

Stream connectivity and habitat diversity are critical components of healthy rivers. Within these systems, native fish have evolved to be reliant on a variety of habitat types to complete their life cycle, thus requiring free movement within rivers and streams and between estuarine and freshwater environments. In south-eastern Australia, approximately half of all freshwater fish species migrate as part of their life cycle (Fairfull and Witheridge 2003) including key species such as Murray cod, golden perch, silver perch, Australian bass, sea mullet, short finned and long-finned eels, freshwater mullet and freshwater herring. Migration distances can vary from a few metres during a fish's lifespan, to over a 1000 km on an annual scale for species such as the iconic Murray cod and golden perch.

Impeding fish passage through the construction of dams, weirs, floodgates and waterway crossings can negatively impact native fish by:

- interrupting spawning or seasonal migrations;
- restricting access to preferred habitat, available food resources and breeding partners;
- reducing genetic flow between populations;
- increasing susceptibility to predation and disease through aggregation below barriers;
- fragmenting previously continuous communities; and
- disrupting downstream movement of adults and impeding larval drift through the creation of still water (lentic) environments.

Natural flow regimes are essential in maintaining connectivity between upstream and downstream reaches (longitudinal connectivity) and adjacent riparian and floodplain habitats (lateral connectivity). In-stream structures that span the whole channel (e.g. weirs and causeways) can impede natural flows and act as physical and hydrological barriers to fish movement, thus isolating upstream and downstream habitats (Williams *et al.* 1996; Pethebridge *et al.* 1998; Thorncraft and Harris 2000; and Fairfull and Witheridge 2003). Additionally, levees, floodgates and other off-stream structures (e.g. sediment basins and gross pollutant traps) can disrupt lateral connectivity by isolating seasonal or ephemeral habitats on floodplains and wetlands. For fish that have large-scale migrations in their life cycles, particularly anadromous (marine-to-freshwater) and catadromous (freshwater-to-marine) species, preventing fish passage can cause local extinctions above barriers and reduce population numbers downstream (Thorncraft and Harris 2000).

The installation and operation of in-stream structures and other mechanisms that alter natural flow regimes of rivers and streams has been listed as a *Key Threatening Process* under the *Fisheries Management Act 1994* and the *Threatened Species Conservation Act 1995*. Recommendations put forward by the Acts specifically note the impact of in-stream structures on the life histories of threatened freshwater fish species including silver perch (*Bidyanus bidyanus)*, Macquarie perch (*Macquaria australasica*), purple spotted gudgeon (*Mogurnda adspersa*), olive perchlet (*Ambassis agassizii)*, Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), Murray cod (*Maccullochella peelii peelii)*, and trout cod (*Maccullochella macquariensis*).

2.2 Barriers to fish passage

All native fish need to move between habitat areas at some stage in their life cycle to spawn, seek food, or find shelter; and for many species migrations over long extended distances are required to complete their life cycle (Thorncraft and Harris 1996; Smith and Pollard 1998). Man-made structures that span the width of the waterway can act as barriers to fish passage by creating a physical blockage, a hydrological barrier, or by forming artificial conditions that act as behavioural barriers to fish. The impact of such barriers on fish passage will vary depending on the design of the structure; the nature of flow, debris and sediment movement in the waterway; and the swimming capabilities of resident fish.

In NSW alone, there exist over 4,000 **weirs** and **dams** on rivers and streams (NSW Weir Inventory database; Fig. 2.1). Water impoundment structures are classified as being either fixed crest or adjustable release in design. Fixed crest weirs (also known as run-of-the river weirs) have a set height that water is impounded at, with water generally cascading over the crest of the weir at a natural flow rate barring extensive water extraction from the weir pool. As a result, fixed crest structures generally have only a minor impact on a the hydrological flow patterns of a waterway, with the main impact of such structures being the creation of a physical barrier to fish passage and the loss of upstream lotic habitat. Alternatively, adjustable release

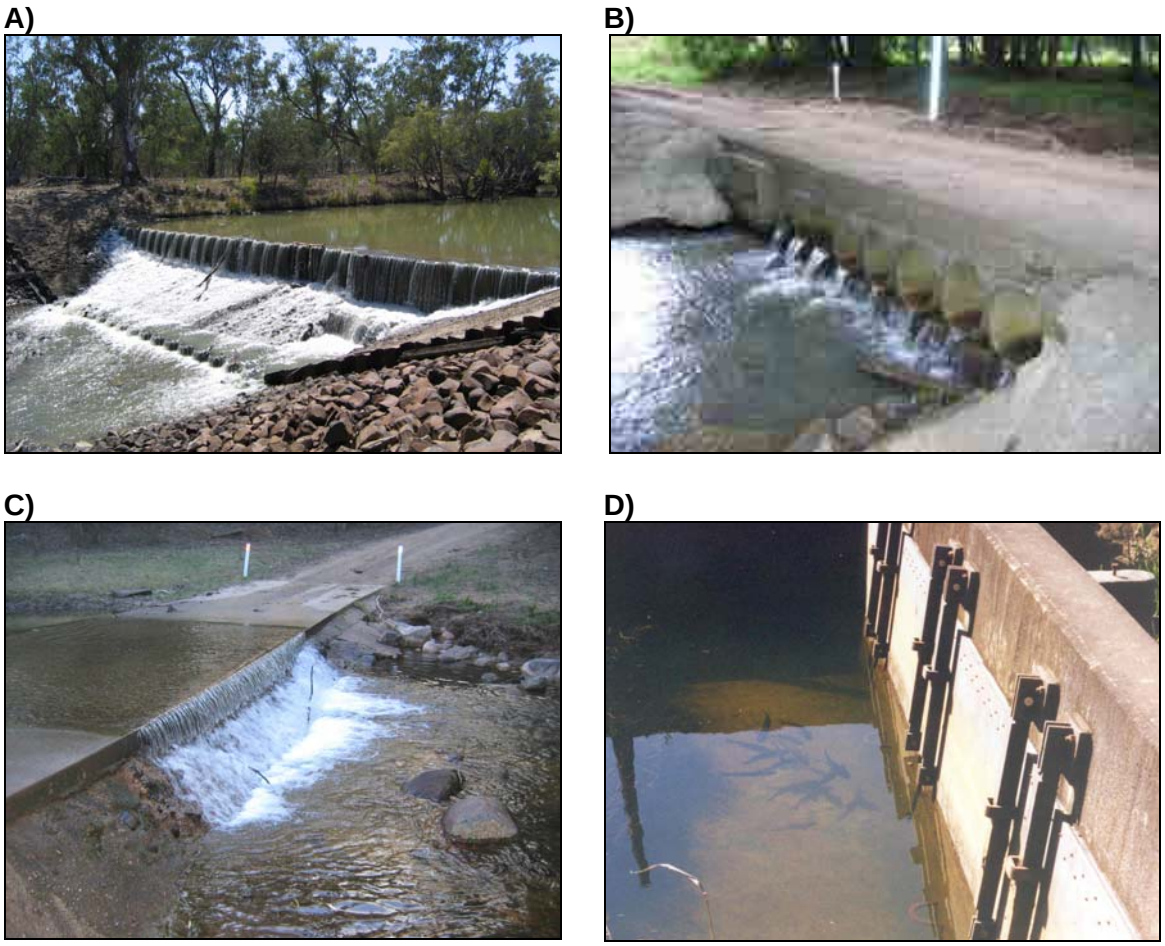

FIGURE 2.1: Waterway crossing barriers to migrating fish include A) weirs, B) culverts, C) causeways and D) Floodgates. Barrier types demonstrated in the photos include excessive headloss (A - C), shallow flow depths (B, C), excessive water velocities (B – following minor river rises), and complete blockage (D).

weirs and dams incorporate gates, valves, removable drop boards, and spillways that allow the flow of water in the system to be regulated to match stakeholder demands. Unlike fixed crest structures, adjustable release weirs can have much more far ranging effects on the ecology of a waterway including altered hydrological flow patterns and reduced water quality parameters (e.g. water temperature and dissolved oxygen). As with fixed crest weirs; however, adjustable release structures also impinge upon fish migration either as physical (excessive headloss) or hydrological barriers (high flow velocity).

Until recently, management of fish passage barriers has centred on the effects of weirs and dams while little attention has been given to the extent of the impact of poorly designed road crossings. Similar to weirs; **bridges**, **arch structures**, **culverts**, **causeways**, and **fords** can impinge upon fish migration patterns by acting as physical, hydrological, and behavioural barriers (see Fig. 2.1). NSW DPI recently completed a detailed audit of road crossings in coastal catchments (NSW DPI 2006), which highlighted in excess of 500 barriers to migrating fish in the Northern Rivers CMA region and 161 barriers requiring remediation in the Sydney Metropolitan region (NSW DPI, 2005).

The vertical walls of dams, weirs, causeways, and floodgates are the most commonly perceived barriers to migrating fish. However, hydrological barriers including excessive water velocity and turbulence that result from poorly designed fishways and culvert structures can further impede fish passage (Mallen-Cooper 1994). The degree to which a structure acts as a hydrological barrier will also be dependent upon the distance over which fish have to swim to negotiate the structure (Videler and Wardle 1991). Fish generally use two different swimming modes: fast burst swimming for covering short distance and a cruising speed for longer journeys. Depending upon the design of the crossing, fish may be able to ascend part way up barriers or poorly designed fishways, only to be washed back downstream after their energy has been expended (subsequently predisposing them to predation or disease through fatigue).

Changes in habitat features associated with in-stream structures may also present behavioural barriers to migrating fish. Species that are able to pass into weir reservoirs may find the pooled lentic (still water) system unsuitable due to the loss of critical lotic (riverine) habitat features such as riparian vegetation cover, aquatic macrophytes, and large woody debris. Similarly, altered water temperature and aquatic dissolved oxygen regimes within and below weirs, in addition to lowered pH levels behind floodgates can also deter migrating fish (Gehrke *et al.* 2001).

The location of waterway crossings within the catchment is another factor determining the impact of barriers on fish. Obstructions located lower in the catchment often drown out several times a year when rising water levels overcome headloss barriers (the difference in water level across the structure), thereby enabling fish to periodically pass (Harris *et al.* 1992). Alternatively, barriers located higher up the catchment generally drown out less frequently due to the steeper topography and comparatively smaller drainage areas present behind the structure.

2.3 Ecological impacts of weirs

The environmental impact of dams and weirs is widely recognised as one of the key contributors to riverine degradation. The impact from alterations to natural hydrology, changes to stream geomorphology, disruption of localised erosion and sedimentation processes, evaporative water loss, creation of still water environments, impediment of larval drift and extractive water use have had a severe negative impact on the

abundance and diversity of native fish populations and the quality of aquatic habitats throughout the world. They affect fish in a variety of ways, including; disrupting life-cycles, reducing gene pools and creating conditions where fish become more susceptible to disease and predation. Moreover, exotic species such as carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), gambusia (*Gambusia holbrooki*) and redfin perch (*Perca fluviatilis*) that are considered habitat generalists thrive in disturbed habitats compared to native fish which are habitat specialists. As a consequence, in flow-modified waterways native fish fauna diversity, abundance, breeding success and ratio to introduced species is reduced compared to unregulated streams (Gehrke and Harris 2001).

Water quality in reservoirs poses many problems not only for the supply of water to humans, but also to the survival of native flora and fauna within and along the watercourse. Larger weirs (> 10 metres) can alter temperature regimes within their impoundments through stratification where a warm surface layer forms over a colder, denser layer near the bottom of the reservoir. Given that most regulated weirs and dams release stored water from the bottom of the structure, cold water pollution results which can impact upon waterways kilometres downstream. Cold water pollution significantly decreases an animal's growth rate while also delaying seasonal spawning runs of fish by depressing temperature sensitive metabolic rates. Thermal stratification in reservoirs also impacts upon aquatic oxygen levels by producing an anoxic bottom layer that forms when organic material settles on the bed and is broken down by oxygen-depleting bacteria. Diffusion of oxygen into these bottom layers is prevented by the existing thermal stratification, resulting in the release of hypoxic water below the weir that can affect the distribution of oxygen-sensitive macroinvertebrates and fish species.

The construction of weirs and dams also results in the inundation of stream-side habitat with ponded water. The drown-out of adjacent riparian zones detrimentally effects the survival of bank-side vegetation communities resulting in the mortality of riparian flora. Deleterious impacts associated with vegetation dieback along reservoir banks include increased erosion and sedimentation along with associated water quality reduction, proliferation of weed species, reduced macrophyte growth especially within the littoral zone, and loss of vegetative shade cover. Additionally, the reestablishment of riparian communities at regulated reservoirs is problematic due to widely fluctuating water levels.

Weirs can also alter the way a river channel interacts with its neighbouring floodplain. The design of such structures generally entails flood containment which can isolate floodplains and wetlands while simultaneously reducing the carbon input entering from lowland rivers (and vice versa). Additionally, access to floodplains are essential to the reproduction of numerous species including silver perch (*Bidyanus bidyanus*) and golden perch (*Macquaria ambigua*) that spawn in such habitats when food resources are abundant. Effective management of floodplain barriers is required to ensure that ecological functioning is maintained.

Weirs and dams also impact on channel geomorphology by trapping sediments from upstream and inadvertently storing them in the reservoir. Without a supply of sediment to replenish areas that have been eroded downstream by increased flow velocities and turbulence below the structure (otherwise known as Clearwater erosion), the natural sediment balance is disrupted. Additionally, the manipulation of flows and the associated increased flow velocities below a weir or dam can result in the alteration of natural stream morphology by increasing erosion rates which can result in the deepening and widening of rivers.

The sedimentation that occurs within weir pools further affects organisms within the stream by filling in fish habitat holes, smothering benthic organisms, and in some cases affecting fish respiration. The reduction in stream depth allows a greater surface area of the waterway to be subjected to sunlight penetration and evaporation, increasing water temperature particularly during the summer months. Turbid conditions resulting from sediments in the weir pool or increased erosion downstream can decrease light penetration into the water column and limit photosynthesis, thereby reducing the overall productivity of the system.

The significance of addressing the environmental impact of dams and weirs is reflected in the attention received across all levels of government and within Natural Resource Management forums. Within the Murray Darling Basin Commission's Native Fish Management Strategy, over half of the objectives are directly related to mitigating the impact of weirs on fish habitat through structural modification or improved storage management. The Murray Darling Basin Commission is implementing the strategy by committing funds to improving fish passage along the length of the Murray River as part of the Living Murray Initiative. Additionally, the Commission is seeking ways to improve the management of available resources and maximise the delivery of water to the environment to restore critical variability in the flow regime for major inland rivers.

2.4 Policies and Legislation

The NSW Government recognises the significant impact that barriers present to aquatic biota within estuarine and riverine ecosystems. As part of this approach, the Government released the *State Weirs Policy* in 1997 which aims to mitigate or prevent the environmental impacts of weirs, road crossings, and floodgates in NSW. This goal is supported by the adoption of the following management principles:

1. *The construction of new weirs, or enlargement of existing weirs, shall be discouraged;*
2. *Weirs that are no longer providing significant benefits to the owner or user shall be removed, taking into consideration the environmental impact of removal;*
3. *Where retained, owners shall be encouraged to undertake structural changes to reduce their impact on the environment (e.g. installation of fishway);*
4. *Where retained, owners of weirs with regulatory works shall prepare and adhere to operational plans to reduce the environmental impact of weirs;*
5. *Where retained, gated off-take structures and fishways on all weirs shall be maintained in good working order;*
6. *Wetlands and riparian vegetation adjacent to weirs should be protected from permanent inundation;*
7. *Areas of environmental degradation caused by the impacts of weirs upstream and downstream of the weir pools, should where possible be rehabilitated; and*
8. *A respect for the environmental impact of weirs should be encouraged in all agencies and individuals that own, manage, or derive benefits from weirs.*

The *State Weirs Policy* is a component of the NSW water reforms initiated by the NSW Government in 1995. Implementation of the *State Weirs Policy* is a whole-of-government responsibility with the Department of Natural Resources (DNR) as the lead agency. DNR licences weirs under the Water Management Act 2000 and Water Management Amendment Bill 2005. The Act aims to provide a mechanism for protecting and restoring water sources and their ecosystems, giving priority to environmental water, whilst still allowing improved access rights to watercourses and

aiding in the arrangement of water management partnerships between local communities and the government. NSW DPI plays a significant role in the administration of the policy by protecting the interests and aquatic biodiversity of native fish.

In 1994, the *Fisheries Management Act* came into effect and specifically addressed the issue of fish passage. Under sections 218-220 of the Act (1994), NSW DPI has the responsibility to ensure that the construction of any new weir or the modification of an existing structure does not deleteriously impact upon resident fish populations. Fairfull and Witheridge (2003) and NSW Fisheries (2003) provide a comprehensive overview of the legislative and policy requirements that must be observed during the planning, design, and construction of waterway crossings in NSW.

Together these legislative tools, and associated NSW Government policies on fish passage, act to regulate the construction of structures that can impede fish passage. In addition, reinstating connectivity between upstream and downstream habitats and adjacent riparian and floodplain areas through the remediation of fish passage barriers has become an essential part of aquatic habitat management and rehabilitation programs in NSW.

2.5 Regional Setting and Landuse

The Murrumbidgee CMA (MCMA) region covers an area of approximately 84000 km^2 and is dominated by the Murrumbidgee River. A major tributary of the Murray-Darling River system, the Murrumbidgee originates in the Fiery Range of the Snowy Mountains and flows for over 1,600 km. Other major waterways in the region include the Tumut River, which is the Murrumbidgee's largest tributary (4000 k m^2), and the Yass River. With 14 major water storages located in the catchment, a large percentage of the waterways in the region are regulated for irrigation and environmental flows. Burrinjuck Dam near Yass and Blowering Dam near Tumut regulate the majority of the downstream flow into over 10,000 km of irrigation channels.

The Murrumbidgee catchment is characterised by a diverse range of climates and vegetation, varying from the cooler, alpine districts of the Snowy Mountains and the Monaro Plains, through to the rich belts of the South West Slopes and plains used primarily for grain crops and grazing, and the hotter, drier shrub and grass plains of the semi-arid western Riverina. Within the whole Murrumbidgee valley rain falls predominantly during the winter/spring season, and apart from a small area located in the upper catchment, average precipitation is exceeded by evaporation.

The Murrumbidgee catchment is home to over half a million people. This overall population increases by nearly 2% per year with most additions being to the urban populations of NSW's largest inland city, Wagga Wagga (currently 57,000 people) and Australia's capital city, Canberra (currently 314,000 people). As a consequence, natural resources in the region are under mounting strain as managers struggle to maintain sustainable practices in an environment of low rainfall, economic and population growth.

The MCMA region is highlighted as a major provider of food in NSW, with agricultural production injecting over $1.9 billion annually into the Australian economy. The Riverina area supports an irrigation industry for over 3,500 land holdings which collectively use 1.2 million megalitres of water per year, providing 25% of NSW's fruit and vegetable production, 42% of the States grape and half of Australia's rice production. Other land use in the region includes beef production, dryland

agriculture, sheep and wool, cropping and softwood plantations. Additionally, tourism is a fast emerging industry in the area, creating in excess of $500 million per year, and a significant boost to the regions economy.

2.6 Aquatic Biodiversity in the Murrumbidgee Region

The aquatic habitat in the MCMA area comprises fast-flowing freshwater montane streams, intermittent and semi-permanent billabongs, lowland main drainage channels, and floodplain wetlands. The extensive range of aquatic habitats provide niche environments such as deep pools and shallow riffles, gravel beds, boulders, snags (large woody debris), aquatic and riparian vegetation, and riparian overhangs and bank undercuts. This multiplicity in habitat supports a diverse assemblage of fish species including 23 species of native fish and over 400 native invertebrate species. Native fish species observed in the region include: freshwater catfish (*Tandanus tandanus*); Australian smelt (*Retropinna semoni*); bony herring (*Nematalosa erebi)*; mountain galaxias (*Galaxias olidus*); the endangered western population of olive perchlet (*Ambassis agassizii)*; the endangered western population of purple spotted gudgeon (*Mogurnda adspersa*); the endangered trout cod (*Maccullochella macquariensis)*; and Murray hardyhead (*Craterocephalus fluviatilis)* and the vulnerable silver perch (*Bidyanus bidyanus*), southern pygmy perch (*Nannoperca australis*) and Macquarie perch (*Macquaria australasica*). Introduced species including goldfish (*Carassius auratus*), common carp (*Cyprinus carpio*) and gambusia (*Gambusia holbrooki*) are also found in the region.

The MCMA region also supports an extensive range of terrestrial and non-piscine aquatic species, including 132 species, 3 populations and 3 ecological communities which are listed as endangered or vulnerable, for example: the endangered river snail (*Notopala sublineata*), the endangered malee worm-lizard (*Aprasis inaurita*) and the endangered Southern bell frog (*Litoria raniformis*).

Of particular note in the MCMA region is the aquatic ecological community in the natural drainage system of the lower Murray River Catchment. This region and its associated communities are identified as having a threatened conservation status. The area includes the regulated portions of the Murray River below Hume Dam, Murrumbidgee River below Burrinjuck Dam, as well as the waterways of the Tumut River below Blowering Dam, in addition to their tributaries and branches

All aquatic species found within the MCMA area are dependent on a diverse array of habitats. As a result of extensive modification to waterways during the past two centuries, the ever-increasing pressures from land-use in the region and the impact of introduced faunal and floral species, healthy freshwater habitats in the Murrumbidgee region are essential for conserving aquatic biodiversity. Of the 63 subcatchments identified in the Murrumbidgee Catchment (NSW DLWC, 1999), 25 of which were assessed, 12 were defined as high priority subcatchments including the Houlaghans and upper Yass subcatchments. 17 subcatchments in the MCMA region were additionally recognised by NSW Fisheries and NPWS as having specific conservation values. Moreover, the Goodradigbee, Numeralla (east), and Queanbeyan subcatchments were highlighted as having high conservation value (HCV) for the purpose of protecting the regions biodiversity. In addition, the Goodradigbee River is the only upper catchment river classified as “wild and scenic” for the majority of its length due to the natural land use in that subcatchment area.

Wetlands provide specialised habitat for fish and aquatic invertebrates, in addition to other fauna such as waterbirds, frogs and reptiles. Within the MCMA region there are a number of wetland areas which are recognised internationally for their

ecological significance. These include the RAMSAR listed Fivebough and Tuckerbil Swamps, which are both renowned for the diversity and abundance of waterbirds which inhabit them, and cover an area of 400 hectares and 289 hectares respectively, and the Lowbidgee Wetlands. The Lowbidgee wetlands located on the floodplain of the Murrumbidgee River between Maude and Balranald, covers an area of over 200,000 ha. Identified as the state's largest lignum wetland, the Lowbidgee wetlands are an essential, highly productive ecosystem, and are the most important breeding site in eastern Australia for the Straw-necked Ibis (*Threskiornis spinicollis*

Aquatic habitat rehabilitation, in particular reinstating stream connectivity, is essential for maintaining aquatic biodiversity and protecting the integrity of rivers, lakes and wetlands in NSW. This particular project was designed to identify weirs where the greatest environmental gains could be made when undertaking remediation works.

3. PROJECT METHODOLOGY

3.1 Initial Weir Review

The Initial NSW Weir Review (2002) was commissioned by the State Weir Review Committee to provide a preliminary overview of the impact of weirs across the State, as well as to identify and shortlist priority structures that warranted further attention. The review consisted of a desktop database assessment followed by a subsequent field investigation of all identified weirs. The desktop assessment initially involved accessing the Licensing Administration Database System (LAS) created by the Department of Land and Water Conservation to identify the location and contact details for licensed weirs on named waterways. Adjacent landholders and structural owners were subsequently contacted and informed of the Weir Review Program, upon which permission was gained to inspect the structures. Where possible, meetings were arranged on-site with the relevant stakeholders to discuss the social, ecological and hydrological issues associated with the weir / dam.

Following desktop and field data collection, weirs were prioritised and ranked on a catchment scale using criteria developed by Pethebridge *et al.* (1998) that included such factors as: river size, location in catchment, presence of threatened species, available upstream habitat, number of downstream obstructions, presence of a fishway, and whether anthropogenic impacts such as thermal pollution were recorded. It should be noted that the initial ranking of barriers was based on fish passage considerations only for the purpose of highlighting high priority weirs that have a significant, deleterious impact upon NSW's native fish species. Although not included in the initial prioritisation process, socio-economic issues were investigated and reported upon in the initial weir review to provide guidance in future assessments. The outcomes of the prioritisation process were subsequently presented, reviewed, and accepted with comment by the relevant River Management Committees.

3.2 Selection of weirs for detailed review

Due to the sheer number of weirs and dams in NSW, detailed assessments of every structure were not feasible. As a result, the Initial Weir Review incorporated a rapid assessment of weirs in the State for the purpose of providing a 'snap shot' view of environmental considerations at each site relative to fish passage. The application of a rapid assessment technique was a simple and effective way of highlighting the extent of the problem and determining broad regional priorities to aid in informing future planning directives. However, numerous environmental, social, cultural, and economic considerations need to be considered by natural resource managers when reviewing the operational status of water impoundment structures. It is under this premise that the Detailed Weir Review was conducted to provide a comprehensive assessment of the impacts and remediation options available for improving fish passage and waterway health at priority structures highlighted in the Initial Weir Review (2002).

350 weirs are located in the Murrumbidgee CMA region, 195 of which are sited on named waterways. Of the 350 weirs, a total of 102 weirs were inspected and assessed in the Murrumbidgee catchment as part of the Initial Weir Review (2002), of which 30 were designated as structures requiring further investigation. Of the 30 identified weirs, 7 structures were selected for detailed reviews for this study. Information gathered during the initial reviews pertaining to environmental, social, cultural, and economic factors was considered in the selection of structures to incorporate into the Detailed Weir Review. Additionally, consultation occurred with

regional NSW DPI Conservation Managers, State Water representatives, and regional staff from the Department of Natural Resources to further highlight regional issues that would influence the selection of priority structures.

Following structural selection, detailed assessments were performed on short-listed priority weirs to supplement and augment information previously obtained in the Initial Weir Review (2002). Detailed analysis involved field and desk top assessment which required consultation with structure owners, local community members, adjacent landholders, and fishing groups that held a vested interest in the weir and adjoining reaches.

3.3 Desktop assessment and consultation

Prior to the site visit, a detailed desktop investigation was conducted to determine location information (e.g. section of the catchment), structural details (e.g. required uses and interested stakeholders, available upstream habitat), hydrological patterns, and further environmental considerations (ranges of threatened and protected species and archived water quality information). Structure owners, respective state government departments, fishing clubs, and community groups were consulted during this process to ascertain: construction dates, average flows, frequency of structural drown-out events, previous occurrence of blue-green algae in the weir pool, fish caught or observed in the vicinity of the weir, licensing information, and water extraction devices linked to the works of each weir. Where possible, volume of water discharged (ML/day) on the date of the field assessment, average yearly flows, and drown out event data were acquired from the nearest Department of Natural Resources river gauge.

3.4 Field assessment

Fieldwork in the region was conducted from April 2004 – May 2005. On-site visits were conducted where feasible with structure owners (e.g. State Water), which allowed queries to be answered and sites normally inaccessible to the public to be entered. A detailed assessment proforma (Appendix A) was completed for each structure, with location details and digital photographs also recorded.

Information obtained in addition to fields previously recorded during the Initial Weir Review included: extent of barrier impact (e.g. headloss); structural stability; position of the weir relative to upstream and downstream man-made barriers; hydrological information (including the length of the weir pool and depth behind the structure); evidence of siltation behind the structure; adjacent bank stability; occurrence of riparian fencing or stock access; riparian vegetation condition; presence of aquatic and riparian weeds; and class of waterway on which the weir was located.

NSW DPI applies a ‘Class’ system to assign aquatic habitat values to waterways (Fairfull and Witheridge 2003) (see Table 3.1); however, due to the previous prioritisation of weirs in the initial review the majority of structures assessed during this study were located on Class 1 waterways. All data recorded in the Detailed Weir Review Project was downloaded into the Department of Primary Industries Fish Habitat Database prior to comparative analysis to determine regional remediation priorities.

Table 3.1. NSW DPI Classification of Fish Habitat in NSW Waterways	
Classification	**Characteristics of Waterway Type**
Class 1 Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek); habitat of a threatened fish species or 'critical habitat'.
Class 2 Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.
Class 3 Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (eg fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.
Class 4 Unlikely fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events (eg dry gullies or shallow floodplain depressions with no permanent aquatic flora present).

3.5 Prioritisation process

A weir prioritisation scheme was developed to assist in ranking priorities structures requiring remediation in NSW (Appendix B). Although weirs included in the Detailed Weir Review Project had previously been assessed and prioritised as a component of the Initial Weir Review, it was deemed necessary to further rank these priority structures to incorporate the additional data collected, thereby providing regional CMAs with targeted, informed data when selecting structures for remediation. The prioritisation scheme was developed to determine regional priorities by ranking weirs based on the following categories: a) stream habitat value b) structural impact, c) environmental criteria, and d) modification criteria.

An initial prioritisation was conducted based upon stream habitat and structural impact criteria, which were viewed as the primary variables affecting fish passage. Stream habitat criteria was based upon habitat class, location of the barrier in the catchment, number of downstream obstructions, and the amount of habitat (i.e. stream length in km) opened to unimpeded fish passage. Table 3.1 outlines the characteristics of each waterway class that was used in the weir prioritisation scheme, with Class 1 systems receiving a high ranking while Class 4 systems recorded a null score. Moreover, a higher weighting was placed on weirs that, if remediated, would provide access for migrating fish to longer sections of unimpeded habitat.

Structural impact criteria assessed whether the weir was a physical or hydrological barrier to migrating fish. Headloss over a structure, otherwise known as the "waterfall effect', was measured under low-flow conditions, with larger values representing a greater fish passage barrier. Additional physical barriers included excessive slope (> 1:20) and presence of debris, with each of these barriers being recorded as presence (true) vs. absence (false). Weirs were assessed to be debris barriers based upon the conditions at the time of the assessment rather than upon the potential of the structure (e.g. vertical slot fishways) to accumulate debris. Hydrological barriers were determined as displaying excessive water velocity or insufficient flow depth (< 100 mm), and were assessed over the full range of hydrological flows until the structure drowned out. For weirs inspected for the Murrumbidgee detailed review, excessive headloss (> 100 mm) was the only significant barrier recorded.

Following the initial prioritisation, a secondary prioritisation incorporating environmental and structural modification criteria was conducted to further delineate rankings. Environmental criteria incorporated aquatic and riparian habitat condition (i.e. good, fair, and poor), sedimentation in the weir pool, and threatened species habitat. Within the known ranges of species of conservation concern, priority rankings were determined by the quality of the surrounding aquatic habitat based on habitat class (Class 1-2: high ranking; Class 3: low ranking; Class 4: no ranking).

Modification criteria assessed structural use and the ease of remediating the weir. Additionally, weir inspections noted that a number of structured required immediate maintenance that would enact the Fisheries Management Act (1994) which stipulates for the remediation of fish passage if repair works are undertaken. Finally, weirs that were noted as candidates for removal received a higher ranking than weirs requiring fishways or structural modification to remediate fish passage due to the reduced costs and short timescales associated with the former option.

The weir prioritisation scheme was applied to all structures investigated, with results for the Murrumbidgee presented in Section 4. It should be noted that the prioritisation of barriers carried out in this investigation is provisional in nature. Although social, cultural, and economic issues were considered during the Detailed Weir Reviews in order to provide an objective outcome, a degree of subjectivity is still required when assessing structures prior to the allocation of funding for remedation.

4. DETAILED WEIR REVIEW SUMMARY

4.1 Operational Details

A total of 30 structures were considered for detailed weir reviews in the Murrumbidgee CMA region. Weirs in the MCMA located on mainstem rivers or major tributaries that offered important ecological benefits were primarily owned by State Water. As a result, the 7 detailed weir reviews carried out in the MCMA region, were all State Water owned. All weirs assessed were considered in working condition with only minor maintenance required. Appendix E provides a summary of operational and environmental parameters recorded for all 7 structures assessed during the Murrumbidgee project.

All but one of the structures assessed in the Murrumbidgee were large, adjustable release weirs, all of which utilised a number of sluice gates to control flows. The remaining, smaller Beavers Creek Weir was a fixed crest structure which utilised two pipe culverts to release flows. Weir height and width varied from 2.2 metres by 22 metres in dimension, respectively, to 5.6 metres by 80 metres. Re-regulating purposes for irrigational use was the most common application of pooled water resources, with domestic and stock uses also recorded. Two of the weirs assessed; Maude Weir and Redbank Weir had dual purposes; re-regulating flows for irrigation and a diversionary role, directing flows into the Lowbidgee Flood Control and Irrigation District (FC & ID).

4.2 Ecological Considerations

Each weirs assessed in the Murrumbidgee was located on a Class 1 systems (major fish habitat). Excessive headloss was the principal barrier recorded at each weir, in association with turbulence and excessive water velocity which collaboratively confounded fish passage further. Submerged orifice fishways were recorded on three of the weirs (Berembed, Yanco and Hay); such designs generally preclude fish passage in native species due to high water velocities and excessive slope that are characteristic of the design. Submerged orifice fishways were originally developed for inclusion on North American and European streams supporting salmonoid species. However, compared to their northern hemisphere counterparts, Australian native fish are relatively poor swimmers (Kapitzke and Patterson 2002). Mallen-Cooper (2000) provides a comprehensive overview of design standards required in Australian fishways that will promote effective fish passage over a range of species and size classes. Furthermore, the larger weir structures assessed can additionally be classified as undershot weirs, due to the nature of flows being released through the base of vertical lift gates. Undershot weirs are known to have negative impacts on fish larvae (up to 40% mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002).

Fish passage barriers have a significant impact on the distribution, abundance, and diversity of native species by disrupting migrational patterns associated with spawning and recruitment into preferential habitat. For four of the structures assessed during this project, remediation of fish passage would improve access to over 100 km of significant feeding and spawning grounds, with two of these structures (Beavers Creek and Berembed Weir) providing in excess of 350 km. All of the weirs assessed had further barriers to fish passage located downstream. However, the next barrier downstream of Redbank Weir sited on the Murrumbidgee River, has been fitted with a Deedler Lock fishway which is in the process of being converted to a automated system. This has created an extensive section of waterway

downstream of Redbank to the confluence of the Murrumbidgee River with no major barriers to fish passage.

Migration of fish past instream barriers occurs at opportunistic times following structural drown out; however, the timing of such events may not coincide with annual or seasonal migration patterns. Structural drown out frequencies of weirs inspected during this review were rare. The majority of the weirs assessed are large structures, fitted with gates which can be automatically raised in times of high flow and flood thus reducing the potential for structural stress. Therefore, fish passage is inhibited the majority of the time and even with the gates open, the high water velocities which would occur during these flood events would further restrict upstream fish migration. Beaver Creek Weir, the smaller of the weirs reviewed drowns out when flows exceed 7000 ML/day (or 1% of the time). Drownout frequency is primarily dependent upon the degree of headloss, channel geomorphology, and location within the catchment.

The health of freshwater systems is dependent upon the quality of adjacent riparian land, which has a direct impact upon aquatic physico-chemical processes (e.g. water temperature, nutrient input, and erosion and sedimentation). Bank-side vegetative condition at weirs assessed during the review were predominantly in an unhealthy condition due to historic land clearing practices, presence of weed species, and unfettered access of cattle to the waterway. Minor to major bank erosion was recorded at all structures and riparian rehabilitation projects are recommended for all weir sites.

4.3 Remediation Recommendations

The preferred options of NSW DPI for remediating fish passage at the barriers inspected in the Murrumbidgee Detailed Weir Review Project are outlined in Table 4.1 along with estimated costs. Weir removal would present the greatest benefit to the health of the waterway by providing unrestricted fish passage and natural sediment fluxes, while also removing liability associated with the structure for the weir owner. However, all of the structures assessed are still required by the regions landowners, local councils and local communities, and as such the primary recommendation put forth by NSW DPI is the construction of fishways at all of the seven weirs assessed. Four of these being Deedler Fishlocks and three being vertical-slot fishways. The recommended fishway design for each weir was chosen due to the specifics of each weir site, including height of weir, slope, head water and tail water heights and fish species present. In addition, alternative fishway design options are available for each weir as outlined in Table 4.1.

The recommendations put forth by NSW DPI to remediate fish passage at the weirs inspected in the Murrumbidgee Detailed Weir Review Project are supported by the NSW *State Weirs Policy* which was developed as a collaborate government initiative between the Department of Natural Resources, Department of Environment and Conservation, and Department of Primary Industries. The *State Weirs Policy* aims to halt and, where possible, reduce and remediate the environmental impact of weirs. Specifically, the Policy states that "*where weirs are retained, owners shall be encouraged to undertake structural changes to weirs to reduce their environmental impact on the environment*." This policy applies to not only structures assessed during this review, but also for any weir undergoing license renewal. If significant ecological impacts are noted for the structure in question, and no clear need is demonstrated, then the barrier should be considered for removal or modification to mitigate deleterious environmental impacts.

4.4 Weir Remediation Priorities in the Murrumbidgee

A component of this project aimed to develop a method of ranking waterway barriers to determine priority structures for remediation (see Appendix B). The Weir Prioritisation Scheme takes into account a range of operational and ecological factors, including the impact of the structure on fish passage, the quality and condition of instream and surrounding habitat, and remediation considerations. The ranking scheme was applied to the 7 structures inspected during the Detailed Weir Review Project, with Table 4.1 summarising the outcomes. Although all structures included in this report are considered a high priority for remediating fish passage, the Weir Prioritisation Scheme provides an initial gauge as to where the greatest environmental gains can be achieved. Structures such as Beavers Creek Weir and Berembed Weir attained a top ranking due to the quality and quantity of habitat that would be available for unimpeded fish migration if the weirs were remediated.

Although ease of remediation was considered in the prioritisation process (i.e. removal versus modification versus fishway installation), specific socio-economic issues, as well as cultural concerns, were not factored into the rankings. Additionally, a note should be made that actual costs for fishway installation or weir removal could fluctuate significantly from estimates provided in this report. Financial resources targeted for the implementation of recommendations contained within this review need to be determined within the context of the Government's natural resource management priorities. However, the environmental and ecological benefits associated with improving fish passage at weirs have been well established, including improved fish stocks and higher aquatic biodiversity.

4.5 Socio-economic considerations in the Murrumbidgee

Weirs and provision of permanent water supplies are inextricably linked to the social and economic development of all communities. In areas such as the Murrumbidgee catchment, low or sporadic rainfall only serves to increase their importance to surrounding communities. The construction of barriers to fish passage on the Murrumbidgee River may have had a deleterious effect on native fish populations, however it has undoubtedly allowed for the significant social and economic expansion of communities on and adjacent to the river. As a consequence, any future management options for weirs within the Murrumbidgee need to consider the associated impacts on economic development, recreational amenity, existing social networks and the long-term viability of remote and regional communities.

The seven (7) priority structures identified through the Murrumbidgee Detailed Weir Review form a unique case as they are all owned and operated by the State Water Corporation. Since 2002, State Water has been closely involved with the then NSW Fisheries (now NSW Department of Primary Industries) to develop a statewide approach to addressing issues of fish passage at State Water assets This collaborative approach has been refined and adopted within SWC's Environmental Management Plan 2006-2010. A key component of this collaboration has been an assessment of social and economic factors associated with any proposed modification to existing infrastructure. Any future modifications to the structures highlighted in this study will undoubtedly involve close consultation with the State Water Corporation, and as such, individual economic and social assessments will be carried out. However, as the seven structures highlighted as priorities for remediation as part of this review are all situated on the main stem or an anabranch of the Murrumbidgee River, a brief discussion of the likely impacts is useful.

Social Impacts

The most significant social impacts that can occur as a result of modifications to existing barriers are at sites of weir removals. As the provisional recommendations for all seven barriers are for the installation of fishways (see Table 4.1), the social impacts on adjacent or surrounding communities are likely to minimal. In fact the proposed outcome of improved fish passage to create more favourable conditions for the recruitment and survival of native fish would provide positive social benefits through improved recreational amenity from more productive angling opportunities.

The construction of the fishways would also deliver enhanced biodiversity values within the river providing a valuable contribution to the well-being of local communities. The strong relationship between communities within the Murrumbidgee catchment and river health is likely to be enhanced through proactive measures to improve the abundance and diversity of native fish. Furthermore, the investment in works and measures to improve native fish habitat serves as a strong educational and awareness tool promoting the cause of river health and its importance to local communities.

Negative social impacts of fishway installation or other proposed management changes are likely to be minimal. The proposed modification to the existing barriers recommend some minor alterations to existing storage levels through extending the period of time (where possible) that gates are kept free of the water during winter. This has the potential to impact upon some recreational pursuits such as waterskiing and boating, and any such move would need to be thoroughly discussed with local communities prior to implementation. However the ongoing need to capture flows for annual domestic and irrigation purposes would only allow changes to existing regimes to be very minor in nature, and as a consequence social impacts are also likely to be very minor. The fishways themselves will take up a minimal area of land, typically within existing State Water boundaries where community access is currently prohibited.

Economic Impacts

The installation of fishways on the seven priority structures is unlikely to have any direct economic impacts on individuals or local communities, however there is the potential for indirect impacts as part of meeting the cost of construction. A 2004 Independent Pricing and Review Tribunal (IPART) ruling in relation to State Water assets found that the costs of mitigating the environmental impact of dams and weirs should be shared between customers (ie. irrigators) and the NSW Government. This ruling has greatest relevance to structures where modifications or refurbishments are planned and a legislative obligation is triggered under Section 218 of the Fisheries Management Act (1994). In these instances, there is an indirect economic cost to landholders and communities though the requirement to meet fish passage obligations being built into the price of water. However, how this ruling would relate to costs of fishway construction at sites where there was no associated modification or upgrade works planned is uncertain. As previously stated, the modification of any of the barriers identified through this review would require significant consultation with State Water, and such issues would need to be thoroughly addressed at such a time.

Positive economic impacts of weir modifications are more difficult to define, however there are certainly potential benefits to the tourism and recreational fishing industries through improved angling opportunities. Within the southwest and Murray Regions of NSW, the total expenditure by recreational fisherman directly related to utilising the recreational fishing resource is estimated at $19M per annum. An increased abundance of native fish and improved natural recruitment would enhance recreational fishing opportunities within the region, which in turn would see an

increase in investment. The remedial impact of fishways on the native fish population would also reduce the existing reliance on native fish stocking. Since 1998, more 4.7 million native fish have been stocked into freshwater systems of NSW with the cost of this program shared between local communities and the NSW Government. An increased abundance of native fish and improved natural recruitment would also reduce the existing reliance on native fish stocking.

5. INDIVIDUAL DETAILED WEIR REVIEW REPORTS

Information used to prioritise each weir is detailed in the Individual Detail Weir Review reports that appear in the following section. Individual weir reports provide comprehensive accounts of the structures operational details, system hydrology, ecological considerations, proposed remediation options (along with projected costs), and preferred option of NSW DPI for improving fish passage at the weir.

Table 4.1: Summary of weirs assessed during the Murrumbidgee Detailed Weir Review Project							
Priority Ranking	**Barrier Name**	**Watercourse**	**Ownership**	**Operational Fishway**	**Recommendation**	**Estimated Cost of preferred option**	**Estimated Cost of alternative option**
1	Beavers Creek Weir	Beavers Creek/ Old Man Creek	State Water	No	Vertical Slot Fishway	$300-500K	$200-300K
2	Berembed Weir	Murrumbidgee River	State Water	No, Submerged Orifice	Deelder Fishlock	$500K - $1M	$300-500K
3	Yanco Weir	Murrumbidgee River	State Water	No, Submerged Orifice	Deelder Fishlock	$300-500K	$500K-$1M
4	Gogeldrie Weir	Murrumbidgee River	State Water	No	Deelder Fishlock	$500K-$1M	>$1M
5	Hay Weir	Murrumbidgee River	State Water	No, Submerged Orifice	Deelder Fishlock	$300-500K	$500K-$1M
6	Maude Weir	Murrumbidgee River	State Water	No	Vertical Slot Fishway	$500K-1M	>$1M
7	Redbank Weir	Murrumbidgee River	State Water	No	Vertical Slot Fishway	$500K-1M	>$1M

Note – "Priority Ranking" refers to the structures for which detailed weir reviews were undertaken. Please refer to the text in "Project Methodology" for information on determining sites for detailed review.

1. BEAVERS CREEK WEIR, BEAVERS CREEK/ OLD MAN CREEK

FIGURE 1.1: Beavers Creek Weir, from downstream looking upstream (09.06.2005, 3.7ML/day)

1.1 Description and Setting

Beavers Creek Weir (Figure 1.1) is located in the Mid Murrumbidgee Catchment between Narrandera and Wagga Wagga on an anabranch of the Murrumbidgee River. The weir is approximately 2.5 metres high and 22 metres across the length of the crest, and is constructed of concrete, sheet piling and rock fill. The weir is a fixed crest structure, with a regulating gate comprising 2 pipe culverts. Beavers Creek Weir acts as a barrier to fish passage during flows of less than approximately 7,000 ML/day. At these flows the weir restricts fish due to excessive headloss, velocity, and increased turbulence across the face of the structure.

Beavers Creek Weir is ranked as a high remediation priority within the Murrumbidgee CMA region due to the following factors:

- Class 1 fish habitat - major, permanently flowing waterway and presence of one or more threatened fish species. The site is within the expected distribution range of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizzi*), southern pygmy perch (*Nannoperca australis*), Murray hardyhead (*Craterocephalus fluviatilis*), trout cod (*Macullochella macquariensis*), southern purple spotted gudgeon (*Mogurnda adspersa*), and Macquarie perch (*Macquaria australasica*). Only three of the seven listed threatened species (silver perch, Macquarie perch and trout cod) were found during sampling carried out in the Murrumbidgee Catchment in 2004. Gilligan (2004) states that it is highly likely the other four species not sampled have become locally extinct;
- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);

- Instream and riparian habitat is relatively good condition upstream and downstream from this site. Presence of instream fish habitat including woody debris and aquatic vegetation.
- Improved stream connectivity: the next upstream barrier to fish is Burrunjuck Dam, located approximately 360km away. The next barrier downstream is Yanco Weir on the Murrumbidgee River approximately 65km away, downstream from the confluence of Old Man Ck and the Murrumbidgee River, both structures are owned and operated by State Water;
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

1.2 Hydrology

Flows within the Murrumbidgee River are regulated by Burrinjuck and Blowering Dams which are located upstream of the Murrumbidgee-Tumut junction. There are no major barriers to fish passage upstream between Beavers Creek Weir and Burrinjuck Dam on the Murrumbidgee River.

Beavers Creek is an anabranch of the Murrumbidgee River approximately 90km in length, and bypasses Berembed Weir. The waterway is referred to as Old Man Creek some 30km below the weir.

The closest DNR river gauge is located at Mundowey on Beavers Creek (station 410137) downstream of the weir. Information with regard to flows within the Murrumbidgee River at Beavers Creek Weir were sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), staff from State Water, DNR and NSW DPI, and describes data acquired between 16/05/1999 – 31/11/2005.

Preliminary investigations estimate that the weir in its current condition would drown out with flows in excess of 7,000 ML/day. The time weighted flow duration curve for Beavers Creek at Mundowey indicates that flows would exceed 7,000 ML/day less than 1% of the time. It is therefore expected that the weir obstructs fish passage during most flow conditions.

1.3 Operational Details

Beavers Creek Weir is owned and operated by State Water. The weir was built in 1920 to conserve water upstream for irrigation, stock and domestic for users. Discussions with State Water in the past have referred to the potential upgrade of this site. Fish passage is a high priority and should be incorporated into any on ground works at this site.

1.4 Ecological Considerations

Fish passage may be possible less than <1% of the time, however the timing of these flows may not necessarily coincide with spawning migrations of any or all of the resident fish species within the Murrumbidgee River.

The following native fish species were identified in the report "*Fish Communities of the Murrumbidgee Catchment: status and trends*" (Gilligan 2005) and are historically expected to occur throughout the Murrumbidgee Catchment: freshwater eels, fly specked hardyhead, two spined blackfish, river blackfish, mountain galaxias, flat-head galaxias, western carp gudgeon, Midgley's carp gudgeon, Lake's carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbowfish,

short-headed lamprey, southern pygmy perch, bony herring, flatheaded gudgeon, dwarf flat-headed gudgeon, Australian smelt and freshwater catfish. The following threatened species were also identified: silver perch, olive perchlet, Murray hardyhead, trout cod, southern purple spotted gudgeon, and Macquarie perch. Since Europeans have inhabited this area, the following species have been introduced: goldfish, common carp, eastern gambusia, oriental weatherloach, rainbow trout, brown trout and redfin perch.

During sampling for the above mentioned study (Gilligan 2005), only 13 of the 20 species known to have historically occurred in the Murrumbidgee Catchment were captured, indicating that some species may have become locally extinct, whilst the abundance of others is declining.

The fish community of the Murrumbidgee Catchment is described by Gilligan (2005) as severely degraded. Gilligan (2005) recommends that the CMA undertake to address issues identified in the Native Fish Strategy (2003) including: rehabilitation of instream and riparian vegetation; rehabilitation of wetlands; eliminating cold water pollution; improving environmental flow management; reinstating fish passage; contributing to the control of alien species; and ensuring community ownership and support.

Beavers Creek is known as a local haven for fish during the summer months when irrigation flows are released down the Murrumbidgee River. The warmer, more protected habitat is integral to the local fish community.

A) B)

FIGURE 1.2: A) Downstream and B) Upstream of Beavers Creek Weir

Riparian rehabilitation works within Beavers / Old Man Creek have recently been completed by Conservation Volunteers Australia and were funded through the Fish Habitat Grant Program (managed by NSW DPI). The works involved riparian and aquatic revegetation as well as introducing snags into the waterway to create fish habitat within Berry Jerry State Forest. A demonstration reach is also being developed by NSW DPI and the Murrumbidgee CMA, and undertake the rehabilitation of a reach of Old Man Creek. The project will involve riparian landholders, who will actively participate by carrying out a number of activities including riparian and instream revegetation, willow control, fencing, and erosion protection works. Reinstating fish passage throughout Beavers / Old Man Creek will complement the habitat rehabilitation works already under way.

At the time of the inspection the banks downstream of the weir were eroded and there was minimal vegetation cover. Dominant riparian plants included common rush, and remnant and regenerating river red gums. In the weir pool there were also scattered stands of willows (Figure 1.2). Since the inspection on the 09.06.2005 some of the stands of willows upstream and downstream of the weir have been removed. It is imperative that the site is monitored and any re-shooting willows be treated over the next two years or more. The reinstatement of fish passage at this site should be undertaken in conjunction with a rehabilitation project to address the willows and encourage native revegetation through riparian fencing.

1.5 Proposed Remediation Actions

The weir is still required, and its removal is not considered a viable option. State Water is in the process of reviewing their entire infrastructure within the Murrumbidgee Catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

- **Option 1 – Vertical Slot Fishway**
  The construction of a vertical slot fishway is the most effective option for this site, with the most appropriate location being on the left hand bank. Vertical slot fishways are considered one of the most effective fishway designs and are the preferred option where threatened species are present (this site is within the expected distribution of as many as seven threatened species). With varying headloss, vertical slot fishways are more effective in passing a greater range of fish size classes than other fishway types.

  The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway outlined in the projected remediation costs is based on $150,000 per vertical metre, although this value is dependant on site location, access, and various structural and hydrological conditions.

- **Option 2 – Deelder Fishlock**
  A Deelder Fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishlock works by attracting fish through an entrance similar to that of a pool type fishway, but instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris, 2000). The holding area where the fish accumulate is sealed and water is directed into the chamber until water levels are equal to the water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

  The Deelder fishlock design is considered a cost effective option for fish passage and up until 2002, had not been applied to Australian rivers. The Deelder fishlock was constructed at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions” (Baumgartner, 2003). Monitoring of fish passage at this site continues and will look at fish passage under various flow conditions and will

determine whether this design is applicable for application at other sites across NSW.

It is possible that the Deelder fishlock design could be applied to Beavers Creek Weir. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is in an experimental stage the Deelder fishlock has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods.

The costs associated with the construction of the Deelder fishlock are much greater when there is no existing fishway infrastructure already in place. The cost to build the fishlock from scratch may be less than that of the vertical slot fishway because less construction materials would be required. The Deelder fishlock should be fully automated and provided the infrastructure was available, this option should be investigated.

- **Option 3 – Partial Width Rock Ramp Fishway**
  Beavers Creek Weir is estimated to drown out <1% of the time, meaning fish passage is not possible for the vast majority of the time, except during high flow (flooding) conditions. The construction of a partial width rock ramp fishway designed to pass fish prior to drown out of the structure would make a significant contribution to improving the passage of native fish and provide a significant benefit. As with Option 1, the rock ramp fishway could be constructed on the left hand side of the weir away from the existing regulating infrastructure.

  The rock ramp fishway could be constructed perpendicular to the weir with a return leg placing the entrance close the weir, where an attraction flow across the weir could be incorporated (by cutting a low flow notch in the weir adjacent to the fishway entrance). The reasoning behind the installation of a rock ramp fishway is to place rock downstream of the existing structure so that a gradient of 1:20 is formed. Strategically placed rock ridges create resting pools that are connected by riffles, and allow fish passage to a greater range of fish species and size classes outside the current requirement of flooding conditions. Detailed specifications for the construction of rock ramp fishways can be obtained from NSW DPI and must be considered in the preparation of any engineering designs for such a structure.

1.6 Projected Remediation Costs

Projected cost	$50K - $150K	$150K - $300K	$300K - $500K	$500K - $1M	>$1M
Option 1				✔	
Option 3			✔		
Option 2		✔			

1.7 Recommendation

The construction of a vertical slot fishway (Option 1) is the preferred remediation action for this site. Investigations into the construction of a Deelder fishlock would also be advisable and may be achieved at a lower cost than the vertical slot fishway.

1.8 Benefits Associated with Remediation

The Murrumbidgee River and its associate tributaries contain important fish habitat that should be protected. The reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Beavers Creek Weir, unimpeded access for fish and other aquatic organisms would be provided to in excess of 90km of habitat within Beavers Creek / Old Man Creek alone. The construction of a fishway at this site would also create a bypass for fish around Berembed Weir on the main channel of the Murrumbidgee River.

2. BEREMBED WEIR, MURRUMBIDGEE RIVER

FIGURE 2.1: Berembed Weir, Murrumbidgee River (09.03.2005, 2782 ML/day)

2.1 Description and Setting

Berembed Weir (Figures 2.1) is located between Narrandera and Wagga Wagga on the Murrumbidgee River within the Mid Murrumbidgee Catchment. Berembed Weir is approximately 4.5 metres at its lowest point, 68 metres across the length of the crest and comprises a concrete weir, a lock chamber, and steel sluice gates. The weir is a regulating structure that is responsible for maintaining a water supply for diversion into the Murrumbidgee Irrigation Area. The weir has an ineffective submerged orifice fishway (Figure 2.2) that does not currently pass fish. No drown out data is available for this site. However, due to the size of this structure, and its non-functioning fishway, Berembed Weir prevents fish passage over most flow conditions. During normal operation, the vertical lift gates are raised gradually to prevent structural drownout of the concrete spillway to prevent structural damage during extreme high flow conditions. At this time there would also be little or no fish passage past the weir due to excessive water velocities.

Berembed Weir is ranked as a high remediation priority within the Murrumbidgee CMA region due to the following factors:

- Class 1 fish habitat - major, permanently flowing waterway and presence of one or more threatened fish species. The site is within the expected distribution range of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizzi*), southern pygmy perch (N*annoperca australis*), Murray hardyhead, (*Craterocephalus fluviatilis*), trout cod (*Macullochella macquariensis*), southern purple spotted gudgeon (*Mogurnda adspersa*), and Macquarie perch (*Macquaria australasica*). Only three of the seven listed threatened species perch, Macquarie perch and trout cod) were found during sampling carried out in 2004 (silver. Gilligan (2004) states that it is highly likely that the other four species not sampled have become locally extinct within the Murrumbidgee system;

- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: the next barrier downstream is Yanco Weir on the Murrumbidgee River 65km away, whilst the next barrier upstream is Burrinjuck Dam on the Murrumbidgee River, approximately 360km away. Both structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

2.2 Hydrology

Flows within the Murrumbidgee River are regulated by Burrinjuck and Blowering Dams which are located upstream of the Murrumbidgee-Tumut junction. There are no known barriers to fish passage between Berembed Weir and Burrinjuck Dam on the Murrumbidgee River. The next downstream barrier is Yanco Weir, approximately 65km away.

The closest DNR river gauge is located downstream of Berembed Weir on the Murrumbidgee River (station 410023). Information with regard to flows within the Murrumbidgee River at Beavers Creek Weir can be sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and describes data acquired between 21/01/2000 – 03/11/2005.

2.3 Operational Details

Berembed Weir is owned and operated by State Water. The Weir was built in 1910 to conserve water upstream for irrigation stock and domestic for users. At Berembed Weir water from the weir pool is diverted to the Murrumbidgee Irrigation Area via Bundidgery storage, which is maintained by Murrumbidgee Irrigation.

The weir is a regulating structure, consisting of two bays with two electronically operated vertical lift steel gates. Due to its size, the structure does not drown out. In addition, when the gates are closed, fish passage is also not possible, which currently occurs throughout most of the year. The weir gates are opened for a short time during winter (although this is during a time of low fish activity), and are gradually opened when high flows are expected down the Murrumbidgee River to prevent overtopping and potential structural failure of the weir.

Berembed Weir also currently has a non-functioning submerged orifice fishway located on the left hand side of the vertical lift gates (which are at the centre of entire weir structure). This fishway was built prior to 1985 and was based on European designs which aimed to pass salmonoid fish species – such designs have since been recognised as ineffective in passing our native fish species. Both the fishway and weir have been listed as a heritage item under the *NSW Heritage Register.* The heritage listing of a weir requires that it is maintained, and strict guidelines are put in place to ensure that the heritage values for which the structure represents are protected. If the fishway were to be modified to reinstate fish passage past the weir, approval must be sought, and an application would be required under Section 60 of the *Heritage Act 1977.*

A) B)

FIGURE 2.2: A) Vertical lift gates and B) Submerged orifice fishway

2.4 Ecological Considerations

Limited fish passage may be possible for short periods when the gates are partially lifted; however studies have shown that this can have negative impacts of fish larvae due to the undershot nature of the gates. In addition, the timing of this operation may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Murrumbidgee River (such as the opening of gates for a short time during winter). Although the weir has a fishway, both NSW DPI and the Murrumbidgee Catchment Blueprint have identified Berembed fishway as ineffective. Fish passage has been addressed as a key element to restoring the riverine environment to favour native fish over introduced species such as carp in the blueprint.

The following native fish species were identified in the report "*Fish Communities of the Murrumbidgee Catchment: status and trends*" (Gilligan 2005) and are historically expected to occur throughout the Murrumbidgee Catchment: freshwater eels, fly specked hardyhead, two spined blackfish, river blackfish, mountain galaxias, flat-head galaxias, western carp gudgeon, Midgley's carp gudgeon, Lake's carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbowfish, short-headed lamprey, southern pygmy perch, bony herring, flatheaded gudgeon, dwarf flat-headed gudgeon, Australian smelt, and freshwater catfish. The following threatened species were also identified: silver perch, olive perchlet, Murray hardyhead, trout cod, southern purple spotted gudgeon, and Macquarie perch.

Following European settlement, the following species have been introduced: goldfish, common carp, eastern gambusia, oriental weatherloach, rainbow trout, brown trout and redfin perch – all of which have a direct or indirect impact on native fish populations.

During sampling for the above mentioned study (Gilligan 2005), only 13 of the 20 species known to have historically occurred in the Murrumbidgee Catchment were captured, indicating that some species may have become locally extinct and the abundance of others is declining. The fish community of the Murrumbidgee Catchment is described by Gilligan (2005) as severely degraded and recommends that the CMA undertake to address issues identified in the Native Fish Strategy (2003) including: rehabilitation of instream and riparian vegetation; rehabilitation of wetlands; eliminating cold water pollution; improving environmental flow management; reinstating fish passage; contributing to the control of alien species; and ensuring community ownership and support.

While the vertical lift gates remain closed at Berembed Weir, fish passage is not possible. In addition, the weir is an undershot weir, which is known to have negative impacts on fish larvae (up to 40% mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002; NSW DPI *in prep*). It is therefore important that we understand the effect of weirs on fish communities so that we can better manage them to assist in the protection of native fish in the entire Murrumbidgee Catchment.

At the time of the inspection the banks downstream of the weir were eroded and possessed minimal vegetation cover (Figure 2.3). In the weir pool there was an accumulation of sediment on the left hand side, with several scattered stands of willows. The reinstatement of fish passage at this site should be carried out in conjunction with a fish habitat rehabilitation project to address the accumulation of sediment, willow removal, and encourage native revegetation through riparian fencing. Any fish passage and riparian rehabilitation works that are carried out at Berembed Weir will complement the demonstration reach currently being developed downstream of Beavers Creek Weir on Old Man Creek by NSW DPI, the Murrumbidgee CMA, and private landholders.

A) B)

FIGURE 2.3: Murrumbidgee River A) downstream and B) upstream of Berembed Weir

2.5 Proposed Remediation Actions

Berembed Weir is still required, and its removal is not considered a viable option. State Water is currently in the process of reviewing their entire existing infrastructure within the Murrumbidgee Catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

The weir is a total barrier to fish passage except when the gates are lifted. As a result it is recommended that fish passage options be further investigated at this site, and the options for management of the vertical lift gates be assessed.

- **Option 1 – Retrofit existing fishway with a Denil Insert**
  There is some scope for improvements to the existing fishway that may allow it to function more effectively. At present it presents a total barrier to fish passage, alienating fish from the Murrumbidgee River upstream to Burrunjuck Dam. Currently the fishway consists of a concrete channel covered with timber racks with an estimated gradient of 1:6. The required gradient to allow fish passage for native species is estimated to be in excess of 1:20. There

are many cells within this channel, which are created by concrete baffles with a single submerged orifice. At the time of inspection the upstream side of the weir was heavily silted, with ongoing maintenance of the silt surrounding the exit of the fishway being required. Currently the flows through the gates are creating an attraction flow for fish, which is likely to be impeding their ability to locate the entrance to the fishway. Modifications required to improve fish passage at this site include the following;

- Retrofitting the existing fishway channel with a Denil insert. The Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than Vertical Slot fishways because they can be constructed on steeper slopes with less materials required for their construction (Baumgartner 2005);
- Natural lighting should be established throughout the concrete channel by retaining the existing wooden covers or replacing them with steel mesh.

There are limitations with the use of Denil inserts, however. Larnerier (1990) identified Denil fishways as only being effective in passing fish greater than 200mm in length. Mallen Cooper (2000) recommended Denil fishways be constructed on slope no greater than 1:12, as slopes greater than this limit the movement of smaller fish. Experimental work undertaken in NSW has shown that bony herring could ascend Denil fishways with a slope of 1:12; however their movement was greatly restricted on steeper slopes. Mallen Cooper (2000) further recommended that Denil fishway design should not be used where adult Murray Cod are present, as it has not yet been established whether this species will use the Denil design.

The NSW River Survey (1994) identifies a high abundance of both bony herring and Murray cod in the Murrumbidgee River. Despite this, Thorncraft and Harris (2000) recommended that a Denil insert should be considered for Berembed Weir and presented the Deelder Lock fishway as an alternative option.

- **Option 2 – Deelder Fishlock**

A Deelder Fishlock is a low level lock fishway which operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishlock operates by attracting fish through an entrance similar to that of a pool type fishway; however, instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris 2000). The holding area where the fish accumulate is then sealed and water is directed into the chamber until water levels are equal to the upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage and, up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low flow conditions” (Baumgartner 2003). Monitoring of fish

passage at this site continues and will observe fish passage under various flow conditions to determine whether this design is applicable for other sites across NSW.

Further investigations into Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River including Berembed and Yanco Weirs, which currently have ineffective, submerged orifice fishways. As with Balranald Weir, the Deelder fishlock at both these weirs could be incorporated into the existing fishways at a relatively low cost.

It is therefore possible that the Deelder fishlock design could be applied to Berembed Weir. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock at Balranald has already proven to be effective in passing a wide range of native fish species and size classes during low flow periods.

- **Option 3 – Vertical Slot Fishway**
  The construction of a vertical slot fishway at this site would be the most effective option to provide fish passage at this site. Vertical slot fishways are considered one of the most effective fishway designs due to their ability to operate at sites with varying headloss, and is the preferred option where threatened species are present (as many as seven threatened species are expected to occur at this site). The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on $150,000 per vertical metre and is dependant on site location, access and various structural and hydrological conditions.

2.6 Projected Remediation Costs

The values for the cost of the remediation options at this site provided below should be taken as an estimate only.

Projected cost	$50K - $150K	$150K - $300K	$300K - $500K	$500K - $1M	>$1M
Option 1		✔			
Option 2			✔		
Option 3				✔	

2.7 Recommendation

A submission to the NSW Heritage Council will be required in order to undertake any works at the weir or fishway. It is recommended that negotiations be held regarding the refurbishment of the existing fishway, rather than changes to the existing weir structure itself. A Deelder fishlock may be more effective then the Denil insert, however greater modifications would be required. The Denil insert may be able to be fitted in the existing channel without major refurbishment. Despite this, it is recommended that the installation of a Deelder fishlock be the first priority investigated (Option 2), due to the size of the structure, and the fishlock's ability to

pass a wide range of fish species and size classes. In addition, appropriate management of the vertical lift gates to limit their effect on fish larvae is also a priority for this site. During low diversion periods (during the winter months), the vertical lift gates should be raised clear of the water to reinstate a natural flow regime and effective fish passage. Where possible, investigations should be undertaken to determine if this management option is available during fish migration periods (spring/summer).

2.8 Benefits Associated with Remediation

The Murrumbidgee River and its associate tributaries possess important fish habitat that should be protected. As such, the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Berembed Weir, unimpeded access for fish and other aquatic organisms would be provided to potential habitat in excess of 425km, both upstream and downstream from the Berembed Weir.

3. GOGELDRIE WEIR, MURRUMBIDGEE RIVER

FIGURE 3.1: Gogeldrie Weir (09.03.2005, 667 ML/day)

3.1 Description and Setting

Gogeldrie Weir (Figure 3.1) is located approximately 30km downstream of Narrandera on the Murrumbidgee River within the Lower Murrumbidgee Catchment. The weir is a regulating structure, which consists of a concrete sill on sheet metal piling cut-off walls with six electrically operated steel sluice gates, approximately 12.2 metres wide and 6.1 metres high. The weir does not have a fishway. No drownout data is available for this site. However, due to the size of this structure, Godeldrie Weir prevents fish passage over most flow conditions. Under current management, the vertical lift gates are raised gradually to prevent structural drownout during extreme high flow conditions. At this time there would also be little or no fish passage past the weir due to excessive water velocities.

Limited fish passage is possible when the gates are partially lifted however; studies have shown that this can have negative impacts of fish larvae due to the undershot nature of the gates.

Gogeldrie Weir is ranked as a high remediation priority within the Murrumbidgee CMA region due to the following factors:

- Class 1 fish habitat – major, permanently flowing waterway and presence of one or more threatened fish species. The site is within the expected distribution range of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizzi*), southern pygmy perch (*Nannoperca australis*), Murray hardyhead (*Craterocephalus fluviatilis*), trout cod (*Macullochella macquariensis*), southern purple spotted gudgeon (*Mogurnda adspersa*), and Macquarie perch (*Macquaria australasica*). Only three of the seven listed

threatened species were found (silver perch, Macquarie perch and trout cod) during sampling carried out in 2004. Gilligan (2004) states that it is highly likely the other four species not sampled have become locally extinct within the Murrumbidgee system;

- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: The next upstream barrier to fish is Yanco Weir, located approximately 26km away. The next barrier downstream is Hay Weir on the Murrumbidgee River approximately 250km away. Both structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where headloss and velocity are minimal).

3.2 Hydrology

Flows within the Murrumbidgee River are regulated by Burrinjuck and Blowering Dams which are located upstream of the Murrumbidgee-Tumut junction. There are two known barriers to fish passage upstream of Gogeldrie Weir on the Murrumbidgee River: Yanco and Berembed Weirs.

The closest DNR river gauge is located downstream of Gogeldrie Weir on the Murrumbidgee River (station 410082). Information with regard to flows within the Murrumbidgee River downstream of Gogeldrie Weir can be sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and describes data acquired between 18.12.1974 –11.10.2005.

3.3 Operational Details

Gogeldrie Weir is owned and operated by State Water. The Weir was built in 1959 to regulate river flow and divert water into the Coleambally Canal, which supplies the Coleambally Irrigation Area. Water is also diverted via Coononcoocabil Lagoon into the Sturt Canal to supply part of the Murrumbidgee Irrigation Areas and associated districts.

The weir gates currently remain closed throughout the year except for a short time in winter and during flooding conditions. The gates are gradually opened when high flows are expected down the Murrumbidgee River to prevent overtopping of the weir and potential structural failure of the weir.

3.4 Ecological Considerations

Very limited fish passage may be possible for short periods of the time; however the timing of passage may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Murrumbidgee River. The Murrumbidgee Catchment Blue Print identified Gogeldrie Weir as a "major barrier to fish passage". Fish passage has been addressed as a key element to restoring the riverine environment to favour native fish over introduced species such as carp by NSW DPI and the Murrumbidgee CMA.

The following native fish species were identified in the report "*Fish Communities of the Murrumbidgee Catchment: status and trends*" (Gilligan 2005), and are historically expected to occur throughout the Murrumbidgee Catchment: freshwater eels, fly specked hardyhead, two spined blackfish, river blackfish, mountain galaxias, flat-

head galaxias, western carp gudgeon, Midgley's carp gudgeon, Lake's carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbowfish, short-headed lamprey, southern pygmy perch, bony herring, flatheaded gudgeon, dwarf flat-headed gudgeon, Australian smelt, and freshwater catfish. The following threatened species were also identified: silver perch, olive perchlet, Murray hardyhead, trout cod, southern purple spotted gudgeon, and Macquarie perch. In addition to the native species above, since European settlement, the following species have also been introduced to the Murrumbidgee catchment: goldfish, common carp, eastern gambusia, oriental weatherloach, rainbow trout, brown trout and redfin perch.

During sampling for the above mentioned study (Gilligan 2005) only 13 of the 20 species known to have historically occurred in the Murrumbidgee Catchment were captured, indicating that some species may have become locally extinct and the abundance of others is declining.

The fish community of the Murrumbidgee Catchment is described by Gilligan (2005) as severely degraded. Gilligan (2005) recommends that the CMA address the following issues as identified in the Native Fish Strategy (2003): rehabilitation of instream and riparian vegetation; rehabilitation of wetlands; eliminating cold water pollution; improving environmental flow management; reinstating fish passage; contributing to the control of alien species, and ensuring community ownership and support.

While the vertical lift gates remain closed at Gogeldrie Weir, fish passage is not possible. In addition, the weir is an undershot weir, which is known to have negative impacts on fish larvae (up to 40% mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002; NSW DPI *in prep*). It is therefore important that we understand the effect of weirs on fish communities so that we can better manage them and assist in the protection of native fish throughout the Murrumbidgee Catchment.

At the time of the inspection there was no bank erosion surrounding the site, however there were dense clusters of willows lining the banks both upstream and downstream of the structure (Figure 3.2). State Water has since undertaken willow removal along a 200 metre stretch of the river bank upstream from the weir, although there are still a large number of willows still to be removed. The dominant vegetation cover at the site was casuarinas and river red gums. Reinstatement of fish passage at this site should be undertaken in conjunction with a fish habitat rehabilitation project to address removal of willows, and encourage native revegetation through riparian fencing.

3.5 Proposed Remediation Actions

Gogeldrie Weir is still required to provide a water source for irrigation off-takes for the surrounding area and its removal is not considered a viable option. State Water is in the process of reviewing their existing infrastructure within the Murrumbidgee Catchment. Recommendations made as a result of this report will be further discussed with State Water to determine solutions that will improve fish passage at this site.

The weir is a total barrier to fish passage except when the gates are lifted free of the water, as a result it is recommended that fish passage options be further investigated at this site, and the options for management of the vertical lift gates be assessed.

- **Option 1 – Vertical Slot Fishway**
  The construction of a vertical slot fishway is the most effective option for this site. With the likely varying head loss occurring at the site, the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs. Vertical slot fishways are considered one of the most effective fishway designs and are the preferred option where threatened species are present (as many as seven threatened species potentially occur at this site). The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway (below) is based on an estimate of approximately $150,000 per vertical metre, which is dependant on site location, access and various structural and hydrological conditions. The value below should therefore be taken as an estimate only.

- **Option 2 – Deelder Fishlock**
  A Deelder Fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishlock works by attracting fish through an entrance similar to that of a pool type fishway, but instead of swimming up a channel, the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris 2000). The holding area where the fish accumulate is then sealed and water is directed into the chamber until water levels are equal to the upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

  The Deelder fishlock design is considered a cost effective option for fish passage, although it was not until 2002 that this type of fishway was applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch and the threatened silver perch. The outcome of the subsequent monitoring at this site has proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions” (Baumgartner 2003). Monitoring of fish passage at the Balranald site continues, and will observe fish passage under various flow conditions to determine whether this design is applicable for application at other sites across NSW.

  Further investigations into Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River including Berembed and Yanco Weirs, which currently have ineffective, submerged orifice fishways.

  It is possible that a fully automated Deelder fishlock design could be applied to Gogeldrie Weir, and would be more cost effective than the vertical slot design (Option 1). The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods. Baumgartner (*pers. Com.* 2005) recommends that the Deelder fishlock may have a suitable application for weirs less than six metres in height. Although the vertical lift gates at Gogeldrie Weir are in excess of six metres in height, water levels would be much less than this throughout both irrigation and non- irrigation flow periods. The fishway would therefore require an operating range for flows of less than six metres.

3.6 Projected Remediation Costs

The values for the cost of the remediation options at this site provided below should be taken as an estimate only.

Projected cost	$50K - $150K	$150K - $300K	$300K - $500K	$500K- $1M	>$1M
Option 1					✔
Option 2				✔	

3.7 Recommendation

It is recommended that a Deelder fishlock (Option 2) be investigated for this site. In addition, appropriate management of the vertical lift gates to limit their effect on fish larvae is also a priority for Gogeldrie Weir. When water is not required to be held back for irrigation use (during the winter months), the vertical lift gates should be raised clear of the water to reinstate a natural flow regime and effective fish passage at this time. Where possible, investigations should be undertaken to determine if this management option is available during fish migration periods (spring/summer).

3.8 Benefits Associated with Remediation

The Murrumbidgee River and its associate tributaries contain important fish habitat that should be protected. As such, the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Gogeldrie Weir, unimpeded access for fish and other aquatic organisms would be provided to potential habitat in excess of 276km, both upstream and downstream.

A) B)

FIGURE 3.2: Murrumbidgee River A) downstream and B) upstream of Golgeldrie Weir

4. HAY WEIR, MURRUMBIDGEE RIVER

FIGURE 4.1: Hay Weir, Murrumbidgee River (08.03.2005, 453 ML/day).

4.1 Description and Setting

Hay Weir (Figure 4.1) is located approximately 24km downstream of Hay on the Murrumbidgee River within the Lower Murrumbidgee Catchment. The weir is a regulating structure approximately 6 metres high and 40 metres across the length of the crest, and is constructed of concrete with three steel vertical lift gates. Hay Weir has an ineffective submerged orifice fishway located on the left hand side that does not currently pass fish. The weir acts as a barrier to fish passage due to the presence of the steel gates when closed, and the high water velocities created when the gates are raised.

Hay Weir is ranked as a high remediation priority within the Murrumbidgee CMA region due to the following factors:

- Class 1 fish habitat - major, permanently flowing waterway and presence of one or more threatened fish species. This site is within the expected distribution range of silver perch (*Bidyanus bidyanus*), olive perchlet, (*Ambassis agassizzi*), southern pygmy perch, (*Nannoperca australis*), Murray hardyhead (*Craterocephalus fluviatilis*), trout cod (*Macullochella macquariensis*), southern purple spotted gudgeon (*Mogurnda adspersa*), and Macquarie perch (*Macquaria australasica*). Only three of the seven listed threatened species (silver perch, Macquarie perch and trout cod) were found during sampling carried out in 2004. Gilligan (2004) states that it is highly likely that the other four species not sampled have become locally extinct within the sites sampled across the Murrumbidgee system;
- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);

- Improved stream connectivity: the next upstream barrier to fish is Gogeldrie Weir, located approximately 250km away. The next barrier downstream is Maude Weir on the Murrumbidgee River approximately 48km away. Both of these structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

4.2 Hydrology

Flows within the Murrumbidgee River are regulated by Burrinjuck and Blowering Dams which are located upstream of the Murrumbidgee-Tumut junction. There are three known barriers to fish passage upstream of Hay Weir on the Murrumbidgee River: Yanco Weir, Gogeldrie Weir and Berembed Weir.

Hay Weir and Maude Weir supply water to local irrigation districts, and a number of individual irrigators have licences to draw water directly from the Murrumbidgee River.

The closest DNR river gauge is located downstream of Hay Weir on the Murrumbidgee River (station 410136). Information with regard to flows within the Murrumbidgee River downstream of Hay Weir can be sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and describes data acquired between 02.01.1982 – 10.11.2005.

4.3 Operational Details

Hay Weir is owned and operated by State Water. The Weir was built in 1981 to regulate flows in the Murrumbidgee River for irrigation, stock and domestic use. The weir is a regulating structure with three vertical lift gates.

The gates currently remain closed throughout the year during all but flooding conditions. At this time, the gates are gradually opened as high flows are expected down the Murrumbidgee River to prevent overtopping of the weir and potential structural failure of the weir.

Hay weir also has a non-functioning submerged orifice fishway located on the left hand side of the vertical lift gates. There are ten cells within the fishway built on a slope of 1:6 (17%), which is too steep to pass our native fish species. The fishway was built in 1981 during weir construction and was based on European designs which aimed to pass salmonoid fish species. Such designs have since been recognised as ineffective in passing native fish species, with current fishway designs being based on slopes of 1:20 maximum.

4.4 Ecological Considerations

Currently there may be opportunity for limited fish passage of large bodied fish species through the existing submerged orifice fishway; however fish passage is not possible for juvenile fish and smaller species through the fishway. Fish passage upstream past the weir may also be possible when the gates are lifted during high flows, however the timing of these flows may not coincide with spawning migrations of all or any of the resident fish species within the Murrumbidgee River (occurring in spring and early summer). The Murrumbidgee Catchment Blueprint identified Hay Weir as having an ineffective fishway. Fish passage has been cited as a key element to restoring the riverine environment to favour native fish over introduced species such as carp by both NSW DPI and the Murrumbidgee CMA.

The following native fish species were identified in the report "*Fish Communities of the Murrumbidgee Catchment: status and trends*" (Gilligan 2005), and are historically expected to occur throughout the Murrumbidgee Catchment: freshwater eels, fly specked hardyhead, two spined blackfish, river blackfish, mountain galaxias, flat-head galaxias, western carp gudgeon, Midgley's carp gudgeon, Lake's carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbowfish, short-headed lamprey, southern pygmy perch, bony herring, flatheaded gudgeon, dwarf flat-headed gudgeon, Australian smelt, and freshwater catfish. The following threatened species were also identified: silver perch, olive perchlet, Murray hardyhead, trout cod, southern purple spotted gudgeon, and Macquarie perch. Since European settlement, the following species have been introduced to the Murrumbidgee system: goldfish, common carp, eastern gambusia, oriental weatherloach, rainbow trout, brown trout and redfin perch.

During sampling for the above mentioned study (Gilligan 2005), only 13 of the 20 species known to have historically occurred in the Murrumbidgee Catchment were sampled, indicating that some species may have become locally extinct, whilst the abundance of others is declining. The fish community of the Murrumbidgee Catchment is described by Gilligan (2005) as severely degraded and he recommends that the Murrumbidgee CMA undertake to address the following issues as identified in the Native Fish Strategy (2003): rehabilitation of instream and riparian vegetation; rehabilitation of wetlands; eliminating cold water pollution; improving environmental flow management; reinstating fish passage; contributing to the control of alien species; and ensuring community ownership and support.

While the vertical lift gates remain closed fish passage is not possible. In addition, the weir is an undershot weir, which is known to have negative impacts on fish larvae (up to 40% of mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002; NSW DPI *in prep*). It is therefore important that we understand the effect of weirs on fish communities so that they can be better managed to assist in the protection of native fish and their habitats throughout the entire Murrumbidgee Catchment.

At the time of the inspection the banks downstream of Hay Weir were severely eroded, with minimal to no riparian vegetation cover downstream (Figure 3 and 4). The dominant overstory vegetation cover comprised of casuarinas and river red gums. The reinstatement of fish passage at this site should be undertaken in conjunction with a fish habitat rehabilitation project to address bank erosion and slumping, and to encourage native revegetation through riparian fencing. This project would require a coordinated approach between landholders and State Water along the banks of the Murrumbidgee.

4.5 Proposed Remediation Actions

Hay Weir is still required, with removal not considered a viable option. State Water is in the process of reviewing their existing infrastructure within the Murrumbidgee Catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

The weir is a major barrier to fish passage at all times other than when the gates are lifted. As a result, it is recommended that fish passage options be further investigated for this site, with options for improved management of the vertical lift gates also assessed to facilitate fish passage during normal structure operation.

- **Option 1 – Retrofit existing fishway with a Denil Insert**
  There is some scope for improvements to the existing fishway that may allow it to function more effectively. In its original state the fishway consists of a concrete channel with ten cells at an estimated gradient of 1:6 across the structure. The required gradient to allow native fish passage is currently in excess of 1:20. During present operation, an attraction flow is created for fish when the gates are opened, impeding their ability to locate the fishway entrance on the left hand side.

  The modifications required to increase fish passage through the existing fishway would include the following:

  - Retrofitting the existing fishway channel with a Denil insert would achieve an increase in fish passage. The Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than vertical slot fishways as they can be constructed on steeper slopes, thus requiring less materials in their construction (Baumgartner 2005).

  There are limitations with the use of Denil inserts, however. Larnerier (1990) identified Denil fishways as only being effective in passing fish greater than 200mm in length. Mallen Cooper (2000) recommended Denil fishways be constructed on slope no greater than 1:12, as slopes greater than this limit the movement of smaller fish. Experimental work undertaken in NSW has shown that bony herring could ascend Denil fishways with a slope of 1:12; however their movement was greatly restricted on steeper slopes. Mallen Cooper (2000) further recommended that Denil fishway design should not be used where adult Murray Cod are present, as it has not yet been established whether this species will use the Denil design.

  The NSW River Survey (1994) identifies a high abundance of both bony herring and Murray cod in the Murrumbidgee River. Despite this, Thorncraft and Harris (2000) recommended that a Denil insert should be considered for Hay Weir and presented the Deelder Fishlock an alternative option.

- **Option 2 – Deelder Fishlock**
  A Deelder Fishlock is a low level lock fishway which operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishlock operates by attracting fish through an entrance similar to that of a pool type fishway; however, instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris 2000). The holding area where the fish accumulate is then sealed and water is directed into the chamber until water levels are equal to the upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

  The Deelder fishlock design is considered a cost effective option for fish passage and up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions” (Baumgartner 2003). Monitoring of

fish passage at this site continues and will observe fish passage under various flow conditions to determine whether this design is applicable for other sites across NSW.

Further investigations into Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River including Berembed and Yanco Weirs, which currently have ineffective, submerged orifice fishways. As with Balranald Weir, a Deelder fishlock could be incorporated into the existing Hay Weir fishway, at a relatively low cost.

It is therefore possible that the Deelder fishlock design could be applied to Hay Weir. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock at Balranald has already proven to be effective in passing a wide range of native fish species and size classes during low flow periods.

- **Option 3 – Vertical Slot Fishway**
  The construction of a Vertical Slot Fishway at this site would be the most effective option for fish passage at this site. Vertical slot fishways are considered one of the most effective fishway designs due to their ability to operate at sites with varying headloss, and is the preferred option where threatened species are present (as many as seven threatened species are expected to occur at this site). The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on $150,000 per vertical metre and is dependant on site location, access and various structural and hydrological conditions.

4.6 Projected Remediation Costs

The values for the cost of the remediation options at this site provided below should be taken as an estimate only.

Projected cost	$50K - $150K	$150K - $300K	$300K - $500K	> $500K-1M	>$1M
Option 1		✔			
Option 2			✔		
Option 3				✔	

4.7 Recommendation

It is recommended that a Deelder fishlock (Option 2) be investigated for this site as the most cost effective solution to fish passage. In addition, appropriate management of the vertical lift gates to limit their effect on fish larvae is also a priority for this site. During low diversion periods (during the winter months), the vertical lift gates should be raised clear of the water to reinstate a natural flow regime and effective fish passage. Where possible, investigations should be undertaken to

determine if this management option is available during fish migration periods (spring/summer).

4.8 Benefits Associated with Remediation

The Murrumbidgee River and its associate tributaries possess important fish habitat that should be protected. As such, the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Hay Weir, unimpeded access for fish and other aquatic organisms would be provided to potential habitat in excess of 298km upstream and downstream of Hay Weir.

A) B)

FIGURE 4.2: Murrumbidgee River A) downstream and B) upstream of Hay Weir

5. MAUDE WEIR, MURRUMBIDGEE RIVER

FIGURE 5.1: Maude Weir, Murrumbidgee River (07.03.2005, 276 ML/day)

5.1 Description and Setting

Maude Weir (Figure 5.1) is located approximately 55km west of Hay on the Murrumbidgee River within the Lower Murrumbidgee Catchment. The weir is approximately 5.6 metres high and 50 metres across the length of the crest. It is a concrete regulating structure which possesses three vertical lift steel gates. Maude Weir does not have an existing fishway, and as such acts as a barrier to fish passage when the vertical lift gates are closed and when the gates are partially raised (as a result of the high water velocities).

Maude Weir is ranked as a high remediation priority within the Murrumbidgee CMA region due to the following factors:

- Class 1 fish habitat - major, permanently flowing waterway and presence of one or more threatened fish species. The site is within the expected distribution range of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizzi*), southern pygmy perch (*Nannoperca australis*), Murray hardyhead (*Craterocephalus fluviatilis*), trout cod (*Maculloch*ella *macquariensis*), southern purple spotted gudgeon (*Mogurnda adspersa*), and Macquarie perch (*Macquaria australasica*). Only three of the seven listed threatened species (silver perch, Macquarie perch and trout cod) were found during sampling carried out in 2004. Gilligan (2004) states that it is highly likely that the other four species not sampled have become locally extinct within the Murrumbidgee system;
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);

- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: The next upstream barrier to fish is Hay Weir, located approximately 48km away; the next barrier downstream is Redbank Weir on the Murrumbidgee River approximately 124km away. Both these structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

5.2 Hydrology

Flows within the Murrumbidgee River are regulated by Burrinjuck and Blowering Dams which are located upstream of the Murrumbidgee-Tumut junction. There are four known barriers to fish passage upstream of Maude Weir on the Murrumbidgee River, Hay Weir, Yanco Weir, Gogeldrie Weir and Berembed Weir.

The closest DNR river gauge is located downstream of Maude Weir on the Murrumbidgee River (station 410040). Information with regard to flows within the Murrumbidgee River downstream of Maude Weir can be sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and describes data acquired between 12.11.1974 – 10.11.2005.

5.3 Operational Details

Maude Weir is owned and operated by State Water. The weir was built in 1939 to regulate flows in the Murrumbidgee River for irrigation, stock and domestic use. Maude Weir provides diversions to Lowbidgee Flood Control and Irrigation District (FC&ID) through the Caira and Nimmie Regulators. Maude Weir is a dual purpose weir, with re-regulatory and diversionary functions. When the weir is not diverting flows to the FC&ID (outside winter and spring), it re-regulates flows in the Murrumbidgee River downstream of Hay Weir. Maude Weir also provides a pumping pool for use by the Maude community.

The weir is a regulating structure with three vertical lift gates that partially open to release flows downstream as required, at other times the gates remain closed throughout the year in all but flooding conditions. At these times the gates are gradually opened as high flows are expected down the Murrumbidgee River to prevent overtopping of the weir and potential structural failure.

5.4 Ecological Considerations

Fish passage may be possible when the gates are infrequently raised clear of the water for maintenance, however the timing of this operation may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Murrumbidgee River (spring and early summer). The Murrumbidgee CMA Blueprint has identified fish passage as a key element to restoring the riverine environment to favour native fish over introduced species such as carp.

The following native fish species were identified in the report "*Fish Communities of the Murrumbidgee Catchment: status and trends*" (Gilligan 2005) and are historically expected to occur throughout the Murrumbidgee Catchment: freshwater eels, fly specked hardyhead, two spined blackfish, river blackfish, mountain galaxias, flat-head galaxias, western carp gudgeon, Midgley's carp gudgeon, Lake's carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbowfish, short-headed lamprey, southern pygmy perch, bony herring, flatheaded gudgeon,

dwarf flat-headed gudgeon, Australian smelt, and freshwater catfish. The following threatened species were also identified: silver perch, olive perchlet, Murray hardyhead, trout cod, southern purple spotted gudgeon, and Macquarie perch. Since European settlement, the following species have been introduced into the Murrumbidgee system: goldfish, common carp, eastern gambusia, oriental weatherloach, rainbow trout, brown trout and redfin perch – all of which have a direct or indirect on native fish populations.

During sampling for the above mentioned study (Gilligan 2005), only 13 of the 20 species known to have historically occurred in the Murrumbidgee Catchment were sampled, indicating that some species may have become locally extinct, whilst the abundance of others is declining. The fish community of the Murrumbidgee Catchment is described by Gilligan (2005) as severely degraded and he recommends that the CMA undertake to address the following issues as identified in the Native Fish Strategy (2003): rehabilitation of instream and riparian vegetation; rehabilitation of wetlands; eliminating cold water pollution; improving environmental flow management; reinstating fish passage; contributing to the control of alien species; and ensuring community ownership and support.

While the vertical lift gates remain closed at Maude Weir, fish passage is not possible. In addition, the weir is an undershot weir, which is known to have negative impacts on fish larvae (up to 40% mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002; NSW DPI *in prep*). It is therefore important that we understand the effect of weirs on fish communities so that we can better manage them to assist in the protection of native fish in the entire Murrumbidgee Catchment.

At the time of the inspection the banks upstream and downstream of the weir were moderately vegetated (Figure 5.2). The dominant vegetation cover was casuarinas and river red gums, with willows covering the banks upstream and downstream of the weir. The reinstatement of fish passage at this site should be undertaken in conjunction with a fish habitat rehabilitation project to address willow control and encourage native revegetation through riparian fencing.

A) B)

FIGURE 5.2: Murrumbidgee River A) downstream and B) upstream of Maude Weir

5.5 Proposed Remediation Actions

Maude Weir is still required and removal is not considered a viable option. State Water is in the process of reviewing their existing infrastructure within the Murrumbidgee Catchment. Recommendations made as a result of this report will be

further discussed with State Water to determine a solution that will improve fish passage at this site.

The weir is a major barrier to fish passage except when the gates are lifted free of the water. It is recommended that fish passage options be further investigated at this site, and the options for improved management of the vertical lift gates be assessed.

- **Option 1 – Deelder Fishlock**
  A Deelder Fishlock is a low level lock fishway which operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishlock operates by attracting fish through an entrance similar to that of a pool type fishway; however, instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris 2000). The holding area where the fish accumulate is then sealed and water is directed into the chamber until water levels are equal to the upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

  The Deelder Fishlock design is considered a cost effective option for fish passage and, up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch and the threatened silver perch. The outcome of the subsequent monitoring at this site has proved that "the Deelder fishlock was extremely effective at providing passage for Australian native fish under low flow conditions" (Baumgartner 2003). Monitoring of fish passage at this site continues and will observe fish passage under various flow conditions to determine whether this design is applicable for other sites across NSW.

  Further investigations into Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River including Berembed and Yanco Weirs, both of which currently have ineffective, submerged orifice fishways. As with Balranald Weir, the Deelder fishlock could be incorporated into the existing fishways at both these weirs at a relatively low cost.

  It is possible that the Deelder fishlock design could be applied to Maude Weir. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock at Balranald has already proven to be effective in passing a wide range of native fish species and size classes during low flow periods. It should be understood that the cost of constructing a Deelder fishlock at Maude Weir would be much greater than at other sites due to the lack of existing fishway infrastructure that would allow the Deelder fishlock to be retrofitted. The overall cost associated with the Deelder fishlock however, would be less than the vertical slot fishway as fewer construction materials would be required.

- **Option 2 – Vertical Slot Fishway**
  The construction of a vertical slot fishway at Maude Weir is likely to be the most effective option for this site. Vertical slot fishways are considered one of the most effective fishway designs due to their ability to operate at sites with varying headloss, and is the preferred option where threatened species are

present (as many as seven threatened species are expected to occur at this site). The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on $150,000 per vertical metre and is dependant on site location, access and various structural and hydrological conditions. The fishway should be constructed on the side that has the easiest access for construction and ongoing maintenance.

5.6 Projected Remediation Costs

The values for the cost of the remediation options at this site provided below should be taken as an estimate only.

Projected cost	$50K - $150K	$150K - $300K	$300K - $500K	> $500K-1M	>$1M
Option 1				✔	
Option 2					✔

5.7 Recommendation

It is recommended that a Vertical Slot Fishway (Option 2) be further investigated for this site, as it would provide the most effective solution to fish passage. A Deelder fishlock (Option 1) could also be considered however Maude Weir is 5.6m in height, which is nearing the maximum height recommended for the Deelder fishlock (six metres). In addition, appropriate management of the vertical lift gates to limit their effect on fish larvae is also a priority for this site. During low diversion periods (during the winter months), the vertical lift gates should be raised clear of the water to reinstate a natural flow regime and effective fish passage. Where possible, investigations should be undertaken to determine if this management option is available during fish migration periods (spring/summer).

5.8 Benefits Associated with Remediation

The Murrumbidgee River and its associate tributaries possess important fish habitat that should be protected. As such, the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Maude Weir, unimpeded access for fish and other aquatic organisms would be provided to potential habitat in excess of 172km upstream and downstream of Maude Weir.

6. REDBANK WEIR, MURRUMBIDGEE RIVER

FIGURE 6.1: Redbank Weir, Murrumbidgee River (07.03.2005, 242 ML/day).

6.1 Description and Setting

Redbank Weir (Figure 6.1) is located approximately 58km North of Balranald on the Murrumbidgee River within the Lower Murrumbidgee Catchment. The weir is a regulating structure approximately 5.6 metres high and 80 metres across the length of the crest. It is constructed of concrete and has three steel vertical lift gates. The weir does not have an existing fishway and as such acts as a barrier to fish passage when the vertical lift gates are closed and when the gates are partially raised (as a result of the high water velocities).

Redbank Weir is ranked as a high remediation priority within the Murrumbidgee CMA region due to the following factors:

- Class 1 fish habitat - major, permanently flowing waterway and presence of one or more threatened fish species. The site is within the expected distribution range of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizzi*), southern pygmy perch (*Nannoperca australis*), Murray hardyhead (*Craterocephalus fluviatilis*), trout cod (*Macullochella macquariensis*), southern purple spotted gudgeon (*Mogurnda adspersa*), and Macquarie perch (*Macquaria australasica*). Only three of the seven listed threatened species (silver perch, Macquarie perch and trout cod) were found during sampling carried out in 2004. Gilligan (2004) states that it is highly likely the other four species not sampled have become locally extinct within the sample sites used within the Murrumbidgee system;
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);

- Improved stream connectivity: the next upstream barrier to fish is Maude Weir, located approximately 124km away; the next weir downstream is Balranald Weir on the Murrumbidgee River approximately 100km away. Both structures are owned and operated by State Water. In 2002 the submerged orifice fishway at Balranald Weir was retrofitted with a Deelder Fishlock and currently passes a wide range of fish species and size classes (effectively providing fish passage in the Murrumbidgee River downstream of Redbank Weir to the next barrier on the mainstem of the Murray River); and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal). Redbank Weir never experiences structural drown out (where water flows over the crest).

6.2 Hydrology

Flows within the Murrumbidgee River are regulated by Burrinjuck and Blowering Dams which are located upstream of the Murrumbidgee-Tumut junction. There are five known barriers to fish passage upstream of Redbank Weir on the Murrumbidgee River: Maude Weir, Hay Weir, Yanco Weir, Gogeldrie Weir and Berembed Weir.

Redbank Weir is located downstream of the confluence of the Murrumbidgee and Lachlan Rivers.

The closest DNR river gauge is located downstream of Redbank Weir on the Murrumbidgee River (station 410041). Information with regard to flows within the Murrumbidgee River downstream of Redbank Weir can be sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and describes data acquired between 12.11.1974 – 10.11.2005.

6.3 Operational Details

Redbank Weir is owned and operated by State Water. The Weir was built in 1939 to regulate flows in the Murrumbidgee River for irrigation, stock and domestic use. Redbank Weir provides diversions to Lowbidgee Flood Control and Irrigation District (FC&ID). As with Maude Weir, Redbank Weir is a dual purpose weir, with re-regulatory and diversionary functions. When the weir is not diverting flows to the FC&ID (outside winter and spring), it re-regulates flows in the Murrumbidgee River downstream of Maude Weir. Redbank Weir is regarded as a “full sister” to Maude Weir as it is very similar in construction and purpose.

The weir is a regulating structure with three vertical lift gates which partially open to release flows downstream as required. At other times the gates remain closed throughout the year in all but flooding conditions, when the gates are gradually opened as high flows are expected down the Murrumbidgee River to prevent overtopping and potential structural failure of the weir.

6.4 Ecological Considerations

Some fish passage may be possible when the gates are infrequently raised clear of the water for maintenance, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Murrumbidgee River (spring and early summer). The Murrumbidgee CMA Blueprint has identified fish passage as a key element to restoring the riverine environment to favour native fish over introduced species such as carp.

The following native fish species were identified in the report "*Fish Communities of the Murrumbidgee Catchment: status and trends*" (Gilligan 2005) and were historically expected to occur throughout the Murrumbidgee Catchment: freshwater eels, fly specked hardyhead, two spined blackfish, river blackfish, mountain galaxias, flat-head galaxias, western carp gudgeon, Midgley's carp gudgeon, Lake's carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbowfish, short-headed lamprey, southern pygmy perch, bony herring, flatheaded gudgeon, dwarf flat-headed gudgeon, Australian smelt, and freshwater catfish. The following threatened species have also been identified: silver perch, olive perchlet, Murray hardyhead, trout cod, southern purple spotted gudgeon, and Macquarie perch. Since European settlement, the following species have been introduced into the Murrumbidgee catchment: goldfish, common carp, eastern gambusia, oriental weatherloach, rainbow trout, brown trout and redfin perch- all of which have a direct or indirect effect on the native fish population.

During sampling for the above mentioned study (Gilligan 2005), only 13 of the 20 species known to have historically occurred in the Murrumbidgee Catchment were sampled, indicating that some species may have become locally extinct and the abundance of others is declining. The fish community of the Murrumbidgee Catchment is described by Gilligan (2005) as severely degraded and recommends that the CMA undertake to address issues identified in the Native Fish Strategy (2003) including: rehabilitation of instream and riparian vegetation; rehabilitation of wetlands; eliminating cold water pollution; improving environmental flow management; reinstating fish passage; contributing to the control of alien species; and ensuring community ownership and support.

While the vertical lift gates remain closed at Redbank Weir, fish passage is not possible. In addition, the weir is an undershot weir, which is known to have negative impacts on fish larvae(up to 40% mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002; NSW DPI *in prep*). It is therefore important that we understand the effect of weirs on fish communities so that we can better managed them to assist in the protection of native fish in the entire Murrumbidgee Catchment.

At the time of the inspection the banks downstream of the weir were eroded with minimal vegetation cover (Figure 6.2). The dominant overstory vegetation cover was river red gums, and willows were present upstream from the weir. The reinstatement of fish passage at this site should be undertaken in conjunction with a fish habitat rehabilitation project to address willow control and encourage native revegetation through riparian fencing.

A) B)

FIGURE 6.2: Murrumbidgee River A) downstream and B) upstream of Redbank Weir

6.5 Proposed Remediation Actions

Redbank Weir is still required, with its removal not considered a viable option. State Water is currently in the process of reviewing their existing infrastructure within the Murrumbidgee Catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

The weir is a major barrier to fish passage except when the gates are lifted free of the water. As a result it is recommended that fish passage options be further investigated at this site, and options for improved management of the vertical lift gates be assessed.

- **Option 1 – Deelder Fishlock**
  A Deelder Fishlock is a low level lock fishway which operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishlock operates by attracting fish through an entrance similar to that of a pool type fishway; however, instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris 2000). The holding area where the fish accumulate is then sealed and water is directed into the chamber until water levels are equal to the upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

  The Deelder fishlock design is considered a cost effective option for fish passage and, up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch and the threatened silver perch. The outcome of the subsequent monitoring at this site has proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low flow conditions” (Baumgartner 2003). Monitoring of fish passage at this site continues and will observe fish passage under various flow conditions to determine whether this design is applicable for other sites across NSW.

  Further investigations into Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River including Berembed and Yanco Weirs, both of which currently have ineffective, submerged orifice fishways. As with Balranald Weir, the Deelder fishlock at both these weirs could be incorporated into the existing fishways at a relatively low cost.

  It is possible that the Deelder fishlock design could be applied to Redbank Weir. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock at Balranald has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods. As with Maude weir, it should be understood that the cost of constructing a Deelder fishlock at Redbank Weir would be much greater than at other sites due to the lack of existing fishway infrastructure that would allow the Deelder fishlock to be retrofitted.

- **Option 2 – Vertical Slot Fishway**
  The construction of a vertical slot fishway at Redbank Weir is likely to be the most effective option for this site. Vertical slot fishways are considered one of the most effective fishway designs due to their ability to operate at sites with varying headloss, and is the preferred option where threatened species are present (as many as seven threatened species are expected to occur at this site). The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on $150,000 per vertical metre and is dependant on site location, access and various structural and hydrological conditions. The fishway should be constructed on the side that has the easiest access for construction and ongoing maintenance. The value below should be taken as an estimate only.

6.6 Projected Remediation Costs

The values for the cost of the remediation options at this site provided below should be taken as an estimate only.

Projected cost	$50K - $150K	$150K - $300K	$300K - $500K	$500K-1M	>$1M
Option 1				✔	
Option 2					✔

6.7 Recommendation

It is recommended that a Vertical Slot Fishway (Option 2) be further investigated for this site, as it would provide the most effective solution to fish passage. A Deelder fishlock (Option2) could also be considered, however Redbank Weir is 5.6m in height, which is nearing the maximum height recommended for the Deelder fishlock (six metres). In addition, appropriate management of the vertical lift gates to limit their effect on fish larvae is also a priority for this site. During low diversion periods (during the winter months), the vertical lift gates should be raised clear of the water to reinstate a natural flow regime and effective fish passage. Where possible, investigations should be undertaken to determine if this management option is available during fish migration periods (spring/summer).

6.8 Benefits Associated with Remediation

The Murrumbidgee River and its associate tributaries possess important fish habitat that should be protected. As such, the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Redbank Weir, unimpeded access for fish and other aquatic organisms would be provided to potential habitat in excess of 224km upstream and downstream of Redbank Weir.

7. YANCO WEIR, MURRUMBIDGEE RIVER

FIGURE 7.1: Yanco Weir (09.03.2005, 2380 ML/day).

7.1 Description and Setting

Yanco Weir (Figure 7.1) is located approximately 30km downstream of Narrandera on the Murrumbidgee River within the Mid Murrumbidgee Catchment. The weir is a regulating structure approximately 3.8 metres high and 40 metres across the length of the crest. It is constructed of concrete and has two steel vertical lift gates. The weir also has an ineffective submerged orifice fishway, which is currently ineffective in passing fish. As such, the weir acts as a barrier to fish passage during flows less than approximately 25,000ML/day. When flows are less than this the weir restricts fish due to excessive head loss, velocity and increased turbulence across the face of the structure. When the vertical lift gates are closed there is no fish passage possible. Similarly, when the gates are partially raised, high water velocities and turbulence experienced through the gates are too great to allow the upstream passage of fish.

Yanco Weir is ranked as a high remediation priority within the Murrumbidgee CMA region due to the following factors:

- Class 1 fish habitat - major, permanently flowing waterway and presence of one or more threatened fish species. The site is within the expected distribution range of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizzi*), southern pygmy perch (*Nannoperca australis*), Murray hardyhead (*Craterocephalus fluviatilis*), trout cod (*Macullochella macquariensis*), southern purple spotted gudgeon (*Mogurnda adspersa*), and Macquarie perch (*Macquaria australasica*). Only three of the seven listed threatened species (silver perch, Macquarie perch and trout cod) were found during sampling carried out in 2004. Gilligan (2004) states that it is highly likely that the other four species not sampled have become locally extinct within the Murrumbidgee system;

- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: the next upstream barrier to fish is Berembed Weir, located approximately 65km away; next barrier downstream is Gogeldrie Weir on the Murrumbidgee River 30km away. Both structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

7.2 Hydrology

Flows within the Murrumbidgee River are regulated by Burrinjuck and Blowering Dams which are located upstream of the Murrumbidgee-Tumut junction. There is one known barrier to fish passage upstream of Yanco Weir on the Murrumbidgee River: Berembed Weir.

The closest DNR river gauge is located downstream of Yanco Weir on the Murrumbidgee River (station 410036). Information with regard to flows within the Murrumbidgee River downstream of Yanco Weir can be sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and describes data acquired between 05.11.1974 – 23.06.2005.

Yanco Weir prevents fish passage during most flow conditions; although Baumgartner (2005) estimates that the weir in its current condition would drown out with flows in excess of 25,000ML/day. The time weighted flow duration curve for the Murrumbidgee River downstream of Yanco Weir indicates that flows would exceed 25,000ML/day less than 4% of the time. In addition, current operation of the regulating gates may influence the possibility of structure overtopping.

7.3 Operational Details

Yanco Weir is owned and operated by State Water. The original weir was built in 1920 to divert water into the effluent Yanco and Colombo Creeks for irrigation, stock and domestic purposes. The weir is comprised of two components: the main weir (built in 1980) is constructed of concrete with two electronically operated sluice gates, approximately 12 metres wide and 3.8 metres high; the second section (the original weir, which is separated from the main weir by an island), is a fixed crest concrete structure approximately 76 metres long and 3.8 metres high. The second section acts to prevent flow through that part of the river channel except during flood conditions.

Currently the gates remain closed throughout the year except for a short time in winter and during flooding conditions. At these times the gates are gradually opened as high flows are expected down the Murrumbidgee River to prevent overtopping of the weir and potential structural failure.

The weir currently has a non-functioning submerged orifice fishway located on the left hand side of the vertical lift gates. This fishway was built in 1980 during the construction of the weir and was based on the European designs which aimed to pass salmonoid fish species. Such designs have since been recognised as ineffective in passing native fish species.

In September 2005 a fish pump trial commenced at Yanco Weir to determine whether a hydraulic device currently used in aquaculture practices could be applied to weirs like Yanco Weir to facilitate the movement of native fish upstream past the barrier. The trials associated with this study have not yet been completed.

7.4 Ecological Considerations

Fish passage at Yanco weir may possible less than 4% of the time (dependant on the operation of the gates) in addition, the timing when fish passage is possible may not coincide with spawning migrations of all or any of the resident fish species within the Murrumbidgee River (spring and early summer). Although the weir has a fishway, NSW DPI and the Murrumbidgee Catchment Blueprint have identified it as ineffective. Fish passage has been addressed as a key element to restoring the riverine environment to favour native fish over introduced species such as carp in the blueprint.

The following native fish species were identified in the report "*Fish Communities of the Murrumbidgee Catchment: status and trends*" (Gilligan 2005) and are historically expected to occur throughout the Murrumbidgee Catchment: freshwater eels, fly specked hardyhead, two spined blackfish, river blackfish, mountain galaxias, flat-head galaxias, western carp gudgeon, Midgley's carp gudgeon, Lake's carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbowfish, short-headed lamprey, southern pygmy perch, bony herring, flatheaded gudgeon, dwarf flat-headed gudgeon, Australian smelt, and freshwater catfish. The following threatened species were also identified: silver perch, olive perchlet, Murray hardyhead, trout cod, southern purple spotted gudgeon, and Macquarie perch. Since European settlement, the following species have been introduced: goldfish, common carp, eastern gambusia, oriental weatherloach, rainbow trout, brown trout and redfin perch – all of which have a direct or indirect effect on native fish populations.

During sampling for the above mentioned study (Gilligan 2005), only 13 of the 20 species known to have historically occurred in the Murrumbidgee Catchment were sampled, indicating that some species may have become locally extinct and the abundance of others is declining. The fish community of the Murrumbidgee Catchment is described by Gilligan (2005) as severely degraded and recommends that the CMA undertake to address issues identified in the Native Fish Strategy (2003) including: rehabilitation of instream and riparian vegetation; rehabilitation of wetlands; eliminating cold water pollution; improving environmental flow management; reinstating fish passage; contributing to the control of alien species; and ensuring community ownership and support.

While the vertical lift gates remain closed at Yanco Weir, fish passage is not possible. In addition, the weir is an undershot weir, which is known to have negative impacts on fish larvae (up to 40% mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002: NSW DPI *in prep*). It is therefore important that we understand the effect of weirs on fish communities so that we can better manage them to assist in the protection of native fish in the entire Murrumbidgee Catchment.

At the time of inspection the right hand bank downstream of the weir was eroded with minimal vegetation cover (Figure 7.2), although willows were present upstream and downstream of the weir. The reinstatement of fish passage at this site should be undertaken in conjunction with a fish habitat rehabilitation project to address willow control and encourage native revegetation through riparian fencing.

A) B)

FIGURE 7.2: Murrumbidgee River A) downstream and B) upstream of Yanco Weir

7.5 Proposed Remediation Actions

The weir is still required, with its removal not considered a viable option. State Water is currently in the process of reviewing their existing infrastructure within the Murrumbidgee Catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

The weir is a total barrier to fish passage except when the gates are lifted free of the water. As a result it is recommended that fish passage options be further investigated at this site, and the options for management of the vertical lift gates be assessed.

- **Option 1 – Retrofit existing fishway with a Denil Insert**
  There is some scope for improvements to the existing fishway that may allow it to function more effectively. In its original state the fishway consisted of a concrete channel with 15 cells at an estimated gradient of 1:6. During site inspections carried out during 2004, the baffles that formed the internal walls had been removed and the fishway was inoperable, alienating fish from the Murrumbidgee River below the structure upstream to Burrunjuck Dam. The required gradient to allow fish passage for native fish species is currently in excess of 1:20. Currently the flows through the gates are creating an attraction flow for fish, which is likely to be impeding their ability to locate the entrance to the fishway.

  Modifications required to increase fish passage at Yanco weir would include the following:

  - Retrofitting the existing fishway channel with a Denil insert. The Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than vertical slot fishways because they can be constructed on steeper slopes with less materials required for their construction (Baumgartner 2005).

  There are limitations with the use of Denil inserts, however. Larnerier (1990) identified Denil fishways as only being effective in passing fish greater than 200mm in length. Mallen Cooper (2000) recommended Denil fishways be constructed on slope no greater than 1:12, as slopes greater than this limit

the movement of smaller fish. Experimental work undertaken in NSW has shown that bony herring could ascend Denil fishways with a slope of 1:12; however their movement was greatly restricted on steeper slopes. Mallen Cooper (2000) further recommended that the Denil fishway design should not be used where adult Murray Cod are present, as it has not yet been established whether this species will use the Denil design.

The NSW River Survey (1994) identifies a high abundance of both bony herring and Murray cod in the Murrumbidgee River. Despite this, Thorncraft and Harris (2000) recommended that a Denil insert should be considered for Berembed Weir and presented the Deelder Lock fishway as an alternative option.

- **Option 2 – Deelder Fishlock**
  A Deelder Fishlock is a low level lock fishway which operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishlock operates by attracting fish through an entrance similar to that of a pool type fishway; however, instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris 2000). The holding area where the fish accumulate is then sealed and water is directed into the chamber until water levels are equal to the upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

  The Deelder fishlock design is considered a cost effective option for fish passage and, up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch and the threatened silver perch. The outcome of the subsequent monitoring at this site has proved that "the Deelder fishlock was extremely effective at providing passage for Australian native fish under low flow conditions" (Baumgartner 2003). Monitoring of fish passage at this site continues and will observe fish passage under various flow conditions to determine whether this design is applicable for other sites across NSW.

  Further investigations into Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River including Berembed and Yanco Weirs, which currently have ineffective, submerged orifice fishways. As with Balranald Weir, the Deelder fishlock at both these weirs could be incorporated into the existing fishways at a relatively low cost.

  It is therefore possible that the Deelder fishlock design could be applied to Yanco Weir. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock at Balranald has already proven to be effective in passing a wide range of native fish species and size classes during low flow periods.

- **Option 3 – Vertical Slot Fishway**
  The construction of a vertical slot fishway at this site would be the most effective but also the most expensive option for this site. Vertical slot fishways are considered one of the most effective fishway designs due to

their ability to operate at sites with varying headloss, and are the preferred option where threatened species are present (as many as seven threatened species are expected to occur at this site). The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway (below) is based on $150,000 per vertical metre, although this is dependant on site location, access and various structural and hydrological conditions. The value below should be taken as an estimate only. To minimise cost, it may therefore be more appropriate to build the vertical slot fishway on the concrete weir spillway, rather than the main gated weir. Provided a low flow channel and associated attraction flow could be created at the concrete weir, it would be a viable option. In addition, access to the main weir would not be compromised provided a steel grate could be placed over the fishway exit (upstream end).

7.6 Projected Remediation Costs

The values for the cost of the remediation options at this site provided below should be taken as an estimate only.

Projected cost	$50K - $150K	$150K - $300K	$300K - $500K	> $500K-1M	>$1M
Option 1		✔			
Option 2			✔		
Option 3				✔	

7.7 Recommendation

It is recommended that a Deelder fishlock (Option 2) be further investigated at this site. In addition, appropriate management of the vertical lift gates to limit their effect on fish larvae is also a priority for this site. During low diversion periods (during the winter months), the vertical lift gates should be raised clear of the water to reinstate a natural flow regime and effective fish passage. Where possible, investigations should be undertaken to determine if this management option is available during fish migration periods (spring/summer).

7.8 Benefits Associated with Remediation

The Murrumbidgee River and its associate tributaries possess important fish habitat that should be protected. As such, the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Yanco Weir unimpeded access for fish and other aquatic organisms would be provided to potential habitat in excess of 95km upstream and downstream of Yanco Weir.

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6. APPENDICES

Appendix A: Detailed Weir Assessment Proforma

Please note: It is important to complete as much of this form as possible in the office to avoid unnecessary delays in the field.

PRELIMINARY QUESTIONS: Fish Passage

1. Is the structure a barrier to fish passage (a drop of 10cm can create a barrier, as can high velocities through round piped culverts) **YES**/ NO.

(i) Please describe (eg. Drop >10cm, Slope >1:20, Increased velocity, Increased turbulence, Debris, Minimum Flow depth (<200mm)……..

(ii) Significance of the structure as a barrier to fish passage: headloss (height of fall from headwater to tailwater)……..cm

(iii) Description of water flow over structure

Vertical fall/ steep cascade/ moderate cascade/ gentle incline/ high velocity through pipe/ moderate velocity through pipe/ other……..

Date of review :

Name of Reviewer :

Contact phone No:

SECTION 1 OWNERSHIP AND LICENCE INFORMATION

1a *Barrier/ Structure location information:*

Name of weir:

General directions, landmarks etc:

Name of nearest town:

Grid Reference:

Name of Watercourse:

Catchment Management Area:

Local Government Area:

(it is essential that a topographic map be attached for the location of each weir)

1b *Structure Ownership details:*

Type (eg. private, local Govt., state Govt):

Owner Name: .....

1c *Land Ownership details:*
Owner of land on which structure is built

DIPNR/ State Water/ Crown Land/ Private / Other ……..

Is access to the structure via Easement / Public road / Other ……

Property Boundaries on which structure is located Lot……Dp……

Plan Number/s ……

1d *Contact person for weir assessment details:*

Position Title: Owner name:

Office Address:

Phone: Mobile:

1e *Weir Licence details (if applicable):*

Licence No: .....

Date of issue: ..... Date of expiry: .....

Licensing Office: .....

License Type (stock/domestic/irrigation/other):……..

SECTION 2 STRUCTURAL AND OPERATIONAL DETAILS

2a (i) *Type of Structure* (Please describe):

(ii) *Barrier Construction material:*

Concrete ☐

Earth & rock ☐

Sheet piling ☐ with rock fill ☐ or other ……

Cribwork or gabion modules ☐ with rock fill ☐ or other ……

(cribwork type/material eg. steel or timber)……

2b S*tructure dimensions:*

…….. (m) crest length (length in metres at the weir crest)

…….. (m) vertical height (from the downstream toe to weir crest)

2c (i) *Barrier type (eg. fixed or adjustable release structure):*

Fixed Crest Structure ☐ Adjustable release structure ☐

(ii) *Release operations (if gated or regulated):*

…….. mechanism (eg. Gates, valves, removable boards, spillway etc.)

..... release frequency

..... duration

..... season of opening

(iii) *Additional features of structure (eg. Bottom release valve, skimmer box or siphon outlet configuration – for surface release, existing fishway, navigation lock, spillway, automated operation etc.):*

2d (i) *Is the structure critical to the operations of the property or land use adjacent?*

Yes / No

Please provide brief details:

.....

2d (ii) *Could the current operation of the structure be modified to improve environmental conditions?*

.....

2e (i) *What is the current condition of the structure?*

working ☐ unserviceable ☐ decommissioned ☐

(ii) *In terms of structural stability, does the structure require any of the following?* Yes / No

immediate maintenance ☐ modification ☐ replacement ☐

Please provide details:

SECTION 3 WEIR/BARRIER USE

3a (i) Date of construction:

(ii) Original use or purpose/s (if known):

3b (i) Current purpose/s of the structure (eg. Irrigation, flood control, town water supply, re regulation, domestic, stock, industrial, drought water storage, recreation, river crossing, access). Please comment.

(ii) Additional uses (eg. Recreation, aesthetic, road crossing, environment, boundary fence). Please comment.

3c (i) Number of direct weir pool users (eg. Pumping licences upstream & downstream licenses served)

List Users;

1 …….. 2 ……

3 …….. 4 ……

4 …….. 6 ……

(For more users please use separate sheet)

(ii) Number of licensed customers using weir pool
(Please fill out attached sheet – Appendix 1 to provide details of these customers)

(iii) Number of Riparian Stock and Domestic pumps using weir pool

(iv) Additional beneficiaries of structures (eg. Local community water supply, fishing groups)

3d (i) List any recognised Heritage or cultural values associated with the structure. (Check heritage list)
See Austral & ERM (2003) for details and also check the heritage resister at http://www.heritage.nsw.gov.au.

.....

(ii) List any areas of Aboriginal Heritage significance associated with the structure.

(Contact should be made with local Aboriginal Lands Council & Department Environment & Conservation office to discuss aboriginal issues).

…….....

3e What types of land use operates in the riparian and floodplain zones adjacent to the weir pool?

…….....

…….....

SECTION 4 WEIR SETTING

4a (i) *What is the stream classification of the watercourse at the weir location? (please refer to appendix 2)*

(ii) *How wide is the watercourse upstream of the weir pool (beyond the influence of the weir)?*

(m)

(iii) *Is the watercourse a tributary, anabranch, or floodrunner?*

4b (i) *What is the total catchment area upstream of the weir?*

……..... (sq. km)

(ii) *What is the proportion of the catchment controlled by the weir (upstream to the next river bed obstruction include natural and artificial).*

……..... %

4c (i) *What is the distance upstream of the weir to the next major river bed obstruction (eg. Weir or other barrier)? Please name structure.*

(km) Structure name and/or type

(ii) *What is the distance downstream of the barrier to the next major river bed obstruction (including natural)?*

(km) Structure name and/or type

(iii) *Is the barrier a Coastal River?* Yes / No

If Yes is the barrier a tidal barrage or located in the tidal zone or immediately upstream of the estuary?

Please provide details:

……..

(iv) *Do upstream water users pump freshwater from weir pool? If yes how may they be affected by removal of the structure?(Obtain advise as necessary eg hydrologist)……*

4d *What section of the catchment is the structure located (circle one)?*

Upper *Middle* *Lower*

SECTION 5 HYDROLOGY INFORMATION

5a (i) *What is the average depth of water in the pool immediately upstream of the barrier?*

……..... (m)

5a (ii) *What is the height of the stream banks above the crest of the structure?*

……(m)

5b *Is there a defined weir pool? If yes, how long is it?*

Yes / No (m)

5c (i) *Is there a continuous flow across the crest of the barrier? Or through a pipe, gate or other regulator?*

Yes / No Yes / No

(ii) *Is the stream regulated or unregulated* Regulated / Unregulated

(iii) *How does the flow vary?* (eg daily, seasonally, flood, rainfall)

Comments:

….

5d *How frequently does drownout occur?*

…..... (per year) OR don't know

5e (i) *Is there information on the water quality in the weir pool or releases?* *Yes / No*

If yes where is the information held or located?

….

(ii) *Is there evidence of salinity, acid sulphate soils, scalding, or other soil problems in the vicinity of the weir pool?*

Yes / No / don't know

Please describe:

….

(iii) *Has there been any changes to groundwater levels in the vicinity of the weir pool?*

Yes / No / don't know

SECTION 6 GEOMORPHIC INFORMATION

6a *Are there any signs of bed erosion downstream of the barrier?*

Yes / No / don't know

Comments:

6b (i) *What is the condition of the stream banks adjacent to the barrier?*

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

(ii) *What is the condition of the stream banks upstream of the barrier?*

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

6b (iii) *What is the condition of the stream banks downstream of the barrier?*

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

6c (i) *Is there any evidence of siltation in the weir pool?*

Yes / No / don't know

Please describe:……

(ii) *If yes, what is the difference in bed level on the upstream and downstream side of the barrier wall?*

…..... (m)

(iii) *Has any mining or other associated activities taken place in the catchment upstream of the structure?*

Is there any chance of contaminated sediment behind structure ie. Heavy metals etc?

(Please provide details……

6d (i) *Is there an accumulation of debris around the structure? (eg LWD, sediment, gross pollutants etc)*

Yes / No Please describe

(ii) *If yes, is it causing problems to the structure or operation of gates, spillways or fish ladders associated with the weir?*

Yes / No

Please describe:

……

6e (iii) *Is desnagging carried out upstream of the structure?*

Yes / No / don't know

SECTION 7 ECOLOGICAL CONSIDERATIONS

7a (i) *Does the structure have a fishladder, rock ramp, or some other allowance for fish passage?*

Yes / No structure type: ….....

(ii) *If yes, has there been fish monitoring and/or an inspection to support fish passage?*

Yes / No / don't know

Comments:

(iv) *What native fish species are present or are expected to occur at this site (ie. Refer to guidelines + local knowledge if available).*

……
……

(v) *What introduced fish species are present or are expected to occur at this site (ie. Refer to guidelines + local knowledge).*

……
……

7b (i) *Has there been any outbreak of nuisance aquatic/riparian weeds within the weir pool area eg. lippia, water hyacinth, willows ?*

Yes / No
Comments:.....

(ii) *Have there been any outbreaks of blue-green algae?*

Yes / No/ don't know

If yes, what time of year and how frequently do outbreaks occur?

…..... season …..... (frequency)

7c (i) *How extensive is the vegetation cover on the banks of the river? (<50m from water line).*

Well vegetated ☐ moderately vegetated ☐ poorly vegetated ☐

Dominant species present (including native and introduced):

…..

Please comment on native riparian vegetation and introduced plant species:

…..

(ii) *Is there any evidence of dieback occurring near the weir pool?*

Yes / No

Comments:

…..

…..

7d *What percent of the weir pool area is colonised by aquatic vegetation eg. Phragmites, cumbungi?*

<5% ☐ 5-10% ☐ 10-30% ☐ <30% ☐

Dominant species present (including native and introduced):

…..

7e *Are there any rare and threatened flora and fauna species, populations or communities known to occur in the area?*

Yes / No / Don't know

Comments

……

……

7f (i) *Is the river bank along the weir pool fenced?*

Yes / No / partial one side / both sides

Comments:

…..

(ii) Do stock have access to the river?

Yes / No / partial one side / both sides

Comments:

…..

SECTION 8 RECOMMENDATIONS

8a ***Removal Option*** *YES/ NA (please circle)*

(i) Is the structure required by the adjacent Landholders? Yes / No.

Comments:

…….

(ii) Is the structure required by the Community, fishing club, access, aesthetics? Yes / No.

Comments:

…….

(iii) Is the structure acting as a bed control structure? (Seek advice from DIPNR if unsure)

……

(iv) If the Answer to Question 8 (i)-(iii) is No

Is demolition of the structure supported by owner? Yes / No

Comments:

……

(v) Would any person or group object to the weir being demolished?

Please describe:

…….

…….

(v) Is the weir remote/difficult to access? Yes / No

If Yes, please describe access/location (Is there all weather access?)

……

……

(VI) **ESTIMATED COST OF REMOVAL/PARTIAL (USE COST MATRIX- APPENDIX 3) OR CONTRACTOR QUOTE?**

8b **Fishway options** *YES/ NA (please circle)*

(i) Does the structure lend itself to the addition of a fishway? YES/ NO

(ii) Fishway type best suited to the structure (Please take into account habitat, fish species, hydrology of watercourse)?

Vertical slot/ Full Width Rock Ramp/ Partial Width Rock Ramp/ Denil Insert/ Lock/ Other

(III) ESTIMATED COST OF FISHWAY BASED ON APPROX. $150 000 PER VERTICAL METER?

=

Comments (Include supporting literature and any correspondence with fishway experts):

……

……

……

8c **Modification of Structure to allow for fish passage**

(i) Please describe proposed works (eg. Box culverts etc)?

……

……

(II) ESTIMATED COST OF PROPOSED WORKS

8d **Suggested management action (eg removal of drop boards, gated weir opening, removal of debris)**

Comments (Include supporting literature and correspondence)

……

……

……

……

8e **No action recommended**

Comments (Include supporting literature and correspondence)

……

……

……

……

SECTION 9 ADDITIONAL INFORMATION

For further information:

- Austral Archaeology Pty Ltd & ERM Australia Pty Ltd. (2003) Heritage Assessment of 206 River Structures, Coastal and Central Regions, NSW, (Final Report and Appendix A: Group Two, Volume One).
- NSW DPI (Fisheries). Aquatic Habitat Rehabilitation database.
- Pethebridge, R., Lugg, A. and Harris, J. (1998) Obstructions to fish passage in New South Wales south coast streams. Final report series No 4. Cooperative Research Centre for Freshwater Ecology, NSW Fisheries, Cronulla NSW. ISSN 1440-3544
- Williams R.J., and Watford F.A. (1996) An inventory of impediments to tidal flow in NSW estuarine fish habitats *Wetlands (Australia)* 15, 44-54.

Appendix B: Weir Prioritisation Scheme for the Murrumbidgee CMA Region

INITIAL PRIORITISATION					
A) STREAM HABITAT VALUE					**SCORE**
Primary aquatic habitat rating					
Habitat Class	1	2	3	4	
Location in the system	Lower	Middle	Upper		
Downstream obstructions	0	1-2	3 - 5	> 5	
Habitat opened if remediated	> 100 km	50 – 100 km	20 - 50 km	10 - 20 km	< 10 km
B) STRUCTURE IMPACT CRITERIA					
Environmental effect rating					
Physical barrier: Headloss	> 2000 mm	1000 - 2000 mm	500 – 1000 mm	100 - 500 mm	
Drown out frequency per annum	> 4	2 - 4	1		
SECONDARY PRIORITISATION					
C) ENVIRONMENTAL CRITERIA					
Secondary aquatic habitat rating					
Instream habitat condition	Good	Fair	Poor		
Riparian condition	Good	Fair	Poor		
Siltation	None	Minor	Major		
Threatened species	Habitat Class 1-2	Habitat Class 3	None		
D) MODIFICATION CRITERIA					
Structure use and remediation cost					
Maintenance Required	Yes	No			
Redundant Weir	Yes	No			
Ease of Remediation	Removal	Modification	Fishway installation		
Ancillary uses	Flood mitigation	Bed Control	Recreation		
				TOTAL	

Appendix C.1: Freshwater Fish in the Murrumbidgee NSW

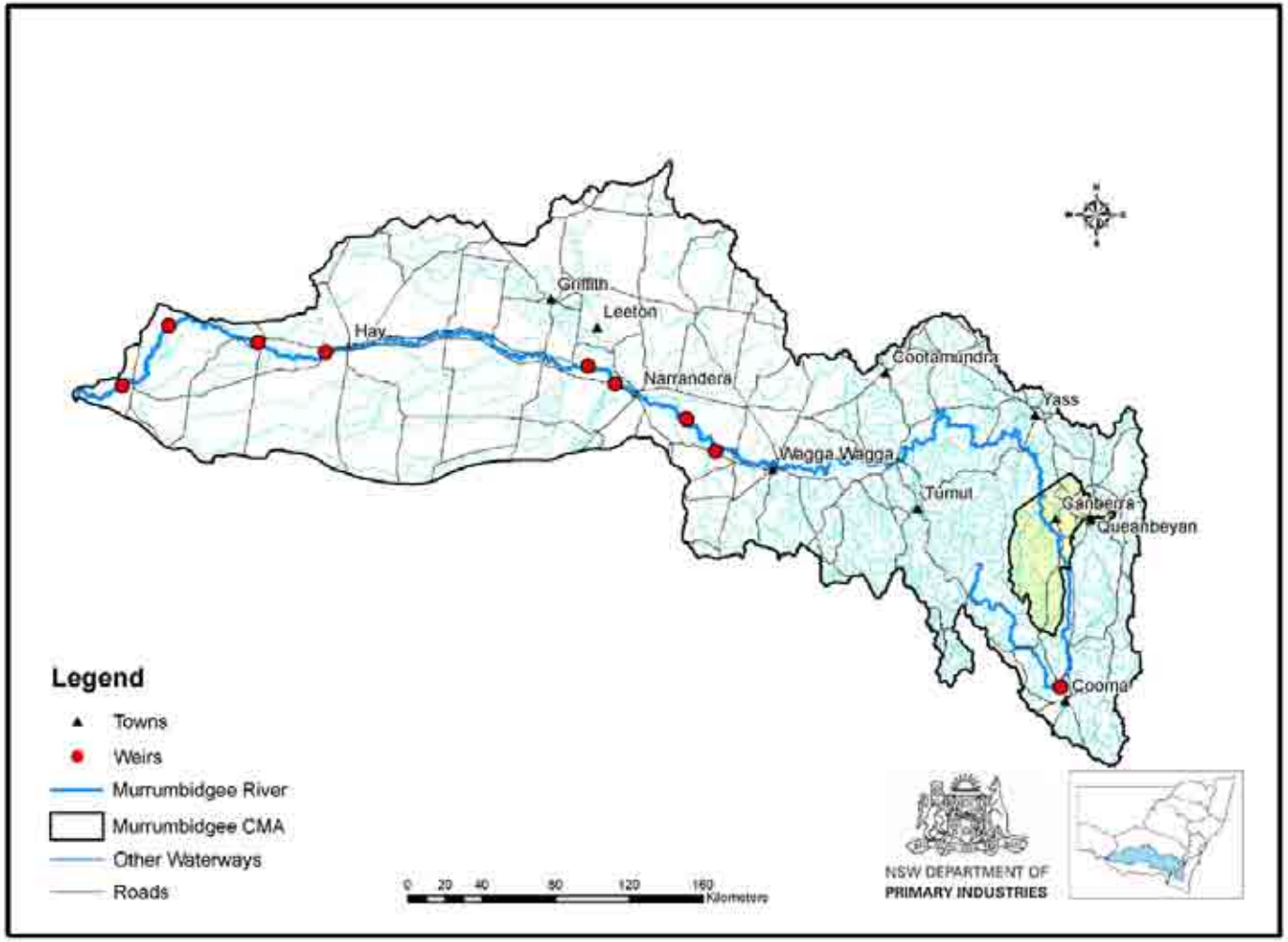
Scientific Name	Common Names	Status	Migration and habitat
Ambassis agassizii	Olive perchlet	Threatened species (Endangered western population)	Local migration; Freshwater streams and swamps in lowland and slope environments
Bidyanus bidyanus	Silver perch	Threatened species (vulnerable - FM Act)	Large scale migration; Habitat is predominantly in lowland and slope waterways
Craterocephalus fluviatilis	Murray hardyhead	Endangered species	Once widespread, now found in lowland rivers, lakes and billabongs.
Craterocephalus stercusmuscarum	Flyspecked hardyhead	Unknown	Local migration; Freshwater streams in lowland habitat
Gadopsis marmoratus	River blackfish	Common	Local migration; Widespread in slope and montane waterways
Galaxias olidus	Mountain galaxias	Common	Local migration; Moderate and high elevations in coastal and inland rivers
Galaxius rostratus	Murray jollytail	Not particularly common	More likely at lower elevations within Murray-Darling system.
Hypseleotris klunzingeri	Western carp gudgeon	Common	Unknown migration; Common in lowland and slope waterways
Hyseleotris sp.1	Midgley's Carp Gudgeon	Common	Northern section of Murray-Darling system
Hyseleotris sp.2	Lake's Carp Gudgeon	Relatively common	Streams, backwaters and drains of northern Murray-Darling system
Leiopotherapon unicolor	Spangled perch	Common	Local migration; Warm waters in inland streams, backwaters and dams
Maccullochella macquariensis	Trout cod	Endangered Species –	Formerly widespread throughout catchment, now found largely due to stocking programs.
Maccullochella peelii peelii	Murray cod	Threatened Species – vulnerable (EPBC)	Local migration; Habitat predominantly in lowland and slope waterways
Macquaria ambigua	Golden perch	Relatively common	Large scale migration; Common in lowland and slope waterways
Macquaria australasica	Macquarie perch	Vulnerable	More common in upper reaches of rivers and tributaries
Melanotaenia fluviatilis	Murray River rainbowfish	Relatively common	Local migration; Waters in lowland and slope environments
Mogurnda adspersa	Purple-spotted gudgeon	Threatened Species (Endangered Western Population)	Local migration; Waters in lowland and slope environments
Nannoperca australis	Southern pygmy perch	Vulnerable	Well vegetated small streams, lakes, billabongs and wetlands.
Nematalosa erebi	Bony herring	Relatively common	Local migration; Waterways of lowland and slope environments
Philypnodon grandiceps	Flathead gudgeon	Unknown	Uncertain; Lowland and slope waterway environments
Retropinna semoni	Australian smelt	Common	Local migration; Common in lowland and slope waterways
Tandanus tandanus	Freshwater catfish	Relatively Common	Local migration; Lowland lakes and slow-flowing rivers

Appendix C.2: Introduced Freshwater Fish in the Murrumbidgee, NSW

Scientific Name	Common Names	Status	Migration and habitat
Carassius auratus	Goldfish	Exotic	Local migration; Widespread in lowland rivers
Cyprinus carpio	Common carp	Exotic (Noxious)	Local migration; Still gentle flowing rivers, being abundant in weir pool environments
Gambusia holbrooki	Gambusia	Exotic (Noxious)	Unknown migration; Widespread throughout inland waterways of NSW
Misgurnus anguillicaudatus	Oriental weatherloach	Exotic	Highly invasive, can move overland, aquarium release.
Oncorhynchus mykiss	Rainbow trout	Exotic (Stocked)	Local migration; Associated with cold water below or in impoundments
Perca fluviatilis	Redfin perch	Exotic (Noxious)	Local migration; Associated with cold water below or in impoundments
Salmo trutta	Brown trout	Exotic (Stocked)	Local migration; Montane regions along the Great Dividing Range

Sources: Thorncraft & Harris (2000), McDowall (1996), Allen *et al.* (2002) and Yearsley *et al.* (2001).

Appendix D: Location of Priority Weirs in the Murrumbidgee CMA, NSW



Appendix E: Summary of Weirs Assessed In Murrumbidgee Detailed Weir Review

Priority Rank	Barrier Name	GPS Coordinates (degrees decimal)	Watercourse	Ownership	Construction date	Dimensions (height X width m)	Operational Fishway	Recommendation	Estimated Cost $$ of preferred option	Estimated Cost $$ of alternative option
1	Beavers Creek Weir	(35.064144, 147.126740)	Beavers Creek/ Old Man Creek	State Water	1920	2.5 x 22	No	Vertical Slot Fishway	$300-500K	$200-300K
2	Berembed Weir	(-34.879377, 146.836695)	Murrumbidgee River	State Water	1910	4.5 x 68	No, Submerged Orifice	Deelder Fishlock	$500K - $1M	$300-500K
3	Yanco Weir	(-34.703395, 146.416957)	Murrumbidgee River	State Water	1920	3.8 x 40	No, Submerged Orifice	Deelder Fishlock	$300-500K	$500K-$1M
4	Gogeldrie Weir	(-34.616531, 146.257147)	Murrumbidgee River	State Water	1959	6.1 x 12.2	No	Deelder Fishlock	$500K-$1M	>$1M
5	Hay Weir	(-34.524777, 144.713086)	Murrumbidgee River	State Water	1981	6.0 x 40	No, Submerged Orifice	Deelder Fishlock	$300-500K	$500K-$1M
6	Maude Weir	(-34.476277, 144.304199)	Murrumbidgee River	State Water	1939	5.6 x 50	No	Vertical Slot Fishway	$500K-1M	>$1M
7	Redbank Weir	(-34.378674, 149.783153)	Murrumbidgee River	State Water	1939	5.6 x 80	No	Vertical Slot Fishway	$500K-1M	>$1M
N/A	Balranald Weir	(-34.665179, 143.492902)	Murrumbidgee River	State Water			Yes	Deelder Fishlock completed in 2002. Ongoing Monitoring required.	approx. $300K	N/A
N/A	Cooma Weir	(-36.168192, 149.093373)	Murrumbidgee River	Monaro Shire Council			Yes	Partial Width Rock Ramp completed in 2000. Ongoing Monitoring required.	N/A	N/A


aquatic habitat rehabilitation
making more fish
...naturally