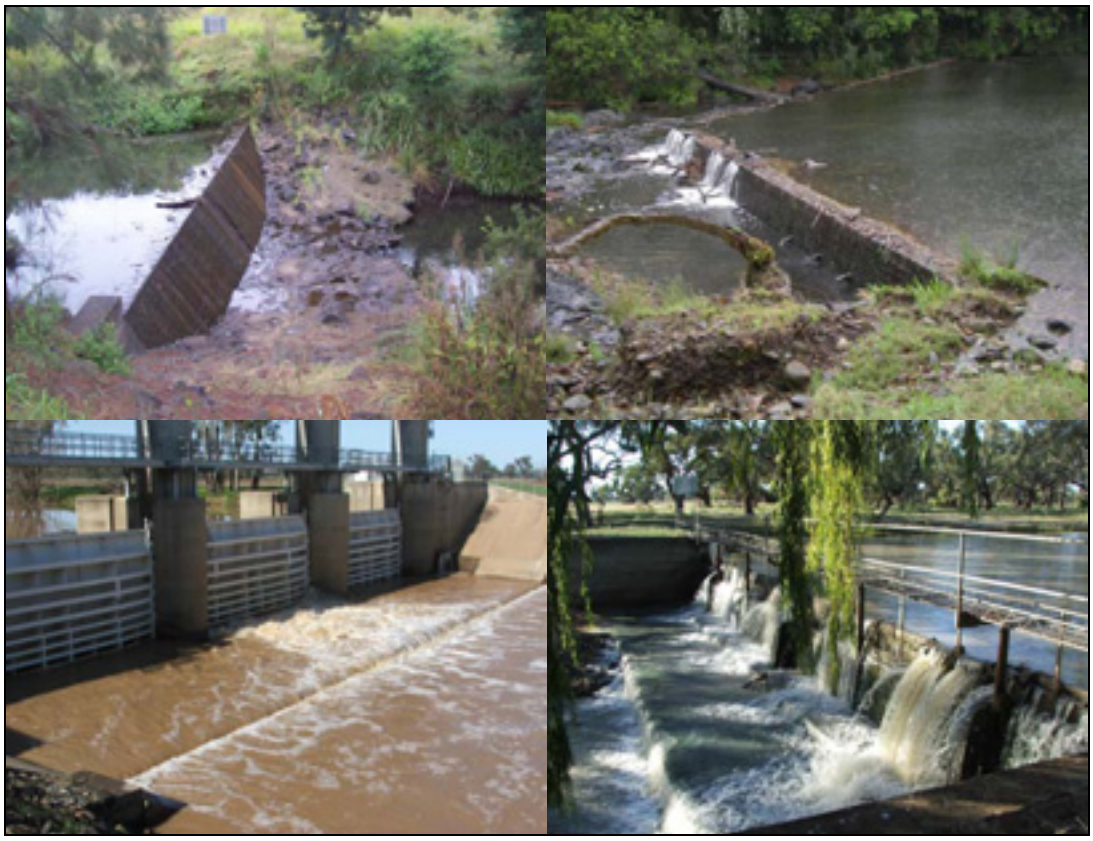
REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW



REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

CENTRAL WEST CMA REGION

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Environmental TRUST

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The information contained in this publication is based on knowledge and understanding at the time of writing (July 2006). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check the currency of the information with the appropriate officer of NSW Department of Primary Industries or the user‘s independent adviser.

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Cover photos: Cob-o-corn Weir, Cob-o-corn Creek, Northern Rivers CMA (upper left); Stroud Weir, Karuah River, Hunter/Central Rivers CMA (upper right); Mollee Weir, Namoi River, Namoi CMA (lower left); and Hartwood Weir, Billabong Creek, Murray CMA (lower right).

EXECUTIVE SUMMARY

The highly modified nature of catchments in NSW 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 and between estuarine and freshwater environments. Unfortunately, riverine connectivity has been severely disrupted within Australia through the installation of numerous instream structures that impede the natural flow regime and act as physical, hydrological, and behavioural barriers to fish movement. In NSW alone, several thousand weirs, dams and poorly designed road crossings exist on waterways, 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 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 109 weir structures within the 13 CMA regions of NSW were selected for Detailed Weir Reviews, with a thorough assessment of each structure undertaken. The individual detailed review reports presented in this project provide a comprehensive overview of each structure including operational details, system hydrology, ecological considerations, and the preferred remediation option of NSW DPI for improving fish passage at the weir.

As a primary recommendation, NSW DPI encourages the removal of redundant structures from waterways, with weir removal providing the greatest benefit to the health of the waterway by enabling unrestricted fish passage and reinstatement of natural sediment fluxes within a system. However, due to the requirement for regulation of flows and impoundment of water for irrigation purposes in many areas of NSW, removal of certain structures cannot be proposed as a primary remediation option. Recommendations put forth by NSW DPI to remediate or remove the weirs inspected throughout the NSW catchments as part of the Detailed Weir Review Project are supported by the NSW *State Weirs Policy*.

ACKNOWLEDGEMENTS

This project was funded through the Environmental Trust Program 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 preparation were: Milly Hobson, Shaun Morris, Matthew Gordos, Charlotte Grove, Scott Nichols, Cameron Lay, Sharon Molloy, Sam Davis, Adam Vey, and Anthony Townsend, with maps produced by Ben Maddox. In addition, valuable assistance was provided by regional DPI Fisheries Conservation Mangers including Allan Lugg, David Ward, Trevor Daly, Scott Carter, and Pat Dwyer.

Representatives of all NSW Catchment Management Authorities, Department of Natural Resources, State Water, and local government authorities provided extensive advice and assistance 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 catchments of NSW. The project was funded in November 2003 through the NSW Environmental Trust and was managed by the NSW Department of Primary Industries (now incorporating NSW Fisheries).

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, evaluating 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 current project builds on the outcomes of the NSW Initial Weir Review (NSW, Fisheries, 2002) by undertaking detailed reviews for high-priority structures within the thirteen catchments of NSW. 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. This will provide a clear process towards mitigating a structure's environmental impact once funding is secured, with the Detailed Weir Review project also serving 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.

The primary objectives of the project were to:

- Identify high priority weir structures within each CMA region that have a major impact on fish passage and aquatic habitat condition;
- Assess high priority weirs by reviewing social, ecological, cultural and logistical issues that are associated with each structure;
- Prioritise high priority weirs within each CMA region, and;
- Recommend remediation options to improve fish passage at each weir structure.

[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 1000km 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). Instream structures that span the whole channel (e.g. weirs and causeways) can impede natural flows, acting as physical and hydrological barriers to fish movement and isolating upstream and downstream habitats (Williams *et al.* 1996; Pethebridge *et al.* 1998; Thorncraft and Harris 2000; Fairfull and Witheridge 2003). Additionally, levees, floodgates and other off-stream structures (e.g. 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 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 licensed weirs and dams on rivers and streams (NSW Weir Inventory database). 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 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. NSW DPI recently completed a detailed audit of road crossings in coastal catchments (NSW DPI 2006), which highlighted in excess of 1,700 barriers to migrating fish in the coastal waterways of NSW.

In tidal reaches, waterway crossings (especially those over irrigation/agricultural drains) commonly incorporate floodgates that restrict fish passage between flood events. Floodgates include hinge-flap, winch, sluice, and auto-tidal designs; with most of these structures acting as passive one-way valves that aid in draining water from low-lying land behind the gate while excluding tidal ingress. When water levels behind the floodgate are higher than the downstream levels, the gates open and the floodwaters discharge into the estuary. When water levels are elevated on the downstream side of the floodgate however, the structure is forced into the closed position, thus restricting the movement of water and fish into the drain.

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 instream structures 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 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, flow-modified waterways possess reduced native fish fauna diversity, abundance, breeding success and ratio to introduced species when compared to unregulated streams (Gehrke and Harris 2001).

Water quality in reservoirs pose 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, which can affect the distribution of oxygen-sensitive macroinvertebrates and fish species.

The construction of weirs and dams also results in the inundation of streamside habitat. 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 re-establishment of riparian communities at regulated reservoirs is problematic due to widely fluctuating water levels.

Weirs and floodgates 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 is essential to the reproduction of numerous species including silver perch 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. For 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.

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, and 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 present. It should be noted that the initial ranking of barriers was based only on fish passage considerations for the purpose of highlighting high priority weirs that have a significant, deleterious impact upon NSW 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 assessment of every structure was 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).

A total of 1,163 weirs were inspected and assessed in the thirteen NSW catchments as part of the Initial Weir Review (2002), of which 355 were designated as structures requiring further investigation. Of these 355 identified weirs, 109 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 the selection of structures, detailed assessments were performed on priority weirs to supplement and augment information previously obtained in the Initial Weir Review (2002). Detailed analysis involved field and desktop 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[3] 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 (Table 3.1).

NSW DPI applies a ‘Class’ system to assign aquatic habitat values to waterways, as outlined in Table 3.1 (Fairfull and Witheridge 2003). 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 or high quality Class 2 systems.

[3] **Drown out** refers to when a structure is no longer having an impact on the passage of fish within a waterway. At this time, water levels are higher than the structure itself, allowing minimal disruption to water movement, and providing free passage of fish within a system. Compare with **over topped**, which refers to when a structure has water flowing over the top of the weir crest.

All data recorded in the Detailed Weir Review Project was downloaded into the NSW Department of Primary Industries Fish Habitat Database prior to comparative analysis to determine regional remediation priorities for each catchment.

Table 3.1. Classification of fish habitat in NSW waterways (Fairfull and Witheridge 2003).

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.
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 (e.g. 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 (e.g. 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 priority 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 on stream habitat and structural impact criteria, which were viewed as the primary variables affecting fish passage. Stream habitat criteria were based on habitat class, location of the barrier in the catchment, number of downstream obstructions, and the amount of habitat (i.e. stream length in kilometres) 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 the lowest score. Location of the barrier in the catchment (e.g. tidal / lower / middle / upper) was determined by geomorphological and hydrological characteristics of the system, in addition to stream order and elevation. Barriers located within the tidal or lower reaches of the catchment with few-to-no obstructions downstream were ranked higher than weirs positioned in the upper headwaters. Moreover, a higher weighting was placed on weirs that, if remediated, would provide longer sections of unimpeded fish passage.

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 the only major physical barrier recorded during the project. This parameter was measured under low flow conditions, with larger values representing a greater fish passage barrier and receiving a higher weighting. Hydrological barriers were categorised as displaying excessive water velocity and were assessed in association with the drown out occurrence of the structure.

Drown out values for structures were calculated from relevant time weighted flow duration data, with structures that rarely drowned out receiving a higher weighting than those structures that readily drowned out.

In association with the structural impacts assessed during the review, it was also noted if the weir was an undershot structure where the water is released from below the weir. These types of structures are known to have negative impacts on fish larvae (Marttin and Graaf 2002; Baumgartner 2005), and were given a higher weighting value during the prioritisation process.

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 / 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).

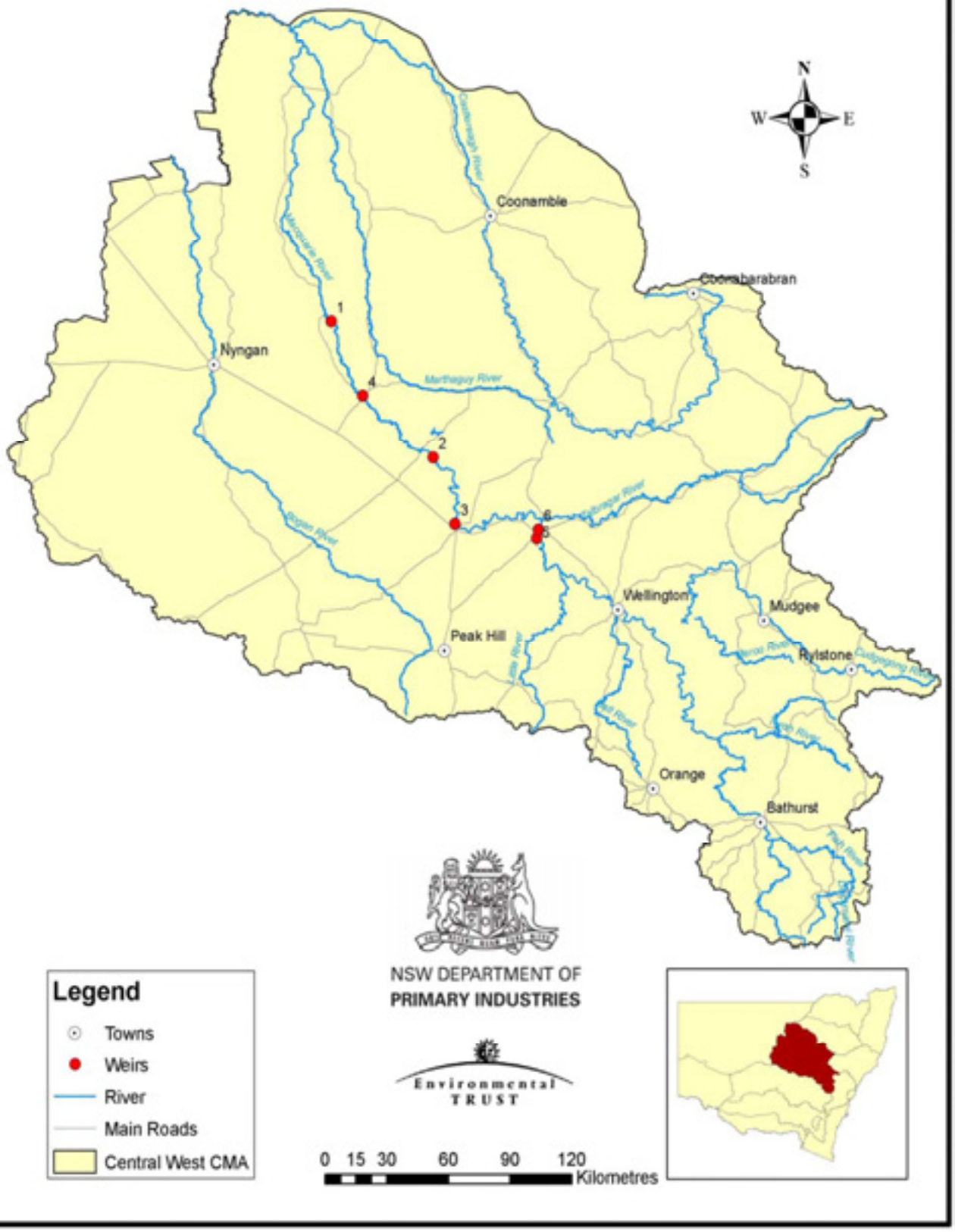
Modification criteria assessed structural use and the ease of remediating the weir. Occasionally structures were recorded during the Detailed Weir Review that were no longer used by the licensee or adjacent property owners. These obsolete weirs received a higher priority score due to the ease (e.g. low costs and short timescales) associated with remediation. Additionally, weir inspections noted that a number of structures required immediate maintenance that would enact the *Fisheries Management Act* 1994, which stipulates for the remediation of fish passage if repair works are undertaken. 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 each catchment displayed in their respective summary tables. Included in the summary tables are details of priority structures where remediation works have been completed or commenced. These structures have not been reviewed in this report, however information has been included in the tables to highlight the number of priority structures within each catchment. It should also 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 remediation.

4. INDIVIDUAL DETAILED WEIR REVIEW REPORTS

Information used to prioritise each weir is detailed in the Individual Detail Weir Review reports for each catchment that appear in the following sections. Individual weir reports provide comprehensive accounts of the structures operational details, system hydrology, ecological considerations, proposed remediation options (along with projected costs), and preferred NSW DPI option for improving fish passage at the weir. A complete data set for each weir is stored in the NSW Department of Primary Industries Fish Habitat Database – this data can be accessed by contacting NSW DPI staff.

5. Central West CMA - Detailed Weir Review Sites



Central West CMA Summary Table

Rank	Barrier Name	Latitude	Longitude	Structure Type	Watercourse	Ownership	Operational Fishway	Recommendation	Estimated Cost of preferred option ($)	Estimated Cost of alternative option ($)	Potential Increase in Habitat Area (km)
1	Marebone Weir	-31.387800	147.697300	Adjustable crest (vertical lift gates)	Macquarie River	State Water	No (dual Vertical Slot Fishway present)	Deelder Fishlock	500K - 1M	>1M	100
2	Gin Gin Weir	-31.938900	148.142200	Fixed crest (concrete)	Macquarie River	State Water	No	Vertical Slot Fishway	>1M	500K - 1M	95
3	Narromine Weir	-32.212600	148.238600	Fixed crest (rock fill)	Macquarie River	Narromine Shire Council	No	Full Width Rock Ramp Fishway	250 - 500K	250 - 500K	120
4	Warren Shire Council Weir	-31.687000	147.834100	Fixed crest (concrete)	Macquarie River	Warren Shire Council	No	Vertical Slot Fishway	>1M	500K - 1M	102
5	Dubbo City Council Weir	-32.271600	148.594600	Fixed crest (concrete)	Macquarie River	Dubbo City Council	No	Vertical Slot Fishway	>1M	500K - 1M	135
6	Dubbo Weir	-32.235500	148.602300	Adjustable crest (dropboards)	Macquarie River	State Water	No	Removal	100 - 250K	500K - 1M	75.5
N/A	Carinda Weir	-30.466200	147.677200	Fixed crest	Mathaguy Creek	State Water	N/A	Removal of entire structure completed in 04/05 financial year	10K	N/A	N/A
N/A	Warren Weir	-31.737000	147.866000	Fixed crest	Macquarie River	State Water	Yes	Vertical Slot Fishway constructed 2004, with ongoing monitoring by DPI	1.5M	N/A	N/A

MAREBONE WEIR, MACQUARIE RIVER

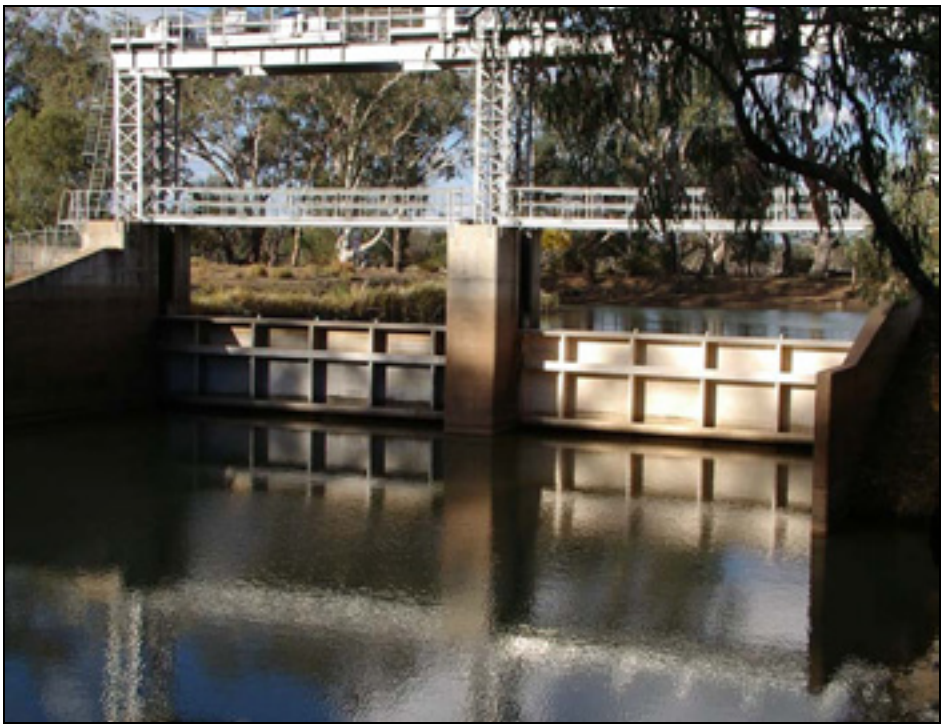


Figure 1. Marebone Weir, Macquarie River (19.06.2005, 2.9ML/day).

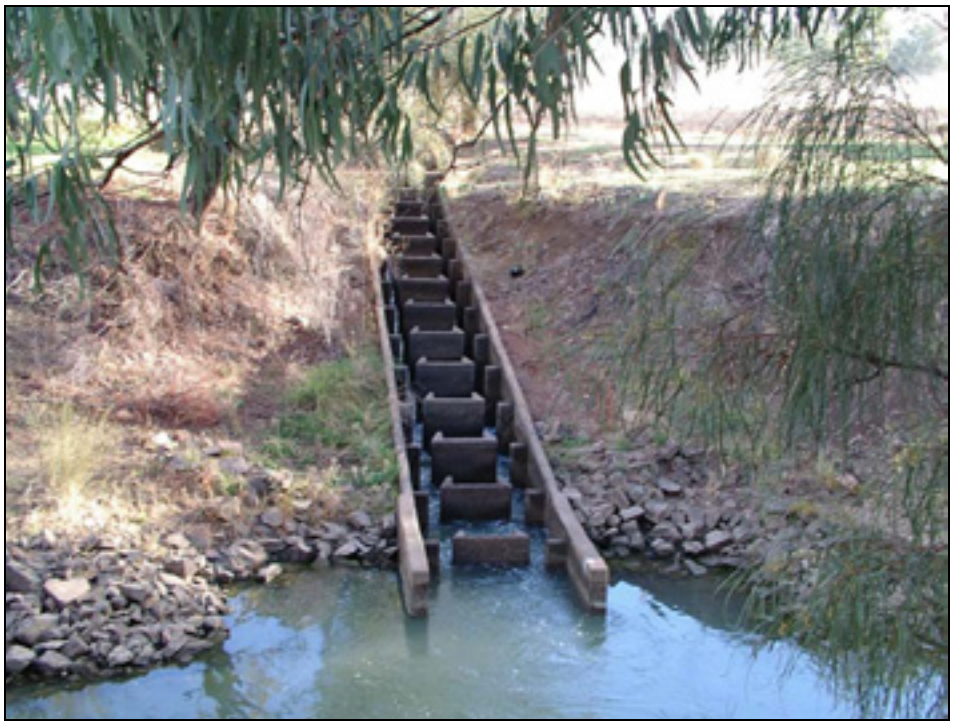


Figure 2. Marebone Weir fishway, Macquarie River (19.06.2005, 2.9ML/day).

Description and Setting

Marebone Weir (Figure 1) is located approximately 60km downstream of the township of Warren on the Macquarie River in the Lower Macquarie River catchment.

The weir is approximately 3.3 metres in height and is approximately 30 metres across the length of the crest. Marebone Weir is an undershot structure consisting of two vertical lift gates that act as a barrier to fish passage at all but high flow conditions. In flood or high flow conditions the vertical lift gates are raised to prevent overtopping of the structure. There is currently a dual vertical slot fishway present at the site (Figure 2), which is ineffective at passing fish upstream past the weir but may allow some limited passage downstream.

Marebone Weir is ranked as a high remediation priority within the Central West 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 Macquarie River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), endangered river snail (*Notopala sublineata*), and trout cod (*Maccullochella macquariensis*));
- Diverse range of native fish (High Conservation Value);
- 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 or 'core habitats');
- Improved stream connectivity: the next upstream barrier to fish passage is Michael Egan Weir located at Warren approximately 62km away. There are no licensed major barriers below Marebone Weir and the Macquarie Marshes, although there are several rock bed control structures in the Breakaway Channel in the Macquarie Marshes Nature Reserve that obstruct fish passage. The Breakaway Channel is a distributary of the Macquarie that rejoins the main channel downstream of the reserve; and
- Drown out of the gated weir does not occur (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

The flows within the Macquarie catchment are regulated by Burrendong Dam, which is located in the upper catchment approximately 35km upstream of Wellington. Burrendong Dam is primarily used to augment water in the Macquarie River for town water, stock, domestic, irrigation and environmental releases into the river and the Macquarie Marshes. The Macquarie Marshes is an extensive Ramsar listed wetland system of approximately 220,000 hectares, and commences 50km downstream of Warren below Marebone Weir.

Flow data used in the hydrological assessment of this site was obtained from the DNR river gauge downstream of Marebone Weir (station 421090). Information with regard to flows within the Macquarie River downstream of Marebone Weir were sourced from the DNR website and staff members, using data acquired between 12.04.1986 – 8.12.2005.

Licensing details of existing upstream water extractors was not available during the development of this report.

Operational Details

The weir was built in 1977 for conservation of water for irrigation, stock, and domestic supply, and currently regulates flows within the Macquarie River and allows diversion of water into Marra Creek and Marebone Break.

Figure 3. Macquarie River downstream of Marebone Weir (14.11.2003, 208.9ML/day).

Figure 4. Macquarie River upstream of Marebone Weir (14.11.2003, 208.9ML/day).

The concrete weir is owned and operated by State Water and is an adjustable release structure employing two vertical lift steel gates for this purpose. Structural drown out of the gated structure does not occur. Limited fish passage may be possible when the gates are raised during flooding conditions, or when infrequent maintenance is carried out on the structure.

At around the same time of construction, a dual vertical slot fishway was installed at the site to provide fish passage. As with most early fishways, this fishway was based on northern hemisphere prototypes, which have since been proven to be ineffective at passing Australian fish species.

The fishway is built on a slope of approximately 1:6, which is likely to create an impassable gradient and velocity to native fish species of the Macquarie River catchment in all but very high flow conditions. Excessive head loss and turbulence within the fishway also has the potential to impede fish passage. Although it is unlikely that upstream fish passage is possible, there may be some limited fish passage in a downstream direction.

Ecological Considerations

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native fish species are expected to occur within the Macquarie River: freshwater catfish, golden perch, Murray cod, spangled perch, bony herring, Australian smelt, Darling River hardyhead, fly specked hardyhead, crimson spotted rainbow fish, carp gudgeon, flathead gudgeon, with the threatened silver perch, olive perchlet, purple spotted gudgeon, trout cod, and the endangered river snail (*Notopala sublineata*) also expected to be present. Introduced species including common carp, goldfish, and eastern gambusia also occur in the Macquarie River.

The Macquarie River surrounding Marebone Weir possesses some important fish habitat components including instream large woody debris, which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and for the growth of algae (thereby creating a food source for macroinvertebrates). At the time of the inspection, the banks upstream and downstream of the site were moderately vegetated (Figure 3 and 4).

Marebone Weir is an undershot weir, which is a design that has been reported 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; Baumgartner 2005). It is therefore important to understand the effect of weirs on fish communities to assist with better management outcomes for protection of native fish and aquatic habitats in the Central West catchment.

Proposed Remediation Actions

Marebone 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 management of the vertical lift gates be re-assessed. It should be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

- **Option 1 –** Fishlock (Deelder or similar)

A fishlock operates in a similar manner to a boat lock. The fishway 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 upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens. The only lock fishway built in NSW to date is at Yarrawonga Weir on the River Murray. This fishlock has been shown to be effective in transporting fish over the 12 metre high weir, although several operating and exit arrangements require modification (Thorncraft and Harris 2000).

For smaller structures (less than 5 metres), the Deelder fishlock 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 trials of 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 the Deelder fishlock design could be applied to Marebone 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 has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods.

A limitation of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. If power is not easily accessible at this site, a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further issue for consideration is the maintenance requirements at remote or unstaffed sites. Routine inspections of automated mechanisms, and fishway operation would need to be incorporated into the works schedule of the managing authority.

- **Option 2 –** Replacement of the existing fishway with a vertical slot fishway

The removal of the existing fishway and its replacement with a vertical slot fishway is also a viable option at Marebone Weir. Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, and purple spotted gudgeon) and when located on the main stem or major tributary of a waterway.

With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs, and the concrete construction of the weir makes it an ideal anchor for securing the vertical slot fishway and its associated infrastructure. The construction of a vertical slot fishway on the right hand bank is likely to be the most expensive, but most effective option for fish passage remediation at Marebone Weir.

The entrance to the existing fishway is too far downstream, making it difficult for fish to find. Should any refurbishment or replacement of this structure occur, it is recommended that the downstream fishway entrance be moved closer to the lift gates, so that it is more easily located in all flow conditions.

Projected Remediation Costs

Projected cost	$50K - $100K	$100K- $250K	$250K - $500K	$500K - $1M	> $1M
Option 1				✔	
Option 2					✔

Recommendation

It is recommended that the installation of a Deelder fishlock be investigated (Option 1) due to its cheaper cost compared to installation of a vertical slot fishway (Option 2).

Appropriate management of the vertical lift gates to limit their affect on fish larvae is also a priority for this site. Additionally, 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).

Benefits Associated with Remediation

The Macquarie River contains important fish habitat that should be protected, and the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment.

The reinstatement of fish passage at Marebone Weir on the Macquarie River would open in excess of 100km of potential fish habitat either side of the weir to fish and other aquatic organisms.

The Macquarie Marshes, located approximately 50km downstream, provide ideal nursery conditions, allowing the development and subsequent recruitment of native fish. By providing fish passage at Marebone Weir, juvenile fish will again be able to migrate upstream and repopulate the Macquarie River and its tributaries beyond Marebone Weir.

GIN GIN WEIR, MACQUARIE RIVER

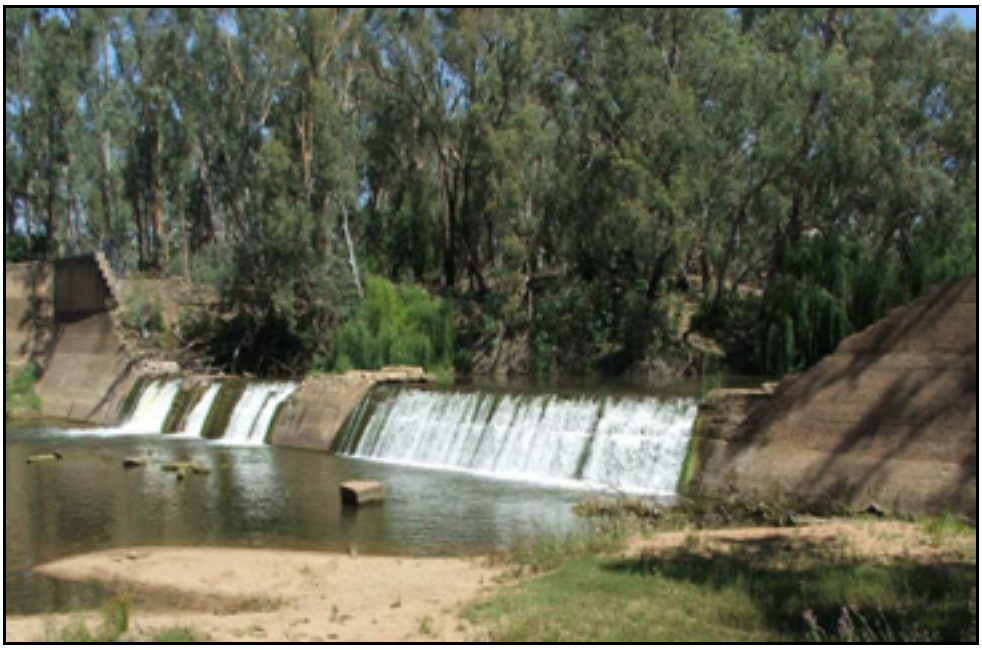


Figure 1. Gin Gin Weir, Macquarie River (21.12.2004, 333ML/day).

Description and Setting

Gin Gin Weir (Figure 1) is located approximately 50km downstream of Narromine on the Macquarie River in the Lower Macquarie River catchment. The weir is a concrete, fixed crest structure approximately 4 metres in height and approximately 100 metres across the length of the crest. The weir acts as a barrier to fish passage at flows less than approximately 50-70,000ML/day due to excessive head loss, increased turbulence, and increased velocity across the face of the structure.

Gin Gin Weir is ranked as a high remediation priority within the Central West 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 Macquarie River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), and the endangered river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Location within the catchment (fish habitat located in the lower end of the catchment have a higher conservation need due to the higher prevalence of spawning grounds or 'core habitats');
- Improved stream connectivity: the next upstream barrier to fish passage is the Narromine Shire Council Weir approximately 50km away; the next barrier downstream is the Warren Shire Council Weir on the Macquarie River approximately 45km away; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocities are minimal).

Hydrology

The flows within the Macquarie catchment are regulated by Burrendong Dam, which is located in the upper catchment approximately 35km upstream of Wellington. Burrendong Dam is primarily used to augment water in the Macquarie River for town water, stock, domestic, irrigation and environmental releases into the river and the Macquarie Marshes wetlands. The Macquarie Marshes is an extensive Ramsar listed wetland system of approximately 220,000 hectares and commences 50km north of the township of Warren.

Flow data used in the hydrological assessment of this site was obtained from the DNR river gauge at Gin Gin Weir (station 421031). Information with regard to flows within the Macquarie River was sourced from the DNR website and staff members, and describes data acquired between 25.04.1990 – 29.06.2005.

Preliminary investigations estimate that Gin Gin Weir would drown out at flows in excess of 50-70,000ML/day. The time weighted flow duration curve for the Macquarie River at Gin Gin Weir indicates that flows would exceed 50-70,000ML/day less than 1% of the time (based on flow data 1990 – 2005).

Operational Details

The weir is owned and operated by State Water. Construction of the weir began in 1896 for the conservation of water for irrigation, stock and domestic supply in the Macquarie River, and to divert water down Ewenmar Cutting into Crooked and Ewenmar Creeks. Currently the weir does not back up water far enough for the diversion of water into these creeks. The weir is also currently used for recreation, and is valued by the community for its aesthetics. It is believed that damage to the weir occurred in 1903, and was later blasted to reduce the crest height to its current level of 4 metres (Opus and Golder 1999). No regulating infrastructure is associated with the weir, and there is no fishway present.

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 all or any of the resident fish species within the Macquarie River system. Furthermore if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure.

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native fish species are expected to occur within the Macquarie River: freshwater catfish, golden perch, Murray cod, spangled perch, bony herring, Australian smelt, Darling River hardyhead, fly specked hardyhead, crimson spotted rainbow fish, carp gudgeon, flathead gudgeon, with the threatened silver perch, olive perchlet, purple spotted gudgeon, trout cod, and the endangered river snail (*Notopala sublineata*) also expected to be present. Introduced species including common carp, goldfish, and eastern gambusia also occur in the Macquarie River.

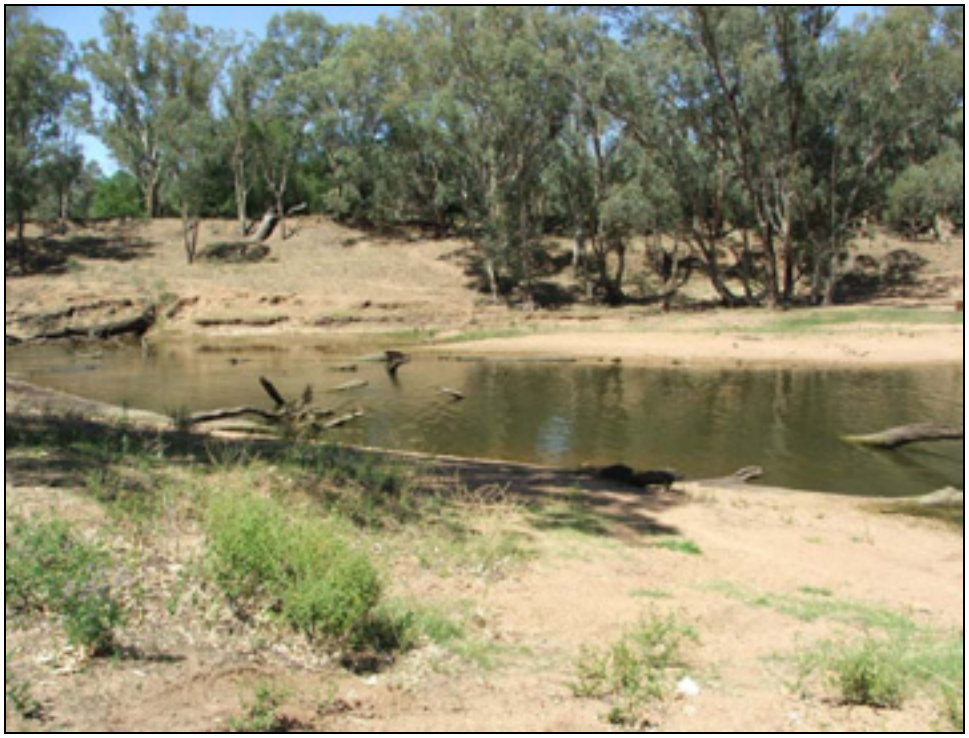


Figure 2. Macquarie River downstream of Gin Gin Weir (21.12.2004, 333ML/day).

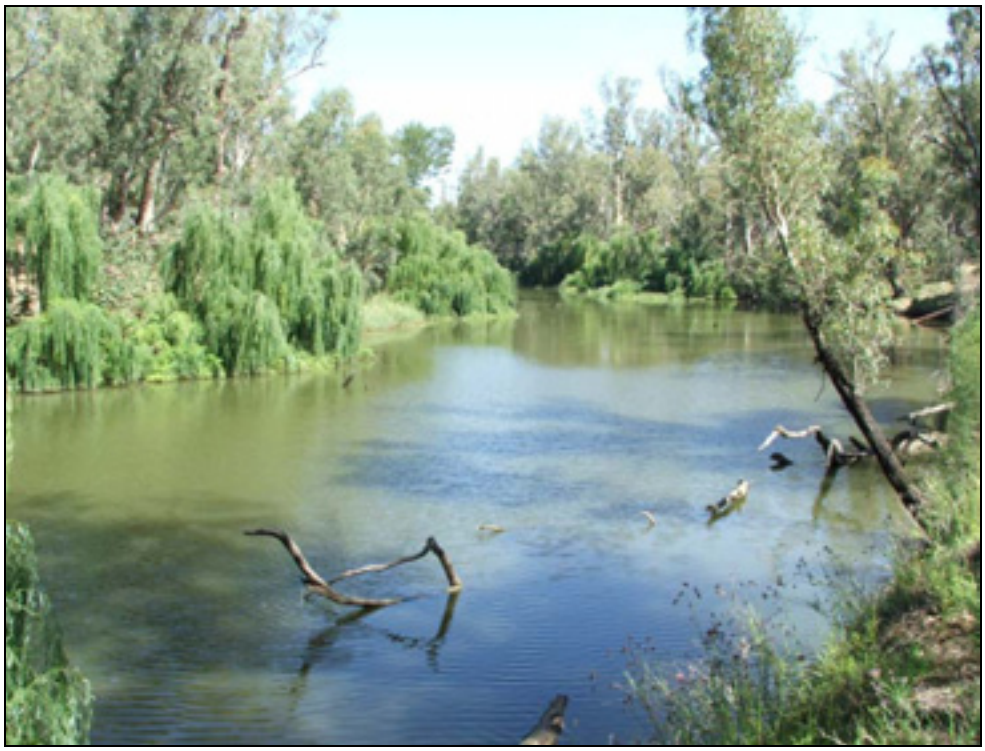


Figure 3. Macquarie River upstream of Gin Gin Weir (21.12.2004, 333ML/day).

The Macquarie River surrounding Gin Gin Weir contains important fish habitat components including instream large woody debris, which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and for the growth of algae (thereby creating a food source for macroinvertebrates).

The area surrounding the weir has moderately vegetated banks both upstream and downstream of the site (Figures 2 and 3). Willows and other pest plant species are present upstream of the weir. The removal of these pest species is advised in conjunction with any fish passage remediation works at this site to enhance the habitat available to native fish.

Proposed Remediation Actions

As a result of the weir not drowning out regularly (or at all), it is recommended that fish passage options be further investigated at this site. It should be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present (this site is within the expected distribution of silver perch olive perchlet trout cod and purple spotted gudgeon). With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs. The concrete construction of the Gin Gin Weir makes it an ideal anchor for securing the vertical slot fishway and its associated infrastructure.

The weir could be constructed on the left hand bank using an attraction flow on the inside bend of the river, an area that may represent the natural line of upstream fish passage due to lower velocities present at this location during higher flows. In addition, access for fishway construction is also easiest from the left hand bank. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access and various structural and hydrological constraints. The installation of a vertical slot fishway is the preferred option for fish passage remediation at Gin Gin Weir.

- **Option 2 –** Fishlock (Deelder or similar)

A fishlock operates in a similar manner to a boat lock. The fishway 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 upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens. The only lock fishway built in NSW to date is at Yarrawonga Weir on the River Murray. This fishlock has been shown to be effective in transporting fish over the 12 metre high weir, although several operating and exit arrangements require modification (Thorncraft and Harris 2000).

For smaller structures (less than 5 metres), the Deelder fishlock 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.

It is possible that the Deelder fishlock design could be applied to Gin Gin 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 has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods.

A limitation of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. If power is not easily accessible at this site, a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further issue for consideration is the maintenance requirements at remote or unstaffed sites. Routine inspections of automated mechanisms, and fishway operation would need to be incorporated into the works schedule of the managing authority.

Projected Remediation Costs

Projected cost	$50K - $100K	$100K- $250K	$250K - $500K	$500K - $1M	> $1M
Option 1					✔
Option 2				✔	

Recommendation

It is recommended that a vertical slot fishway (Option 1) be considered for the remediation of fish passage at this site. The Deelder fishlock could also be considered if a power supply could be sourced at this site.

Benefits Associated with Remediation

The Macquarie River contains 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 Macquarie River catchment.

The reinstatement of fish passage at Gin Gin Weir on the Macquarie River would open up access to approximately 95km of potential fish habitat either side of the structure.

NARROMINE COUNCIL WEIR, MACQUARIE RIVER

Figure 1. Narromine Council Weir, Macquarie River (21.12.2004, 333ML/day).

Description and Setting

The Narromine Council Weir (Figure 1) is located approximately 2km downstream of the Narromine CBD on the Macquarie River in the Lower Macquarie River catchment. The weir is a fixed crest structure constructed of large rock fill, approximately 3.5 metres in height and approximately 60 metres across the length of the crest. Narromine Council Weir acts as a barrier to fish passage at flows of less than approximately 20-30,000ML/day due to excessive head loss, increased turbulence, and velocity across the face of the structure.

Narromine Council Weir is ranked as a high remediation priority within the Central West 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 Macquarie River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), endangered river snail (*Notopala sublineata*), and trout cod (*Maccullochella macquariensis*));
- Diverse range of native fish (High Conservation Value);
- 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 or 'core habitats');
- Improved stream connectivity: the next natural barrier is Minore Falls approximately 30 km upstream; the next artificial upstream barrier to fish passage is Dubbo Weir, approximately 70km away. The next barrier downstream is the Gin Gin Weir, approximately 50km away; and

- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Macquarie catchment are regulated by Burrendong Dam, located in the upper catchment, approximately 35km upstream of Wellington. Burrendong Dam is primarily used to augment water in the Macquarie River for town water, stock, domestic, irrigation and environmental releases into the river and Macquarie Marshes. The Macquarie Marshes is an extensive Ramsar listed wetland system of approximately 220,000 hectares, and commences 50km downstream of the township of Warren.

Flow data used in the hydrological assessment of this site was obtained from the DNR river gauge at Gin Gin Weir (station 421031). Information with regard to flows within the Macquarie River were sourced from the DNR website and staff members, using data acquired between 25.04.1990 – 29.06.2005.

Preliminary investigations estimate that Narromine Council Weir would drown out with flows in excess of 20-30,000ML/day. The time weighted flow duration curve for the Macquarie River at Gin Gin Weir, located downstream from Narromine, shows that flows would exceed 20-30,000ML/day less than 2.3% of the time.

Operational Details

Narromine Council Weir was built in 1982 for the conservation of water for the town of Narromine. The weir is owned and operated by Narromine Shire Council and, although Narromine's town water supply is now supplied by ground water, the weir pool continues to be used for recreation purposes and is valued by the community for its aesthetics. The weir is a fixed crest structure, constructed of large rock fill, with no regulating infrastructure or fishway present.

Ecological Considerations

Fish passage may be possible less than 2.3% of the time, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Macquarie River system.

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following species native species are expected to occur within the Macquarie River: freshwater catfish, golden perch, Murray cod, spangled perch, bony herring, Australian smelt, Darling River hardyhead, fly specked hardyhead, crimson spotted rainbow fish, carp gudgeon, flathead gudgeon, with the threatened silver perch, olive perchlet, purple spotted gudgeon, trout cod, and the endangered river snail (*Notopala sublineata*) also expected to be present. Introduced species including common carp, goldfish, and eastern gambusia also occur in the Macquarie River catchment.

The Macquarie River at Narromine is just beyond the limit of cold water pollution from Burrendong Dam. The site possesses some important fish habitat components including instream large woody debris, which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and for the growth of algae (thereby creating a food source for macroinvertebrates). The weir site has moderately vegetated banks either side of the weir, with native species, willows and other pest plant species present upstream and downstream of the site (Figures 2 and 3).

The removal of pest species is advised in conjunction with any fish passage remediation works at this site to enhance the habitat available to native fish.

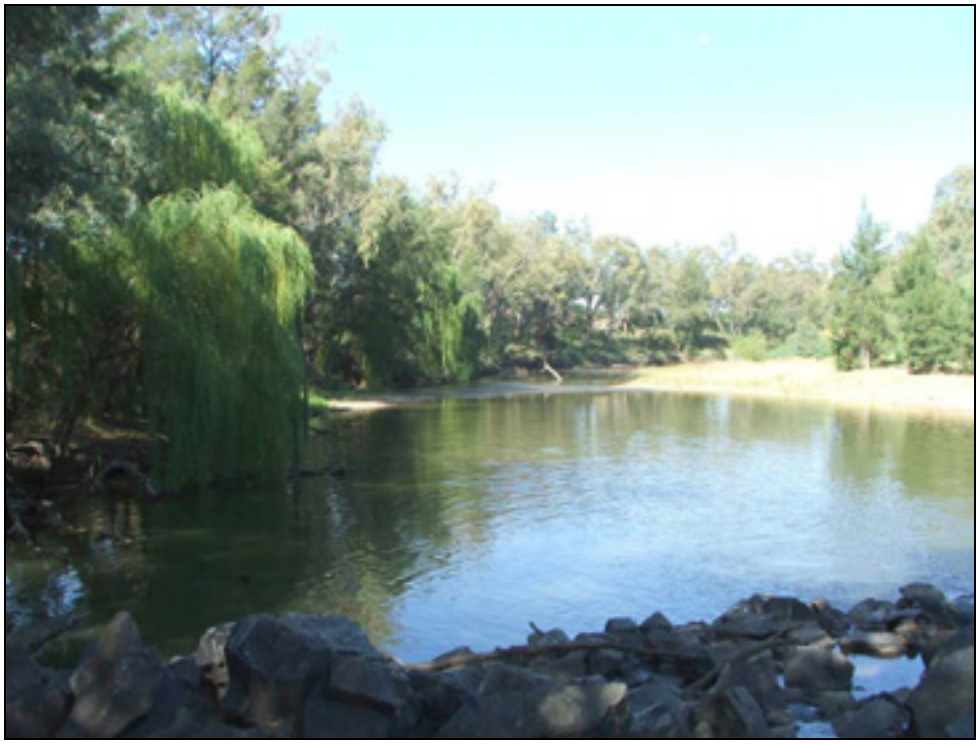


Figure 2. Macquarie River downstream of Narromine Shire Council Weir (21.12.2004, 333ML/day).

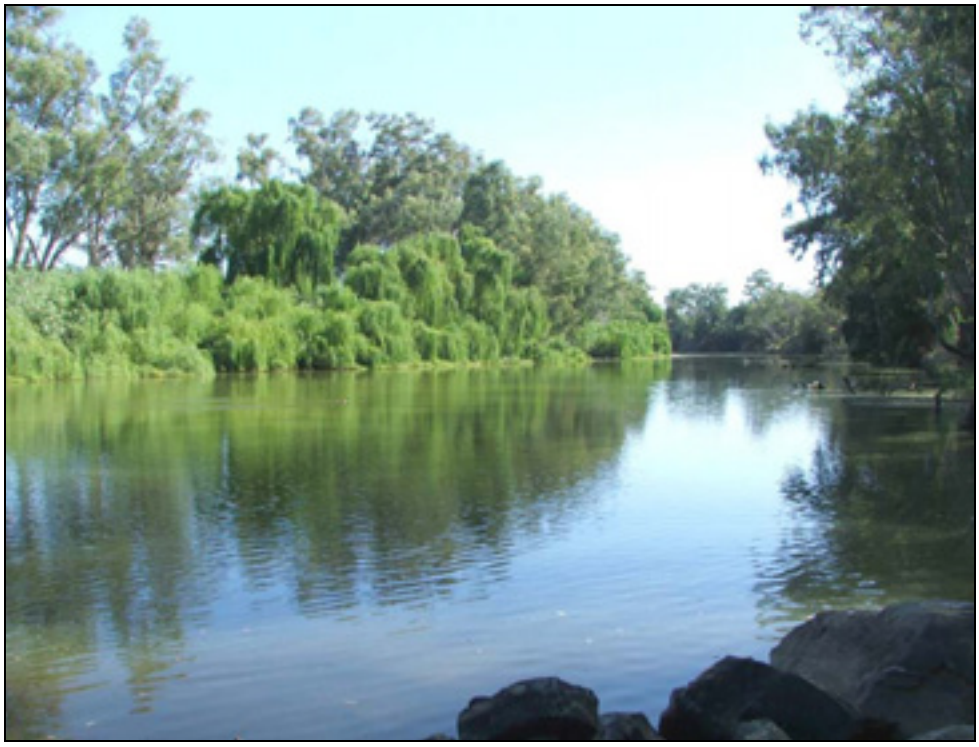


Figure 3. Macquarie River upstream of Narromine Shire Council Weir (21.12.2004, 333ML/day).

Proposed Remediation Actions

As the weir does not drown out regularly, it is recommended that fish passage options be further investigated at this site. It should be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

All options will require modification of the crest of the weir to create a low flow channel at or near the fishway. Currently there is large rock approximately 400mm in diameter with large crevices across the entire structure, in some places water appears to be flowing through the rock and not cascading over the top of the structure. During the site inspection, several native and exotic fish species were observed dead in the rock work after becoming trapped. It is recommended that some of the large rock be removed to the level of the maximum headwater height, and smaller rocks placed to form a low flow channel. In addition to the rock ridges, geofabric should be used to line any rock ramp fishway to maintain a minimum depth of 500mm within the fishway and assist the upstream movement of fish.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, purple spotted gudgeon, trout cod and the endangered river snail). With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs.

This current rock fill weir may require major modifications to facilitate the installation of a vertical slot fishway, such as the construction of a concrete retaining wall parallel with the rock crest. Geofabric would also be required to line the upstream side of the weir to prevent water leaking through the structure and direct water through the fishway. In addition, the weir would need to be lowered significantly on the side where the fishway is to be installed to ensure adequate attraction flows were created. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access and various structural and hydrological constraints.

- **Option 2 -** Partial width rock ramp fishway

The construction of a partial width rock ramp fishway would make a significant contribution to improving the passage of native fish prior to drown out of the structure. Existing rock at the weir site could be rearranged and incorporated into the fishway, so that the existing spillway is extended to create a gradient of 1:20. The most effective design would be a reverse dog-leg arrangement where the fishway is perpendicular to the weir on the left hand bank with a return so that the entrance is located close to the weir to take advantage of attraction flows. The fishway itself would comprise several rock ridges to create resting pools and small rises in elevation between the pools. This modification would provide passage to a greater range of fish species and size classes over a greater range of flows, and is considered the most cost effective option for this site. This option is considered the most cost effective solution for this site.

- **Option 3 –** Full width rock ramp fishway

The construction of a full width rock ramp fishway would provide similar benefits as a partial width rock ramp fishway (Option 2), although would be operable over a greater range of flows. The main disadvantage of a full width rock ramp fishway is the increased cost associated with construction, which is predominantly due to the considerable amount of rock requiring importation to the site.

The weir currently stands at approximately 3.5 metres in height, and as such, both the partial width and full width rock ramp fishways would extend approximately 70 metres downstream to achieve the required 1:20 slope (this would be dog-legged for the partial width rock ramp fishway). A low flow channel with a pool depth of approximately 500mm would need to be incorporated into the centre of the full width rock ramp structure to allow for fish passage at lower flows, with fish passage being possible toward the outer edges of the structure at higher flows. Detailed specifications relating to rock ramp fishways can be obtained from NSW DPI and must be considered prior to the development of engineering designs.

Projected Remediation Costs

Projected cost	$50K - $100K	$100K- $250K	$250K - $500K	$500K - $1M	> $1M
Option 1					✔
Option 2			✔		
Option 3			✔		

Recommendation

Although a vertical slot fishway would enable fish passage over a wider range of flows than other fishway designs, without major modifications to the existing weir itself the opportunity for construction of a vertical slot fishway is currently not possible. A full width rock ramp fishway (Option 3) is therefore the preferred remediation action for this site.

Benefits Associated with Remediation

The Macquarie River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment.

The reinstatement of fish passage at Narromine Council Weir on the Macquarie River would provide access to approximately 120km of potential fish habitat either side of the weir.

WARREN SHIRE COUNCIL WEIR, MACQUARIE RIVER

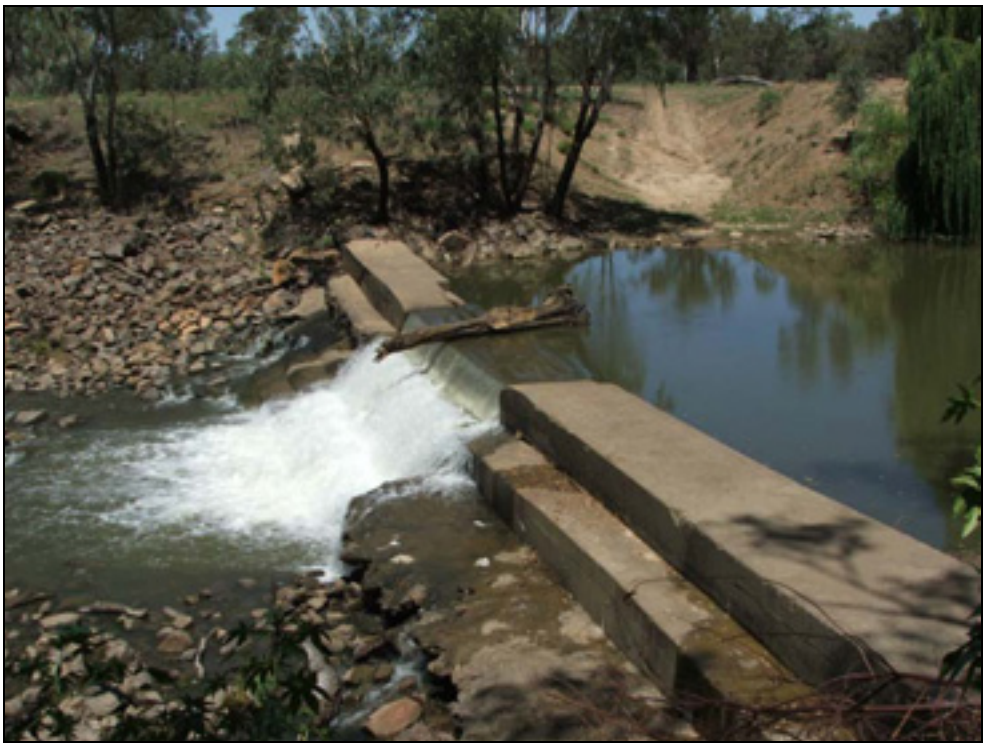


Figure 1. Warren Shire Council Weir, Macquarie River (22.12.2004, 210ML/day).

Description and Setting

The Warren Shire Council Weir, also known as the Brian Egan Weir (Figure 1) is located 3km downstream of the township of Warren on the Macquarie River in the Lower Macquarie River catchment. The fixed crest weir is approximately 4 metres in height and approximately 40 metres across the length of the crest. The weir has no regulating infrastructure associated with it and acts as a barrier to fish passage during flows less than approximately 8,500ML/day due to excessive head loss, increased turbulence, and velocity across the face of the structure.

The Warren Shire Council Weir is ranked as a high remediation priority within the Central West 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 Macquarie River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), endangered river snail (*Notopala sublineata*), and trout cod (*Maccullochella macquariensis*));
- 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 or 'core habitats');
- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: the next upstream barrier to fish passage is Gin Gin Weir approximately 40km upstream, although a second weir with a vertical slot fishway ("Warren Weir") is located approximately 10km upstream of Warren Shire Council Weir. Fish passage at this site continues to be

monitored by NSW DPI. The next barrier downstream is Marebone Weir which is located on the Macquarie River approximately 62km away. These other structures are all 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).

Hydrology

The flows within the Macquarie catchment are regulated by Burrendong Dam, which is located in the upper catchment approximately 35km upstream of Wellington. Burrendong Dam is primarily used to augment water in the Macquarie River for town water, stock, domestic, irrigation and environmental releases into the river and the Macquarie Marshes. The Macquarie Marshes is an extensive Ramsar listed wetland system of approximately 220,000 hectares, and commences 50km north of Warren.

The flow data used in the hydrological assessment of this site was obtained from the DNR river gauge at the Warren Weir (station 421004). Information with regard to flows within the Macquarie River was sourced from the DNR website and staff members, using data acquired between 01.10.1974 – 06.10.2005.

There are five other barriers to fish passage located upstream from this weir on the Macquarie River and include Gin Gin Weir, Narromine Weir, Dubbo Weir, and Dubbo City Council Weir.

It has been estimated that the weir would drown out with flows in excess of 8,500ML/day. The time weighted flow duration curve for the Macquarie River at this location shows that flows would exceed 8,500ML/day less than 5% of the time.

There is currently several licensed water extractors who utilise the water in the upstream weir pool including Warren Shire Council, which has a license to extract water for irrigation of parks and sporting grounds at the town of Warren.

Operational Details

Warren Shire Council Weir was built in 1989 to secure town water from the Macquarie River prior to the establishment of the railway line. As the name suggest, the weir is owned and managed by Warren Shire Council. The weir is constructed entirely of concrete currently, and has no fishway present.

At the time of the inspection the structure was leaking and Council were concerned about the structural integrity of the weir. Council were advised that as this weir was a priority site in the Central West CMA, and that fish passage should be investigated. Council were also advised that if the weir was modified, provision of fish passage was a requirement of the *NSW Fisheries Management Act 1994* which states that "the Minister may require a person who constructs, alters or modifies a dam or weir to provide fish passage". Consultation must be carried out with NSW DPI if future works are planned at this site.

Ecological Considerations

The Lower Macquarie River has been identified as a High Conservation Value area in an agreement between the Department of Environment and Conservation and NSW DPI, because of the high fish species diversity and presence of threatened fish species.

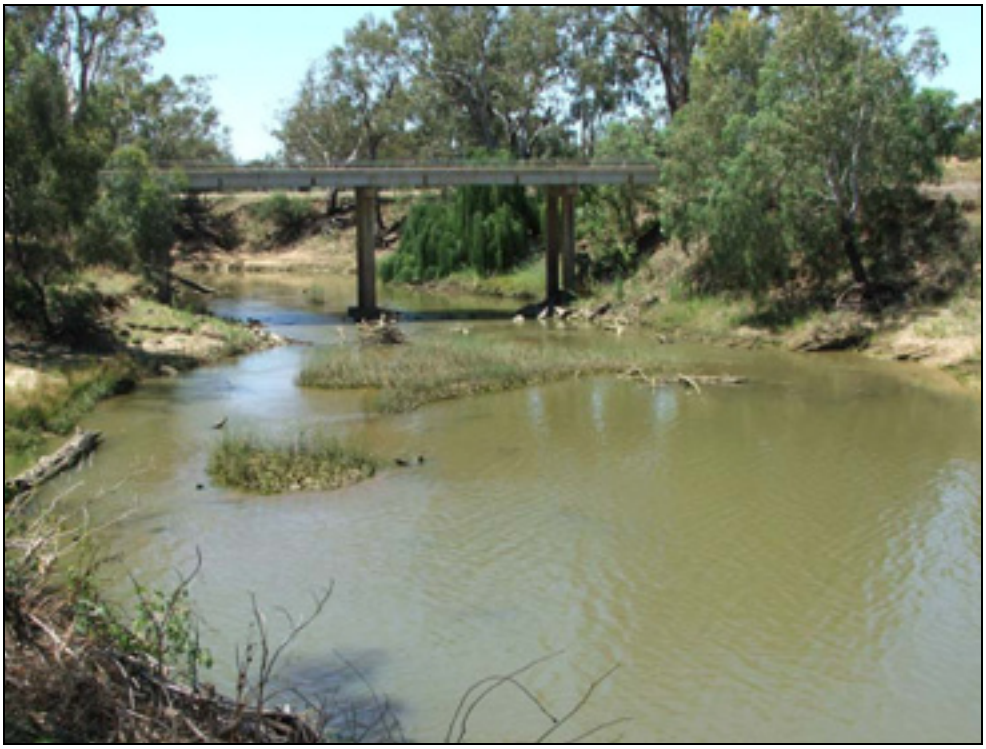


Figure 2. Macquarie River downstream of Warren Shire Council Weir (22.12.2004, 210ML/day).

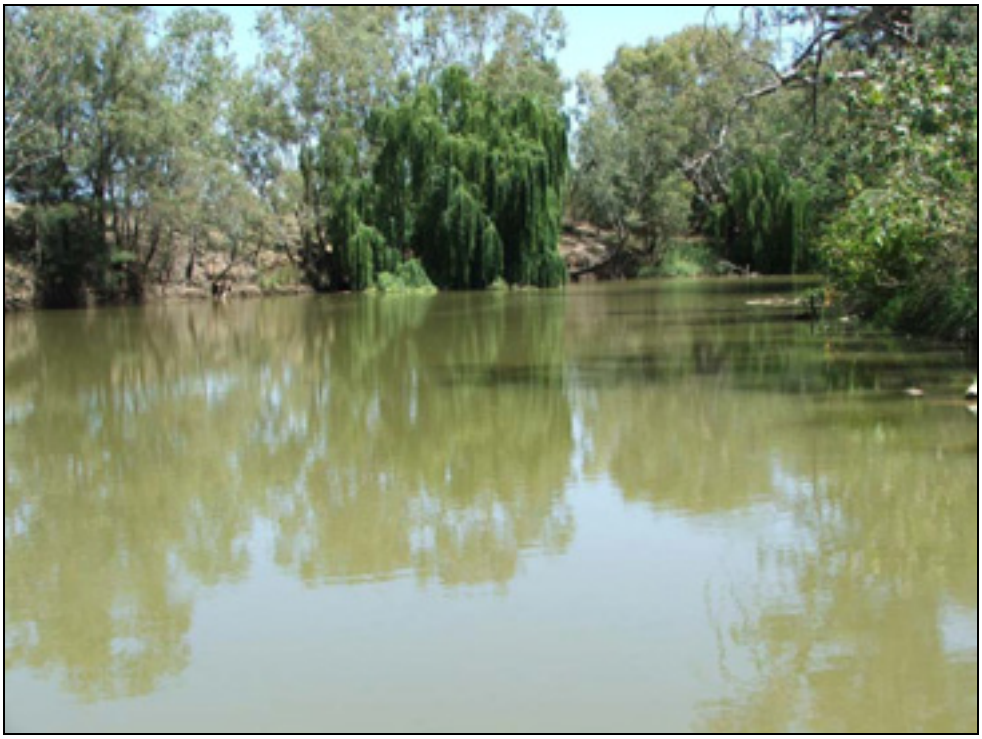


Figure 3. Macquarie River upstream of Warren Shire Council Weir (22.12.2004, 210ML/day).

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Macquarie River: freshwater catfish, golden perch, Murray cod, spangled perch, bony herring,

Australian smelt, Darling River hardyhead, fly specked hardyhead, crimson spotted rainbow fish, carp gudgeon, flathead gudgeon, with the threatened silver perch, olive perchlet, purple spotted gudgeon, and the endangered river snail (*Notopala sublineata*) also expected to be present. Introduced species including common carp, goldfish, and eastern gambusia also occur in the Macquarie River catchment.

Fish passage may be possible less than 5% of the time when the structure becomes drowned out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Macquarie River system. Furthermore if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could continually miss the opportunity to move past the structure.

The Macquarie River at Warren possesses important fish habitat components including instream woody debris, which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition woody debris also provides an important substrate for fish to lay eggs and for the growth of algae (thereby creating a food source for macroinvertebrates).

The area surrounding Warren Shire Council Weir has moderately vegetated banks either side of the site (Figures 2 and 3). Willows and other pest plant species are present upstream and adjacent to the weir. The removal of these pest species is advised in conjunction with any fish passage remediation works at this site. Stock access was visible on the left hand bank as vegetation had been grazed and bank erosion was evident. Riparian fencing and revegetation would also enhance the fish habitat at this site.

Proposed Remediation Actions

As this weir drowns out very infrequently, it is recommended that fish passage options be further investigated at this site. The weir currently leaks, indicating that structural modifications to the weir would be required prior to the construction of any fishway, and repair work providing an ideal opportunity to undertake fish passage remediation at this site. It should be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, purple spotted gudgeon, trout cod, and the endangered river snail *Notopala sublineata*). With varying head loss, the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs.

The concrete construction of the weir makes it an ideal anchor for securing the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access, and various structural and hydrological

constraints. This option is the preferred solution for fish passage remediation at the Warren Shire Council Weir.

- **Option 2 –** Fishlock (Deelder or similar)

A fishlock operates in a similar manner to a boat lock. The fishway 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 upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens. The only lock fishway built in NSW to date is at Yarrawonga Weir on the River Murray. This fishlock has been shown to be effective in transporting fish over the 12 metre high weir, although several operating and exit arrangements require modification (Thorncraft and Harris 2000).

For smaller structures (less than 5 metres), the Deelder fishlock 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 trials of 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 the Deelder fishlock design could be applied to Warren Shire Council 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 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 than other fishway designs when there is no existing fishway infrastructure in place. However, the cost to build the fishlock at this site may be less than that of the vertical slot fishway due to less construction materials being required.

A limitation of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. If power is not easily accessible at this site, a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further issue for consideration is the maintenance requirements at remote or unstaffed sites. Routine inspections of automated mechanisms, and fishway operation would need to be incorporated into the works schedule of the managing authority.

- **Option 3** – Full width rock ramp fishway

The construction of a rock ramp fishway at this site is not as favourable as on the main stem of the Macquarie River. The main benefit of constructing a full width rock ramp fishway at this site would be that the added weir reinforcement, which would strengthen the weir structure. The design comprises a series of transverse rock ridges to break up linear velocities and create resting pools that are connected by small riffles, which serve to decrease the headloss encountered across the structure, and provide passage to a greater range of fish species and size classes during adequate flow periods.

However it is difficult to secure a rock ramp fishway unless a considerable amount of concrete and steel pylons are used. The main disadvantage for construction of a full width rock ramp fishway is the increased cost. This is predominantly due to the considerable amount of rock needing to be imported to the site and the large amount of concrete and steel pylons required to secure the structure in place.

The weir currently stands at approximately 4 metres in height, and as such would extend approximately 80 metres downstream to achieve the required 1:20 slope. A low flow channel with a pool depth of approximately 500mm would need to be incorporated into the centre of the structure to allow for fish passage at lower flows.

Detailed specifications for the construction of rock ramp fishways can be obtained from NSW DPI and need to be considered in the preparation of any engineering designs.

Projected Remediation Costs

Projected cost	$50K - $100K	$100K- $250K	$250K - $500K	$500K - $1M	> $1M
Option 1					✔
Option 2				✔	
Option 3				✔	

Recommendation

Structural integrity of the weir must be addressed prior to the construction of any fishway. The construction of a vertical slot fishway (Option 1) is the preferred option for fish passage remediation at this site.

Benefits Associated with Remediation

The Macquarie River contains important fish habitat that should be protected, with reinstatement of fish passage along the entire system generating substantial benefits to the ecology of the catchment. The Lower Macquarie River has been classified as having a High Conservation Value (HCV) by Department of Environment and Conservation (DEC) and NSW DPI due to its high species diversity and presence of one or more threatened species.

The reinstatement of fish passage at Warren Shire Council Weir on the Macquarie River would provide access to approximately 102km of potential fish habitat either side of the weir.

DUBBO CITY COUNCIL WEIR, MACQUARIE RIVER

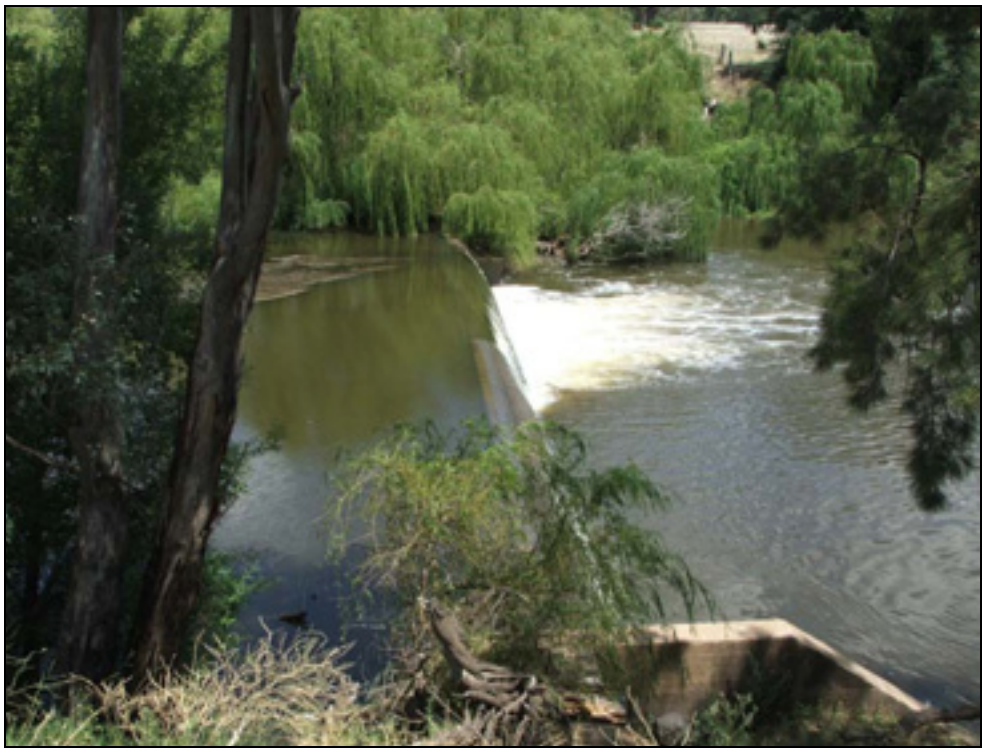


Figure 1. Dubbo City Council Weir, Macquarie River (21.12.2004, 377.5ML/day).

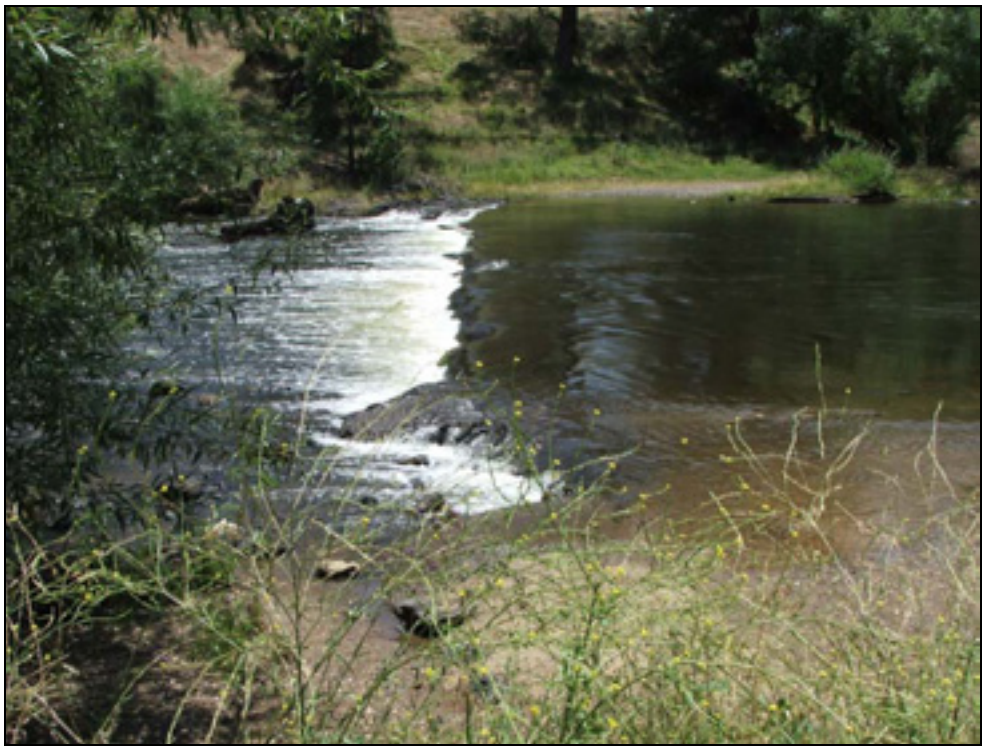


Figure 2. Falls Road Crossing upstream of Dubbo City Council Weir, Macquarie River (22.12.2004, 452ML/day).

Description and Setting

The Dubbo City Council Weir (Figure 1) is located in South Dubbo near the water treatment works on the Macquarie River (Mid Macquarie River catchment). The weir is a fixed crest structure approximately 4 metres high and approximately 40 metres across the length of the crest; it has no regulating infrastructure associated with it. The weir acts as a barrier to fish passage when flows are less than approximately 18,000/day due to excessive head loss, increased turbulence, and increased velocity across the face of the structure. Dubbo City Council is currently in the process of pursuing fish passage options at this site and a preliminary investigation report has been completed.

The Dubbo City Council Weir is ranked as a high remediation priority within the Central West CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species or populations (the Macquarie River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), and trout cod (*Maccullochella macquariensis*));
- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: the next upstream barrier to fish passage is the State Water owned Burrendong Dam located on the Macquarie River approximately 130km away. There is also a low level road barrier located upstream between Wellington and Burrendong Dam, which may drown out more frequently than the Dubbo City Council Weir. The next barrier located approximately 5km downstream is a weir originally built by the Water Conservaton and Irrigation Commission (WC & IC). Current ownership of this weir is thought to lie with DNR or State Water, although this has yet to be confirmed; and
- Low frequency of drown out <2% of time over the last 30 years (at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

The flows within the Macquarie River catchment are regulated by Burrendong Dam, which is located in the upper catchment approximately 35km upstream of Wellington. Burrendong Dam is primarily used to augment water in the Macquarie River for town water, stock, domestic, some irrigation and for environmental releases into the river and Macquarie Marshes wetlands. The Macquarie Marshes is an extensive Ramsar listed wetland system of approximately 220,000 hectares and commences 50km north of township of Warren.

Other than Burrendong Dam, there is one other moderate barrier to fish passage located upstream of Dubbo City Council Weir on the Macquarie River. The structure is a road crossing located between Wellington and Burrendong Dam (Figure 2). It is estimated that this structure blocks fish passage until flows are as high as 10,000ML/day.

Several major tributaries flow into the Macquarie River downstream of Wellington, whereas flow upstream is largely governed by the Burrendong Dam valve capacity (<8,750ML/day) unless the dam is above full supply level and water is overtopping the spillway.

The valve capacity of the dam and minor tributaries entering upstream of the crossing are therefore the limiting factors in providing fish passage over the Falls Road crossing.

Flow data was obtained from the DNR river gauge at the Dubbo Weir (State Water) (station 421004) and was used in the hydrological assessment of this site. Information with regard to flows within the Macquarie River was sourced from the DNR website and staff members and describes data acquired between 22.10.1974 – 04.04.2005.

Preliminary investigations estimate that the Dubbo City Council Weir would drown out with flows in excess of 18,000ML/day (In the high flow of November 2005, the Dubbo Council Weir drowned out prior to the river peaking at 18,400ML/day at Dubbo). The time weighted flow duration curve for the Macquarie River at this location shows that flows would exceed 18,000ML/day <2% of the time.

There are currently several licensed water extractors who utilise the upstream weir pool including Dubbo City Council, which has a license to extract water for domestic supply to the township of Dubbo.

Further licensing details of existing upstream water extractors were not available during the development of this report.

Operational Details

Dubbo City Council Weir was built in the 1930's to secure town water from the Macquarie River and was last modified in 1989. The weir is constructed of concrete with a canoe chute located on the left hand bank, although there is currently no fishway present. The weir is owned and managed by Dubbo City Council. At the time of the inspection willows were observed to be colonising the area adjacent to the structure, with concerns being expressed by Council about the structural integrity of the weir if the willows were to remain.

Ecological Considerations

Fish passage may be possible <2% of the time when the structure is drowned out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Macquarie River system. Furthermore if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure.

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Macquarie River: freshwater catfish, golden perch, Murray cod, spangled perch, bony herring, Australian smelt, Darling River hardyhead, fly specked hardyhead, crimson spotted rainbow fish, carp gudgeon, flathead gudgeon, with the threatened silver perch and olive perchlet also expected to be present. Introduced species including common carp, goldfish and eastern gambusia also occur in the Macquarie River.

Other species not listed on the database but have been observed in the Macquarie catchment below Burrendong Dam include trout cod and purple spotted gudgeon.

The Macquarie River at Dubbo possesses important fish habitat components including instream large woody debris, which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and for the growth of algae (thereby creating a food source for macroinvertebrates).

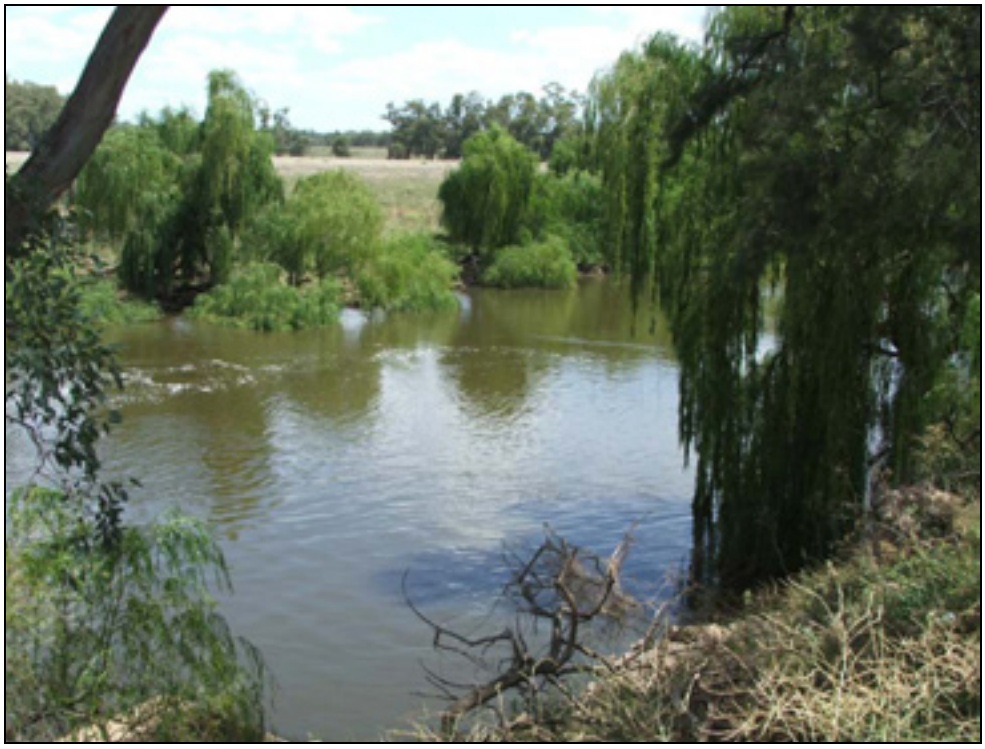


Figure 3. Macquarie River downstream of Dubbo City Council Weir (21.12.2004, 377.5ML/day).

The weir site has moderately vegetated banks either side of the structure (Figure 3). Willows and other pest plant species are present upstream and downstream of the weir. The removal of these pest species is recommended in conjunction with any fish passage remediation works at this site to enhance the habitat available to native fish.

This site is currently being influenced by the cold water releases from Burrendong Dam. During a recent study, water temperatures were found to be substantially lower at sites 300-400km downstream from Burrendong Dam during the release of irrigation flows (Astles *et al.* 2003). During their study silver perch populations showed a decrease in growth and increased mortality during cold water releases Cold water pollution is also known to restrict, and in some instances prevent, natural spawning events from taking place. Conversely, another study reports a recovery of temperature to within 1 – 2°C of 'natural' within the first 150km downstream of the dam (Burton 2001).

It is recommended that cold water pollution be addressed at Burrendong Dam in conjunction with fish passage remediation projects across the Macquarie catchment. Multi-level off-takes have been successful in addressing cold water releases from large impoundments across NSW including Windamere, Pindari, Chaffey, and Splitrock Dams.

Although release of water from higher in the water column can have thermal benefits, water quality can often be compromised through the growth of blue-green algae.

Future management of these sites need to be addressed to ensure that water temperature and water quality comply with the requirements of fish and other aquatic fauna and flora within the Macquarie River catchment.

Proposed Remediation Actions

As Dubbo City Council Weir does not drown out regularly, it is recommended that fish passage options be further investigated at this site. As indicated in the "*Dubbo Weir Fishway Preliminary Investigation Report*" prepared by NSW Department of Commerce, a vertical slot fishway would cater for fish passage during high and low flow periods (Department of Commerce 2004). It should be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred fishway design option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, trout cod, and purple spotted gudgeon). At sites where varying head losses are encountered the vertical slot fishway would be more effective in passing a greater range of fish size classes. The concrete composition of the Dubbo City Council Weir makes it an ideal anchor for securing a vertical slot fishway and its associated infrastructure. The weir could be constructed on the left hand bank and utilise the existing canoe chute. The cost of the vertical slot fishway is based on broad estimate of $150,000 per vertical metre, although this is dependant on site location, access and various structural and hydrological constraints. This option is the preferred option for fish passage remediation at the Dubbo City Council Weir.

- **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 fishway 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 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 at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable to other sites across NSW.

It is possible that the Deelder fishlock design could be applied to the Dubbo City Council 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 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 than other fishway designs when there is no existing fishway infrastructure or power at the site. However, the cost to build the fishlock at this site may be less than that of the vertical slot fishway due to less construction materials being required.

A further issue for consideration is the maintenance requirements of this type of fishway. Routine inspections of automated mechanisms, and fishway operation would need to be incorporated into the works schedule of the managing authority.

Projected Remediation Costs

Projected cost	$50K - $100K	$100K- $250K	$250K - $500K	$500K - $1M	> $1M
Option 1					✔
Option 2				✔	

Recommendation

The construction of a vertical slot fishway (Option 1) is the preferred option for fish passage remediation at this site. The structural integrity of the weir must be addressed prior to construction of any fishway. Willow removal at the weir is recommended at this time.

In addition, it is recommended that fish passage options be addressed at the Falls Road crossing upstream of this site (Figure 2). A partial width rock ramp fishway with a low flow channel across the road could be constructed on the crossing. An assessment of the vehicle traffic load and continuing need for the crossing should also be carried out.

Benefits Associated with Remediation

The Macquarie River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system generating substantial benefits to the ecology of the catchment.

The reinstatement of fish passage at the Dubbo City Council Weir in conjunction with fish passage remediation at The Falls Road crossing on the Macquarie River would open up access to approximately 135km of potential fish habitat either side of the weir.

DUBBO WEIR, MACQUARIE RIVER

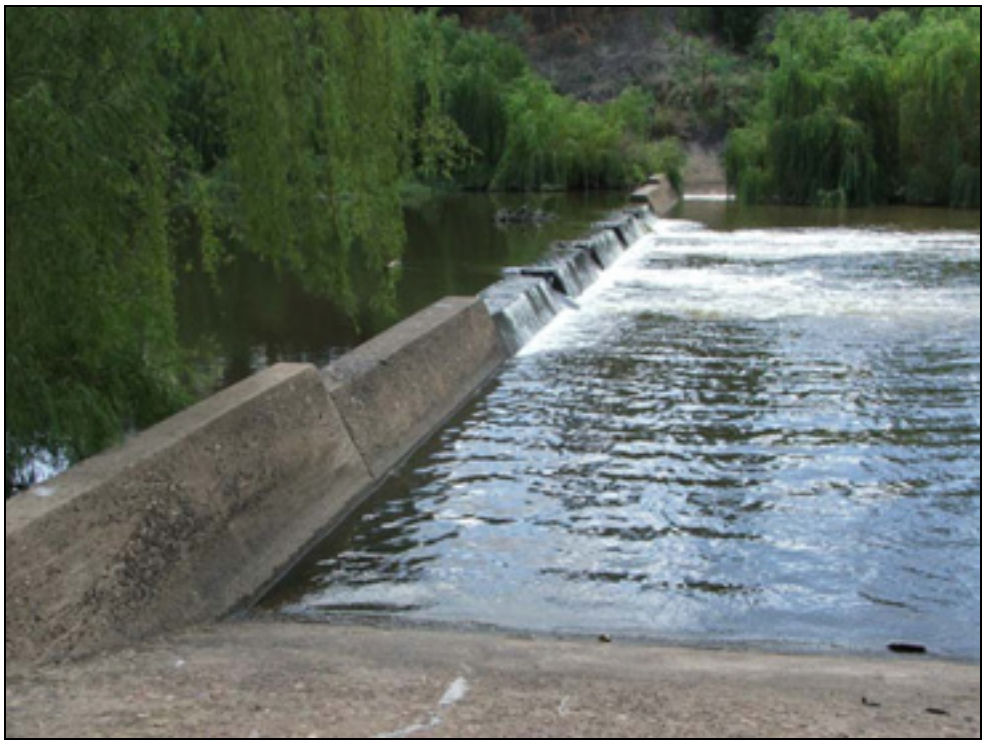


Figure 1. Dubbo Weir, Macquarie River (21.12.2004, 377.5ML/day).

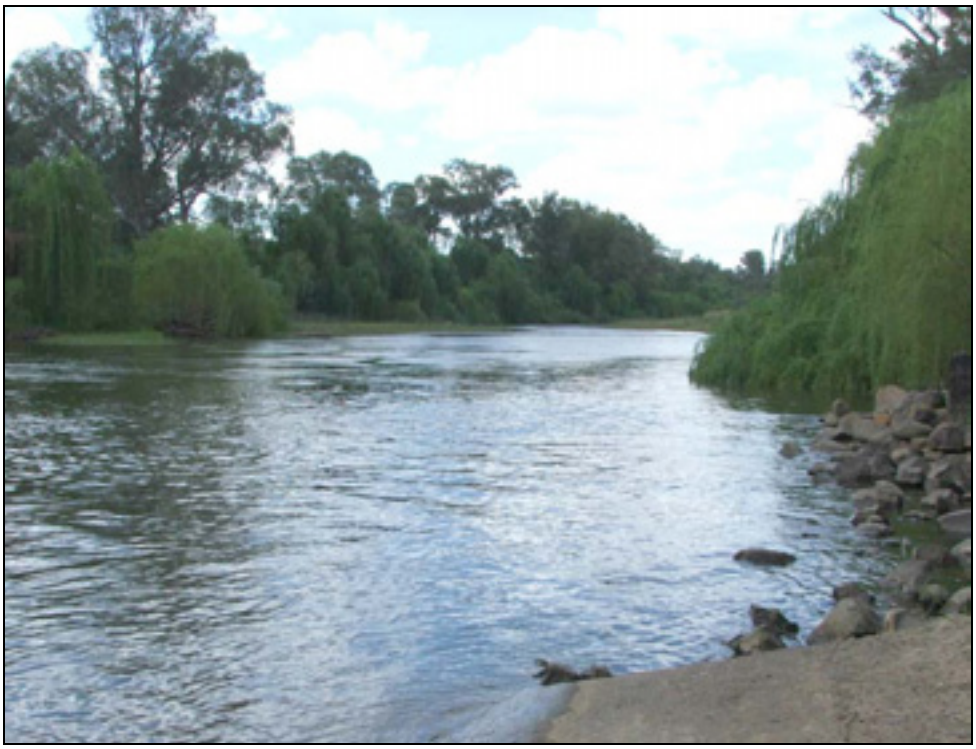


Figure 2. Macquarie River downstream of Dubbo Weir (21.12.2004, 377.5ML/day).

Description and Setting

Dubbo Weir (Figure 1) is located approximately 1km downstream of the CBD near 'Devils Hole' on the Macquarie River in the Mid Macquarie River catchment.

The weir is approximately 1.5 metres in height and approximately 65 metres across the length of the crest. Dubbo Weir is a fixed crest structure with provision for four drop boards to increase the height of the weir pool. Although the drop boards are currently not in place, the weir still acts as a barrier to fish passage at flows less than 18,000ML/day due to excessive head loss, increased turbulence, and velocity across the face of the structure.

Dubbo Weir is ranked as a high remediation priority within the Central West 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 Macquarie River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), and the endangered river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: the next upstream barrier to fish passage is the Dubbo City Council Weir approximately 5.5km away; the next man made barrier downstream is the Narromine Shire Council Weir on the Macquarie River approximately 70km away, although there is a natural barrier (Minore Falls), approximately 35km downstream; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

The flows within the Macquarie River catchment are regulated by Burrendong Dam, which is located in the upper catchment approximately 35km upstream of Wellington. Burrendong Dam is primarily used to augment water in the Macquarie River for town water, stock, domestic, irrigation and environmental releases into the river and the Macquarie Marshes wetlands. The Macquarie Marshes is an extensive Ramsar listed wetland system of approximately 220,000 hectares and commences 50km north of the township of Warren.

Flow data was obtained from the DNR river gauge at Dubbo (station 421001) and was used in the hydrological assessment of this site. Information with regard to flows within the Macquarie River was sourced from the DNR website and staff members, and describes data acquired between 22.10.1974 – 04.04.2005.

Preliminary investigations and site assessment during a high flow event indicated that Dubbo Weir would drown out with flows in excess of 18,00ML/day. In an observed high flow event in November 2005, the Macquarie River peaked at 18,400ML/day, with the weir being drowned out for less than 12 hours. The time weighted flow duration curve for the Macquarie River at this location shows that flows would exceed 18,000ML/day less than 2% of the time.

There are at least three water extractors that are located upstream of the weir. The pump sites are located at either deep holes or on outside bends or both and would be largely unaffected by any management of the weir.

Further discussions between these license holders, DNR and NSW DPI would be required before a decision was made regarding the future management of this site.

Operational Details

Historical records indicate that the weir was built in 1940 to provide water for a wartime army camp. The weir is currently not licensed. Historical records show that the weir was originally built by the Water Conservation and Irrigation Commission, with State Water being the current owners.

The weir is not being maintained at present, and its current use is purely for aesthetics and some recreation. Council do not use this weir for town water as the Dubbo City town water supply weir (Dubbo City Weir) is located a further 5km upstream.

The concrete weir has four bays that previously held drop boards to manipulate weir pool water levels. There are at least three riparian extractors located upstream of Dubbo Weir, although their ability to draw water is unlikely to be dependant on the presence of this weir (extractors use deep holes to ensure consistent water supply). If the removal or partial removal of this weir was to be considered, however, then water security for these extractors may be achieved by increasing the depth of individual pumps or modifying existing pumping infrastructure to meet their requirements.

There is a water supply pipe line that crosses the river in the vicinity of Dubbo Weir, and this may even have been incorporated in the weir structure. Any decision to modify this weir must fully explore the possibility that the pipe is located here. Engineering designs should be obtained and relevant stakeholders should be fully consulted.

Ecological Considerations

Fish passage may be possible less than 2% of the time, however the timing of these flows may not necessarily coincide with spawning activity or migrations of all or any of the resident fish species within the Macquarie River system. The short window of opportunity presented during the November 2005 high flow event allowed for localised fish movement only. Any species undergoing large scale migration from further downstream would have been unable to reach the barrier to negotiate it during the drown out period as they would have only begun to migrate on cues such as rising water levels. If the structure is only drowns out for short periods, water levels at the structure may drop as fish are moving upstream, and prior to them reaching the weir. At these times fish living some distance away from the structure could continually miss the opportunity to move past the structure.

The High Conservation Database (HCV) database (NSW DPI accessed 10.08.05) states that the following species native species are expected to occur within the Macquarie River: freshwater catfish, golden perch, Murray cod, spangled perch, bony herring, Australian smelt, Darling River hardyhead, fly specked hardyhead, crimson spotted rainbow fish, carp gudgeon, flathead gudgeon, with the threatened silver perch, olive perchlet, purple spotted gudgeon, trout cod and the endangered river snail also expected to be present. Introduced species including common carp, goldfish and eastern gambusia also occur in the Macquarie River.

This site is currently being influenced by the cold water releases from Burrendong Dam. Cold water pollution can restrict, and in some instances prevent natural spawning events from taking place. During a recent study of Burrendong Dam, water temperatures were found to be substantially lower at sites 300-400km downstream during the release of irrigation flows (Astles *et al.* 2003).

During their study silver perch populations showed a decrease in growth and increased mortality during cold water releases. Conversely, another study reports a recovery of temperature to within 1 – 2°C of 'natural' within the first 150km downstream of the dam (Burton 2001).

It is recommended that cold water pollution be addressed at Burrendong Dam in conjunction with fish passage remediation projects across the entire Macquarie catchment. Multi-level off-takes have been successful in addressing cold water releases from large impoundments across NSW including Windamere, Pindari, Chaffey, and Splitrock Dams. Although release of water from higher in the water column can have thermal benefits, water quality can often be compromised through the growth of blue-green algae. Future management of these sites need to be addressed to ensure that water temperature and water quality comply with the requirements of fish and other aquatic fauna and flora within the Macquarie River catchment.

The Macquarie River surrounding Dubbo Weir possesses important fish habitat components including instream large woody debris, which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and for the growth of algae (thereby creating a food source for macroinvertebrates).

The weir site has moderately vegetated banks both upstream and downstream of the site (Figure 2). Willows and other pest plant species are present either side of the weir. The removal of these pest species is advised in conjunction with any fish passage remediation works at this site to enhance the habitat available to native fish.

Proposed Remediation Actions

As this weir does not drown out regularly, it is recommended that fish passage options be further investigated at this site. It should be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

- **Option 1 -** Complete removal of the weir

The complete removal of the weir would provide the greatest benefit to the native fish and associated aquatic flora and fauna within the Macquarie catchment. The weir is currently not being maintained, and the removal of this structure should be considered a viable option following further consultation with DNR, State Water, Dubbo City Council, and nearby landholders. Access to the site is possible with an excavator, allowing works on the weir to be undertaken and construction debris removed.

It should be noted that although the removal of the structure would decrease water levels within the Macquarie River at this location, it is believed that there would be no negative impact on the ability of upstream diverters to remove water (although it is recommended that bed and water level surveys be undertaken prior to any works being carried out). Removal of the weir would also provide an opportunity to improve riparian habitat condition through reinstatement of a more natural water regime, and the removal of willows and other pest plant species.

- **Option 2 -** Partial removal of the weir

As this weir may provide some recreational and aesthetic value to the community, the partial removal of the weir may be an alternative fish passage remediation option for this site. Partial removal may allow the weir to be lowered so that structural drown could occur more readily. If the weir was lowered so that a head loss of no more than 200mm was created, it is possible that a greater range of fish species would be able to negotiate the weir, while still retaining the aesthetic values of the upstream weir pool.

- **Option 3 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, purple spotted gudgeon, and trout cod). With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs. The concrete construction of the weir makes it an ideal anchor for securing the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access, and various structural and hydrological constraints.

Projected Remediation Costs

Projected cost	$50K - $100K	$100K- $250K	$250K - $500K	$500K - $1M	> $1M
Option 1		✔			
Option 2		✔			
Option 3				✔	

Recommendation

The complete removal of the weir (Option1) is the preferred fish passage remediation for this site. The weir is currently not licensed and is not being maintained - removing Dubbo Weir would complement the fish passage remediation project planned for the Council owned town water supply weir (Dubbo City Weir) upstream.

It should be noted that removal of the weir would change the local aesthetics of the Macquarie River, through lowering of the water level, but improving the riparian zone vegetation (especially if combined with pest plant species removal).

Consultation with the appropriate stakeholders including extractors and recreational beneficiaries should occur prior to any onground works being carried out at this site. If further consultation determines that the structure is still required, it is recommended that the construction of a vertical slot fishway (Option 3) be considered. Again, it is important to engage the community in the decision making process so that a favourable outcome for all stakeholders can be achieved.

Benefits Associated with Remediation

The Macquarie River contains important fish habitat that should be protected. The reinstatement of fish passage along the entire Macquarie River system would generate substantial benefits to the ecology of the catchment. The reinstatement of fish passage at Dubbo Weir on the Macquarie River would provide access to approximately 75.5km of potential fish habitat either side of the weir.

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7. 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…….

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 ***Structure 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)**

……

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

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

Comments:

……

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

Please describe:

….....

….....

(vi) **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)

……

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8e No action recommended

Comments (Include supporting literature and correspondence)

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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, Lugg and Harris (1998) Obstructions to fish passage in New South Wales south coast streams. NSW Fisheries final report series No 4 ISSN 1440-3544
- Williams RJ, Watford FA (1996) An inventory of impediments to tidal flow in NSW estuarine fish habitats *Wetlands (Australia)* 15, 44-54.

Appendix B: Weir Prioritisation Scheme for NSW Coastal CMAs

INITIAL PRIORITISATION					
A) STREAM HABITAT VALUE					**SCORE**
Primary aquatic habitat rating					
Habitat Class	1	2	3	4	
Location in the system	Tidal	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: Weir Prioritisation Scheme for NSW Inland CMAs

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	1-5	5-10	>10		
Habitat opened if remediated	>150 km	100 – 150 km	50 - 100 km	20 - 50 km	<20 km	
B) STRUCTURE IMPACT CRITERIA						
Environmental effect rating						
Physical barrier: Headloss	>3000 mm	2000 - 3000 mm	1000 – 2000 mm	200 - 1000 mm		
Drown out frequency per annum	>5%	1-5%	0%			
Undershot Structure	Yes	No				
SECONDARY PRIORITISATION						
C) ENVIRONMENTAL CRITERIA						
Secondary aquatic habitat rating						
Instream habitat condition	Good	Fair	Poor			
Riparian condition	Good	Fair	Poor			
Threatened species	Habitat Class 1-2	Habitat Class 3	None			
D) MODIFICATION CRITERIA						
Structure use and remediation cost						
Redundant Weir	Yes	No				
Ease of Remediation	Removal	Modification	Fishway installation			
					TOTAL	


aquatic habitat rehabilitation
making more fish
...naturally