# REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

# NSW DETAILED WEIR REVIEW

## REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

## NORTHERN RIVERS CMA REGION

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Environmental TRUST

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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

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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.

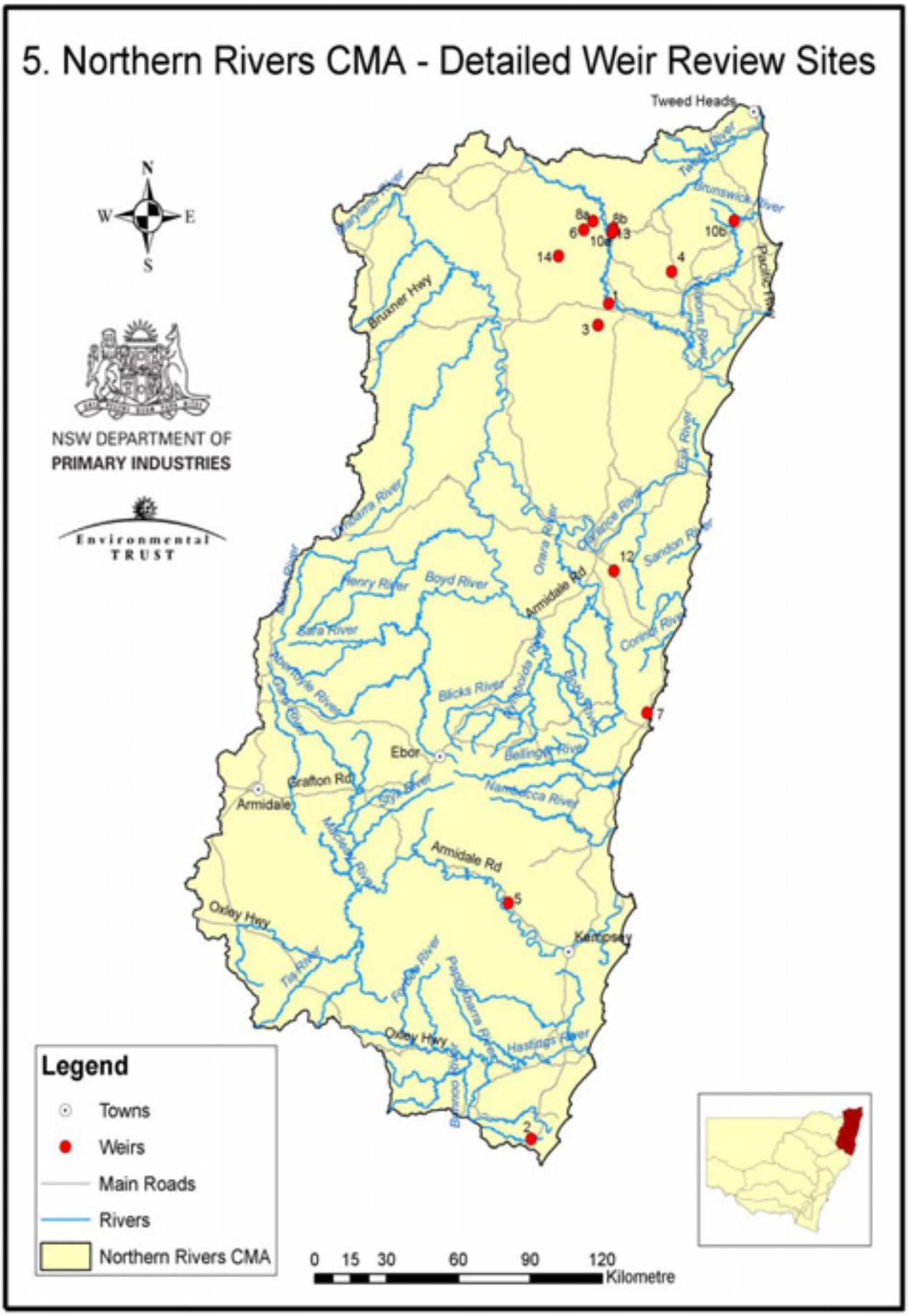
Following the initial prioritisation, a secondary prioritisation incorporating environmental and structural modification criteria was conducted to further delineate rankings. Environmental criteria incorporated aquatic and riparian habitat condition (i.e. good / fair / poor), sedimentation in the weir 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. Northern Rivers CMA - Detailed Weir Review Sites
Tweed Heads
N
W
E
S
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
Environmental
TRUST
Brunswick River
Pacific Hwy
Brisner Hwy
Richmond River
Clarence River
Sandon River
Boyd River
Henry River
Orara River
Armidale Rd
Bellinger River
Nambucca River
Ebor
Grafton Rd
Armidale
Oxley Hwy
Kempsey
Hastings River
Legend
Towns
Weirs
Main Roads
Rivers
Northern Rivers CMA
0 15 30 60 90 120
Kilometre

## Northern Rivers 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 | Cookes Weir | -28.842940 | 152.988530 | Adjustable crest (dropboards) | Richmond River | State Water | No | Removal | 50 - 150K | 50 - 150K | 212.5 |
| 2 | Stewarts River Weir | -31.720296 | 152.697759 | Fixed Crest (concrete) | Stewarts River | Private Landholder | No | Full-width Rock Ramp | 50 - 150K | <50K | 63.5 |
| 3 | Shannon Brook Weir | -28.918100 | 152.948960 | Adjustable crest (dropboards) | Shannon Brook | State Water | No (ineffective submerged orifice fishway present) | Removal | <50K | 50 - 150K | 106.0 |
| 4 | Goolmangar Creek Weir | -28.733950 | 153.224700 | Fixed Crest (sheet piling) | Goolmangar Creek | State Water | No | Full-width Rock Ramp | 250 - 500K | <50K | 60.0 |
| 5 | Hickeys Creek Weir | -30.907290 | 152.611370 | Adjustable crest (dropboards) | Hickeys Creek | State Water | No | Removal | <50K | 150 - 250K | 60.0 |
| 6 | Cob-o-corn Weir | -28.589800 | 152.895290 | Fixed Crest (concrete) | Cob-o-Corn Creek | State Water | No | Removal | <50K | 250 - 500K | 90.0 |
| 7 | Pine Brush Creek Weir | -30.252557 | 153.133318 | Fixed Crest (concrete and gabion) | Pine Brush Creek | Opal Cove Resort | No | Full-width Rock Ramp | >500K | 250 - 500K | 3.0 |
| 8a | Eden Creek Weir | -28.559480 | 152.930130 | Fixed Crest (concrete) | Eden Creek | State Water | No | Removal | <50K | 250 - 500K | 101.0 |
| 8b | Fawcetts Creek Weir 3 | -28.584640 | 153.005260 | Fixed Crest (concrete and rock) | Fawcetts Creek | State Water | No | Removal | <50K | 250 - 500K | 42.0 |
| 10a | Fawcetts Creek Weir 1 | -28.600230 | 153.000546 | Fixed Crest (concrete and rock) | Fawcetts Creek | State Water | No | Removal | <50K | >500K | 56.0 |
| 10b | Mullumbimby Weir 2 | -28.558320 | 153.459580 | Fixed Crest (concrete and rock) | Mullumbimby Creek | State Water | No | Removal | <50K | 250 - 500K | 8.0 |
| 12 | Glenugie Creek Weir | -29.764400 | 153.009090 | Fixed Crest (concrete and rock) | Glenugie Creek | State Water | No | Removal | <50K | 50 - 150K | 42.5 |
| 13 | Fawcetts Creek Weir 2 | -28.594910 | 153.006910 | Fixed Crest (concrete and rock) | Fawcetts Creek | State Water | No | Removal | <50K | >500K | 3.0 |
| 14 | Sextonville Weir | -28.680000 | 152.800000 | Fixed Crest (concrete) | Doubtful Creek | State Water | No (ineffective submerged orifice fishway present) | Removal | <50K | 250 - 500K | 50.0 |

## *COOKES WEIR, RICHMOND RIVER, CASINO*

**Figure 1.** Cookes Weir over the Richmond River near Casino. View of the weir is from the left bank (17-03-05, 0.573 metres, 22.5ML/day).

### *Description and setting*

Cookes Weir (Figure 1) is located approximately 5km west of Casino on the mainstem Richmond River and is accessed via an easement through farm tracks on both the right and left bank. The weir is constructed of concrete and contains a centrally placed drop-board structure that allows the height of the weir pool to be managed (Figure 2). Measuring 2.5 metres high by 28 metres wide, Cookes Weir pools water over 5km upstream at depths > 2 metres, resulting in a total usable capacity of 6.0ML. Water cascades over the crest of the weir, with fish passage being restricted due to excessive headloss (200mm) during low-flow conditions. However, weir drown out quickly occurs following minor river rises during which fish passage occurs.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Cookes Weir as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- The Richmond River (Class 1) is the mainstem river for the Richmond catchment, supporting a diverse range of habitat types and native fish species including Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*);

- The historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*) originally encompassed the Richmond and Clarence catchment;
- Jabour Weir, located 12.5km downstream, pools water to within 200mm of the crest of Cookes Weir;
- Approximately 200km of unimpeded habitat is available upstream of the weir for fish passage;
- Remediation of fish passage at Cookes Weir would build upon the benefits achieved for improved fish passage resulting from the removal of Norco Weir; and
- Instream habitat condition along the Richmond River ranges from good to excellent.

### *Hydrology*

Cookes Weir is located within the middle reaches of the mainstem Richmond River. Waterflow is perennial except when water extraction exceeds environmental flows during dry periods. Upstream of the weir pool, the Richmond River ranges from 10-20 metres wide, with depth generally between 1-2 metres. Hydrological flows for the Richmond River were determined from DIPNR river gauge #203004 located approximately 10km downstream of Cookes Weir. Flows within the Richmond River vary from 0.5 – 54,000ML/day and are dictated by rainfall levels in the upper reaches of the catchment. Water generally overtops the weir, with structural drown out occurring during flows in excess of 50ML/day, or approximately for 60% of the time. However, the timing of drown out flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Richmond River.

### *Operational Details*

Cookes Weir was constructed in 1966 for drought protection, providing Casino with an emergency water supply. The structure, now owned by State Water, is still used today for its original purposes as well as for irrigation, stock (beef), and domestic watering. Over fifteen landholders adjoin the weir pool, with seven of these owners possessing water extraction licenses totalling 433ML per annum, which provides State Water with annual revenue of approximately $4000. Additionally, most landholders use the weir pool for stock and domestic purposes.

Water levels within the impoundment are generally maintained at maximum levels; however, the central drop boards can be removed to top up Jabour Weir, the principle water supply for Casino, during dry periods. The weir is considered to be in working condition, with a satisfactory structural safety level being achieved (Opus and Golder, 1999). Minor erosion is evident around the left bank abutment.

### *Ecological Considerations*

Cookes Weir is the fourth of five anthropogenic barriers that restrict fish passage on the mainstem Richmond River between the Pacific Ocean and the township of Kyogle, approximately 160km AMD. Grays Falls, a natural barrier approximately 100 km from the Richmond River mouth, is shortly followed by Norco Weir (101km AMD), Manyweathers Weir (103km AMD), Jabour Weir (104km AMD), Cookes Weir (116km AMD), and Kyogle Weir (160km AMD). Permits have been issued for the removal of Norco Weir, while management strategies have been formulated for Manyweathers and Jabour Weir to remediate fish passage.

Additionally, Kyogle Shire Council is investigating water reuse schemes that would service the existing requirements provided by Kyogle Weir. Remediation of fish passage at Cookes Weir would therefore address one of the final remaining barriers to fish passage on the mainstem Richmond River.

A)

B)

**Figure 2.** (A) View of drop board structure in Cookes Weir. (B) Riparian and instream habitat immediately downstream of Cookes Weir, Richmond River.

The Richmond catchment supports a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Additionally, the river provides refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Cookes Weir include the koala (*Phascikarctis cinereus*), Superb Fruit Dove (*Ptilinopus superbus*), Black Bittern (*Ixobrychus flavicollis*), Glossy Black Cockatoo (*Calyptorhynchus banksii*), and the Grey Headed Flying Fox (*Pteropus poliocephalus*).

Water quality at Cookes Weir is described as excellent except during drought periods when stagnant pools form. The weir displays moderately to poorly vegetated banks with minor erosion present both upstream and downstream of the structure presumably due to cattle access. Riparian vegetation is primarily composed of casuarinas, callistemons, and a mix of rainforest and eucalypt species; while groundcover is dominated by pasture grasses, introduced weeds (e.g. lantana and castor oil) and *Lomandra histrix*. Despite fencing on both sides of the creek, cattle appear to gain regular access to the waterway. Thus, overall creek health would be improved by maintaining riparian fencing followed by revegetating disturbed banks that scale up to 10 metres above the water level. Siltation, if present, is minor within the weir pool, with no difference in bed level being recorded on the upstream and downstream side of the weir.

### *Proposed Remediation Actions*

- **Option 1 –** Remove central drop boards

Removal of the central drop boards would reduce the water level within the upstream weir pool by approximately 200mm to the level of water pooled upstream by Jabour Weir.

This option would remediate the small hydraulic step resulting from Cookes Weir, thereby allowing fish passage to 200km of upstream habitat. During declared drought periods, the drop boards could be reinserted to provide an emergency water supply for Casino, if deemed necessary. Selection of this remediation option would require investigation into the hydraulic capacity of the drop board structure to ensure that water velocities were not excessive for resident fish species attempting to pass through. Removal of the drop boards would not diminish the recreational nor aesthetic values of the existing weir pool. Effect of removing the drop boards upon weir stability would need to be investigated.

- **Option 2 –** Removal of Cookes Weir

The complete removal of the structure would provide the greatest benefit to the health of the Richmond River by providing unrestricted fish passage and natural sediment fluxes. Additionally, State Water would no longer be liable for the structure. Implementation of this option would require investigation into the variability of weir pool height for Jabour Weir below the maximum usable capacity to determine the likely reduction in pool height above Cookes Weir. With water levels at a maximum usable capacity at Jabour weir, removal of Cookes Weir would result in a minor fall in pool height (200mm). The effect of this reduction upon the servicing of upstream water licenses would need to be investigated, with compensation required if alternative water sources were necessary to meet landholder demand. Usable weir capacity for Jabour and Cookes Weir combined would vary little with the removal of Cookes Weir.

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

A partial width rock-ramp could be constructed within the location of the current drop board structure. To produce an attractant flow for the rock-ramp, the pool height above Cookes Weir would need to be dropped by 100mm. The rock-ramp design would ensure stabile pool heights above Cookes Weir regardless of water levels within Jabour Weir. Additionally, given that headloss across the fishway would be < 200mm, the entrance to the rock-ramp would be located near the face of Cookes Weir which would aid in attracting migrating fish.

If the pool height behind Jabour Weir varies markedly below the baseline weir height, licensed landholders above Cookes Weir may be compromised by Options 1 and 2. Option 3 would ensure the maintenance of pool levels above Cookes Weir while still providing for fish passage. State Water's preferred option over the short-term is to maintain the weir in its current capacity, while a proposed long-term strategy is to investigate the construction of a new structure near Jabour Weir that drowns out the two existing weirs while incorporating the necessary measures to ensure fish passage.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | ✔ | | | | |
| **Option 2** | | ✔ | | | |
| **Option 3** | | ✔ | | | |

**Option 1.** Initial costs of removing the drop-boards would be less than $1,000; however, costs associated with long-term maintenance (e.g. debris removal) and OHS considerations centering on working on the weir structure are unknown.

**Option 2.** Removal of the weir would likely cost in excess of $100,000 due to the difficulty associated with water pooling upstream from Jabour Weir. Final costs would require preparatory surveys, production of an REF, and waste disposal.

**Option 3.** A partial-width rock-ramp would need to be approximately 2.5 metres high and designed to fit within the existing concrete drop-board structure. Similar to Option 2, costs would be higher than normally predicted due to the pooling of water upstream from Jabour Weir.

### *Recommendation*

The preferred remediation action for this site is removal of the drop boards (Option 1) over the short term. Monitoring should then commence to investigate fish passage efficiency, as well as the effect of pool height fluctuations upon existing licensed landholders upstream of Cookes Weir. If required, licensed landholders could be compensated for the redesign of existing water extraction equipment, or the construction of alternative water supply sources (e.g. bores or off-stream dams). Assuming that removal of the drop boards has not compromised upstream license holders, the weir should be investigated for removal (Option 2). If considerable fluctuations in pool height above Cookes Weir occur following removal of the drop boards, implementation of Option 3 would be warranted.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that the Richmond River provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Cookes Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 200km.

## *STEWARTS RIVER WEIR, STEWARTS RIVER, JOHNS RIVER*

**Figure 1.** Stewarts River Weir over the Stewarts River near Johns River as viewed from the downstream left bank.

### *Description and setting*

Stewarts River Weir (Figure 1) is located approximately 1km north of Johns River on the mainstem Stewarts River, and is accessible via private property. The fixed crest concrete weir acts as a tidal barrage that limits the intrusion of brackish water from Watson Taylors Lake located approximately 3km downstream. The weir measures 0.5 metres high by 20 metres wide and pools water 600 metres upstream at depths > 1.5 metres. Water cascades over the crest of the weir, with fish passage being restricted due to excessive headloss (200mm) along the left bank during low-flow conditions. However, the weir quickly drowns out following minor river rises during which fish passage is unimpeded.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Stewarts River Weir as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- The Stewarts River is the mainstem river for the Stewarts catchment (Class 1), supporting a diverse range of habitat types and native fish species including Australian bass (*Macquaria novemaculeata*) and Striped mullet (*Mugil cephalus*);
- The weir acts as a tidal barrage, and if remediated would remove the only significant barrier on Stewarts River;
- The weir drowns out quickly during minor river rises and king tides;

- Approximately 50km of unimpeded habitat is available upstream of the weir for fish passage; and
- Instream and riparian habitat condition along the Stewarts River ranges from good to excellent.

### *Hydrology*

Stewarts River Weir is located at the high water mark within the lower reaches of the mainstem Stewarts River. Water flow is perennial except when water extraction exceeds environmental flows during dry periods. Upstream of the weir pool, the Stewarts River ranges from 5-15 metres wide, with water depth generally between 1-2 metres. Structural drown out occurs several times a year following moderate to heavy rainfall in the catchment. Additionally during king tides, brackish water is backed up to the crest of the weir from Watson Taylors Lake effectively drowning out the structure.

### *Operational Details*

Stewarts River Weir is a private structure constructed in 1981 for the conservation of water for irrigation, stock, and domestic use on an adjacent dairy farm. Still used for its original purpose, the weir also acts as a tidal barrage given its location just above the mean high water mark. However, discussions with the owners indicate that the weir drowns out during king tides. The weir services a single water extraction license (135ML per annum) held by the structural owner, while the only other landholder with access to the weir pool only draws water for stock and domestic use. No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir is considered to be in working condition, with no maintenance required.

### *Ecological Considerations*

Remediation of fish passage at Stewarts River Weir would address the main significant barrier to fish passage within the Stewarts catchment, thus opening up 50km of upstream habitat. However, two minor road crossing barriers are present in the upper reaches of the catchment that restrict fish access to a further 10km of upstream habitat.

Stewarts River supports a diverse range of native fish species including migratory species such as the Australian bass (*Macquaria novemaculeata*) and Striped mullet (*Mugil cephalus*). Terrestrial species of conservation concern located within the vicinity of Stewarts River Weir include the Australasian Bittern (*Botaurus poiciloptilus*), Square-tailed Kite (*Lophoictinia isura*), Painted Honeyeater (*Grantiella picta*), Eastern Little Mastiff Bat (*Mormopterus norfolkensis*), Common Planigale (*Planigale maculate*), Yellow-bellied Glider (*Petaurus australis*), and Rufous Bettong (*Aepyprymnus rufescens*).

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation, which is limited within Stewarts River due to riparian shading, is dominated by submerged macrophytes. Water quality in Stewarts River above the Pacific Highway Bridge is described as excellent except during drought periods when stagnant pools form. Acid sulfate soils are known to occur downstream of the bridge in the lower tidal reaches of the system.

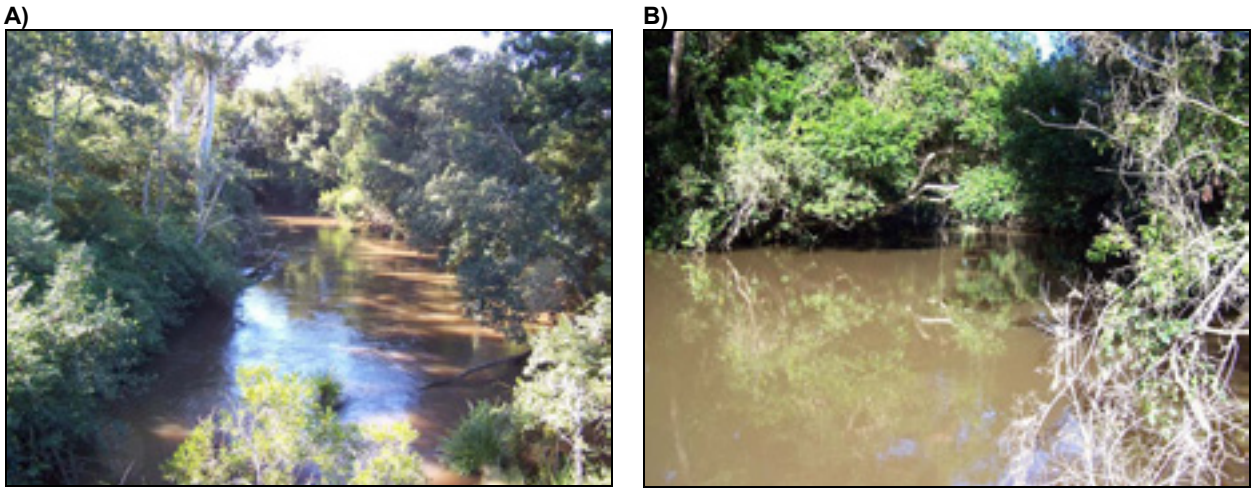



**Figure 2.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Stewarts River Weir, Stewarts River.

The weir pool displays intact, vegetated banks with minor erosion due to unrestricted cattle access. Riparian vegetation is primarily composed of mixed sub temperate rainforest species (e.g. Bangalow Palms, Waterhousia floribunda, and Guioa), with groundcover considered sparse and dominated by introduced weeds (e.g. lantana and privet) and *Lomandra hystrix* (Figure 2). Overall creek health would be improved by the insertion of riparian fencing followed by the revegetation of disturbed banks, which reach up to 3 metres above the water level. Siltation is considered minor within the weir pool due to the low height of the structure, with a difference in bed level of 300mm being recorded across the face of the weir.

### *Proposed Remediation Actions*

- **Option 1 –** Full-width rock ramp fishway

Due to the low height of the weir, a full-width rock-ramp would provide the best option of remediating fish passage while maintaining the structure. Full-width rock ramp fishways are generally considered one of the most effective designs for passing various species and size classes of fish within Australian streams. Due to the small size of the river, flows would be concentrated to the centre of the structure to ensure fish passage during low-flow conditions.

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

Due to the small headloss experienced across the structure and the ease with which the weir drowns out, a partial-width rock-ramp fishway could be designed starting on the right bank that extends parallel to the face of the weir. Implementation of this option would require a redesign of the weir crest to provide attractant flows both through the rock-ramp as well as near the entrance of the fishway.

- **Option 3 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of the Stewarts River by providing unrestricted fish passage and natural sediment fluxes.

However, removal of the tidal barrage would significantly affect the quantity and quality of water extracted by the current weir owner for the adjacent dairy enterprise. Implementation of this option would likely compromise the ability of the dairy farm to operate unless an alternative, reliable source of water could meet landholder demand. Bore water is available near the weir site; however the rate of water extraction may be insufficient to support irrigation practices.

The weir pool is currently used for irrigation, stock, and domestic use by the adjacent landholders, with water generally being pumped during dry spells to maintain consistent pastures for dairy cattle. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weir, with neither landholder interested in seeing the structure removed. Additionally, given that the structure is a tidal barrage, removal would affect not only the quantity but also the quality of water at the weir. Thus, landholder sentiment would support Options 1 and 2, which would ensure the stability of the structure and the provision of a reliable source of water.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | ✔ | | | |
| **Option 2** | | ✔ | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** Full-width rock ramp fishways are one of the most effective fishway designs for passing fish, but are also one of the most expensive to construct. The cost of inserting a full-width rock ramp fishway at Stewarts River Weir would likely exceed $100,000.

**Option 2.** A partial-width rock-ramp running parallel to the face of the weir would likely costs around $75,000, including the redesign of the existing weir to provide adequate attractant flows.

**Option 3.** Due to the small size of the structure, removal of the weir would likely cost less than $20,000 including preparatory surveys, production of an REF, and waste disposal.

### *Recommendation*

The preferred remediation option for Stewarts River Weir is the insertion of a full-width or partial-width rock-ramp (Options 1 and 2). A full-width rock-ramp fishway would provide the greatest benefit for remediating fish passage while maintaining the existing weir; however, the benefits may not warrant the extra costs compared to a partial-width rock-ramp fishway. Although removal of the weir would be supported by NSW DPI, the weir owner is reluctant to consider this option due to the loss of a secure source of freshwater which would compromise current dairy operations.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that the Stewarts River provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Stewarts River Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 50km.

## *SHANNON BROOK WEIR, SHANNON BROOK, CASINO*

**Figure 1.** Shannon Brook Weir on Shannon Brook near Casino as viewed from the left bank (23-08-05: 0.639 metres, 65.514ML/day).

### *Description and setting*

Shannon Brook Weir (Figure 1) is located approximately 10km southwest of Casino on the Shannon Brook waterway, and is accessible via an easement that is reached by farm tracts on either side of the structure. The weir is constructed of concrete and fitted with a drop-board structure that allows the height of the weir pool to be managed (Figure 2A). Additionally, the weir also displays a submerged orifice fishway (Figure 2B). Measuring 2.2 metres high by 28 metres wide, Shannon Brook Weir pools water approximately 1.3km upstream at depths > 2 metres, resulting in a total usable capacity of 13.5ML. Water cascades over the crest of the structure when the weir pool is full, with fish passage restricted due to excessive headloss (1750mm). Australian fish are known to possess a low sustained swimming threshold, therefore few species are likely to successful traverse the submerged orifice fishway at Shannon Brook Weir, which favours strong swimmers.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Shannon Brook Weir as a medium remediation priority within the Northern Rivers CMA region due to the following factors:

- Shannon Brook (Class 2) is a low-lying tributary of the Richmond River, historically supporting a diverse range of habitat types and native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*), and

migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*);

- No structure is known to impede fish passage either downstream or upstream of the weir. Remediation of fish passage at Shannon Brook Weir would therefore provide over 200km of unimpeded habitat for migrating fish;
- State Water has indicated that the weir no longer serves its original purpose and thus can be removed; and
- Instream and riparian habitat condition along Shannon Brook is severely degraded, with present day conditions attributed to widespread land clearing especially in the riparian zone and floodplain.

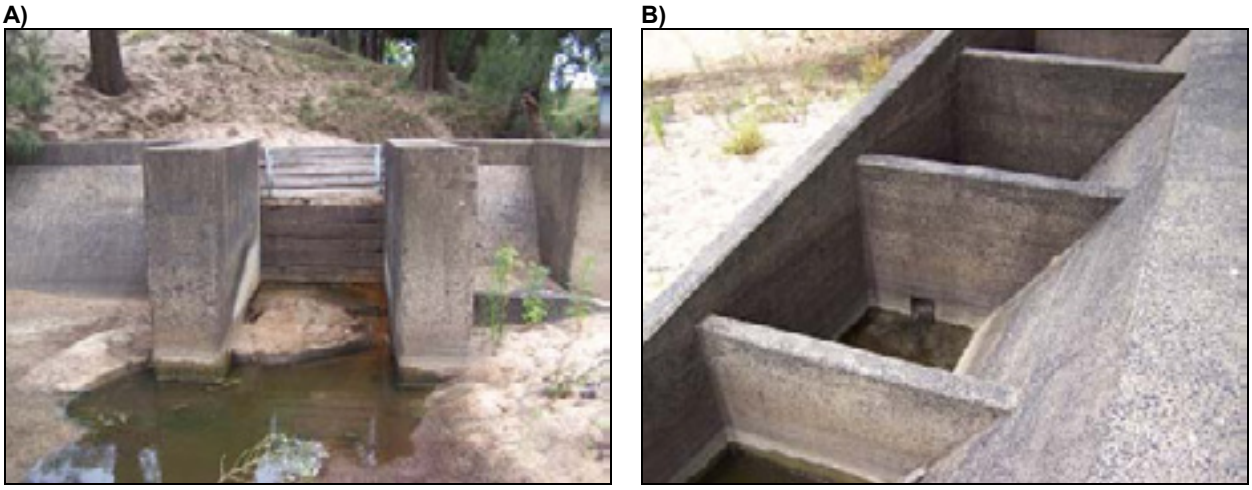



**Figure 2.** View of (A) the removable drop board structure along the weir's right bank and (B) the centrally placed submerged orifice fishway.

### *Hydrology*

Shannon Brook is a low lying tributary of the Richmond River. Waterflow is dependent upon recent rainfall levels, with no-flow conditions being recorded for 48.7% of the year. Hydrological flows for the Shannon Brook were determined from DIPNR river gauge #203041 located at Yorklea approximately 10km downstream of Shannon Brook Weir. Flows within Shannon Brook vary from 0 - 7400ML/day and are dictated by rainfall in the upper reaches of the subcatchment. Water rarely overtops the weir, with structural drown out occurring during flows in excess of 1000ML/day, or approximately for 1% of the year. Upstream of the weir pool, Shannon Brook ranges from 5-10 metres wide, with low-flow depth generally < one metre.

### *Operational Details*

Shannon Brook Weir was constructed in 1970 for drought protection. The structure, now owned by State Water, has no current use except to water stock. No water was observed in the weir pool at the time of the first visit (17-03-05), while a scour valve near the bottom left bank abutment was passing flows through the structure during the second visit (23-08-05). Four landholders adjoin the weir pool, with none of these owners possessing water extraction licenses. A single pump is used for watering stock; however the pump draws water from the scour hole immediately downstream of the weir.

No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir is considered to be in a working condition, with a satisfactory structural safety level being achieved (Opus and Golder, 1999).

### *Ecological Considerations*

The Richmond catchment supports a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Shannon Brook Weir would remove the only known barrier to fish passage in the system, thus opening over 100km of habitat to unimpeded fish migration. Terrestrial species of conservation concern located within the vicinity of Shannon Brook Weir include the koala (*Phascikarctis cinereus*), Powerful Owl (*Ninox strenua*), Superb Fruit Dove (*Ptilinopus superbus*), Black Bittern (*Ixobrychus flavicollis*), Glossy Black Cockatoo (*Calyptorhynchus banksii*), Little Bentwing Bat (*Miniopterus australis*), and Grey Headed Flying Fox (*Pteropus poliocephalus*).

Water quality within Shannon Brook is described as fair to good except during drought periods when stagnant pools form. The weir displays poorly vegetated banks with extensive erosion present both upstream and downstream of the structure, presumably due to cattle access and associated clearing of riparian and floodplain vegetation. Riparian vegetation is sparse, primarily composed of casuarinas (*Casuarina cunninghamiana*), *Callistemon spp*., and tuckeroos (*Cupaniopsis anacardioides*). Groundcover is dominated by pasture grasses, introduced weeds (e.g. lantana and castor oil) and sparse patches of *Lomandra histrix*. Despite fencing on both sides of the creek, cattle appear to gain regular access to the waterway. Thus, overall creek health would be improved by maintaining riparian fencing and revegetating disturbed banks that reach up to 4 metres above the weir pool. Siltation in the weir pool is minor, with a 300mm difference in bed level being recorded across the structure. A highly mobile sandy substrate dominates the banks and stream bed (Figure 3).

A) B)

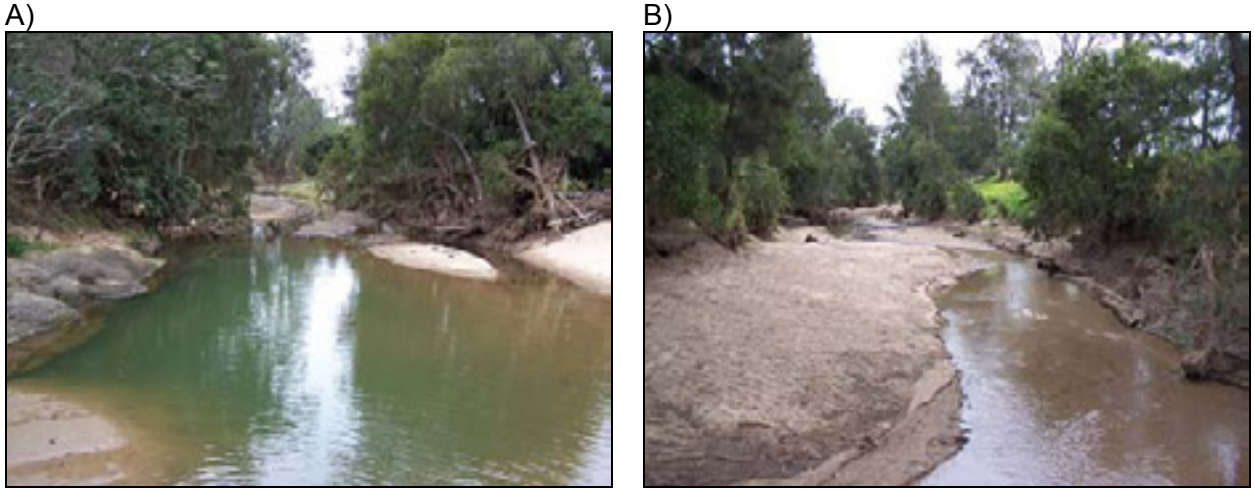


**Figure 3.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Shannon Brook Weir, Shannon Brook.

### *Proposed Remediation Actions*

No existing water extraction license is serviced by the weir, with only one adjacent landholder drawing water for stock from below the weir. Landholder sentiment towards the weir has varied over time, with requests for the weirs removal and retention being voiced.

- **Option 1 –** Remove drop boards

Removal of the drop boards in conjunction with blocking the scour valve along the left abutment would provide fish passage during low-flow conditions within Shannon Brook. At present, no water is pooled within the weir, thus removal of the drop boards would not alter the ability of adjacent landholders to acquire water for stock or domestic use. Effect of removing the drop boards upon upstream bank stability would need to be investigated, given that water flow would be redirected towards the upstream right bank.

- **Option 2 –** Removal of Shannon Brook Weir

The complete removal of the structure would provide the greatest benefit to the health of the Shannon Brook system by providing unrestricted fish passage. Additionally, State Water would no longer be liable for the site. Implementation of this option would require investigation into bed stability, given that bed composition is composed primarily of highly mobile sand. However, the weir is not acting as a bed control structure, thus removal would presumably reinstate natural sediment fluxes. Removal of the structure should coincide with riparian fencing and revegetation to promote bank stabilization.

- **Option 3 –** Partial removal of Shannon Brook Weir

This option would involve the partial removal of the structure down to bed level to promote fish passage. The remaining portion of the weir would act as a bed control structure to limit the mobilization of bed substrate.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | ✔ | | | | |
| **Option 2** | | ✔ | | | |
| **Option 3** | | ✔ | | | |

**Option 1.** Initial costs of removing the drop-boards would be less than $1,000, with no further maintenance required for the structure. If this option is pursued, an agreement should be reached that if the drop boards are reinstated, State Water must remediate fish passage through the insertion of a suitable, working fishway design.

**Option 2.** Removal of the weir would likely cost in excess of $50,000. Final costs would include preparatory surveys, production of an REF, landholder consultation, waste disposal, and bank stabilisation.

**Option 3.** Partial removal of Shannon Brook Weir would likely cost the same as a full removal (Option 2).

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) following investigation into the likely changes to channel geomorphology. The bed substrate is highly mobile, with bed equilibrium likely to occur following the first flush after removal.

Additionally, bed rock is located immediately downstream of the structure and may provide an adequate foundation for ensuring bed stability. Weir removal would not only ensure unrestricted fish passage within the system, but also re-establish natural sediment fluxes. Currently, the weir does not act as a bed control structure as bed levels on either side of the structure vary by only 300mm. It is recommended that the left and right bank abutments be left in place to assist in maintaining bank stability at the site. Consultation should occur with the adjacent landholder that pumps water from the downstream scour hole to ensure that stock and domestic needs will still be met in the absence of the weir.

Option 1 is also a viable and acceptable option for improving fish passage in the short term. However, implementation of Option 1 should come with the explicit understanding that the drop boards would not be reinserted by State Water or adjacent landholders. Option 3 should be investigated if channel and bank stability is compromised by a full removal. The investigation must determine whether the remaining section of the structure would promote the formation of a downstream scour pool and associated headloss barrier.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Shannon Brook provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Shannon Brook Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 100km.

## *GOOLMANGAR CREEK WEIR, GOOLMANGAR CREEK, LISMORE*

**Figure 1.** Goolmangar Creek Weir on Goolmangar Creek near Lismore.

### *Description and setting*

Goolmangar Creek Weir (Figure 1) is located approximately 15km northwest of Lismore on Goolmangar Creek in the middle reaches of the Richmond River catchment, and is accessible via an easement reached by a public road. The fixed-crest weir is constructed of sheet piling, measuring 2 metres high by 20 metres wide. Water is pooled approximately 1km upstream at depths > 2 metres, resulting in a total usable capacity of 11.5ML. Fish passage is blocked at the site due to excessive headloss (1400mm) except during structural drown out which occurs 2 - 3 times per year.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Goolmangar Creek Weir as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Goolmangar Creek is a perennial flowing tributary (Class 2) of the Richmond River that supports a diverse range of native fish species;
- Goolmangar Creek is within the known historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*);
- Remediation of fish passage at Goolmangar Creek Weir would open up 34km of upstream habitat;
- Goolmangar Creek is a tributary of the Wilsons River, with no known barrier to fish migration occurring downstream of the weir to the sea; and

- Instream and riparian habitat condition along Goolmangar Creek is considered fair to good.

### *Hydrology*

Goolmangar Creek is a mid level, perennial flowing tributary (Class 2) that joins the Wilsons River, which is itself a significant tributary of the Richmond River. Upstream of the weir pool, the watercourse is approximately 10 – 15 metres wide with low-flow depth generally < 1 metre. A river gauge is not present on Goolmangar Creek or adjacent tributaries; however, landholders indicate that the creek maintains a constant base flow throughout the year except during periods of extreme drought. Structural drown out occurs 2 - 3 times a year following significant rainfalls, providing the only means of fish passage in the upstream direction.

### *Operational Details*

Goolmangar Creek Weir was constructed in 1970 for drought protection, as well as to provide a pumping pool for irrigation, stock (dairy and beef), and domestic use. The structure, now owned by State Water, currently services three water extraction licenses totalling 244ML per annum, which provides annual revenue of approximately $2000. Water is primarily pumped from the weir pool for the purpose of irrigating pasture grasses for dairy cattle during dry spells, with three additional pumps being used for stock and domestic purposes. No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir is considered to be in a working condition, with a satisfactory structural safety level being achieved (Opus and Golder, 1999).

### *Ecological Considerations*

The Richmond catchment supports a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Goolmangar Creek Weir would remove the main significant barrier to fish passage on the system, thus opening 34 km of habitat to unimpeded fish migration. Seven additional barriers have been identified in the upper reaches of the Goolmangar subcatchment; however, these structures (six road crossing, one weir) are viewed as minor obstructions relative to the impact of the weir upon migrating fish. Additionally, there is no known barrier below Goolmangar Creek Weir, a distance of over 135km. The creek also provides valuable refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Goolmangar Creek Weir include the Australasian Bittern (*Botaurus poiciloptilus*), Square-tailed kite (*Lophoictinia isura*), Barred Cuckoo-Shrike (*Coracina lineaa*), Rose Crowned Furit Dove (*Ptilinopus regina*), Superb Fruit Dove (*Ptilinopus superbus*), Powerful Owl (*Ninox strenua*), and Masked Owl (*Tyto novaehollandiae*).

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation, which is limited within Goolmangar Creek due to shading by riparian vegetation, is dominated by red azolla.

Water quality within Goolmangar Creek is described as good to excellent except during drought periods when stagnant pools form. The weir and surrounding reaches display well vegetated, intact banks, despite the lack of riparian fencing. Although stock have access to the creek, the adjacent steep banks preclude cattle from accessing the water in most locations.

**Figure 2.** Riparian and instream habitat immediately downstream of the weir.

Vegetation within the riparian zone is primarily composed of casuarinas (*Casuarina cunninghamiana*), subtemperate rainforest species, and introduced species (e.g. *Camphor laurel*), while groundcover adjacent to the waterway is dominated by *Lomandra histrix*, tobacco bush, and lantana). Siltation was not recorded within the weir pool, with a minor scour pool (0.5 metres deep) observed immediately downstream of the structure.

### *Proposed Remediation Actions*

- **Option 1 –** Full-width rock ramp fishway

Given the current design of the weir, a full-width rock-ramp fishway could be inserted to remediate fish passage at the weir. Full-width rock-ramp fishway are generally considered one of the most effective designs for passing various size classes of fish within Australian streams.

- **Option 2 –** Partial removal followed by insertion of rock-ramp fishway

This option would involve the partial removal of the structure followed by the insertion of a full or partial width rock-ramp. Weir height would be reduced from 2 metres to < 1 metre, significantly reducing the cost of inserting a fishway onto the structure. The remaining portion of the weir would continue to pool water upstream for stock and domestic use, but water extraction licenses may be compromised.

- **Option 3 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Goolmangar Creek by removing the main barrier to fish passage in the system. Additionally, State Water would no longer be liable for the site. Consultation and compensation would need to occur with adjacent and upstream landholders to ensure that existing water needs (e.g. three licenses) could be met by alternative means.

The weir pool is currently used for irrigation, stock, and domestic use by several upstream landholders, with water generally being pumped during dry spells to maintain consistent pastures for dairy and beef cattle. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weir, with landholders uninterested in seeing the structure removed. Thus, landholder sentiment would support Option 1, which would ensure the stability of the structure and the provision of a reliable source of water.

State Water supports the maintenance of the structure in its current state, which avoids the need to consult with adjacent landholders regarding structural removal or modification as proposed in Options 2 and 3. However, eventually the weir will require maintenance, which will enact the *Fisheries Management Act* (1994), which stipulates that fish passage must be remediated. It is anticipated at that time that the structure will be removed given the relative costs associated with remediating fish passage compared to the income generated from water licenses.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | ✔ | |
| **Option 2** | | ✔ | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** Due to the size and location of the structure, insertion of a full-width rock-ramp fishway or associated structure would cost in excess of $400,000.

**Option 2.** Reducing the height of the weir would significantly reduce the cost of inserting a fishway. Further cost savings could be achieved by inserting only a partial-width rock ramp fishway; however, a full-width rock ramp fishway would ensure the future stability of the structure while providing improved fish passage.

**Option 3.** Removal of the weir would likely cost less than $50,000. Final costs would include preparatory surveys, production of an REF, consultation and compensation of affected stakeholders, waste disposal, and bed/bank stabilisation.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 3) following investigation into the likely changes to channel geomorphology and bed stability. Weir removal would not only ensure unrestricted fish passage within the system, but also re-establish natural sediment fluxes. However, removal of the weir would likely compromise the ability of existing water licenses to be served, thus impacting upon the operations of the surrounding properties.

Moreover, landholder support would be for the maintenance of the structure, with strong opposition being voiced against the weir's removal.

Further investigation would be required to determine whether the height of the structure could be reduced without compromising the water resource needs of adjacent landholders. Reducing the height of the structure would significantly reduce the cost of remediating fish passage and allow the insertion of a partial or full-width rock-ramp fishway.

Although Option 1 would remediate fish passage and maintain the existing weir pool, funds would presumably be better directed to the remediation of higher priority structures on the mainstem Richmond River (e.g. Manyweathers and Cookes Weir).

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Goolmangar Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Goolmangar Creek Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 35km.

## *HICKEYS CREEK WEIR, HICKEYS CREEK, KEMPSEY*

**Figure 1.** Hickeys Creek Weir on Hickeys Creek near Kempsey, as viewed from downstream.

### *Description and setting*

Hickeys Creek Weir (Figure 1) is located approximately 30km northwest of Kempsey on Hickeys Creek, a tributary of the Macleay River, and is accessible via an easement reached by farm tracts along the left bank. The adjustable-crest weir, which is constructed primarily of concrete with downstream rock protection (Figure 2), measures 2 metres high by 11 metres wide. The weir contains a centrally placed drop board structure, and although the drop boards have been removed permanently the floor of the drop board bay still pools water upstream. The impoundment of water extends approximately 100 metres upstream at depths < 2 metres, resulting in a total usable capacity of < 1.0ML. Fish passage is restricted at Hickeys Creek Weir due to excessive headloss (250mm) resulting from water flowing through the central drop board structure (Figure 1).

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Hickeys Creek Weir as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Hickeys Creek is a perennial flowing tributary (Class 2) of the Macleay River that supports a diverse range of native fish species including Australian Bass (*Macquaria novemaculeata*);
- No water extraction licenses are serviced by the structure, with stock watering the only known use;

- Remediation of fish passage at Hickeys Creek Weir would open 60km of habitat to unimpeded movement;
- Hickeys Creek Weir is one of only two known barriers in the Hickeys Creek subcatchment;
- Below the weir there are no known barriers to migrating fish to the sea, a distance of 90km; and
- Instream and riparian habitat condition along Hickeys Creek is considered fair to good.

**Figure 2.** View of Hickeys Creek Weir from the left bank displaying downstream rock protection. The right bank is bedrock controlled.

### *Hydrology*

Hickeys Creek Weir is located within the middle reaches of the Hickeys Creek subcatchment. The creek is a perennial flowing tributary that joins the Macleay River approximately 8km downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 – 10 metres wide with low-flow depth generally < one metre. Adjacent landholders indicate that the creek maintains a low base flow throughout the majority of the year except during periods of extreme drought when the creek flows subsurface. Structural drown out occurs several times a year following moderate to heavy rainfalls, during which fish passage is facilitated.

### *Operational Details*

Hickeys Creek Weir was constructed in 1970 to provide a pumping pool for stock and domestic use on an adjacent dairy farm. The weir contains a centrally placed drop board structure; however the boards have been permanently removed. Additionally, a small pipe (200mm) continues to convey water beneath the weir. The structure, now owned by State Water, currently serves no existing water extraction license but continues to function as a stock (beef cattle) watering hole for a single upstream

landholder. No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir leaks badly and is considered to have failed even though it still retains a weir pool. An audit of the weir recorded an unsatisfactory safety level (Opus and Golder, 1999), with State Water ceasing maintenance of the structure. The weir is currently undercut on both the left and right banks.

### *Ecological Considerations*

The Macleay River catchment supports a diverse range of native fish species including migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Hickeys Creek Weir would remove the main barrier to fish passage in the system, thus opening 60km of habitat to migrating fish. The remaining barrier is a log-sill ford road crossing located approximately 3.5km upstream of the weir that impedes migrating fish at low flow conditions due to excessive headloss (200mm).

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation is limited within Hickeys Creek due to shading by riparian vegetation, with red azolla dominating. Hickeys Creek also provides valuable refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Hickeys Creek Weir include the Rufous Scrub-bird (*Atrichornis rufescens*), Yellow-bellied Sheath-tailed bat (*Saccolaimus flaviventris*), Little Bent-wing Bat (*Miniopterus australis*), Common Planigale (*Planigale maculate*), Yellow-bellied Glider (*Petaurus australis*), and Long-nosed Potoroo (*Potorous tridactylus*).

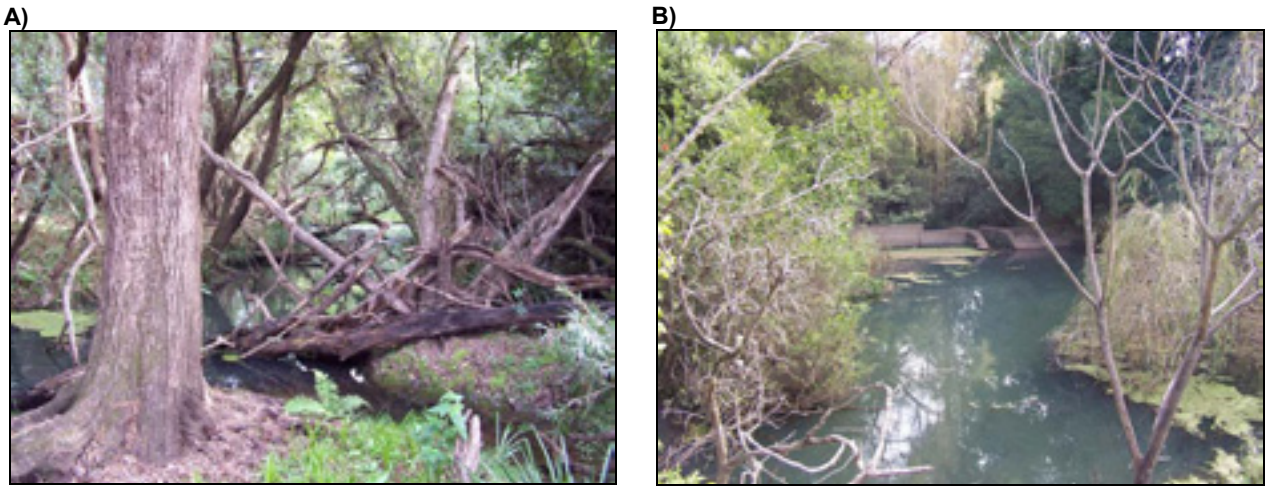



**Figure 3.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Hickeys Creek Weir, Hickeys Creek.

Water quality within Hickeys Creek is described as good to excellent except during drought periods when stagnant pools form. The weir and surrounding reaches display moderately-to-well vegetate banks (Figure 3), with minor erosion being recorded on the upstream side of the structure due to cattle access on both sides of the creek. Downstream of the weir, riparian vegetation is considered to be in excellent condition with a 10 metre buffer on either side of the creek.

Vegetation within the riparian zone is primarily composed of casuarinas, callistemon, pioneer rainforest species (Sandpaper fig, Waterhousia), and a mix of exotic weeds including willows. Groundcover upstream of the weir is considered sparse with pasture grasses and *Lomandra histrix* dominating. Siltation was not recorded within the weir pool and thus is not considered a management issue.

### *Proposed Remediation Actions*

- **Option 1 –** Full-width rock-ramp fishway

Due to the low height and narrow width of the weir, a full-width rock-ramp would provide the best option of remediating fish passage and maintaining the structure. Full-width rock ramp fishways are generally considered one of the most effective designs for passing various species and size classes of fish within Australian streams. Investigation would be required to determine whether flows within Hickeys Creek would suit a rock-ramp design, or whether an alternative fishway design would be more effective. Insertion of a full-width rock ramp fishway would require structural works on the centrally located drop board structure.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Hickeys Creek by removing one of the two main barriers to fish passage in the system. Additionally, State Water would no longer be liable for the site, which is known as a local swimming hole. Implementation of this option would require investigation into bed stability to ensure that removal did not facilitate a headcut upstream. Consultation should occur with the adjacent landholder to ensure that existing water needs (e.g. stock and domestic) will not be compromised significantly by the weir removal.

- **Option 3 –** Breaching the weir

Breaching the weir would involve the removal of the floor from the drop board bay down to the existing bed level, thus ensuring unrestricted fish passage at the site. The remaining breached structure would deteriorate over time and eventually wash away. However, while the structure continued to exist, State Water would still be liable for damage / injury resulting from the weir.

The weir pool is currently used for stock and domestic watering by a single landholder, with no existing water extraction license being serviced. Since the weir only pools water 100 metres upstream, removal of the structure would not significantly impact the operations of the property. However, the existing property owner has questioned the need to spend capital funds on removing a structure that, in their viewpoint, has little impact upon the ecology of the system. State Water receives no financial benefit from maintaining the weir and has indicated that their preferred option is to remove the structure, which would eliminate the public liability concerns associated with the weir.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | ✔ | |
| **Option 2** | ✔ | | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** Full-width rock ramp fishways are one of the most effective fishways for passing migratory species, but are also one of the most expensive to construct. The likely cost of inserting a full-width rock ramp fishway at Hickeys Creek Weir would exceed $250,000.

**Option 2.** Removal of the weir would likely cost less than $20,000. Final costs would include preparatory surveys, production of an REF, landholder consultation, waste disposal, and bed/bank stabilisation.

**Option 3.** Breaching the weir would likely cost less than $5,000. However, State Water would still be held liable for any damage / injury resulting from the remaining sections of the weir.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) following investigation into the likely changes to channel geomorphology and bed stability. Weir removal would not only ensure unrestricted fish passage over 60km, but would also re-establish natural sediment fluxes. Moreover, State Water would no longer be liable for any damage/ injury associated with the operation of a weir that fails to service a current water extraction license. Consultation should occur however with the adjacent landholder to ensure that stock and domestic needs will not be significantly affected in the absence of the weir.

The cost of Options 1 would likely not provide the associated benefit given that the structure drowns out regularly and is located in the middle reaches of Hickeys Creek. Funds would presumably be better spent addressing fish passage barriers located further down the catchment on the mainstem Macleay River. Additionally, insertion of the rock-ramp fishway would maintain the liability risk for State Water.

Option 3 produces the same outcome as removal of the structure; however, State Water would still be liable for damages/injury associated with the dilapidated state of the weir.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Hickeys Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Hickeys Creek Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 60km.

## *COB-O-CORN WEIR, COB-O-CORN CREEK, KYOGLE*

**Figure 1.** View of the Cob-o-corn Weir from the downstream right bank.

### *Description and setting*

Cob-o-corn Weir (Figure 1) is located approximately 15km west of Kyogle on Cob-o-corn Creek in the upper reaches of the Richmond River catchment, and is accessible via a public road along the left bank. The fixed-crest weir is constructed primarily of concrete, measuring 1.9 metres high by 19 metres wide. Water is pooled approximately 450 metres upstream at depths > 2 metres, resulting in a total usable capacity of 4.3ML. Water cascades over the weir crest onto a large concrete capped apron, with fish passage being restricted due to excessive headloss (1900mm).

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Cob-o-corn Weir as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Cob-o-corn Creek is a Class 2, perennial flowing upper level tributary of the Richmond River that supports a diverse range of native fish;
- Cob-o-corn Creek is within the known historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*);
- No water extraction licenses are serviced by the weir, with State Water indicating that the structure could potentially be removed;
- No known obstruction to fish passage occurs upstream of the weir, thus providing 40km of unimpeded fish access;

- Below Cob-o-corn Weir, the next downstream barrier to migrating fish is Cookes Weir on the mainstem Richmond River at a distance of 50km; and
- Instream and riparian habitat condition along Cob-o-corn Creek is considered good to excellent in condition.

### *Hydrology*

Cob-o-corn Creek (Class 2) is an upper level, perennial flowing tributary that joins Eden Creek, a significant tributary of the Richmond River, approximately 500 metres downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 – 10 metres wide with low-flow depth generally < 1 metre. A river gauge is not present on Cob-o-corn Creek or nearby tributaries; however, adjacent landholders indicate that the creek maintains a constant base flow throughout the year except during periods of extreme drought. Structural drown out occurs 2 - 3 times a year following significant rainfalls, providing the only means of fish passage in the upstream direction.

### *Operational Details*

Cob-o-corn Weir was constructed in 1970 for drought protection as well as to provide a pumping pool. The structure, now owned by State Water, currently serves no existing water extraction license but continues to function as a pumping pool for stock and domestic use by one of the three adjacent landholders. A water extraction license exists for 35ML per annum immediately downstream of the structure for irrigation, with no additional weir beneficiaries known for the structure (e.g. local community, fishing groups). The weir is considered to be in a working condition, with a satisfactory structural safety level being achieved (Opus and Golder, 1999).

### *Ecological Considerations*

The Richmond catchment supports a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Cob-o-corn Weir would remove the only known barrier to fish passage on the system, thus opening 40km of habitat to unimpeded fish migration. Additionally, there is no known barrier on Eden Creek below the junction of Cob-o-corn Creek till the confluence with the Richmond River and Cookes Weir, a distance of 50km. The creek also provides valuable refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Cob-o-corn Weir include the koala (*Phascikarctis cinereus*), Glossy Black Cockatoo (*Calyptorhynchus banksii*), Barred Cuckoo-Shrike (*Coracina lineate*), White-eared Monarch (*Monarcha leucotis*), and the Grey Headed Flying Fox (*Pteropus poliocephalus*).

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation, which is limited within Cob-o-corn Creek due to shading by riparian vegetation, is dominated by submerged aquatic macrophytes.

Water quality within Cob-o-corn Creek is described as good to excellent except during drought periods when stagnant pools form. The weir and surrounding reaches display well vegetated, intact banks, with both sides of the weir pool fenced, thereby

restricting cattle access to the waterway and adjacent riparian vegetation. Vegetation within the riparian zone is primarily composed of casuarinas (*Casuarina cunninghamiana*), *Callistemon spp*., and a mix of rainforest hardwoods, while groundcover adjacent to the waterway is dominated by *Lomandra histrix* and introduced weeds (e.g. tobacco bush and lantana). Siltation is present within the weir pool, with a 1500mm difference in bed level being recorded from the upstream to downstream side of the structure. Additionally, a scour pool one metre deep and 10 metres wide is located immediately below the concrete apron.

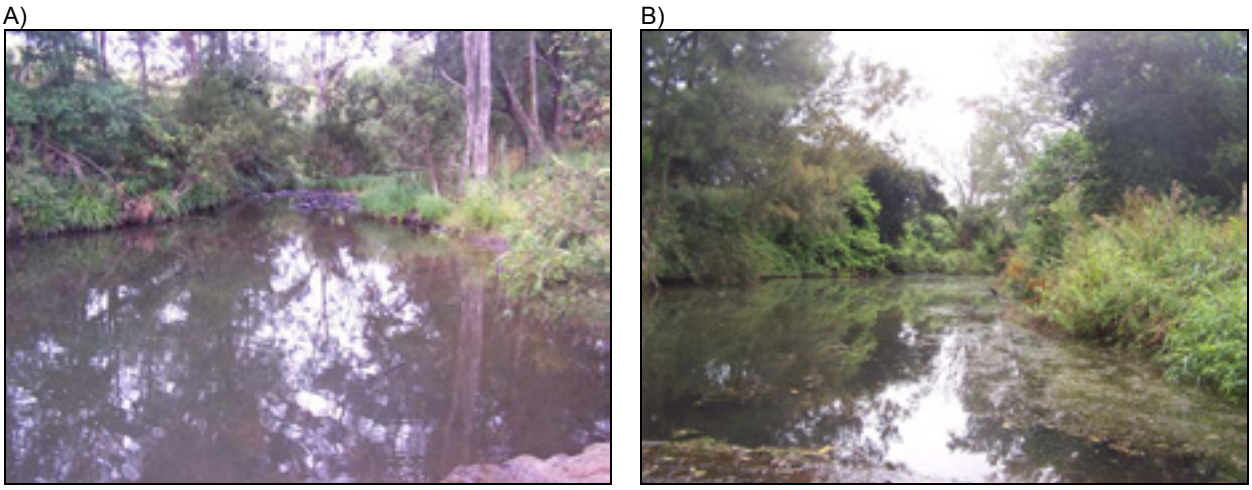



**Figure 2.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Cob-o-corn Weir.

### *Proposed Remediation Actions*

No existing water extraction license is serviced by the weir, with only one adjacent landholder drawing water for stock. Landholder sentiment towards the weir has varied over time, with requests for the weirs removal and retention being voiced.

- **Option 1 –** Vertical-slot fishway

Given the current design of the weir, a vertical slot fishway is a viable option to remediate fish passage at the weir. Vertical slot fishways are generally considered the most effective design for passing various size classes and species of fish within Australian streams. Investigation would be required to determine whether flows within Cob-o-corn Creek would suit a vertical slot design, or whether a partial-width reverse leg rock-ramp would be more effective. Additionally, the design of the weir would need to be altered to provide the necessary attractant flows, while attention to the downstream scour hole would need to be addressed.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Cob-o-corn Creek by removing the only known barrier in the system. Additionally, State Water would no longer be liable for the site. Implementation of this option would require investigation into bed stability and sediment movement associated with siltation within the weir. Caution is needed to avoid a headcut moving upstream of the weir site which is presumably acting as a bed control structure.

Consultation should occur with adjacent and downstream landholders to ensure that existing water needs (e.g. stock and domestic) will not be compromised by the weir removal.

- **Option 3 –** Partial removal followed by insertion of rock-ramp

This option would involve the partial removal of the structure followed by the insertion of a full or partial width rock-ramp. Weir height would be reduced from 1.9 metres to < 1 metre, significantly reducing the cost of inserting a fishway onto the structure. The remaining portion of the weir, along with the full-width rock-ramp, would act as a bed control structure, avoiding the progression of a headcut upstream. Additionally, a weir pool would still persist, providing adequate water resources for current stock and domestic needs.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | | ✔ |
| **Option 2** | ✔ | | | | |
| **Option 3** | | | | ✔ | |

**Option 1.** Due to the size and location of the structure, insertion of a vertical slot fishway or associated structure would cost in excess of $500,000. Costs would need to include the refurbishment of the structure, while also addressing the downstream scour pool.

**Option 2.** Removal of the weir would likely cost less than $50,000. Final costs would include preparatory surveys, production of an REF, waste disposal, and bed/bank stabilisation.

**Option 3.** Reducing the height of the weir would significantly reduce the cost of inserting a fishway. Further cost savings could be achieved by inserting only a partial-width rock ramp; however, a full-width rock ramp would ensure the future stability of the structure.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) following investigation into the likely changes to channel geomorphology and bed stability. Weir removal would not only ensure unrestricted fish passage within the system, but also re-establish natural sediment fluxes. Additionally, the weir does not service a current water extraction license. Consultation should occur however with the adjacent landholders to ensure that stock and domestic needs will still be met in the absence of the weir.

The cost of Options 1 and 3 would likely not provide the associated benefit given that the structure is located in an upper level tributary of the Richmond catchment, within only 40km of habitat available upstream. If removal of the weir is not a viable option, funds would presumably be better spent addressing fish passage barriers located further down the catchment on the mainstem Richmond River (e.g. Cookes and Manyweathers Weir) at the current time.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Cob-o-corn Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Cob-o-corn Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 40km.

## *PINE BRUSH CREEK WEIR, PINE BRUSH CREEK, COFFS HARBOUR*

**Figure 1.** Pine Brush Creek Weir on Pine Brush Creek near Coffs Harbour as viewed from the downstream left bank.

### *Description and setting*

Pine Brush Creek Weir (Figure 1) is located approximately 5km north of Coffs Harbour on Pine Brush Creek, and is accessible via private land. The fixed crest concrete weir, which is constructed of concrete and gabion modules, acts as a tidal barrage that limits the intrusion of brackish water past the structure. The weir measures 2.8 metres high by 20 metres wide, pooling water 200 metres upstream at depths > 2 metres. Water cascades over the crest of the weir, with fish passage limited by excessive headloss (2200mm). Given the height of the structure and the relatively small size of the Pine Brush Creek catchment, the weir is a permanent barrier to migrating fish species except following major river rises (i.e. 4 metre rises) which occur only 1 – 2 times per year.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Pine Brush Creek Weir as a low remediation priority within the Northern Rivers CMA region due to the following factors:

- The Pine Brush Creek (Class 1) is a small, coastal catchment that historically supported a diverse range of habitat types and native fish species;
- The weir is a tidal barrage that is located < 500 metres from the entrance to the ocean;

- Remediation of the weir would remove one of two significant barriers on Pine Brush Creek, thus opening up approximately 150 metres of habitat to fish passage;
- The weir pool from the existing structure currently drowns out a second weir located 150 metres upstream of the Pine Brush Creek Weir by approximately 200mm (Figure 3). Removal of Pine Brush Creek Weir would require removal of this second structure to significantly improve fish passage in the system;
- Weir drown out occurs rarely, with fish passage taking place only after major river rises; and
- Instream and riparian habitat condition along the Pine Brush Creek ranges from good to excellent.

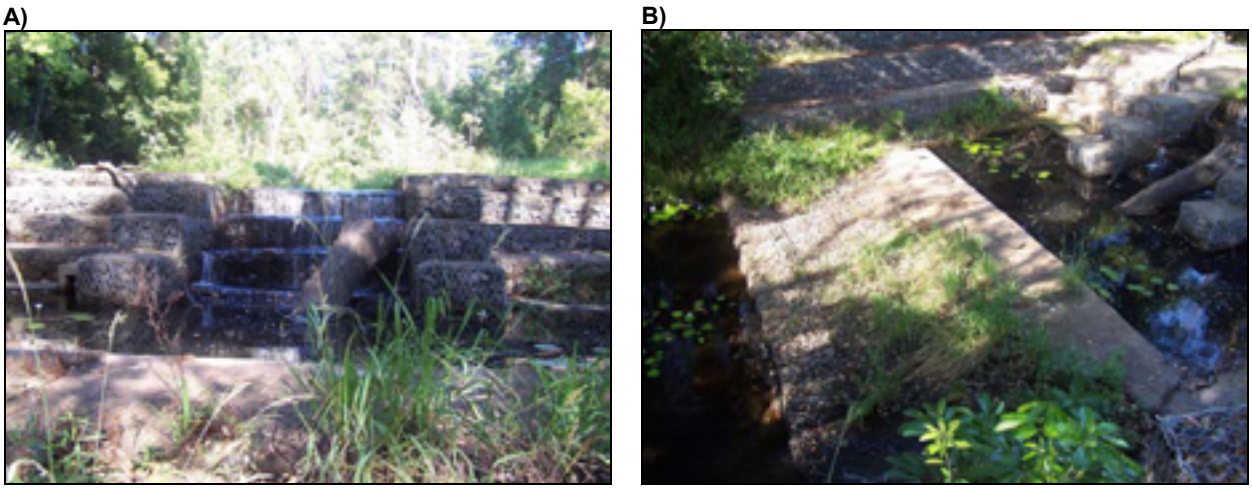



**Figure 2.** (A) Pine Brush Creek Weir from the downstream direction showing the cascading water flow, and (B) view of the downstream concrete gabion apron that further impedes fish passage.

### *Hydrology*

Pine Brush Creek Weir is located at the high water mark within the lower reaches of Pine Brush Creek. The creek is the main waterway for a small coastal system that starts in the hills behind Coffs Harbour and exits directly into the ocean approximately 500 metres downstream of the weir. Water flow is perennial except when water extraction exceeds environmental flows during dry periods. Upstream of the weir pool, Pine Brush Creek ranges from 5-10 metres wide, with water depth generally < one metre. Structural drown out occurs 1-2 times a year following heavy rainfall in the catchment, with low-flow conditions returning quickly (several days) following the cessation of precipitation.

### *Operational Details*

Pine Brush Creek Weir is a private structure constructed in 1993 for the conservation of water for a nearby hotel resort. Water from the weir pool is primarily used to water greens on an adjacent golf course; however, the weir also acts as a tidal barrage given its location just above the mean high water mark. The weir services a single water extraction license (83ML per annum) held by the structural owner, with no other properties having access to the weir pool. Also, no additional weir beneficiaries are known for the structure (e.g. local community, fishing groups).

The weir is considered to be in a working condition, with only minor maintenance required to address the undermining of the downstream concrete apron.

**Figure 3.** A second weir is located 150 metres upstream of Pine Brush Creek Weir, but is drowned out by 200mm of water by the downstream structure.

### *Ecological Considerations*

Remediation of fish passage at Pine Brush Creek Weir would address the main barrier to fish passage within the catchment. The creek historically supported a diverse range of native fish species including migratory species such as Australian bass (*Macquaria novemaculeata*) and Striped mullet (*Mugil cephalus*). Terrestrial species of conservation concern located within the vicinity of Pine Brush Creek Weir include the Freckled Duck (*Stictonetta naevosa*), Black Bittern (*Ixobrychus flavicollis*), Barred Cuckoo Shrike (*Coracina lineate*), White-eared Monarch (*Monarcha leucotis*), Grey-headed Flying Fox (*Pteropus poliocephalus*), Little Bent-wing Bat (*Miniopterus australis*), and Brush-tailed Phascogale (*Phascogale tapoatafa*).

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation, which is limited within Pine Brush Creek due to riparian shading, is dominated by submerged macrophytes. Water quality in Pine Brush Creek above the Pacific Highway Bridge is described as excellent except during drought periods when stagnant pools form.

The weir pool displays extensive erosion on the right bank due to massive bank failure, while minor erosion was noted on the left bank. Riparian vegetation cover is considered extensive in the catchment and is primarily composed of mixed sub temperate rainforest species and eucalypts, with groundcover dominated by introduced weeds (e.g. lantana) and *Lomandra histrix*.

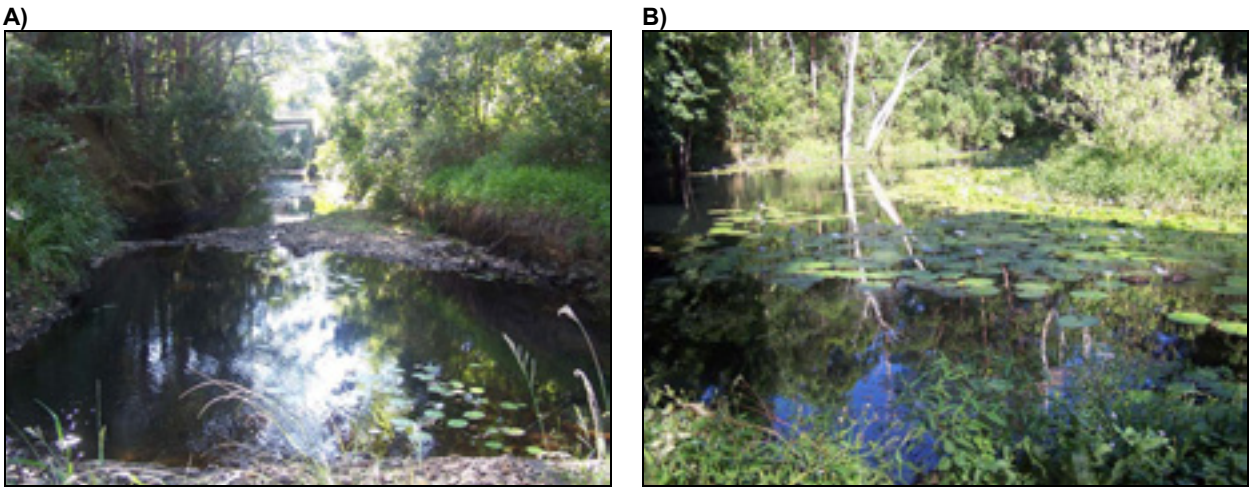



**Figure 4.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Pine Brush Creek Weir, Pine Brush Creek.

Siltation was noted within the weir pool, with a difference in bed level of 1000mm recorded across the face of the weir.

### *Proposed Remediation Actions*

- **Option 1 –** Full-width rock ramp fishway

Full-width rock ramps are generally considered one of the most effective designs for passing various species and size classes of fish within Australian streams. Due to the small size of the river, flows would be concentrated to the centre of the structure to ensure fish passage during low-flow conditions. Significant cost savings could be achieved through the lowering of the weir height; however, investigations would need to determine the effect of lowering upon weir pool capacity as well as whether tidal intrusion would be blocked.

- **Option 2 –** Vertical slot fishway

Insertion of a vertical slot fishway would provide the greatest benefit for improving fish passage at Pine Brush Creek while still maintaining the weir pool. Investigation would be required to determine whether flows within the creek would suit a vertical slot design, or whether an alternative fishway (e.g. full-width rock ramp fishway) would be more effective. Additionally, the design of the weir would need to be altered to direct flows primarily down the fishway during low-flow conditions.

- **Option 3 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of the Pine Brush Creek by providing unrestricted fish passage and natural sediment fluxes. However, removal of the tidal barrage would significantly affect the quantity and quality of water extracted by the current weir owner. Implementation of this option would likely compromise the ability of the adjacent resort to operate unless an alternative, reliable source of water could meet landholder demand. Additionally, removal of the existing structure would expose a second weir located 150 metre that would further impede fish passage.

The weir pool functions to irrigate the adjacent golf course used by resort patrons. Although the surrounding area is considered to receive a high rainfall, removal of the structure would likely compromise the current operations of the resort through the loss of an established weir pool as well as through salt water intrusion that would limit water extraction operations. Thus, the weir owner would support Options 1 and 2, which ensures the stability of the structure and the provision of a reliable source of water.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | | ✔ |
| **Option 2** | | | | ✔ | |
| **Option 3** | ✔ | | | | |

**Option 1.** Full-width rock ramps are one of the most effective fishway designs for passing fish, but they are also one of the most expensive to construct. The likely cost of inserting a full-width rock ramp at Pine Brush Creek Weir would exceed $500,000 due to the excessive headloss (2200mm) that needs to be addressed.

**Option 2.** A vertical slot fishway would likely cost in excess of $400,000 at the site due to the size and redesign of the current weir structure.

**Option 3.** Due to the size of the structure, removal of the weir would likely cost in excess of $35,000, including preparatory surveys, production of an REF, stakeholder consultation and compensation, and waste disposal.

### *Recommendation*

The preferred remediation option for Pine Brush Creek is removal of the existing weir, which would provide the greatest benefit for remediating fish passage at the site. Removal of the existing weir would also need to address the drowned out structure located 150 metres upstream, which upon removal of Pine Brush Creek Weir would become a barrier itself. However, the current weir owner would be reluctant to consider removal of Pine Brush Creek Weir due to the loss of a secure source of freshwater, which would compromise current resort operations.

Although insertion of a full-width rock-ramp or vertical slot fishway would improve fish passage at the site, Pine Brush Creek Weir is considered a low remediation priority. Therefore, funds would be better directed at this point towards higher priority structures that would provide far greater benefits than those achieved at Pine Brush Creek.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that the Pine Brush Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Pine Brush Creek Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 3km.

## *EDEN CREEK WEIR, EDEN CREEK, KYOGLE*

**Figure 1.** Eden Creek Weir on Eden Creek near Kyogle as viewed from the left bank.

### *Description and setting*

Eden Creek Weir (Figure 1) is located approximately 15km northwest of Kyogle on Eden Creek in the upper reaches of the Richmond River catchment, and is accessible via an easement adjacent to a public road along the left bank. The fixed-crest weir is constructed primarily of concrete, measuring 2.7 metres high by 23 metres wide. Water is pooled approximately 600 m upstream at depths > 2 metres, resulting in a total usable capacity of 2.5ML. Water cascades over the weir crest, with fish passage being restricted due to excessive headloss (1750mm).

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Eden Creek Weir as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Eden Creek (Class 2) is a perennial flowing upper level tributary of the Richmond River that supports a diverse range of native fish species;
- Eden Creek is within the known historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*);
- No water extraction licenses are serviced by the structure, with pumping for stock and domestic the only known use;
- No known obstruction to fish passage occurs upstream of the weir, thus providing 43km of unimpeded fish access;

- Below Eden Creek Weir, the next downstream barrier to migrating fish is Cookes Weir on the mainstem Richmond River at a distance of 58km; and
- Instream and riparian habitat condition along Eden Creek is considered fair to good.

### *Hydrology*

Eden Creek Weir is located within the middle reaches of the Eden Creek subcatchment. The creek is a perennial flowing tributary that joins the Richmond River approximately 50km downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 – 10 metres wide with low-flow depth generally < 1 metre. Adjacent landholders indicate that the creek maintains a low base flow throughout the majority of the year except during periods of extreme drought when the creek stops flowing. Structural drown out occurs 2 - 3 times a year following significant rainfalls, providing the only means of fish passage.

### *Operational Details*

Eden Creek Weir was constructed in 1969 for drought protection as well as to provide a pumping pool for stock and domestic use. The structure, now owned by State Water, currently serves no existing water extraction license but continues to function as a pumping pool for stock and domestic use by two of the five adjacent landholders. No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir is considered to be in a working condition, with a satisfactory structural safety level being achieved (Opus Golder Audit). However, siltation has significantly reduced the capacity of the weir pool immediately upstream of the structure.

### *Ecological Considerations*

The Richmond catchment supports a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Eden Creek Weir would remove the main significant barrier to fish passage on the system, thus opening 43km of habitat to migrating fish. Additionally, there is no known barrier on Eden Creek below the weir through the confluence with the Richmond River to Cookes Weir, a distance of 58km.

The creek provides valuable refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Eden Creek Weir include the Koala (*Phascikarctis cinereus*), Glossy Black Cockatoo (*Calyptorhynchus banksii*), Barred Cuckoo-Shrike (*Coracina lineate*), White-eared Monarch (*Monarcha leucotis*), and the Grey Headed Flying Fox (*Pteropus poliocephalus*).

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation, which is limited within Eden Creek due to shading by riparian vegetation, is dominated by submerged aquatic macrophytes.

A)

B)

**Figure 2.** Riparian and instream habitat immediately downstream (A) and upstream (B) of Eden Creek Weir.

Water quality within Eden Creek is described as good to excellent except during drought periods when stagnant pools form. The weir and surrounding reaches display moderately vegetated banks, with minor erosion being recorded both upstream and downstream of the structure due to cattle access on both sides of the creek.

Vegetation within the riparian zone is primarily composed of casuarinas (*Casuarina cunninghamiana*), *Callistemon spp*., and a mix of rainforest hardwoods, while groundcover adjacent to the waterway is considered sparse with *Lomandra histrix* and introduced weeds (e.g. tobacco bush and lantana) dominating. Siltation has significantly reduced the water holding capacity of the weir pool, with water depth immediately upstream of the weir being <0.5 metres Moreover, a 2500mm difference in bed level is present from the upstream to downstream side of the structure.

### *Proposed Remediation Actions*

- **Option 1 –** Vertical-slot fishway

Given the current design of the weir, a vertical slot fishway could be inserted to remediate fish passage at the weir. Vertical slot fishways are generally considered the most effective design for passing various size classes of fish within Australian streams. Investigation would be required to determine whether flows within Eden Creek would suit a vertical slot design, or whether a partial-width reverse leg rock-ramp would be more effective. Additionally, the design of the weir would need to be altered to provide the necessary attract flows, while attention to the downstream scour hole would need to be addressed.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Eden Creek by eliminating the only significant barrier in the system. Additionally, State Water would no longer be liable for the site.

Implementation of this option would require investigation into bed stability and sediment movement associated with siltation behind the weir. Caution is needed to avoid a headcut moving upstream from the weir, which is presumably acting as a bed control structure. Consultation should occur with adjacent and downstream landholders to ensure that existing water needs (e.g. stock and domestic) will not be compromised significantly by the weir removal. Removal of the structure could be staged over successive years to limit the effect of lowering the weir pool upon upstream bank stability.

- **Option 3 –** Partial removal followed by insertion of rock-ramp

This option would involve the partial removal of the structure followed by the insertion of a full or partial width rock-ramp. Weir height would be reduced from 2.7 metres to < 1.5 metres, significantly reducing the cost of inserting a fishway onto the structure. The remaining portion of the weir, along with the full-width rock-ramp, would act as a bed control structure, avoiding the progression of a headcut upstream while also limiting the mobilization of accumulated sediment behind the weir. Additionally, a weir pool would still persist, providing adequate water resources for current stock and domestic needs.

The weir pool is currently used for stock and domestic watering by two landholders, with no existing water extraction license being serviced. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weir, with adjacent landholders reluctant to see the structure removed. Thus, landholder sentiment would support Option 1 or 3, which would ensure the stability of the structure and the provision of a reliable source of water.

State Water receives no financial benefit from maintaining the weir. In a review undertaken by State Water, the preferred options were first to investigate the sale of the Eden Creek Weir to adjacent landholders followed by the removal of the structure if such an option was not viable. Eventually though, the weir will require maintenance which will enact the *Fisheries Management Act* (1994) which stipulates that fish passage must be remediated. Alternatively, State Water could leave the structure to fall into a state of disrepair.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | | ✔ |
| **Option 2** | ✔ | | | | |
| **Option 3** | | | | ✔ | |

**Option 1.** Due to the size and location of the structure, insertion of a vertical slot fishway or associated structure would cost in excess of $500,000. Costs would need to include the refurbishment of the structure, while also addressing the downstream scour pool.

**Option 2.** Removal of the weir would likely cost less than $50,000. Final costs would include preparatory surveys, production of an REF, waste disposal including siltation buildup, and bed/bank stabilisation.

**Option 3.** Reducing the height of the weir would significantly reduce the cost of inserting a fishway.

Further cost savings could be achieved by constructing only a partial-width rock ramp; however, a full-width rock ramp would ensure the future stability of the structure.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) following investigations into the likely changes to channel geomorphology and bed stability. Weir removal would not only ensure unrestricted fish passage within the system, but also re-establish natural sediment fluxes. Additionally, the weir is not servicing a current water extraction license. Consultation should occur however with the adjacent landholders to ensure that stock and domestic needs will not be significantly affected in the absence of the weir. Removal of the weir could be staged over successive years to limit the effect of drawing down the weir pool on upstream bank stability. Moreover, gravel extraction would need to occur prior to removal to avoid mobilizing the stored sediment load behind the weir wall.

The cost of Options 1 and 3 would likely not provide the associated benefit given that the structure is located in an upper level tributary of the Richmond catchment. Funds would presumably be better spent addressing fish passage barriers located further down the catchment on the mainstem Richmond River (e.g. Cookes and Manyweathers Weir).

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Eden Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Eden Creek Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 43km.

## *FAWCETTS CREEK WEIR 3, FAWCETTS CREEK, KYOGLE*

**Figure 1.** View of Fawcetts Creek Weir 3 from the left bank.

### *Description and setting*

Fawcetts Creek Weir 3 (Figure 1) is located approximately 7km north of Kyogle on Fawcetts Creek in the upper reaches of the Richmond River Catchment, and is accessible via an easement reached by a farm tract along the left bank. The fixed crest weir, which is the most upstream of the three weir structures located within a 3km stretch of Fawcetts Creek, measures 1.75 metres high by 15.0 metres wide and is constructed of rock fill that is concrete capped. The weir pools water 500 metres upstream at depths > 2 metres, resulting in a total usable capacity of < 1.5ML. Water cascades over the crest of the weir, with fish passage being restricted due to excessive headloss (1750mm), slope, and turbulence till the structure drowns out.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Fawcetts Creek Weir 3 as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Fawcetts Creek is a Class 2 perennial flowing, upper level tributary of the Richmond River that supports a diverse range of native fish;
- Fawcetts Creek is within the known historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*);
- The weir is in a state of disrepair, with the central portion of the structure already failing. State Water has decommissioned the weir with no maintenance proposed;

- Below Fawcetts Creek Weir 1, the next downstream barrier to migrating fish is Cookes Weir at a distance of 55km;
- Approximately 40km of unimpeded habitat is available upstream of the weir; and
- Riparian and instream habitat within Fawcetts Creek ranges from fair to excellent.

### *Hydrology*

Fawcetts Creek is a perennial flowing tributary that joins the Richmond River approximately 8km downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 metres wide and generally < 1 metre deep. A river gauge is not present on Fawcetts Creek; however, adjacent landholders indicate that the creek maintains base flow levels throughout the year except during periods of extreme drought. Structural drown out occurs 2 - 3 times a year following significant rainfall, providing the only means of fish passage in the upstream direction. However, the timing of structural drown out may not necessarily coincide with spawning migrations of resident fish in the Richmond catchment.

### *Operational Details*

Fawcetts Creek Weir 3 was constructed in 1968 as a result of funds provided by the Water Conservation and Irrigation Commission for emergency drought unemployment relief. The structure, now owned by State Water, is still used today for the original purposes of irrigation, stock (beef), and domestic use. Six landholders adjoin the weir pool, with four of the owners possessing water extraction licenses totalling 453ML per annum (although only one is active). Water is primarily pumped from the weir pool for the purpose of irrigating pasture grasses for beef cattle during dry spells, with one additional pump being used for stock and domestic purposes. State Water obtains an annual income of approximately $1500 from the licenses at Fawcetts Creek Weir 3.

Water flow over the crest of the weir is dictated by rainfall in the upper reaches of the Fawcetts Creek subcatchment. Irrigators tend to cease water extraction when water stops flowing over the weir crest during drought periods. Given the small water holding capacity of the weir (< 1.5ML), available water reserves during dry periods would likely be insufficient to maintain intensive irrigation of pasture grasses.

Repair works on the weir have occurred on three separate occasions, with the most recent maintenance including the addition of a thin concrete cap that was applied to prevent the structure from washing away. However, the current condition of Fawcetts Creek Weir 3 is described as poor, with the structural safety level ranking as unsatisfactory (Opus Golder Audit). The centre of the weir face has failed, with rock fill being washed away (Figure 2). Additionally, the left abutment is in disrepair, with water leaking from beneath the weir thus compromising the ability of the structure to effectively pool water at low-flow conditions. Unless repair work is undertaken, the weir will fail during a flood event.

### *Ecological Considerations*

Four additional barriers in the form of road crossings have been recorded on tributaries in the upper reaches of the Fawcetts Creek subcatchment above Fawcetts Creek Weir 3; however, approximately 40km of habitat is available to migrating fish above the weir. Additionally, the impact of the road crossing barriers upon fish passage is viewed as minor (< 300mm headloss) relative to the weir.

Two additional weirs owned by State Water (Fawcetts Creek Weir 1 and 2) are located on Fawcetts Creek less than 3km downstream from Fawcetts Creek Weir 3. Four additional barriers in the form of road crossings have been recorded on tributaries in the upper reaches of the Fawcetts Creek subcatchment above Fawcetts Creek Weir 3; however, approximately 40km of habitat is available to migrating fish above the weir. Additionally, the impact of the road crossing barriers upon fish passage is viewed as minor (< 300mm headloss) relative to the weir. Two additional weirs owned by State Water (Fawcetts Creek Weir 1 and 2) are located on Fawcetts Creek less than 3km downstream from Fawcetts Creek Weir 3. Both weirs, which are of similar scale to Weir 3, are significant barriers to fish passage for the majority of the year. Additionally, Weirs 1 and 2 are in a similar dilapidated state, with State Water decommissioning both structures with no intention to conduct further maintenance.

**Figure 2.** Structural damage observed in the central portion of Fawcetts Creek Weir 3.

Fawcetts Creek is a perennial flowing tributary of the Richmond River that historically supported a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Additionally, the creek continues to provide refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Fawcetts Creek include the Glossy Black Cockatoo (*Calyptorhynchus banksii*), Barred Cuckoo-Shrike (*Coracina lineate*), White-eared Monarch (*Monarcha leucotis*), and Grey Headed Flying Fox (*Pteropus poliocephalus*). Water quality for Fawcetts Creek is described as excellent except during drought periods when stagnant pools form.

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth.

Aquatic vegetation, which is limited within Fawcetts Creek due to shading by riparian vegetation, is dominated by red azolla located on the surface layer of the weir pool (Figure 3).

The weir displays moderately vegetated banks with minor erosion present both upstream and downstream of the structure presumably due to cattle access. Riparian vegetation is composed of rainforest hardwoods, eucalypts, casuarinas, and exotics trees (e.g. *Camphor laurel*); while groundcover is dominated by pasture grasses and *Lomandra histrix*. Extensive erosion is evident on the left bank adjacent to the weir where bank failure has occurred recently. Despite fencing on both sides of the creek, cattle appear to gain regular access to the waterway. Thus, overall creek health would be improved by maintaining riparian fencing and revegetating disturbed banks that reach up to 6 m above the water level. Siltation is evident within the weir pool, with the difference in bed level on the upstream and downstream side of the weir being 1.4 metres.

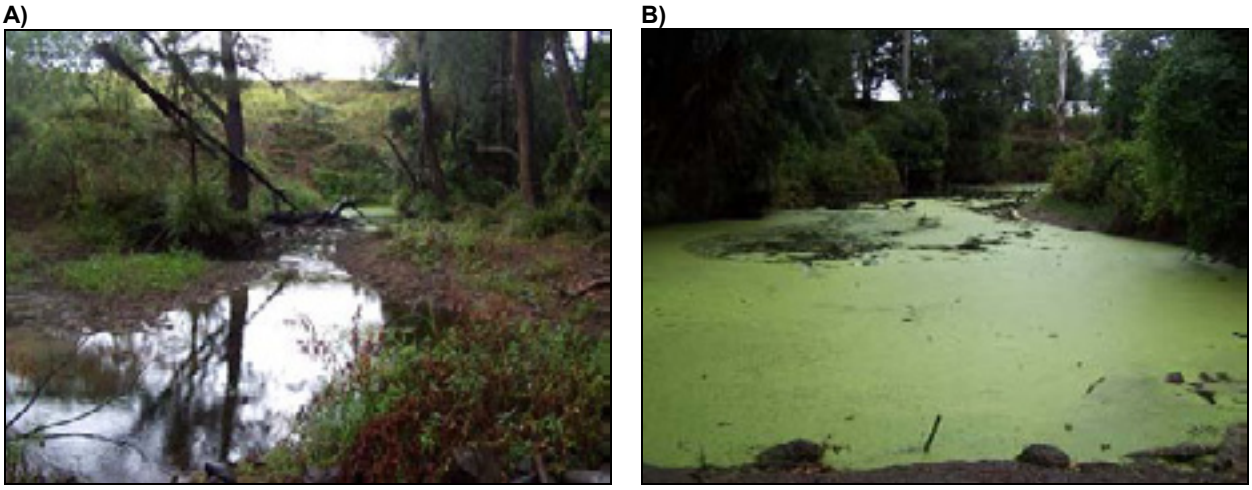



**Figure 3.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Fawcetts Creek Weir 3, Fawcetts Creek.

### *Proposed Remediation Actions*

- **Option 1 –** Full width rock ramp fishway

This option would address the structural stability issues concerning the weir while also providing improved fish passage within Fawcetts Creek. The dilapidated state of the existing structure precludes the installation of a vertical slot fishway or a partial-width rock ramp, making a full-width rock ramp the most cost-effective fishway option. To reduce costs, the height of the weir could be lowered, with adjacent landholders benefiting from a reconditioned weir that would not leak. The decision to insert a full-width rock ramp fishway should however be viewed in context with the remediation of the two downstream weirs that also impede fish passage, as well as with the fact that State Water has decommissioned all three weirs and has no plans to further maintain the structures.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Fawcetts Creek by providing unrestricted fish passage and natural sediment fluxes. Additionally, State Water would no longer be liable for the site or the dilapidated state of the weir. However, removal of the structure would result in the loss of the pumping pool for which four licenses are served. Therefore, alternative measures would need to be explored to determine the capacity to deliver the required water allocations during dry periods. Additionally, recreational values such as swimming would likely diminish at the site in the short term. Removal of the structure would also require detailed surveys investigating changes to fauna and floral communities, channel geomorphology, and sediment mobility and chemistry.

- **Option 3 –** Do nothing

The preferred option of State Water would result in the weir eventually washing away over a series of floods, with no cost being incurred. Fish passage would be remediated slowly over time resulting in the same outcome achieved through removal except that the aesthetics of the site would diminish from the strewn debris associated with the weir. Additionally, State Water would be liable for environmental, property, or personal damage / injury resulting from structural failure.

The weir pool is currently used for irrigation, stock, and domestic use by one licensed landholder, with water generally being pumped during dry spells to maintain consistent pastures for beef cattle. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weirs. Thus, landholder sentiment would support Option 1, which would ensure the stability of the structure and the provision of a reliable source of water.

State Water has decommissioned all three weirs on Fawcetts Creek, with no intention to expend further resources to their maintenance. State Water supports the "Do Nothing" strategy, which involves no capital investment, while also avoiding the need to consult with adjacent landholders regarding removal of the structure as proposed in Option 2. As part of the "Do Nothing" strategy, State Water has expressed interest in selling the weir to adjacent landholders to limit liability and save costs.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | ✔ | |
| **Option 2** | ✔ | | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** The predicted cost for insertion of a full-width rock ramp would likely be in excess of $400,000. The cost of this option would be reduced substantially if the height of the structure were reduced to 1.0 metre; however upstream licenses may not be served by a decrease in weir height.

**Option 2.** Removal of the weir is estimated at ~ $25,000, including preparatory surveys, production of an REF, waste disposal, compensation to water license holders, and revegetation of adjacent banks.

**Option 3.** No direct cost would be associated with the "Do Nothing" strategy. However, State Water would still be held liable for any damage / injury resulting from the weir.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) in conjunction with consultation and compensation of licensed landholders regarding the redesign of water extraction equipment. Implementation of Option 2 will negate further liability associated with the weir for State Water, while leaving the site in a tidy state. Alternatively, the costs associated with a full-width rock ramp (Option 1) are viewed as excessive for a weir that State Water has already decommissioned. Moreover, Option 3 will disenfranchise the adjacent property owners, with the perception that government agencies have turned a blind eye to state infrastructure.

Remediation of fish passage at Fawcetts Creek Weir 3 should be viewed in context with proposed works at the two remaining weirs located immediately downstream (< 3km). However, a single strategy for the Fawcetts Creek weirs should be avoided as the adjacent landholders to each weir have varying needs and viewpoints towards the structures.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Fawcetts Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at the three Fawcetts Creek weirs would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 40km.

## *FAWCETTS CREEK WEIR 1, FAWCETTS CREEK, KYOGLE*

**Figure 1.** Fawcetts Creek Weir viewed from left bank displaying damage to the toe of the structure.

### *Description and setting*

Fawcetts Creek Weir 1 (Figure 1) is located approximately 5km north of Kyogle on Fawcetts Creek in the upper reaches of the Richmond River Catchment, and is accessible via an easement that is reached through a farm tract on the left bank. The fixed crest weir, which is the first of three weir structures located within a 3km stretch of Fawcetts Creek, measures 2.4 metres high by 10 metres wide and is constructed of rock fill that is concrete capped. The weir pools water 900 metres upstream at depths > 2 metres, resulting in a total usable capacity of 1.5ML. Water cascades over the crest of the weir, with fish passage being restricted due to excessive headloss (1800mm), slope, and turbulence until the structure drowns out.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Fawcetts Creek Weir 1 as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Fawcetts Creek is a Class 2 perennial flowing, upper level tributary of the Richmond River that supports a diverse range of native fish;
- Fawcetts Creek is within the known historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*);
- The weir is in a state of disrepair, with the left bank abutment and toe of the structure already failing. State Water has decommissioned the weir with no maintenance proposed;

- The next downstream barrier to migrating fish is Cookes Weir at a distance of 55km;
- Approximately 40km of unimpeded habitat is available upstream of the third Fawcetts Creek weir; and
- Riparian and instream habitat within Fawcetts Creek ranges from fair to excellent.

### *Hydrology*

Fawcetts Creek is a perennial flowing tributary that joins the Richmond River approximately 5km downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 metres wide and generally < 1 metre deep. A river gauge is not present on Fawcetts Creek; however, adjacent landholders indicate that the creek maintains a flow throughout the year except during periods of extreme drought. Structural drown out occurs several times a year following significant rainfalls, providing the only means of fish passage in the upstream direction. However, the timing of structural drown out may not necessarily coincide with spawning migrations of resident fish in the Richmond catchment.

### *Operational Details*

Fawcetts Creek Weir 1 was constructed in 1967 as a result of funds provided by the Water Conservation and Irrigation Commission for emergency drought unemployment relief. The structure, now owned by State Water, is still used today for the original purposes of irrigation, stock (dairy and beef), and domestic use. Three landholders adjoin the weir pool, with two of the owners possessing water extraction licenses totalling 80ML per annum. Water is primarily pumped from the weir pool for the purpose of irrigating pasture grasses for dairy cattle during dry spells, with two additional pumps being used for stock and domestic purposes. State Water obtains an annual income of less than $1000 from the licenses at Fawcetts Creek Weir 1.

Water flow over the crest of the weir is dictated by rainfall in the upper reaches of the Fawcetts Creek subcatchment. Irrigators tend to cease water extraction when water stops flowing over the weir crest during drought periods. Given the small water holding capacity of the weir (1.5ML), available water reserves during dry periods would likely be insufficient to maintain intensive irrigation of pasture grasses.

Repair works were conducted on the weir in 1986, including the addition of a thin concrete cap that was applied to prevent the structure from washing away. However, the current condition of Fawcetts Creek Weir 1 is described as poor, with the structural safety level ranking as unsatisfactory (Opus Golder Audit). The left abutment is in disrepair as well as the toe of the structure (Figures 1 and 2), while water leaks from beneath the weir's right abutment. Unless repair work is undertaken, the weir will fail during a flood event.

### *Ecological Considerations*

Two additional weirs owned by State Water (Fawcetts Creek Weir 2 and 3) are located on Fawcetts Creek less than 3km upstream of Fawcetts Creek Weir 1. Both weirs, which are of similar scale to Weir 1, are significant barriers to fish passage for the majority of the year. Additionally, the upstream weirs are in a similar dilapidated state; however, State Water has decommissioned both structures with no intention to conduct further maintenance.

**Figure 2.** View of left bank abutment on Fawcetts Creek Weir 1 displaying structural damage.

A)

B)

**Figure 3.** Riparian and instream habitat immediately downstream (A) and upstream (B) of Fawcetts Creek Weir 1.

A further four barriers in the form of road crossings have been recorded on tributaries in the upper reaches of the Fawcetts Creek subcatchment; however, approximately 40km of habitat is available to migrating fish above the uppermost weir.

Fawcetts Creek is a perennial flowing tributary of the Richmond River that historically supported a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Additionally, the creek continues to provide refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*).

Terrestrial species of conservation concern located within the vicinity of Fawcetts Creek include the Glossy Black Cockatoo (*Calyptorhynchus banksii*), the Barred Cuckoo-Shrike (*Coracina lineate*), the 'white-eared Monarch (*Monarcha leucotis*), and the Grey Headed Flying Fox (*Pteropus poliocephalus*). Water quality for Fawcetts Creek is described as excellent except during drought periods when stagnant pools form.

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators, while also providing a substrate for algal growth. Aquatic vegetation, which is limited within Fawcetts Creek due to shading by riparian vegetation, is dominated by red azolla that is located on the surface film of the weir pool.

The weir displays moderately vegetated banks with minor erosion present both upstream and downstream of the structure presumably due to cattle access. Riparian vegetation is composed of rainforest hardwoods, eucalypts, casuarinas, and exotics trees (e.g. *Camphor laurel*), while groundcover is dominated by pasture grasses and *Lomandra histrix*. Extensive erosion is evident on the left bank adjacent to the weir where bank failure recently occurred. Overall, creek health would be improved by riparian fencing and revegetation along the banks, which reach up to 6 metres above water level. At present, cattle have free access to the edge of both banks.

## *Proposed Remediation Actions*

- **Option 1 –** Full width rock ramp fishway

This option would address the structural stability issues concerning the weir while also providing improved fish passage within Fawcetts Creek. The dilapidated state of the existing structure precludes the installation of a vertical slot fishway or a partial-width rockway, making a full-width rock ramp the most cost-effective fishway option. To reduce costs, the height of the weir could be dropped, with adjacent landholders benefiting from a reconditioned weir that would not leak. The decision to insert a full-width rock ramp fishway should however be viewed in context with the remediation of the two upstream weirs that also impede fish passage, as well as with the fact that State Water has decommissioned the weir and has no plans to further maintain the structure.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Fawcetts Creek by providing unrestricted fish passage and natural sediment fluxes. Additionally, State Water would no longer be liable for the site or the condition of the weir. However, removal of the structure would result in the loss of the pumping pool for which two licenses are served. Therefore, alternative measures would need to be explored to determine the capacity to deliver the required water allocations during dry periods. Additionally, recreational values such as swimming would likely diminish at the site in the short term. Removal of the structure would also require detailed surveys investigating changes to fauna and floral communities, channel geomorphology, and sediment mobility and chemistry.

- **Option 3 –** Do nothing

The preferred option of State Water would result in the weir eventually being washed away over a series of floods, with no cost being incurred. Fish passage would be remediated slowly over time resulting in the same outcome achieved through removal except that the aesthetics of the site would diminish due to the strewn debris from the weir. Additionally, State Water would be liable for environmental, property, or personal damage / injury resulting from the failure of the weir.

The weir pool is currently used for irrigation, stock, and domestic use by two adjacent landholders, with water generally being pumped during dry spells to maintain consistent pastures for dairy and beef cattle. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weirs, with neither landholder interested in seeing the structures removed either purposefully or naturally. Thus, landholder sentiment would support Option 1, which would ensure the stability of the structure and the provision of a reliable source of water.

State Water has decommissioned all three weirs on Fawcetts Creek, with no intention to expend further resources to their maintenance. State Water supports the "Do Nothing" strategy, which involves no capital investment, while also avoiding the need to consult with adjacent landholders regarding removal of the structure as proposed in Option 2. As part of the "Do Nothing" strategy, State Water has expressed interest in selling the weir to adjacent landholders to limit liability and save costs.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | | ✔ |
| **Option 2** | ✔ | | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** The predicted cost for insertion of a full-width rock ramp would likely be in excess of $700,000. The cost of this option would be reduced substantially if the height of the structure was reduced from 2.4 metres to 1 – 1.5 metres.

**Option 2.** Removal of the weir is estimated at < $35,000, including preparatory surveys, production of an REF, waste disposal, compensation to water license holders, and revegetation of adjacent banks.

**Option 3.** No direct cost would be associated with the "Do Nothing" strategy. However, State Water would still be held liable for any damage / injury resulting from the weir.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) in conjunction with consultation and compensation of licensed landholders regarding the redesign of water extraction equipment.

Implementation of Option 2 will negate further liability associated with the weir for State Water, while leaving the site in a tidy state. Alternatively, the costs associated with a full-width rock ramp (Option 1) are viewed as excessive for a weir that State Water has already decommissioned. Moreover, Option 3 will disenfranchise the adjacent property owners, with the perception that government agencies have turned a blind eye to State infrastructure.

Remediation of fish passage at Fawcetts Creek Weir 1 should be viewed in context with proposed works at the two remaining weirs located immediately upstream (< 3km). However, a single strategy for the Fawcetts Creek weirs should be avoided as the adjacent landholders to each weir have varying needs and viewpoints towards the structures.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Fawcetts Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at the three Fawcetts Creek weirs would provide unimpeded access for fish and other aquatic organisms to upstream habitat in excess of 40km.

## *MULLUMBIMBY WEIR 2, MULLUMBIMBY CREEK, MULLUMBIMBY*

**Figure 1.** Mullumbimby Weir 2 on Mullumbimby Creek as viewed weir from the downstream left bank.

### *Description and setting*

Mullumbimby Weir 2 (Figure 1) is located approximately 5km west of Mullumbimby on Mullumbimby Creek, a tributary of Brunswick River. Access to the weir occurs through an easement reached through school grounds. The fixed-crest weir, which is constructed primarily of concrete with downstream rock protection, measures 0.8 metres high by 13.5 metres wide. Water is pooled approximately 600 metres upstream at depths < one metre, resulting in a total usable capacity of 3.7ML. Water cascades over the weir crest, with fish passage being restricted due to excessive headloss (500mm).

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Mullumbimby Weir 2 as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Mullumbimby Creek is a perennial flowing, Class 2 tributary of the Brunswick River that supports a diverse range of native fish species;
- No water extraction licenses are serviced by the structure, with pumping for stock and domestic the only known use;
- Remediation of fish passage Mullumbimby Weir 2 would open 3km of habitat to unimpeded movement; and
- Instream and riparian habitat condition along Mullumbimby Creek is considered fair to good.

### *Hydrology*

Mullumbimby Weir 2 is located within the upper reaches of the Mullumbimby Creek subcatchment. The creek is a perennial flowing tributary that joins the Brunswick River approximately 7km downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 – 10 metres wide with low-flow depth generally < one metre. Adjacent landholders indicate that the creek maintains a low base flow throughout the majority of the year except during periods of extreme drought when the creek flows subsurface. Structural drown out occurs 2 - 3 times a year following significant rainfalls, providing the only means of fish passage.

### *Operational Details*

Mullumbimby Weir 2 was constructed in 1970 for drought protection as well as to provide a pumping pool for stock and domestic use. The structure, now owned by State Water, currently serves no existing water extraction license but continues to function as a pumping pool for stock and domestic use by a single upstream landholder. No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir is considered to be in working condition, with a satisfactory structural safety level being achieved (Opus Golder Audit). However, siltation has significantly reduced the capacity of the weir pool immediately upstream of the structure.

### *Ecological Considerations*

The Brunswick River catchment supports a diverse range of native fish species including migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Mullumbimby Weir 2 would remove the second of two significant barriers to fish passage on the system, thus opening 3km of habitat to migrating fish. Mullumbimby Weir 1, located approximately 5km downstream of the second weir, is slated for removal following the augmentation of the user's water supply through Byron Shire Council's effluent reuse scheme proposed in the coming years. The next upstream barrier from Mullumbimby Weir 2 is a box culvert road crossing on Yankee Creek Road at a distance of 2.6km that displays a headloss of 400mm. The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation is limited within Mullumbimby Creek due to shading by riparian vegetation, with Red Azolla dominating.

Mullumbimby Creek also provides valuable refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Mullumbimby Weir 2 include the koala (*Phascikarctis cinereus*), Long-nosed Potoroo (*Potorous tridactylus*), Glossy Black Cockatoo (*Calyptorhynchus banksii*), Red-tailed Black Cockatoo (*Calyptorhynchus banksii*), Rose Crowned Fruit Dove (*Ptilinopus regina*), Australasian Bittern (*Botaurus poiciloptilus*), Black Bittern (*Ixobrychus flavicollis*), Barred Cuckoo-Shrike (*Coracina lineate*), White-eared Monarch (*Monarcha leucotis*), Eastern Long-eared Bat (*Nyctophilus bifax*), Common Blossum Bat (*Syconycteris australis*), and Grey Headed Flying Fox (*Pteropus poliocephalus*).

Water quality within Mullumbimby Creek is described as good to excellent except during drought periods when stagnant pools form.

The weir and surrounding reaches display moderately-to-well vegetate banks, with minor erosion being recorded on the upstream side of the structure due to cattle access on both sides of the creek.

Downstream of the weir, the adjacent property owners (including a private primary/secondary school) have implemented riparian revegetation that has provided a 10 metre buffer on either side of the creek (Figure 2).

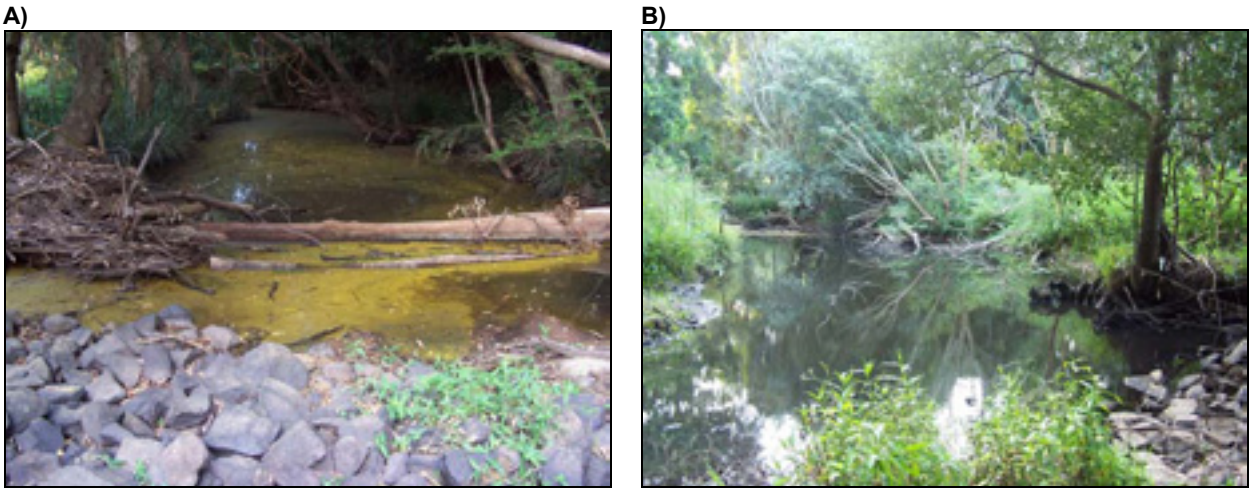



**Figure 2.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Mullumbimby Weir 2, Mullumbimby Creek.

Vegetation within the riparian zone is primarily composed of sub-temperate rainforest species and a mix of exotic weeds including Camphor and Coral Trees. Groundcover upstream of the weir is considered sparse with *Lomandra histrix* dominating. Siltation has significantly reduced the water holding capacity of the weir pool, with water depth immediately upstream of the weir less than 0.5 metre. Moreover, a 400mm difference in bed level occurs from the upstream to downstream side of the structure.

### *Proposed Remediation Actions*

- **Option 1 –** Full-width rock-ramp fishway

Due to the low height and narrow width of the weir, a full-width rock-ramp fishway would provide the best option of remediating fish passage while maintaining the structure. Full-width rock ramp fishways are generally considered one of the most effective designs for passing various species and size classes of fish within Australian streams. Investigation would be required to determine whether flows within Mullumbimby Creek would suit a rock-ramp fishway design, or whether an alternative fishway design would be more effective.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Mullumbimby Creek by removing one of the two main barriers to fish passage in the system. Additionally, State Water would no longer be liable for the site. Implementation of this option would require investigation into bed stability and sediment movement associated with siltation within the weir pool.

Consultation should occur with adjacent and upstream landholders to ensure that existing water needs (e.g. stock and domestic) would not be compromised significantly by the weir removal.

- **Option 3 –** Do nothing

The "Do Nothing" strategy would result in the weir eventually being washed away over a series of floods over the coming decades, with no cost being incurred by State Water. Fish passage would be remediated slowly over time resulting in the same outcome achieved through removal except that the aesthetics of the site would diminish resulting from the strewn debris from the weir. Additionally, State Water would be liable for environmental, property, or personal damage / injury resulting from the failure of the weir.

The weir pool is currently used for stock and domestic watering by a single landholder, with no existing water extraction license being serviced. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weir, with adjacent upstream landholders reluctant to see the structure removed. Thus, upstream landholder sentiment would support Option 1, which would ensure the stability of the structure and the provision of a reliable source of water. The two downstream landholders, including a private school, support the removal of the structure based upon environmental grounds. Additionally, the school is concerned about liability issues given the ease of access to the weir for its students.

State Water receives no financial benefit from maintaining the weir and has indicated that their preferred option is removal, which would eliminate public liability concerns.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | ✔ | |
| **Option 2** | ✔ | | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** Full-width rock ramps are one of the most effective fishway designs for passing fish, but are also one of the most expensive to construct. The likely cost of inserting a full-width rock ramp fishway at Mullumbimby Weir 2 would exceed $250,000.

**Option 2.** Removal of the weir would likely cost less than $50,000. Final costs would include preparatory surveys, production of an REF, landholder consultation and compensation, waste disposal, and bed/bank stabilisation.

**Option 3.** No direct cost would be associated with the "Do Nothing" strategy. However, State Water would still be held liable for any damage / injury resulting from the weir.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) following investigations into the likely changes to channel geomorphology and bed stability.

Weir removal would not only ensure unrestricted fish passage over 3km, but would also re-establish natural sediment fluxes. Moreover, State Water would no longer be liable for any damage/ injury associated with the weir, which currently fails to service a water extraction license. Consultation should occur however with the adjacent landholders to ensure that stock and domestic needs will not be significantly affected in the absence of the weir.

The cost of Options 1 would likely not provide the associated benefit given that the structure is located in the upper reaches of Mullumbimby Creek. Funds would presumably be better spent addressing fish passage barriers located further down the catchment on the mainstem Brunswick River. Additionally, insertion of the rock-ramp fishway would maintain the liability risk for State Water.

Option 3 produces the same outcome as removal of the structure; however, State Water would still be liable for damages/injury associated with the dilapidated state of the weir.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Mullumbimby Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Mullumbimby Weir 2 would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 3km.

## *GLENUGIE CREEK WEIR, GLENUGIE CREEK, GRAFTON*

**Figure 1.** Glenugie Creek Weir on Glenugie Creek near Grafton as viewed from the downstream left bank.

### *Description and setting*

Glenugie Creek Weir (Figure 1) is located approximately 10km south of Grafton on Glenugie Creek in the lower reaches of the Clarence River catchment, and is accessible via an easement approached by farm tracts along the left bank. The fixed-crest weir, which is constructed primarily of concrete with downstream rock protection (Figure 1), measures 1.1 metres high by 19 metres wide. Water is pooled approximately 600 metres upstream at depths > 2 metres, resulting in a total usable capacity of < 4.0ML. Water cascades over the weir crest, with fish passage being restricted due to excessive headloss (1100mm) and slope except during structural drown out.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Glenugie Creek Weir as a medium remediation priority within the Northern Rivers CMA region due to the following factors:

- Glenugie Creek is an ephemeral (Class 2), low level tributary of the Clarence River that supports a diverse range of native fish species;
- No known obstruction to fish passage occurs upstream of the weir, thus providing 41km of unimpeded fish access;
- Below Glenugie Creek Weir, the next downstream barrier to migrating fish is an unlicensed weir at a distance of 2.5km (Figure 2); and

- Instream and riparian habitat condition along Glenugie Creek is considered fair to good.

A) B)

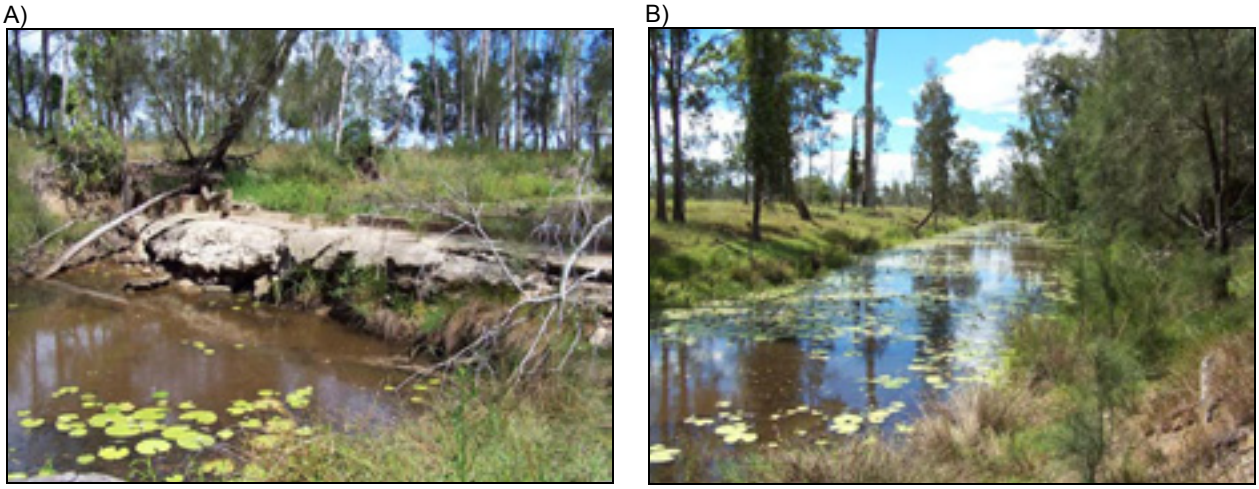


**Figure 2.** A) Unlicensed structure on Glenugie Creek located approximately 2km downstream of Glenugie Creek Weir. B) View of instream and riparian habitat below unlicensed weir.

### *Hydrology*

Glenugie Creek is an ephemeral flowing tributary that joins the mainstem Clarence River within the lower reaches of the system. Upstream of the weir pool, the watercourse is approximately 5 – 10 metres wide with low-flow depth generally < one metre. A river gauge is not present on Glenugie Creek or adjacent tributaries; however, adjacent landholders indicate that the creek maintains a low base flow for significant periods of the year, but generally dries up during the winter dry season and droughts. Structural drown out occurs 2 - 3 times a year following significant rainfalls, providing the only means of fish passage in the upstream direction.

### *Operational Details*

Glenugie Creek Weir was originally constructed for drought protection as well as to provide a pumping pool for stock and domestic use. Two landholders adjoin the weir pool, with a single water extraction license being serviced (135 ML per annum). Water is primarily pumped from the weir pool for irrigation and stock watering during dry spells. No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir is considered to be in working condition, with a satisfactory structural safety level being achieved (Opus Golder Audit). State Water, which now owns the structure, obtains an annual income of less than $1000 from the license at Glenugie Creek Weir.

Water flow over the weir crest is dictated by rainfall in the upper reaches of the catchment. Irrigators tend to cease water extraction when water stops flowing during drought periods. Given the small water holding capacity of the weir (< 4ML), available water reserves during dry periods would likely be insufficient to maintain intensive irrigation practices. Several turkey dams exist within close proximity to the weir pool, with water extracted to fill the dams following minor river rises.

### *Ecological Considerations*

The Clarence catchment supports a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Glenugie Creek Weir would remove a significant barrier to fish passage on the system, thus opening 41 km of habitat to unimpeded fish migration. Terrestrial species of conservation concern located within the vicinity of Glenugie Creek Weir include Black Bittern (*Ixobrychus flavicollis*), Square-tailed Kite (*Lophoictinia isura*), Regent Honeyeater (*Xanthomyza phrygia*), Yellow-bellied Sheath-tailed Bat (*Saccolaimus flaviventris*), Black Flying Fox (*Pteropus alecto*), Little Bent-wing Bat (*Miniopterus australis*).

A)

B)

**Figure 3.** Riparian and instream habitat (A) immediately downstream and (B) upstream of Glenugie Creek Weir, Glenugie Creek.

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators while also providing a substrate for algal growth. Aquatic vegetation is dominated by submerged aquatic macrophytes, which cover approximately 30% of the weir pool.

Water quality within Glenugie Creek is described as fair to good except during drought periods when stagnant pools form. The weir and surrounding reaches display well vegetated, intact banks; with the weir pool partially fenced which restricts cattle access to the waterway and adjacent riparian vegetation (Figure 3). Flora within the riparian zone is primarily composed of casuarinas (*Casuarina cunninghamiana*) and eucalypts, while groundcover adjacent to the waterway is sparse in locations but dominated by *Lomandra histrix* and pasture grasses. Siltation is present within the weir pool, with an 800mm difference in bed level being recorded from the upstream to downstream side of the structure.

### *Proposed Remediation Actions*

- **Option 1 –** Full-width rock ramp fishway

Given the current design of the weir, a full-width rock-ramp fishway could be inserted to remediate fish passage at the weir. Full-width rock-ramp fishways are considered one of the most effective designs for passing various species and size classes of fish within Australian streams. Investigation would be required to determine whether flows within Glenugie Creek would suit the proposed fishway design, or whether an alternative fishway design would be more effective or cost beneficial.

- **Option 2 –** Partial removal followed by insertion of rock-ramp fishway

This option would involve the partial removal of the structure followed by the insertion of a full or partial width rock-ramp. Weir height would be reduced from 1.1 to 0.5 metres, significantly reducing the cost of inserting a fishway onto the structure. Additionally, a weir pool would still persist, providing adequate water resources for current stock and domestic needs. Consultation would need to take place to ensure that the existing water license could be serviced by the remaining weir pool as well as from the adjacent turkey dams.

- **Option 3 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Glenugie Creek by removing a significant barrier in the system to fish passage. Additionally, State Water would no longer be liable for the site. Implementation of this option would require investigation into bed stability and sediment movement associated with siltation within the weir. Consultation should occur with adjacent and downstream landholders to ensure that existing water needs (e.g. irrigation, stock and domestic) will not be compromised by the weir removal.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | | ✔ |
| **Option 2** | | ✔ | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** Due to the size and location of the structure, insertion of a vertical slot fishway or associated structure would cost in excess of $500,000.

**Option 2.** Reducing the height of the weir would significantly reduce the cost of inserting a fishway. Further cost savings could be achieved by inserting only a partial-width rock ramp fishway.

**Option 3.** Removal of the weir would likely cost less than $50,000. Final costs would include preparatory surveys, production of an REF, landholder consultation and compensation, waste disposal, and bed/bank stabilisation.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 3) following investigations into the likely changes to channel geomorphology and bed stability. Weir removal would not only ensure unrestricted fish passage within the system, but also re-establish natural sediment fluxes. Consultation and compensation would need to occur to ensure that the existing water license could be served by alternative means. Moreover, stock and domestic needs would still need to be met in the absence of the weir. Removal of the weir is the second option preferred by State Water, with the agency supporting the attempted sale of the structure to adjacent landholders. Such an option would reduce the liability and maintenance requirements to State Water, but would instead shift these to the new owner. Eventually, the weir would require maintenance, which would enact the *Fisheries Management Act* (1994) entailing the owner to remediate fish passage.

The cost of Options 1 and 2 would likely not provide the associated benefit given that the structure is located on a small tributary with only 41km of habitat available upstream. Additionally, an unlicensed weir blocks fish passage 2.5km downstream of Glenugie Creek Weir, with funds presumably better spent addressing the removal / remediation of this structure (Figure 2).

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Glenugie Creek provides fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at Glenugie Creek Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 41km.

## *FAWCETTS CREEK WEIR 2, FAWCETTS CREEK, KYOGLE*

**Figure 1.** View of the top section of Fawcetts Creek Weir 2 from right bank.

### *Description and setting*

Fawcetts Creek Weir 2 (Figure 1) is located approximately 6km north of Kyogle on Fawcetts Creek in the upper reaches of the Richmond River Catchment, and is accessible via an easement reached through a farm tract along the left bank. The fixed crest weir, which is the middle of three structures located within a 3km stretch of Fawcetts Creek, measures 2 metres high by 11.5 metres wide and is constructed of rock fill that is concrete capped. The weir pools water 1.3km upstream at depths > 2 metres, resulting in a total usable capacity of 1.5ML. Water cascades over the crest of the weir, with fish passage being restricted due to excessive headloss (1600mm), slope, and turbulence till the structure drowns out.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Fawcetts Creek Weir 2 as a high remediation priority within the Northern Rivers CMA region due to the following factors:

- Fawcetts Creek is a Class 2 perennial flowing, upper level tributary of the Richmond River that supports a diverse range of native fish;
- Fawcetts Creek is within the known historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*);
- The weir is in a state of disrepair, with the middle portion of the structure already failing. State Water has decommissioned the weir with no further maintenance proposed;

- Below Fawcetts Creek Weir 1, the next downstream barrier to migrating fish is Cookes Weir at a distance of 55km;
- Approximately 40km of unimpeded habitat is available upstream of the third Fawcetts Creek weir; and
- Riparian and instream habitat within Fawcetts Creek ranges from fair to excellent.

### *Hydrology*

Fawcetts Creek is a perennial flowing tributary that joins the Richmond River approximately 5km downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 metres wide and generally < 1 metre deep. A river gauge is not present on Fawcetts Creek; however, adjacent landholders indicate that the creek maintains a flow throughout the year except during periods of extreme drought. Structural drown out occurs several times a year following significant rainfalls, providing the only means of fish passage in the upstream direction. However, the timing of structural drown out may not necessarily coincide with spawning migrations of resident fish in the Richmond catchment.

### *Operational Details*

Fawcetts Creek Weir 2 was constructed in 1968 as a result of funds provided by the Water Conservation and Irrigation Commission for emergency drought unemployment relief. The structure, now owned by State Water, is still used today for the original purposes of irrigation, stock (dairy and beef), and domestic use. Five landholders adjoin the weir pool, with four of the owners possessing water extraction licenses totalling 280ML per annum (only two licenses are viewed as active). Water is primarily pumped from the weir pool for the purpose of irrigating pasture grasses for dairy and beef cattle during dry spells, with one additional pump being used for stock and domestic purposes. State Water obtains an annual income of around $3500 from the licenses at Fawcetts Creek Weir 2.

Water flow over the crest of the weir is dictated by rainfall in the upper reaches of the Fawcetts Creek subcatchment. Irrigators tend to cease water extraction when water stops flowing over the weir crest during drought periods. Given the small water holding capacity of the weir (1.5ML), available water reserves during dry periods would likely be insufficient to maintain intensive irrigation of pasture grasses.

Repair works were conducted on the weir in 1984, including the addition of a thin concrete cap that was applied to prevent the structure from washing away. However, the current condition of Fawcetts Creek Weir 2 is described as poor, with the structural safety level ranking as unsatisfactory (Opus Golder Audit). The centre of the weir face has failed, with rock fill being washed away and vegetation growing amongst the rubble (Figure 2). Additionally, the left and right abutment are in a state of disrepair, with water leaking from beneath the weir on both sides thus compromising the ability of the structure to effectively pool water at low-flow conditions. Unless repair work is undertaken, the weir will fail during a flood event.

### *Ecological Considerations*

Two additional weirs owned by State Water (Fawcetts Creek Weir 1 and 3) are located on Fawcetts Creek less than 2km apart from Fawcetts Creek Weir 2. Both weirs, which are of similar scale to Weir 2, are significant barriers to fish passage for the majority of the year.

Additionally, Weirs 1 and 3 are in a similar dilapidated state; however, State Water has decommissioned both structures with no intention to conduct further maintenance. A further four barriers in the form of road crossings have been recorded on tributaries in the upper reaches of the Fawcetts Creek subcatchment; however, approximately 40km of habitat is available to migrating fish above the uppermost weir.

**Figure 2.** Damage to the central portion of the structure demonstrating weir failure.

Fawcetts Creek is a perennial flowing tributary of the Richmond River that historically supported a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Additionally, the creek continues to provide refuge for various waterbirds as well as the common platypus (*Ornithorhynchus anatinus*). Terrestrial species of conservation concern located within the vicinity of Fawcetts Creek include the Glossy Black Cockatoo (*Calyptorhynchus banksii*), the Barred Cuckoo-Shrike (*Coracina lineate*), the White-eared Monarch (*Monarcha leucotis*), and the Grey Headed Flying Fox (*Pteropus poliocephalus*). Water quality for Fawcetts Creek is described as excellent except during drought periods when stagnant pools form.

The creek contains important fish habitat components including large woody debris, intact riparian zones, and persistent waterholes. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators, while also providing a substrate for algal growth. Aquatic vegetation, which is limited within Fawcetts Creek due to shading by riparian vegetation, is dominated by red azolla located on the surface layer of the weir pool.

The weir displays moderately vegetated banks with minor erosion present both upstream and downstream of the structure presumably attributed to cattle access. Riparian vegetation is composed of rainforest hardwoods, eucalypts, casuarinas, and exotics trees (e.g. willows and *Camphor laurel*); while groundcover is dominated by pasture grasses and *Lomandra histrix*. Given the free access of cattle to both banks, overall creek health would be improved by riparian fencing and revegetation along the banks that reach up to 6 metres above the water level.

A)

B)

**Figure 3.** Riparian and instream habitat immediately downstream (A) and upstream (B) of Fawcetts Creek Weir 2.

### *Proposed Remediation Actions*

- **Option 1 –** Full width rock ramp fishway

This option would address the structural stability issues concerning the weir while also providing improved fish passage within Fawcetts Creek. The dilapidated state of the existing structure precludes the installation of a vertical slot fishway or a partial-width rock ramp, making a full-width rock ramp the most cost-effective fishway option. To reduce costs, the height of the weir could be lowered, with adjacent landholders benefiting from a reconditioned weir that would not leak. The decision to insert a full-width rock ramp fishway should however be viewed in context with the remediation of the two adjacent weirs that also impede fish passage, as well as with the fact that State Water has decommissioned all three weirs and has no plans to further maintain the structure.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Fawcetts Creek by providing unrestricted fish passage and natural sediment fluxes. Additionally, State Water would no longer be liable for the site or the dilapidated state of the weir. However, removal of the structure would result in the loss of the pumping pool for which four licenses are served. Therefore, alternative measures would need to be explored to determine the capacity to deliver the required water allocations during dry periods. Additionally, recreational values such as swimming would likely diminish at the site in the short term. Removal of the structure would also require detailed surveys investigating changes to fauna and floral communities, channel geomorphology, and sediment mobility and chemistry.

- **Option 3 –** Do nothing

The preferred option of State Water would result in the weir eventually washing away over a series of floods, with no cost being incurred. Fish passage would be remediated slowly over time resulting in the same outcome achieved through removal except that the aesthetics of the site would diminish due to the strewn debris

from the weir. Additionally, State Water would be liable for environmental, property, or personal damage / injury resulting from the failure of the weir.

The weir pool is currently used for irrigation, stock, and domestic use by four adjacent landholders, with water generally being pumped during dry spells to maintain consistent pastures for dairy and beef cattle. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weirs, with landholders interested in seeing the structures maintained. Thus, landholder sentiment would support Option 1, which would ensure the stability of the structure and the provision of a reliable source of water.

State Water has decommissioned all three weirs on Fawcetts Creek, with no intention to expend further resources to their maintenance. State Water supports the "Do Nothing" strategy, which involves no capital investment, while also avoiding the need to consult with adjacent landholders regarding removal of the structure as proposed in Option 2. As part of the "Do Nothing" strategy, State Water has expressed interest in selling the weir to adjacent landholders to limit liability and save costs.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | | ✔ |
| **Option 2** | ✔ | | | | |
| **Option 3** | ✔ | | | | |

**Option 1.** The predicted cost for insertion of a full-width rock ramp would likely be in excess of $600,000. The cost of this option would be reduced substantially if the height of the structure were lowered from 2 metres to 1 metre; however upstream licenses may not be served by a decrease in weir height.

**Option 2.** Removal of the weir is estimated at less than $35,000, including preparatory surveys, production of an REF, waste disposal, compensation to water license holders, and revegetation of adjacent banks.

**Option 3.** No direct cost would be associated with the "Do Nothing" strategy. However, State Water would still be held liable for any damage / injury resulting from the weir.

### *Recommendation*

The preferred remediation action for this site is removal of the structure (Option 2) in conjunction with consultation and compensation of licensed landholders regarding the redesign of water extraction equipment. Implementation of Option 2 will negate further liability associated with the weir for State Water, while leaving the site in a tidy state. Alternatively, the costs associated with a full-width rock ramp (Option 1) are viewed as excessive for a weir that State Water has already decommissioned. Moreover, Option 3 will disenfranchise the adjacent property owners, with the perception that government agencies have turned a blind eye to state infrastructure.

Remediation of fish passage at Fawcetts Creek Weir 2 should be viewed in context with proposed works at the two remaining weirs located immediately downstream (< 1km) and upstream (< 2km).

However, a single strategy for the Fawcetts Creek weirs should be avoided as the adjacent landholders to each weir have varying needs and viewpoints towards the structures.

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that Fawcetts Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. Reinstating fish passage at the three Fawcetts Creek weirs would provide unimpeded access for fish and other aquatic organisms to upstream habitat in excess of 40km.

## *SEXTONVILLE WEIR, DOUBTFUL CREEK, KYOGLE*


**Figure 1.** Sextonville Weir on Doubtful Creek near Kyogle as (A) viewed from the left bank. The weir incorporates a submerged orifice fishway (close up in B).

### *Description and setting*

Sextonville Weir (Figure 1A) is located approximately 20km southwest of Kyogle on Doubtful Creek in the upper reaches of the Richmond River catchment, and is accessible via a public road and easement along the right bank. The fixed-crest weir, which measures 2.7 metres high by 20 metres wide, is constructed primarily of concrete and fitted with a submerged orifice fishway (Figure 1B). The weir pools water approximately 500 metres upstream at depths > 2 metres, resulting in a total usable capacity of 5.0ML. Water cascades over the weir crest, with fish passage being restricted due to an excessive headloss of 2000mm. Australian fish are known to possess a low sustained swimming threshold; therefore few species are likely to successful traverse the submerged orifice fishway at Sextonville Weir, which favours strong swimmers.

Prioritisation of weirs in the Northern Rivers CMA region has highlighted Sextonville Weir as a medium remediation priority within the Northern Rivers CMA region due to the following factors:

- Doubtful Creek is an ephemeral (Class 3), upper level tributary of the Richmond River that historically supported a diverse range of native fish;
- Doubtful Creek is within the known historical range of the endangered Eastern Freshwater Cod (*Maccullochella ikei*);
- No water extraction licenses are serviced by the structure, with pumping for stock and domestic the only known use;

- No known obstruction to fish passage occurs upstream of the weir, thus providing 5km of unimpeded fish access;
- Below Sextonville Weir, the next downstream barrier to migrating fish is Cookes Weir on the mainstem Richmond River at a distance of 45km; and
- Instream and riparian habitat condition along Eden Creek is considered fair to good.

### *Hydrology*

Doubtful Creek is located within the upper reaches of the Richmond catchment. The creek is an ephemeral flowing tributary that joins the Richmond River approximately 35km downstream of the weir. Upstream of the weir pool, the watercourse is approximately 5 – 10 metres wide with low-flow depth generally < 1 metre. Adjacent landholders indicate that the creek maintains a low base flow throughout the majority of the year, with water holes drying up following protracted dry periods. Structural drown out occurs 1 - 2 times a year following significant rainfalls, thereby providing the only means of fish passage.

### *Operational Details*

Sextonville Weir was constructed in 1970 for drought protection as well as to provide a pumping pool for stock and domestic use. The structure, now owned by State Water, currently serves no existing water extraction license but continues to function as a pumping pool for stock and domestic use by a single landholder. No additional weir beneficiaries are known for the structure (e.g. local community, fishing groups). The weir is considered to be in a working condition, with a satisfactory structural safety level being achieved (Opus Golder Audit). No water was observed in the weir pool at the time of the initial visit (17-03-05), with local conditions described as dry but not drought declared.

### *Ecological Considerations*

The Richmond catchment supports a diverse range of native fish species including the endangered Eastern Freshwater Cod (*Maccullochella ikei*) and migratory species such as the Australian bass (*Macquaria novemaculeata*) and Freshwater mullet (*Myxus petardi*). Remediation of fish passage at Sextonville Weir would remove the main significant barrier to fish passage on the system, thus opening 5km of habitat to migrating fish. Additionally, there is no known barrier to fish passage below the weir past the confluence with the Richmond River to Cookes Weir, a distance of 45km. Terrestrial species of conservation concern located within the vicinity of Sextonville Weir include the koala (*Phascikarctis cinereus*), Glossy Black Cockatoo (*Calyptorhynchus banksii*), Square-tailed kite (*Lophoictinia isura*), Black Bittern (*Ixobrychus flavicollis*), Superb Fruit Dove (*Ptilinopus superbus*), Masked Owl (*Tyto novaehollandiae*), Little Bentwing Bat (*Miniopterus australis*), and Grey Headed Flying Fox (*Pteropus poliocephalus*).

Water quality within Doubtful Creek is described as good to excellent except during drought periods when water flow ceases. The weir and surrounding reaches display moderately vegetated, intact banks, with fencing restricting cattle access on both sides of the creek. Vegetation within the riparian zone is primarily composed of casuarinas (*Casuarina cunninghamiana*), *Callistemon spp*., and a mix of rainforest hardwoods, while groundcover adjacent to the waterway is dominated by *Lomandra histrix* and introduced weeds (e.g. tobacco bush and lantana). Siltation was not recorded behind the weir; however, a one metre deep scour hole was noted on the downstream side of the structure.


**Figure 2.** (A) View of the downstream scour hole beneath Sextonville Weir. (B) Riparian and instream habitat immediately upstream of the weir.

### *Proposed Remediation Actions*

- **Option 1 –** Denil fishway

Given the design of the weir, a Denil fishway could be retrofitted into the current submerged orifice fishway to remediate fish passage. Denil fishways are still considered experimental within Australia, thus an investigation would need to be conducted into the slope and hydrodynamics of the modified structure, while matching these with the swimming ability of various fish species and size classes within Doubtful Creek. Additionally, attention would need to be given to the minimum required flow levels for a Denil fishway design. Finally, the design of the weir would need to be altered to provide the necessary attract flows, while attention to the downstream scour hole would need to be addressed.

- **Option 2 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Doubtful Creek by removing the only significant barrier in the system. Additionally, State Water would no longer be liable for the site. Implementation of this option would require investigation into bed stability associated with the downstream scour hole. Caution is needed to avoid a headcut from moving upstream of the existing weir, which is presumably acting as a bed control structure. Consultation should occur with adjacent landholders to ensure that existing water needs (e.g. stock and domestic) will not be compromised significantly by weir removal.

- **Option 3 –** Partial removal followed by insertion of rock-ramp fishway

This option would involve the partial removal of the structure followed by the insertion of a full or partial width rock-ramp. Weir height would be reduced from 2.7 metre to < 1 metre, significantly reducing the cost of inserting a fishway onto the structure. The remaining portion of the weir, along with the full-width rock-ramp, would act as a bed control structure, avoiding the progression of a headcut upstream from the downstream scour hole. Additionally, a weir pool would still persist, providing adequate water resources for current stock and domestic needs.

The weir pool is currently used for stock and domestic watering by a single landholder, with no existing water extraction license being serviced. Although the surrounding area is considered to receive a high rainfall, recent droughts have reinforced the value of the weir, with adjacent landholders reluctant to see the structure removed. Thus, landholder sentiment would support Option 1 or Option 3, which would ensure the stability of the structure and the provision of a reliable source of water.

State Water receives no financial benefit from maintaining the weir. However, their preferred option at the moment is the "Do Nothing" strategy, which requires no immediate capital investment. Eventually, the weir will require maintenance, which will enact the *Fisheries Management Act* (1994), which stipulates that fish passage must be remediated. Alternatively, State Water could leave the structure to fall into a state of disrepair.

### *Projected Remediation Costs*

| Projected cost | < $50K | $50K - $150K | $150K - $250K | $250K - $500K | > $500K |
|---|---|---|---|---|---|
| **Option 1** | | | | ✔ | |
| **Option 2** | ✔ | | | | |
| **Option 3** | | | | ✔ | |

**Option 1.** Due to the size and location of the structure, insertion of a denil fishway or associated structure would cost in excess of $250,000. Costs would need to include the refurbishment of the structure, while also addressing the downstream scour pool.

**Option 2.** Removal of the weir would likely cost less than $50,000. Final costs would include preparatory surveys, production of an REF, waste disposal, and bed/bank stabilisation.

**Option 3.** Lowering the height of the weir would significantly reduce the cost of inserting a fishway. Further cost savings could be achieved by inserting only a partial-width rock ramp; however, a full-width rock ramp would ensure the future stability of the structure.

### *Recommendation*

The preferred remediation action for the site is removal of the structure (Option 2) following investigations into the likely changes to channel geomorphology and bed stability. Weir removal would not only ensure unrestricted fish passage within the system, but also re-establish natural sediment fluxes. Additionally, the weir is not servicing a current water extraction license.

Consultation should occur however with the adjacent landholders to ensure that stock and domestic needs will not be significantly affected by the absence of the weir. Attention to the downstream scour pool would be required to prevent a headcut from progressing upstream following removal.

The cost of Options 1 and 3 would not provide the associated benefit given that the structure is located on an intermittently flowing (i.e. Class 3), upper level tributary of the Richmond catchment. Funds would presumably be better spent addressing fish passage barriers located further down the catchment on the mainstem Richmond River (e.g. Cookes and Manyweathers Weir).

### *Benefits Associated with Remediation*

NSW DPI staff are in agreement that sections of Doubtful Creek provide important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about benefits to the ecology of the catchment. Reinstating fish passage at Sextonville Weir would provide unimpeded access for fish and other aquatic organisms to upstream habitat in excess of 5km.

## 6. REFERENCES


Baumgartner, L.J. (2005). *Effects of Weirs on Fish Movements in the Murray – Darling Basin.* Thesis Submitted for the Degree of Doctor of Philosophy. University of Canberra, Canberra, Australia.

Fairfull, S. and Witheridge, G. (2003). Why do fish need to cross the road? Fish passage requirements for waterway crossings. NSW Fisheries, Cronulla, 16pp.

Gehrke, P.C. and Harris, J.H. (2001). Regional-scale effects of flow regulation on lowland riverine fish communities in New South Wales, Australia. *Regulated Rivers: Resource Management*. 17: 369-391.

Gehrke, P.C., Gilligan, D.M., and Barwick, M. (2001). Fish communities and migration into the Shoalhaven River: before construction of a fishway. NSW Fisheries Final Report Series, no. 26.

Mallen-Cooper, M. (1994). Swimming ability of adult golden perch, *Macquaria ambigua* (Percicthyidae), and adult silver perch, *Bidyanus bidyanus* (Teraponidae), in an experimental vertical slot fishway. *Australian Journal of Marine and Freshwater Research.* 45: 191-198.

Marttin and Graaf (2002). The effect of a sluice gate and its mode of operation on mortality of drifting fish larvae in Bangladesh. Management and Ecological Note. ***In:*** *Fisheries Management and Ecology.* 9: 123 – 125.

NSW Fisheries (2002). Initial weir and floodgate review. Report for the State Weir Review Committee. NSW Fisheries, Ballina.

NSW Fisheries (2003). Policy and guidelines for fish friendly waterway crossings. Fishnote Series NSWF1181, NSW Fisheries, Cronulla NSW.

Opus and Golder (1999). Consultancy to undertake safety audit of 203 weirs, regulators, and 94 related structures. Final report Northern Areas. March 1999.

Pethebridge, R., Lugg, A., and Harris, J. (1998). Obstructions to fish passage in New South Wales south coast streams. Final Report Series 4, Cooperative Research Centre for Freshwater Ecology and NSW Fisheries, Cronulla, NSW.

Smith, A.K, and Pollard, D.A. (1998). Policy and guidelines. NSW Fisheries Office of Conservation, Sydney. 76 pp.

Thorncraft G.A. and Harris J.H. (1996). Assessment of rock-ramp fishways. Report for the Environmental Trusts, NSW Environmental Protection Authority, Border Rivers Commission, Department of Land and Water Resources, and Wyong Council. Fisheries Research Institute, Cronulla.

Thorncraft, G. and Harris, J.H. (2000). Fish passage and fishways in NSW: A status report. Cooperative Research Centre for Freshwater Ecology Technical Report 1/2000.

Williams, R.J., Watford, F.A. and M.A. Taylor (1996). *A summary of aspects of FRDC project 94/041 "Restoration of estuarine fisheries habitat" relevant to tidal obstructions in New South Wales estuaries.* NSW Fisheries Research Institute, Cronulla, NSW, 109pp.

# 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)

……

……

……

……

**8e No action recommended**

Comments (Include supporting literature and correspondence)

……

……

……

……

## SECTION 9 ADDITIONAL INFORMATION

**For further information:**


- Austral Archaeology Pty Ltd & ERM Australia Pty Ltd, (2003), Heritage Assessment of 206 River Structures, Coastal and Central Regions, NSW, (Final Report and Appendix A: Group Two, Volume One).
- NSW DPI (Fisheries) Aquatic Habitat Rehabilitation database
- Pethebridge, 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