Namoi CMA CATCHMENT MANAGEMENT AUTHORITY

The Assessment & Modification of Barriers to Fish Passage in the Namoi Catchment

Natural Heritage Trust

Helping Communities Helping Australia

A Commonwealth Government Initiative

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NSW Department of Primary Industries

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Cover photos (from left to right): Mollee Weir, Namoi River; Barraba Weir with vertical-slot fishway, Manilla River; Jewry Street causeway, Peel River, and; concrete-capped water supply pipe, Peel River.

EXECUTIVE SUMMARY

As a result of funding from the Namoi Catchment Management Authority, NSW Department of Primary Industries undertook a project entitled '*The Assessment and Modification of Barriers to Fish Passage in the Namoi Catchment*'.

A total of 496 instream structures across eight Local Government Areas were assessed with respect to their impacts on fish passage. 162 of these structures were identified as fish passage barriers, with 31 of these listed as High Priority and requiring immediate remediation. Included in these structures were nine causeways, eight weirs, five fords, five water gauge structures, three culverts and one water-supply pipe. Remediation of fish passage at all 31 high priority sites will open up in excess of 1,000km of additional free passage for fish in the Namoi catchment.

The ability of native fish to move freely up and downstream within our rivers and wetlands is vital to their survival. Fish need to move in order to feed, find shelter and reproduce. Impeding fish passage through the construction of dams, weirs, floodgates and waterway crossings can negatively impact native fish by creating physical, hydrological or behavioural barriers that:

- interrupt spawning or seasonal migrations,
- restrict access to preferred habitat and available food resources,
- reduce genetic flow between populations,
- increase susceptibility to predation and disease through accumulations below barriers,
- fragment previously continuous communities, and
- disrupt downstream movement of adults and impede fish larval drift through the creation of still water (lentic) environments

This project was undertaken to identify barriers to fish passage in the Namoi catchment and in doing so provide the CMA with information necessary to undertake targeted remediation works. Potential sites were identified using topographic maps combined with expert knowledge from regional state agencies, with field assessments taking place between February and October 2005. Data collected included information on structure location, ownership details, environmental considerations, impacts on fish passage, and habitat condition. A prioritisation scheme was developed to assist in ranking instream structures requiring remediation. The scheme was developed to determine regional priorities, ranking sites based on the categories of a) Habitat value b) Structure impact, and c) Modification criteria.

A range of remediation options have been recommended for reinstating fish passage at High Priority sites, including:

- Basic management and maintenance of sites, such as the regular removal of sediment and debris;
- Modification of structures, such as retrofitting low-flow channels, modifying outlet levels, and installing fishways, and;
- Complete removal and, where necessary, replacement of structures.

Demonstration sites have been established as part of this project to illustrate best practice techniques associated with the design, construction, and remediation of instream barriers. Four case study sites have been selected from the list of High

Priority structures, and include the Hansons Causeway, “Wittagoona” Causeway, Mayvale Road Culvert, and the Barraba Weir. To date the Hansons Causeway and “Wittagoona” Causeway have been remediated, resulting in 7km of fish passage opened up in the Cockburn River and 56km reinstated in the Namoi River, respectively.

This project has assisted in meeting management targets set by the Namoi Catchment Management Authority in their regional Catchment Action Plan. When setting goals and targets for aquatic habitat conservation a clear understanding of the extent of habitat condition and degradation is required to ensure the best management actions are implemented.

CONTENTS

TABLES

1. INTRODUCTION

The following report outlines the results of a project entitled "*The Assessment and Modification of Barriers to Fish Passage in the Namoi Catchment*". The project was conducted by the NSW Department of Primary Industries (DPI Fisheries Management Branch) for the Namoi Catchment Management Authority (NCMA), and was funded through the Natural Heritage Trust program (Contract Number NAC0006-04).

1.1 Project aims and objectives

The project was designed to expand on the findings of the Initial NSW Weir Review by conducting a detailed field audit of road crossings and other structures that may present a barrier to fish passage on Class 1 and Class 2 waterways (Table 1) in the Namoi catchment. The project endeavoured to provide direction for expenditure of funds targeted for fish passage, as outlined in the NCMA Investment Strategy 2004-2007, and in doing so support the Management Targets of the Namoi Catchment Blueprint/Action Plan.

The scope of this project was restricted to Class 1 Waterway Types (Major Fish Habitat) and Class 2 Waterway Types (Moderate Fish Habitat) in accordance with the classification scheme of Fairfull & Witheridge (2003). Fish passage within these habitat classes is considered to be of the highest priority, and remediation of fish passage in these waterway types would result in beneficial flow on effects for lower fish habitat classes.

Table 1: Classification and characteristics of Waterway Type (source: Fairfull & 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).

The primary objectives of the project were to:

- Identify and assess instream structures in the NCMA area that may be barriers to fish passage,
- Prioritise instream barriers that restrict fish passage across the region,
- Recommend remediation options to improve fish passage at all High Priority sites, and
- Demonstrate methods of remediating instream barriers in the region, by promoting and applying "fish-friendly" principles in regards to instream works.

2. BACKGROUND

2.1 Fish passage in NSW

There are 3,327 licensed weirs and dam structures (DNR Database) that occur on New South Wales waterways, however this number does not include barriers such as waterway crossings, with the total number of instream barriers in NSW waters expected to be much higher (NSW Fisheries, 2002). The installation and use of these structures can have a significant impact on stream connectivity and habitat diversity, both of which are critical components of healthy rivers. Many fish have evolved to be reliant on a variety of different habitat types throughout their life cycle, ensuring that the free passage of fish within rivers and streams is an important component of aquatic ecology. As a result of this, the maintenance of connectivity between upstream and downstream habitats (longitudinal connectivity) and adjacent riparian and floodplain habitats (lateral connectivity) is an essential part of aquatic habitat management.

Impeding fish passage through the construction of dams, weirs, floodgates and waterway crossings can negatively impact native fish by creating physical, hydrological or behavioural barriers that:

- interrupt spawning or seasonal migrations,
- restrict access to preferred habitat and available food resources,
- reduce genetic flow between populations,
- increase susceptibility to predation and disease through accumulations below barriers,
- fragment previously continuous communities, and
- disrupt downstream movement of adults and impeding fish larval drift through the creation of still water (lentic) environments (Fairfull and Witheridge, 2003).

The impact of instream structures on fish passage will vary depending on a) the design of the structure b) the nature of flow, debris and sediment movement in the waterway, and c) the swimming capabilities of fish (dependent on species and age) present in the waterway.

In general, bridges and arch structures have the least impact on fish passage as they normally involve limited disturbance to the stream flow or the aquatic habitat of a waterway (Fairfull and Witheridge, 2003). Fish are able to swim under most bridge types during a range of hydrological conditions without encountering any form of blockage.

Culverts are waterway crossings with round or box-shaped cells designed to convey flow underneath the roadway. Some culverts are able to pass fish at low flows but become a hydrological barrier during freshes and small floods. If a piped or box culvert has excessive variation in water level across the outlet (causing a waterfall effect), the crossing may also act as a barrier to fish at low flows. In addition to this, culverts can restrict fish movement due to a lack of lighting, excessive flow velocities and due to debris blocking the opening.

Low-level crossings such as causeways are generally constructed at or near bed-level. These crossings are designed to convey water across the road surface as sheet flow, with some structures possessing low-flow pipes. Fords are a type of

low-level crossing that are formed directly on the channel bed ("wet crossing"). Both types of low-level crossings can drown out reasonably frequently, however at low flows they may act as a barrier to fish. In particular, causeways often provide inadequate flow depth for fish and a fall in water level at the structure crest or the low-flow pipe can cause a waterfall effect.

Instream structures that span the whole channel, including regulating structures such as weirs, levees and floodgates can impede natural flows and act as physical and hydrological barriers to fish movement, isolating upstream and downstream habitats, as well as seasonal or ephemeral habitats on floodplains and wetlands (Thorncraft and Harris, 2000; and Fairfull and Witheridge, 2003).

The importance of free fish passage for native fish is recognised under the *Fisheries Management Act* 1994, which has provisions that deal specifically with blocking fish passage. In addition to these conditions, the installation and operation of instream structures, as well as the alteration of natural flow regimes, have been listed as *Key Threatening Processes* under the *Fisheries Management Act* 1994 and the *Threatened Species Conservation Act* 1995. These legislative tools, and associated NSW Government policies such as the NSW Weirs Policy, act to regulate the construction of instream structures that may present a barrier to fish passage.

2.2 Fish passage in the Namoi catchment

The Namoi catchment is located in the north-eastern area of the Murray-Darling Basin and includes all waterways between the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mt. Kaputar to the north (DLWC, 1999). The waterways in the Namoi catchment drain a populated region of approximately 100,000 residents. There are a number of large urban centres that provide services to a predominantly agricultural region. The infrastructure associated with this development is concentrated along the Namoi River and its major tributaries, resulting in modification of the catchment, causing environmental problems such as a reduction in water quality and the loss of riparian vegetation and aquatic habitat (Harris, 2004).

Intensive landuse practices, such as cotton production, livestock production and horticulture, are dependent on the waterways of the catchment, especially for irrigation purposes. The infrastructure required to support this landuse, including diversion channels, dams and weirs, has impacted directly on the health and connectivity of river systems. Flow regulating structures, including the three major water storages of Keepit, Split Rock and Chaffey Dams, and other regulating weirs such as Mollee, Gunidgera (Plate 1) and Weeta, are used to provide measured water flows. The construction of these, and numerous other weirs, has significantly reduced the frequency of natural flood events and produced major instream barriers to fish passage in the Namoi catchment.

Accompanying the agricultural infrastructure in the Namoi catchment is the development required to support the urban centres in the region. This includes the construction of both public and private transport networks, which impact on the condition of the aquatic environment. The construction of waterway crossings

such as culverts (Plate 2), causeways (Plate 3), and fords (Plate 4) have the potential to elevate surface run-off, whilst also causing instream barriers.

Additional structures associated with regional development that aim to improve, maintain or monitor the aquatic habitat may also impact fish passage. Bed control structures (Plate 5) and water gauging structures (Plate 6) have been constructed in the Namoi catchment to provide streambed and bank stability and to monitor water flows in the region, respectively. Their instream presence however, may also result in barriers to fish passage if not suitably designed or maintained.

2.3 Namoi catchment – Aquatic habitat and biodiversity

The freshwater environment of the Namoi catchment is comprised of an extensive range of aquatic habitats including swamps, floodplains, wetlands, streams and rivers. Within these broad habitat types, niche habitats such as pools and riffles, gravel beds, snags, aquatic vegetation and riparian vegetation are present, diversifying the habitat available to aquatic species in the Namoi catchment.

This extensive range of aquatic habitat supports a diverse assemblage of species, including over 20 freshwater finfish species (see Appendix A and B). Six of these species are introduced, competing with 16 native fish species, found within the catchment. The pressures from introduced species, as well as other factors such as reduced water quality, increased fishing pressure, and habitat degradation, have resulted in the population densities of native fish being significantly lower than historical levels (Harris, 2004). All of these native species are potamodromous, undergoing migrations within the freshwater systems as part of their lifecycles potentially resulting in widespread distribution throughout the catchment (Harris *et al*, 1994).

Within these native species, four are listed as threatened in NSW waters. The western populations of the Olive Perchlet (*Ambassis agassizii*) and the Purple Spotted Gudgeon (*Mogurnda adspersa*) are listed as endangered under the *Fisheries Management Act* 1994. Silver Perch (*Bidyanus bidyanus*) and Murray Cod (*Maccullochella peelii peelii*) species are listed as vulnerable under the *Fisheries Management Act* 1994 and *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act), respectively. All of these species have an expected distribution in the Namoi catchment, with historical records indicating their presence throughout the entire catchment. Pressures such as habitat degradation, including the loss of aquatic plants and competition and predation from introduced fish species have affected the populations of these species.

The region also supports an array of aquatic macroinvertebrates including insects, yabbies and freshwater mussels. The macroinvertebrate communities of the Namoi catchment are moderately to significantly impaired, predominantly due to the pressures associated with flow regulation and agricultural landuse issues (Harris, 2004). The threatened River Snail species *Notopala sublineata*, which is listed as an endangered species in NSW under the *Fisheries Management Act* 1994, has an expected distribution in the Namoi catchment. This freshwater snail was once widespread in the Murray-Darling Basin, with pre 1980 records showing their distribution in the lower end of the Namoi catchment (NSW DPI, 2005). Activities associated with river flow management have rapidly reduced their populations.

Plate 1: Gunidgera Weir, Namoi River, Narrabri LGA (Code: 419/970000/B0104).

Plate 2: Box culvert, Gunidgera Creek Narrabri LGA (Code: UPN6).

Plate 3: Causeway, Mooki River, Gunnedah LGA (Code: MIA).

Plate 4: Ford, Mooki River, Tamworth LGA (Code: PCA).

Plate 5: Bed control structure, Cockburn River, Tamworth LGA (Code: BCS8).

Plate 6: Water gauge structure, Cockburn River, Tamworth LGA (Code: WGS13).

All these aquatic species are dependent on healthy waterways and access to a range of diverse habitats for their survival. In recognition of this, the aquatic ecological community of the natural drainage of the lowland Darling catchment, which includes the Namoi catchment, is listed as an Endangered Ecological Community under the *Fisheries Management Act* 1994. This includes all native fish and aquatic invertebrates that occur within the natural rivers and their associated tributaries downstream of the major dams in the Namoi catchment, recognising the rarity, vulnerability and habitat importance of the region (NSW DPI, 2005).

3. PROJECT METHODS

3.1 Previous fish passage investigations

Several studies have previously been undertaken by natural resource management agencies within the Namoi catchment, addressing fish passage, river health and aquatic ecology issues. These studies were reviewed as part of the current project to identify knowledge gaps relating to instream structures in the Namoi catchment.

Elder (2001) reviewed the nine Cockburn River bed control structures that were constructed between 1994 and 2000 in the Tamworth Regional LGA. These instream structures were built to prevent bed lowering, and consist of Mangfall sills and Schauberger ramps. The review identified damage that had occurred to the structures during flood events, focussing on the structural stability of the structures and recommendations for remedial works (Table 2).

Table 2: Review of Cockburn River instream structures (source: Elder, 2001).

Structure Type	05/06 Code	Waterway	Proposed Action
Mangfall Sill 1	BCS1	Cockburn River	Revegetation of riparian strip, but no structural works required
Mangfall Sill 2	BCS2	Cockburn River	Repair damage to right-hand side using rock
Mangfall Sill 3	BCS4	Cockburn River	No repairs required
Mangfall Sill 4	BCS5	Cockburn River	Reconstruct collapsed sections of Mangfall sill
Mangfall Sill 5	BCS6	Cockburn River	Rebuild slumped sections of structure, including fishway
Mangfall Sill 6	BCS7	Cockburn River	Rectify height difference between crest boulders and backfill scoured channel
Schauberger Ramp	BCS8	Cockburn River	No repairs required

In 2002 NSW Fisheries (now incorporated in NSW DPI) completed a statewide review of weir structures identified in the Department of Land and Water Conservation (DLWC) Weirs Inventory. This initial weir review focused on licensed structures that were accessed through the DLWC's Licensing Administration database System (LAS). A total of 120 weir licences were registered in the Namoi catchment, of which 75 weir structures actually existed and were found on named watercourses (NSW Fisheries, 2002). Following the Initial Weir Review, a Detailed Weir Review was conducted (See Appendix C), which identified seven structures that required structural or operational modifications (Table 3).

Table 3: Weir structures identified for fish passage remediation actions (source: NSW DPI, 2006).

Name	05/06 Code	Waterway	Proposed Action
Barraba Weir	UMA78	Manilla River	Removal, depending on associated issues
Calala Gauging Weir	WGS13	Peel River	Removal, depending on alternative gauging options
Gunidgera Weir	419/970000/B0104	Namoi River	Installation of Deelder fishlock
Jewry Street Weir	LPRA	Peel River	Removal, depending on associated issues
Mollee Weir	419/970000/B0103	Namoi River	Installation of Deelder fishlock
Walgett Shire Council Weir	419/970000/B0068	Namoi River	Removal, depending on associated issues
Weeta Weir	419/970000/B0106	Namoi River	Recommended for a vertical slot fishway

The current report builds upon these previous studies by identifying and assessing road crossings that potentially impede fish passage, whilst also incorporating other bed control structures and water gauging structures that occur in the catchment.

3.2 Desktop and field analysis

The field assessment of remaining instream structures was identified by:

- Assessment of 1:25,000 topographic maps for potential waterway crossing barriers,
- A list of known bed control structures within the Namoi Catchment from the NCMA Riparian Officer,
- An Excel spreadsheet containing information of water gauging structures and their controls from the DNR Hydrographic Co-ordinator, and
- Regional staff of the Department of Natural Resources (DNR), State Water, NCMA and NSW DPI, who were contacted to provide any advice or comments regarding potential waterway barriers in the Namoi catchment.

The total number of sites identified for assessment in the Namoi catchment was 496. An assessment proforma was developed prior to fieldwork to ensure that data gathering was consistent and transferable to the prioritisation process (Appendix D). A total of 430 sites were assessed during the study, with the majority of fieldwork conducted between February and October 2005. Information for the remaining 66 sites was gathered from the Initial Weir Review database. For each of the sites, location details (GPS readings or map grid references) and digital photographs were recorded.

In addition to this information, all sites identified for on-ground assessment required further desktop research to determine the geophysical setting, aquatic habitat quality (availability and condition) and biodiversity parameters for each instream structure. This information was obtained through various sources including:

- Available catchment data that included flow duration, catchment condition reports, River Styles™ assessments, and Stressed Rivers Assessments,
- Fishfiles and the NSW DPI Freshwater Fish Database for fish species distribution, and
- Waterway crossing and land tenure details from Land & Property Information sources and topographic maps.

3.3 Prioritising fish passage barriers

A prioritisation scheme was developed to assist in ranking instream structures requiring remediation (Appendix E). The scheme was developed to determine regional priorities by ranking sites based on the categories of a) Habitat value b) Structure impact, and c) Modification criteria. The ranking process took into account various factors associated with each structure including the quality and condition of existing aquatic habitat, the potential impact on fish movement, and the modification possibilities, such as potential costs and ancillary uses.

The process involved weighting these factors for each structure to produce a final score that was used to determine priority levels, with a higher score resulting in a greater priority level. Approximately 20% of the structures were classified as High Priority barriers, with a further 60% classified as Medium Priority and 20% classified as Low Priority structures.

This process provided a simple and effective method of determining regional priorities, allowing for the rapid assessment of each structure on a catchment scale. However, during potential remediation actions it is acknowledged that many associated environmental, social, cultural and economic considerations must also be reviewed before the actions occur.

Recommendations were made on how the High Priority structures could be modified to improve fish passage, with case studies developed to demonstrate the best practice remediation options for fish passage. Details on initial investigations that have been conducted to identify possible demonstration sites, including information on design options, site rehabilitation, works permitting and funding assistance for each selected structure is included in this report (Section 5.3). A list of the remaining High Priority structures that outlines their details and remediation options is also included in this report (Section 5.2) and will be made available to Local Councils, waterways managers and other structure owners for their consideration in future works programs.

4. ASSESSMENT RESULTS

4.1 Summary of field assessments by Local Government Area

The project included the assessment of 496 instream structures across eight LGAs in the Namoi catchment, a region that covers an area of approximately 42,000km^2. The majority of these structures were deemed to have negligible impact on fish passage, however 162 structures were identified as potential barriers to fish passage, requiring some form of remediation action.

Table 4 displays the LGAs present within the Namoi catchment, outlining the number of sites assessed in each area and the number of sites recommended for fish passage remediation.

Table 4: Summary of instream structures identified as potential fish passage barriers occurring within the LGAs of the NCMA region.

Local Government Authority	LGA as % of Study Area (42,000km^2)	Approximate population of LGA	Total # of sites assessed as a potential barrier	Total # of sites recommended for remediation
Coonamble	0.97	4, 758	0	0
Gunnedah	12.72	12, 379	41	9
Liverpool Plain	8.70	7, 112	41	15
Narrabri	19.51	14, 383	91	33
Tamworth Regional	26.40	51, 813	276	90
Walcha	2.85	3, 287	5	0
Walgett	14.40	8, 207	39	14
Warrumbungle Shire	14.45	11, 000	3	1
Total			**496**	**162**

The total number of sites assessed as potential fish barriers within each LGA reflected both the geographical and population size of the area, with larger and more populated LGAs possessing a greater number of sites. These areas encompass a greater degree of urbanisation, as well as a larger number of drainage systems. This trend was also evident in the number of sites recommended for remediation, with the larger and more populated LGAs having a greater number of priority sites recommended for remediation.

The lowest number of assessed sites occurred in the Coonamble, Walcha and Warrumbungle Shire LGAs, with both Coonamble and Walcha having no sites recommended for remediation. The subcatchments incorporated in these areas, with the exception of the Coonamble LGA, were identified as an area with low stress value for fish passage. The Tamworth Regional and Narrabri LGAs had the greatest number of sites assessed and recommended for remediation.

4.2 Types of fish passage barriers in the Namoi catchment

There were several types of instream structures assessed during the study including weirs, causeways, culverts, fords, bridges, bed control structures, water gauging structures and floodgates. Table 5 outlines the total number of these structure types that were assessed during the study.

Table 5: Summary of instream structure types assessed in the Namoi Catchment.

Instream Structure Type	Coonamble	Gunnedah	Liverpool Plain	Narrabri	Tamworth Regional	Walcha	Walgett	Warrumbungle Shire	Total
Weir	0	4	5	28	20	0	11	1	69
Causeway	0	6	10	9	41	0	3	0	69
Culvert	0	1	3	12	33	0	0	0	49
Ford	0	12	5	14	66	0	3	2	102
Bridges	0	17	17	27	99	5	21	0	186
Bed control	0	0	1	0	9	0	0	0	10
Water gauge	0	0	0	0	6	0	1	0	7
Floodgate	0	1	0	1	1	0	0	0	3
Other	0	0	0	0	1	0	0	0	1
Total	0	41	41	91	276	5	39	3	**496**

The most common instream structures identified during the project were bridges (186), ford crossings (102), weirs (69) and causeways (69). The remaining 70 structures were composed of other potential barriers such as culverts, bed control structures, water gauge structures and floodgates, with the “Other” classification encompassing water-supply pipes.

The majority of instream structures were found in the Tamworth Regional and Narrabri LGAs. Of the common structure types, Tamworth Regional LGA had the greatest number of bridges (99), ford crossings (66) and causeways (41). The Narrabri LGA had the greatest number of weirs (28), as well as a relatively large number of the other common structures.

4.3 Summary of sites recommended for remediation

In this study, 334 sites were not recommended for remediation predominantly because the instream structure was deemed to have negligible impact on fish passage, being a very minor obstruction to fish only at certain times with fish regularly being able to negotiate the structure (Appendix J).

The remaining 162 sites assessed in the Namoi catchment were identified as fish passage barriers that would require remediation to enhance fish passage. Appendix F summarises the number of instream structures recommended for remediation, highlighting the priority level determined for each barrier.

A range of remediation options have been suggested for these sites, including:

- Basic management and maintenance of sites, such as the regular removal of sediment and debris, and the opening of floodgates.
- Modification of structures, such as retrofitting low-flow channels, modifying outlet levels, and installing fishways (see Appendix G for fishway types).
- Complete removal and, where necessary, replacement of structures.

The most common instream structures identified as fish passage barriers were weirs (69), causeways (34) and culverts (25). Weirs generally have a greater impact on fish passage than culverts or low-level crossings due to their design and function, which commonly results in them being larger structures that occur on perennial waterways. The most common instream structures assessed during the project were bridges, however no sites were identified as fish passage barriers reflecting their minimal disturbance to flow and aquatic habitat of a waterway.

Of the 162 sites identified as fish passage barriers, 31 were classified as High Priority that required immediate remediation actions.

5. DISCUSSION

5.1 Remediation priorities

The importance of protecting and managing the aquatic habitat of the Namoi catchment has been recognised by the NCMA, addressing management targets in both the Namoi Catchment Blueprint (2003) and the Namoi CMA Investment Strategy 2004-2007 (2005). The intent of fish passage related management targets is to identify and prioritise instream structures that act as a barrier to water flow and the movement of aquatic biodiversity, and to implement on-ground works at priority structures to secure fish passage and improve water quality.

The current study has contributed to these management actions by achieving the following outcomes:

- Development of a fish passage barrier inventory for the NCMA region;
- On-ground application of a fish passage barrier assessment method;
- Application of a prioritisation method to rank fish passage barriers;
- Identification of remediation options for High Priority structures;
- Demonstration of applying "fish-friendly" remediation methods for Case Study structures, and;
- Promotion and distribution of the findings for the report.

Instream structures that were identified as fish passage barriers (162 sites) were further classified as High Priority, Medium Priority or Low Priority according to their final ranking score, as represented in Appendix K. Information regarding Medium Priority structures is listed in Appendix H and geographically presented in Appendix L, whilst the information for Low Priority structures is displayed in Appendix I and geographically mapped in Appendix M.

The High Priority structures (31 sites) have been further analysed on a regional scale, exploring remediation options to restore fish passage, with Table 6 summarising their information, Map 1 portraying their location and Section 5.2 outlining their issues and management options in further detail.

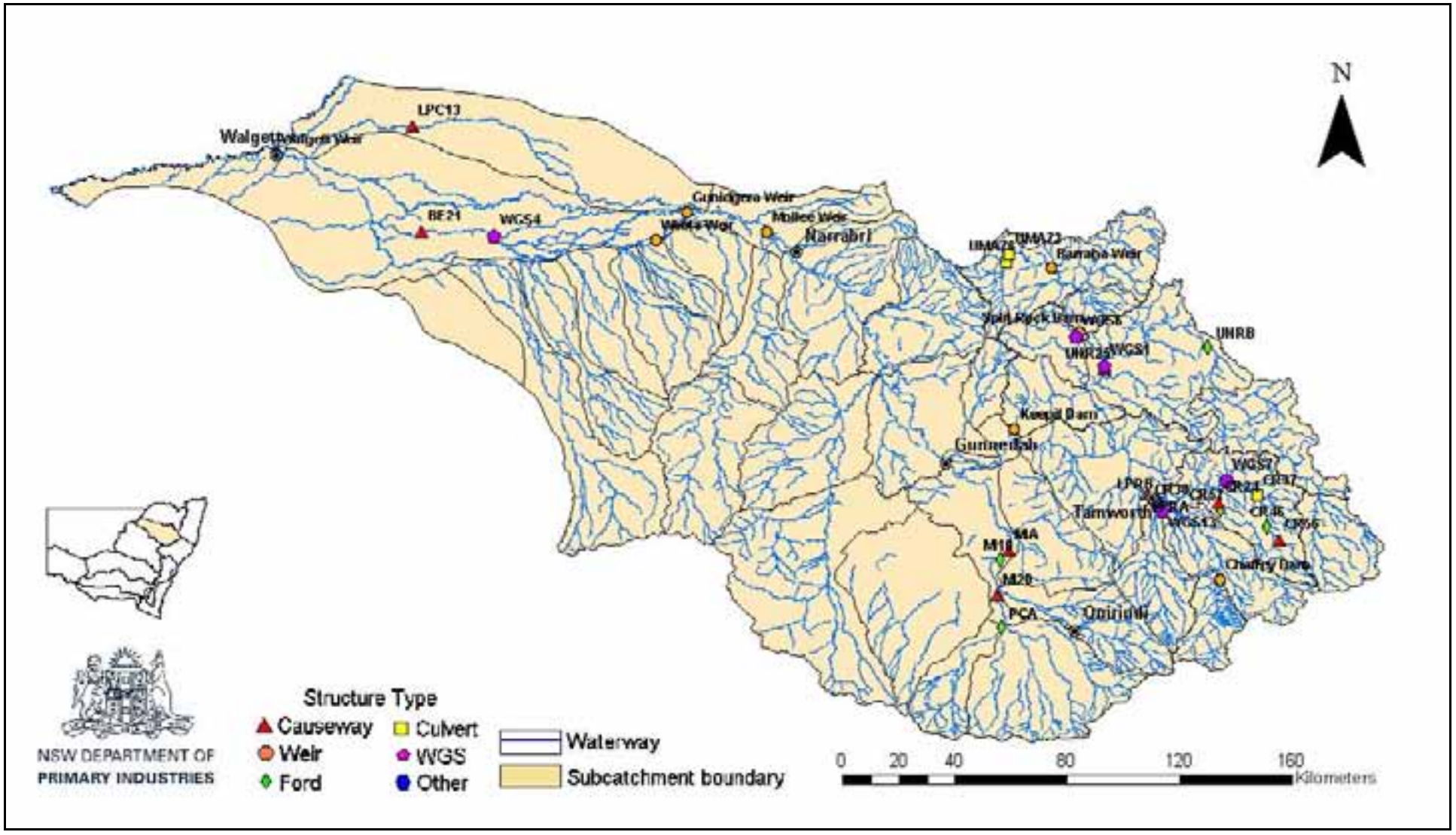
Overall the High Priority sites included nine causeways, eight weirs, five fords, five water gauge structures, three culverts and one water-supply pipe. It can also be noted that the top three sites are all significant weir structures that occur on the mainstream of major waterways, and as a result of this have been recommended for remediation in previous reports (NSW DPI, 2006).

Table 6: High Priority fish passage barriers in the Namoi region.

Rank*	LGA	Structure Type	Issue/Recommendation
1	Narrabri	Weir (Gunidgera Weir)	Install a Deelder fishlock
1	Narrabri	Weir (Weeta Weir)	Install a vertical slot fishway
3	Narrabri	Weir (Mollee Weir)	Install a Deelder fishlock
3	Walgett	Causeway ("Stoney Crossing")	Remove and replace with bridge structure
5	Walgett	Weir (Bugilbone WGS)	Remove and seek alternative gauging technologies / investigate fishway options
6	Walgett	Weir (Walgett Weir)	Remove if not required / add rock ramp fishway to the structure
6	Tamworth	Ford	Remove if structure not required
8	Gunnedah	Weir (Keepit Dam)	Install a high level fishlift
9	Tamworth	Causeway (Jewry St)	Remove if structure not required and replace with bed control structure
9	Tamworth	Culvert (Mayvale Road)	Modify cells by retrofitting bed level channels into the base of the structure
11	Tamworth	Water-supply Pipe	Install a partial rock ramp fishway
11	Tamworth	Causeway (Hansons)	Partial removal of structure if not required and the creation of a riffle section
13	Gunnedah	Causeway	Remove and replace with multicell box culvert
13	Tamworth	Ford	Remove and replace with a train carriage bridge
13	Tamworth	Weir (Peel River WGS)	Remove and seek alternative gauging technologies / investigate fishway options
16	Tamworth	Ford	Remove and replace with a train carriage bridge
16	Tamworth	Weir (Barraba Weir)	Remove if structure not required / retrofit existing vertical slot fishway
18	Tamworth	Weir (Chaffey Dam)	Install a high level fishlift
18	Walgett	Causeway	Remove and replace with multicell box culvert.
18	Tamworth	Causeway	Remove and replace with a train carriage bridge
18	Tamworth	Culvert	Partial removal / retrofit bridge section in low flow channel.
18	Tamworth	Causeway ("Wittagoona")	Partial removal / retrofit bridge section in low flow channel.
23	Tamworth	Weir (Split Rock Dam)	Install a high level fishlift
23	Tamworth	Ford	Modify and replace structure with bed level ford
23	Tamworth	Causeway (Caroona Crossing)	Remove if structure not required and replace with bed control structure
26	Tamworth	Culvert ("Plumthorpe")	Remove and replace with multicell box culvert
26	Tamworth	Weir (Manilla River WGS)	Remove and seek alternative gauging technologies / construction of partial width rock ramp fishway
28	Gunnedah	Ford	Modify and replace structure with bed level ford
28	Tamworth	Causeway	Remove and replace with multicell box culvert
28	Tamworth	Weir (Namoi River WGS)	Remove and seek alternative gauging technologies / investigate fishway options
28	Tamworth	Weir (Swamp Oak WGS)	Remove and seek alternative gauging technologies / construction of partial width rock ramp fishway

* Rank obtained from the total of the Habitat Criteria, Structure Impact and Modification Criteria used in the assessment process (Appendix E).

<u>Map 1</u>: Location of High Priority fish barriers in the Namoi catchment.



5.2 High priority structures – Issues and management options

Gunidgera Weir (419/970000/B0104)

Gunidgera Weir (Plate 7) is located in the lower end of the catchment on the Namoi River, approximately 3km north of Wee Waa. The weir is approximately 5m in height and 50m across the length of the crest. Gunidgera Weir is a regulating structure that acts as a barrier to fish passage throughout the majority of flow conditions, except during high flow events. When flows are low however, the weir restricts fish passage due to excessive headloss and increased turbulence across the face of the structure. There is currently an ineffective fishway at this site.

Recommended management options at this site include the installation of a Deelder fishlock, replacing the existing submerged orifice fishway. Appropriate management of the vertical lift gates to limit its affect on fish larvae and the natural flow regime is also an essential strategy for this site. Implementing these management options will reinstate over 50km of waterway for fish passage.

Weeta Weir (419/970000/B0106)

Weeta Weir (Plate 8) is located in the lower end of the catchment on the Namoi River, approximately 40km southwest of Wee Waa. The weir is approximately 2m in height and 45m across the length of the crest. Weeta Weir is a regulating structure that currently has an ineffective submerged orifice fishway. The weir acts as a barrier to fish passage during low flows due to excessive headloss and increased turbulence across the face of the structure.

The recommended fish passage remediation action is to install a vertical slot fishway. This has been a previous recommendation made by NSW DPI, formerly suggested during the planning process to upgrade the weir. The management of the vertical lift gate is also an essential action at this site so as to limit the potential effects on fish larvae, as well as the natural flow regime of the Namoi River. There are only four instream barriers downstream of this structure and by successfully implementing these management strategies there is the potential to open up approximately 70km of aquatic habitat.

Mollee Weir (419/970000/B0103)

Mollee Weir (Plate 9) is situated on the Namoi River in the lower end of the catchment and is located approximately 20km west of Narrabri. The weir is approximately 5m in height and 60m across the length of the crest. Mollee Weir is a regulating structure that acts as a barrier to fish passage throughout the year except during high flow conditions. When flows are less than this, the weir restricts fish passage due to excessive headloss and increased turbulence across the face of the structure. There is currently an ineffective submerged orifice fishway associated with this structure.

Recommended management options at this site include the installation of a Deelder fishlock, replacing the existing submerged orifice fishway. Management of the vertical lift gates is also essential at this site to limit the potential effects on fish larvae and the natural flow regime. Through implementing these management strategies approximately 220km of waterway will be reinstated.

Plate 7: Gunidgera Weir (419/970000/B0104)

Plate 8: Weeta Weir (419/970000/B0106)

Plate 9: Mollee Weir (419/970000/B0103)

Plate 10: Stoney Crossing (BE21)

Plate 11: Bugilbone water gauge (WGS4)

Plate 12: Walgett Weir (419/970000/B0068)

Stoney Crossing (BE21)

The Stoney Crossing (Plate 10) Causeway is located in the lower end of the catchment on the Namoi River, near the town of Pilliga. The structure is approximately 0.5m high and 30m in length and is built directly on the bed, slightly above the natural channel level. This construction has resulted in the causeway acting as a barrier to fish passage due to the excessive headloss of approximately 0.5m, as well as the associated increase in velocities over the crossing.

The proposed remediation option at this site is to remove the current crossing and replace it with a bridge structure. Further investigation needs to be undertaken to assess the feasibility of this option. There are only two additional barriers downstream of this structure on the Namoi River and, by implementing the suggested remediation actions, approximately 90km of aquatic and riparian habitat would be reinstated.

Bugilbone Water Gauging Structure (WGS4)

The Bugilbone gauging structure (Plate 11) is situated on the Namoi River in the lower end of the catchment. The structure is constructed of both natural bedrock and concrete, and is approximately 15m in length across the channel. The concrete section of this structure is approximately 0.5m high and 1.5m in length. However, it is located directly in the low-flow channel of the system, creating a barrier to fish passage due to excessive headloss and increased turbulence, especially in the low-flow channel of the waterway.

It is recommended that the concrete section be completely removed to enhance fish passage at this site. When investigating this option it is important to consider alternative gauging technology that may replace the current structure. If alternative stream gauging innovations cannot be pursued, the recalibration of the current gauging system at this site must be taken into consideration. Remediation at this site has the potential to reinstate approximately 85km of waterway.

Walgett Weir (419/970000/B0068)

The Walgett Shire Council Weir (Plate 12) is located in the lower end of the Namoi catchment on the Namoi River, just within the town limits of Walgett. The weir is located 4km upstream of the Namoi River and Barwon River junction, and is approximately 1.8m in height and 30m across the length of the crest. Walgett Shire Council Weir is a fixed crest structure with no regulating infrastructure associated with it and is used for town water supply. The weir acts as a barrier to fish passage during flows less than approximately 1500 ML/day, with flows below this resulting in excessive headloss, as well as increased turbulence and velocity across the face of the structure.

The complete removal of this weir is the preferred remediation option for fish passage at this site. If, after further consultation between Walgett Shire Council, DNR and DPI, it is determined that the weir is still required to augment town water supply then a full width rock ramp fishway is recommended to reinstate fish passage at the barrier. There are no barriers downstream of this structure in the Namoi catchment, and by implementing the recommended actions there is the potential to open up over 70km of aquatic habitat.

Macdonald River Ford (UNRB)

This ford crossing (Plate 13) occurs on the Macdonald River in the upper section of the Namoi catchment, near the town of Kingstown. The crossing is approximately 15m long and uses natural river rock as its base, however the structure also incorporates concrete blocks on the downstream side. This aspect of the crossing has resulted in excessive headloss of approximately 0.3m, impacting on the passage of fish at this site.

It is recommended that the complete removal of the concrete blocks be conducted at this site to reinstate fish passage. There is the potential to open up over 150km of waterway by remediating this site, significantly benefiting aquatic and riparian habitat.

Keepit Dam (419/950000/B0101)

Keepit Dam is situated on the Namoi River in the middle section of the catchment near the town of Gunnedah and approximately seven kilometres upstream of the junction of the Peel and Namoi Rivers. The structure is currently used for irrigation, recreation and flood-mitigation purposes. Keepit Dam is a high, radial-gate dam that is approximately 35m in height. The significant size of the structure has resulted in it creating a major barrier to fish passage in the Namoi catchment.

The significant size of Keepit Dam makes it difficult to recommend a feasible and cost effective fish remediation option, however based on developing research it is suggested that a high-level fishlift be incorporated into the site. By reinstating fish passage at this site, over 130km of waterway would be reconnected.

Jewry Street Causeway (LPRA)

The Jewry Street Causeway (Plate 14) crossing is located on the Peel River within the town limits of Tamworth. The disused crossing is located approximately 50km upstream of the junction of the Namoi and Peel Rivers and is approximately 1.2m in height and 10m across the length of the crest. The causeway acts as a barrier to fish passage during flows less than approximately 1200 ML/day due to excessive headloss and increased turbulence across the face of the structure.

The complete removal of the structure would provide the greatest benefit to the aquatic environment of the Peel River and provide significant improvements in the availability of aquatic and riparian habitat. When investigating this recommendation it is essential to take into account the potential erosion impacts that may jeopardise the structural integrity of the upstream bridge. This may result in the additional construction of a bed control structure at the site with appropriate fish passage infrastructure. Addressing the fish passage issue at this site would complement recommended fish passage works at the upstream concrete capped pipeline, significantly benefiting the aquatic environment by reconnecting over 230km of waterway.

Plate 13: Macdonald River Ford (UNRB)

Plate 14: Jewry Street Causeway (LPRA)

Plate 15: Mayvale Road Culvert (UMA76)

Plate 16: Concrete Capped Pipe (LPRB)

Plate 17: Hansons Causeway (CR38)

Mayvale Road Culvert (UMA76)

The multicell box culvert (Plate 15) on Mayvale Road is located on the Manilla River in the middle section of the catchment, just outside the town limits of Barraba. The crossing is approximately 4m high and 30m long, and contains seven individual cells with a single low flow pipe through the base. The inappropriate design and construction of the culvert has resulted in its effective flow area being above the natural channel flow, resulting in an excessive headloss of approximately 0.5m. As a result of this excessive headloss, as well as the high velocity associated with the low-flow pipe, the crossing acts as a barrier to fish passage.

Remediation options for this site include the removal of the low flow pipe and the creation of a series of low flow channels in the concrete slab of three cells. The modification of this crossing would complement recommended fish passage works to the immediate downstream High Priority barriers of the "Plumthorpe" Culvert (UMA73) and the Barraba Weir (UMA78), significantly benefiting the aquatic habitat of the Manilla River. By reinstating fish passage at this single site, an area of over 30km will be opened up.

Paradise Concrete Capped Pipe (LPRB)

The concrete capped water supply pipeline (Plate 16) is located on the Peel River within the town limits of Tamworth, approximately 50km upstream of the junction of the Namoi and Peel Rivers. The Council owned pipeline is approximately 0.5m high and 10m long, and occurs immediately downstream of the old Paradise Weir site and directly below Paradise Bridge. This pipeline is a barrier to fish passage during both low and high flows because of the excessive headloss and increased turbulence that is associated with the instream sections of the structure.

It is recommended that a partial width rock ramp fishway be incorporated into the existing concrete structure. The suggested modifications to the structure include creating a ramp on the left hand bank with an approximate gradient of 1:20, along with the strategic placement of several rock ridges to create resting pools that are connected by riffles. These modifications would result in the upstream and downstream passage of fish, and would complement recommended fish passage works to the Jewry Street Causeway (LPRA). By reinstating fish passage at this site an approximate habitat area of 7km would be opened up.

Hansons Causeway (CR38)

This redundant causeway crossing (Plate 17) is located on the Cockburn River, only metres upstream of the Cockburn and Peel Rivers junction and within the town limits of Tamworth. The structure is approximately 1m high and 20m long, with its deteriorated condition significantly altering the natural flow of the waterway. The height of this structure has resulted in a major drop on the downstream side, creating excessive headloss and increased turbulence, both of which impact on fish passage at this site.

The preferred remediation option is the partial removal of approximately 10m of the structure down to the natural bed level, also incorporating the removal of willow trees associated with the site. It is believed that this will reinstate the

natural flow within the system and lead to the creation of riffle zones at the junction of the two rivers, with the remaining concrete section concentrating flows and providing bank stabilisation. Through implementing these management strategies it is estimated that approximately 7km of aquatic habitat will be reconnected along the Cockburn River.

Breeza Causeway (MIA)

This causeway (Plate 18) is situated in the lower end of the catchment on the Mooki River near the small town of Breeza in the Gunnedah LGA. The structure is currently used for heavy vehicle access and is located between a road and a railway bridge. The crossing is constructed of rock, and is in excess of 1m high and 10m long. As a result of this, the causeway presents a major barrier to fish passage predominantly through excessive headloss.

The suggested remediation option for this site is to remove and replace the current structure with a multicell box culvert. When considering this option it is important to ensure that the effective flow area of the crossing is at least equal to the natural channel flow, as well as investigate potential effects to the surrounding road and rail infrastructure. Fish passage remediation at this site has the potential to reinstate over 180km of aquatic habitat.

Swamp Oak Creek Ford (CR46)

This private road crossing (Plate 19) is situated in the middle section of the catchment on Swamp Oak Creek, a major tributary of the Cockburn River. The ford is located near the small town of Weabonga, within the Tamworth LGA. The crossing is approximately 15m long and uses natural river rock as its base, however the structure also incorporates the use of a large timber log on the downstream side to pool water upstream. This aspect of the crossing has resulted in excessive headloss of approximately 1m, significantly impacting on fish passage at this site.

It is recommended that the downstream timber log associated with this crossing be removed, with the ford then being replaced by a train carriage bridge design. This option recycles old train carriages, using them as road crossings by removing the sides to allow for effective water flow. Through implementing successful remediation options at this site, aquatic habitat of approximately 20km would be reinstated allowing for the movement of native fish.

Peel River Water Gauging Structure (WGS13)

The Peel River water gauge structure (Plate 20) is located on the Peel River in the middle section of the Namoi Catchment. The structure is situated in the eastern suburb of Calala, approximately 200m upstream of the Tamworth Water Treatment Station. The water gauge is a fixed weir structure that is composed of a vertical flume “San Dimas Weir”, and is approximately 1.2m in height and 10m across the length of the crest. The structure acts as a barrier to fish passage during flows less than approximately 350 ML/day, restricting fish passage due to excessive headloss, as well as increased velocity and turbulence through the vertical flume. There is also a temporary sandbag weir that occurs downstream to secure town water supplies during periods of low flow.

Plate 18: Breeza Causeway (MIA)

Plate 19: Swamp Oak Creek Ford (CR46)

Plate 20: Peel River water gauge (WGS13)

Plate 21: Mulla Creek Ford (CR57)

Plate 22: Barraba Weir (UMA78)

The complete removal of the structure is the recommended remediation option for this site, as well as the appropriate management of the downstream temporary weir to ensure its removal during key migration periods. When investigating this option it is important to consider alternative gauging technology that may replace the current structure. If alternative stream gauging innovations cannot be pursued, the structure will have to remain in place and fishway options further investigated. By implementing the suggested strategies at this site approximately 40km of waterway would be reinstated.

Mulla Creek Ford (CR57)

This private road crossing (Plate 21) is located on Mulla Creek, a major tributary of the Cockburn River, and is situated in the middle of the catchment near the small town of Limbri. The crossing is approximately 15m long and uses natural river rock as its base, however the structure also incorporates the use of large rocks along the left hand side of the crossing and on the downstream end to pool water upstream. This aspect of the crossing has resulted in excessive headloss of approximately 0.5m, significantly impacting on fish passage at this site.

It is recommended that the downstream rocks associated with this crossing be removed, with the ford then being replaced by a train carriage bridge design. This option recycles old train carriages, using them as road crossings by removing the sides to allow for effective water flow. The modification of this ford crossing has the potential to reinstate approximately 15km of aquatic and riparian habitat, benefiting the associated aquatic biodiversity of the region.

Barraba Weir (UMA78)

The Barraba Weir (Plate 22) is located on the Manilla River just within the town limits of Barraba, approximately 100m upstream of the Manilla River Bridge. The weir is approximately 1.5m in height and 25m across the length of the crest. This barrier is a fixed crest structure with no regulating infrastructure associated with it, however it does currently possess an ineffective vertical slot fishway. As a result of this, the weir acts as a barrier during flows less than approximately 500 ML/day, restricting fish passage due to excessive headloss at the entrance and exit of the fishway, as well as increased turbulence and velocity within the cells of the vertical slot fishway and across the face of the weir.

The suggested fish passage remediation action for this site is to remove the weir, however if this option is not feasible then modifications to the existing weir and fishway should be made to enhance its functionality. Modifications to the structure should include the removal of the weir wall at the fishway down to the base level, the addition of extra vertical slot baffles, a reduction in the slot width of the existing baffles, the addition of a very small detention basin where the tailwater exits, and the construction of a small rock ramp leading up to this detention basin. These improvements will assist in pooling water within the fishway, reducing the existing headloss, as well as the excessive velocities and turbulence.

The modification of this barrier would complement recommended fish passage works to the immediate upstream High Priority structures of the “Plumthorpe” Culvert (UMA73) and the Mayvale Road Culvert (UMA76). By reinstating fish

passage at this single site, an area of approximately 30km will be opened up to the aquatic ecology of the Manilla River.

Chaffey Dam (419/971800/B0100)

Chaffey Dam is situated on the Peel River in the middle section of the catchment near the town of Woolomin in the Tamworth LGA. The fixed crest structure is currently used for irrigation and town water supplies, as well as recreation purposes. Chaffey Dam is approximately 35m in height, with this significant size resulting in the dam creating a major barrier to fish passage in the catchment.

The significant size of Chaffey Dam makes it difficult to recommend a feasible and cost effective fish remediation option, however based on developing research it is suggested that a high-level fishlift be incorporated into the site. By reinstating fish passage at this site, over 60km of waterway would be reconnected.

Pian Creek Causeway (LPC13)

This private road crossing (Plate 23) is located on the highly impacted Pian Creek, a tributary of the Namoi River, and is situated in the lower end of the catchment near the town of Burren Junction. The crossing is approximately 0.5m in height and 12m long and is constructed of concrete built directly on the bed, above the natural channel level. This construction has resulted in the causeway acting as a barrier to fish passage due to the associated excessive headloss.

The suggested remediation option for this site is to remove and replace the current structure with a multicell box culvert. This structure should incorporate a low-flow channel to ensure fish passage during the majority of flow levels. Through completing remediation works at this crossing there is the potential to reinstate over 35km of waterway.

Mulla Creek Causeway (CR24)

This private road crossing (Plate 24) is located on Mulla Creek, a major tributary of the Cockburn River, and is situated in the middle of the catchment near the small town of Limbri. The crossing is approximately 1m in height and 18m long and is constructed of concrete, with the downstream side of the causeway experiencing erosion effects from high flows resulting in a plunge pool and bank erosion. The presence of the instream crossing significantly impacts on fish passage due to excessive headloss, as well as an associated increase in turbulence.

It is recommended that the causeway be replaced by a train carriage bridge design. This option recycles old train carriages, using them as road crossings by removing the sides to allow for effective water flow. Complementing this remediation action, it is also suggested that bank stabilisation efforts and riparian management also be considered at this site. The modification of the causeway has the potential to reinstate approximately 12km of aquatic and riparian habitat.

Plate 23: Pian Creek Causeway (LPC13)

Plate 24: Mulla Creek Causeway (CR24)

Plate 25: Swamp Oak Creek Culvert (CR37)

Plate 26: "Wittagoona" Causeway (UNR25)

Swamp Oak Creek Culvert (CR37)

This multicell pipe culvert (Plate 25) on a private road is located on Swamp Oak Creek, a major tributary of the Cockburn River, in the middle of the catchment near the small town of Limbri. The crossing is approximately 1.5m high and 30m long, and contains four individual pipes through the concrete construction. The inappropriate design and construction of the culvert has resulted in its effective flow area being in excess of 0.5m above the natural channel flow, resulting in excessive headloss. As a result of this, as well as the high velocity and turbulence associated with the pipes, the crossing acts as a barrier to fish passage.

The partial removal of this structure and subsequent retrofitting with a bridge section is the suggested remediation action for this site. Investigations into potential erosion and bed lowering on the downstream side may need to be conducted prior to remediation actions. Removal should focus on the piped section of the crossing, with the retrofitting taking place in the low-flow channel of the waterway. This action would ensure fish passage during the majority of flow levels. Through completing remediation works at this crossing there is the potential to reinstate over 20km of waterway.

"Wittagoona" Causeway (UNR25)

This privately owned causeway (Plate 26) occurs on the "Wittagoona" property near the town of Manilla, and is situated on the Namoi River in the middle section of the Namoi catchment. The causeway is constructed of rock and concrete with a low-flow pipe running through, and is approximately 0.5m high and 14m long. Recent compliance works have resulted in the partial fitting of a bridge section on the right hand side, however fish passage is still blocked in the low-flow channel of the waterway. This barrier is caused by the excessive headloss of the structure, as well as increased velocity through the low-flow pipe.

It is recommended that the causeway undergo partial removal in the low-flow channel area and replacement with a low-level bridge section to reinstate fish passage at this site. The works conducted would be similar to that on the right hand side of the structure, ensuring suitable access and effective fish passage. Reinstating fish passage at this crossing has the potential to reconnect in excess of 56km of aquatic habitat on the main stem Namoi River.

Split Rock Dam (419/950799/B0102)

Split Rock Dam is situated on the Manilla River in the middle section of the catchment between the towns of Manilla and Barraba in the Tamworth LGA. The fixed crest structure is currently used for irrigation and recreation purposes. The Dam has an approximate vertical height of 60m, with this significant size resulting in Split Rock Dam creating a major barrier to fish passage in the catchment.

The significant size of Split Rock Dam makes it difficult to recommend a feasible and cost effective fish remediation option, however based on developing research it is suggested that a high-level fishlift be incorporated into the site. By reinstating fish passage at this site 25km of waterway would be reconnected.

Mooki River Ford (PCA)

This ford crossing (Plate 27) is located on the Mooki River in the middle section of the Namoi catchment near the locality of Pine Ridge. The crossing is approximately 0.3m high and 15m long and uses natural river rock as its base, however the structure also incorporates the use of large rocks on the downstream end to pool water upstream. This aspect of the crossing has resulted in excessive headloss of approximately 0.3m, significantly impacting on fish passage at this site.

It is recommended that the downstream rocks associated with this crossing be removed, with the ford then being reinstated at the natural bed level of the channel to ensure effective flow over the crossing. The modification of this ford crossing has the potential to open up a habitat area of over 44km.

Caroona Crossing (MI20)

This weir-like structure (Plate 28) on the Mooki River is the remains of a redundant causeway crossing and is located in the middle section of the catchment near the town of Caroona. The structure is situated immediately downstream of a bridge crossing and is approximately 1m in height and 8m long. The crossing is a fixed crest structure constructed of rock with low-flow pipes associated with it. This instream structure acts as a barrier to fish passage during low flows due to excessive headloss, as well as increased turbulence and velocity across the face of the structure.

The suggested remediation option for this structure is to remove the current crossing and replace it with a bed control structure that incorporates fish passage technology. This would include a partial rock ramp fishway that runs centrally through the bed control structure, using strategically placed rocks to simulate pool and riffle conditions. By implementing these remediation works effective fish passage would be achieved, reinstating approximately 29km of aquatic habitat.

“Plumthorpe” Culvert (UMA73)

The multicell pipe culvert (Plate 29) on the “Plumthorpe” property is located on the Manilla River in the middle of the catchment, just outside the town limits of Barraba. The crossing is approximately 0.5m high and 35m long, and contains four individual cells through the base. The inappropriate design and construction of the culvert has resulted in a combination of minimal flow depth and high velocity associated with the pipes, resulting in the crossing acting as a barrier to fish passage.

Remediation options for this site include the removal of the pipe culvert and replacement with a suitable box culvert design. When considering this option it is important to ensure that the effective flow area of the crossing is at least equal to the natural channel flow of the waterway. The modification of this crossing would complement recommended fish passage works to the immediate upstream High Priority barrier of the Mayvale Road Culvert (UMA76) and the immediate downstream High Priority barrier of the Barraba Weir (UMA78), significantly benefiting the aquatic habitat of the Manilla River. By reinstating fish passage at this single site, an area of approximately 30km will be opened up.

Plate 27: Mooki River Ford (PCA)

Plate 28: Caroona Crossing (MI20)

Plate 29: “Plumthorpe” Culvert (UMA73)

Plate 30: Manilla River gauge (WGS6)

Plate 31: Mooki River Ford (MI10)

Plate 32: Ingalba Flat Causeway (CR56)

Manilla River Water Gauging Structure (WGS6)

The Manilla River gauging structure (Plate 30) is located immediately downstream of Split Rock Dam between the towns of Manilla and Barraba in the Tamworth Regional LGA. The fixed crest structure is constructed of concrete and is approximately 0.5m high and 30m long. The structure acts as a barrier to fish passage due to excessive headloss, as well as increased turbulence and velocity across the face of the structure.

The complete removal of the gauge is the recommended remediation option for this site. When investigating this option it is important to consider alternative gauging technology that may replace the current water gauging structure. If alternative stream gauging innovations cannot be pursued, the structure will have to remain in place and fishway options further investigated. By implementing the suggested strategies at this site approximately 75km of waterway would be reinstated.

Mooki River Ford (MI10)

This private road crossing (Plate 31) is located on the Mooki River and is situated in the lower section of the catchment near the town of Breeza. The crossing is approximately 0.2m high and 5m long and uses natural river rock as its base, however the structure also incorporates the use of large rocks on both the upstream and downstream side of the crossing to pool water upstream. This aspect of the crossing has resulted in excessive headloss of approximately 0.2m, impacting on fish passage at this site.

It is recommended that the upstream and downstream rocks associated with this crossing be removed, with the ford then being reinstated at the natural bed level of the channel to ensure effective flow over the crossing. The modification of this ford crossing has the potential to open up a habitat area of approximately 20km.

Ingalba Flat Road Causeway (CR56)

The concrete causeway (Plate 32) is located on Swamp Oak Creek, a major tributary of the Cockburn River, in the upper section of the catchment near the town of Weabonga. The crossing is approximately 1m in height and 12m long, with no associated low-flow infrastructure and the downstream side of the causeway experiencing erosion effects from high flows. The presence of the instream crossing significantly impacts on fish passage due to excessive headloss, as well as an associated increase in turbulence across the face of the structure.

The suggested remediation option for this site is to remove and replace the current structure with a multicell box culvert. When considering this option it is important to ensure that the effective flow area of the crossing is at least equal to the natural channel flow. Fish passage remediation at this site has the potential to reinstate over 19km of aquatic and riparian habitat.

Swamp Oak Creek Water Gauging Structure (WGS7)

This water gauge (Plate 33) is located on Swamp Oak Creek, a major tributary of the Cockburn River, in the middle section of the Namoi Catchment near the town of Limbri. The instream barrier is a fixed v-notch weir structure that is constructed of concrete and is approximately 0.5m in height and 22m across the length of the crest. The structure acts as a barrier to fish passage during low flows, restricting fish passage due to excessive headloss, as well as increased velocity and turbulence through the vertical flume.

The complete removal of the structure is the recommended remediation option for this site. When investigating this option it is important to consider alternative gauging technology that may replace the current gauge. If alternative stream gauging innovations cannot be pursued, the structure will have to remain in place and fishway options further investigated. By implementing the suggested strategies at this site approximately 14km of waterway would be reinstated.

Namoi River Water Gauging Structure (WGS1)

The Namoi River water gauging station (Plate 34) is located on the Namoi River on the "North Cuerindi" property near the town of Manilla. The gauge is a fixed weir structure that is constructed of concrete, and is approximately 0.3m in height and 10m across the length of the crest. The structure acts as a barrier to fish passage during low flows, restricting fish passage due to excessive headloss, as well as increased velocity and turbulence across the face of the gauge.

The complete removal of the structure is the recommended remediation option for this site. When investigating this option it is important to consider alternative gauging technology that may replace the current gauge. If alternative stream gauging innovations cannot be pursued, the structure will have to remain in place and fishway options further investigated, with a partial width rock ramp being a feasible option for this site. By implementing the suggested strategies at this site over 70km of waterway would be reinstated on the main stem of the Namoi River.

Plate 33: Swamp Oak Creek water gauge (WGS7)

Plate 34: Namoi River water gauge (WGS1)

5.3 Demonstration site case studies

Demonstration sites have been established as part of this project to illustrate best practice techniques associated with the design, construction, and remediation of instream barriers to fish passage in the Namoi catchment. Four case study sites have been selected from the list of High Priority structures. Their selection has been based on consultation with regional staff from NSW DPI, Namoi CMA, local councils and landholders, taking into consideration environmental conditions, time constraints and funding assistance. The four sites selected include "Wittagoona" Causeway, Hansons Causeway, Mayvale Road Culvert, and the Barraba Weir, with information about their progress to date discussed below. Further details about the remediation of these sites will be presented upon their completion.

Case Study 1: "Wittagoona" Causeway (UNR25)

The causeway is a privately owned crossing that provides access to agricultural land on the "Wittagoona" property. NSW DPI Conservation Management staff approached the landholder regarding compliance concerns associated with recent works that had been conducted on the crossing, which had not incorporated fish passage requirements. Remediation by the landholder reinstated fish passage adjacent to the western bank of the river, however complete remediation for fish passage will involve the removal of a section of concrete on the eastern side of the river down to the natural bed-level to reinstate the low-flow channel. The landholder agreed to the proposed actions, and provided in-kind contributions of equipment, including a 20 tonne excavator, and labour.

Arrangements were made to implement the remediation action, with NSW DPI Conservation Management staff on-site to oversee works in early February 2006, when the flow of the Namoi River reached favourable levels of less than 20ML/d. The works involved the removal of a 12m section of the concrete causeway down to natural bedrock level (Figure 1). The removed area will be replaced with a bridge section to allow fish passage in the low-flow channel, reinstating 56km of aquatic habitat.

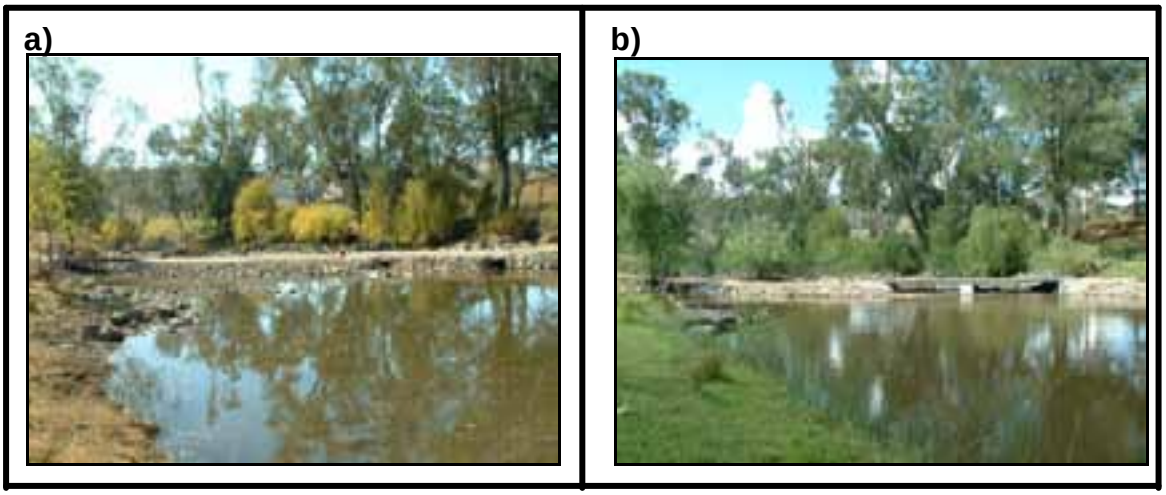


Figure 1: "Wittagoona" Causeway a) before remediation works, and b) after remediation works.

Case Study 2: Hansons Causeway (CR38)

This redundant causeway located on the Cockburn and Peel River junction has recently been used to increase water levels of a pumping pool utilised by a local construction company. NSW DPI Conservation Management staff approached the company regarding an associated compliance issue, with work to the causeway included in the proposed remediation of the site. Discussions were held between representatives from NSW DPI, Namoi CMA and Hanson Construction Materials, with suitable designs to reinstate fish passage developed by NSW DPI. Hanson Construction Material agreed to the proposed actions, as well as providing in-kind contributions of excavation equipment, and labour.

Remediation works were conducted in late January 2006, with NSW DPI Conservation Management staff on-site to oversee works. The works involved the removal of willow trees, the realignment of large woody debris, and the removal of a 10m section of the concrete causeway down to natural bedrock level (Figure 2). Monitoring of the site will continue, with it anticipated that subsequent high flows in the Cockburn River would produce natural scouring in the remediated area to form a riffle section at the junction with the Peel River, reinstating 7km of suitable fish passage.

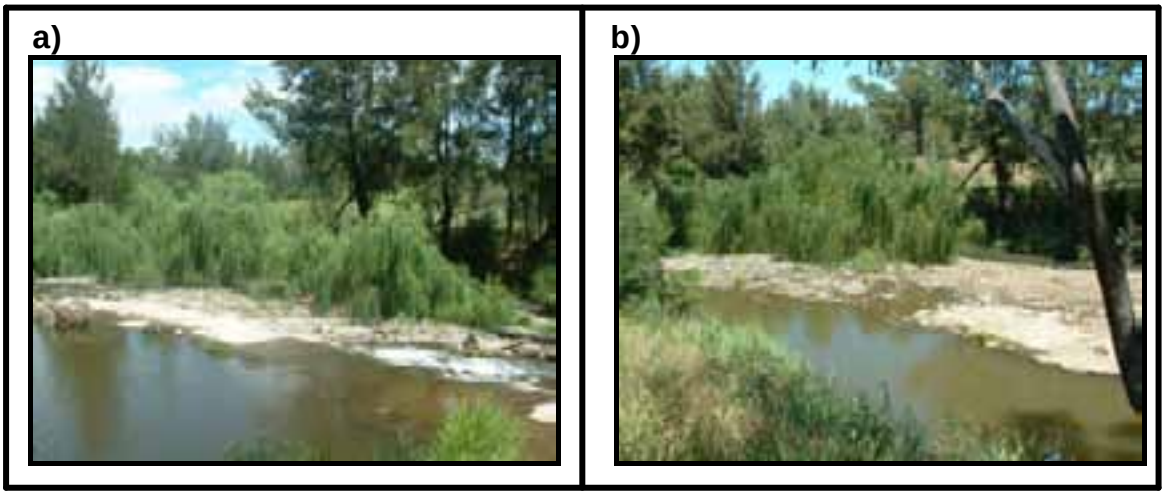


Figure 2: Hansons Causeway a) before remediation works, and b) after remediation works.

Case Study 3: Mayvale Road Culvert (UMA76)

The crossing is owned by the Tamworth Regional Council and provides primary access to residents of the Barraba area. NSW DPI approached the council concerning fish passage remediation works at the site in conjunction with the proposed upgrade of the Barraba Weir. Site inspections involving staff from NSW DPI and Tamworth Regional Council have taken place, discussing the remediation option for the culvert and associated actions that may need to be incorporated at the site including an engineering survey for structural integrity. Implementation of the remediation work is set to commence in mid 2006, with funding being provided by the Namoi CMA as part of this project.

Case Study 4: Barraba Weir (UMA78)

Barraba Weir is an unlicensed structure owned by Tamworth Regional Council and was constructed as part of a beautification scheme, being primarily used for aesthetics and not town water supply. The weir currently has a non-functioning vertical slot fishway associated with its infrastructure. Discussions and site inspections have been conducted by representatives from NSW DPI, DNR and the local council concerning the licensing arrangements, necessity of the structure and fish passage requirements at this site.

Recent discussions have involved negotiations between NSW DPI and Tamworth Regional Council over the proposed remediation works for the site, focussing on either the removal of the structure or suitable modifications to its infrastructure. Future work concerning Barraba Weir will involve the production of engineering designs, permit application, and funding negotiation. Funding for the project will include a $10,000 grant from the Fish Habitat Grant Program provided by the Recreational Fishing Freshwater Trust Expenditure Committee (RFFTEC), as well as Namoi CMA funding as part of this project. Implementation of on-ground works is set to commence during 2006.

6. SUMMARY

The project entitled "*The Assessment and Modification of Barriers to Fish Passage in the Namoi Catchment*" was designed and completed to achieve the following outcomes:

- Identify and assess instream structures in the NCMA area that are barriers to fish passage,
- Prioritise instream barriers that restrict fish passage across the region,
- Recommend remediation options to improve fish passage at all priority sites, and
- Demonstrate methods of remediating instream barriers in the region, by promoting and applying "fish-friendly" principles in regards to instream works.

The data collected from the overall audit is available in a separate Microsoft Excel file on the accompanying CD entitled *"Namoi Data"*, providing information on all instream structures in the catchment, as well as those identified as barriers. The recommendations made in relation to remediation options for each High Priority site have been provided as a basic indication of the scale and extent of remediation required (e.g. complete structure removal, retrofitting, minor modification, maintenance etc).

Details in relation to undertaking waterway crossing remediation, as well as design and construction guidelines for new waterway crossings, can be obtained from several source documents including:

- *Why do fish need to cross the road? Fish passage requirements for waterway crossings*. (Fairfull & Witheridge, 2003),
- *Fish passage requirements for waterway crossings – Engineering Guidelines*. (Witheridge, 2002),
- *Fish Passage in Streams – Fisheries guidelines for design of stream crossings*. (Cotterell, 1998).

Permit and works approval requirements in relation to waterway crossing construction, modification and maintenance in NSW can be found in:

- *Policy and Guidelines for Fish Friendly Waterway Crossings* (NSW Fisheries, 2003), and
- *Policy and Guidelines for Aquatic Habitat Management and Fish Conservation* (NSW Fisheries, 1999).

7. ACKNOWLEDGEMENTS

This project was funded through the Natural Heritage Trust Program and undertaken by the NSW Department of Primary Industries on behalf of the Namoi Catchment Management Authority.

The NSW DPI Aquatic Habitat Rehabilitation Program managed the project including research, fieldwork and report preparation, with valuable assistance from regional NSW DPI Conservation staff.

The Namoi Catchment Management Authority, Department of Natural Resources, State Water, local Councils and local landholders provided extensive advice and assistance towards the project.

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9. APPENDICES

Appendix A – Freshwater native finfish of the Namoi catchment, NSW

Scientific Name	Common Names	Status	Migration and habitat
Ambassis agassizii	Olive perchlet	Threatened species (Endangered western population)	Local migration; Freshwater streams and swamps in lowland and slope environments
Bidyanus bidyanus	Silver perch	Threatened species (vulnerable - *Fisheries Management Act* 1994)	Large scale migration; Habitat is predominantly in lowland and slope waterways
Craterocephalus stercusmuscarum	Flyspecked hardyhead	Unknown	Local migration; Freshwater streams in lowland habitat
Gadopsis marmoratus	River blackfish	Common	Local migration; Widespread in slope and montane waterways
Galaxias olidus	Mountain galaxias	Common	Local migration; Moderate and high elevations in coastal and inland rivers
Hypseleotris compressa	Empire gudgeon	Common	Unknown migration; Common in lowland and slope habitats
Hypseleotris klunzingeri	Western carp gudgeon	Common	Unknown migration; Common in lowland and slope waterways
Leiopotherapon unicolor	Spangled perch	Common	Local migration; Warm waters in inland streams, backwaters and dams
Maccullochella peelii peelii	Murray cod	Threatened species (vulnerable - EPBC)	Local migration; Habitat predominantly in lowland and slope waterways
Macquaria ambigua	Golden perch	Relatively common	Large scale migration; Common in lowland and slope waterways
Melanotaenia fluviatilis	Crimson-spotted rainbowfish	Relatively common	Local migration; Waters in lowland and slope environments
Mogurnda adspersa	Purple-spotted gudgeon	Threatened species (Endangered western population)	Local migration; Waters in lowland and slope environments
Nematalosa erebi	Bony herring	Relatively common	Local migration; Waterways of lowland and slope environments
Philypnodon grandiceps	Flathead gudgeon	Unknown	Uncertain; Lowland and slope waterway environments
Retropinna semoni	Australian smelt	Common	Local migration; Common in lowland and slope waterways
Tandanus tandanus	Freshwater catfish	Relatively common	Local migration; Lowland lakes and slow-flowing rivers

Sources: Thorncraft & Harris (2000), McDowall (1996), Allen *et al.* (2002) and Harris (2004).

Appendix B – Freshwater introduced finfish of the Namoi catchment, NSW

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

Sources: Thorncraft & Harris (2000), McDowall (1996), Allen *et al.* (2002) and Harris (2004).

Appendix C – Namoi catchment Detailed Weir Review summary

Priority	Barrier Name	Watercourse	Ownership	Operational Fishway	Preferred Option	Estimated Cost of Preferred Option ($)	Alternative Option	Estimated Cost of Alternative Option ($)
1	Mollee Weir	Namoi River	State Water	No	Construct Deelder Fishlock	250 – 500k	Construct Vertical Slot Fishway	>1M
2	Gunidgera Weir	Namoi River	State Water	No	Construct Deelder Fishlock	250 – 500k	Construct Vertical Slot Fishway	>1M
3	Weeta Weir	Namoi River	State Water	No	Construct Vertical Slot Fishway	250 – 500k	Construct Deelder Fishlock	<200k
4	Walgett Shire Council Weir	Namoi River	Walgett Shire Council	No	Removal	<50k	Construct Full Width Rock Ramp Fishway	150 – 250k
5	Jewry Street Weir	Peel River	Tamworth Regional Council	No	Removal	<50k	Construct Full Width Rock Ramp Fishway	250 – 500k
6	Calala Gauging Weir	Peel River	State Water/DIPNR	No	Removal	<50k	Fishway Options Study	250 – 500k
7	Barraba Weir	Manilla River	Tamworth Regional Council	No	Removal	<50k	Retrofit Existing Vertical Slot Fishway	<50k

Appendix D – Urban waterway fish passage barrier assessment form

URBAN WATERWAYS FISH PASSAGE - DESKTOP ASSESSMENT FORM

ASSESSOR: _____ **DATE:** _____ **CROSSING ID:** _____
CATCHMENT: _____ **WATERWAY:** _____
STREAM ORDER: _____ **ELEVATION:** _____ **LGA:** _____

1. LOCATION INFORMATION
1a Location
Nearest Town: _____ Road Name (or Nearest Road): _____

1b Section of Catchment *(please circle)***:** Upper Middle Lower

1c Approximate upstream catchment area (sqkm) _____

2. FISH BARRIER IMPACTS
2a. Fish Barrier Type *(circle)*
Bridge - single or multiple span or arched structure raised above channel bed.
Culvert - cell to convey water underneath roadway: **Pipe / Box**
Weir - instream structure designed to back water upstream: **Fixed Crest / Adjustable Release**
Causeway - low-level crossing designed to convey water over roadway surface
Ford - low level crossing formed directly on channel bed in a shallow section of a watercourse.
Floodgate - gated levee to regulate flow between floodplain and stream channel.
Other

2b If barrier blocks fish passage, approximately how much habitat upstream would become available if crossing was modified to allow for fish passage _____km

2c Approximate distance to the next potential obstruction to fish passage:
Upstream _____km Downstream _____km

Is it Natural / Man-made? **Is it Natural / Man-made?**

3. OWNERSHIP DETAILS
3a Ownership of this obstruction & land on which the structure lies *(circle)*:
Federal State Local Government Private Landholder

3b Owner of the next potential obstruction *(circle)*:
Upstream: Federal State Local Government Private Landholder
Downstream: Federal State Local Government Private Landholder

4. ENVIRONMENTAL CONSIDERATIONS
4a Threatened and protected aquatic species present *(circle)*:
Olive perchlet Eastern freshwater cod Purple spotted gudgeon Oxleyan pygmy perch
Macquarie perch Australian grayling Black cod Estuary cod

4b. Other key aquatic species present: _____

Also attach predicted species list for catchment from "Fishfiles" or "Freshwater Fish Database".

4c. Environmental status: _____

Consider terrestrial threatened species, critical habitat, conservation rating and protected area status.

Appendix D – Urban waterway fish passage barrier assessment form

URBAN WATERWAYS FISH PASSAGE - FIELD ASSESSMENT FORM

ASSESSOR: _____ **DATE:** _____ **CROSSING ID:** _____
GPS or GRID ref: _____ **PHOTO NUMBERS:** _____

1. LOCATION INFORMATION
1a Surrounding Land Uses *(please circle)***:**
Industrial Urban Park Forested Grazing Cropping
Description of land use _____

1b Structure Accessibility (Easement / Public Road / Other_____)

2. STRUCTURE DETAILS
2a Structure Description
Culvert type No. of cells Size of cells Width ____ m Breadth ____m Height ____m
Construction material *(circle)*: Concrete / Timber / Steel / Rock / Gravel / Sand-Fines

2b If a Road – Is it Sealed? *(circle)*: Sealed Unsealed N/A **Is it in Use?** Yes / No

3. FISH BARRIER IMPACTS
3a Is there a fishway? Yes / No **Type:** _____ **Working?** Yes / No

3b Fish Passage: Does the site potentially or actually block fish passage? Yes / No

3c If yes, what type of blockage *(circle)*:
Drop (>10cm) Increased Velocity Minimal Flow Depth (< 200mm) Lack of Light
Slope (>1:20) Increased Turbulence Debris (large woody / sediment)

3d If yes, is it *(circle)*: a complete barrier / major obstacle / moderate obstacle / minor obstacle

3e Does water exist upstream of the site: Yes / No **If yes, is it due to the structure?** Yes / No
If yes, what is the **average length** of pool _____m and **depth** of the pool _____m

3f Is there flow over/through the site: Yes / No

3g If yes, what is the water flow like? *(circle)*
Vertical Fall (**Height**____m) Steep Cascade High Velocity through Pipe Low flow
Gentle Incline Moderate Cascade Moderate Velocity through Pipe No flow

3h If location of the next obstruction is not the one identified in the desktop study please record the new location (GPS or road name): Upstream: _____
Downstream: _____ **Ownership:** _____

4. HABITAT DETAILS
4a Bank Height at crossing _____m **4b Channel Width at crossing** _____m

4c Habitat features: (substrate type: pools, riffles, gravel beds, macrophytes, snags, overhangs)

4d Condition of aquatic habitat *(circle)*: excellent good fair poor very poor

5. COMMENTS (EXTRA SITE / STRUCTURE INFO)

6. RECOMMENDATIONS

Appendix E – Fish passage prioritisation scheme (Namoi catchment)

WATERWAY OBSTRUCTIONS PRIORITY RANKING SCHEME FOR THE NAMOI CMA

CROSSING ID: _____ SUBCATCHMENT: _____ WATERWAY: _____ TOWN: _____ ASSESSOR: _____

A) STREAM HABITAT VALUE CRITERIA					
Primary Aquatic Habitat Rating		**5**	**3**	**1**	**SCORE**
Habitat Class		1	2	3	
Location in the System		Lower (< 300m)	Middle (300 – 700m)	Upper (> 700m)	
Secondary Aquatic Habitat Rating		**3**	**2**	**1**	
Downstream Obstructions		Few (< 5)	Moderate (5 –20)	Many (> 20)	
Distance to next Barrier Downstream		Greater than 40km	5 – 40km	Less than 5km	
Upstream Habitat		Abundant (> 40km)	Moderate (5 – 40km)	Limited (< 5km)	
Instream Habitat Condition		Good	Fair	Poor	
Environmental Status		Protected Area	Suitable Landuse	Other	
				SUBTOTAL	
B) STRUCTURE IMPACT CRITERIA					
Environmental Effect Rating		**3**	**2**	**1**	**SCORE**
Physical Barrier	Vertical Drop OR Slope	> 500mm OR > 1:10	150 – 300mm OR 1:10 – 1:20	< 150mm OR < 1:20	
	Debris		Present	Absent	
Hydrological Barrier	Velocity	High	Medium	Low	
	Flow Depth	< 100mm	100 – 200mm	> 200mm	
Light Penetration & Substrate Condition		High Behavioural Impact	Medium Behavioural Impact	Low Behavioural Impact	
Water Quality Impacts & Controls		Significant Impact (unsealed)	Moderate Impact (Unsealed but Controlled)	Minimal Impact (Sealed)	
				SUBTOTAL	
C) MODIFICATION CRITERIA					
Structure Use and Remediation Cost Rating		**3**	**2**	**1**	**SCORE**
Structure Use		Redundant	Serves some purpose	Essential	
Ancillary Uses		None known	Possible	Confirmed uses	
Remediation Works Required		Minor changes (Maintenance)	Moderate changes (Retrofitting or Removal)	Major changes (Complete replacement)	
				SUBTOTAL	
				TOTAL	

ID'D BY: SECONDARY NAME:

Appendix F –Instream structures recommended for remediation

Summary of fish passage barrier types assessed in the Namoi catchment and their associated priority level.

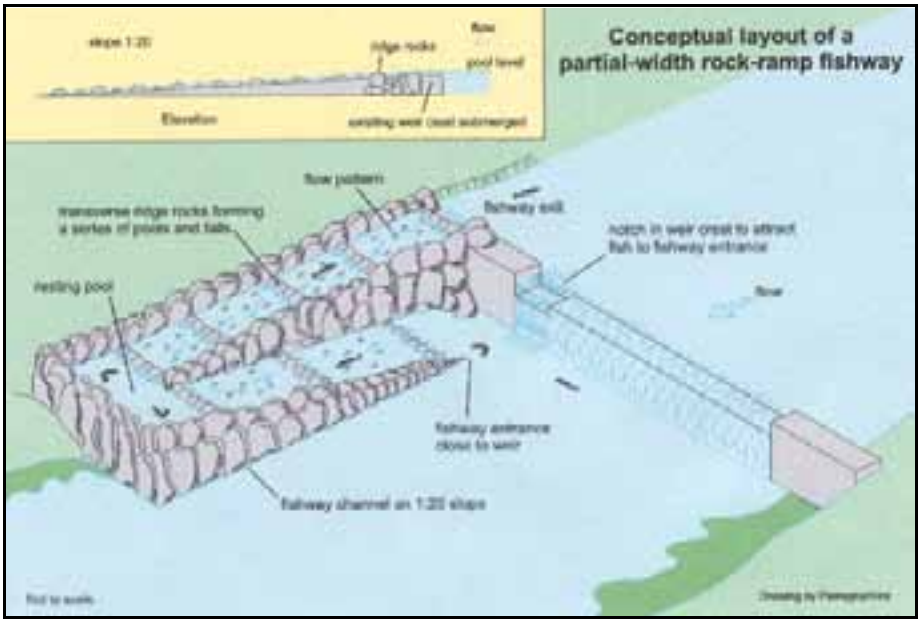
Fish Passage Barrier	Coonamble	Gunnedah	Liverpool Plain	Narrabri	Tamworth Regional	Walcha	Walgett	Warrumbungle Shire	Total
High Priority									
Weir	0	1	0	3	3	0	1	0	**8**
Causeway	0	1	0	0	6	0	2	0	**9**
Culvert	0	0	0	0	3	0	0	0	**3**
Ford	0	1	0	0	4	0	0	0	**5**
Bridges	0	0	0	0	0	0	0	0	**0**
Bed control	0	0	0	0	0	0	0	0	**0**
Water gauge	0	0	0	0	4	0	1	0	**5**
Floodgate	0	0	0	0	0	0	0	0	**0**
Other	0	0	0	0	1	0	0	0	**1**
Subtotal	0	3	0	3	21	0	4	0	31
Medium Priority									
Weir	0	0	4	12	3	0	8	1	**28**
Causeway	0	2	7	0	15	0	0	0	**24**
Culvert	0	0	2	4	13	0	0	0	**19**
Ford	0	1	0	0	9	0	0	0	**10**
Bridges	0	0	0	0	0	0	0	0	**0**
Bed control	0	0	0	0	8	0	0	0	**8**
Water gauge	0	0	0	0	2	0	0	0	**2**
Floodgate	0	0	0	0	0	0	0	0	**0**
Other	0	0	0	0	0	0	0	0	**0**
Subtotal	0	3	13	16	50	0	8	1	91
Low Priority									
Weir	0	3	1	13	14	0	2	0	**33**
Causeway	0	0	0	0	1	0	0	0	**1**
Culvert	0	0	0	0	3	0	0	0	**3**
Ford	0	0	0	0	1	0	0	0	**1**
Bridges	0	0	0	0	0	0	0	0	**0**
Bed control	0	0	1	0	0	0	0	0	**1**
Water gauge	0	0	0	0	0	0	0	0	**0**
Floodgate	0	0	0	1	0	0	0	0	**1**
Other	0	0	0	0	0	0	0	0	**0**
Subtotal	0	3	2	14	19	0	2	0	40
Total	**0**	**9**	**15**	**33**	**90**	**0**	**14**	**1**	**162**

Appendix G – Details of fishways employed in Australia

Rock ramp fishways

Rock ramp fishways were developed as a simple and relatively low-cost alternative to more formally engineered fishway designs. This design is particularly effective in overcoming low barriers and may be subsequently constructed in association with stream erosion control works. This type of fishway is particularly valuable for providing fish passage at existing low weirs.

Rock ramp fishways are generally built on slopes that attempt to match the surrounding geomorphic features within the waterway (although these are typically between 1:20 and 1:30 slope). In this design, large rocks are placed to form a series of small pools and falls at about 2m intervals. Fish ascend rock ramp fishways by darting through sections of high water velocity that occur between large rocks, and resting in the pools created by the rock ridges. Fish alternate between these movements, continuing through until they exit.



Reference:

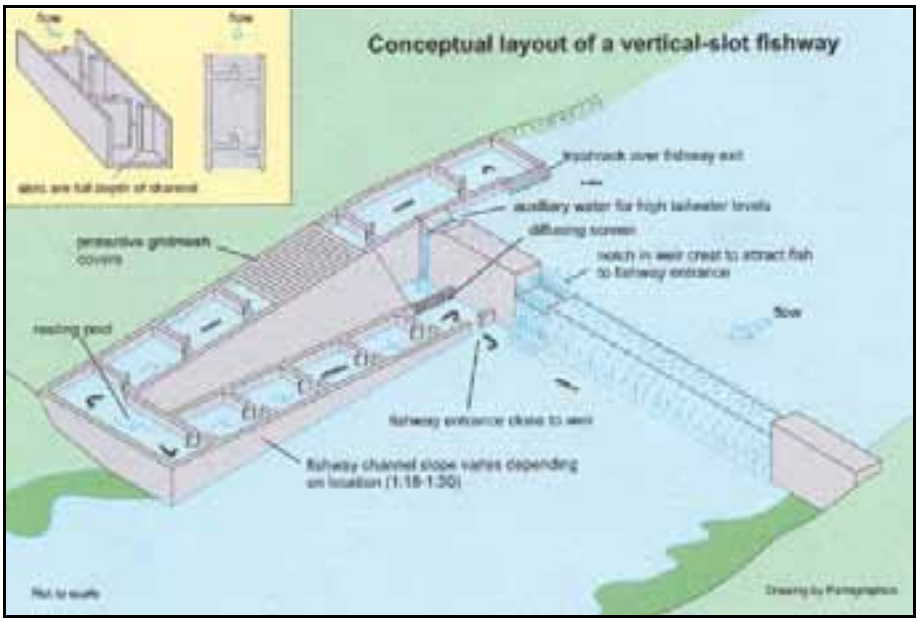
Thorncraft, G. and Harris, J.H. (2000) *Fish passage and fishways in NSW: A Status Report.* Cooperative Research Centre for Freshwater Ecology Technical Report 1/2000.

Appendix G – Details of fishways employed in Australia

Vertical slot fishways

Vertical slot fishways comprise a more engineered and controlled version of a rock ramp fishway. In this design resting pools are essentially concrete cells, with the entrance/exit to/from each of the pools being a vertical slot at either end. The maximum water velocity occurs as water falls through each slot, with the downstream pool acting to dissipate hydraulic energy as well as providing resting areas for ascending fish. The slope of the channel and the interval between slots controls the water velocity allowing the fishway to be designed to suit the swimming ability of particular ascending fish.

Vertical slot fishways have flexibility of operation over varying headwater and tailwater levels, as well as allowing fish to pass through the fishway at any depth. This type of fishway is more expensive than a rock ramp fishway, and requires larger volumes of water to operate.



Reference:

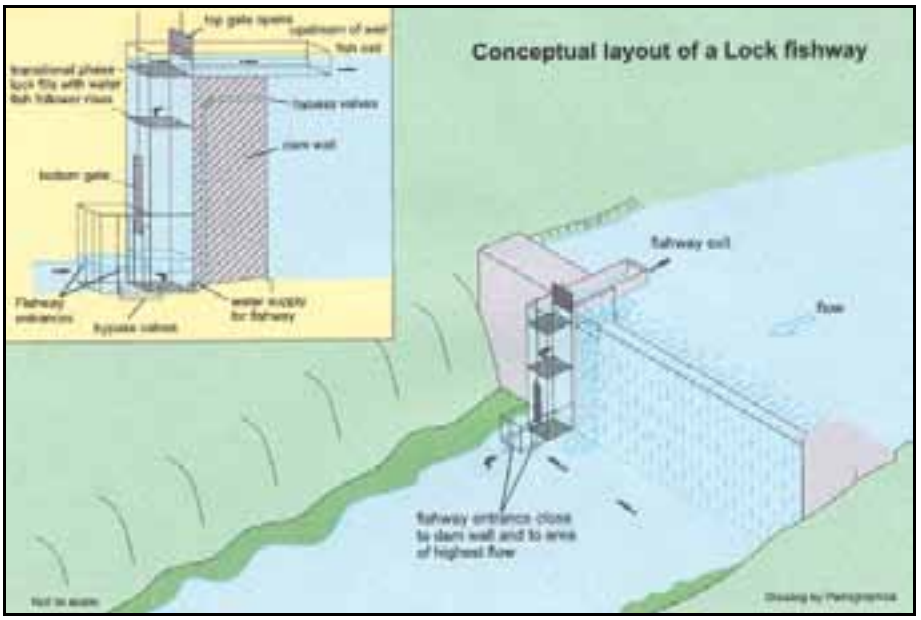
Thorncraft, G. and Harris, J.H. (2000) *Fish passage and fishways in NSW: A Status Report.* Cooperative Research Centre for Freshwater Ecology Technical Report 1/2000.

Appendix G – Details of fishways employed in Australia

Lock fishways

Lock fishways are employed on very large (high) structures where the installation of other fishway designs becomes impractical. Lock fishways operate by attracting fish through an entrance similar to a rock ramp or vertical slot fishway, but instead of swimming up a channel, fish accumulate in a holding area at the base of the lock. This holding area is then sealed and slowly filled with water to reach a level equal to the water upstream of the barrier. Fish are then able to swim out of the lock at the upstream pool level.

The first lock fishway in New South Wales waters was on the Murray River at Yarrawonga Weir, and has been shown to be effective in transporting fish over the 12m high weir. The Deelder fish lock is a variation of the lock fishway design, and is predominantly used on lower barriers. There is a functioning example of this fishway design present on the Murrumbidgee River at Balranald in the state's west.

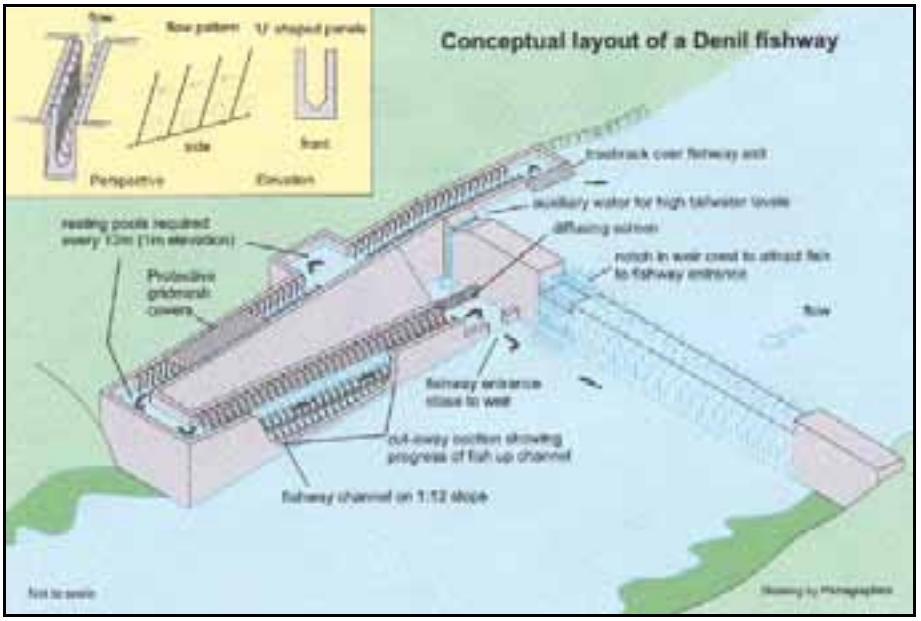


Reference:
Thorncraft, G. and Harris, J.H. (2000) *Fish passage and fishways in NSW: A Status Report.* Cooperative Research Centre for Freshwater Ecology Technical Report 1/2000.

Appendix G – Details of fishways employed in Australia

Denil fishways

This design uses a sloping channel similar to that of pool-type fishways, however Denil fishways have a series of internal upstream-sloping 'U'-shaped baffles without intervening pools. The Denil design allows steeper channels to be used because they are hydraulically efficient, resulting in shorter and cheaper fishways. This feature of the design allows for the prefabrication and installation of Denil inserts into many existing ineffective pool-type fishways. The operational depth range of Denil fishways is not as flexible as other fishway designs, with a reduction in the operational range of headwaters and tailwaters.



Reference:

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.

Appendix H – List of Medium Priority fish passage barriers in the Namoi

Rank*	Code	Structure Type	Waterway	LGA
32	UPR59	Ford	Duncans Creek	Tamworth
32	LPR63	Culvert	Timbumburi Creek	Tamworth
32	UNR44	Culvert	Halls Creek	Tamworth
32	LPR87	Culvert	Tangaratta Creek	Tamworth
32	WSC22	Culvert	Werries Creek	Tamworth
32	WSCD	Culvert	Quipolly creek	Tamworth
32	GGC51	Ford	Goonoo Goonoo Creek	Tamworth
32	UPN6	Culvert	Gunidgera Creek	Narrabri
32	BCS7	Bed control structure	Cockburn River	Tamworth
41	LPR74	Causeway	Sandy Creek	Tamworth
41	QC19	Causeway	Jacob and Joseph Ck	Tamworth
41	UMR8	Ford	Macdonald River	Tamworth
41	QC34	Causeway	Quirindi Creek	Liverpool Plain
41	BA7	Ford	Coxs Creek	Gunnedah
41	CC40	Causeway	Dunnadie Creek	Gunnedah
41	LG20	Causeway	Coomoo Coomoo Ck	Liverpool Plain
41	CR61	Causeway	Mulla Creek	Tamworth
41	CR34	Causeway	Swamp Oak Creek	Tamworth
41	BCS1	Bed control structure	Cockburn River	Tamworth
41	BCS2	Bed control structure	Cockburn River	Tamworth
52	UMA54	Causeway	Manilla River	Tamworth
52	WC7	Causeway	Borambil Creek	Liverpool Plain
52	UPN20	Culvert	Pian Creek	Narrabri
52	BCS8	Bed control structure	Cockburn River	Tamworth
56	419/961301/B0027	Weir ('Windella')	Pian Creek	Walgett
56	LPR68	Culvert	Timbumburi Creek	Tamworth
56	UNR69	Causeway	Oaky Creek	Tamworth
56	LM12	Causeway	Borah Creek	Tamworth
56	RC22	Causeway	Rangira Creek	Gunnedah
56	QC51	Causeway	Basin Creek	Tamworth
56	BA87	Causeway	Bundella Creek	Liverpool Plain
56	CR63	Culvert	Mulla Creek	Tamworth
56	CR36	Causeway	Swamp Oak Creek	Tamworth
56	CR52	Ford	Swamp Oak Creek	Tamworth
56	419/961302/B0039	Weir	Drildool Warrambool	Walgett
67	LPR83	Culvert	Timbumburi Creek	Tamworth
67	GGCA	Culvert	Goonoo Goonoo Ck	Tamworth
67	LG13	Culvert	Coomoo Coomoo Ck	Liverpool Plain
67	BCS4	Bed control structure	Cockburn River	Tamworth
71	419/970100/B0057	Weir ('Keelendi')	Baradine Creek	Walgett
71	GGC44	Ford	Swamp Creek	Tamworth
71	QC35	Causeway	Quirindi Creek	Liverpool Plain
71	WC14	Culvert	Borambil Creek	Liverpool Plain
71	LG17	Causeway	Yarraman Creek	Liverpool Plain
71	CR33	Causeway	Swamp Oak Creek	Tamworth
71	419/961301/B0035	Weir	Pian Creek	Walgett
71	BCS9	Bed control structure	Quirindi Creek	Tamworth
79	419/961300/B0024	Weir ('Hazeldean')	Gunidgera Creek	Narrabri
79	419/961301/B0026	Weir (O'Rourkes Dam)	Pian Creek	Narrabri
79	419/971811/B0111	Weir (Dungowan Dam)	Dungowan Creek	Tamworth
79	UNR31	Causeway	Ireland Creek	Tamworth
79	LG12	Causeway	Coomoo Coomoo Ck	Liverpool Plain
79	WSC27	Weir	Werris Creek	Liverpool Plain
79	419/961300/B0025	Weir	Gunidgera creek	Narrabri

* Rank obtained from the total of the Habitat Criteria, Structure Impact and Modification Criteria used in the assessment process (Appendix E).

Appendix H – List of Medium Priority fish passage barriers in the Namoi

Rank*	Code	Structure Type	Waterway	LGA
85	UNRA	Culvert	Halls Creek	Tamworth
85	LM13	Causeway	Borah Creek	Tamworth
85	UPN13	Culvert	Pian Creek	Narrabri
85	CR64	Ford	Swamp Oak Creek	Tamworth
85	CR50	Ford	Swamp Oak Creek	Tamworth
85	BCS5	Bed control structure	Cockburn River	Tamworth
85	WGS14	Water gauge structure	Warrah Creek	Tamworth
85	WGS3	Water gauge structure	Cockburn River	Tamworth
94	419/962002/B0055	Weir ('Lowana')	Talluba Creek	Narrabri
94	419/970100/B0071	Weir ('Bungle')	Baradine Creek	Walgett
94	UNR68	Causeway	Halls Creek	Tamworth
94	419/961304/B0040	Weir ('Woodvale')	Myall camp Warrambool	Narrabri
98	UNR60	Culvert	Hellhole Creek	Tamworth
98	UMA44	Ford	Manilla River	Tamworth
98	EHC25	Culvert	Horsearm Creek	Narrabri
98	419/961301/B0033	Weir (Dundee Weir)	Pian Creek	Walgett
98	419/961301/B0037	Weir	Pian Creek	Narrabri
98	419/961305/B0046	Weir	Cubbaroo Warrambool	Narrabri
98	QC44	Weir	Jacob and Joseph Ck	Liverpool Plain
105	BCS6	Bed control structure	Cockburn River	Tamworth
106	419/961300/B0020	Weir ('Purlewa')	Gunidgera Creek	Narrabri
106	419/962100/B0062	Weir	Turragulla Creek	Walgett
106	UPR13	Culvert	Calala Creek	Tamworth
106	UNR50	Causeway	Spring Creek	Tamworth
106	UNR12	Ford	Burnt Yard Creek	Tamworth
106	SR25	Causeway	Eumur Creek	Tamworth
106	419/961305/B0044	Weir	Cubbaroo Warrambool	Narrabri
113	419/970300/B0073	Weir ('Watroa')	Barra Creek	Narrabri
113	WSC26	Culvert	Werries Creek	Tamworth
113	419/961304/B0042	Weir	Myall camp Warrambool	Narrabri
116	419/962000/B0054	Weir ('Keelendi')	Turragulla Creek	Walgett
116	419/970106/B0072	Weir ('Wyoming')	Pauls Creek	Warrumbungle
116	419/971202/B0075	Weir	Quipolly Creek	Liverpool Plain
116	419/971810/B0085	Weir	Duncans Creek	Tamworth
116	419/971811/B0086	Weir	Dungowan Creek	Tamworth
116	419/971821/B0113	Weir (Moore Ck Dam)	Moore Creek	Liverpool Plain
116	419/961304/B0041	Weir	Myall camp Warrambool	Narrabri

* Rank obtained from the total of the Habitat Criteria, Structure Impact and Modification Criteria used in the assessment process (Appendix E).

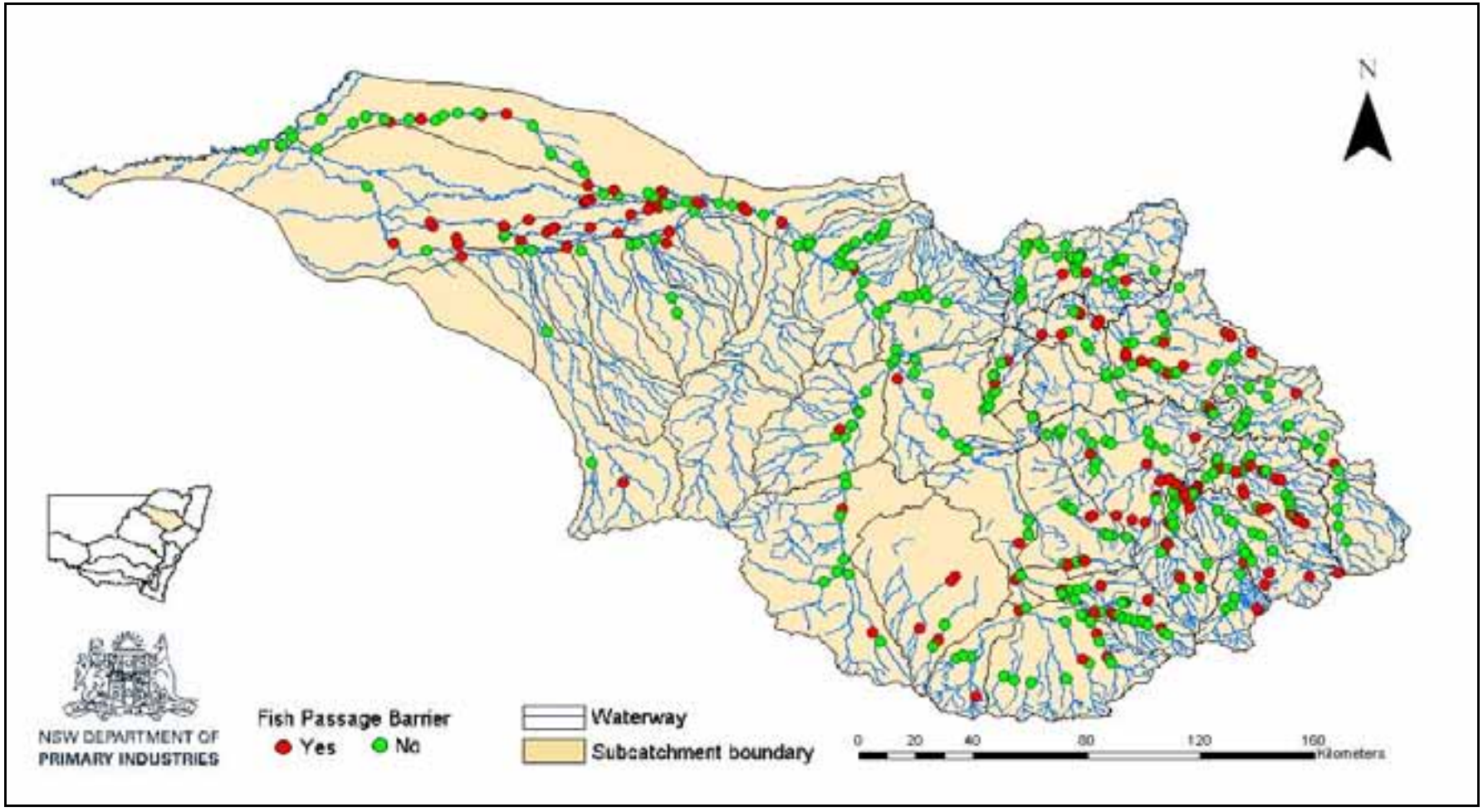
Appendix I – List of Low Priority fish passage barriers in the Namoi

Rank*	Code	Structure Type	Waterway	LGA
123	419/950909/B0007	Weir	Oaky Creek	Tamworth
123	419/971202/B0114	Weir (Quipolly Ck Dam)	Quipolly Creek	Tamworth
123	CR19	Culvert - Box	Moonbi Creek	Tamworth
123	BCS10	Bed control structure	Werris Creek	Liverpool Plain
127	419/970701/B0074	Weir	Merri merri Creek	Narrabri
127	419/972700/B0097	Weir	Deadmans Gully	Narrabri
127	419/961300/B0021	Weir (Weeta)	Gunidgera Creek	Narrabri
127	419/961300/B0023	Weir	Gunidgera Creek	Narrabri
127	UPR11	Culvert - Box	Calala Creek	Tamworth
127	419/961304/B0043	Weir	Myall camp Warrambool	Narrabri
127	419/961305/B0045	Weir	Cubbaroo Warrambool	Narrabri
127	419/961305/B0047	Weir	Cubbaroo Warrambool	Narrabri
135	419/961300/B0105	Weir (Gunidgera Reg)	Gunidgera Creek	Narrabri
135	419/950909/B0008	Weir	Oaky Creek	Tamworth
135	419/960202/B0016	Weir ('Rangari')	Rangira Creek	Gunnedah
135	419/962004/B0056	Weir ('Keelendi')	Gil gil Creek	Walgett
135	UNR55	Ford	Bungendore Creek	Tamworth
140	419/950902/B0006	Weir (Conner Ck Dam)	Conners Creek	Tamworth
140	419/960202/B0014	Weir ('Rangari')	Rangira Creek	Gunnedah
140	419/962000/B0053	Weir	Turragulla Creek	Walgett
140	419/961300/B0022	Weir	Gunidgera Creek	Narrabri
140	MMR5	Culvert - Pipe	Pringles Rocky Creek	Tamworth
140	419/961301/B0036	Weir	Pian Creek	Narrabri
140	419/961301/B0038	Weir	Pian Creek	Narrabri
147	419/971202/B0116	Weir (Quipolly Ck Dam)	Quipolly Creek	Tamworth
148	419/960202/B0015	Weir ('Rangari')	Rangira Creek	Gunnedah
148	419/961900/B0051	Weir	Sheep station Creek	Narrabri
148	419/961900/B0052	Weir	Sheep station Creek	Narrabri
148	UMA42	Causeway	Connors Creek	Tamworth
148	EHC101	Floodgate	Barra Creek	Narrabri
153	419/950917/B0009	Weir	Sawyers Creek	Tamworth
153	419/971868/B0089	Weir	Warrimoo Creek	Tamworth
155	419/951308/B0010	Weir ('Rimbanda')	Dog trap Gully	Tamworth
155	419/971224/B0078	Weir	Chinamans Creek	Tamworth
157	419/971225/B0080	Weir	Spring Creek	Liverpool Plain
157	419/971805/B0084	Weir	Burnt hut Creek	Tamworth
157	419/971852/B0087	Weir	Terrible Billy Creek	Tamworth
160	419/971224/B0079	Weir	Chinamans Creek	Tamworth
160	419/971855/B0088	Weir ('Wata')	Buckley Gully	Tamworth
162	419/971805/B0083	Weir (Sheba Dams)	Burnt hut Creek	Tamworth

* Rank obtained from the total of the Habitat Criteria, Structure Impact and Modification Criteria used in the assessment process (Appendix E).

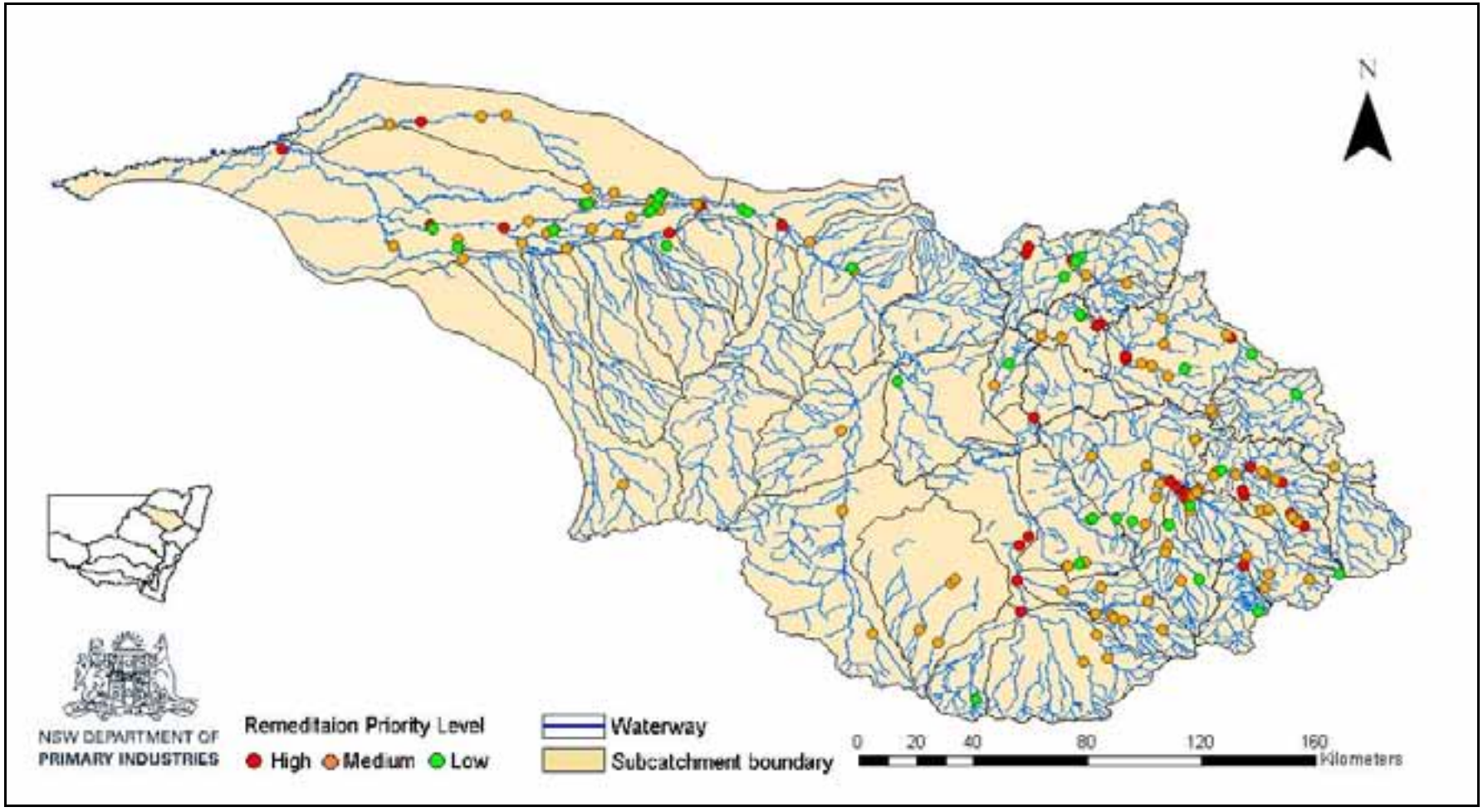
Appendix J – All instream structures assessed in the Namoi catchment

<u>Map 1</u>: All instream structures assessed in the Namoi catchment.



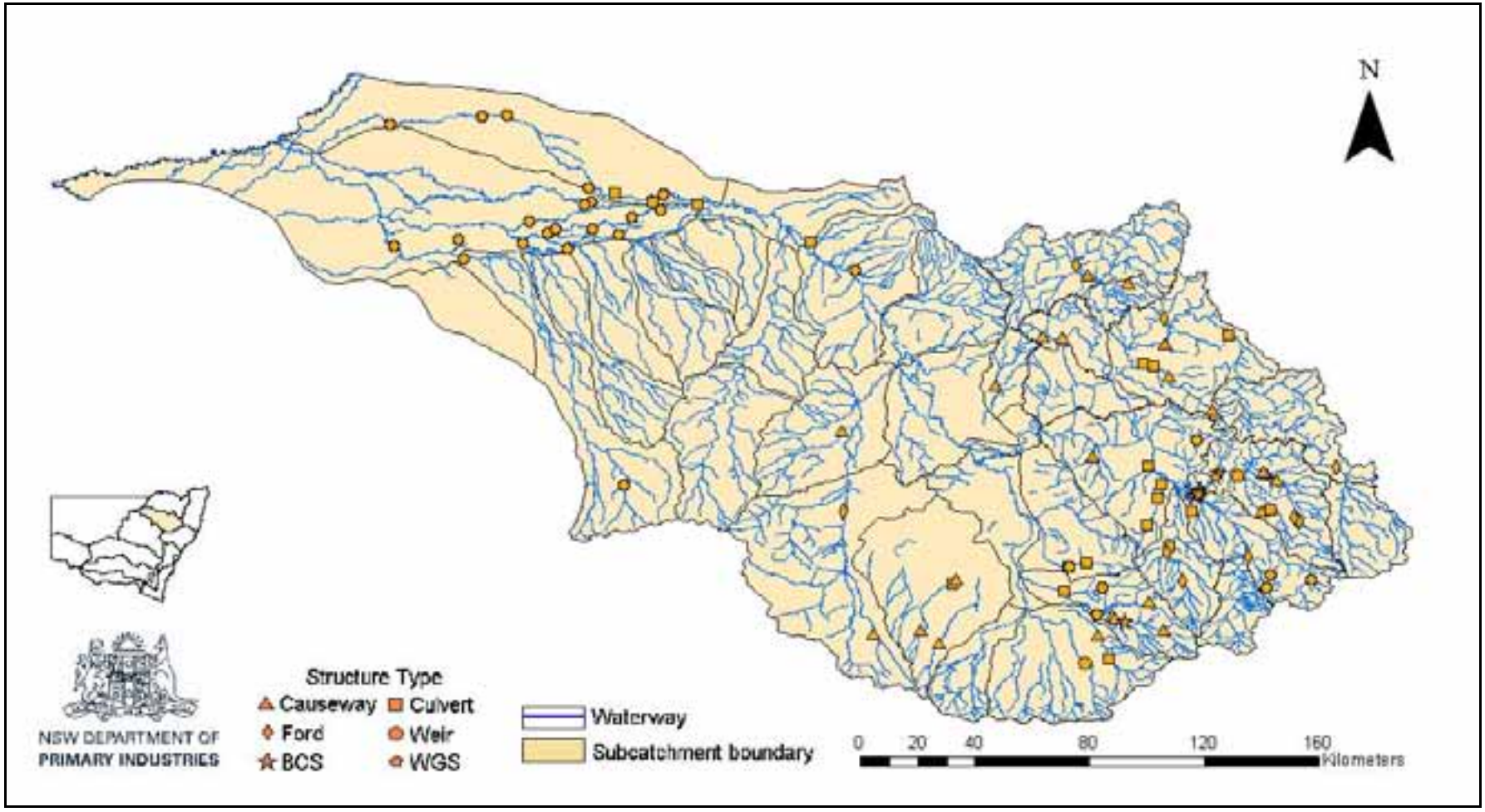
Appendix K – Fish passage barriers in the Namoi catchment

Map 2: Fish passage barriers in the Namoi catchment.



Appendix L – Medium Priority fish passage barriers in the Namoi catchment

Map 3: Medium Priority fish barriers in the Namoi catchment.



Appendix M – Low Priority fish passage barriers in the Namoi

Map 4: Low Priority fish passage barriers in the Namoi catchment.