Operation of Peel River Drought Protection Works, Tamworth, NSW.

Chaffey to Dungowan Pipeline: Annual Compliance Report 2021

Author	Jeremy Stacy, Environmental Adviser
Review	Evan Webb, Manager Environmental Services
Revision history	Final

Declaration of accuracy

In making this declaration, I am aware that sections 490 and 491 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) make it an offence in certain circumstances to knowingly provide false or misleading information or documents. The offence is punishable on conviction by imprisonment or a fine, or both. I declare that all the information and documentation supporting this compliance report is true and correct in every particular. I am authorised to bind the approval holder to this declaration and that I have no knowledge of that authorisation being revoked at the time of making this declaration.

Signed	
Full Name	Ronan Magaharan
Position	Executive Manager, Operations
Organisation (including ABN)	WaterNSW ABD 21 147 934 787
Date:	27 July 2022

Table of Contents

List of Tables

Appendices

1. Introduction

Chaffey Dam is located on the Peel River approximately 43 kilometres (km) south-east of Tamworth, between the towns of Nundle and Woolomin, NSW.

Water NSW obtained approval to operate a temporary drought mitigation pipeline to supply water directly from Chaffey Dam to the Tamworth water supply network via the Chaffey Dam to Dungowan Pipeline in June 2020. The pipeline extends underground approximately 18km from Chaffey Dam to Dungowan and connects with the existing Dungowan Dam to Calala water treatment plant pipeline operated by Tamworth Regional Council (TRC).

The pipeline was constructed to operate during severe drought to increase town water security for Tamworth when the Chaffey Dam storage fell below 20% capacity. During operation, water deliveries to TRC were made via the pipeline resulting in no water deliveries to TRC being made via releases to the Peel River.

On 3 June 2020, WaterNSW received authorisation by the NSW Minister for Water, Property and Housing under the *Water Supply (Critical Needs) Act 2019,* to operate the pipeline in accordance with the conditions of approval. Approval under NSW WSCN Act expired on 30 September 2021.

On 12 June 2020, WaterNSW received approval EPBC 2019/8590 with conditions, from the Commonwealth Minister for the Environment for the controlled activity to operate the pipeline during drought. The approval contained a number of conditions including but not limited to; annual monitoring and compliance reporting; and the development and implementation of a Biodiversity Offset Management Plan (BOMP, GHD 2020). The approval EPBC 2019/8590 to operate the temporary drought mitigation pipeline, has effect until 1 May 2030. The drought ceased September 2020 and the pipeline is not in operation.

The approved action to operate the pipeline commenced 17 June 2020. This report has been prepared to fulfil the annual compliance reporting requirements of EPBC 2019/8590.

2. Description of Activities

WaterNSW (ABN: 21 147 934 787) is the approval holder for the Chaffey Dam to Dungowan Pipeline Drought Operation project (EPBC 2019/8590) approximately 43 km south-east of Tamworth, approved on 12 June 2020. The construction was completed in March 2020. Operation of the pipeline to deliver water to Tamworth Regional Council's Calala water treatment plant commenced 17 June 2020 and continued to 29 July 2020. The delivery of water via the pipeline has not occurred since 29 July 2020.

This report relates to the activities undertaken during the reporting period from 17 June 2020 to 16 June 2021. Activities completed in response to EPBC2019/8590 approval include:

- Implement the Drought Operations Delivery of Peel Environmental Water Plan and operate the pipeline in accordance with NSW conditions of approval and continue until expiry of the Authorisation.
- Convene a technical advisory group and invite Commonwealth Environmental Water Holder to nominate a representative.
- Notifications of commencement of pipeline operation and notification of operation phase changes within prescribed timeframes.
- Prepare and submit for approval a Biodiversity Offset Management Plan to compensate for impacts to Murray Cod and Silver Perch.
- Implementation of management actions & prescribed activities within the BOMP (GHD 2020).
    - Undertake Peel River Habitat survey
    - Identify potential pump locations and preferred sites.
    - Prepare and send expression of Interest to pump owners.
- Preparation of this annual compliance report.

The preparation of the annual compliance report (this report) was delayed due to the need to seek clarification and advice from the Department in regard to timing of the report as the ability to operate the pipeline under the EPBC 2019/8590 ceased when the drought ceased in September 2020. This advice was sought November 2021 and a response was not received at WaterNSW until 14 June 2022.

3. Compliance Review – Conditions as per EPBC 2019/8590

The approval notice – to operate a temporary drought mitigation pipeline to supply water directly from Chaffey Dam to the Tamworth water supply network (EPBC 2019/8590) issued on 12 June 2020, requires annual reporting from the commencement of the action, 17 June 2020, against the conditions of consent. Table 2 below outlines these conditions and provides a statement of compliance for the reporting year to 16 June 2021. This report fulfils the requirements of EPBC 2019/8590 Condition 12.

Table 1: Compliance tracking 2020-21

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2021	Evidence / Comments
n/a	**EPBC 2019/8590 Notice of Approval letter.**	**1**	EPBC notices to be available on WaterNSW website	Make EPBC approval available on WaterNSW website. Weblink to DAWE EPBC approval	WaterNSW	15/06/2020	EPBC 2019/8590 Approval Peel Valley - WaterNSW website	compliant	ARK reference D2020/58692 Approval link to DAWE EPBC website
1	Annexure A Part A	2	The approval holder must implement the Drought Operations - Delivery of Peel Environmental Water Plan for the life of the approval. In addition the approval holder must comply with NSW conditions of authorisation where those conditions relate to environmental water releases and operation of the technical advisory group.	Submission of Delivery plan - submitted with referral Pipeline operated in accordance with State and Commonwealth approval conditions. PEWTAG provided monitoring data as available	WaterNSW , Operations - AS	12 June 2020 until cessation of drought	Peel Valley - WaterNSW website	compliant	implemented; incorporated into WSCN authorisation conditions; ARK D2020/58721 EPBC Approval D2020/58692 Monitoring data collected as requirement of NSW authorisation F2019/5571 Drought ceased September 2020 WSCN Authorisation expired 30 September 2021
2	Annexure A Part A	2	The approval holder must notify the technical advisory group at least five business days prior to commencing the next phase of operation.	Notice to be sent within time frame required and posted on project website	WaterNSW , Operations - AS	43999	Peel Valley - WaterNSW website	compliant	Notices posted to website
3	Annexure A Part A	2	The approval holder must invite the Commonwealth Environmental Water Holder to nominate a representative to become a member of the technical advisory group.	Email invitation	WaterNSW , Operations - AS	43994	ARK D2021/120098	compliant	D2021/120098 CEWH members identified in PEWTAG terms of reference, page 6
4	Annexure A Part A	2	To compensate for impacts to Murray Cod and Silver Perch, the approval holder must, within 20 business days of commencement of the action, submit a Biodiversity Offset Management Plan (BOMP) for approval by the Minister. If the Minister approves the BOMP, then the BOMP must be implemented.	Draft Biodiversity Offset Management Plan	WaterNSW – Env Serv JS	submitted 15/7/20	ARK D2021/119441	compliant	draft submitted to department 15/7/20 D2021/119441
5	Annexure A Part A	2	The approval holder must make all reasonable efforts to ensure the BOMP (in full) meets the following requirements and promptly address any feedback from the Department on unapproved versions of the BOMP so that the BOMP is suitable for the Minister to approve within three months of the commencement of the action.	Biodiversity Offset Management Plan	WaterNSW – Env Serv JS	plan approved 29 October 2020	https://www.waternsw.com.au/__data/assets/pdf_file/0016/161620/Biodiversity-Offset-Plan-EPBC-2019-8590.pdf	compliant	BOP D2020/101647 Plan approval D2020/116788

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2021	Evidence / Comments
6	Annexure A Part A	2	The BOMP must: **a.** be prepared by a suitably qualified ecologist, and be consistent with the Department's Environmental Management Plan Guidelines and the EPBC Act Environmental Offset Policy; **b.** propose an offset package, including direct habitat restoration works and conservation measures relevant to Murray Cod and Silver Perch **c**. include, but not be limited to: **i.** specific objectives to demonstrate improvements in habitat quality and conservation outcomes for Murray Cod and Silver Perch over the life of the approval; **ii**. specific management actions, and timeframes for implementation, to be carried out to meet the specific objectives to improve habitat quality and conservation outcomes for Murray Cod and Silver Perch; **iii**. key performance indicators to demonstrate the improvements in habitat quality and conservation outcomes for Murray Cod and Silver Perch; **iv**. the nature, timing and frequency of monitoring to determine the success of management actions against key performance indicators; **v**. indicative corrective actions that will be implemented in the event monitoring activities indicate key performance indicators are not or are unlikely to be achieved; **vi.** the roles and responsibilities for implementing the management actions; **vii.** evidence of consistency with relevant conservation advices, recovery plans and/or threat abatement plans; **viii**. commitments to maintain or improve the extent and quality of habitat and populations of other EPBC Act listed threatened species and ecological communities in the offset area; and a timeline and legal mechanism for implementing the offset(s).	Biodiversity Offset Management Plan	WaterNSW – Env Serv JS	plan approved 29 October 2020	ARK D2020/101647	compliant	BOP D2020/101647 Approval D2020/116788
7	Annexure A Part B	3	The approval holder must notify the Department in writing of the date of commencement of the action within 10 business days after the date of commencement of the action. The approval holder must notify the Department in writing of the date of commencement of each phase of operation within 10 business days after the date of commencement of each phase of operation.	Send advice via email at each change of operation phase.	WaterNSW , Operations - AS	Notice #1 - 17 June 2020 - Commencement of Action Notice #2 - 1 July 2020 Notice #3 - 29 July 2020	ARK D2021/120827 D2021/120845 D2021/120866	compliant	Media Release - https://www.waternsw.com.au/about/newsroom/2020/chaffey-to-tamworth-pipeline-operational

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2021	Evidence / Comments
8	Annexure A Part B	3	The approval holder must maintain accurate and complete compliance records.	Maintain approval tracking spreadsheet and identified records within	WaterNSW – Env Serv JS; Ops	implemented compliance tracking	ARK	compliant	This spreadsheet tracks compliance ARK D2022/18480
9	Annexure A Part B	3	If the Department makes a request for compliance records in writing, the approval holder must provide electronic copies of compliance records to the Department within the timeframe specified in the request.	Notice from Department to be received	WaterNSW PM EnvServ	No requests received		compliant	No requests received
10	Annexure A Part B	3	The approval holder must: **a.** submit plans electronically to the Department; **b**. publish each plan on the website within 20 business days of the date of this approval, or the date that the plan is approved by the Minister or of the date a revised action management plan is submitted to the Minister or the Department, unless otherwise agreed to in writing by the Minister; **c**. exclude or redact sensitive ecological data from plans published on the website or provided to a member of the public; and **d.** keep plans published on the website until the end date of this approval.	Submit plans via email to Department Post Approval PostApproval@awe.gov.au Approved plans to be published to WaterNSW website https://www.waternsw.com.au/supply/drought-information/regional-nsw/peel-valley	WaterNSW – Env Serv JS	BOP submitted to DAWE BOP, published to WNSW project website	https://www.waternsw.com.au/__data/assets/pdf_file/0016/161620/Biodiversity-Offset-Plan-EPBC-2019-8590.pdf BOP D2020/101647 Approval D2020/116788	compliant	BOP D2020/101647 Approval D2020/116788
11	Annexure A Part B	3	The approval holder must ensure that any monitoring data (including sensitive ecological data), surveys, maps, and other spatial and metadata required under a plan, is prepared in accordance with the Department's Guidelines for biological survey and mapped data (2018) and submitted electronically to the Department in accordance with the requirements of the plan.	Submit with annual compliance report via email to Department EPBCMonitoring@awe.gov.au	WaterNSW Project Delivery PM; Env Serv	Nil monitoring to date	Offset yet to be implemented.	not applicable	No offset monitoring reports prepared to date. Offset implementation due October 2022.

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2021	Evidence / Comments
12	Annexure A Part B	3	The approval holder must prepare a compliance report for each 12 month period following the date of commencement of the action, or otherwise in accordance with an annual date that has been agreed to in writing by the Minister. The approval holder must: a. publish each compliance report on the website within 60 business days following the relevant 12 month period; b. notify the Department by email that a compliance report has been published on the website and provide the weblink for the compliance report within five business days of the date of publication; c. keep all compliance reports publicly available on the website until this approval expires; d. exclude or redact sensitive ecological data from compliance reports published on the website; and e. where any sensitive ecological data has been excluded from the version published, submit the full compliance report to the Department within five business days of publication.	Compliance report to be prepared and published to WaterNSW website https://www.waternsw.com.au/supply/drought-information/regional-nsw/peel-valley Biodiversity monitoring report to be prepared as per BOP requirements; Email notification to DAWE EPBCMonitoring@awe.gov.au to advise of compliance report availability and link to publication on WaterNSW website	WaterNSW – Env Serv, WQS	Compliance report not prepared within 60 days of approval anniversary. Monitoring of Biodiversity offsets not commenced within reporting period.	Report published to website 29 July 2022 This report ARK D2022/67509	not applicable	Letter was sent to DAWE post approvals 4 November 2021 requesting confirmation of conditions in particular regarding need for compliance reporting - D2021/117921 (no response received); Biodiversity Offsets implementation due October 2022 and monitoring in accordance with BOMP has not commenced. Email sent to Post Approvals 27/4/2022 requesting confirmation of previous correspondence and new issues raised regarding implementation timeline. Email received from DAWE on the 14/6/2022 indicating the need for compliance reporting despite cessation of the operation.
13	Annexure A Part B	4	The approval holder must **notify** the Department in writing of any: incident; non-compliance with the conditions; or non-compliance with the commitments made in plans. The notification must be given as soon as practicable, and no later than two business days after becoming aware of the incident or non-compliance. The notification must specify: **a.** any condition which is or may be in breach; **b**. a short description of the incident and/or non-compliance; and **c.** the location (including co-ordinates), date, and time of the incident and/or non-compliance. In the event the exact information cannot be provided, provide the best information available.	Send advice via email to Department: EPBCMonitoring@awe.gov.au	WaterNSW	Clarification of conditions requested November 2021	D2021/117921 D2022/57622	compliant	Letter sent via email to DAWE post approvals 4 November 2021 requesting confirmation of conditions; D2021/117921; D2022/060557. The letter acknowledged the absence of reporting and WaterNSW understanding that it wasn't a requirement. Email sent to Post Approvals 27/4/2022 requesting confirmation of previous correspondence and new issues raised regarding implementation timeline. Nil response received; Nominated contact left DAWE, email resent 1/6/2022 Response received from DAWE 14 June 2022 D2022/57622
14	Annexure A Part B	4	The approval holder must **provide** to the Department the details of any incident or noncompliance with the conditions or commitments made in plans as soon as practicable and no later than 10 business days after becoming aware of the incident or non-compliance, specifying: **a.** any corrective action or investigation which the approval holder has already taken or intends to take in the immediate future; **b**. the potential impacts of the incident or non-compliance; and **c.** the method and timing of any remedial action that will be undertaken by the approval holder.	Send advice via email to Department: EPBCMonitoring@awe.gov.au	WaterNSW	Report not prepared within 60 days of approval anniversary	D2021/117921 D2022/060557	compliant	Letter sent via email to DAWE post approvals 4 November 2021 requesting confirmation of conditions; D2021/117921; D2022/060557. The letter acknowledged the absence of reporting and WaterNSW understanding that it wasn't a requirement.

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2021	Evidence / Comments
15	Annexure A Part B	4	The approval holder must ensure that independent audits of compliance with the conditions are conducted as requested in writing by the Minister.	as per written advice received from Minister	WaterNSW	Nil to date	not applicable	not applicable	Nil requests to date
16	Annexure A Part B	4	For each independent audit, the approval holder must: **a**.provide the name and qualifications of the independent auditor and the draft audit criteria to the Department; **b**.only commence the independent audit once the audit criteria have been approved in writing by the Department; and **c**.submit an audit report to the Department within the timeframe specified in the approved audit criteria.		WaterNSW	Nil to date	not applicable	not applicable	No audits undertaken to date
17	Annexure A Part B	4	The approval holder must publish the audit report on the website within 10 business days of receiving the Department's approval of the audit report and keep the audit report published on the website until the end date of this approval.	Nil to date	WaterNSW	Nil to date	not applicable	not applicable	No reports prepared to date
18	Annexure A Part B	4	The approval holder may, at any time, apply to the Minister for a variation to an action management plan approved by the Minister under condition 4, or as subsequently revised in accordance with these conditions, by submitting an application in accordance with the requirements of section 143A of the EPBC Act. If the Minister approves a revised action management plan (RAMP) then, from the date specified, the approval holder must implement the RAMP in place of the previous action management plan.	Nil to date	WaterNSW	Nil to date	not applicable	not applicable	no variations sought during reporting period

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2021	Evidence / Comments
19	Annexure A Part B	44	Within 30 days after the completion of the action, the approval holder must notify the Department in writing and provide completion data.	notification letter/email EPBCMonitoring@awe.gov.au	WaterNSW - EnvServ	Nil to date	D2022/47990	compliant	Letter sent to DAWE post approvals 4 November 2021 requesting confirmation of cessation conditions; D2021/117921

'Compliance' is achieved when all the requirements of a condition have been met, including the implementation of management plans or other measures required by those conditions.

A designation of 'non-compliance' should be given where the requirements of a condition or elements of a condition, including the implementation of management plans and other measures, have not been met.

A designation of 'not applicable ' should be given where the requirements of a condition or elements of a condition fall outside of the scope of the current reporting period. For example, a condition which applies to an activity that has not yet commenced.

4. Implementation of Offset Plan

The Biodiversity Offset Management Plan (GHD 2020) outlines the key management actions required to achieve the objectives of improving habitat for Murray Cod and Silver Perch. Table 2 below outlines the activities undertaken in order to implement the management actions identified within the BOMP.

The BOMP required a baseline aquatic habitat survey to be undertaken to identify potential suitable sites to receive snags.

The baseline aquatic survey to be undertaken before installation of offset measures is not required be completed during this reporting period. Installation of offsets not able to commence until snagging sites have been selected and pumps suitable to receiving self-cleaning pump screens have been identified. This requires on-site assessment.

The following management actions have been undertaken to date:

Table 2: Summary of actions undertaken

Offset Measure	Action	Performance in accordance with BOMP
1 – Re-snagging Plan Develop plan to install up to 50 snags as habitat for Murray Co and Silver Perch	Peel River Habitat Mapping - January 2021	Compliant
2 – Self-cleaning Pump Screens Install self-cleaning pumps screens on extraction points to seven licenced pumps downstream from Chaffey Dam	Expressions of interest sent to licensed pump owners – April 2021	Compliant

4.1 Covid-19 Restrictions and Impacts to Implementation

During the reporting period WaterNSW ability to progress with the installation of the biodiversity offsets as required by EPBC 2019/8590 conditions 4-6, was impacted by Covid 19 travel restrictions put in place by both the NSW and Victorian State governments. Workplace restrictions put in place by WaterNSW to meet these State restrictions and to protect its employees and contractors to ensure business continuity also had significant impacts on offset delivery.

Continuation of water supply is considered to be an essential service, however ancillary activities undertaken by WaterNSW were not considered as essential during Covid19 restrictions. The implementation of the BOMP was not considered essential to maintaining water supply.

The following activities required to progress with the implementation of the BOMP were not able to be undertaken during the reporting period:

- undertake site pump inspections to assess suitability of licenced pumps to receive self-cleaning pump screens;
    - to identify site constraints.
    - to specify pump screen requirements for manufacture.
- engage installation contractor.
- enter self-cleaning pump screen recipient agreements.
- commence field investigation for re-snagging sites;
    - to identify site constraints.
    - to design placement of snags within the river.
    - to prepare EIA and obtain additional approvals.

The inability to commence the activities due to the restrictions has condensed the available time to install the offsets. The BOMP was approved on 29 October 2020 with the requirement to have the offset measures implemented within 2 years of the plan's approval, 28 October 2022. Effort continues to meet the installation timeframe, however the ability to undertake the field assessments required to complete the implementation has been significantly affected. Ongoing Covid-19 restrictions continued to impact implementation throughout the reporting period and up until the second half of 2021.

Activities to progress the implementation were carried out where restrictions allowed and these are discussed in the Section 2.

The chronology of WaterNSW Covid-19 restrictions is shown in Table 3. This identifies the restrictions in place at WaterNSW before and throughout the reporting period.

Table 3: Covid-19 restrictions affecting implementation

Month/Year	WaterNSW Measure
2020	
March	Pivot to Work From Home and reducing unnecessary travel - Incident Management Team stood up.
April	Lock Down Commenced LGA restrictions in place
May	Company freeze on travel
June	Company freeze on travel
July	Company freeze on travel
August	Only approved travel permitted that is considered essential
September	Only approved travel permitted that is considered essential
October	Only approved travel permitted that is considered essential
November	Company freeze on travel from some LGAs
December	Company freeze on travel from some LGAs

Month/Year	WaterNSW Measure
2021	
January	Only approved travel permitted that is considered essential
February	Only approved travel permitted that is considered essential
March	Only approved travel permitted that is considered essential
April	Only approved travel permitted that is considered essential
May	Only approved travel permitted that is considered essential
June	Lockdown measures for some LGAs
July	Company freeze on non-essential travel - no travel from LGAs of concern

Appendices

Appendix 1 – EPBC 2019/8590 Notice of Approval

Australian Government
Department of Agriculture, Water and the Environment

APPROVAL

Operation of Peel River Drought Protection Works, Tamworth, NSW (EPBC 2019/8590)

This decision is made under sections 130(1) and 133(1) of the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)*. Note that section 134(1A) of the **EPBC Act** applies to this approval, which provides in general terms that if the approval holder authorises another person to undertake any part of the action, the approval holder must take all reasonable steps to ensure that the other person is informed of any conditions attached to this approval, and that the other person complies with any such condition.

Details

Person to whom the approval is granted (approval holder)	WATER NSW
ACN or ABN of approval holder	ABN: 21 147 934 787
Action	To operate a temporary drought mitigation pipeline to supply water directly from Chaffey Dam to the Tamworth water supply network [See **EPBC Act** referral 2019/8590].

Approval decision

My decision on whether or not to approve the taking of the action for the purposes of the controlling provision for the action is as follows.

Controlling Provisions

Listed Threatened Species and Communities	
Section 18	Approve
Section 18A	Approve

Period for which the approval has effect

This approval has effect until 01 May 2030

Decision-maker

Name and position	The Hon Sussan Ley MP Minister for the Environment
Signature	Sussan Ley
Date of decision	12 June 20

Conditions of approval

This approval is subject to the conditions under the EPBC Act as set out in ANNEXURE A.

ANNEXURE A – CONDITIONS OF APPROVAL

Part A – Conditions specific to the action

1. The approval holder must implement the **Drought Operations – Delivery of Peel Environmental Water Plan** for the life of the approval. In addition the approval holder must comply with **NSW conditions of authorisation** where those conditions relate to environmental water releases and operation of the **technical advisory group**.
2. The approval holder must notify the **technical advisory group** at least five **business days** prior to commencing the next **phase of operation**.
3. The approval holder must invite the **Commonwealth Environmental Water Holder** to nominate a representative to become a member of the **technical advisory group**.
4. To compensate for impacts to **Murray Cod** and **Silver Perch**, the approval holder must, within 20 **business days** of **commencement of the action**, submit a Biodiversity Offset Management Plan (BOMP) for approval by the **Minister**. If the **Minister** approves the BOMP, then the BOMP must be implemented.
5. The approval holder must make all reasonable efforts to ensure the BOMP (in full) meets the following requirements and promptly address any feedback from the **Department** on unapproved versions of the BOMP so that the BOMP is suitable for the **Minister** to approve within three months of the **commencement of the action.**
6. The BOMP must:
   a. be prepared by a **suitably qualified ecologist**, and be consistent with the **Department's Environmental Management Plan Guidelines** and the **EPBC Act Environmental Offset Policy**;
   b. propose an offset package, including direct habitat restoration works and conservation measures relevant to **Murray Cod** and **Silver Perch**;
   c. include, but not be limited to:
      i. specific objectives to demonstrate improvements in habitat quality and conservation outcomes for **Murray Cod** and **Silver Perch** over the life of the approval;
      ii. specific management actions, and timeframes for implementation, to be carried out to meet the specific objectives to improve habitat quality and conservation outcomes for **Murray Cod** and **Silver Perch**;
      iii. key performance indicators to demonstrate the improvements in habitat quality and conservation outcomes for **Murray Cod** and **Silver Perch**;
      iv. the nature, timing and frequency of monitoring to determine the success of management actions against key performance indicators;
      v. indicative corrective actions that will be implemented in the event monitoring activities indicate key performance indicators are not or are unlikely to be achieved;
      vi. the roles and responsibilities for implementing the management actions;
      vii. evidence of consistency with relevant conservation advices, recovery plans and/or threat abatement plans;
      viii. commitments to maintain or improve the extent and quality of habitat and populations of other **EPBC Act** listed threatened species and ecological communities in the offset area; and
      ix. a timeline and legal mechanism for implementing the offset(s).

Part B – Standard administrative conditions

Notification of date of commencement of the action

7. The approval holder must notify the **Department** in writing of the date of **commencement of the action** within 10 **business days** after the date of **commencement of the action.** The approval holder must notify the **Department** in writing of the date of **commencement** of each **phase of operation** within 10 **business days** after the date of **commencement** of each **phase of operation**.

Compliance records

8. The approval holder must maintain accurate and complete **compliance records**.
9. If the **Department** makes a request for **compliance records** in writing, the approval holder must provide electronic copies of **compliance records** to the **Department** within the timeframe specified in the request.

Note: **Compliance records** may be subject to audit by the **Department** or an independent auditor in accordance with section 458 of the **EPBC Act**, and or used to verify compliance with the conditions. Summaries of the result of an audit may be published on the **Department**'s **website** or through the general media.

Preparation and publication of plans

10. The approval holder must:
    a. submit **plans** electronically to the **Department**;
    b. publish each **plan** on the **website** within 20 **business days** of the date of this approval, or the date that the **plan** is approved by the **Minister** or of the date a revised action management **plan** is submitted to the **Minister** or the **Department**, unless otherwise agreed to in writing by the **Minister**;
    c. exclude or redact **sensitive ecological data** from **plans** published on the **website** or provided to a member of the public; and
    d. keep **plans** published on the **website** until the end date of this approval.
11. The approval holder must ensure that any **monitoring data** (including **sensitive ecological data**), surveys, maps, and other spatial and metadata required under a **plan**, is prepared in accordance with the **Department's** *Guidelines for biological survey and mapped data* (2018) and submitted electronically to the **Department** in accordance with the requirements of the **plan**.

Annual compliance reporting

12. The approval holder must prepare a **compliance report** for each 12 month period following the date of **commencement of the action**, or otherwise in accordance with an annual date that has been agreed to in writing by the **Minister**. The approval holder must:
    a. publish each **compliance report** on the **website** within 60 **business days** following the relevant 12 month period;
    b. notify the **Department** by email that a **compliance report** has been published on the **website** and provide the weblink for the **compliance report** within five **business days** of the date of publication;
    c. keep all **compliance reports** publicly available on the **website** until this approval expires;
    d. exclude or redact **sensitive ecological data** from **compliance reports** published on the **website**; and
    e. where any **sensitive ecological data** has been excluded from the version published, submit the full **compliance report** to the **Department** within five **business days** of publication.

Note: The first **compliance report** may report a period less than 12 months so that it and subsequent **compliance reports** align with the similar requirement under state approval. **Compliance reports** may be published on the **Department**'s **website**.

Reporting non-compliance

13. The approval holder must notify the **Department** in writing of any: **incident;** non-compliance with the conditions; or non-compliance with the commitments made in **plans**. The notification must be given as soon as practicable, and no later than two **business days** after becoming aware of the **incident** or non-compliance. The notification must specify:
    a. any condition which is or may be in breach;
    b. a short description of the **incident** and/or non-compliance; and
    c. the location (including co-ordinates), date, and time of the **incident** and/or non-compliance. In the event the exact information cannot be provided, provide the best information available.
14. The approval holder must provide to the **Department** the details of any **incident** or non-compliance with the conditions or commitments made in **plans** as soon as practicable and no later than 10 **business days** after becoming aware of the **incident** or non-compliance, specifying:
    a. any corrective action or investigation which the approval holder has already taken or intends to take in the immediate future;
    b. the potential impacts of the **incident** or non-compliance; and
    c. the method and timing of any remedial action that will be undertaken by the approval holder.

Independent audit

15. The approval holder must ensure that **independent audits** of compliance with the conditions are conducted as requested in writing by the **Minister**.
16. For each **independent audit**, the approval holder must:
    a. provide the name and qualifications of the independent auditor and the draft audit criteria to the **Department**;
    b. only commence the **independent audit** once the audit criteria have been approved in writing by the **Department**; and
    c. submit an audit report to the **Department** within the timeframe specified in the approved audit criteria.
17. The approval holder must publish the audit report on the **website** within 10 **business days** of receiving the **Department's** approval of the audit report and keep the audit report published on the **website** until the end date of this approval.

Revision of action management plans

18. The approval holder may, at any time, apply to the **Minister** for a variation to an action management **plan** approved by the **Minister** under condition 4, or as subsequently revised in accordance with these conditions, by submitting an application in accordance with the requirements of section 143A of the **EPBC Act**. If the **Minister** approves a revised action management **plan** (RAMP) then, from the date specified, the approval holder must implement the RAMP in place of the previous action management **plan**.

Completion of the action

19. Within 30 days after the **completion of the action**, the approval holder must notify the **Department** in writing and provide **completion data**.

Part C - Definitions

In these conditions, except where contrary intention is expressed, the following definitions are used:

Business day means a day that is not a Saturday, a Sunday or a public holiday in the state or territory of the action.

Commencement / Commencement of the action means the first instance of any specified activity associated with the action.

Commonwealth Environmental Water Holder means as established under the *Water Act 2007* (Cth.) to manage water acquired by the Australian Government as part of a suite of national water reforms, including the Murray-Darling Basin Plan.

Completion data means an environmental report and spatial data clearly detailing how the conditions of this approval have been met. The **Department**'s preferred spatial data format is **shapefile**.

Completion of the action means all specified activities associated with the action have permanently ceased.

Compliance records means all documentation or other material in whatever form required to demonstrate compliance with the conditions of approval in the approval holder's possession or that are within the approval holder's power to obtain lawfully.

Compliance report(s) means written reports:

i. providing accurate and complete details of compliance, **incidents**, and non-compliance with the conditions and the **plans**;
ii. consistent with the **Department's** *Annual Compliance Report Guidelines* (2014);
iii. include a **shapefile** of any clearance of any **protected matters**, or their habitat, undertaken within the relevant 12 month period; and
iv. annexing a schedule of all **plans** prepared and in existence in relation to the conditions during the relevant 12 month period.

Department means the Australian Government agency responsible for administering the **EPBC Act**.

Department's Environmental Management Plan Guidelines means the *Environmental Management Plan Guidelines, Commonwealth of Australia*, 2014.

Drought Operations – Delivery of Peel Environmental Water Plan means the environmental management plan submitted to the **Department** on 20 April 2020 as Appendix C to the finalised preliminary documentation.

EPBC Act means the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

EPBC Act Environmental Offset Policy means *EPBC Act Environmental Offsets Policy, Commonwealth of Australia*, 2012.

Incident means any event which has the potential to, or does, impact on one or more **protected matter(s)**.

Independent audit: means an audit conducted by an independent and **suitably qualified person** as detailed in the *Environment Protection and Biodiversity Conservation Act 1999 Independent Audit and Audit Report Guidelines* (2019).

Monitoring data means the data required to be recorded under the conditions of this approval.

Minister means the Australian Government Minister administering the **EPBC Act** including any delegate thereof.

Murray Cod means the Murray Cod (*Maccullochella peelii*), listed as a vulnerable species under the **EPBC Act**.

NSW conditions of authorisation means the conditions set out in the NSW authorisation under the NSW *Water Supply (Critical Needs) Act 2019*.

Phase of operation means each discrete phase of the action as specified in Table 1 in the **Drought Operations – Delivery of Peel Environmental Water Plan**.

Plan(s) means any of the documents required to be prepared, approved by the **Minister**, and/or implemented by the approval holder and published on the **website** in accordance with these conditions (includes action management plans and/or strategies).

Protected matter means a matter protected under a controlling provision in Part 3 of the **EPBC Act** for which this approval has effect.

Sensitive ecological data means data as defined in the Australian Government Department of the Environment (2016) *Sensitive Ecological Data – Access and Management Policy V1.0.*

Shapefile means location and attribute information of the action provided in an Esri shapefile format. Shapefiles must contain '.shp', '.shx' , '.dbf' files and a '.prj' file that specifies the projection/geographic coordinate system used. Shapefiles must also include an '.xml' metadata file that describes the shapefile for discovery and identification purposes.

Silver Perch means the Silver Perch (*Bidyanus bidyanus*), listed as a critically endangered species under the **EPBC Act**.

Suitably qualified ecologist means a person who has professional qualifications and at least three (3) years of work experience designing and implementing surveys and management plans for **Murray Cod** and **Silver Perch**, and can give an authoritative assessment and advice on the presence and environmental requirements of **Murray Cod** and **Silver Perch** applying relevant protocols, standards, methods and literature.

Suitably qualified person means a person who has professional qualifications, training, skills and/or experience related to the nominated subject matter and can give authoritative independent assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods and/or literature.

Technical advisory group means the Technical Advisory Group established as specified in the **Drought Operations – Delivery of Peel Environmental Water Plan** and is the same as the Peel Environmental Water Technical Advisory Group established under the **NSW conditions of authorisaton**.

Website means a set of related web pages located under a single domain name attributed to the approval holder and available to the public.

Appendix 2 – Peel River Habitat Survey

PEEL RIVER | HABITAT MAPPING

Habitat mapping and prioritisation report prepared for WaterNSW

Peel River between Chaffey Dam and Tamworth

NSW Department of Primary Industries

Peel River habitat mapping and prioritisation report prepared for WaterNSW

More information:

Rodney Price, Murray Darling Unit / Dubbo

Acknowledgments:

Funding: WaterNSW

Methodology: Sam Davis, Rodney Price

Fieldwork: Rodney Price, David Ward and Evan Knoll

Reporting: Rodney Price, Jimmy Walker

Executive Summary

Extensive aquatic and riparian habitat mapping was completed along a 56 km reach of the Peel River between Chaffey dam and Jewry Street Weir in Tamworth. The mapping focused on specific physical features relating to river health and management, establishing a comprehensive baseline dataset. Information from the habitat mapping was used to identify relationships between river flow height and habitat availability and prioritise candidate sites for complementary works and protection.

The project area was divided into 56 reaches each 1 km in length, with a Decision Support System (DSS) applied to provide aquatic habitat condition rankings. The DSS analysed the abundance and extent of the following habitat features: refugia, Large Woody Habitat (LWH), native revegetation, aquatic macrophytes, rootballs, benches, exotic species, erosion, stock damage and barriers to fish passage. The DSS provided a prioritisation matrix to guide rehabilitation activities and indicated that Management Reaches 1, 11, 12 and 18 are in better ecological health and as such, are considered to be the highest priority reaches for intervention, maintenance and protection. Further analysis also supported the remediation of poor health reaches adjacent to better health reaches, such as undertaking exotic species control in Management Reaches 13 and 14.

Flow relationships were assessed for LWH, in-channel benches and rootballs. Features were separated into Flow Gauging Zones (FGZ) according to the nearest water gauging station. The height recorded for each feature was used to calculate the inundation level in megalitres per day (ML/d). This data will be used to prioritise what environmental assets can be effectively targeted in delivery of water for the environment to benefit native fish and other water dependant biota in the Peel River project area. Analysis revealed that significant proportions of LWH (88.8%) and rootballs (96%) remain inundated under cease-to-flow or very low flow conditions, whilst 22.4% of in-stream benches are inundated under very low flows, increasing to 25.1% at baseflows and increasing to 87.3% inundation under small pulses. The rapid increase in bench inundation between baseflow and small pulse conditions indicate a high potential to greatly increase in-stream productivity utilising relatively low quantities of water for the environment from Chaffey Dam.

Priority actions for on-ground investment in the project area include controlling exotic species, implementing a re-sagging program and remediation of in-stream barriers. Exotic species were recorded in every Management Reach and covered 19% of the total project area. Willows were among the most prolific of exotics, at one point forming a fish passage and flow barrier in the main channel. The control of these and other weed species, commensurate with obligations under the *Biosecurity Act 2015* on both Crown and private land is recommended. LWH loading was an average of 18.1 per km, recorded as the lowest within the Namoi Valley. A resnagging program should prioritise refugia sites and Management Reaches of better ecological health. Five manmade barriers to fish passage were recorded within the project area, requiring flows between 340 ML/d to 1,100 ML/d to drown out. Remediation works should be considered for the existing barriers, particularly redundant road crossings.

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Contents

List of Tables

List of Figures

Introduction

Native freshwater fish stocks have suffered alarming declines since European settlement. Many of the freshwater habitats for juvenile and adult fish have been degraded or lost through urban, industrial and agricultural development. Habitat deterioration is now widely accepted as having a major influence on the decline in diversity and abundance of native fish. As such, aquatic habitat rehabilitation has become progressively more important in New South Wales as the community recognises the benefits of natural, healthy systems. The DPI Fisheries - Murray Darling Unit is at the forefront of aquatic habitat repair and flow management and has a lead role in rehabilitating fish habitat and native fish populations in NSW.

Aquatic habitat is an important element of the riverine environment and consists of stream features such as bed substrates, hydrology, pools, riffles, floodplains, instream and bank vegetation (macrophytes and riparian vegetation), Large Woody Habitat (LWH), undercut banks and rocky outcrops (Rutherford *et al.* 2000). These features along with billabongs, paleochannels, benches and off stream wetlands provide spawning, feeding, shelter and recruitment sites essential for the survival of aquatic fauna such as native fish.

This project aims to identify and quantify in-aquatic habitat and threatening processes within the Peel River from Chaffey Dam to Jewry Street Weir. As part of this project, habitat features were recorded, digitised and then analysed to benchmark aquatic habitat condition and provide natural resource managers with a guide for rehabilitation measures along the river. This approach provides a reach based assessment score that may be used as a guide for investment in river protection and rehabilitation activities that focus on protecting and linking areas with the highest habitat value. The assessment is based on the concept that it is generally more cost-effective to protect reaches of stream that are in good condition (or the best first) than to rehabilitate severely degraded areas (Rutherford *et al.* 2000; Lovett and Edgar, 2002) and expand restoration outward from protected sites (Frissell and Bayles, 1996; Ziemer, 1997; Beechie *et al.* 2008).

Additionally, commence to inundate heights were calculated for key habitat features, including benches, LWH, billabongs, paleochannels and off-stream wetlands, related to the nearest gauging station. Accurate estimates of likely inundation of aquatic habitat from planned and natural flows can be extracted from this information, providing an understanding of when the ecological benefits that these features offer become available in the system. This relationship information can be used to prioritise future water management actions.

Project scope and objectives

Project objectives

The project identified riparian, in channel and aquatic habitat features along the Peel River between Chaffey Dam and Tamworth. The main objectives of this project included:

- document the riparian features of the identified reaches of the target valleys, focusing on native vegetation, weed infestation and existing management activities;
- document the stream bed morphology, including the location, length and depth of pools that may act as drought refugia, the instream habitat features and LWH loading;
- calculate commence-to-inundate flow thresholds of select habitat features where feasible, including benches, cobble/riffle runs, wetland entry/exit points, aquatic macrophytes, and bank overhangs;
- identify and map threats and processes that may influence the extent and condition of aquatic and riparian habitat features, and;
- make recommendations to protect and improve stream health, threatened species habitat enhancement, weed control and improve other habitat features as a guide for rehabilitation measures along the river.

Study area

The Peel River catchment covers approximately 11% of the Namoi valley and contributes an average annual volume of 280,000 ML to the valley (Green et al 2011, DPIE 2020). The Peel River begins upstream from Nundle and extends approximately 210 km downstream to its junction with the Namoi River (Green 2011). The Peel River regulated by Chaffey Dam, located approximately 42 km upstream of Tamworth, which delineates the unregulated and regulated sections of the river. In regards to this report, “regulated” refers to a river with regulatory structures that can control the release of downstream flows.

The project area begins at the Chaffey Dam outlet and follows the regulated Peel River 56 km downstream to Jewry Street Weir, Tamworth (Figure 1). The project area includes the junctions of three major tributaries, including the Cockburn River, Dungowan Creek and Goonoo Goonoo Creek. These tributaries exhibit perennial flows in most years, with all other creeks having a more ephemeral nature (NSW Government 2010). The river within the project area is confined within a narrow valley, but widens downstream with the as more tributaries connect. Flow is typically lotic within the project area, although there are a series of small lentic weir pools (Figure 2; Figure 3).

The landscape surrounding the Peel River has been highly modified as a result of grazing, cropping and intensive agriculture, forestry, mining and urban development. Irrigated pastures comprise a large proportion of irrigated land use (approximately 80%), and approximately 85% of irrigated agriculture is concentrated around the regulated Peel River, downstream of Chaffey Dam (Green et al. 2011).

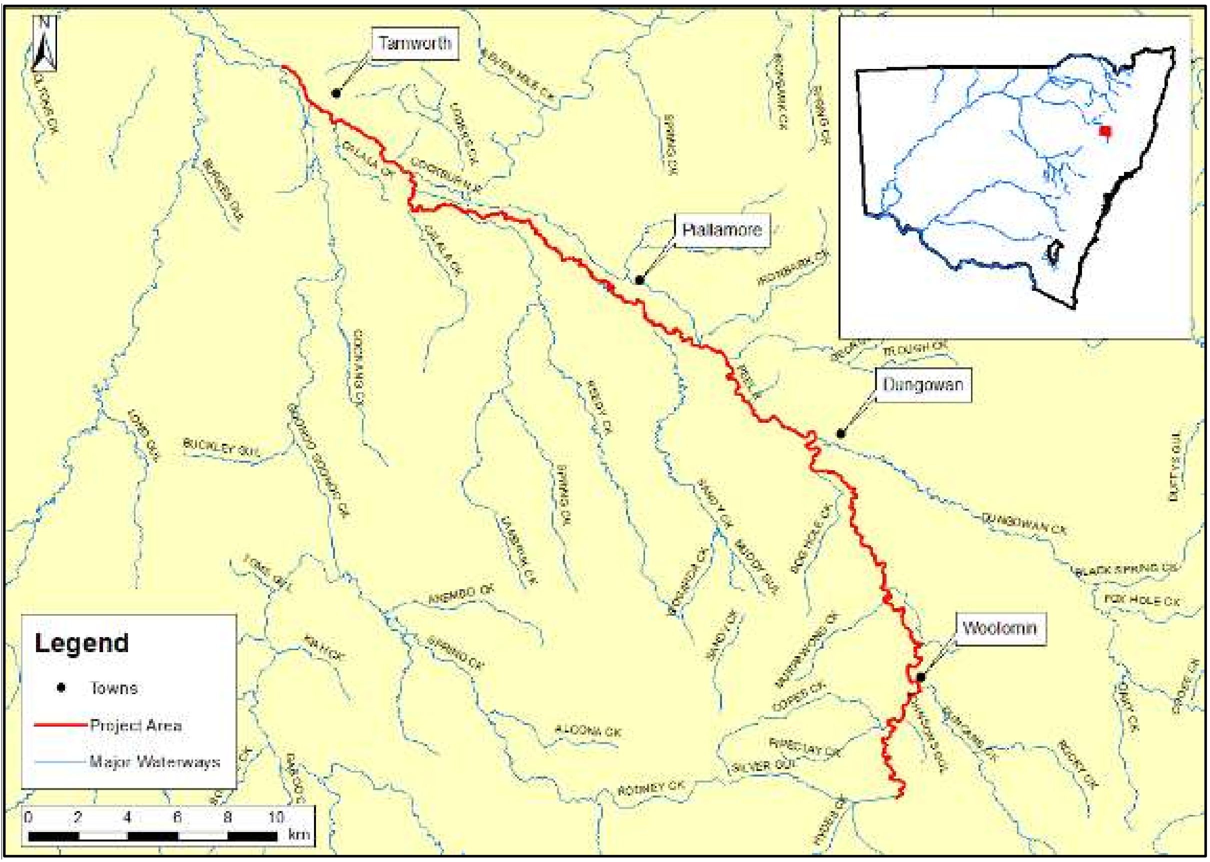

Figure 1: Peel River habitat mapping project area: from Chaffey Dam to Jewry Street Weir

Figure 2. Example of a lotic section of an upper reach of the study area, approximately 10 km downstream of Chaffey Dam

Figure 3. Example of a weirpool section of the study area, looking upstream from Scott Street Bridge, Tamworth

Hydrology

Constructed in 1979, Chaffey dam regulates the Peel River with a total capacity of 100,500 ML (CSIRO 2007). Chaffey dam regulates 41% of inflows and a number of unregulated tributaries also contribute to net outflow; including the 40% from the Cockburn River and 10% from Dungowan and Goonoo Goonoo Creeks (DPIE 2020).

The overall effect of Chaffey Dam is the dampening of flow variability downstream, by storing water during times of high flow and controlling releases to service irrigation orders and township water supply. Green et al. (2011) found that since its construction, areas downstream of the dam have spent a lower proportion of time in flood, high flows or under very low flows. While mitigating the risk of prolonged cease to flow events, this lack of flow variability can have adverse effects on river health including loss of habitat for floodplain specialist native fish, reduced productivity and reduced spawning opportunities for flow-pulse specialist native fish (Sharpe and Stuart 2018). Water for the environment may be utilised to attempt to restore natural flow variability within regulated systems.

Chaffey Dam supplies an Environmental Contingency Allowance of up to 5,000 ML per annum (varies according to available water determination), whilst additional Planned Environmental Water (PEW) provisions state that a minimum 3 ML/day flow must be released from Chaffey Dam, except when a release of greater than 3 ML/day is required to meet basic landholder rights and access licence extraction (NSW Government 2010). The Commonwealth Environment Water Holder (CEWH) also hold Held Environmental Water (HEW) entitlements in the Peel valley, with the current registered entitlement of 1,257 ML (as of 31 October 2020; DEE 2020), the availability of which is based on annual water determination and water allocations as per other water users.

The Peel River interacts with local groundwater dynamics, modelling work shows that 70% of groundwater pumped from Peel valley bores originates from direct leakage from the Peel River

(Broadstock 2009). Likewise, localised extraction of groundwater for irrigation could have an adverse effect on Peel flows and refuge pool duration (O'Rourke 2010).

The Peel River provides habitat to a variety of native freshwater fish (Table 1), with some of these species being listed as Threatened under the *Fisheries Management Act 1994.* Distribution modelling, fish surveys and literature have indicated the presence of threated species in the project area including: Silver Perch, Freshwater Catfish and Southern Purple Spotted Gudgeon (NSW DPIE 2020). A number of exotic species also exist in the project area, including Common Carp, Redfin, Eastern Gambusia and Goldfish.

Table 1: Fish Species present within the Peel Project Area (adapted from NSW DPIE 2020)

Functional group	Species	Distribution
Flow pulse specialist	Golden Perch	🌢
	Silver Perch*+	💧
	Spangled Perch	🌢
River specialist (a)	River Blackfish*	🌢
	Murray Cod+	🌢
	Darling River Hardyhead	🌢
River specialist (b)	Freshwater Catfish*+	💧
	Southern Purple Spotted Gudgeon +∞	💧
Floodplain specialist	Southern Purple Spotted Gudgeon +∞	💧
Generalist	Mountain Galaxias	🌢
	Unspecked Hardyhead	🌢
	Carp Gudgeon	🌢
	Australian Smelt	🌢
	Bony Herring	🌢
	Murray-Darling Rainbow Fish	🌢

*BWS target key species. +Threatened species or population (state and or Cth). ∞SPSG may occur in both floodplain wetlands and in-channel. EWRs should be managed to cater for these species in both habitats. 💧 Indicates species are expected to occur based on MaxEnt modelling (NSW DPI 2016). 🌢 Indicates catch records (NSW DPI 2012) and or Australian Museum Records exist.

Methodology

Habitat mapping

Habitat mapping was undertaken by NSW DPI staff and used methods developed and implemented for similar projects in the Barwon-Darling Rivers (NSW DPI, 2015), Macquarie River (Industry and Investment, 2010), Horton River (NSW DPI, 2013), Little River system (NSW DPI, 2014) and Lachlan River (NSW DPI, 2016).

Project staff completed two field trips to collect the project data, consisting of 10 days of mapping, between 10/8/2020 to 14/8/2020, and 30/8/2020 to 5/9/2020. Over this period, flow in the Peel River was influenced by regulated flows released from Chaffey Dam and unregulated tributary flows. Mapping was generally planned to avoid the peak of these flows so that features were not 'drowned out' or obscured when mapping. Flow ranged from 18 ML/day to 260 ML/day during mapping. There are four available water gauges in the project area: U/S Paradise Weir (419070), Tamworth W/S (419070), Piallamore (419015), and D/S Chaffey (419045).

Two methods of field data collection were used:

- GPS-equipped GIS interface for features above the water surface
- Bluetooth equipped sonar to identify refugia

These two devices enabled the collection of all information necessary to record habitat features and their condition in both aquatic and riparian areas along the Peel River corridor in the project area. Two 'Trimble Nomad', Personal Digital Assistant devices equipped with GPS and GIS interface software were used to record all relevant features visible above the water surface using the three spatial feature classes of point, line and polygon (Table 2).

To improve data collection efficiencies and standards, unique scripting codes were written by NSW DPI technicians to provide prescribed data entry dropdown menus specific to project requirements. This enabled all essential attributes for each recorded feature to be entered into the spatial database at the time of data collection.

Table 2. Typical features recorded on PDAs during habitat mapping.

Point Features	Line Features	Polygon Features
LWH– alignment, complexity, width, length, height	Fencelines	Exotic riparian vegetation – type & extent
Pumpsites: pipe diameter		Aquatic vegetation – type & extent
Wetland/ anabranch: height of entry/exit point and changes in substrate		Erosion
Barriers to fish passage- barrier type, headloss		Stock management
General points of interest (e.g. boat launch sites, recreation)		Instream features– benches with height; refuge habitat with extent and depth, riffles

The data was georectified for analysis, with associated metadata providing the information necessary to perform the reach assessments and scoring (Figure 4).

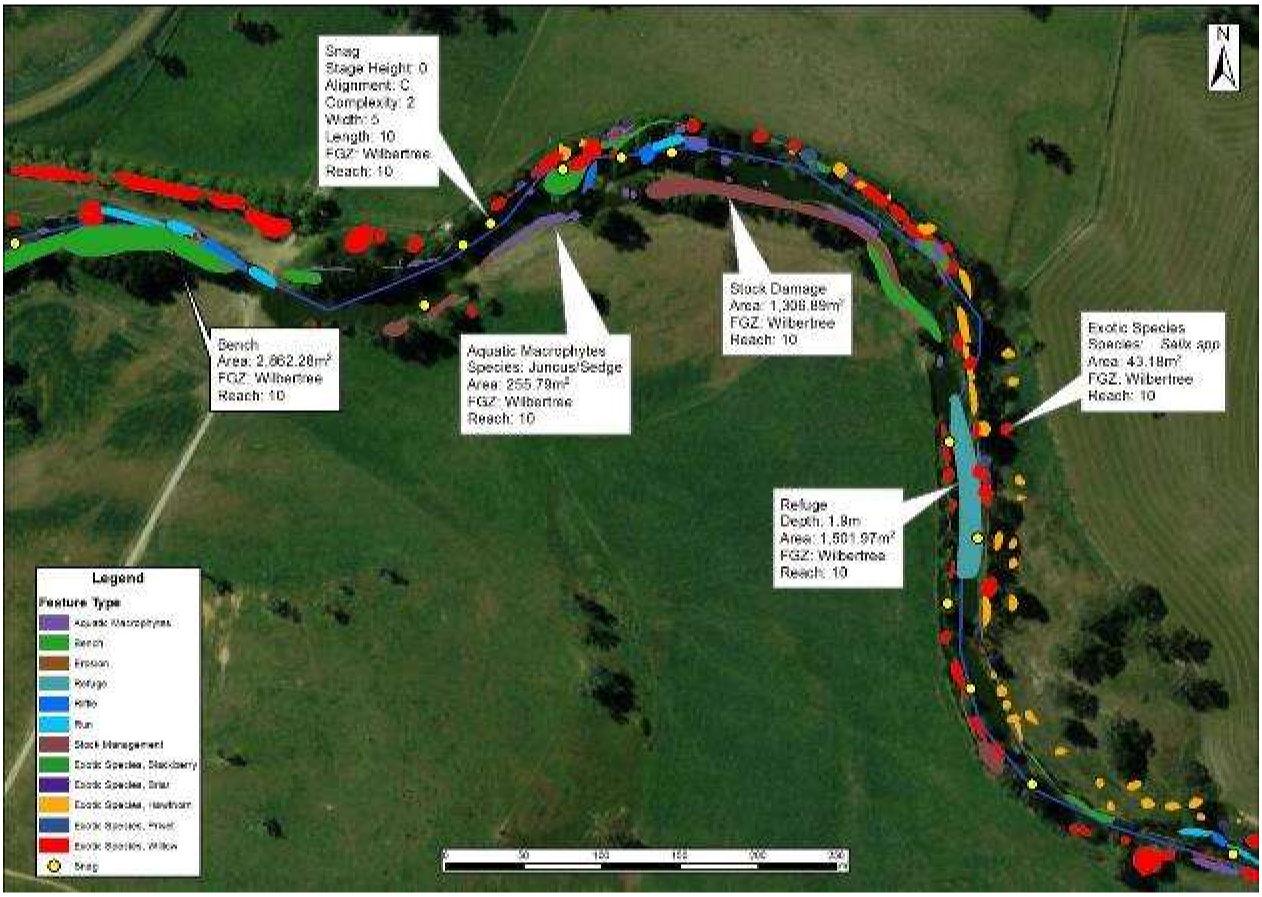

Figure 4. Example of feature types with key attributes used in reach assessment and prioritisation from previous habitat mapping on the Cudgegong River.

Flow relationships

To determine the inundation dynamics of LWH, benches and rootballs in the study area, the commence-to-inundate height (CTIh) was recorded during the habitat mapping component using methods established by Boys (2007) and Southwell (2008) (Figure 5).

The method involved the use of a Haglof Vertex Laser VL400 hypsometer, which uses ultrasonic signals to obtain the range (r) of the habitat feature from the instrument and combines this with the angle of measurement obtained from a tilt sensor (a) to trigonometrically calculate the height of the feature above or below the instrument eye level (o) to determine the height above the water level (CTIh).

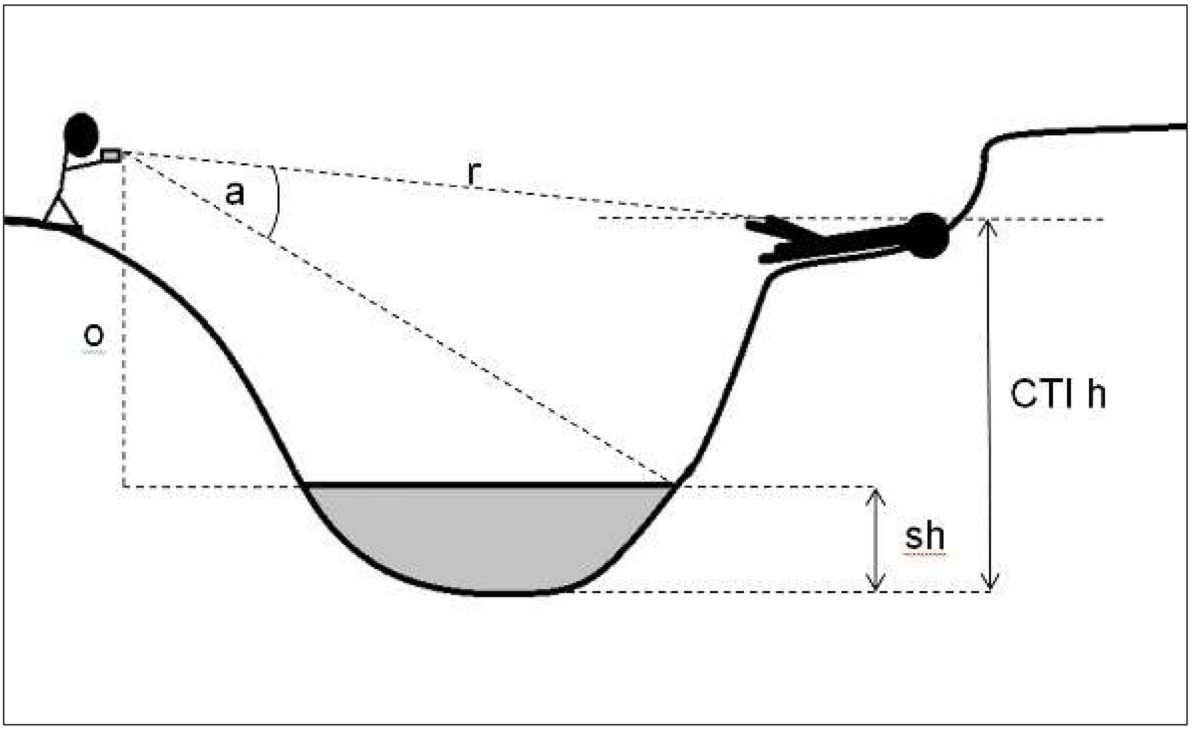

Figure 5. Schematic of methods used to calculate CTI heights of key habitat features along the Peel River

LWH were recorded at the discretion of the observer, taking into account the geomorphology and knowledge of flow levels through the section of river; if a snag was deemed too high to be inundated it was not recorded. The stage height (sh) of the river on the day of mapping was obtained from the relevant gauging stations (U/S Paradise Weir, Tamworth W/S, Piallomore and D/S Chaffey). The inundation height was then turned into an inundation level by using the known height/discharge curve for the nearest gauging station (Southwell, 2008).

It should be noted that due to the large distances encompassed in each of the Flow Gauging Zones (FGZ), there is likely to be a decrease in confidence of accuracy in the inundation volume that is proportional to the distance from the relevant flow gauging station. Another potential factor that impacts on calculating inundation volumes is the presence of weir pools, which may influence results due to the persistently elevated water levels approximately 1 km up stream.

Refuge pools

Aquatic refugia (refuge pools) were recorded in the field by observing stream geomorphology, when a pool was presumed to be deep enough to be considered a refuge the depth was measured using Bluetooth-equipped sonar operated from the bank using a handline and smartphone. This was then verified using GIS, flow data and sonar records to check the bed depth up and downstream of a potential refuge pool site. This process removed any errors that were encountered from the increased depth during high flow periods, allowing the variable flow conditions encountered during the assessment to be considered in the refuge identification process.

Decision Support System

A Decision Support System (DSS), developed by NSW DPI to determine reach scale conservation management priorities, was employed to assess individual habitat features on a management reach basis and scored based on overall health.

Reach grouping and ArcMap toolbox

The first stage of the DSS involved dividing the study area into management reaches (each 1 km in length) in ArcMap by grouping the attributes and splitting the relevant segments of the river line feature class (Figure 6). This management reach scale limits the potential for introducing masking issues that may influence a reach condition score and allows effective, targeted threat management and habitat protection activities.

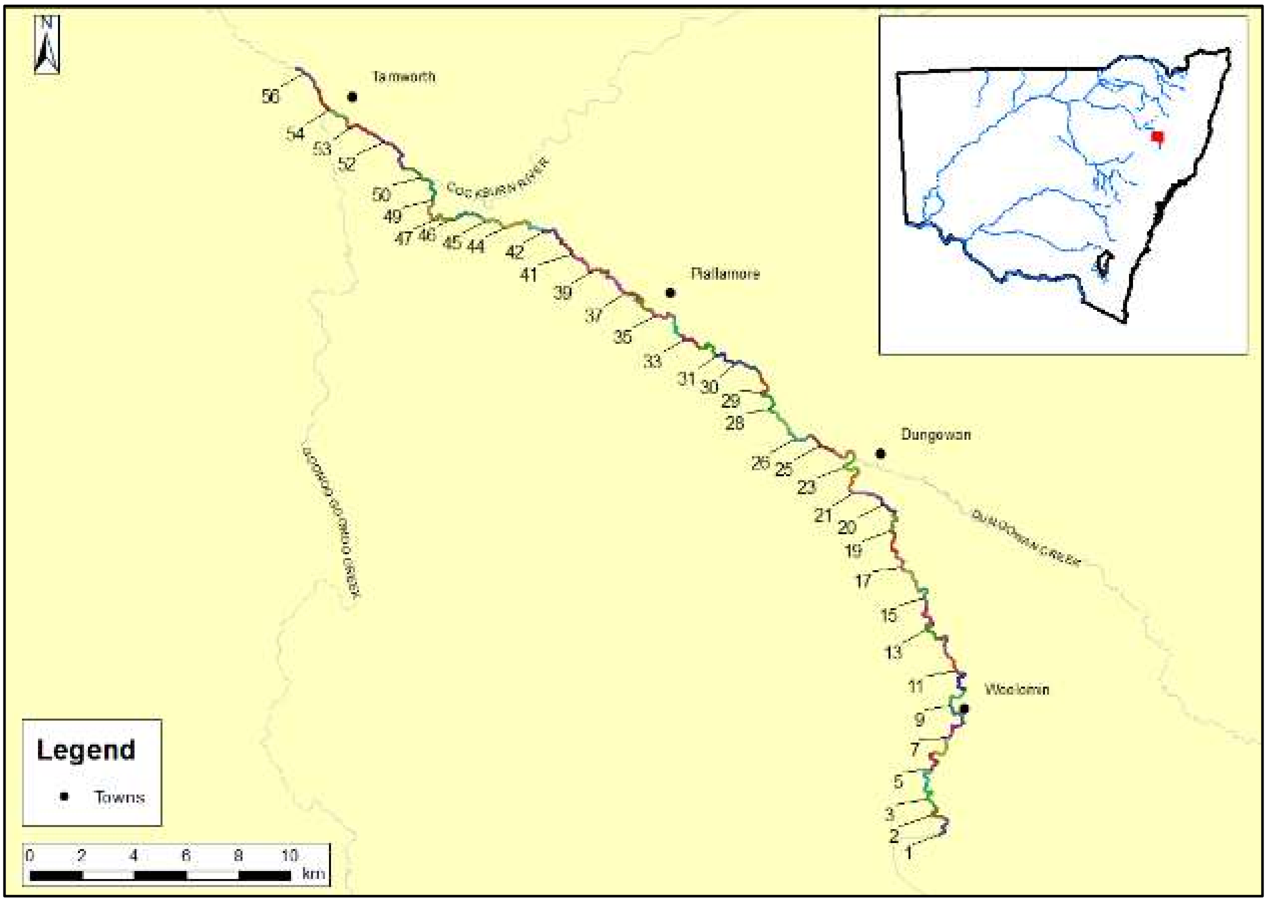

Figure 6. Management Reaches for Chaffey Dam to Jewry Street Weir project area

The second stage of the DSS involved a suite of tools in the ArcMap Toolbox, developed by NSW DPI, containing a series of comprehensive scripts (six in total). These tools use Python programming language to automate the interrogation of ESRI feature classes and identify and summarise individual habitat features by management reach. Some data could not be interrogated using the tool, such as barriers to fish passage, in which case manual collation was necessary.

The tool firstly ran through the river line feature class in ArcMap and consecutively numbered the management reaches, prompting manual correction in the event of gaps in the spatial data. All data points in each habitat feature class that were being interrogated (Appendix A lists the GIS data that was used in the assessment) were assigned the relevant reach number (involving conversion to point feature classes and/or snapping to the river line feature class), then summarised by reach and tabulated. This tabulation was then exported into a series of tab-delimited text files, which in turn were manually imported into the Microsoft Excel® based Prioritisation Module. The format of data output for each habitat feature class is shown in Table 3.

Table 3. The format of data output from the ArcMap Toolbox

Habitat feature class	Output format
LWH	Number, width, length, complexity
Instream refugia	Number, depth, surface area
Exotic plant species	Number, area
Erosion	Number, area
Stock damage	Number, area

Prioritisation Module

The final stage of the DSS involved the development of a Microsoft Excel® based Prioritisation Module to determine conservation and management priorities. Outputs from the ArcMap tool and manual data collation were imported into the Prioritisation Module for individual habitat features for each 1 km management reach. The total bank area within each management reach was calculated to be 4 ha, based on a 20 m corridor along both banks of the river.

A prioritisation scheme was then developed to assist in ranking both individual habitat features and overall reach condition. The scheme helps determine priorities by ranking reaches based on the following categories:

- LWH – total number of LWH
- Instream refugia – total refuge depth (sum of the deepest point of each refuge pool)
- Regeneration of native canopy species - total extent within the reach (ha)
- Exotic plant species – total extent within the reach (ha)
- Erosion – total extent within the reach (ha)
- Stock damage – total extent within the reach (ha)
- Barriers to fish passage – taking into account barrier type, headloss, distance and quality of upstream and downstream habitat, the number of downstream barriers and ancillary uses of the structures

Treatment of habitat features for prioritisation

Data for habitat features differ in terms of type and scale (that is, unit and magnitude) and it is important to note that variables measured at different scales will not contribute equally to the analysis (BioMedware, 2013). For example, LWH data collected as individual points with the count per management reach ranging from 25 to 180, will outweigh native regeneration, exotic plant species, erosion and stock damage that was collected in area units, typically ranging in magnitude from 0.01 to 0.2 ha.

Transforming the data to comparable scales can alleviate this issue by equalising the range of the data. Data were standardised in the prioritisation module to have a mean of 0 and standard deviation of 1 by the function: (value – mean)/standard deviation so that comparison of spatial trends in the parameters could be made on the same scale, then weighted according to relative influence of the habitat feature on protection and rehabilitation priorities as follows:

$$HabitatFeatureScore_{Weighted} = \frac{(habitatfeaturetotal - mean)}{StDev} \times Weight$$

where habitat feature total is the sum of habitat features within each management reach.

The habitat feature scores (weighted) were then combined to generate reach condition scores in terms of overall health and condition. Reach condition scores were subsequently ranked and coded into three groups - better health, moderate health and poorer health - based on the reach condition score and the number or extent of various habitat features. Important to note that there is not an even split into these groups, and; a highly degraded project area may have no reaches coded as being in better health.

Landholder liaison

Landholders were contacted where possible and advised about the mapping. Permission was obtained to travel through and leave vehicles parked on their properties. Subsequent opportunistic landholder liaison occurred by mapping staff as fieldwork progressed through the study area.

Results and Discussion

The habitat feature dataset developed through the fieldwork was processed to identify priority reaches to assist natural resource managers and landholders to make strategic decisions about investment in on-ground works. The DSS provides a ranking of reaches based on overall reach condition score. The main drivers for setting priorities include available instream habitat for native fish, such as refugia and LWH, and impacting habitat features such as the presence of introduced plants, erosion, stock access and damage.

The measures necessary to protect and rehabilitate aquatic habitat condition can be determined by interrogating the relative impact of individual habitat feature scores. These can provide natural resource managers with a clear direction on how to proceed with aquatic and riparian habitat restoration and protection initiatives.

Additionally, the flow relationship data can be used to infer the amount of aquatic habitat that will be inundated at different flows. This provides water managers with the opportunity to set targets for the inundation of specific levels of habitat with appropriate water management. This could be used to specifically target critical breeding habitat and associated ecological functions for identified native fish species and river health.

Native riparian vegetation condition

The riparian area varied in its condition from sections that were well intact with a range of vegetation age cohorts across species, including numerous areas of regeneration, to heavily weed infested sites with species such as privet which, in places formed an impenetrable wall of mid-storey vegetation.

The canopy layer was typically dominated by river oak (*Casuarina cunninghamiana*) in the upper reaches and a combination of river oak and river red gum (*Eucalyptus camaldulensis*) in the mid to lower reaches. Native regeneration was noted throughout the project area including both river oak, river red gum and other Eucalyptus species on higher banks above the flood level, however not all reaches contained regeneration.

Native mid storey species were generally rare but when present consisted of river bottle brush, and various wattle species. Native pasture grasses and understorey species were present in some areas, but were often dominated by understorey weed species.

There were a total of 16 significant gaps in native vegetation in the riparian corridor (>50 m) recorded during the mapping. No clear pattern emerged in the distribution of these gaps, however Management Reach 26 had three significant gaps in its 1 km reach. Additionally, there were numerous areas within the project area where the riparian vegetation would be considered in poor condition with high densities of exotic species amongst native canopy species.

Several cleared sections of riverbank were protected from constant stock grazing pressure and appeared to be managed effectively to maintain groundcover. However, most of the river was not protected and unmanaged grazing pressure was having an obvious impact on riparian and aquatic health. Unprotected areas of riverbank were observed to be in a relatively poor condition with stock damage creating areas devoid of vegetation and susceptible to, or already impacted by erosion. River widening as a result of this was apparent in some locations.

There was a clear difference observed during field surveys with regard to how livestock are managed on different properties. Boundary fences provided a point of contrast and there were many occasions where dense grass cover was found on one side, while bare eroded ground was on the other.

Some of the recommendations outlined in the report, especially those that relate to managing livestock access to the riparian zones, will provide the opportunity for native vegetation to regenerate naturally once grazing and trampling pressure is reduced in these areas.

Exotic plant species

A wide variety of exotic plant species were identified throughout the study area. Table 4 lists the main species of exotic plants identified and their biosecurity duty for the North West LLS Region and/or Weed of National Significance status. From 1 July 2017, the *Biosecurity Act 2015* and its subordinate legislation replaced ten other Acts, increasing efficiency and decreasing regulation in responding to biosecurity risks. It provides a streamlined statutory framework to protect the NSW economy, environment and community from the negative impact of pests, diseases and weeds.

The cumulative total coverage of exotic species was 42.5 ha or approximately 19% of the study area. There was a large increase in the extent of exotic plant species around the township of Tamworth, extending from reach 48 to 56 (Figure 7). Management Reach 49 had the highest extent of exotic plant species with a total of 2.3 ha or 57% coverage. The lowest density was exhibited in Management Reach 19, with a coverage of 0.1 ha or 3% of area.

The three species with the highest extent were privet (9.4 ha), weeping willow (6.2 ha) and elm (2.7ha). A unique exotic feature class (mixed exotics) was attributed to areas infested with a composition of privet, weeping willow and green cestrum, as well as mixed exotics covering an area of approximately 12.6 ha. Other emerging species included ossage orange, blackberry, green cestrum, peppertree and giant bamboo grass. The prevalence of willow throughout the project area is particularly concerning, with one infestation in Management Reach 37 forming a barrier to flow and fish passage.

Table 4. Exotic plant species recorded in the study area

Common Name	Scientific Name	Biosecurity duty (under the Biosecurity Act 2015)
Acer	*Acer negundo*	Not listed
African boxthorn	*Lycium ferocissimum*	Weed of National Significance Prohibition on dealings** *Protect primary production lands that are free of African boxthorn*
Balloon vine	*Cardiospermum grandiflorum*	General Biosecurity Duty*
Blackberry	*Rubus fruticosus* species aggregate	Weed of National Significance Prohibition on dealings** Whole of region: The plant should not be bought, sold, grown, carried or released into the environment. Exclusion zone: Land managers should mitigate the risk of new weeds being introduced to their land; land managers should mitigate spread from their land. Core infestation: Land managers reduce impacts from the plant on priority assets An exclusion zone is established for all lands in the region, except the core infestation area comprising the Gwydir Shire council, Liverpool Plains Shire council and Tamworth Regional council
Black locust/ False locust	*Robinia pseudoacacia*	General Biosecurity Duty

Elm	*Ulmus spp.*	Not listed
Fig	*Ficus carica*	Not listed
Giant reed/ Giant Bamboo Grass	*Arundo donax*	General Biosecurity Duty
Green Cestrum	*Cestrum parqui*	Whole NSW: General Biosecurity Duty* Regional Recommended Measure: Land managers should mitigate the risk of new weeds being introduced to their land. Land managers should mitigate spread from their land. The plant should not be bought, sold, grown, carried or released into the environment. An exclusion zone is established for all lands in the region, except the core infestation area comprising the Gunnedah Shire council, Gwydir Shire council, Narrabri Shire council and Tamworth Regional council
Honey locust	*Gleditsia triacanthos*	General Biosecurity Duty* Regional Recommended Measure Whole of region: The plant should not be bought, sold, grown, carried or released into the environment. Exclusion zone: Land managers should mitigate the risk of new weeds being introduced to their land; the plant should be eradicated from the land and the land kept free of the plant. Core infestation: Land managers reduce impacts from the plant on priority assets An exclusion zone is established for all lands in the region, except the core infestation area comprising the Gunnedah Shire council; Narrabri Shire council and Tamworth Regional council
Madeira Vine	*Andredera cordifolia*	General Biosecurity Duty* Regional Recommended Measure Land managers should mitigate the risk of new weeds being introduced to their land. Land managers reduce impacts from the plant on priority assets.
Ossage Orange	*Maclura pomifera*	Not declared
Palm	*Arecaceae spp.*	Not declared
Paulownia	*Paulownia tomentosa*	Not declared
Pepper tree	*Schinus molle*	Not declared
Poplar	*Populus spp.*	Not declared
Prickly pear	*Optuntia spp.*	Weed Of National Significance General Biosecurity Duty* Prohibition on dealings**
Privet - broad-leaf Privet – European Privet - narrow-leaf	*Ligustrum lucidum* *Ligustrum vulgare* Ligustrum sinense	Regional Recommended Measure Exclusion zone: urban areas of Bathurst Council, Blayney Council, Lithgow Council, Oberon Council, and Orange City Council Whole region: The plant should not be bought, sold, grown, carried or released into the environment. Exclusion zone: The plant is prevented from flowering and fruiting. Land managers should mitigate spread from their land. Land managers should mitigate the risk of the plant being introduced to their land.
Sweet briar	*Rosa rubiginosa*	General Biosecurity Duty* Regional Recommended Measure Land managers should mitigate the risk of new weeds being introduced to their land. Land managers should mitigate spread from their land. The plant should not be bought, sold, grown, carried or released into the environment.
Tobacco bush	*Solanum mauritianum*	General Biosecurity Duty*
Tree of heaven	*Ailanthus altissima*	General Biosecurity Duty*
Wandering Jew	*Tradescantia fluminensis*	General Biosecurity Duty*
Willows	*Salix spp.*	General Biosecurity Duty*

		Prohibition on dealings** All species in the Salix genus have this requirement, except Salix babylonica (weeping willows), Salix x calodendron (pussy willow) and Salix x reichardtii (sterile pussy willow)
White cedar	*Melia azedarach*	Not declared
Wild African olive	*Olea euoprea* subsp. *cuspidata*	General Biosecurity Duty* Regional Recommended Measure Land managers should mitigate the risk of new weeds being introduced to their land. Land managers should mitigate spread from their land. The plant should not be bought, sold, grown, carried or released into the environment.

***General Biosecurity Duty**
All plants are regulated with a general biosecurity duty to prevent, eliminate or minimise any biosecurity risk they may pose. Any person who deals with any plant, who knows (or ought to know) of any biosecurity risk, has a duty to ensure the risk is prevented, eliminated or minimised, so far as is reasonably practicable.
****Prohibition on dealings**
Must not be imported into the State or sold

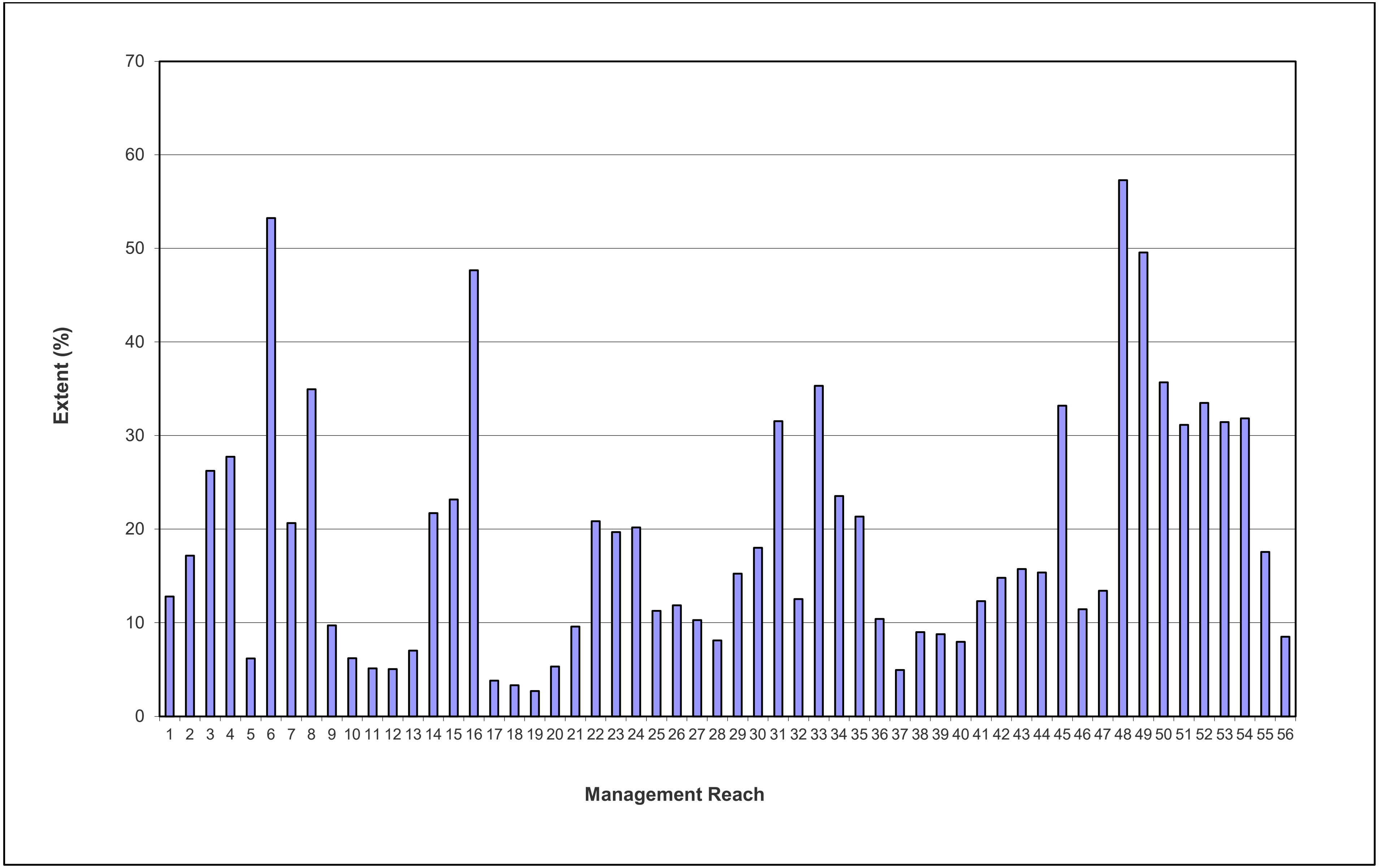

Figure 7. Extent of exotic plant species by Management Reach

Aquatic habitat

Large Woody Habitat

LWH plays an important part in structuring community composition and primary production in river ecosystems, and is a critical part of the habitat structure in many freshwater systems (Nicol *et al.* 2004). Instream LWH provides spawning sites, territorial markers, sheltered pockets and scour holes that are favoured by many native species, while preventing erosion through bank stabilisation (Bond & Lake 2005; Humphries & Walker 2013).

Availability

LWH loading was recorded throughout the study area to identify the availability of instream woody habitat to aquatic fauna. Details recorded included the number, complexity, orientation and CTIh of each LWH.

In the 56 km of river channel that was surveyed, a total of 1,014 LWH were recorded, with an average loading per reach of 18.1 LWH/km. LWH loading appeared to decrease moving downstream, with the lowest abundances in the reaches surrounding Tamworth, from Management Reach 46 to 56 (Figure 8). Other reaches with notably low loading were Management Reaches 6, 15 and 34.

Management Reaches with particularly heavy loading were 4, 23, 24 and 31. Management Reach 23 and 24 are immediately upstream and downstream of the Dungowan Creek confluence. Management Reach 4 and 31 had no obvious cause of their relatively high loading.

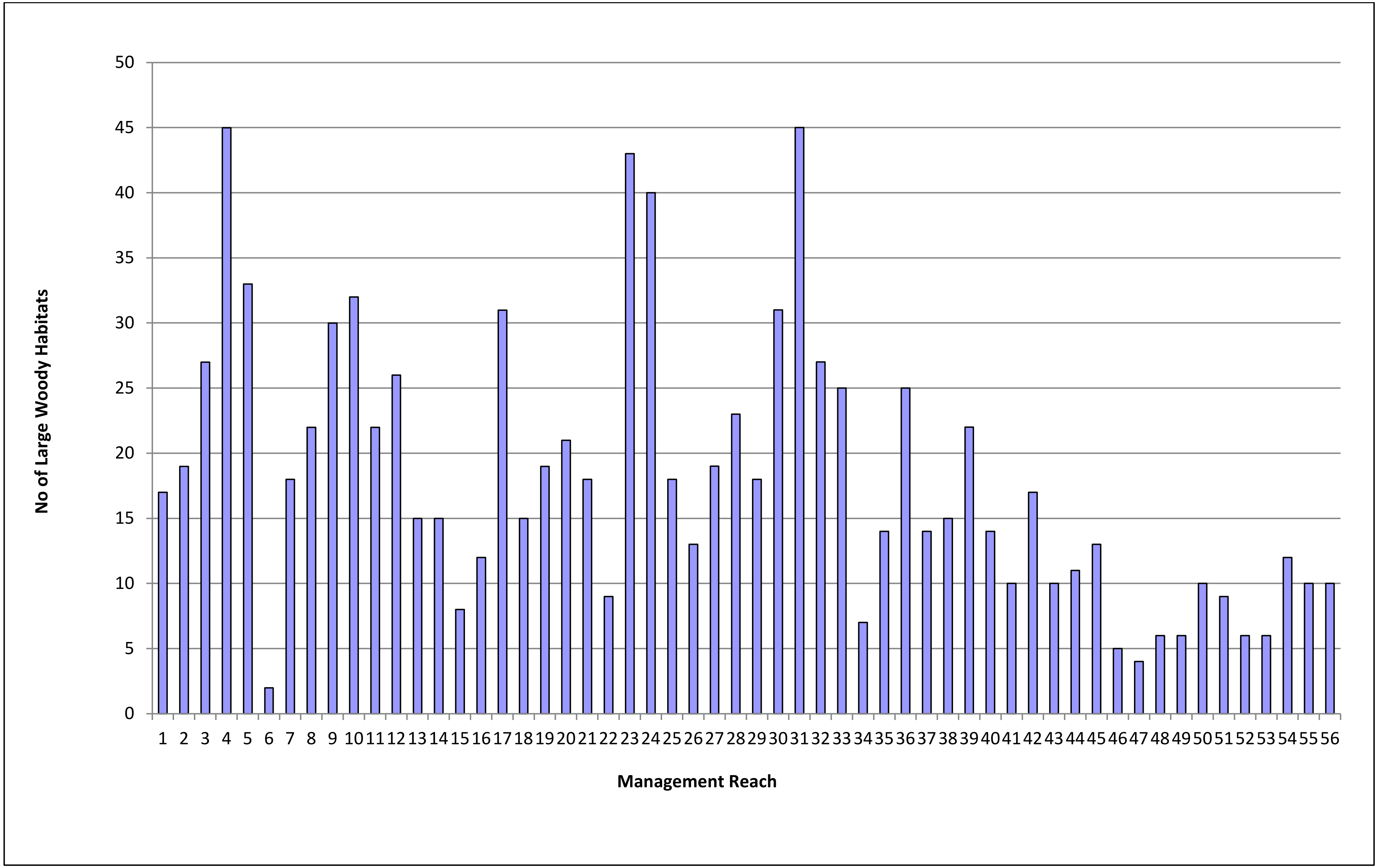

Figure 8. Distribution of LWH by Management Reach

Complexity

There is an ecological basis for differentiating LWH based on size and complexity (Boys, 2011). More complex LWH provide greater protection to aquatic fauna from predators and flow, are more useful as breeding sites and have a greater influence on the creation and maintenance of refuge habitat (Boys pers. comm. 2017; Figure 9).

Grade 1: Woody habitat stand - single trunk or branch

Grade 2: Woody habitat stand – trunk or branch with one or two branchings.

Grade 3: Woody habitat stand – one or more trunks with multiple branchings

Grade 4: Woody habitat stand – highly complex complete tree with multiple branchings, or accumulation of separate branchings

Figure 9. Structural complexity classes used to describe LWH during field work

The majority of LWH throughout the study area was simple, with Class 1 and Class 2 complex LWH dominating (52.4% and 36.2%, respectively), with a smaller proportion rated as Class 3 (8.8%) and Class 4 (2.7%) (Table 5). This high proportion of low-complexity snags appears to be relatively consistent across the project area, with the reaches with the highest loadings dominated by Class 1 and 2 LWH (Figure 9; Figure 10).

The highly valuable Class 4 LWHs were predominantly found in the upper reaches (Management Reaches 1 – 21). No Class 4 LWH were recorded between reach 22 – 55, indicating a significant absence of complex habitat. The proportions of complexity classes within the project area is similar to that observed in other habitat mapping projects such as the Cudgegong River and Lower Darling River (NSW DPIE 2020; NSW DPIE in press.).

Table 5. Number and percentage of LWH by complexity in the project area

Complexity	Number	Percentage (%)
1	531	52.4
2	367	36.2
3	89	8.8
4	27	2.7

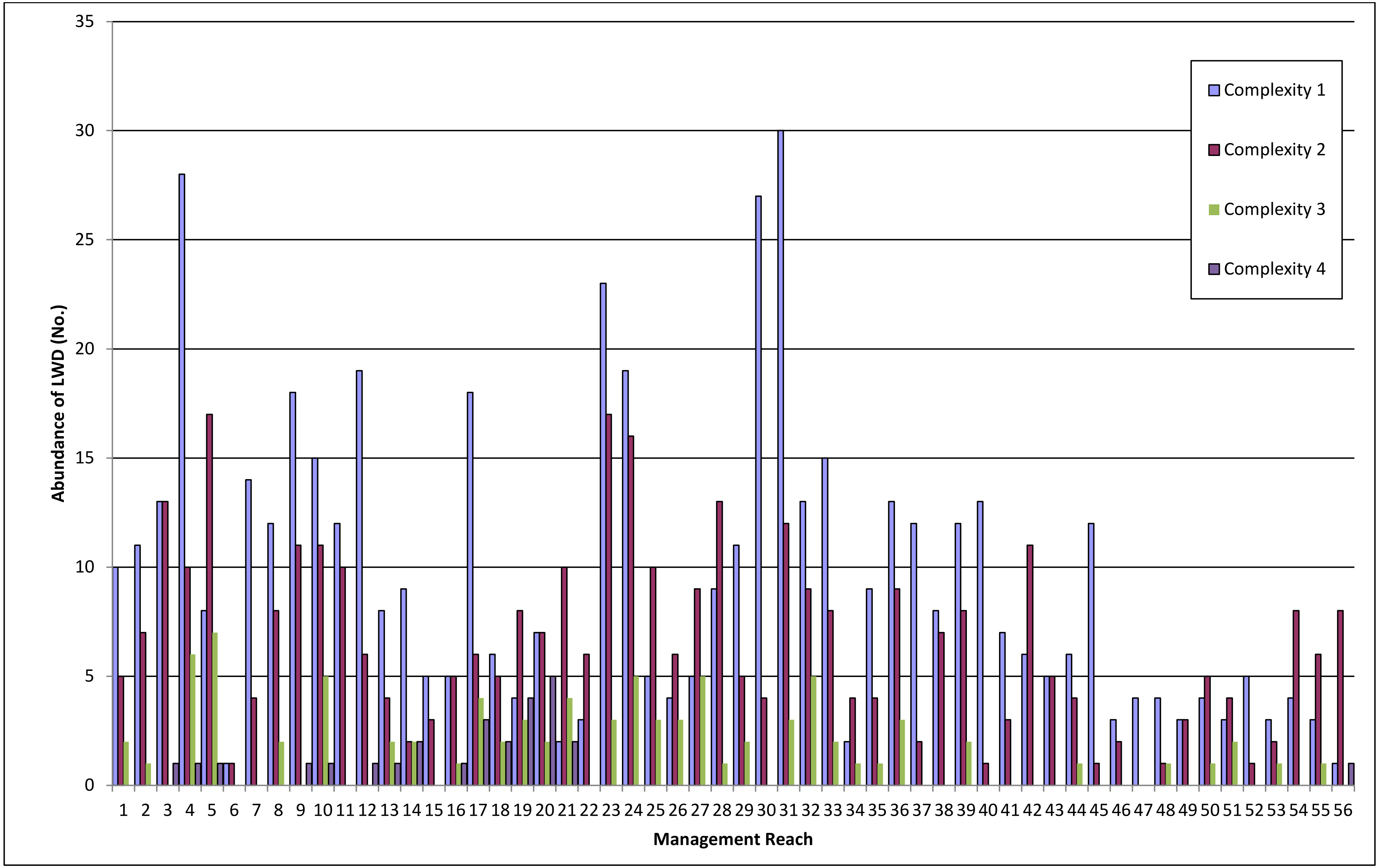

Figure 10. Abundance and complexity of LWH by Management Reach

Large Woody Habitat Score

A large amount of metadata was recorded about individual LWH during the habitat mapping. As well as distribution and complexity, alignment, width, length and stage height were also recorded. All these features can be used to determine a ‘snag score’ that when combined with other LWH in a management reach, can further assist in guiding future investment. For example, a LWH with a perpendicular alignment and larger size is preferred habitat of Murray Cod (pers. comm., John Koen, Arthur Rylah Institute, Vic. DELWP). Based on this analysis, Management Reach 31 had the highest relative snag score, representing a high loading, complexity, size and alignment (Figure 11); while Management Reach 6 had the lowest relative snag score. The snag score has been incorporated into the Management Reach assessment and prioritisation tool.

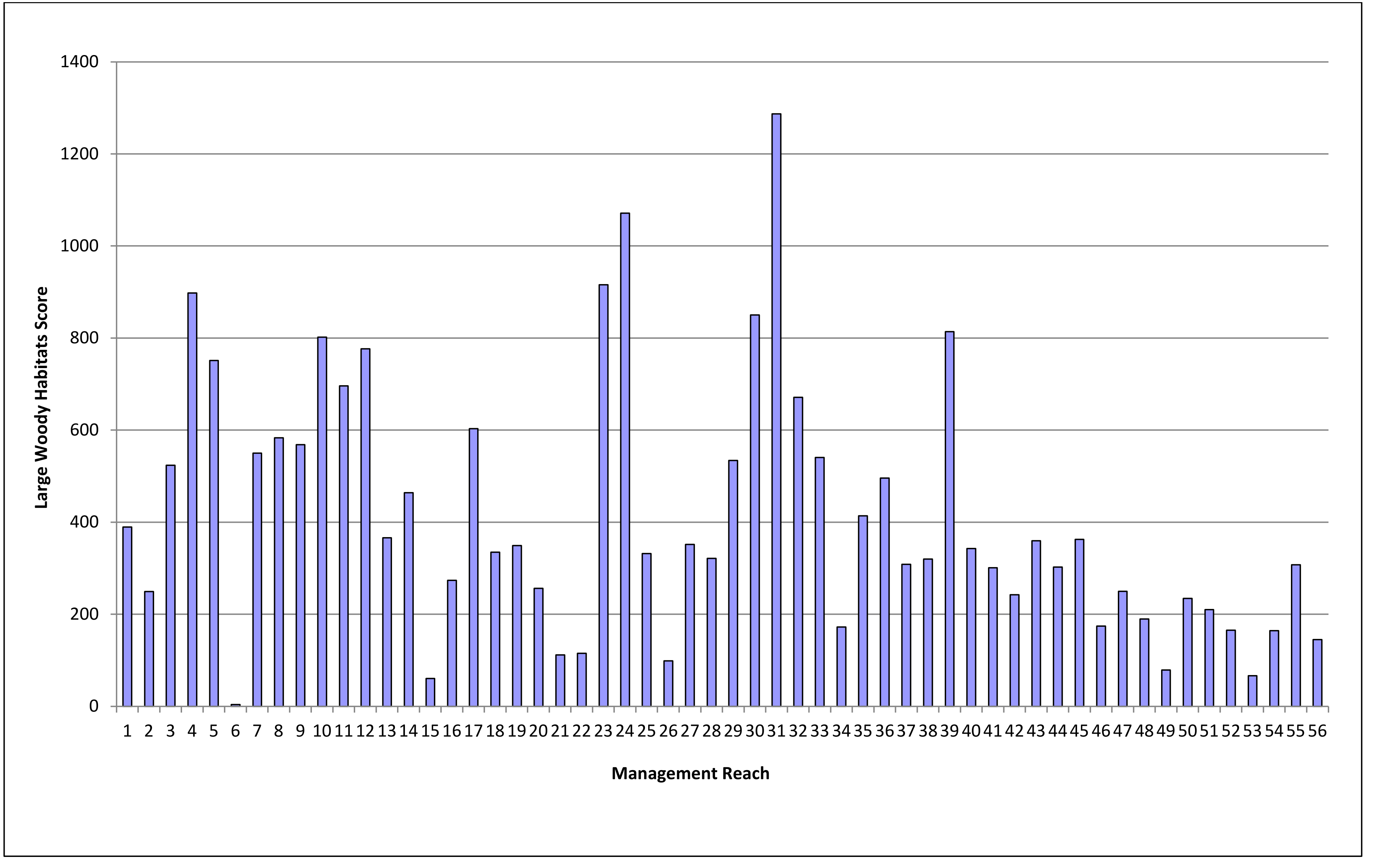

Figure 11. Total LWH score for each Management Reach

Rootballs

Rootballs were defined as undercut/exposed root-masses of large trees located within the river channel (Figure 12). When inundated, rootballs provide important habitat to a range of terrestrial and aquatic species. Bank overhangs are often associated with rootballs and provide important cover and have been found to be used by Murray Cod as breeding sites upstream (Gavin Butler pers comm).

A total of 50 rootballs were recorded within the project area, with an average loading of 1.12 rootballs per km. The distribution of rootballs was uneven across the project area, with rootballs absent from numerous Management Reaches (

Figure 13; Figure 14). The highest abundances of rootballs occurred in Management Reaches 1 (7), 5 (5) and 8 (5).

Figure 12: Example of an undercut rootball habitat recorded in the project area

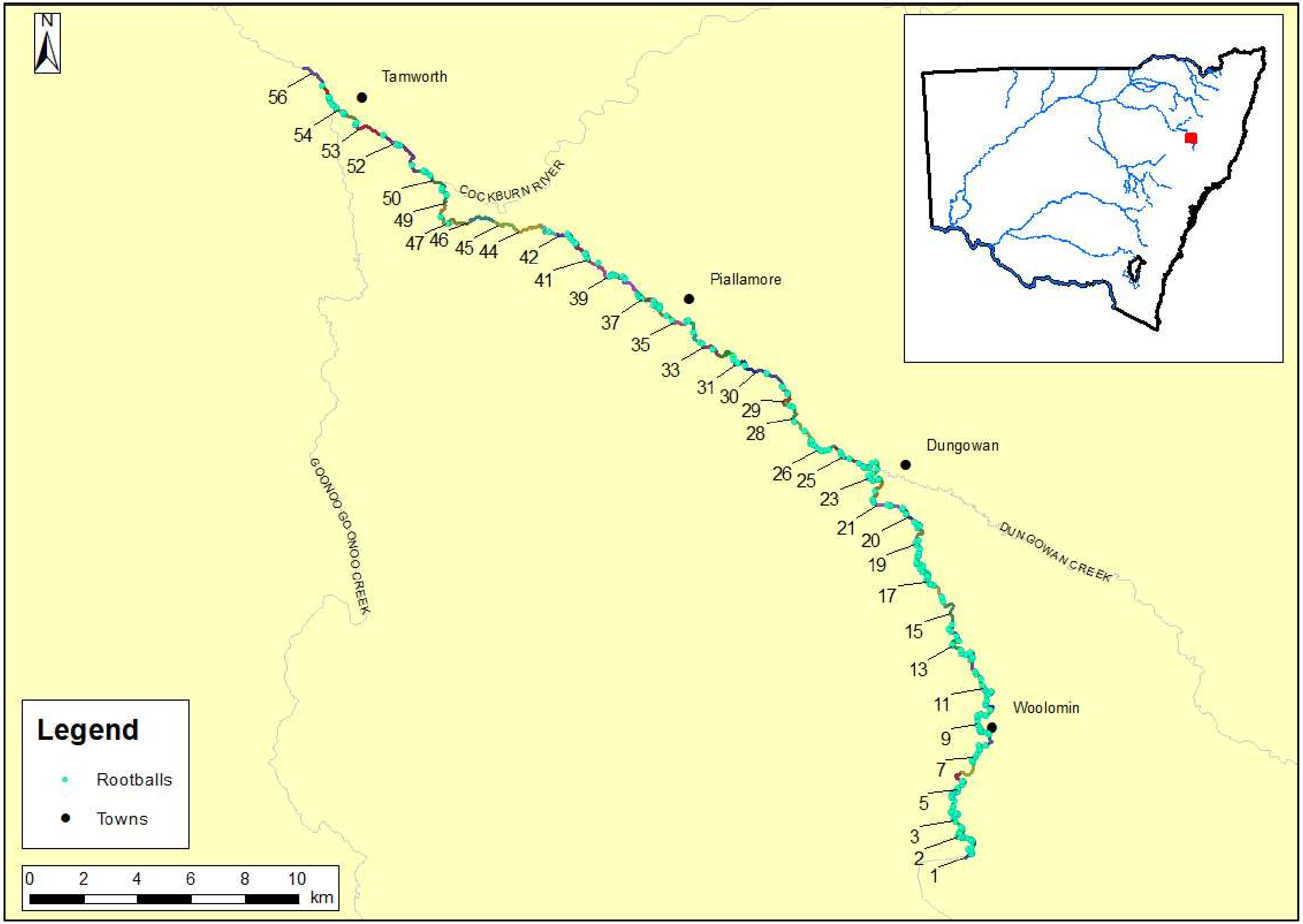

Figure 13: Location of rootballs within the project area

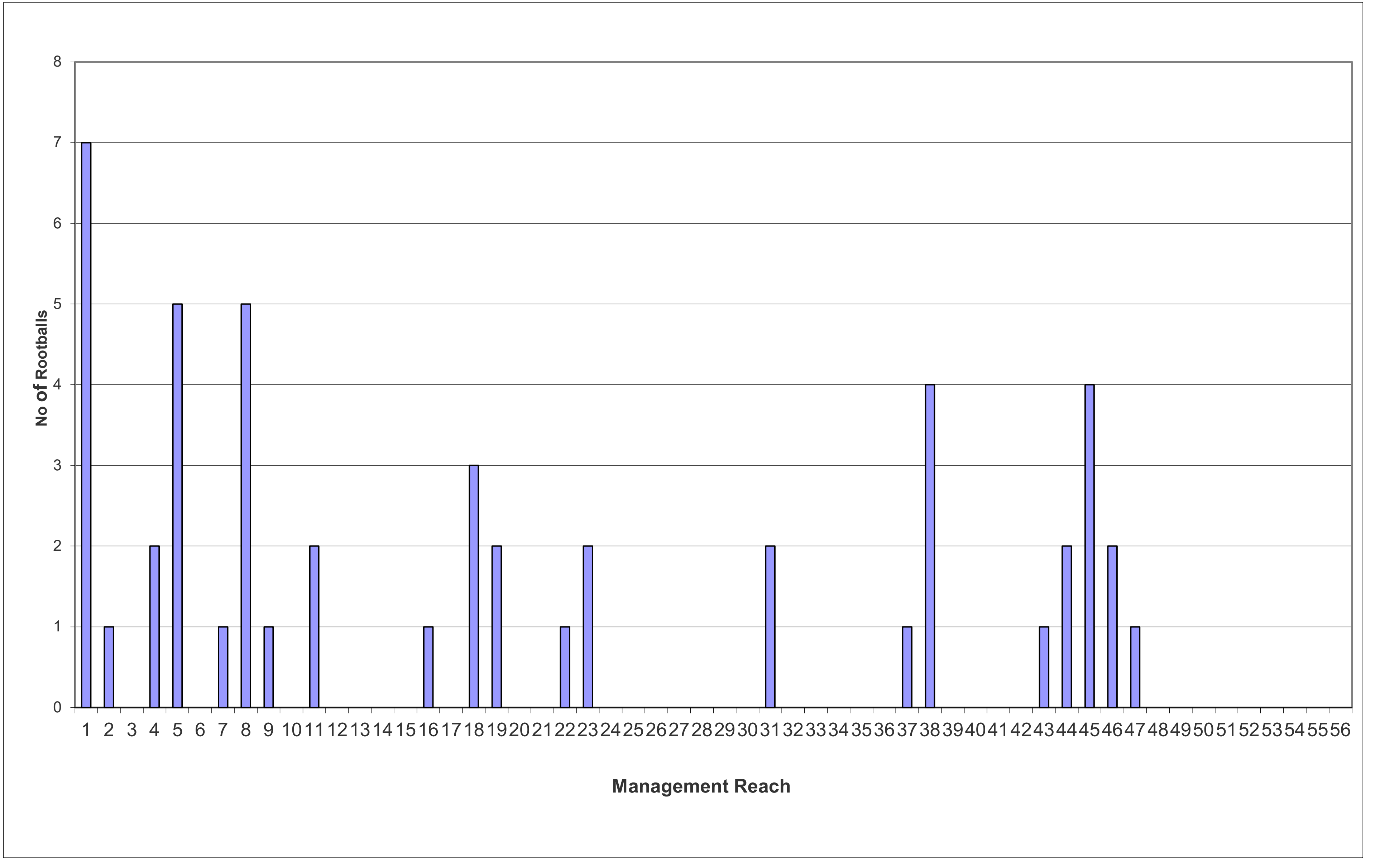

Figure 14: Distribution of rootballs by Management Reach

Drought refugia

Sections of river channel that are deep, relative to the rest of the channel (Figure 15), provide refugia for aquatic biota and hence are critical to the resilience of aquatic ecosystems (Reid *et al.* 2016). Drought refugia were weighted according to this value. It is recognised that a lack of drought refugia could lead to local extinctions of aquatic species, particularly if barriers to fish passage prevent recolonisation.

For the Peel River Habitat Mapping project, refuge areas were defined as areas of water greater than 1.5 m in depth during low flow conditions. Along the 56 km study area,19 areas of refugia were identified (Figure 16). The highest number of refuge areas was recorded in Management Reach 42 (3), 43 (2), 53 (2), and 54 (2) (Figure 16). The average depth of refugia was 2.3 m across the project area. The deepest refuge in the project area was 7.9 m deep and located immediately downstream of Chaffey Dam in Reach 1, (Figure 17).

The habitat feature total for refugia within each Management Reach was calculated as the combined depth of refuge pools at the deepest point (in metres) (Figure 17). This approach does not take into account other health characteristics such as the quality of refuge habitat, shape and surface area, but focuses on the presence of available refuge habitat using total depth as a measure of the persistence of refuge habitat to support resident native fish populations through extended dry periods. Management Reach 1 had the highest combined depth (Figure 17). The Peel River is highly influenced by the local groundwater dynamics, with large quantities of water leaking into local aquifers (O'Rourke 2010). As such, refugia resilience and duration may be impacted if local aquifers are reduced from prolonged cease to flow conditions or excessive irrigation extraction.

Figure 15.Example of fully inundated refuge habitat

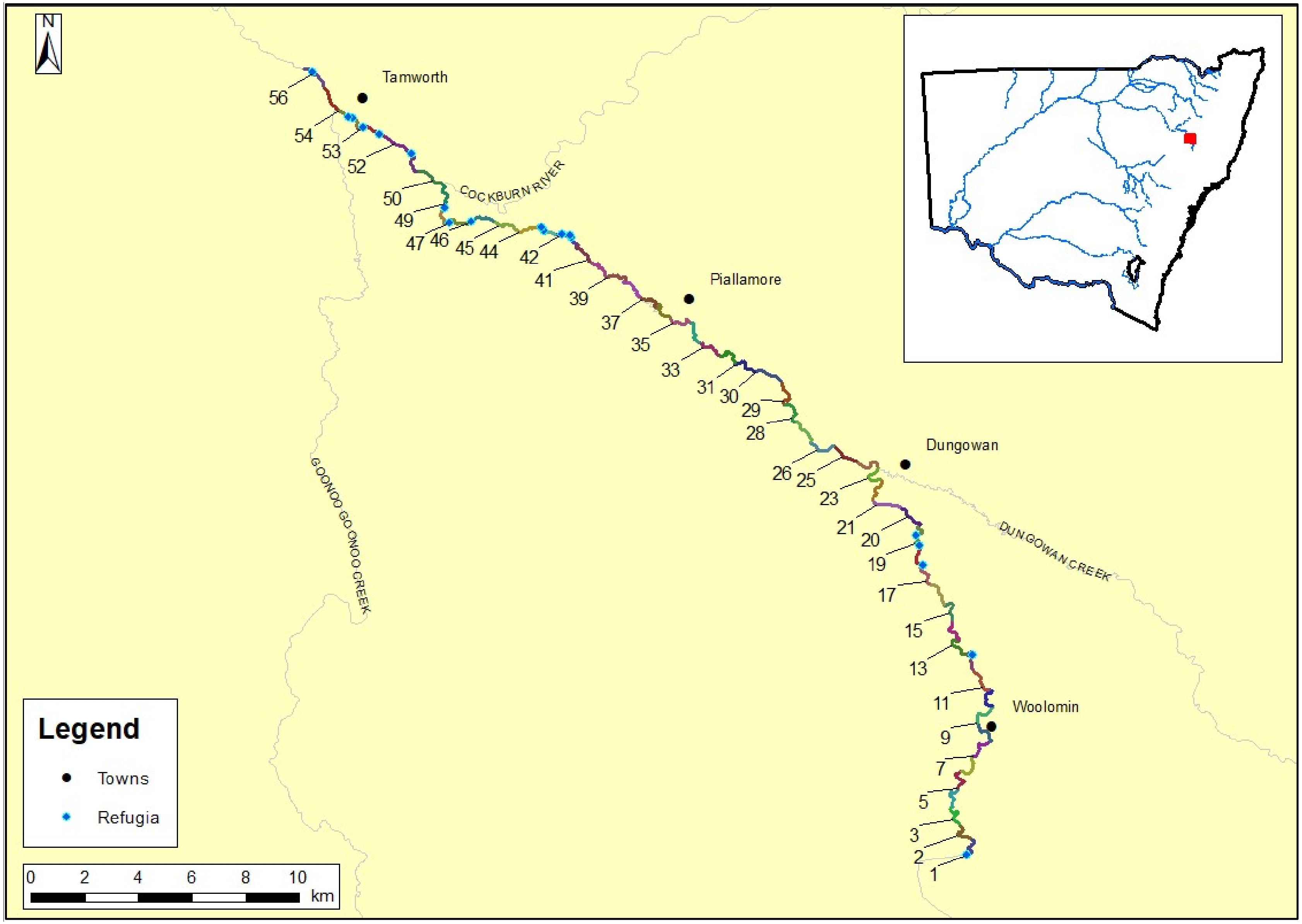

Figure 16. Refuge habitat availability in project area

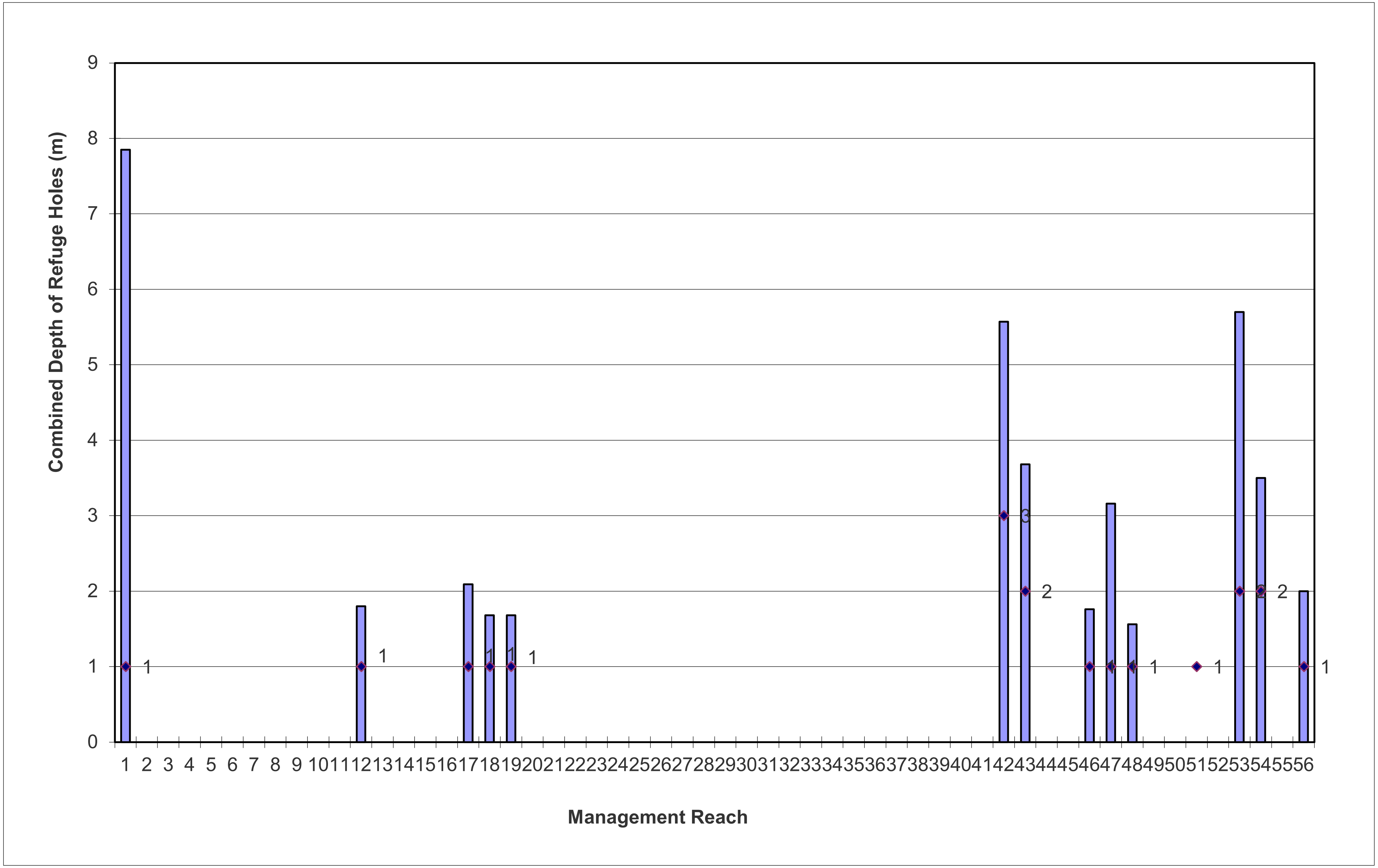

Figure 17.Total combined depth and total count (diamond) of refugia in each Management Reach

Benches

Benches are identified as areas of relatively flat sections within the main channel that play an important function in the aquatic environment by enhancing the diversity of habitat and contributing to productivity processes (NSW DPI, 2015; Figure 18). Benches are an actively accreting fine-grained, bank attached feature within the river channel that influence flow and provide variation in water depth (Vietz *et al.* 2007).

There were 259 benches in the project area covering a total 10.0 ha (Figure 19; Figure 20; Figure 21). Management Reaches 4, 17 and 18 had the greatest number of benches with 13, 12 and 12 respectively. The average area of benches within the project area was 0.03 ha, with Management Reach 52 and 17 having the greatest area of benches at 0.72 and 0.68 ha respectively. No benches were recorded in Management Reaches 15, 44, 45 and 46. The absence of exposed benches observed in Management Reaches 44, 45 and 46 may be due to the raised water heights due to the influence of Calala Gauging Weirpool (0.4m).

The substrate of observed benches was dominated by cobble consolidated (52% of area), silt consolidated (12.7%) and gravel consolidated (22%) (Table 6). Other substrates were observed including cobble, gravel, sand consolidated, silt, sand and rock consolidated. Notably, consolidated substrates accounted for 92% of all bench area. Consolidation refers to a bench that has been stabilised by established terrestrial vegetation, typically as a result of a reduction in frequency and magnitude of flood events. The high prevalence of consolidated benches within the project area is the result of flow dampening by Chaffey Dam. Green et al. (2011) observed that areas downstream of Chaffey Dam have spent a lower proportion of time in flood or high flow and reduced proportion of time under low flows. Therefore, it is likely that many of the benches would have been dynamic and productive, prior to the construction of Chaffey Dam in 1979.

Table 6: Count and total area of bench substrate types within the project area

Substrate type	Number	Total area (ha)	Percent of total area (%)
Cobble Consolidated	116	5.18	52.0
Silt Consolidated	45	1.26	12.7
Gravel Consolidated	44	2.20	22.0
Cobble	32	0.54	5.4
Gravel	15	0.55	5.5
Sand Consolidated	3	0.10	1.0
Silt	2	0.01	0.1
Sand	1	0.01	0.1
Rock Consolidated	1	0.11	1.1

Figure 18. Example of a bench in the project area

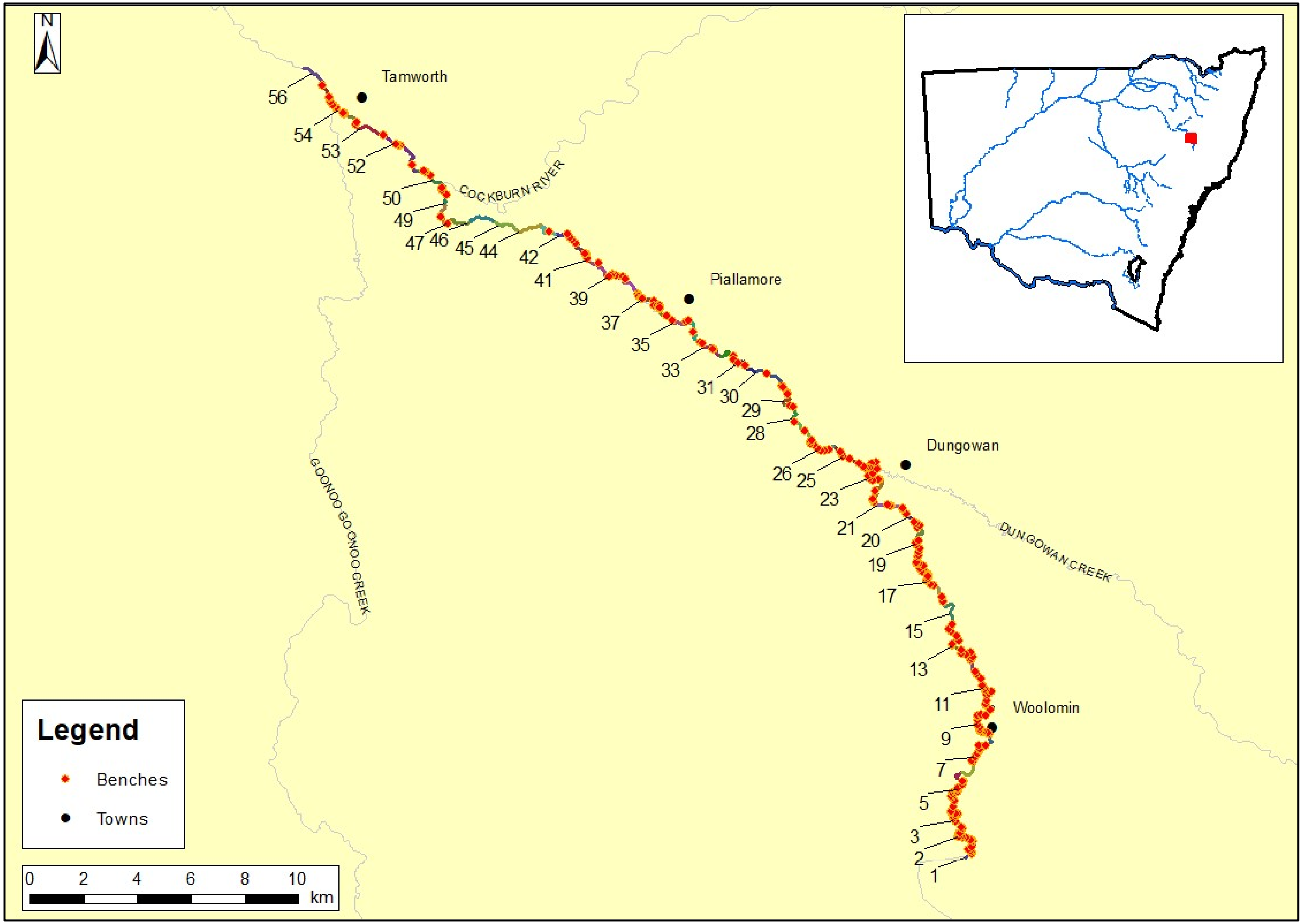

Figure 19. Locations of benches in the project area

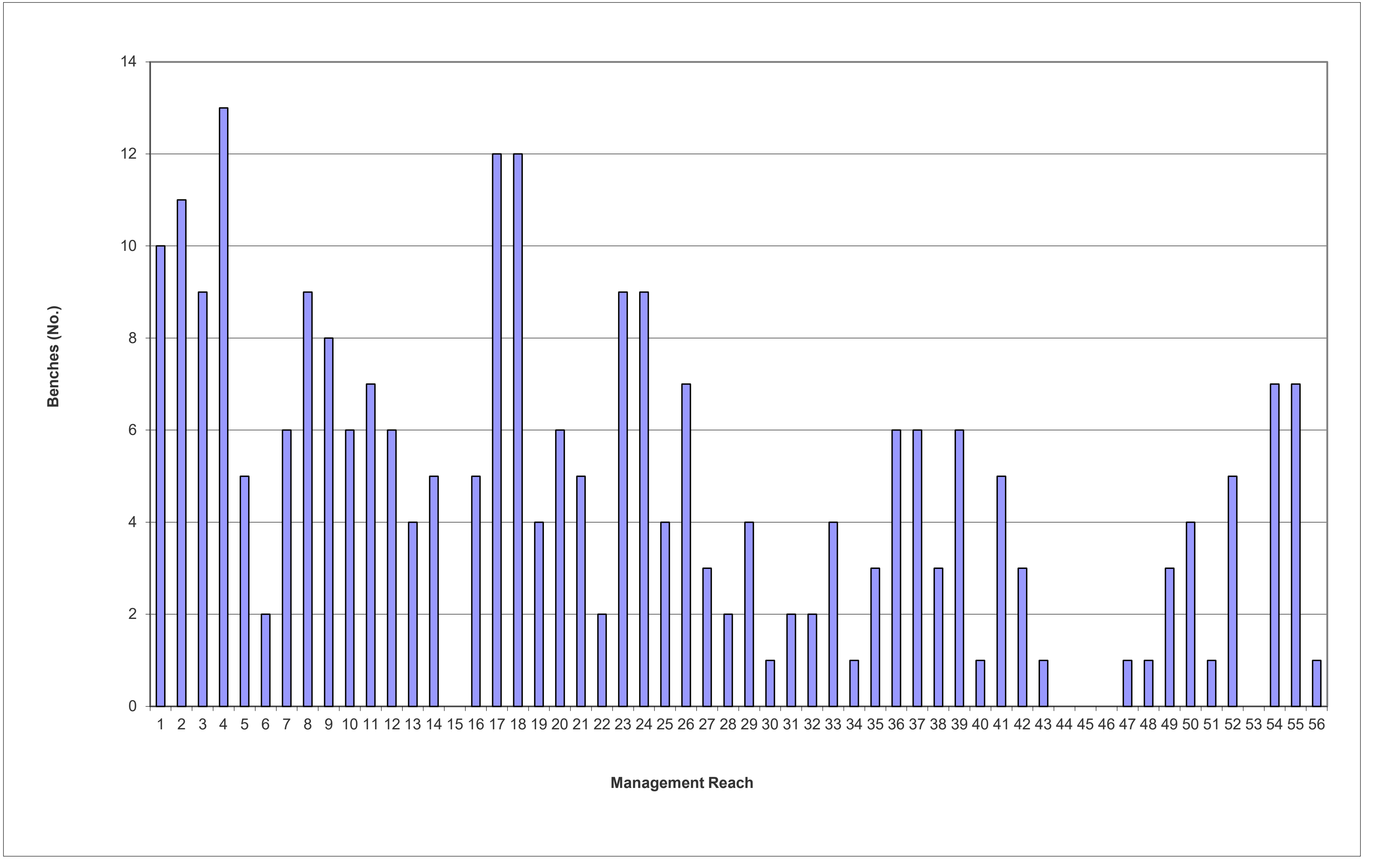

Figure 20. Distribution of benches by Management Reach

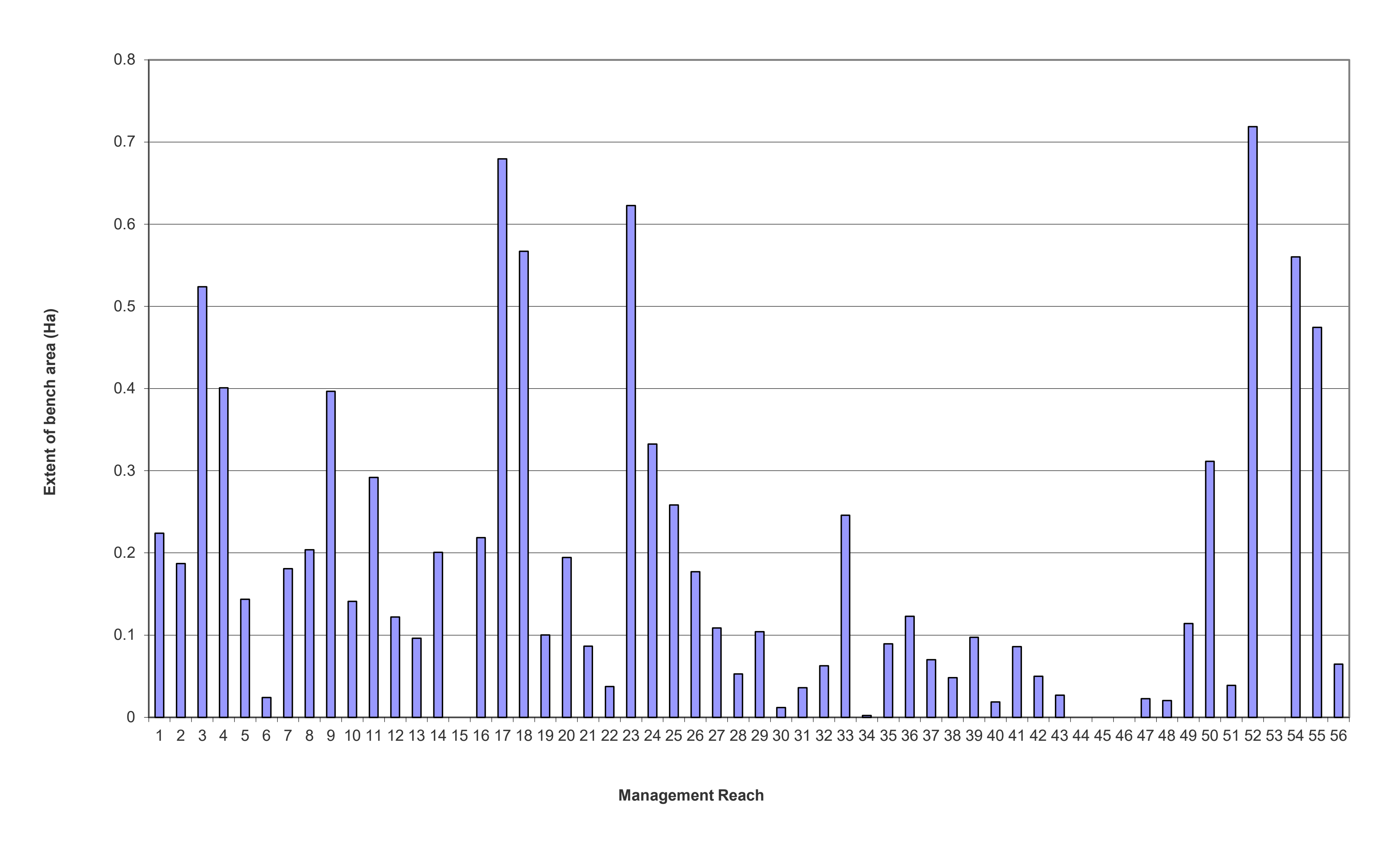

Figure 21. Bench area by Management Reach

Aquatic macrophytes

Macrophytes provide physical structure used by freshwater fish for shelter, refuge and as nesting and spawning sites (Petr, 2000; Thomaz and Cunha, 2010). Macrophytes also provide a direct and indirect food source, as rich foraging microhabitats for fish, as they are inhabited by numerous species of macro-invertebrates (Delariva *et al*. 1994; Petr, 2000; Casatti *et al*. 2003).

Various species of aquatic macrophytes were recorded, including emergent, floating attached and submerged (Table 7). Phragmites was the most common macrophyte within the project area, covering 4.11 ha (Figure 22). Juncus/Sedge and cumbungi were the next most common macrophytes, covering 0.12 and 0.15 ha respectively. Small patches of azolla, water milfoil and watercress were also observed within the project area.

Aquatic macrophytes extent varied greatly between Management Reaches, becoming far more common in the downstream reaches. Areas of high macrophyte extent can be attributed to weir pools creating a static and stable water level allowing for the domination of emergent macrophytes such as phragmites; this process was observed at the following structures within the project area: Jewry Street Crossing (Management Reaches 55 – 56), Calala Gauging Weir (Management Reaches 39 - 46), and an old concrete road crossing downstream of Piallamore (Management Reaches 32 -35) (Figure 23; Figure 24).

A moderate coverage of phragmites and water milfoil was observed between Management Reaches 32 – 35, but no barrier was observed during fieldwork (Figure 23; Figure 24). Further investigation found that WaterNSW had created a temporary weir at Dungowan in December 2019 to prolong water supply to Tamworth (WaterNSW 2019). This temporary weir was removed in June 2020 after the resumption of flows and explains the high abundance of phragmites and watermilfoil in the upstream reaches (Management Reaches 32 - 35).

Prolonged cease-to-flow conditions in the years preceding may explain the relatively low observation of macrophytes in the upper reaches, where no significant weir pools occur and large portions of the Peel were restricted to remnant pools (Rod Price pers. comms.).

Table 7: Macrophyte occurrence and extent within the project area

Macrophyte type	Species	Number	Area (ha)
Azolla	Azolla spp.	3	0.01
Cumbungi	Typha spp.	14	0.15
Juncus/Sedge	Juncus spp., Bolboshoenus spp.	38	0.12
Phragmites	Phragmites australis	224	4.11
Water Milfoil	Myriophyllum salsugineum	8	0.04
Watercress	Nasturtium offcinale	3	0.00

Figure 22. Emergent macrophyte phragmites in Management Reach 1, looking upstream at Chaffey Dam

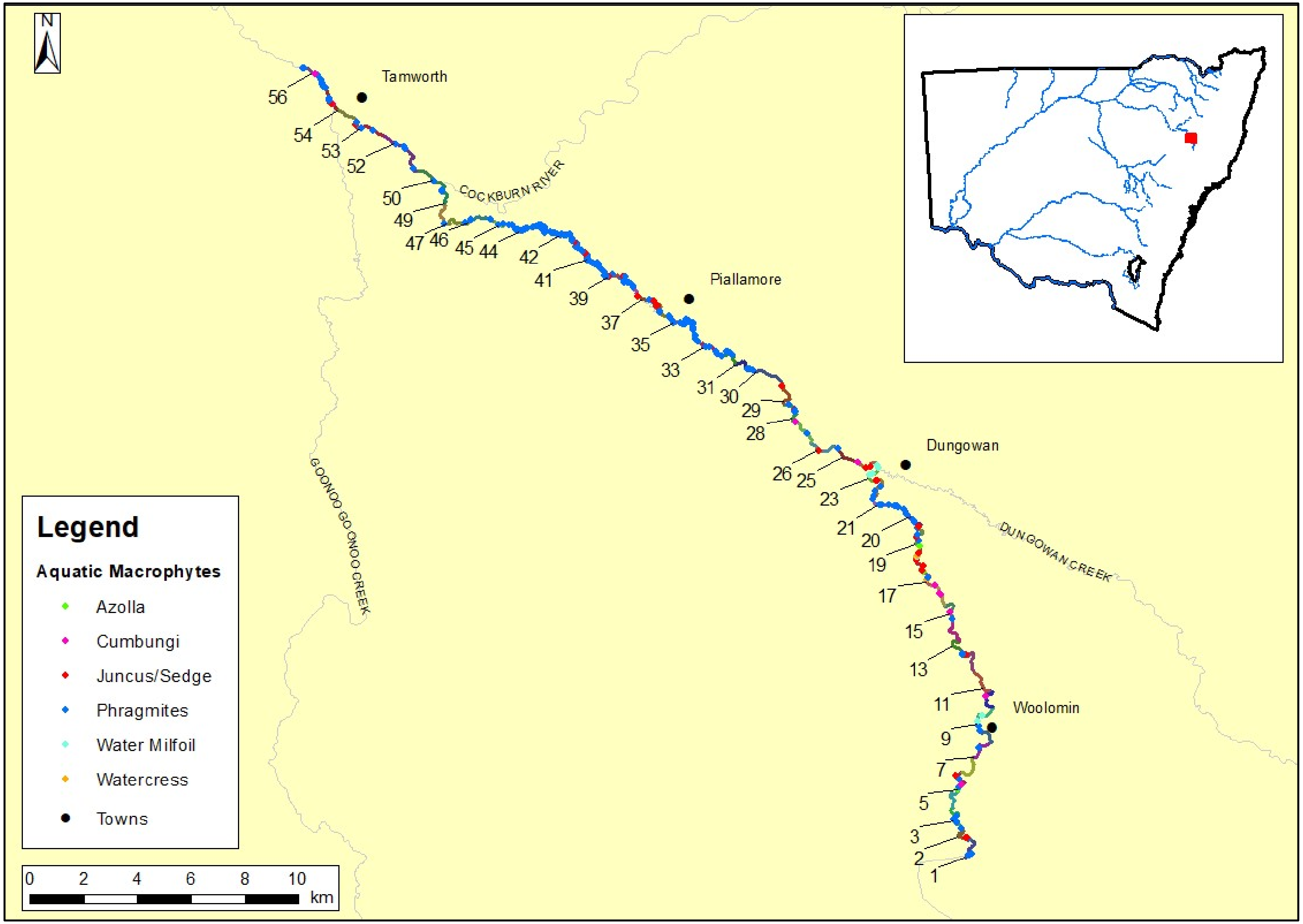

Figure 23. Distribution of macrophyte species in the project area

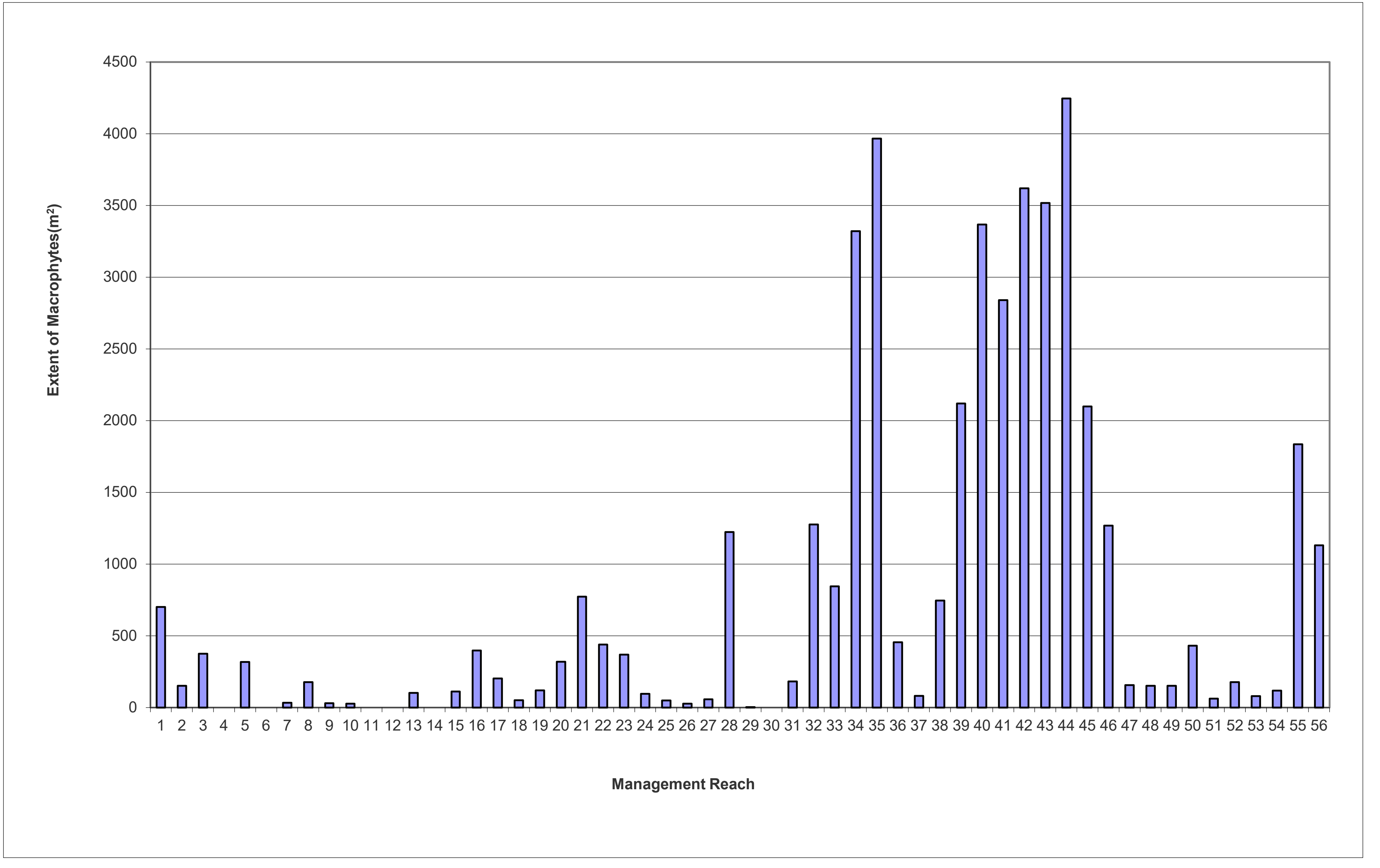

Figure 24: Extent of Aquatic Macrophytes by Management Reaches

Flow relationship results

The use of functional groups of freshwater fish in the Basin and detailed habitat mapping information can assist with managing water for the environment to deliver native fish benefits and develop specific Environmental Water Requirements (EWRs). When developing EWRs there are a number of basic principles related to the biological and ecological criteria for native fish and inland waterways that need to be considered:

- Natural flow regimes - one of the important principles considered in the development of conceptual flow models for fish in the Basin is that the natural flow regimes provide a strong foundation for the rehabilitation of flows; however the impacts of river regulation, including connectivity, access to habitat, and changes to geomorphology, need to be considered and incorporated into specific planning objectives (Mallen-Cooper and Zampatti, 2015).
- Water quality parameters - the importance of water quality, not just water quantity, also needs to be considered when developing and delivering water requirements, with water temperature driving life history responses from the majority of native species, whilst clarity, dissolved oxygen and productivity (related to chemical, nutrient and plankton composition) also play an important role in maximising benefits to species (Jenkins and Boulton, 2003; Górski *et al*. 2013; Zampatti and Leigh, 2013; Mallen-Cooper and Zampatti, 2015). The influence of water quality parameters on guiding flows for fish will result in management actions primarily occurring in the warmer spring and summer months; however the importance of replenishing critical refugia, supporting base flows all year round and late-winter high flow events still need to be considered given their benefits to water quality maintenance and productivity (Robertson *et al*. 2001).
- Fundamental riverine elements – the influence of flow, habitat and connectivity on the dynamics and response of fish populations are inseparable and need to be intimately considered in flow management decisions and actions (Mallen-Cooper and Zampatti, 2015). These three key factors will influence the need for still water or flowing environments, the spatial scale that connectivity and hydraulic complexity needs to be maintained, and the variation in flow needed for habitat access and completion of life history aspects (Mallen-Cooper and Zampatti, 2015). Consideration has been given to determining appropriate flow-height and flow-velocity relationships in the Darling River that account for connectivity and hydraulic requirements of native fish using the overarching principles below to guide the identification of flow rates:
  - Minimum depth for small bodied and moderate bodied fish movement is 0.3m above Cease to Flow (Gippel 2013; O'Connor *et al.* 2015)
  - Minimum depth for large bodied fish movement is 0.5m above Cease to Flow (Fairfull and Witheridge 2003; Gippel 2013; O'Connor *et al.* 2015)
  - Optimal transition of small fresh to large fresh events for the flow specialist spawning and movement response is 2m above Cease to Flow and/or velocity greater than or equal to 0.3-0.4m/s (Mallen-Cooper and Zampatti 2015; Marshall *et al.* 2016).

Differing flow events may be separated into several ecologically significant components with each of these providing a diverse range of ecosystem services. Figure 25 and Table 8 illustrate these ecologically significant flow components, categorising them according to the role they play in river health and fish movement.

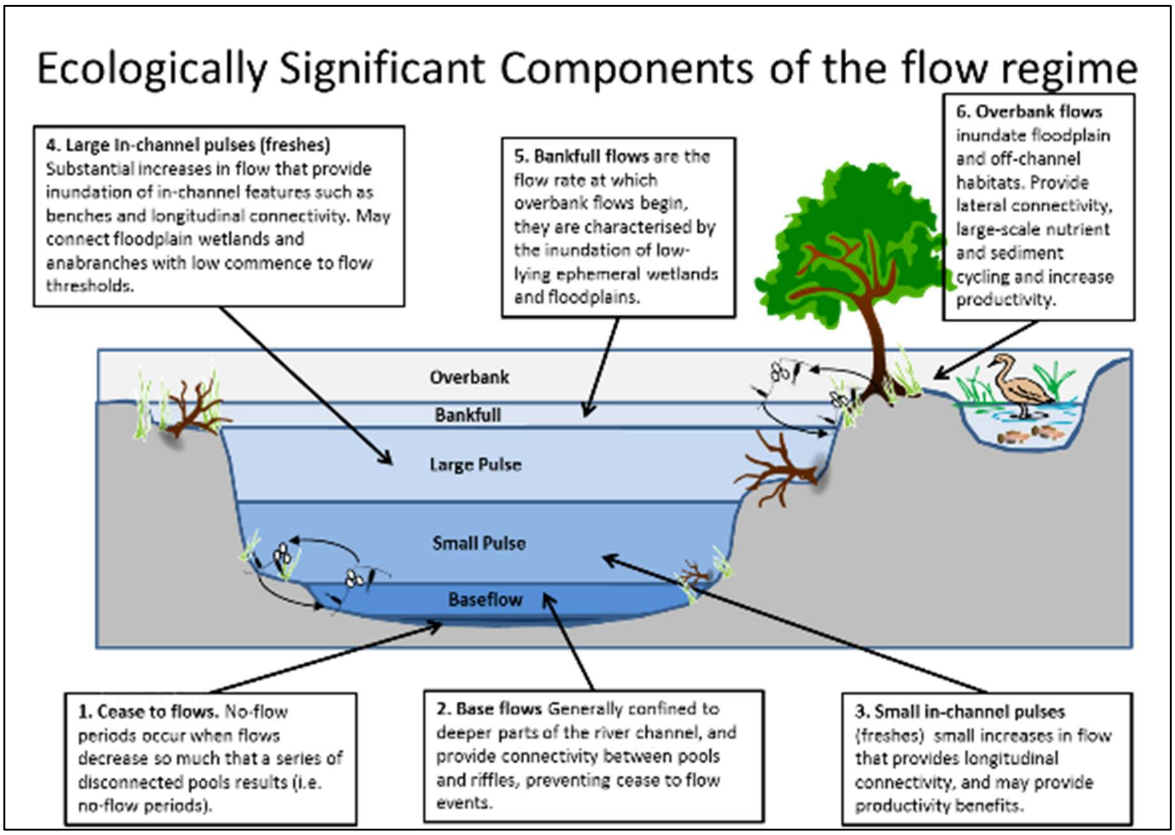

Figure 25. Components of the within-channel flow regime (adapted from Ellis et al. 2016)

Table 8. Definition of the five flow regime components identified for this study (adapted from Ellis et al. 2016; NSW DPI, 2017)

Flow regime component	Definition
Cease to flow	No-flow periods occasionally occur in intermittent streams where flows decrease so much that a series of disconnected pools eventuates. High food availability for predatory species at higher trophic levels may occur initially during cease to flow periods and very low flows, with limited refuge habitat for prey. Ultimately, however, food supply and water quality would be expected to decrease in isolated pools as water levels contract. No-flow periods have been associated with poor body condition; particularly for species at lower trophic levels (Balcombe *et. al*. 2012).
Very low flow	Very low flows typically maintain flow in a channel that prevents cease-to-flow conditions and provides connectivity between some pools. Very low flows are generally used for the survival & maintenance of native species by maintaining adequate water quantity and quality (temperature, dissolved oxygen, salinity etc.) Flow velocity ideally > 0,03 m/s to reduce risk of thermal stratification in pools at some sites. The magnitude of very low flows needs to be adapted seasonally in response to increased temperatures and commencement losses.
Baseflow	Confined to deeper low-lying part of the channel, and would typically inundate geomorphic units such as pools and riffle areas between pools. Base flows (and cease to flows) also allow for the accumulation of allochthonous carbon and vegetation on benches and dry river channel sediments, which then contribute to ecosystem productivity during subsequent flow events. They would generally occur on an ongoing basis in perennial systems. They may be important in maintaining aquatic habitat for fish, plants and invertebrates when low inflow conditions prevail;

	retain longitudinal connectivity for small-bodied fish and maintain reasonable water quality. Base flows maintain drought refuges during dry periods and contribute to nutrient dilution during wet periods or after a flood event. Base flows may also support winter conditioning and oxygenation through riffle habitats, and historically may have benefited small-bodied native species in terminal wetlands. Base flows are commonly maintained by seepage from groundwater and low surface flows (MDBA, 2014).
Small pulse	Generally short increases in flow that provide longitudinal connectivity, and may provide productivity benefits by replenishing soil water for riparian vegetation, inundating low-lying benches and cycling nutrients between different parts of the river channel. Small pulses would generally be considered to be relatively slow flowing (e.g. less than 0.3m/s). They can contribute to the maintenance of refugia and key aquatic habitat such as snags and aquatic vegetation, which supports diverse heterotrophic biofilm generation, with high nutritional value to higher organisms (Wallace *et al.* 2014). Small within-channel pulses would have generally occurred annually throughout the majority of the Basin, and potentially two to three times in a year for perennial systems.
Large pulse	More substantial increases in flow that provide greater inundation of in-channel features such as benches and longitudinal connectivity and may connect floodplain wetlands and anabranches with low commence to flow thresholds. Large within channel pulse are distinct from small pulses in that they provide fast flowing in channel habitats (e.g. velocity greater than 0.3m/s). Large in-channel pulses enhance productivity and nutrient exchange, promote dispersal and recruitment for all species and can trigger spawning in flow dependent species (i.e. Golden Perch and Silver Perch). These flow events are also important for maintaining refuges and minimising geomorphological impacts of regulation (e.g. sedimentation). The shape of these events should reflect the natural rates of flow increase or decrease corresponding to position in the catchment. Maintaining natural rates of change in water level may be important for nesting species such as Murray Cod and Freshwater Catfish, as water level fluctuations that are out of sync with natural patterns and climatic cues can have adverse impacts (e.g. rapid decreases in water levels over short time periods leading to nest abandonment). Large in-channel pulses would have generally occurred annually across most of the Basin, and up to two to three times a year in some systems.
Bankfull flow	The flow rate at which overbank flows begin, or maximum regulated flow releases. Bankfull flows generate similar ecological benefits to large in-channel pulses, potentially at a greater magnitude depending on channel geomorphology. They are characterised by the inundation of low-lying ephemeral wetlands and floodplains. As with large in-channel pulses, the shape of these events should reflect the natural rates of flow increase or decrease corresponding to position in the catchment.
Overbank event	Inundate floodplain and off-channel habitats and are important in providing lateral connectivity, large-scale nutrient and sediment cycling and an increase in productivity. Overbank events can enhance breeding opportunities for many species by creating additional spawning habitat and floodplain productivity benefits which contribute to increased condition and recruitment. Overbank events generally would have occurred between 1 - 25 years (depending on the magnitude of the event) for both intermittent and perennial systems. These events are generally unregulated, although there may be scenarios where water for the environment management activities could augment in-channel flows to create overbank events in which case the shape of these events should reflect the natural rates of flow increase or decrease corresponding to position in the catchment.

Project area flow components

Flow relationships were assessed for LWH, rootballs, and benches. Management Reaches were grouped into Flow Gauging Zones (FGZs) according to the nearest gauge (Table 9; Figure 26). The inundation height for habitat features recorded in the project area were compared against flow data to determine the flow (ML/day) required to inundate each feature.

Thresholds for each flow component (cease-to-flow, very low flow, base flow, small pulse, large pulse, bankfull and overbank) used in this report were taken from the Namoi Long Term Water Plan to investigate the habitat inundation relationships for each flow component. The cumulative total of habitat features inundated was calculated for the maximum flow rate under each flow component (Table 10; Table 11; Table 12; Table 13).

Table 9: Flow Gauging Zones extent within the project area

Management Reaches	Flow Gauging Zone	Reach Length (km)
1 - 23	Chaffey	23
24 - 43	Piallamore	20
44 – 49	Tamworth WS	6
50 - 56	Paradise Weir	7

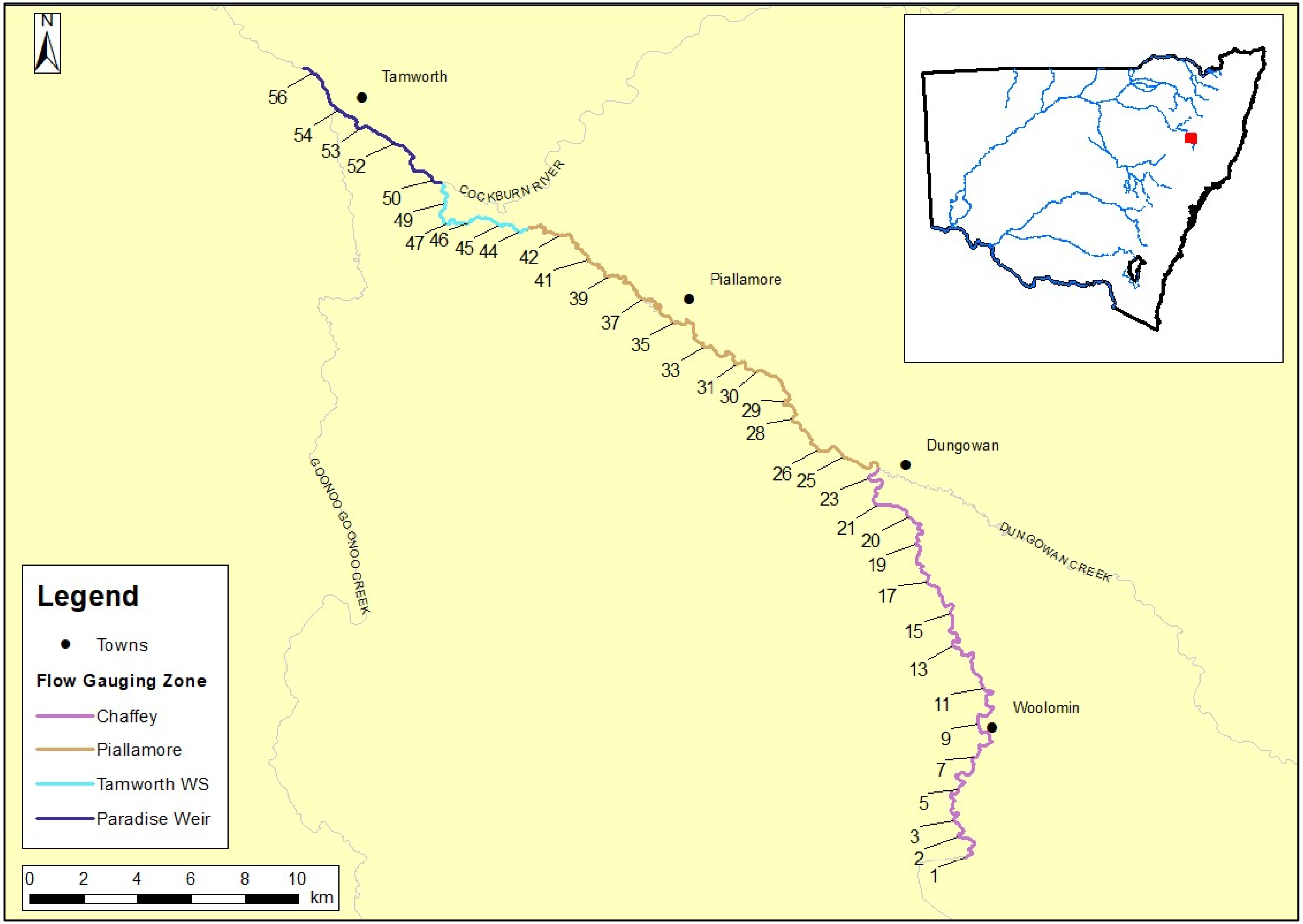

Figure 26: Flow Gauging Zone boundaries used during the project to assess flow relationships for habitat features during the project

Table 10. Summary of flow components, stage height and mean daily flow range for Chaffey FGZ

Component of flow regime	Stage Height (m)	Mean daily flow range (ML/day)	LWH (n)	LWH (%)	Rootballs (n)	Rootballs (%)	Benches (n)	Benches Count (%)	Benches Area (ha)	Bench Area (%)
Cease to flow	0.8	<1	432	86.6	32	97	46	29.5	0.85	15.1
Very low flow	0.9 - 1.2	1 - 100	434	87.0	32	97	46	29.5	0.85	15.1
Baseflow	1.3 - 1.5	100 - 250	435	87.2	32	97	46	29.5	0.85	15.1
Small pulse	1.6 - 1.9	250 - 900	451	88.6	32	97	131	84	3.69	65.4
Large pulse	2.0 - 2.5	900 - 2,900	475	88.8	32	97	131	84	3.69	65.4
Bankfull	2.6	2,900	478	95.2	33	100	131	84	3.69	65.4
Overbank	> 2.7	>2,900	499	100.0	33	100	156	100	5.64	100

Table 11. Summary of flow components, stage height and mean daily flow range for Piallamore FGZ

Component of flow regime	Stage Height (m)	Mean daily flow range (ML/day)	LWH (n)	LWH (%)	Rootballs (n)	Rootballs (%)	Benches (n)	Benches Count (%)	Benches Area (ha)	Bench Area (%)
Cease to flow	0.3	< 1	378	90.6	9	100	0	0	0	0
Very low flow	0.6	1 - 100	378	90.6	9	100	3	4.1	0.03	1.6
Baseflow	0.9	100 - 250	381	91.4	9	100	32	43.8	0.45	22.6
Small pulse	1.8	250 - 1,350	406	97.4	9	100	70	95.9	1.82	90.8
Large pulse	3	1,350 - 5,150	417	100	9	100	73	100	2.00	100
Bankfull	3.1	5,150	417	100	9	100	73	100	2.00	100
Overbank	> 3.2	> 5,150	417	100	9	100	73	100	2.00	100

Table 12. Summary of flow components, stage height and mean daily flow range for Tamworth FGZ

Component of flow regime	Stage Height (m)	Mean daily flow range (ML/day)	LWH (n)	LWH (%)	Rootballs (n)	Rootballs (%)	Benches (n)	Benches Count (%)	Benches Area (ha)	Bench Area (%)
Cease to flow	1.3	< 1	32	91.4	7	87.5	0	0	0	0
Very low flow	1.4 - 1.7	1 - 100	33	94.3	8	100	0	0	0	0
Baseflow	1.8 - 2	100 - 250	33	94.3	8	100	0	0	0	0
Small pulse	2.1 - 2.7	250 - 1,350	35	100	8	100	2	40	0.05	34.5
Large pulse	2.8 - 3.8	1,350 - 5,150	35	100	8	100	5	100	0.16	100
Bankfull	3.9	5,150	35	100	8	100	5	100	0.16	100
Overbank	> 3.9	> 5,150	35	100	8	100	5	100	0.16	100

Table 13. Summary of flow components, stage height and mean daily flow range for Paradise Weir FGZ

Component of flow regime	Stage Height (m)	Mean daily flow range (ML/day)	LWH (n)	LWH (%)	Rootballs (n)	Rootballs (%)	Benches (n)	Benches Count (%)	Benches Area (ha)	Bench Area (%)
Cease to flow	0.1	< 1	58	92.1	0	0	0	0	0.00	0
Very low flow	0.3 - 0.6	1 - 100	58	92.1	0	0	9	36	0.65	29.8
Baseflow	0.7 - 0.8	100 - 250	58	92.1	0	0	13	52	0.94	43.2
Small pulse	0.9 - 1.3	250 - 1,350	61	96.8	0	0	23	92	2.01	92.6
Large pulse	1.4 - 2.1	1,350 - 5,150	61	96.8	0	0	25	100	2.17	100
Bankfull	2.2	5,150	62	98.4	0	0	25	100	2.17	100
Overbank	>2.2	> 5,150	63	100	0	0	25	100	2.17	100

Large Woody Habitat

The inundation height for LWH recorded in the Peel River was compared against flow data to determine the flow (ML/day) required to inundate each LWH as shown in Table 10, Table 11, Table 12 and Table 13. Flow components identified within each FGZ are represented by the colour-coded bands: cease to flow, very low flow, base flow, small pulse, large pulse, bankfull and overbank. Detailed inundation tables, delineated by 0.1 m, can be found in Appendix B.

Chaffey FGZ had the highest loading of LWH at 21.7 LWH/km, followed by Piallamore (20.9 LWH/km) Tamworth, Paradise Weir (9.0 LMW/km) and Tamworth WS (5.8 LWH/km).

Approximately 88.8% of LWH is inundated under cease-to-flow conditions. Inundation increases as flows increase, reaching 89.1% LWH inundation at very low flow conditions, 89.4% under baseflow conditions, 94% under small pulse and 97.4% under large pulse conditions. Bankfull flows inundate 97.8% of LWH and require 2,900 ML/day for the Chaffey FGZ and 5,150 ML/day for Piallamore, Tamworth WS and Paradise Weir FGZ's.

An overbank flow of 12,600 ML/day at Chaffey gauge is required to inundate 100% of observed LWH.

Benches

The inundation height for benches recorded in the Peel River project area were compared against flow data to determine the flow (ML/day) required to inundate the entire bench area recorded (Table 10; Table 11; Table 12; Table 13). Detailed inundation tables, delineated by 0.1 m, can be found in Appendix B.

Flow relationship analysis was conducted on 259 benches. Tamorth WS had the highest loading of benches at 12.2 per km, followed by Chaffey (6.8 benches/km), Piallamore (1.3 benches/km) and Paradise Weir (0.7 benches/km).

Across the entire project area, 17.8% of benches are inundated under cease-to-flow conditions, covering a total area of 0.85 ha. 35.1% of benches are inundated under base blows conditions (250 ML/day), coving an area of approximately 1.5 ha. Small pulse flows (900 ML/day at Chaffey, 1,350 ML/day for all other FGZs) inundate 87% of benches covering an equivalent area of 7.6 ha. Increasing flows from Small pulse to Large pulse results in no additional bench inundation.

Overbank flows of 9,300 ML/day below Chaffey Dam are required to inundate 100% of observed benches within the project area, although only 2,790 ML/day is required for 100% bench inundation within the Piallamore, Tamworth WS and Paradise Weir FGZs.

Rootballs

The inundation height for rootballs recorded in the Peel River project area were compared against flow data to determine the flow (ML/day) required to inundate each rootball as shown in Table 10, Table 11, Table 12 and Table 13. Flow components identified within each FGZ are represented by the colour-coded bands: cease to flow, very low flow, base flow, small pulse, large pulse, bankfull and overbank. Detailed inundation tables, delineated by 0.1 m, can be found in Appendix B.

50 rootballs were recorded within the project area. Chaffey FGZ had the highest loading of rootballs at 1.4 rootballs/km, followed by Tamworth (1.3 rootballs/km), Piallamore (0.5 LWH/km). No rootballs were observed within the Paradise Weir FGZ.

48 rootballs remain inundated under cease to flow conditions, equivalent to 98% of all rootballs within the project area. 99% of rootballs are inundated under very low flow conditions. No further rootballs are inundated under baseflow, small pulse or large pulse conditions.

Bankfull conditions of 3,110 ML/day downstream of Chaffey Dam is required to inundate 100% of rootballs.

Water management implications from flow analysis

As planned environmental flows pass through the river reaches, quantities of LWH are submerged and benches are inundated. The contribution of these features into river productivity processes such as carbon inputs and trophic webs are generally understood but rarely quantified or deliberately targeted in management actions and objectives because of deficits in reach-specific information. The dataset gathered through this project has great potential to inform objective setting and specific environmental outcomes relating to water management and in particular, availability of specific assets during events.

Prior to the 2016 upgrade works, Chaffey Dam's outlet valve had a capacity of 1,100 ML/day (MDBA 2013). Upgrade works increased capacity from 64 to 100 GL and head by approximately 8 m; and is anticipated to slightly increase outlet capacity. This outlet constraint of 1,100 ML/day does not allow enough flow for 100% inundation of habitat features: 12,600 ML/day for LWH; 9,300 ML/day for benches and 3,110 ML/day for rootballs.

However, inundation analysis has demonstrated that significant proportions of habitat remain inundated under baseflow (250 ML/day) conditions; including 89.4% of LWH, 98% of rootballs and 22.5% of bench area. Increasing flows to a small fresh (900 ML/day for Chaffey FGZ or 1,350 ML/day for Piallamore, Tamworth WS and Paradise Weir FGZs) results in a relatively small increase in LWH and rootball inundation; however bench area inundation increases from 22.5% to 75.9%, an equivalent increase of 2.24 ha to 7.57 ha. The relatively high increase in bench area inundation between baseflow and small pulses conditions represents a significant opportunity in implement a wetting and drying regime, whilst operating within the current constraints, resulting in an overall increase system productivity.

Note that flows within the project area are not limited to less than 1,100 ML/day. Unregulated flows from tributary creeks and dam spill during flooding often exceed this value, particularly downstream of the confluences of Dungowan Creek and Cockburn River.

Impacts on habitat condition

Livestock access and damage

Constant livestock grazing reduces natural regrowth of trees, shrubs and grasses and can result in complete loss of some or all of these important vegetation layers on the banks of rivers and streams (Figure 27). Poorly managed grazing pressure can also contribute to bank erosion and loss of productive land. Banks denuded of vegetation are highly susceptible to erosion which in turn leads to increased turbidity and eutrophication of waterways. Livestock manure can also impact on downstream water quality and the health of others using the waterway for recreational (swimming) and commercial use (e.g. aquaculture production, town water; NSW DPI, 2012). Cattle defecate 25% of the time when drinking, with 1 kg of phosphorus from manure potentially resulting in up to 500 kg of algal growth (Fitch *et al.* 2003).

Overall there was very little stock damage occurring within the project area, noting that only 13 of 56 Management Reaches contained stock damage. A total of 0.2 ha of stock damage was recorded within the project area, with the greatest extent being observed within Management Reaches 2 (588 m^2), 3 (293 m^2) and 23 (565 m^2 Figure 28; Figure 29). Riparian fencing appears to be widespread along the project area, presumably as a result of property boundary fencing. Desktop analysis of stock damaged reaches determined that the points of stock damage occurred predominantly within gaps in riparian fencing.

Figure 27. Stock damage is often the result of poorly managed stock access

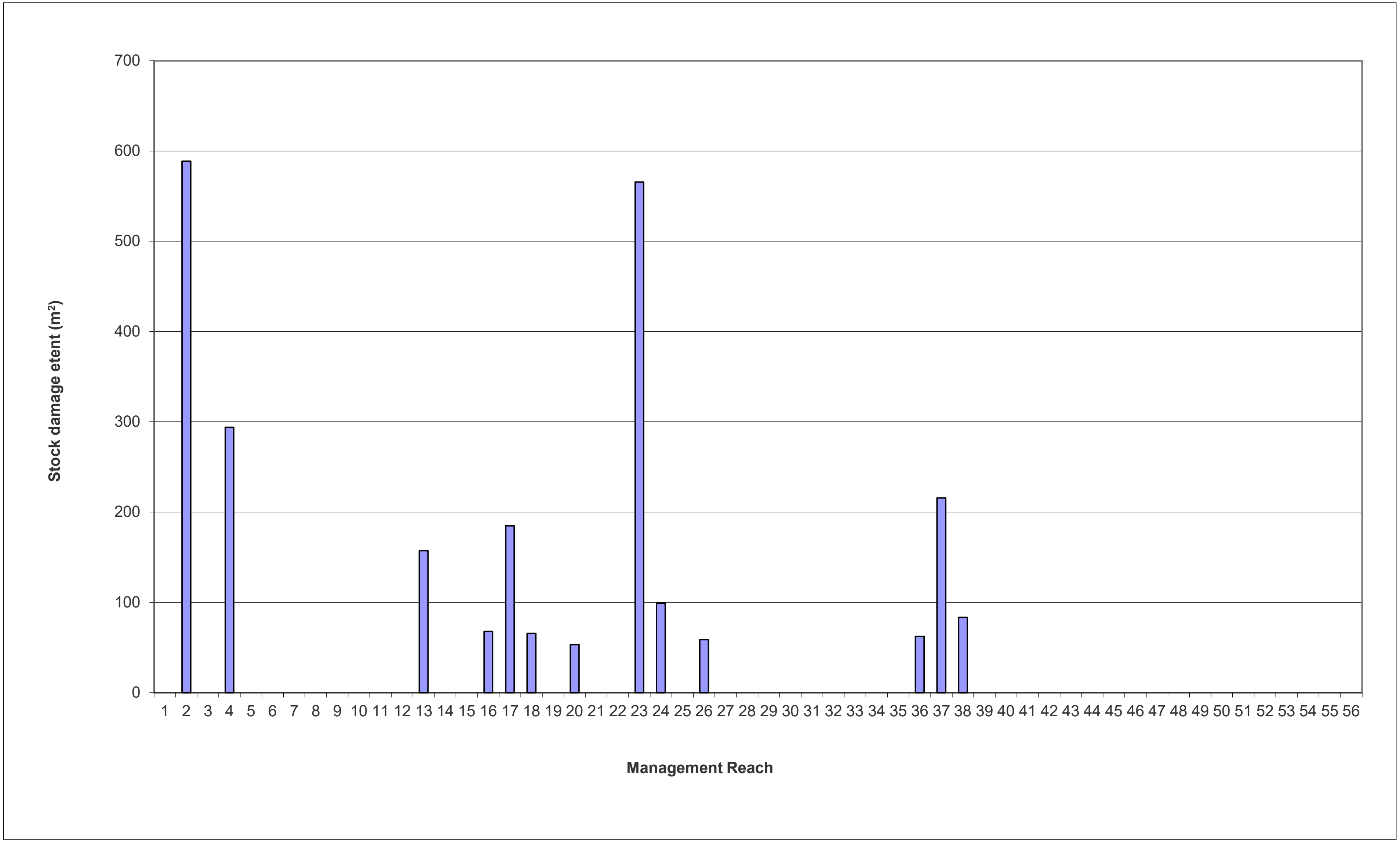

Figure 28. Extent of stock damage by Management Reach

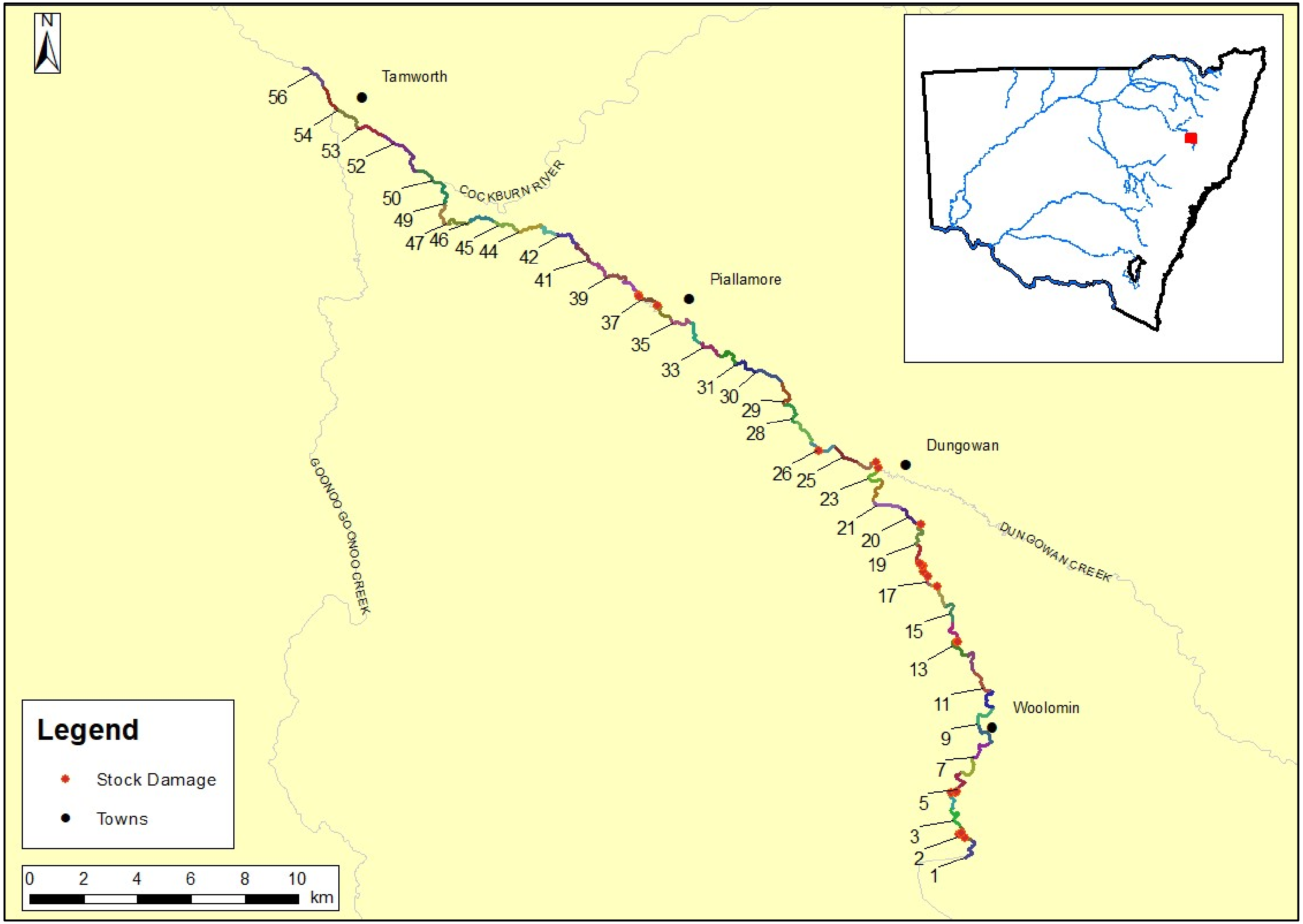

Figure 29. Stock damage sites in the project area

Erosion

While it is a dynamic and natural process, stream bank erosion can be accelerated by the influence of human activities (BRG CMA, 2010). Erosion in waterways can result in siltation of refugia, increased turbidity and increased eutrophication (NSW DPI, 2013). For the aquatic environment, the impacts include; loss of fish habitat, reduction in light penetration and therefore a loss of submerged aquatic macrophytes and increased risk of algal blooms (Reid *et al.* 2017). For agriculture, the loss of riparian land to erosion over subsequent flood events can result in the loss of significant areas of cropping land (Ringwood, 2016).

Erosion covered a total of 0.09 ha across 17 sites (Figure 30). Management Reach 54 has the largest extent of erosion at 196 m^2. Management Reach 36 and 37 also had a relatively high extent of erosion at 188.7 m^2 and 165 m^2 respectively (Figure 31).

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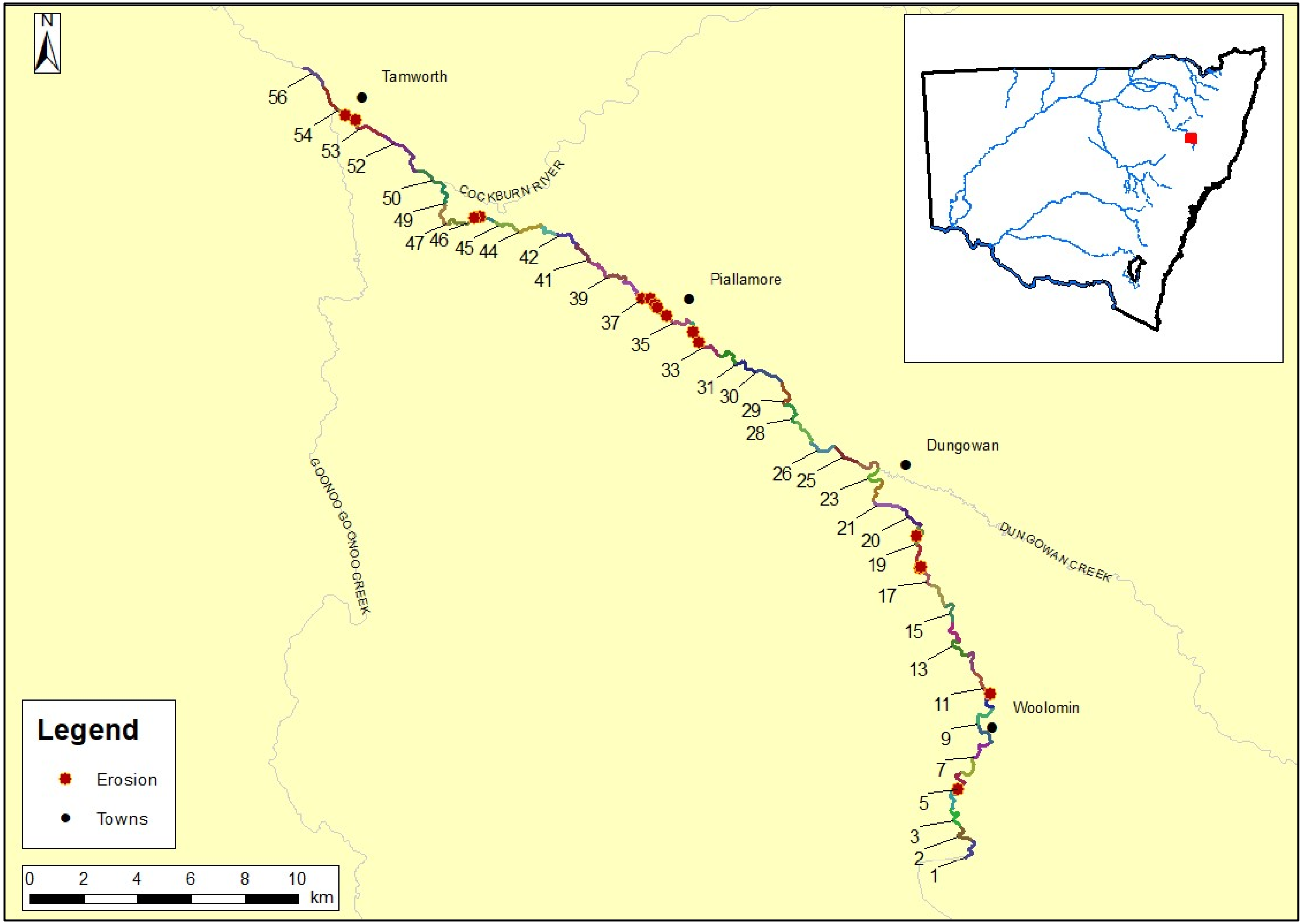

Figure 30. Extent of erosion in the project area

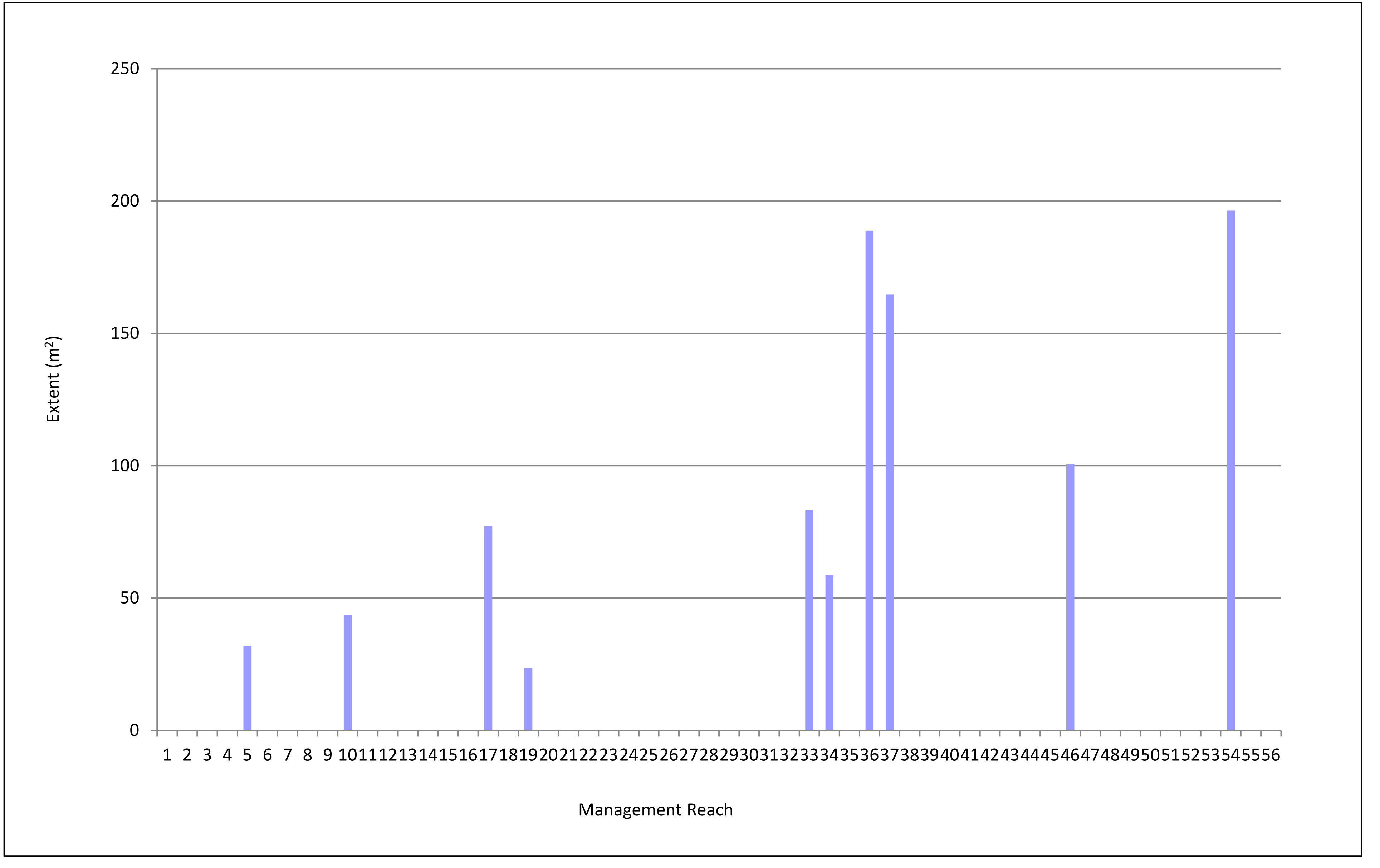

Figure 31. Erosion extent by Management Reach

Fish passage

Australian native fish have evolved to be reliant on a variety of habitat types to complete their life cycle. One of these habitat requirements is the need to migrate both short and long distances to move between varying aquatic environments (Thorncraft and Harris, 2000; Barrett, 2008; Fairfull and Witheridge, 2003). While fish migrations are commonly associated with breeding events, other reasons for native fish species needing to disperse include the search for food, shelter, avoidance of predation and competition pressures. Unfortunately, riverine connectivity has been severely disrupted within Australia by the creation of instream barriers to migratory fish that limit habitat and resource availability and diminish the opportunities for species to adapt to changing environmental conditions (Pethebridge *et al.* 1998). The installation and operation of instream structures and the alteration of natural flow regimes have been recognised as Key Threatening Processes under the *Fisheries Management Act 1994* and the *Threatened Species Conservation Act 1995*.

Five manmade barriers and one willow choke barrier were recorded within the project area (Figure 32; Figure 33).

Unnamed road crossing A is located immediately downstream of Chaffey Dam. Flow velocity is accelerated through a four pipe culvert (each pipe approximately 500 mm), which likely makes fish passage difficult or unlikely. This road crossing was constructed as a temporary measure and developed in consultation with DPI Fisheries. It is expected to be removed entirely before the end of 2020. As such, no drown out height was determined for this barrier.

Unnamed road crossing B is a redundant concrete road crossing, approximately 10 m across, located approximately 2 km downstream of the Piallamore township. During field observations at 97 ML/day it created a 0.2 m head differential, putting it at an estimated gauge height of 0.8 m. From this observation it is estimated that a flow of 188 ML/day is required to drown out this crossing. Based on the most recent 30 years of flow data from WaterNSW, this site is likely to be a barrier for 87% of the time (Figure 34).

Calala Gauging Weir is located in Management Reach 47, approximately 3 km upstream of the Cockburn River junction. It is a small concrete weir with a narrow flume utilised for gauging downstream flows. Fish passage is restricted due to excessive head loss and increased flow velocity through the narrow flume. During field observations at flows of 130 ML/day Calala Gauging Weir generated a headloss of 0.4 m, an equivalent of gauge height of 2.1 m. Based on this calculated height, an estimated flow of 323 ML/day is required to drown out this structure. This is consistent with a Detailed Weir Review (DWR) conducted by NSW DPI in the Namoi Valley in 2006, which estimated a drown out flow of 350 ML/day (NSW DPI 2006). Based on a 350 ML/day drown out flow, Calala Gauging Weir is a barrier to fish passage 91.6% of the time (Figure 35).

Tamworth Water Supply Pipeline is located below the Paradise Bridge in the Tamworth Township, approximately 4 km upstream of the Jewry Street Weir. The structure is comprised of a large concrete capped water supply pipe running across the river channel, forming a barrier via headloss, increased flow velocity and turbulence. During fieldwork at 136 ML/day the Tamworth Water Supply Pipeline created a height difference of 0.5 m, an equivalent gauge height of 1.2 m. Based on this calculated height, this structure should drown out at 1,000 ML/day. This is consistent with the 2006 Namoi Valley (DWR) estimates that Tamworth town weir drowns out at 1,000 ML/day (NSW DPI 2006). Based on a 1,000 ML/day drown out flow, this structure is a barrier to fish passage 89% of the time (Figure 36).

Jewry Street Weir is a redundant road crossing functioning as a fixed crest weir and is located within the Tamworth township. During field observations at 130 ML/day the weir generated a 0.9 m height difference, equivalent to a gauge height of 1.6 m. From this observation, a flow of 2,300 ML/day is required to drown out Jewry Street Weir. The NSW DWR (2006) recorded Jewry Street Weir at 1.5 m high, but calculated the drown out flow at just 1,200 ML/day. The detailed weir review had more resources and expertise in calculating drown out flows, therefore 1,200 ML/day is a more reliable guide. Based on a drown out flow of 1,200 ML/day, and an analysis of the most recent 30 years of flow data, Jewry Street Weir functions as a barrier to fish passage 91% of the time (Figure 37).

Jewry Street Weir and Calala Gauging Weir are both ranked Medium-High priority for fish passage remediation by NSW DPI, due to restricting upstream access to high priority environmental assets. All barrier locations, drown out heights and metadata have all been forwarded to NSW DPI Fisheries fish passage team for registration into the official database.

Figure 32. Images of man-made barriers photographed within the project area. Road Crossing A (top left); Road Crossing B (top right); Calala Gauging Weir (bottom left); Jewry Street Weir (bottom right)

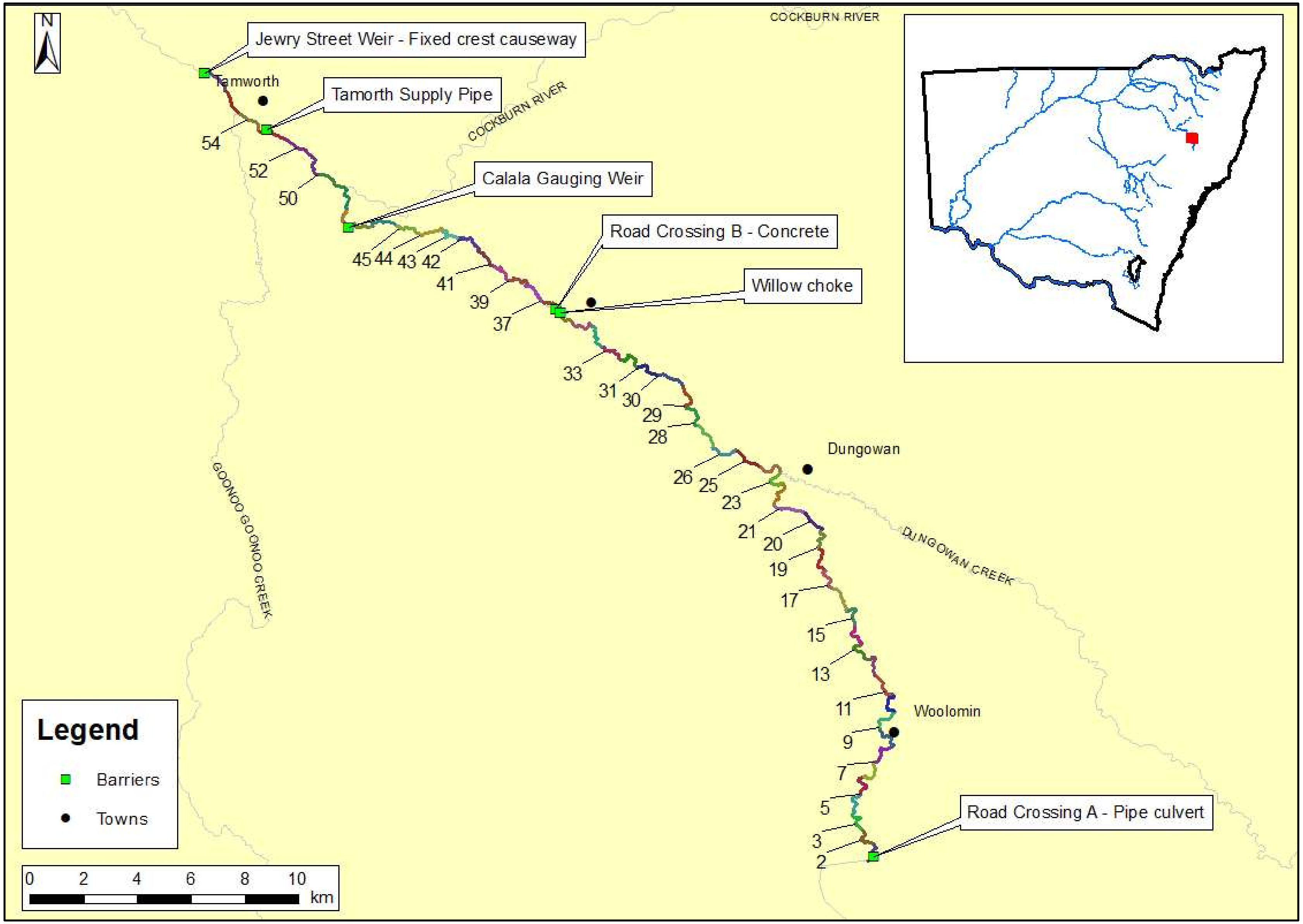

Figure 33. Location of barriers to fish passage created by weirs in the project area

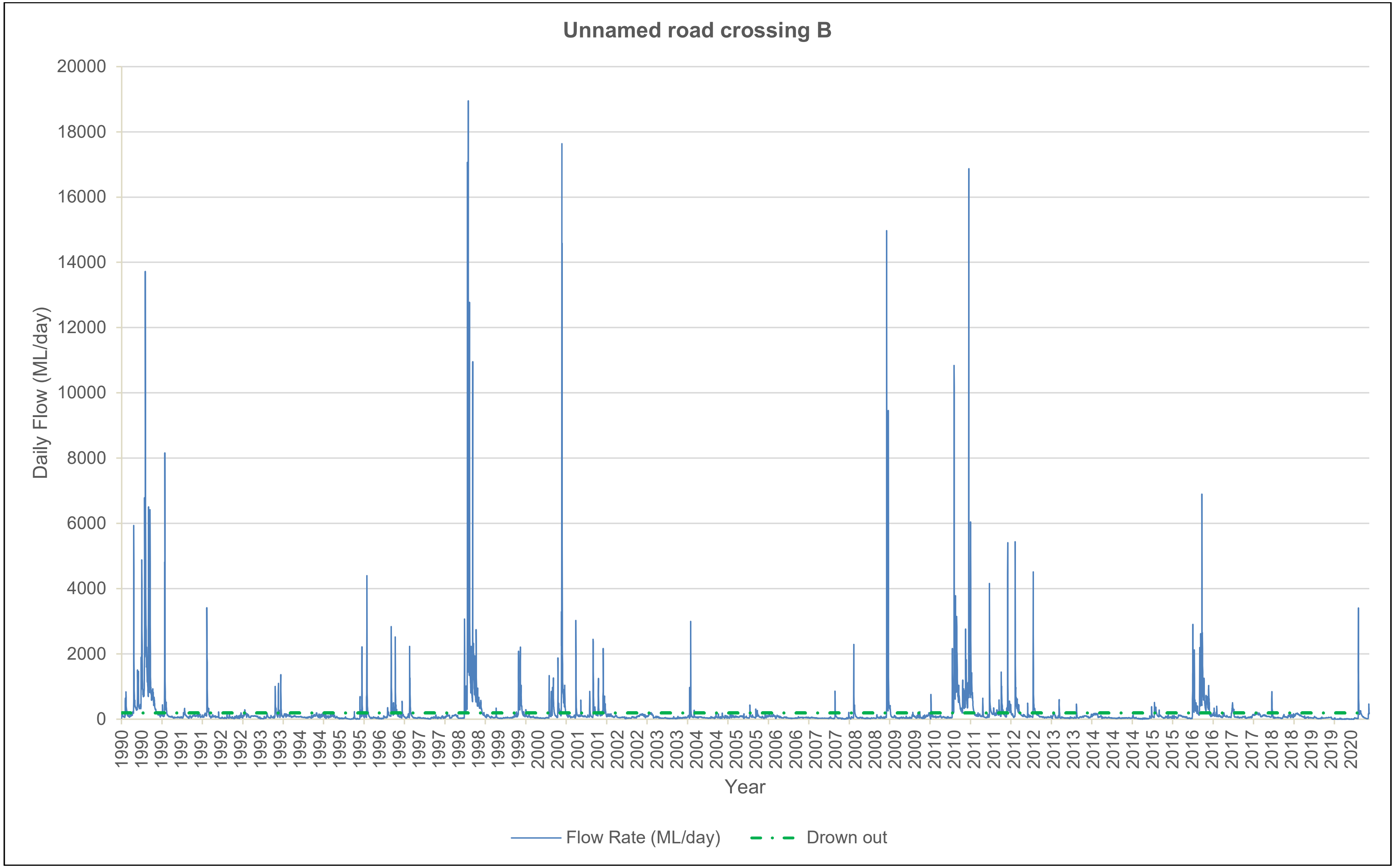

*Figure 34. Fish passage availability at Unnamed road crossing B over a 30 year period. Green line indicates approximate flow volume at which fish passage is possible.*One flow value (30,000 ML/day) in November 2000 was removed to allow finer flow – axis resolution*

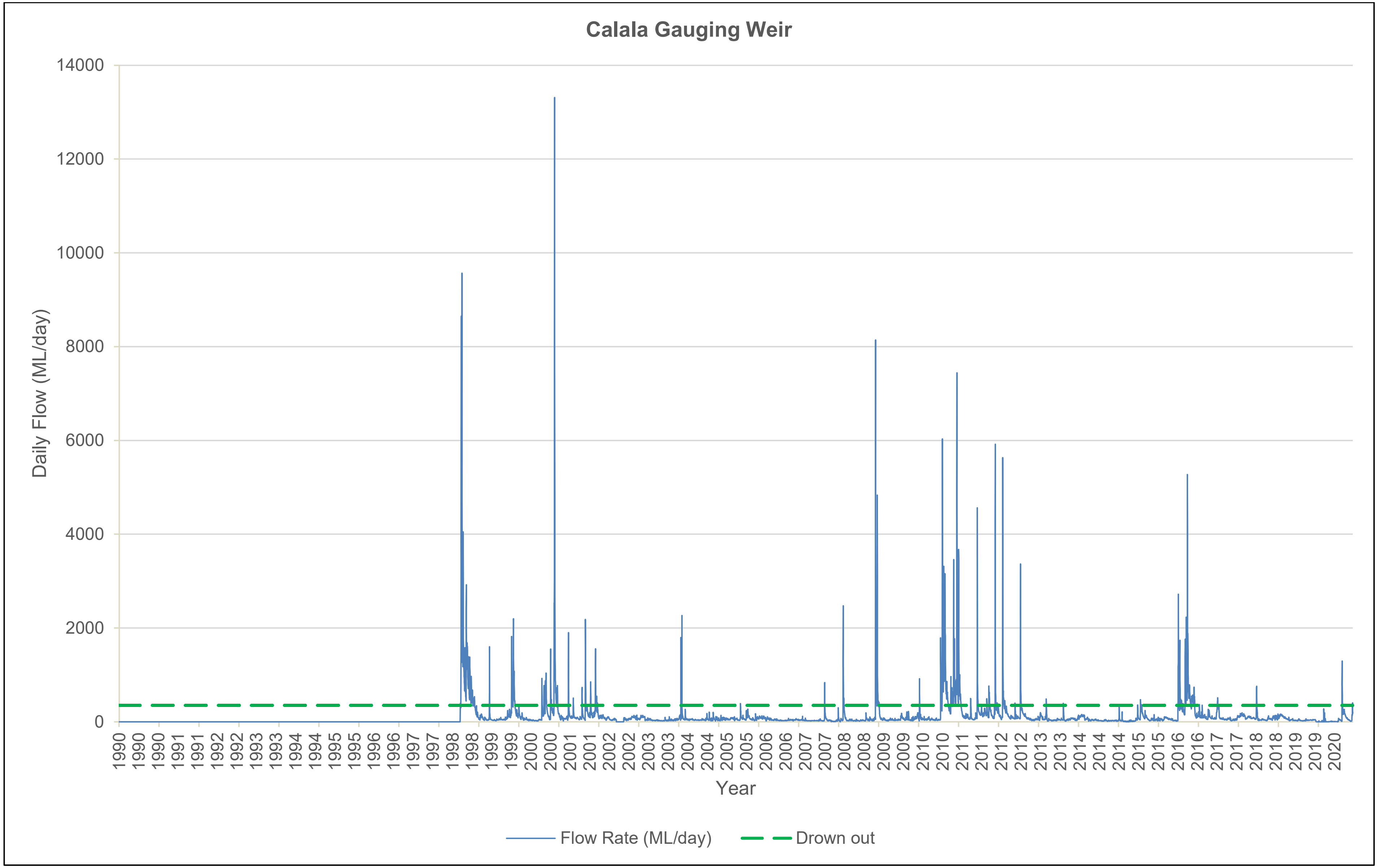

Figure 35. Fish passage availability at Calala Gauging Weir over a 30 year period. Green line indicates approximate flow volume at which fish passage is possible

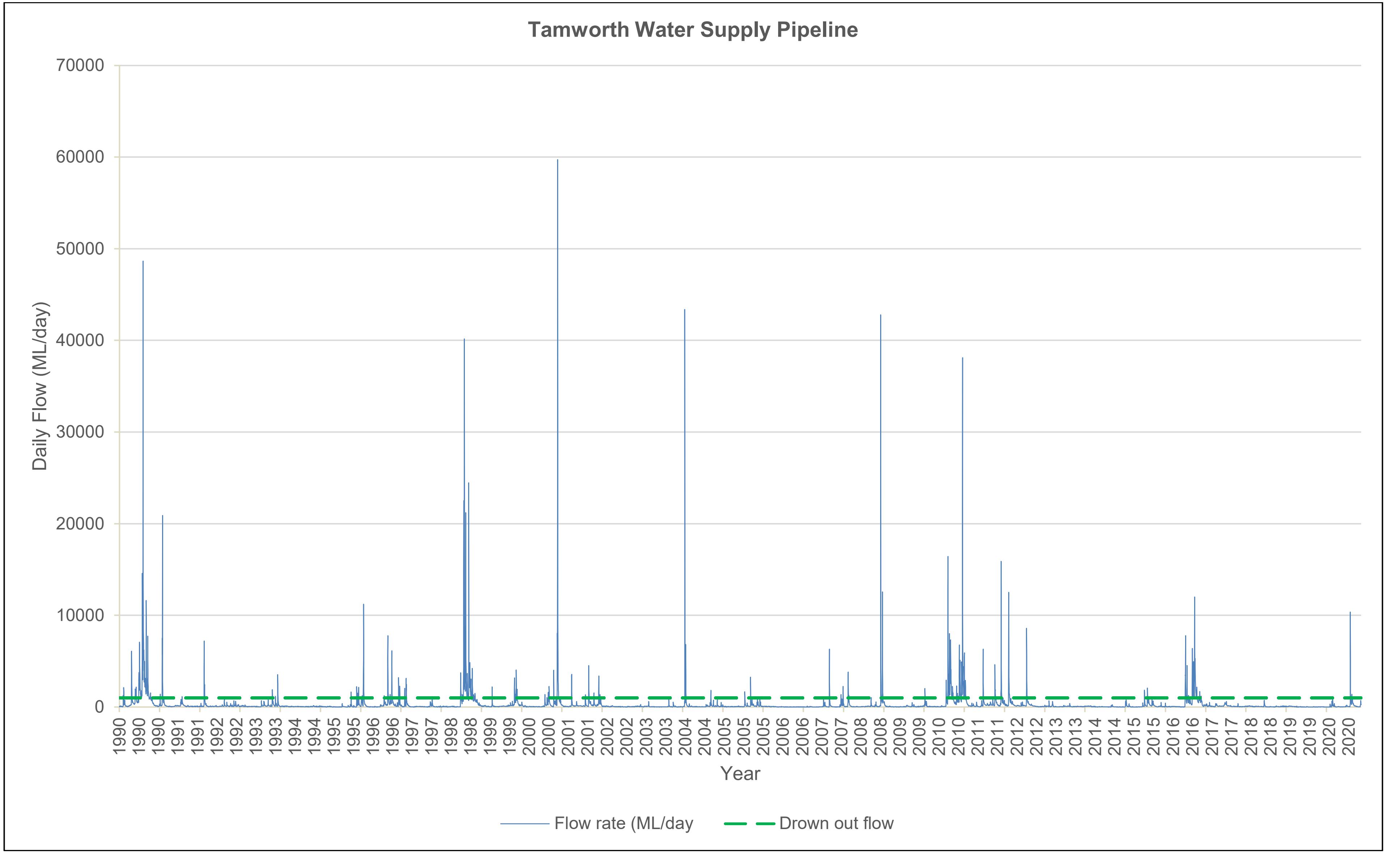

Figure 36. Fish passage availability at Tamworth Water Supply over a 30 year period. Green line indicates approximate flow volume at which fish passage is possible

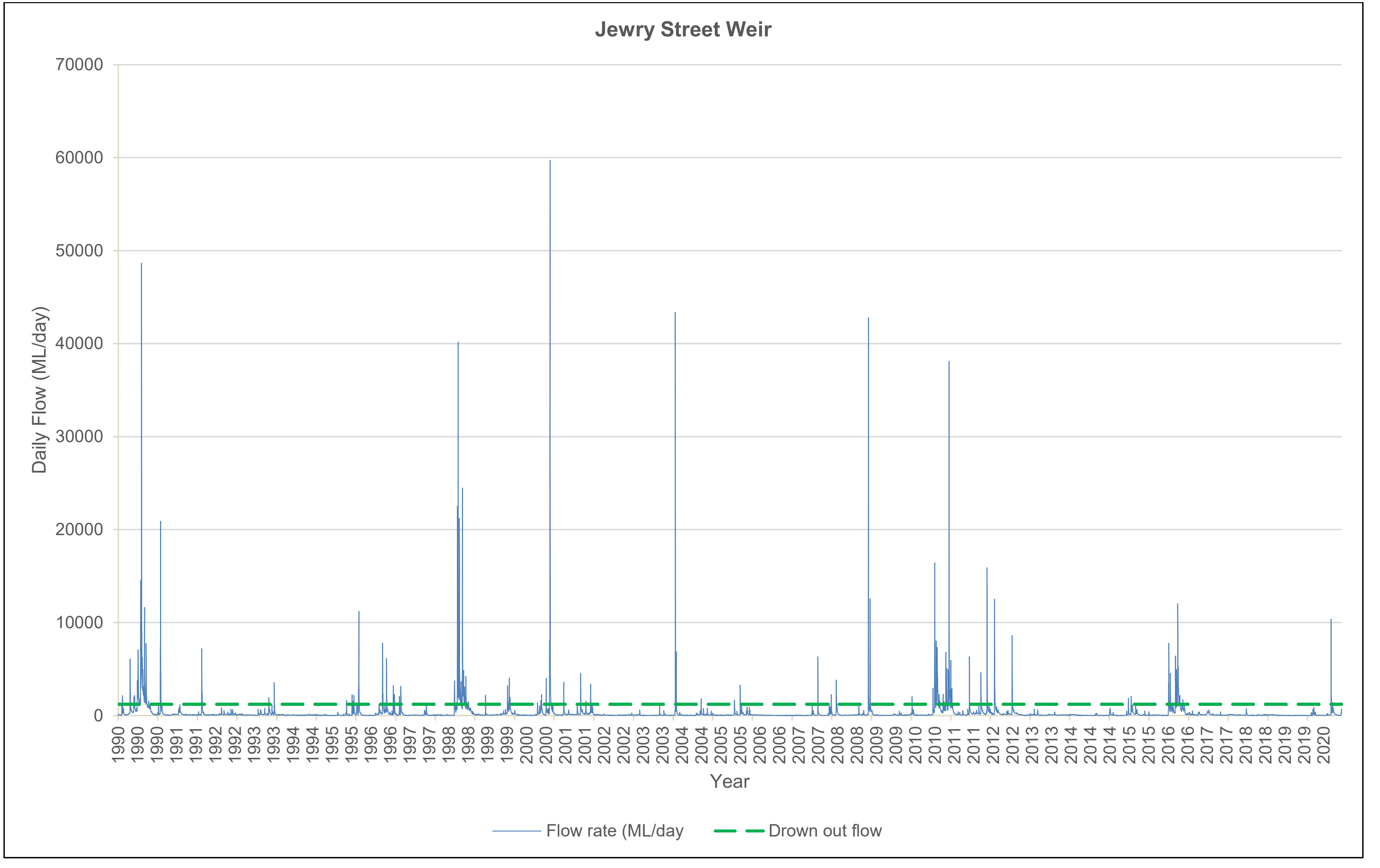

Figure 37. Fish passage availability at Jewry Street Weir over a 30 year period. Green line indicates approximate flow volume at which fish passage is possible

Pump sites

Pumps that extract water from rivers have the potential to draw fish during water abstraction and can physically harm or kill them (Baumgartner *et al.* 2009). Studies in the Condamine Catchment in Queensland have recorded over 12,000 native fish being removed from two 300 mm pumps over a 9-hour period (Norris, 2015).

Pump sites were categorised into three size categories: less than 100 mm, 100 mm to 250 mm, and greater than 250 mm, with smaller pumps generally used for stock and domestic purposes and larger pumps for irrigation and town water supply. There were 59 pumpsites recorded within the project area (Figure 38). The majority (41) were between 100 to 250 mm in diameter, with the remaining pumps (18) were 100 mm or less in diameter. No pumps greater than 250mm were observed (Table 14). Pumpsites were relatively common across Management Reaches (Figure 39), most likely supplying stock and domestic licenses; as well as irrigated pastures, which comprise 85% of the irrigated land use within the regulated Peel River (Green *et al*. 2011). The lack of pumpsites between Management Reaches 52 - 56 is likely due to the adjacent dwellings utilising Tamworth's water supply.

In other parts of the world pump screens are routinely used to reduce the number of fish and debris that enter pumps and irrigation systems. Pump screening considerably reduces the risk of irrigation pumps killing or injuring fish and reduces pump maintenance and operational costs by filtering out debris (Figure 40).

Table 14. Number of each pumpsite size class

Size class of pumpsite (diameter)	Number
<100	18
100 – 250	41
>250	0

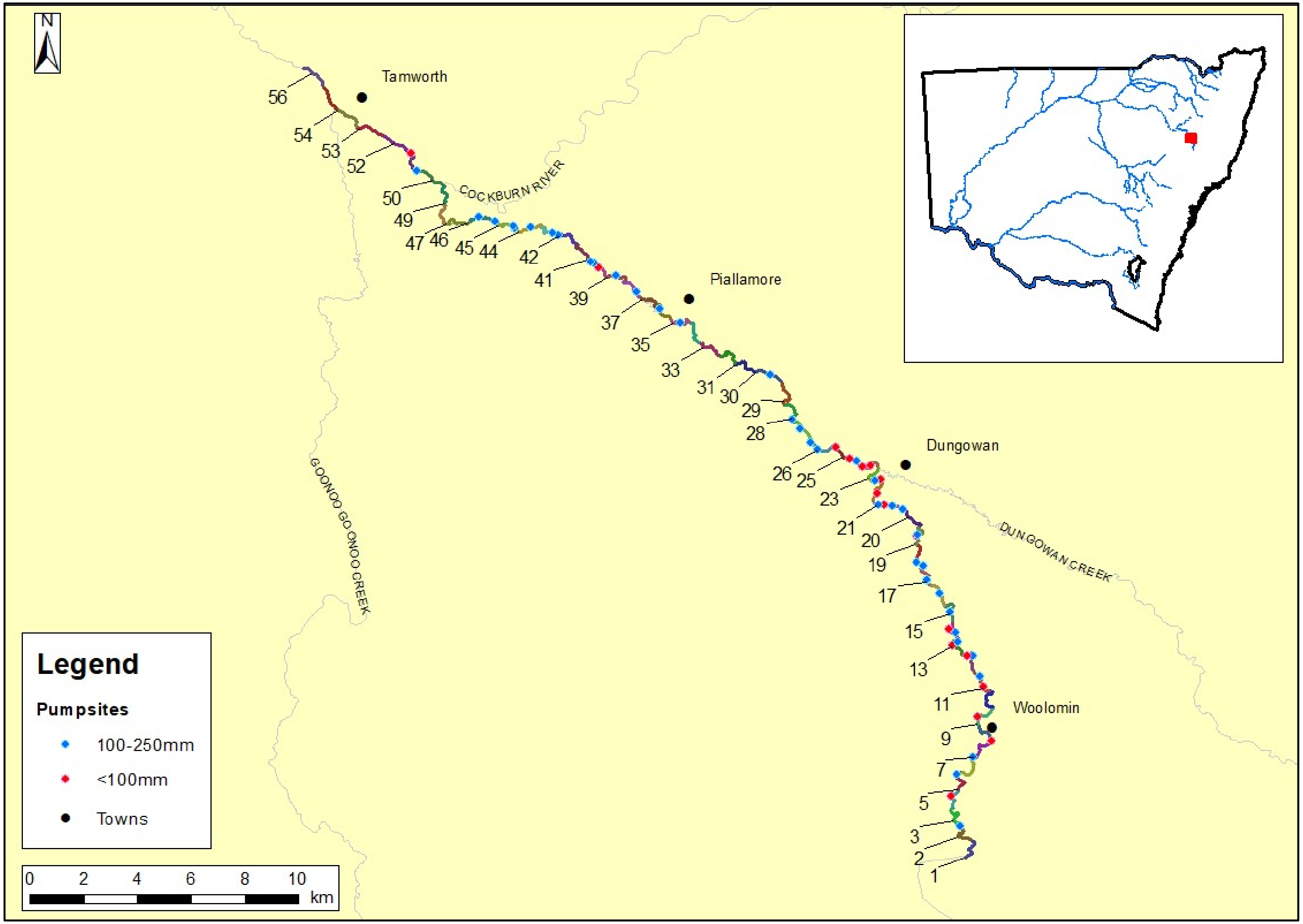

Figure 38. Pumpsite distribution and diameter in the project area

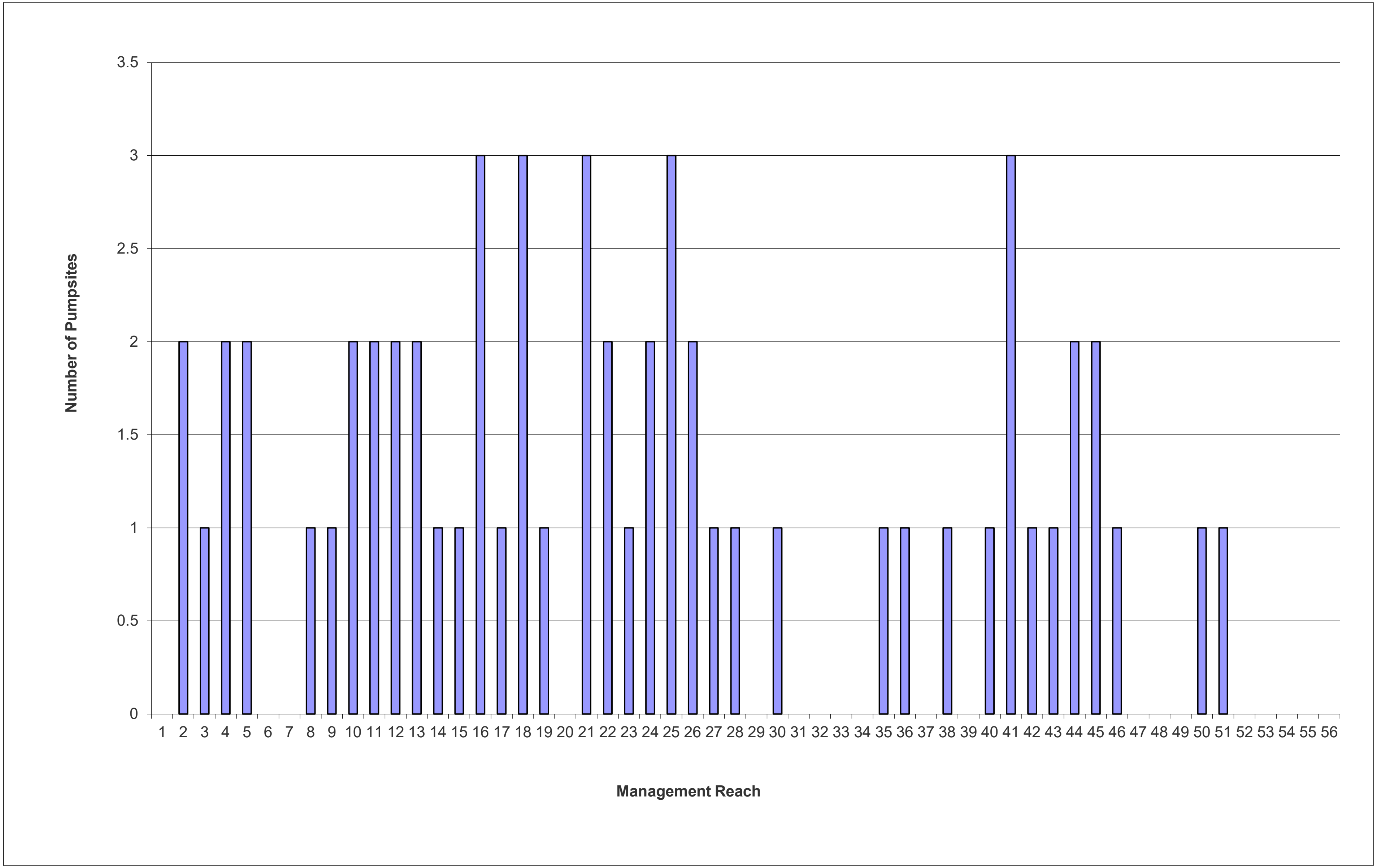

Figure 39. Number of pump sites by Management Reach

Figure 40. Example of a pump with screen on the Lachlan River

Thermal Pollution

Between spring and autumn, the water stored in large dams can form two layers: a warm surface layer overlying a cold bottom layer (Figure 41). The release of cold water from deep below the surface from large dams during warmer months can cause significant disturbances to water temperature regimes in downstream river channels, referred to as “cold water pollution” (Lugg & Copeland 2014). Cold water pollution has numerous detrimental effects on aquatic biota and river health, including inhibiting spawning and reducing in-stream productivity (Boys *et al*. 2009).

Lugg and Copeland (2014) predict that cold water pollution persists for approximately 54 km downstream of Chaffey Dam, affecting nearly the entirety of the project area. This is the case during the spring/summer irrigation season when Chaffey Dam is most stratified.

Chaffey Dam is fitted with a Multi-Level Offtake (MLO), a system design to allow dam releases to be taken from the warmer surface layer of water, hence reducing the impact of cold-water pollution. However the implementation of the MLO is currently constrained by the occurrence of toxic algae blooms in the surface water of Chaffey dam (Sheman *et al.* 2001). If algae blooms exceed water quality guidelines, dam operators are required to comply with the Regional Algal Contingency Plans and draw water from 10 m below supply level in order to minimise algae seeding downstream (Ingleton *et al.* 2008; NSW DPI 2020). As such, the current operation of the Chaffey Dam MLO still generates some cold water pollution.

Studies have observed that the thermocline (boundary between warm and cold water layers) is commonly less than 10 m deep (Foster 2013). Based on this analysis WaterNSW is currently trialling a revised MLO protocol for Chaffey Dam, whereby offtake depth is set at a less conservative estimate, allowing for warmer water to be released into the Peel River. The new protocol is still being reviewed and is being monitored by two temperature loggers downstream of Chaffey Dam (NSW 2020).

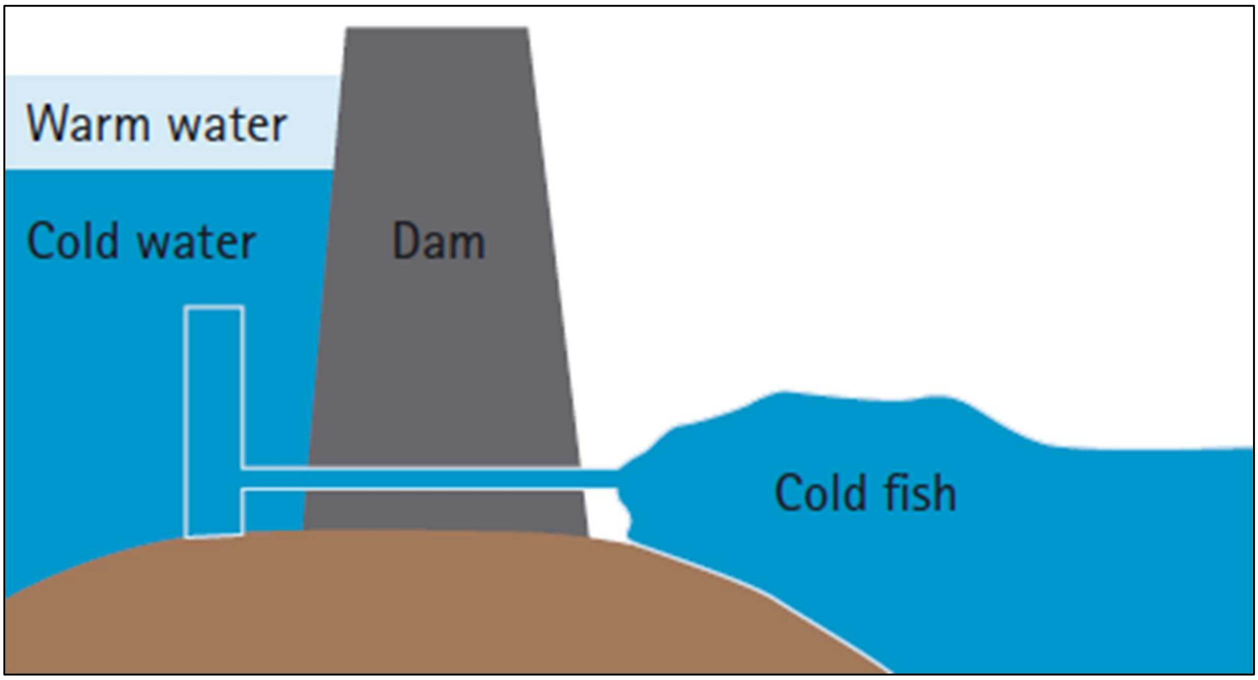

Figure 41. Cold water pollution occurs through drawing of water from the bottom of large storages (NSW DPI, 2005).

Management Reach assessment and recommendations

The DSS provided a ranking of reaches based on overall reach condition score. The main drivers for setting priorities include available instream habitat for native fish, such as drought refuge and LWH but can also be influenced by habitat features such as the presence and extent of exotic plants, erosion, stock damage and artificial barriers to fish passage. The impacts of cold water pollution also influenced the scores to some degree for reaches in the project area.

The results of the DSS prioritisation are provided in Table 15 and Figure 42, showing condition scores by Management Reach for individual habitat features, the combined reach condition scores, priority ranking, and condition classification. This assessment is based on ecological outcomes, therefore other considerations such as social, economic, political and opportunistic factors may influence investment priorities.

Green reaches are considered to be in better health and measures should be taken to protect the existing values from future decline and rehabilitate issues posing the greatest threats to these areas where required;

Amber reaches are considered to be of moderate condition and in need of some repair or rehabilitation; and

Red reaches are considered to contain areas of degraded habitat and in need of comprehensive intervention and rehabilitation and potentially, a much greater level of effort and investment is required when compared with the other reaches.

Table 15. Habitat feature and reach priority scores for Management Reaches

	Habitat Value Scores												
Management Reach	Drought Refuge	Large Woody Habitat (Snags)	Native Plant Regeneration	Macrophytes	Benches	50m Gaps	Exotic Plants	Erosion	Stock Access/ Damage	Barriers	Priority Ranking	Condition Score	Condition
1	3.93	1.30	0.00	0.30	0.74	0.00	-2.07	0.00	0.00	0.00	1	4.21	Better Health
2	0.00	0.83	0.56	0.06	0.47	0.00	-2.73	0.00	-4.93	-3.88	56	-9.61	Poorer Health
3	0.00	1.75	0.00	0.16	1.87	0.00	-4.09	0.00	0.00	0.00	29	-0.32	Moderate Health
4	0.00	2.99	0.00	0.00	0.99	0.00	-4.32	0.00	-2.46	0.00	41	-2.79	Poorer Health
5	0.00	2.51	0.00	0.13	0.36	0.00	-1.07	-0.70	0.00	0.00	15	1.23	Moderate Health
6	0.00	0.01	0.00	0.00	0.07	0.00	-8.17	0.00	0.00	0.00	54	-8.08	Poorer Health
7	0.00	1.83	0.00	0.01	0.63	0.00	-3.25	0.00	0.00	0.00	33	-0.77	Poorer Health
8	0.00	1.94	1.75	0.07	0.67	0.00	-5.41	0.00	0.00	0.00	35	-0.96	Poorer Health
9	0.00	1.90	0.00	0.01	2.02	0.00	-1.60	0.00	0.00	0.00	7	2.34	Moderate Health
10	0.00	2.67	0.00	0.01	0.76	-0.09	-1.07	-0.96	0.00	0.00	13	1.32	Moderate Health
11	0.00	2.32	0.00	0.00	1.72	0.00	-0.91	0.00	0.00	0.00	2	3.14	Better Health
12	0.90	2.59	0.00	0.00	0.50	0.00	-0.90	0.00	0.00	0.00	3	3.10	Better Health
13	0.00	1.22	0.90	0.04	0.49	0.00	-1.20	0.00	-1.31	0.00	23	0.14	Moderate Health
14	0.00	1.55	0.00	0.00	1.04	0.00	-3.41	0.00	0.00	0.00	34	-0.82	Poorer Health
15	0.00	0.20	0.00	0.05	0.00	0.00	-3.63	0.00	0.00	0.00	45	-3.37	Poorer Health
16	0.00	0.91	0.00	0.17	1.25	0.00	-7.33	0.00	-0.56	0.00	50	-5.56	Poorer Health
17	1.05	2.01	0.00	0.08	3.34	-0.28	-0.71	-1.69	-1.54	0.00	9	2.26	Moderate Health
18	0.84	1.12	0.00	0.02	2.21	0.00	-0.64	0.00	-0.55	0.00	4	3.00	Better Health
19	0.84	1.17	0.00	0.05	0.37	0.00	-0.54	-0.52	0.00	0.00	12	1.37	Moderate Health
20	0.00	0.85	1.74	0.13	0.74	0.00	-0.94	0.00	-0.44	0.00	10	2.09	Moderate Health
21	0.00	0.37	0.08	0.33	0.28	0.00	-1.58	0.00	0.00	0.00	31	-0.52	Poorer Health
22	0.00	0.38	0.00	0.19	0.14	0.00	-3.28	0.00	0.00	0.00	40	-2.57	Poorer Health
23	0.00	3.05	0.00	0.16	2.37	0.00	-3.11	0.00	-4.74	0.00	37	-2.26	Poorer Health
24	0.00	3.57	0.99	0.04	1.73	0.00	-3.18	0.00	-0.83	0.00	8	2.32	Moderate Health
25	0.00	1.11	0.00	0.02	0.89	0.00	-1.84	0.00	0.00	0.00	22	0.18	Moderate Health
26	0.00	0.33	2.60	0.01	0.66	0.00	-1.92	0.00	-0.49	0.00	16	1.18	Moderate Health
27	0.00	1.17	0.00	0.02	0.32	0.00	-1.69	0.00	0.00	0.00	27	-0.17	Moderate Health
28	0.00	1.07	0.00	0.52	0.12	0.00	-1.36	0.00	0.00	0.00	20	0.36	Moderate Health
29	0.00	1.78	0.00	0.00	0.41	0.00	-2.44	0.00	0.00	0.00	28	-0.24	Moderate Health

30	0.00	2.83	0.00	0.00	0.03	0.00	-2.85	0.00	0.00	0.00	24	0.01	Moderate Health
31	0.00	4.29	0.00	0.08	0.11	0.00	-4.89	0.00	0.00	0.00	30	-0.41	Moderate Health
32	0.00	2.24	0.00	0.54	0.17	0.00	-2.03	0.00	0.00	0.00	17	0.93	Moderate Health
33	0.00	1.80	0.10	0.36	0.83	0.00	-5.47	-1.83	0.00	0.00	48	-4.20	Poorer Health
34	0.00	0.57	0.00	1.41	0.01	0.00	-3.69	-1.29	0.00	0.00	42	-2.97	Poorer Health
35	0.00	1.38	0.00	1.68	0.23	0.00	-3.36	0.00	0.00	0.00	26	-0.06	Moderate Health
36	0.00	1.65	0.00	0.19	0.55	0.00	-1.71	-4.14	-0.52	-3.72	53	-7.68	Poorer Health
37	0.00	1.03	0.65	0.03	0.18	0.00	-0.88	-3.61	-1.80	-3.72	55	-8.13	Poorer Health
38	0.00	1.07	0.00	0.31	0.18	0.00	-1.49	0.00	-0.70	0.00	32	-0.63	Poorer Health
39	0.00	2.71	0.00	0.90	0.31	0.00	-1.46	0.00	0.00	0.00	6	2.46	Moderate Health
40	0.00	1.14	0.00	1.43	0.05	0.00	-1.34	0.00	0.00	0.00	14	1.28	Moderate Health
41	0.00	1.00	0.00	1.20	0.23	-0.47	-1.99	0.00	0.00	0.00	25	-0.03	Moderate Health
42	2.79	0.81	0.00	1.53	0.20	0.00	-2.37	0.00	0.00	0.00	5	2.97	Moderate Health
43	1.84	1.20	0.00	1.49	0.11	-0.19	-2.51	0.00	0.00	0.00	11	1.95	Moderate Health
44	0.00	1.01	0.06	1.80	0.00	0.00	-2.45	0.00	0.00	0.00	19	0.42	Moderate Health
45	0.00	1.21	0.00	0.89	0.00	-0.19	-5.15	0.00	0.00	0.00	44	-3.23	Poorer Health
46	0.88	0.58	0.00	0.54	0.00	0.00	-1.86	-2.21	0.00	0.00	36	-2.06	Poorer Health
47	1.58	0.83	0.00	0.07	0.20	0.00	-2.16	0.00	0.00	-3.72	43	-3.20	Poorer Health
48	0.78	0.63	0.00	0.06	0.15	-0.47	-8.78	0.00	0.00	0.00	52	-7.62	Poorer Health
49	0.00	0.26	0.00	0.06	0.66	0.00	-7.61	0.00	0.00	0.00	51	-6.63	Poorer Health
50	0.00	0.78	0.00	0.18	2.05	0.00	-5.52	0.00	0.00	0.00	38	-2.50	Poorer Health
51	0.00	0.70	0.00	0.03	0.21	0.00	-4.83	0.00	0.00	0.00	46	-3.89	Poorer Health
52	0.00	0.55	0.00	0.07	4.85	0.00	-5.19	0.00	0.00	0.00	21	0.30	Moderate Health
53	2.86	0.22	0.00	0.03	0.00	0.00	-4.88	0.00	0.00	-2.72	49	-4.48	Poorer Health
54	1.75	0.55	0.00	0.05	3.23	-0.28	-4.94	-4.31	0.00	0.00	47	-3.94	Poorer Health
55	0.00	1.02	0.00	0.78	2.56	-0.75	-2.79	0.00	0.00	0.00	18	0.82	Moderate Health
56	1.00	0.48	0.00	0.48	0.51	-0.28	-1.42	0.00	0.00	-3.32	39	-2.54	Poorer Health

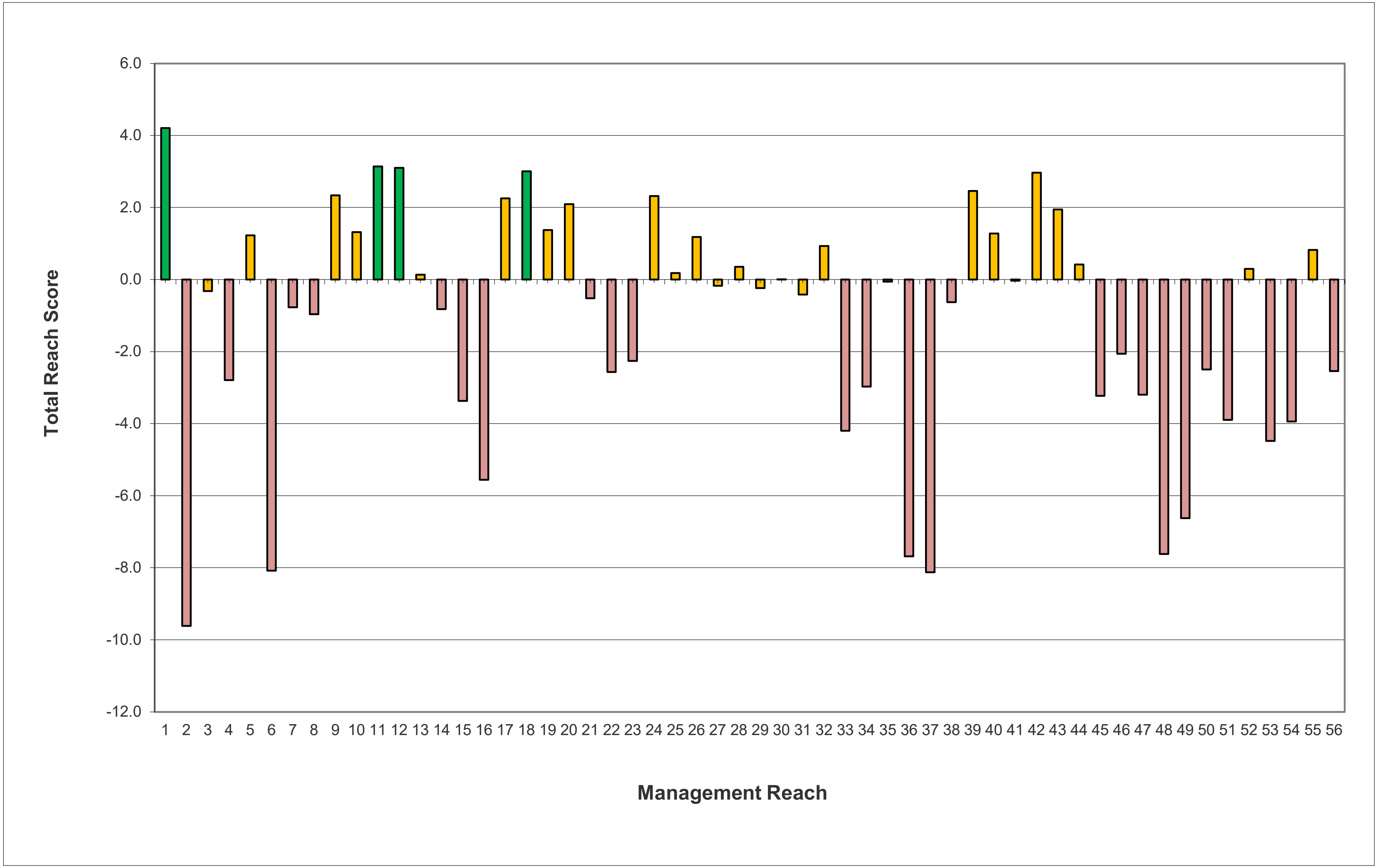

Figure 42. Total Reach Condition Scores by Management Reach

Interventions for Priority Management Reaches

Management Reach 1 (Priority 1)

Summary of key habitat features and issues (Figure 43):

- Current fencing length 250 m, with no stock or erosion damage observed
- Thermal pollution having a negative impact
- Contains a significant drought refuge 8 m deep at the Chaffey dam outlet
- Ten benches at a total area of 200 m^2

Priority protection and rehabilitation activities:

- Ensure that road crossing A is removed responsibly, as incomplete removal can result in a sediment slug in downstream reaches (Jimmy Walker pers. comms.).
- Weed control program focussing on blackberry
- Eradication of willows at the 13 sites they were recorded
- Revegetation with native species in weed control areas. Post-fieldwork analysis determined that some of this Management Reach is within a biodiversity offset area, as such this weed removal should be conducted in-line with its formal management plan.

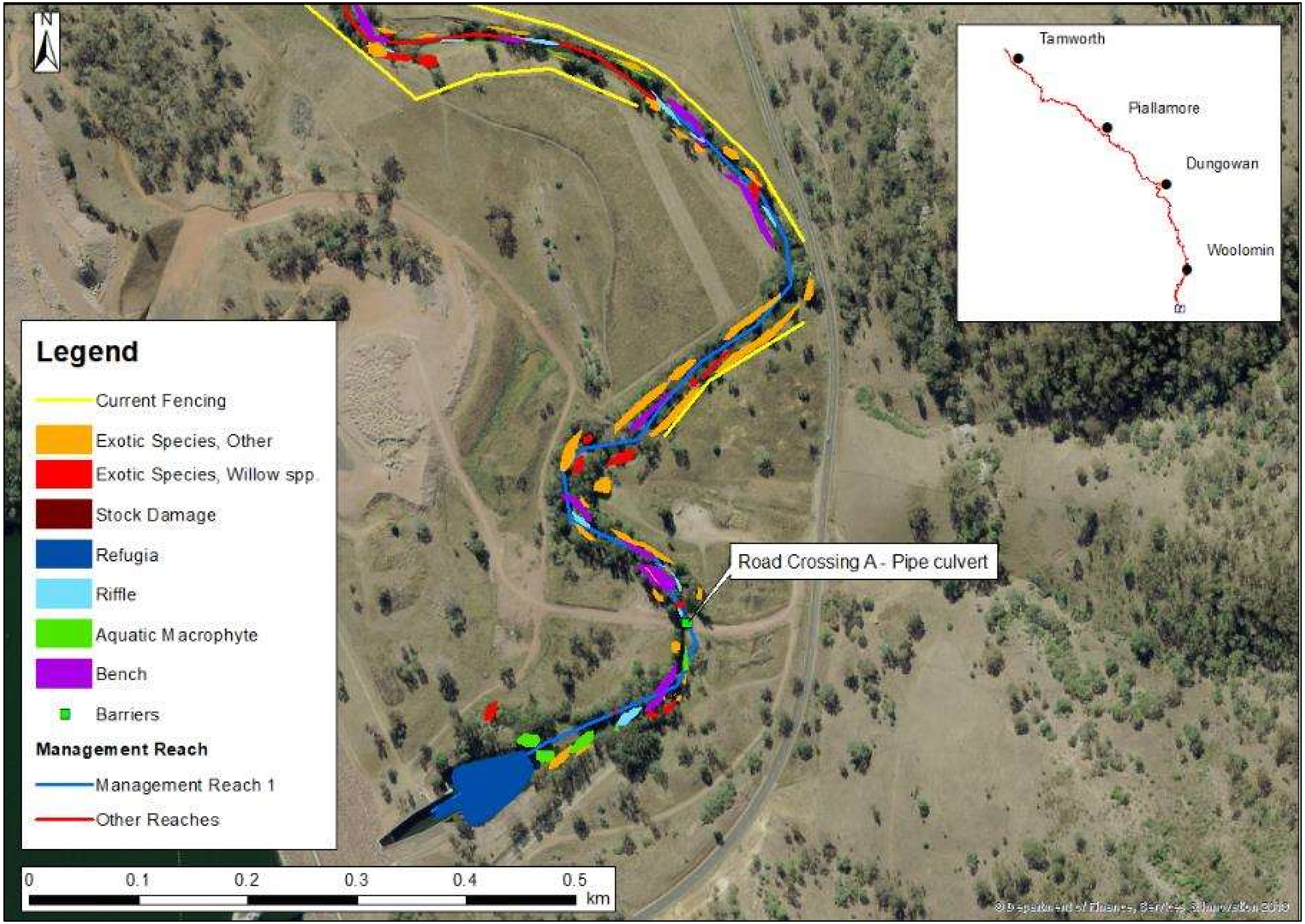

Figure 43. Summary of key habitat features and issues and proposed fence lines in Management Reach 1

Management Reaches 42 & 43 (Priority 2)

Summary of key habitat features and issues (Figure 44; Figure 45):

- Management Reach 42 has the highest occurrence of refugia at three, whilst Management Reach 43 the second most at two
- High coverage of exotic species, particularly Willow, White Cedar and Ossage Orange
- Management Reach 42 and 43 have relatively high coverage of aquatic macrophytes, at 3,619 m^2 and 3,512 m^2 respectively.
- Existing riparian fencing length 1.3 km
- Both reaches have relatively low LWH availability and complexity

Priority protection and rehabilitation activities:

- Complete fencing of reaches (approx. 2.4 km)
- Undertake resnagging, prioritising refuge sites.
- Weed control program focussing on Willow, Ossage Orange and White Cedar
- Revegetation with native species in weed control areas

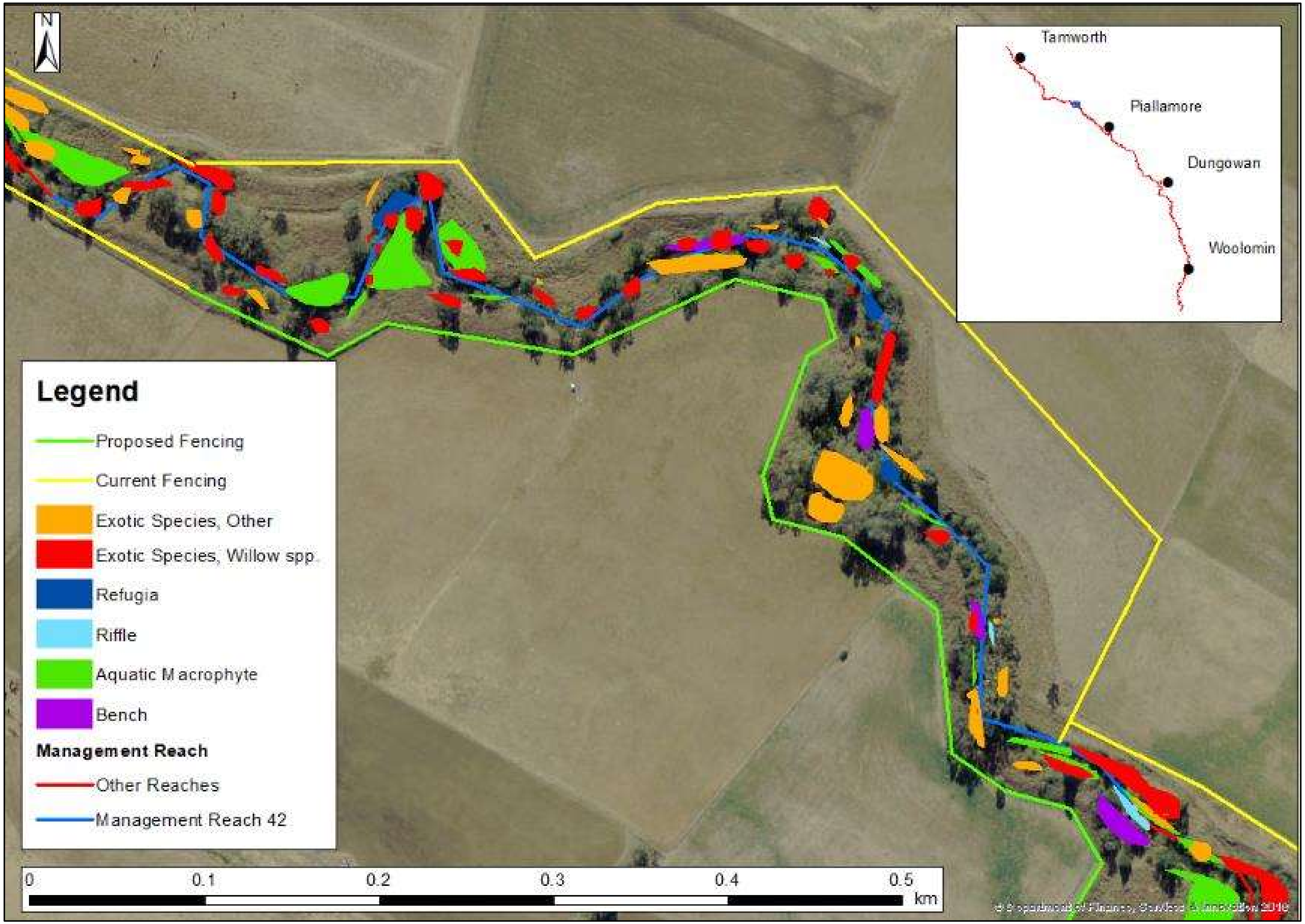

Figure 44. Summary of key habitat features and issues and proposed fence lines in Management Reach 42

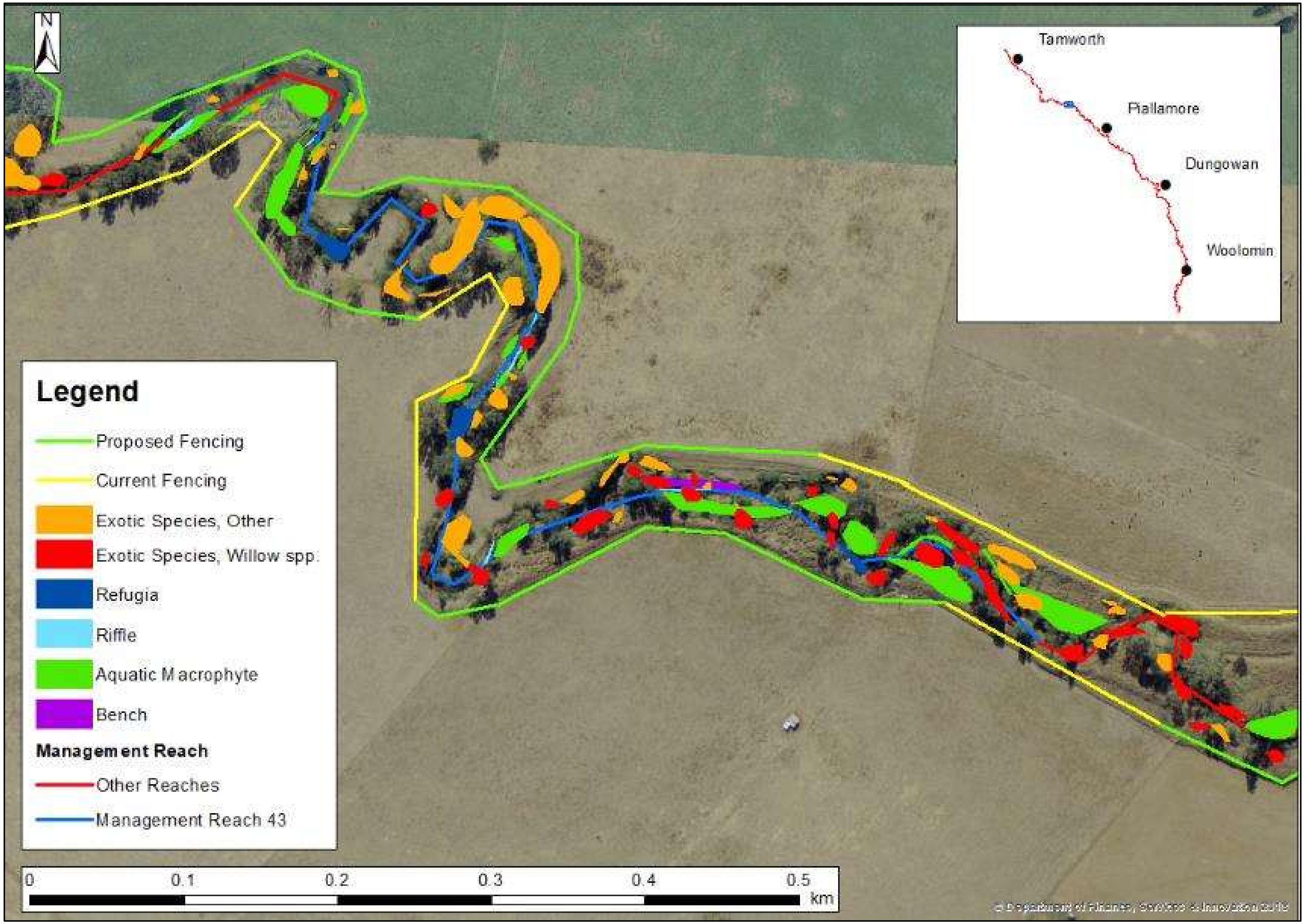

Figure 45. Summary of key habitat features and issues and proposed fence lines in Management Reach 43

Management Reach 13 & 14 (Priority 3)

Summary of key habitat features and issues (Figure 46; Figure 47):

- Adjacent to 4 km of moderate to good health reaches (Management Reach 9 – 12)
- Management Reach 13 has a high extent of stock damage (157 m^2)
- Moderate availability of benches and LWH
- High abundance of exotic species, predominantly privet
- Approximately 2.4 km of existing fencing

Priority protection and rehabilitation activities:

- Reducing exotic species and exotic species within Management Reaches 13 and 14 would result in six continuous km of moderate-good instream habitat for native fish
- Complete fencing around both reaches (approx. 1.9 km)
- Weed control program focusing on privet control
- Revegetation with native species in weed control areas
- Resnagging with complex LWH

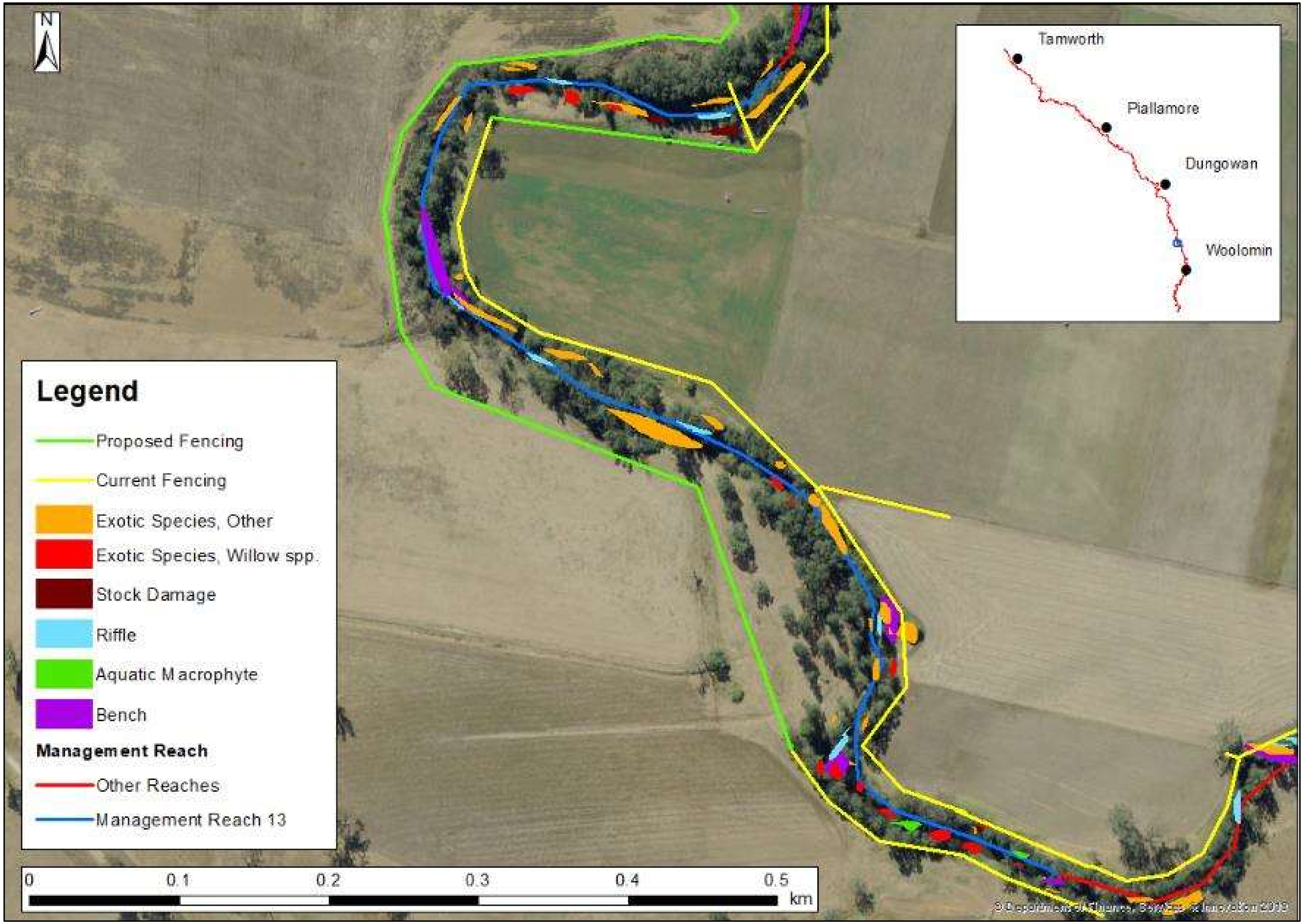

Figure 46. Summary of key habitat features and issues and proposed fence lines in Management Reach 13

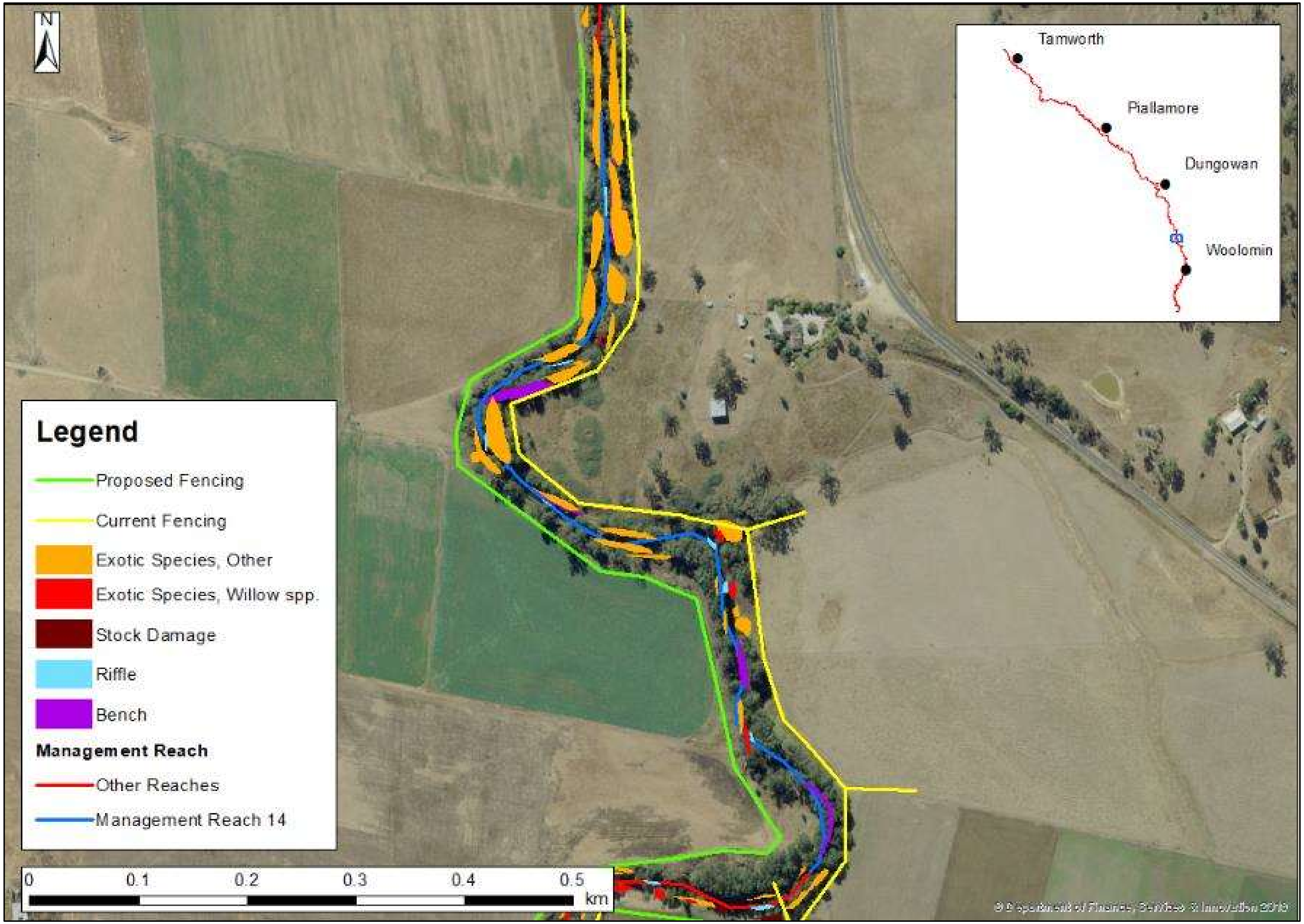

Figure 47: Summary of key habitat features and issues and proposed fence lines in Management Reach 14

Recommendations and future directions

NSW DPI recommends that the priority management reaches be the focus of targeted management actions to protect and rehabilitate the reaches that are in better condition and prevent deterioration. Management Reaches 1, 11, 12 and 18 are ranked in better health based on overall ecological condition score.

The analysis identified a range of immediate and emerging issues affecting the condition of the entire study area. These issues included the presence of significant weeds, riparian management practices and barriers to fish passage, for which recommendations are provided to manage these issues at a study area scale. These include:

- Weeds of National Significance observed throughout the study area included blackberry, prickly pear and African boxthorn. Exotic species covered a total of 42.5 ha or approximately 19% of the study area. All of these weeds have Biosecurity Duties in the Local Government Areas in the project area under the *Biosecurity Act* 2015 and as such, must be managed to reduce their spread and continuously inhibit their reproduction. It is recommended that an awareness program be conducted in collaboration with Local Government and landholders to actively treat these weeds long the length of the project area, prioritising high value reaches identified in the prioritisation module. If any infestations of notifiable weeds are deemed by the landholder to have become unmanageable, they should also be encouraged to report the issue to the Council Weeds Officer for potential deployment of additional resources.
- Implementing a resnagging program via riparian works or community grants would improve fish habitat, as well as having additional benefits such as bank stabilisation and increasing in-stream productivity (Bond & Lake 2005; Humphries & Walker 2013). The average LWH loading within the project area was 18.1 LWH/km, the lowest within the Namoi Valley (NSW DPIE 2020). Refugia sites should be prioritised for re-snagging, as LWH will remain available under cease- to-flow events when shelter is critical to fish survival.
- Five manmade barriers were observed within the project area. Jewry Street Weir, Tamworth Water Pipeline and Calala Gauging Weir should be priority for remediation, as they are minor structures that impede fish passage into the Upper Peel River and Dungowan Creek at 1,100 ML/day, 1,000 ML/day and 340 ML/day respectively. Unnamed Road Crossing B should also be prioritised for remediation, as it is a small, redundant and impedes fish movement in flows less than 188 ML/day.
- This habitat mapping project gathered significant ecological data regarding flow relationship to fish habitat and makes this information readily available. However other material, data and expertise are held by a number of different institutions and agencies. As such, a collaborative analysis of this reports data is required, in conjunction with existing information and expertise. This analysis should be incorporated into existing management decision making in order to further refine and improve flow regime.
- Further investigation and planning is required for water management agencies regarding releases from Chaffey Dam within operational requirements. The maximum release rate from the valves on Chaffey Dam at 100% capacity is approximately 1,350 ML/day (pers. comms. WaterNSW). This rate if achieved, may contribute to large fresh and bankfull flows within the project area reaches; however restricts the ability to achieve similar high flows beyond the project reach with just releases from the dam, noting that contributions from downstream tributaries may make this possible. Additionally, WaterNSW is currently monitoring and reviewing its operation protocols for Chaffey Dams MLO, attempting to mitigate both cold water pollution and downstream algae control. This report recommends environmental water planners review and incorporate these constraints into their decision making.

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Appendix A. Supplementary spatial feature class information

The following is the list of GIS data files that was used for prioritising the 56 reaches in the study area. All data is projected in the Geographic Coordinate System – GDA94 NSW Lambert Conformal Conic. An electronic copy of the project data is available on file provided.

Habitat Data

Feature Class	File Name
Large Woody Habitat (LWH)	Peel_Snags_ReachesAdded1.shp
Exotic Plants	Peel_Exotics.shp
Refuge Hole	Peel_Refuge.shp
Stock Damage	Peel_StockDamage.shp
Erosion	Peel_Erosion.shp
Study Area: Management Reaches	Peel_project_area_Mangement_reach
Study Area: Flow Gauging Zones	Peel_project_area_FGZ

Other Data	
Benches	Peel_Benches.shp
Fencelines	Peel_All_Field_Lines.shp
Aquatic Macrophytes	Peel_Macrophytes.shp
Native riparian regen	Peel_Regen.shp
Pumpsites	Peel_Pumpsites.shp
All Points	Peel_All_Field_Points.shp
All Polygons	Peel_All_Field_Polygons.shp

Appendix B. Commence to inundate tables by FGZ

Large Woody Habitat

Table 16. Inundation frequency for LWH in the Chaffey FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Large Woody Habitat		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	0.80	0.0	432	432	86.6
Very low flow	0.90	0.381	0	432	86.6
Very low flow	1.00	5.20	0	432	86.6
Very low flow	1.10	27.9	0	432	86.6
Very low flow	1.20	66.8	2	434	87.0
Baseflow	1.30	128	0	434	87.0
Baseflow	1.40	201	0	434	87.0
Baseflow	1.50	292	1	435	87.2
Small Pulse	1.60	410	7	442	88.6
Small Pulse	1.70	562	1	443	88.8
Small Pulse	1.80	738	5	448	89.8
Small Pulse	1.90	923	3	451	90.4
Large Pulse	2.00	1140	0	451	90.4
Large Pulse	2.10	1390	4	455	91.2
Large Pulse	2.20	1670	6	461	92.4
Large Pulse	2.30	1980	8	469	94.0
Large Pulse	2.40	2320	4	473	94.8
Large Pulse	2.50	2690	2	475	95.2
Bankfull	2.60	3110	3	478	95.8
Overbank	2.70	3570	1	479	96.0
Overbank	2.80	4060	4	483	96.8
Overbank	2.90	4590	2	485	97.2
Overbank	3.00	5160	1	486	97.4
Overbank	3.10	5770	3	489	98.0
Overbank	3.20	6330	1	490	98.2
Overbank	3.30	6890	2	492	98.6
Overbank	3.40	7460	0	492	98.6
Overbank	3.50	8060	1	493	98.8
Overbank	3.60	8690	0	493	98.8
Overbank	3.70	9330	2	495	99.2
Overbank	3.80	10000	1	496	99.4
Overbank	3.90	10600	1	497	99.6
Overbank	4.00	11300	0	497	99.6
Overbank	4.10	11900	1	498	99.8
Overbank	4.20	12600	1	499	100.0

Table 17: Inundation frequency for LWH in the Piallamore FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Large Woody Habitat		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	0.30	0.0	378	378	90.6
Very low flow	0.40	4.44	0	378	90.6
Very low flow	0.50	34.0	0	378	90.6
Very low flow	0.60	82.0	0	378	90.6
Baseflow	0.70	132	0	378	90.6
Baseflow	0.80	188	0	378	90.6
Baseflow	0.90	260	3	381	91.4
Small pulse	1.00	345	0	381	91.4
Small pulse	1.10	441	8	389	93.3
Small pulse	1.20	544	1	390	93.5
Small pulse	1.30	656	0	390	93.5
Small pulse	1.40	778	1	391	93.8
Small pulse	1.50	913	0	391	93.8
Small pulse	1.60	1080	15	406	97.4
Small pulse	1.70	1250	0	406	97.4
Small pulse	1.80	1440	0	406	97.4
Large pulse	1.90	1640	0	406	97.4
Large pulse	2.00	1860	1	407	97.6
Large pulse	2.10	2070	3	410	98.3
Large pulse	2.20	2300	0	410	98.3
Large pulse	2.30	2530	0	410	98.3
Large pulse	2.40	2790	0	410	98.3
Large pulse	2.50	3090	0	410	98.3
Large pulse	2.60	3400	5	415	99.5
Large pulse	2.70	3740	0	415	99.5
Large pulse	2.80	4080	2	417	100.0
Large pulse	2.90	4450	0	417	100.0
Large pulse	3.00	4830	0	417	100.0
Bankfull	3.10	5250	0	417	100.0
Overbank	3.20	5730	0	417	100.0
Overbank	3.30	6230	0	417	100.0
Overbank	3.40	6760	0	417	100.0
Overbank	3.50	7310	0	417	100.0
Overbank	3.60	7890	0	417	100.0
Overbank	3.70	8470	0	417	100.0
Overbank	3.80	9080	0	417	100.0
Overbank	3.90	9710	0	417	100.0
Overbank	4.00	10400	0	417	100.0
Overbank	4.10	11000	0	417	100.0
Overbank	4.20	11700	0	417	100.0
Overbank	4.30	12500	0	417	100.0
Overbank	4.40	13400	0	417	100.0
Overbank	4.50	14300	0	417	100.0
Overbank	4.60	16800	0	417	100.0
Overbank	4.70	19800	0	417	100.0

Overbank	4.80	25200	0	417	100.0
Overbank	4.90	35900	0	417	100.0

Table 18: Inundation frequency for LWH in the Tamworth FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Large Woody Habitat		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	1.30	0.0	32	32	91.4
Very low flow	1.40	1.46	0	32	91.4
Very low flow	1.50	15.5	0	32	91.4
Very low flow	1.60	45.5	1	33	94.3
Very low flow	1.70	82.6	0	33	94.3
Baseflow	1.80	125	0	33	94.3
Baseflow	1.90	172	0	33	94.3
Baseflow	2.00	239	0	33	94.3
Small pulse	2.10	323	1	34	97.1
Small pulse	2.20	421	0	34	97.1
Small pulse	2.30	535	0	34	97.1
Small pulse	2.40	675	0	34	97.1
Small pulse	2.50	835	0	34	97.1
Small pulse	2.60	1020	1	35	100.0
Small pulse	2.70	1220	0	35	100.0
Large pulse	2.80	1450	0	35	100.0
Large pulse	2.90	1700	0	35	100.0
Large pulse	3.00	1980	0	35	100.0
Large pulse	3.10	2280	0	35	100.0
Large pulse	3.20	2610	0	35	100.0
Large pulse	3.30	2940	0	35	100.0
Large pulse	3.40	3270	0	35	100.0
Large pulse	3.50	3630	0	35	100.0
Large pulse	3.60	4000	0	35	100.0
Large pulse	3.70	4400	0	35	100.0
Large pulse	3.80	4820	0	35	100.0
Bankfull	3.90	5260	0	35	100.0
Overbank	4.00	5720	0	35	100.0
Overbank	4.10	6140	0	35	100.0
Overbank	4.20	6580	0	35	100.0
Overbank	4.30	7030	0	35	100.0
Overbank	4.40	7500	0	35	100.0
Overbank	4.50	7980	0	35	100.0
Overbank	4.60	8470	0	35	100.0
Overbank	4.70	8980	0	35	100.0
Overbank	4.80	9510	0	35	100.0
Overbank	4.90	10000	0	35	100.0
Overbank	5.00	10600	0	35	100.0
Overbank	5.10	11200	0	35	100.0
Overbank	5.20	11800	0	35	100.0
Overbank	5.30	12400	0	35	100.0
Overbank	5.40	13000	0	35	100.0
Overbank	5.50	13600	0	35	100.0
Overbank	5.60	14300	0	35	100.0
Overbank	5.70	14900	0	35	100.0

Overbank	5.80	15600	0	35	100.0
Overbank	5.90	16300	0	35	100.0

Table 19: Inundation frequency for LWH in the Paradise Wei FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Large Woody Habitat		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	1.30	0.0	32	32	91.4
Very low flow	1.40	1.46	0	32	91.4
Very low flow	1.50	15.5	0	32	91.4
Very low flow	1.60	45.5	1	33	94.3
Very low flow	1.70	82.6	0	33	94.3
Baseflow	1.80	125	0	33	94.3
Baseflow	1.90	172	0	33	94.3
Baseflow	2.00	239	0	33	94.3
Small pulse	2.10	323	1	34	97.1
Small pulse	2.20	421	0	34	97.1
Small pulse	2.30	535	0	34	97.1
Small pulse	2.40	675	0	34	97.1
Small pulse	2.50	835	0	34	97.1
Small pulse	2.60	1020	1	35	100.0
Small pulse	2.70	1220	0	35	100.0
Large pulse	2.80	1450	0	35	100.0
Large pulse	2.90	1700	0	35	100.0
Large pulse	3.00	1980	0	35	100.0
Large pulse	3.10	2280	0	35	100.0
Large pulse	3.20	2610	0	35	100.0
Large pulse	3.30	2940	0	35	100.0
Large pulse	3.40	3270	0	35	100.0
Large pulse	3.50	3630	0	35	100.0
Large pulse	3.60	4000	0	35	100.0
Large pulse	3.70	4400	0	35	100.0
Large pulse	3.80	4820	0	35	100.0
Bankfull	3.90	5260	0	35	100.0
Overbank	4.00	5720	0	35	100.0
Overbank	4.10	6140	0	35	100.0
Overbank	4.20	6580	0	35	100.0
Overbank	4.30	7030	0	35	100.0
Overbank	4.40	7500	0	35	100.0
Overbank	4.50	7980	0	35	100.0
Overbank	4.60	8470	0	35	100.0
Overbank	4.70	8980	0	35	100.0
Overbank	4.80	9510	0	35	100.0
Overbank	4.90	10000	0	35	100.0
Overbank	5.00	10600	0	35	100.0
Overbank	5.10	11200	0	35	100.0
Overbank	5.20	11800	0	35	100.0
Overbank	5.30	12400	0	35	100.0
Overbank	5.40	13000	0	35	100.0
Overbank	5.50	13600	0	35	100.0
Overbank	5.60	14300	0	35	100.0
Overbank	5.70	14900	0	35	100.0

Overbank	5.80	15600	0	35	100.0
Overbank	5.90	16300	0	35	100.0

Benches

Table 20: Inundation frequency for benches in the Chaffey FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Benches					
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)	Frequency Area (ha)	Cumulative Area (ha)	Cumulative Area (%)
Cease to flow	0.80	0.0	46	46	29.5	8527	0.9	15.1
Very low flow	0.90	0.381	0	46	29.5	0	0.9	15.1
Very low flow	1.00	5.20	0	46	29.5	0	0.9	15.1
Very low flow	1.10	27.9	0	46	29.5	0	0.9	15.1
Very low flow	1.20	66.8	0	46	29.5	0	0.9	15.1
Baseflow	1.30	128	0	46	29.5	0	0.9	15.1
Baseflow	1.40	201	0	46	29.5	0	0.9	15.1
Baseflow	1.50	292	0	46	29.5	0	0.9	15.1
Small Pulse	1.60	410	0	46	29.5	0	0.9	15.1
Small Pulse	1.70	562	0	46	29.5	0	0.9	15.1
Small Pulse	1.80	738	85	131	84.0	28376	3.7	65.4
Small Pulse	1.90	923	0	131	84.0	0	3.7	65.4
Large Pulse	2.00	1140	0	131	84.0	0	3.7	65.4
Large Pulse	2.10	1390	0	131	84.0	0	3.7	65.4
Large Pulse	2.20	1670	0	131	84.0	0	3.7	65.4
Large Pulse	2.30	1980	0	131	84.0	0	3.7	65.4
Large Pulse	2.40	2320	0	131	84.0	0	3.7	65.4
Large Pulse	2.50	2690	0	131	84.0	0	3.7	65.4
Bankfull	2.60	3110	0	131	84.0	0	3.7	65.4
Overbank	2.70	3570	0	131	84.0	0	3.7	65.4
Overbank	2.80	4060	21	152	97.4	14652	5.2	91.4
Overbank	2.90	4590	0	152	97.4	0	5.2	91.4
Overbank	3.00	5160	0	152	97.4	0	5.2	91.4
Overbank	3.10	5770	0	152	97.4	0	5.2	91.4
Overbank	3.20	6330	0	152	97.4	0	5.2	91.4
Overbank	3.30	6890	0	152	97.4	0	5.2	91.4
Overbank	3.40	7460	0	152	97.4	0	5.2	91.4

Overbank	3.50	8060	0	152	97.4	0	5.2	91.4
Overbank	3.60	8690	0	152	97.4	0	5.2	91.4
Overbank	3.70	9330	0	152	97.4	0	5.2	91.4
Overbank	3.80	10000	4	156	100.0	4873	5.6	100.0
Overbank	3.90	10600	0	156	100.0	0	5.6	100.0
Overbank	4.00	11300	0	156	100.0	0	5.6	100.0
Overbank	4.10	11900	0	156	100.0	0	5.6	100.0
Overbank	4.20	12600	0	156	100.0	0	5.6	100.0

Table 21: Inundation frequency for benches in the Piallamore FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Benches					
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)	Frequency Area (ha)	Cumulative Area (ha)	Cumulative Area (%)
Cease to flow	0.30	0.0	0	0	0.0	0	0	0.0
Very low flow	0.40	4.44	0	0	0.0	0	0	0.0
Very low flow	0.50	34.0	0	0	0.0	0	0	0.0
Very low flow	0.60	82.0	3	3	4.1	330	0.033	1.6
Baseflow	0.70	132	13	16	21.9	1145	0.1475	7.4
Baseflow	0.80	188	10	26	35.6	1821	0.3296	16.5
Baseflow	0.90	260	6	32	43.8	1222	0.4518	22.6
Small pulse	1.00	345	10	42	57.5	3792	0.831	41.5
Small pulse	1.10	441	6	48	65.8	2144	1.0454	52.2
Small pulse	1.20	544	6	54	74.0	1317	1.1771	58.8
Small pulse	1.30	656	5	59	80.8	1789	1.356	67.7
Small pulse	1.40	778	5	64	87.7	1631	1.5191	75.9
Small pulse	1.50	913	1	65	89.0	72	1.5263	76.2
Small pulse	1.60	1080	0	65	89.0	0	1.5263	76.2
Small pulse	1.70	1250	1	66	90.4	115	1.5378	76.8
Small pulse	1.80	1440	4	70	95.9	2803	1.8181	90.8
Large pulse	1.90	1640	1	71	97.3	266	1.8447	92.2
Large pulse	2.00	1860	1	72	98.6	714	1.9161	95.7
Large pulse	2.10	2070	0	72	98.6	0	1.9161	95.7
Large pulse	2.20	2300	0	72	98.6	0	1.9161	95.7
Large pulse	2.30	2530	0	72	98.6	0	1.9161	95.7
Large pulse	2.40	2790	1	73	100.0	857	2.0018	100.0
Large pulse	2.50	3090	0	73	100.0	0	2.0018	100.0
Large pulse	2.60	3400	0	73	100.0	0	2.0018	100.0
Large pulse	2.70	3740	0	73	100.0	0	2.0018	100.0
Large pulse	2.80	4080	0	73	100.0	0	2.0018	100.0
Large pulse	2.90	4450	0	73	100.0	0	2.0018	100.0
Large pulse	3.00	4830	0	73	100.0	0	2.0018	100.0

Bankfull	3.10	5250	0	73	100.0	0	2.0018	100.0
Overbank	3.20	5730	0	73	100.0	0	2.0018	100.0
Overbank	3.30	6230	0	73	100.0	0	2.0018	100.0
Overbank	3.40	6760	0	73	100.0	0	2.0018	100.0
Overbank	3.50	7310	0	73	100.0	0	2.0018	100.0
Overbank	3.60	7890	0	73	100.0	0	2.0018	100.0
Overbank	3.70	8470	0	73	100.0	0	2.0018	100.0
Overbank	3.80	9080	0	73	100.0	0	2.0018	100.0
Overbank	3.90	9710	0	73	100.0	0	2.0018	100.0
Overbank	4.00	10400	0	73	100.0	0	2.0018	100.0
Overbank	4.10	11000	0	73	100.0	0	2.0018	100.0
Overbank	4.20	11700	0	73	100.0	0	2.0018	100.0
Overbank	4.30	12500	0	73	100.0	0	2.0018	100.0
Overbank	4.40	13400	0	73	100.0	0	2.0018	100.0
Overbank	4.50	14300	0	73	100.0	0	2.0018	100.0
Overbank	4.60	16800	0	73	100.0	0	2.0018	100.0
Overbank	4.70	19800	0	73	100.0	0	2.0018	100.0
Overbank	4.80	25200	0	73	100.0	0	2.0018	100.0
Overbank	4.90	35900	0	73	100.0	0	2.0018	100.0

Table 22: Inundation frequency for benches in the Tamworth WS FGZ

			Benches					
Component function	Gauge Height (m)	Flow (ML/day)	Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)	Frequency Area (ha)	Cumulative Area (ha)	Cumulative Area (%)
Cease to flow	1.30	0.0	0	0	0.0	0.0	0.0	0.0
Very low flow	1.40	1.46	0	0	0.0	0.0	0.0	0.0
Very low flow	1.50	15.5	0	0	0.0	0.0	0.0	0.0
Very low flow	1.60	45.5	0	0	0.0	0.0	0.0	0.0
Very low flow	1.70	82.6	0	0	0.0	0.0	0.0	0.0
Baseflow	1.80	125	0	0	0.0	0.0	0.0	0.0
Baseflow	1.90	172	0	0	0.0	0.0	0.0	0.0
Baseflow	2.00	239	0	0	0.0	0.0	0.0	0.0
Small pulse	2.10	323	0	0	0.0	0.0	0.0	0.0
Small pulse	2.20	421	0	0	0.0	0.0	0.0	0.0
Small pulse	2.30	535	1	1	20.0	273.0	0.0	17.4
Small pulse	2.40	675	0	1	20.0	0.0	0.0	17.4
Small pulse	2.50	835	0	1	20.0	0.0	0.0	17.4
Small pulse	2.60	1020	1	2	40.0	270.0	0.1	34.5
Small pulse	2.70	1220	0	2	40.0	0.0	0.1	34.5
Large pulse	2.80	1450	1	3	60.0	598.0	0.1	72.6
Large pulse	2.90	1700	1	4	80.0	204.0	0.1	85.6
Large pulse	3.00	1980	0	4	80.0	0.0	0.1	85.6
Large pulse	3.10	2280	0	4	80.0	0.0	0.1	85.6
Large pulse	3.20	2610	1	5	100.0	227.0	0.2	100.0
Large pulse	3.30	2940	0	5	100.0	0.0	0.2	100.0
Large pulse	3.40	3270	0	5	100.0	0.0	0.2	100.0
Large pulse	3.50	3630	0	5	100.0	0.0	0.2	100.0
Large pulse	3.60	4000	0	5	100.0	0.0	0.2	100.0
Large pulse	3.70	4400	0	5	100.0	0.0	0.2	100.0
Large pulse	3.80	4820	0	5	100.0	0.0	0.2	100.0
Bankfull	3.90	5260	0	5	100.0	0.0	0.2	100.0
Overbank	4.00	5720	0	5	100.0	0.0	0.2	100.0

Overbank	4.10	6140	0	5	100.0	0.0	0.2	100.0
Overbank	4.20	6580	0	5	100.0	0.0	0.2	100.0
Overbank	4.30	7030	0	5	100.0	0.0	0.2	100.0
Overbank	4.40	7500	0	5	100.0	0.0	0.2	100.0
Overbank	4.50	7980	0	5	100.0	0.0	0.2	100.0
Overbank	4.60	8470	0	5	100.0	0.0	0.2	100.0
Overbank	4.70	8980	0	5	100.0	0.0	0.2	100.0
Overbank	4.80	9510	0	5	100.0	0.0	0.2	100.0
Overbank	4.90	10000	0	5	100.0	0.0	0.2	100.0
Overbank	5.00	10600	0	5	100.0	0.0	0.2	100.0
Overbank	5.10	11200	0	5	100.0	0.0	0.2	100.0
Overbank	5.20	11800	0	5	100.0	0.0	0.2	100.0
Overbank	5.30	12400	0	5	100.0	0.0	0.2	100.0
Overbank	5.40	13000	0	5	100.0	0.0	0.2	100.0
Overbank	5.50	13600	0	5	100.0	0.0	0.2	100.0
Overbank	5.60	14300	0	5	100.0	0.0	0.2	100.0
Overbank	5.70	14900	0	5	100.0	0.0	0.2	100.0
Overbank	5.80	15600	0	5	100.0	0.0	0.2	100.0
Overbank	5.90	16300	0	5	100.0	0.0	0.2	100.0

Table 23: Inundation frequency for benches in the Paradise Weir FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Benches					
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)	Frequency Area (ha)	Cumulative Area (ha)	Cumulative Area (%)
Cease to flow	0.10	0.0	0	0	0.0	0	0	0.0
Cease to flow	0.20	0.526	0	0	0.0	0	0	0.0
Very low flow	0.30	4.15	1	1	4.0	635	635	2.9
Very low flow	0.40	17.6	2	3	12.0	1058	1693	7.8
Very low flow	0.50	34.1	2	5	20.0	2017	3710	17.1
Very low flow	0.60	59.9	4	9	36.0	2752	6462	29.8
Baseflow	0.70	119	2	11	44.0	981	7443	34.3
Baseflow	0.80	211	2	13	52.0	1915	9358	43.2
Small pulse	0.90	344	1	14	56.0	955	10313	47.6
Small pulse	1.00	527	0	14	56.0	0	10313	47.6
Small pulse	1.10	740	5	19	76.0	5266	15579	71.8
Small pulse	1.20	1000	1	20	80.0	766	16345	75.4
Small pulse	1.30	1280	3	23	92.0	3734	20079	92.6
Large pulse	1.40	1620	0	23	92.0	0	20079	92.6
Large pulse	1.50	2000	2	25	100.0	1604	21683	100.0
Large pulse	1.60	2360	0	25	100.0	0	21683	100.0
Large pulse	1.70	2750	0	25	100.0	0	21683	100.0
Large pulse	1.80	3180	0	25	100.0	0	21683	100.0
Large pulse	1.90	3640	0	25	100.0	0	21683	100.0
Large pulse	2.00	4140	0	25	100.0	0	21683	100.0
Large pulse	2.10	4670	0	25	100.0	0	21683	100.0
Bankfull	2.20	5250	0	25	100.0	0	21683	100.0
Overbank	2.30	5860	0	25	100.0	0	21683	100.0
Overbank	2.40	6510	0	25	100.0	0	21683	100.0
Overbank	2.50	7200	0	25	100.0	0	21683	100.0
Overbank	2.60	7940	0	25	100.0	0	21683	100.0
Overbank	2.70	8730	0	25	100	0	21683	100.0
Overbank	2.80	9550	0	25	100	0	21683	100.0

Overbank	2.90	10400	0	25	100	0	21683	100.0
Overbank	3.00	11300	0	25	100	0	21683	100.0
Overbank	3.10	12300	0	25	100	0	21683	100.0
Overbank	3.20	13300	0	25	100	0	21683	100.0
Overbank	3.30	14400	0	25	100	0	21683	100.0
Overbank	3.40	15500	0	25	100	0	21683	100.0
Overbank	3.50	16600	0	25	100	0	21683	100.0
Overbank	3.60	17800	0	25	100	0	21683	100
Overbank	3.70	19100	0	25	100	0	21683	100
Overbank	3.80	20400	0	25	100	0	21683	100
Overbank	3.90	21700	0	25	100	0	21683	100
Overbank	4.00	23100	0	25	100	0	21683	100
Overbank	4.10	24600	0	25	100	0	21683	100
Overbank	4.20	26100	0	25	100	0	21683	100
Overbank	4.30	27600	0	25	100	0	21683	100
Overbank	4.40	29200	0	25	100	0	21683	100
Overbank	4.50	30900	0	25	100	0	21683	100
Overbank	4.60	32700	0	25	100	0	21683	100
Overbank	4.70	34500	0	25	100	0	21683	100
Overbank	4.80	36400	0	25	100	0	21683	100

Rootballs

Table 24: Inundation frequency for rootballs in the Chaffey FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Rootballs		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	0.80	0.0	32	32	97.0
Very low flow	0.90	0.381	0	32	97.0
Very low flow	1.00	5.20	0	32	97.0
Very low flow	1.10	27.9	0	32	97.0
Very low flow	1.20	66.8	0	32	97.0
Baseflow	1.30	128	0	32	97.0
Baseflow	1.40	201	0	32	97.0
Baseflow	1.50	292	0	32	97.0
Small Pulse	1.60	410	0	32	97.0
Small Pulse	1.70	562	0	32	97.0
Small Pulse	1.80	738	0	32	97.0
Small Pulse	1.90	923	0	32	97.0
Large Pulse	2.00	1140	0	32	97.0
Large Pulse	2.10	1390	0	32	97.0
Large Pulse	2.20	1670	0	32	97.0
Large Pulse	2.30	1980	0	32	97.0
Large Pulse	2.40	2320	0	32	97.0
Large Pulse	2.50	2690	0	32	97.0
Bankfull	2.60	3110	1	33	100.0
Overbank	2.70	3570	0	33	100.0
Overbank	2.80	4060	0	33	100.0
Overbank	2.90	4590	0	33	100.0
Overbank	3.00	5160	0	33	100.0
Overbank	3.10	5770	0	33	100.0
Overbank	3.20	6330	0	33	100.0
Overbank	3.30	6890	0	33	100.0
Overbank	3.40	7460	0	33	100.0
Overbank	3.50	8060	0	33	100.0
Overbank	3.60	8690	0	33	100.0
Overbank	3.70	9330	0	33	100.0
Overbank	3.80	10000	0	33	100.0
Overbank	3.90	10600	0	33	100.0
Overbank	4.00	11300	0	33	100.0
Overbank	4.10	11900	0	33	100.0
Overbank	4.20	12600	0	33	100.0

Table 25: Inundation frequency for rootballs in the Piallamore FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Rootballs		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	0.30	0.0	9	9	100.0
Very low flow	0.40	4.44	0	9	100.0
Very low flow	0.50	34.0	0	9	100.0
Very low flow	0.60	82.0	0	9	100.0
Baseflow	0.70	132	0	9	100.0
Baseflow	0.80	188	0	9	100.0
Baseflow	0.90	260	0	9	100.0
Small pulse	1.00	345	0	9	100.0
Small pulse	1.10	441	0	9	100.0
Small pulse	1.20	544	0	9	100.0
Small pulse	1.30	656	0	9	100.0
Small pulse	1.40	778	0	9	100.0
Small pulse	1.50	913	0	9	100.0
Small pulse	1.60	1080	0	9	100.0
Small pulse	1.70	1250	0	9	100.0
Small pulse	1.80	1440	0	9	100.0
Large pulse	1.90	1640	0	9	100.0
Large pulse	2.00	1860	0	9	100.0
Large pulse	2.10	2070	0	9	100.0
Large pulse	2.20	2300	0	9	100.0
Large pulse	2.30	2530	0	9	100.0
Large pulse	2.40	2790	0	9	100.0
Large pulse	2.50	3090	0	9	100.0
Large pulse	2.60	3400	0	9	100.0
Large pulse	2.70	3740	0	9	100.0
Large pulse	2.80	4080	0	9	100.0
Large pulse	2.90	4450	0	9	100.0
Large pulse	3.00	4830	0	9	100.0
Bankfull	3.10	5250	0	9	100.0
Overbank	3.20	5730	0	9	100.0
Overbank	3.30	6230	0	9	100.0
Overbank	3.40	6760	0	9	100.0
Overbank	3.50	7310	0	9	100.0
Overbank	3.60	7890	0	9	100.0
Overbank	3.70	8470	0	9	100.0
Overbank	3.80	9080	0	9	100.0
Overbank	3.90	9710	0	9	100.0
Overbank	4.00	10400	0	9	100.0
Overbank	4.10	11000	0	9	100.0
Overbank	4.20	11700	0	9	100.0
Overbank	4.30	12500	0	9	100.0
Overbank	4.40	13400	0	9	100.0
Overbank	4.50	14300	0	9	100.0
Overbank	4.60	16800	0	9	100.0
Overbank	4.70	19800	0	9	100.0

Overbank	4.80	25200	0	9	100.0
Overbank	4.90	35900	0	9	100.0

Table 26: Inundation frequency for rootballs in the Tamworth WS FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Rootballs		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	1.30	0.0	7	7	87.5
Very low flow	1.40	1.46	0	7	87.5
Very low flow	1.50	15.5	0	7	87.5
Very low flow	1.60	45.5	1	8	100.0
Very low flow	1.70	82.6	0	8	100.0
Baseflow	1.80	125	0	8	100.0
Baseflow	1.90	172	0	8	100.0
Baseflow	2.00	239	0	8	100.0
Small pulse	2.10	323	0	8	100.0
Small pulse	2.20	421	0	8	100.0
Small pulse	2.30	535	0	8	100.0
Small pulse	2.40	675	0	8	100.0
Small pulse	2.50	835	0	8	100.0
Small pulse	2.60	1020	0	8	100.0
Small pulse	2.70	1220	0	8	100.0
Large pulse	2.80	1450	0	8	100.0
Large pulse	2.90	1700	0	8	100.0
Large pulse	3.00	1980	0	8	100.0
Large pulse	3.10	2280	0	8	100.0
Large pulse	3.20	2610	0	8	100.0
Large pulse	3.30	2940	0	8	100.0
Large pulse	3.40	3270	0	8	100.0
Large pulse	3.50	3630	0	8	100.0
Large pulse	3.60	4000	0	8	100.0
Large pulse	3.70	4400	0	8	100.0
Large pulse	3.80	4820	0	8	100.0
Bankfull	3.90	5260	0	8	100.0
Overbank	4.00	5720	0	8	100.0
Overbank	4.10	6140	0	8	100.0
Overbank	4.20	6580	0	8	100.0
Overbank	4.30	7030	0	8	100.0
Overbank	4.40	7500	0	8	100.0
Overbank	4.50	7980	0	8	100.0
Overbank	4.60	8470	0	8	100.0
Overbank	4.70	8980	0	8	100.0
Overbank	4.80	9510	0	8	100.0
Overbank	4.90	10000	0	8	100.0
Overbank	5.00	10600	0	8	100.0
Overbank	5.10	11200	0	8	100.0
Overbank	5.20	11800	0	8	100.0
Overbank	5.30	12400	0	8	100.0
Overbank	5.40	13000	0	8	100.0
Overbank	5.50	13600	0	8	100.0
Overbank	5.60	14300	0	8	100.0
Overbank	5.70	14900	0	8	100.0

Overbank	5.80	15600	0	8	100.0
Overbank	5.90	16300	0	8	100.0

Table 27: Inundation frequency for rootballs in the Paradise Weir FGZ

Component function	Gauge Height (m)	Flow (ML/day)	Rootballs		
			Frequency (n)	Cumulative Frequency (n)	Cumulative Frequency (%)
Cease to flow	0.10	0.0	0	0	0.0
Cease to flow	0.20	0.526	0	0	0.0
Very low flow	0.30	4.15	0	0	0.0
Very low flow	0.40	17.6	0	0	0.0
Very low flow	0.50	34.1	0	0	0.0
Very low flow	0.60	59.9	0	0	0.0
Baseflow	0.70	119	0	0	0.0
Baseflow	0.80	211	0	0	0.0
Small pulse	0.90	344	0	0	0.0
Small pulse	1.00	527	0	0	0.0
Small pulse	1.10	740	0	0	0.0
Small pulse	1.20	1000	0	0	0.0
Small pulse	1.30	1280	0	0	0.0
Large pulse	1.40	1620	0	0	0.0
Large pulse	1.50	2000	0	0	0.0
Large pulse	1.60	2360	0	0	0.0
Large pulse	1.70	2750	0	0	0.0
Large pulse	1.80	3180	0	0	0.0
Large pulse	1.90	3640	0	0	0.0
Large pulse	2.00	4140	0	0	0.0
Large pulse	2.10	4670	0	0	0.0
Bankfull	2.20	5250	0	0	0.0
Overbank	2.30	5860	0	0	0.0
Overbank	2.40	6510	0	0	0.0
Overbank	2.50	7200	0	0	0.0
Overbank	2.60	7940	0	0	0.0
Overbank	2.70	8730	0	0	0
Overbank	2.80	9550	0	0	0
Overbank	2.90	10400	0	0	0
Overbank	3.00	11300	0	0	0
Overbank	3.10	12300	0	0	0
Overbank	3.20	13300	0	0	0
Overbank	3.30	14400	0	0	0
Overbank	3.40	15500	0	0	0
Overbank	3.50	16600	0	0	0
Overbank	3.60	17800	0	0	0
Overbank	3.70	19100	0	0	0
Overbank	3.80	20400	0	0	0
Overbank	3.90	21700	0	0	0
Overbank	4.00	23100	0	0	0
Overbank	4.10	24600	0	0	0
Overbank	4.20	26100	0	0	0
Overbank	4.30	27600	0	0	0
Overbank	4.40	29200	0	0	0
Overbank	4.50	30900	0	0	0

Overbank	4.60	32700	0	0	0
Overbank	4.70	34500	0	0	0
Overbank	4.80	36400	0	0	0

Appendix 3 – Expression of Interest Letter

16 March 2021

<Cust_Name>
<Cust_Addr>
<Cust_Email>

Dear <Salutation>,

I am writing to you concerning a program WaterNSW is implementing to install self-cleaning pump intake screens on a number of large pumps along the Peel River.

The intake screens are designed to exclude fish from pump infrastructure and also work to isolate weeds and other debris to reduce system downtime, increase energy efficiency and improve water quality.

The installation of the intake screens is a requirement of our environmental approval to operate the Chaffey pipeline, which was installed in 2020 as an emergency drought response measure to secure water supply for Tamworth.

WaterNSW will pay the full cost of the intake screens and installation. Pump owners would be required to keep the screens operational until 2030 and permit WaterNSW to undertake an annual audit of the screens. We may also require access to the river at the pump site to undertake annual monitoring surveys of the aquatic environment.

No power is required to operate the screens which are self-cleaning, self-propelled and require minimum maintenance. I have enclosed a product sheet to provide more information about the screens proposed (attached to email).

The environmental benefits of the program include reduced mortality of threatened native fish, their larvae and eggs, including the Murray Cod and Silver Perch. The measure will also benefit Platypus and other aquatic fauna. Benefits to pump owners include upgraded infrastructure at no cost, that is self-cleaning and can result in better water quality and reduced maintenance.

WaterNSW is writing to owners of the larger pumps along the Peel River, which are the most suitable for participation in this program. Budget is only available for a limited number of screens and we would very much welcome the opportunity to discuss the program with you further.

WaterNSW would like to confirm participants in the program **by Friday 23 April 2021**, so I encourage you to get in touch to express interest or to ask any questions you may have. Please contact **Jeremy Stacy, Environmental Adviser on 0429 886 377 or at Jeremy.stacy@waternsw.com.au**

Yours sincerely,

Nathaniel S

Nathaniel Selladurai
Project Manager, Assets